ISSN 0236-2945

LIGHT & ENGINEERING

Volume 24, Number 3, 2016

LLC “Editorial of Journal “Light Technik”, Moscow

LIGHT & ENGINEERING
(Svetotekhnika)

СВЕТО ТЕХНИКА

Moscow, 2016

Editorial Office:

VNISI, Rooms 327 and 334
106 Prospekt Mira, Moscow 129626,
Russia
Tel: +7.495.682.26.54
Tel./Fax: +7.495.682.58.46
E-mail: lights-nr@inbox.ru
http://www.sveto-tekhnika.ru

Light & Engineering" is an international scientific Journal subscribed to by readers in many different countries. It is the English edition of the journal "Svetotekhnika" the oldest scientific publication in Russia, established in 1932.

Establishing the English edition "Light and Engineering" in 1993 allowed Russian illumination science to be presented the colleagues abroad. It attracted the attention of experts and a new generation of scientists from different countries to Russian domestic achievements in light and engineering science. It also introduced the results of international research and their industrial application on the Russian lighting market.

The scope of our publication is to present the most current results of fundamental research in the field of illumination science. This includes theoretical bases of light source development, physiological optics, lighting technology, photometry, colorimetry, radiometry and metrology, visual perception, health and hazard, energy efficiency, semiconductor sources of light and many others related directions. The journal also aims to cover the application illumination science in technology of light sources, lighting devices, lighting installations, control systems, standards, lighting art and design, and so on.

"Light & Engineering" is well known by its brand and design in the field of light and illumination. Each annual volume has four issues, with about 80–140 pages per issue. Each paper is reviewed by recognized world experts.

To promote the work of the Journal, the editorial staff is in active communication with Thomson Scientific (Citation index) and other international publishing houses and agencies, such as Elsevier and EBSCO Publishing.

CONTENTS

VOLUME 24 NUMBER 3 2016

LIGHT & ENGINEERING

This edition of Light & Engineering number 3–2016 is intended to present the new directions and fields of research in semiconductor lighting applications and their regulations by the government and the market in China. The published articles, generally in a short thesis form, are devoted to visible light communications, logistics based on management by visible light, and different kinds of research methods and devices, using LED as the visible light source also as well as to photovoltaic industry development. The edition of number is executed at the request of a group of scientists and lectures from several universities of China. Papers are peer-reviewed in China as well as in Russia. In a unique collaboration, this issue sheds light on state of the art research in China. We hope our readers will find many new ideas and parallels in the presented articles, fuelling further international links between researchers in China and other countries.

Julian Aizenberg
Dr., Prof., Editor- in- Chief

Light & Engineering
Vol. 24, No. 3, pp. 6-9, 2016

Svetotekhnika
No. 5, 2016

EXPLORATION OF LITERARY AND ARTISTIC CULTURAL VALUES OF LARGE-SCALE LANDSCAPE LIGHTING ENGINEERING

Lan WANG

The College of Foreign Languages and Cultures (CFLC),
Xiamen University, Xiamen, Fujian 361005, China
E-mail: wanglanxm827@126.com

ABSTRACT

Using lighting projects of a square in Paris as an example, this study analyzes the construction of a lighting system and how it forms different hierarchical relationships within the architectural landscape. At the same time, the article provides opinions on warm lighting and details of the lighting facilities of the square through the combination of the lighting projects and their effects on spectators. The lighting view creates a basis for people's visual expectation and mental experience. In coordination with other elements of the projects, it creates a beautiful evening atmosphere in the city and provides people with the perfect aesthetic experience.

Keywords: lighting projects, artistic cultural value

1. INTRODUCTION

Electronic lighting illuminates an entire city, thereby ensuring that the city remains bright when night falls. In the evenings, every city with a cultural vein exhibits an attractive charm under its lighting. In French cities, the architecture and its people are unified under the lights. The city thus becomes a wonderful piece of artwork that attracts many tourists and generates significant profits [1]. However, if the design of the lighting projects does not fit the people's visual expectation and mental experience, light pollution will occur. Therefore, when designing the landscape lighting of the city, we should combine the city's architecture and the culture with the people's visual expectation and their mental experience, thereby improving the function of lighting for the city. In the planning process of a lighting system, lighting is regarded only as a medium through which people could feel the space and which endows the city with the beauty of the architecture. In addition, the design of the lighting system provides people with another perspective from which to appreciate the landscape. This paper analyzes the construction of a lighting system and forms different hierarchical relationships of the architectural landscapes. Likewise, it offers opinions on warm lighting and details of the lighting projects of a square through a combination of the lighting projects and their effects on spectators.

2. CASE STUDY BACKGROUND

The case study square is a famous square located in the south of Paris. King Louis XV built the square to demonstrate his power and named it after himself. After the French Revolution, it was renamed the Revolutionary Square. The French view it as the symbol of the end of imperial power. In 1795, the Revolutionary Square was renamed the Place de la Concorde. The grand square as we know it today came about after a period of refurbishing [2]. The Obelisk at the centre of the square is made of pink granite. Its surface is engraved with Egyptian hieroglyphs celebrating the reign of the pharaohs. Although no grand landscapes are vi-

Fig.1. Obelisk

sible from this square, its ambience is appreciated by visitors. The visual space provides an excellent effect. The surrounding architecture and statues can all be seen when standing in the middle of the square. The streets, including the Champs Elysees and the riverbanks of the Seine, are visible from the square. The harmonious atmosphere of the area can be perceived visually and directly [3]. The square, which is considered the most important man-made landscape in the history of France, exudes its charm under lighting, and its beauty is even more evident in the evening. When designing the lighting of this square, we should not only respect the architecture but also make full use of the lights [4].

3. METHODOLOGY

In the daytime, the square is the miniature version of the artistic and political history of Paris. In the evening, it presents the stunning scenery. Scitovsky designed this square 200 years ago, and today, the square remains the most magnificent architectural landscape in Paris [5]. This square has an open-ended architectural form, thereby providing an excellent effect of the visual space. The notable characteristics of the square and the surroundings are difficult to notice during the daytime, and the visual experience may be unpleasant. After being designed hierarchically, the space of the square became more abstract, and the lighting effects became more obvious. With the lighting at night, people could perceive a sense of hierarchy and order [6].

First-class Landscaping and Flood Lighting

The Obelisk is the most notable and historically relevant architectural sculpture in the square. This statue was presented to the city by Egypt 100 years ago and is imbued with the characteristics of ancient Egypt. Located in the center of the square, the Obelisk is the tallest structure and is the visual focus of the square. Its design and ornaments exhibit variation. Flood lighting is used for this structure; the light intensity of this lighting mode is stronger than that of other lighting modes. The widely used reflected light makes the sculpture the visual focus of the square, as well as showcasing the simple geometric shape and the visual effect of the sculpture, Fig. 1.

Second-class Landscaping and Layering Lighting

Other historical artworks are also found in the square, specifically the two fountains located in the east and west of the Obelisk: the La Fontaine des Fleuves and the Fountain of Neptune [7]. These fountains have different sculpted figures, shapes, ornaments, and modelling. However, their main colour is bronze, and their secondary colour is gold. Two rows of goldfish-shaped outlets are found at the bottom of the fountains. These outlets could send up a jet of water inside and outside simultaneously. They could also form high, medium, and low water columns. Under the rendering of the lighting system, the fountains could create a sense of multi-level visual space and exude a charm that differs from that of the Obelisk. The soft visual effect of the fountains contrasts with the simplicity and hardness of the sculpture and the characteristics of the fountains are highlighted.

Third-class Landscaping and Silhouette Lighting

Eight statues of goddesses are positioned in all directions of the square. These statues represent the eight largest cities in France in the nineteenth century [8]. The lighting system of most archi-

Fig. 2. Square street lamp

tectural elements around the square uses interior lights. Thus, spill light and obtrusive light caused by multiple uses of lighting are avoided, thereby improving people's ability to view and appreciate the scenery [9]. Silhouette lighting is used to illuminate the eight statues. The lighting effect of the background buildings keeps the foreground statues in the dark, thus ensuring that the statues are outlined clearly against the bright background and shown as silhouettes.

Level Extension and Lighting Illumination

The design of the square is open ended, thereby allowing people to go to the city and other main works of architecture works from all directions. The visual extension allows people to view the Champs Elysees. The dimensional levels of the square are remarkable [10]. The street lights in the square and other equipment illuminate and adorn the Square. The street lights around the square are almost of the same height, serving as a extension to the third-class landscaping and expanding the view of the square.

4. ANALYSIS AND DISCUSSION

The Square is considered the most splendid square in the world because it is an indispensable part of the human landscape in Paris.

When night falls, many tourists come and appreciate the Obelisk and the fountains with their varied water columns. The lights draw attention to the unique beauty and vitality of the square. The unified design of the square with the city architecture and the environment creates an attractive sight that amazes onlookers.

Use of Warm Light in the Square

Lighting colour uniquely influences the atmosphere and people's perception. Therefore, lights play an important role in lighting design and are chosen based on the evaluation of various factors, such as landscape function and landscape characteristics. Nights in Paris are quieter than days. The architectural works in the square are made of stone materials that have a warm tone. Thus, the designers selected a warm yellow colour for the lighting of the square. The atmosphere of this square is more harmonious and stable than that in other architectural landscapes.

Lighting Equipment in Tune with Culture

The Square and its surrounding architecture were built more than 200 years ago. The Obelisk is an ancient relic with a long history. The street lights are the main light sources of the lighting system. Their effects on the square landscape are part of the lighting collage, and the object landscapes and their design should fit historical and cultural demands. The ornaments, including the repetitive patterns and engravings, need to be consistent with the history of the square. The colour of the street lights could use the ground colour and the additional colour of the fountains, Fig. 2. The details of the lighting equipment, which is part of the lighting system, should represent the history and culture of the square, and create beauty by combining architecture with history.

5. CONCLUSION

The lighting project of the square respects the primary architectural landscapes. Warm lighting creates a silent and steady atmosphere for the square. The multiple lighting modes show the hierarchy of the square. Each architectural landscape in the square plays a role, and the sense of dimensional levels is combined with the visual per-

ception. Furthermore, the lighting design focuses on the details and the overall effect, and it is connected with elements, such as history and society. In addition, the lighting project of the square provides suggestions for future lighting design that involves large lights. With good design, the lighting system highlights the landscapes and provides harmonious and warm landscapes for the city. Finally, the lighting projects that involve large lights promote the development of the arts and show respect for history and culture.

ACKNOWLEDGEMENT:

This paper is phase achievements of the national social science fund project "the research of modern scholars' imagination and reconstruction of the image of China" (No. 15BWW022).

REFERENCES:

1. Leymonerie C. Aluminium, a Material for Decorative Arts at the Paris International Exhibition of 1937. Cahiers d'histoire de l'aluminium, 2011, #1, pp. 8–49.

2. Lewis R W. From the "Phoenix of Legends" to the "Ultimate Monument" of the Times Stadia, Spectators, and Urban Development in Postwar Paris. Journal of urban history, 2012, V38, #2, pp. 319–335.

3. Barrio S C. Shopfronts. Madrid, 1925–1955. Lusofona Journal of Architecture and Education, 2014, #8–9, pp. 15–46.

4. Chew III W L. John Quincy Adams: American tourist in Paris, 1815. Napoleonica. La Revue, 2014, #3, pp. 84–125.

5. Ballester P. Leisure parks from the Spanish universal and international exhibitions. Loisir et Société/Society and Leisure, 2014, V37, #1, pp. 38–57.

6. Soppelsa P. Paris's 1900 universal exposition and the politics of urban disaster. French Historical Studies, 2013, V36, #2, pp. 271–298.

7. Fickers A. The techno-politics of colour: Britain and the European struggle for a colour television standard. Journal of British Cinema and Television, 2010, V7, #1, pp. 95–114.

8. Aso M, Guénel A. The Itinerary of a North Vietnamese Surgeon: Medical Science and Politics during the Cold War. Science Technology & Society, 2013, V18, #3, pp. 291–306.

9. Rashid H S J, Place C S, Braithwaite G R. Investigating the investigations: a retrospective study in the aviation maintenance error causation. Cognition, technology & work, 2013, V15, #2, pp. 171–188.

10. Castronovo R. Epistolary Propaganda: Forgery and Revolution in the Atlantic World. boundary 2, 2011, V38, #3, pp. 1–26.

Lan WANG,
Doctoral students in Cultural Anthropology, College of Humanities; Lecturer in The College of Foreign Languages and Cultures (CFLC), Xiamen University

Light & Engineering
Vol. 24, No. 3, pp. 10-13, 2016

Svetotekhnika
No. 5, 2016

ANALYSIS OF THE DESIGN AND RELIABILITY OF A NEW TYPE OF INTELLIGENT LED ILLUMINATION CONTROL SYSTEM

Qiang MAI

Electronic Engineering, Dongguan Polytechnic, Dongguan, 523880 China;
E-mail: 18903036688@189.cn

ABSTRACT

Based on ZigBee technology, this study adopted modularity to design the software and hardware of an intelligent illumination system, proposed a new type of intelligent LED illumination control system, and conducted an analytic test of the reliability of an intelligent LED illumination system. The findings indicate that the intelligent LED illumination control system based on ZigBee technology had superior characteristics of low power consumption, energy efficiency, and environmental protection.

Keywords: ZigBee technology, intelligent illumination, visible light communications, illumination system, LED

1. INTRODUCTION

Traditional illumination systems are gradually being eliminated because of the disadvantages of high energy consumption and wastage, troublesome wiring, and single functionality. Intelligent illumination is set to replace traditional illumination. This study proposed a new type of intelligent LED illumination control system. The design of the master control module was completed using STM-32F103VET6 microprocessor as the core system. ZigBee technology was also used to complete the wireless transmission of information and system control. Intelligent illumination functions, such as constant illuminance, regional illumination, timing control, human body induction auto illumination, and luminance control, were also realized in the LED illumination system.

2. LITERATURE REVIEW

Many scholars in China have studied the design and application of the control system of LED illumination. Wang Xijuan proposed a design scheme for the control system of LED intelligent illumination and replaced incandescent lamp or fluorescent lamp with LED [1]. Ding Jun and Wang Yang discussed the principles and features of LED illumination; they combined an engineering test and discussed the design flow and areas of LED illumination system that requires attention; they provided countermeasures to solve the identified problems [2]. Han Donglin, An Qiang, and Ji Lingyan adopted STC SCM as the core of their system and used such system to collect external signals and provide drive signals; they also designed a new type of illumination control system [3].

3. OVERALL DESIGN OF AN INTELLIGENT LED ILLUMINATION SYSTEM

The intelligent LED illumination system based on ZigBee technology adopted a modular method. Fig. 1 shows the design of the software and hardware of this intelligent illumination system.

The system could expand and collocate flexibly according based on the actual requirements to satisfy use in different places. For example, regional illumination could be performed, and each region could be configured with LED lamps of different quantities.

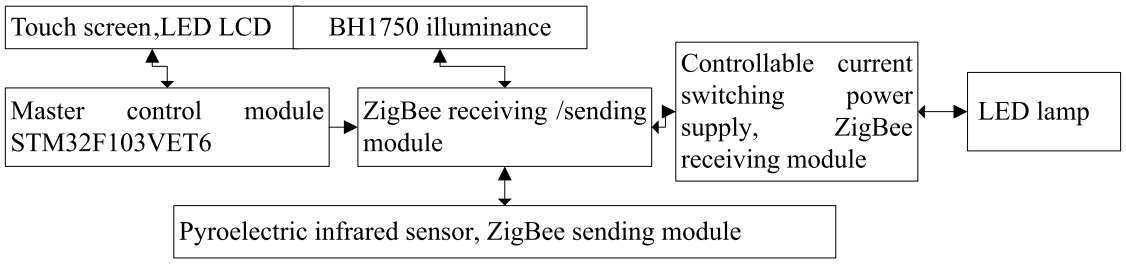


Fig. 1. Block diagram of a new of type intelligent LED illumination control system

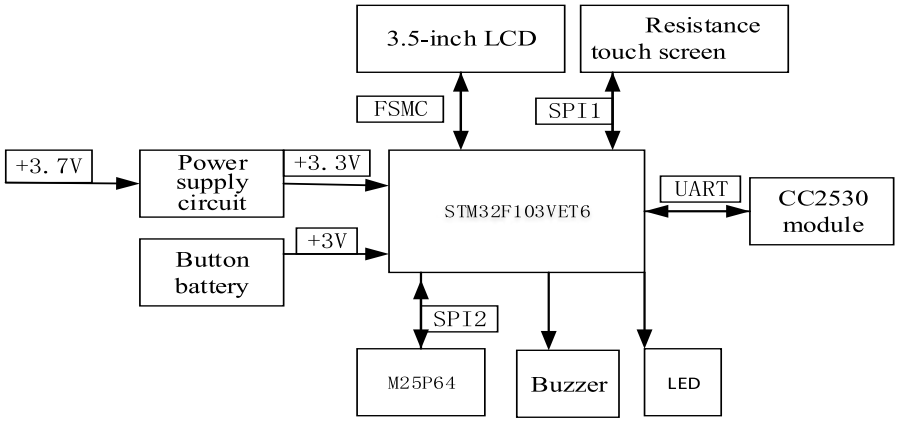


Fig. 2. Hardware structure of the master control module

Hardware circuit design

The master control module, which was the core of the system, coordinates tasks in the entire system, such as processing data and executing decisions. STM32F103VET6 was an ARM processor based on Cortex-M3 kernel and an MCU with high cost performance, high speed, low power consumption, and rich peripherals. The prominent superiority of STM32F103VET6 could meet the control requirements of this system. The master control module was designed using STM32F103VET6 as the core. Fig.2 shows the hardware structure of the master control module.

A lithium battery was used to supply power for the system. A linear power supply chip AMS1117–3.3 with low dropout was used in the power supply circuit to convert 3.7 V of lithium battery into 3.3 V, which was needed for the operation. The module will provide the power supply of RTC through button battery when the main power supply was powered down. A 3.5-inch LCD and a resistive touch screen were then used for display and input to improve refreshing rate of the screen. FSMC interface, which was peculiar to STM32F103VET6, was used to connect the LCD. SPI1 interface was connected to the resistive touch screen. Flash storage chip M25P64 was used to store information, such as word stock, pictures, and configuration files, and it was connected to the MCU through SPI2. CC2530 was 51-kernel SCM of ZigBee 2007 protocol developed using Z-Stack protocol stack from TI Corporation. CC2530 module was connected to the MCU through UART for wireless communication. Buzzer and LED were used for relevant operation tips.

The system selected pyroelectric infrared sensor and ZigBee sending module. The input signals of pyroelectric infrared sensor were sent to interface of IO P1.1 of CC2530 to conduct level detection after amplification by BISS0001 infrared-dedicated chip and to determine whether human body activity occurred. Activity information, such as human body in-and-out region, was sent through CC2530. The master control module will implement follow-up processing after reading the activity information. Examples of follow up processing are switching on and off and adjusting luminance.

BH1750 illuminance sensor and ZigBee sending module were selected for the system. This process realized certain functions such as constant illuminance. Illuminance sensor BH1750 was configured with I2C interface. Pieces of interface of IO P1.1 and P1.2 of CC2530 were used in simulating

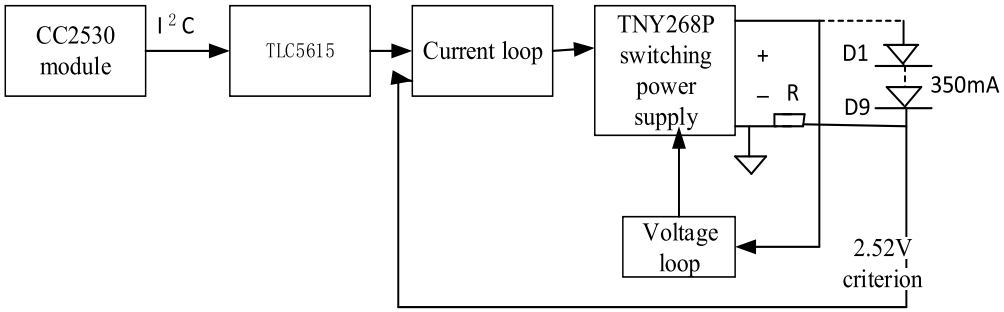


Fig. 3. Schematic diagram of LED illumination module

I2C interface and in establishing communications with BH1750 to read ambient illuminance value. After this value was read, the ambient illuminance value was sent through CC2530. The master control module will then conduct illumination compensation or reduction to realize illumination with constant illuminance.

Fig. 3 shows the LED illumination module.

The driving power of LED illumination module was approximately 9 W. The open circuit voltage was approximately 30 V and maximum current was approximately 350 mA. LED used CreeXLamp1W white-light LED, and the modules used 9-LEDs in series. The driving power supply was designed using TNY268P as the core. TNY268P was a single-switch power chip with high efficiency and energy conservation, high integration, and low cost features. TLC5615 was a D/A chip with I2C interface, and it was controlled by the CC2530 module. The output of TLC5615 has different voltage values. The current loop was a negative feedback circuit consisting of pumped amplifiers. The inputs of the current loop were analog voltage value after TLC5615 digital-to-analog conversion (DAC) and the current feedback value of LED. The functions of the current loop were to regulate current for switching power supply and to establish a constant LED current to realize functions such as regulation of LED luminance and constant illuminance. Voltage loop was also a negative feedback circuit consisting of pumped amplifiers; the main function of the voltage loop was to maintain an open-circuit voltage of switching power supply at approximately 30 V to prevent high open-circuit voltage that would damage the LED lamp.

System software design

The ZigBee wireless communication network adopted by this system has a star structure. The network contained a coordinator and several ZigBee terminal nodes. The communication and data transmission between the terminal nodes and master control module were transited through the coordinator.

The address of the ZigBee node was marked by setting a dial switch on each ZigBee node module to avoid invalid operation caused by conflict of the node's in the system. Frame header marked the beginning of the protocol. Node number was used to distinguish the same sensor module in the same network. Module number was used to distinguish different sensor modules. Command was used by the coordinator to send query command. Data used were those returned by sensor. End mark represented the end of one frame of data.

LCD was used in the master control module to display the current picture. This module managed and controlled the system by receiving input information via touch screen. The master control module used RS232 serial port to communicate with the ZigBee coordinator. LED was controlled through the information of infrared acquisition module and illuminance acquisition module. STM32F103VET6 processor of the master control module used Keil-MDK-integrated development environment and C language. The CC2530 module of the ZigBee coordinator used IAR-integrated development environment and Z-Stack developer's kit for development. The master control module adopted polling mode to complete the control of the whole system by interchangeably asking questions and providing answers. This process was adopted to avoid communication disorder in the ZigBee communication process.

The design of infrared acquisition module program was generally identical with that of illuminance acquisition module program. These programs were electrified to initialize the system and they monitored commands sent by ZigBee coordi-

nator. These programs then sent different information to the ZigBee coordinator according to these commands.

After the LED illumination module was electrified, the system was initialized and the commands sent from ZigBee coordinator were received cyclically. According to the commands, the current of the LED lamp was controlled to realize functions, such as regulation of LED luminance.

4. RELIABILITY ANALYSIS AND CONCLUSION

After testing, the current on the module was consistent with the input current when the input current was below 700 mA. A cutoff current module was tested when the input current was above 700 mA and the current on the module was controlled at 703 mA. Multiple modules were repeatedly tested by considering the component consistency problem. The measured maximum current was 710 mA, and current control error was 1.5%.

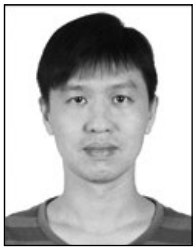
This study realized intelligent control of light according to changes in the surroundings. Intelligent control could realize the inductive control of the scenario, wherein the lamp is switched on when a person enters and switched off when he or she leaves, multi-period timing control, and PC remote control. Intelligent control used the prominent advantages of ZigBee wireless communication technology, such as low power consumption, low cost, lack of wiring requirement, and convenient and simple installation.

REFERENCES:

1. Wang Xijuan. The design of the intelligent control system for LED lighting. Manufacturing Automation, 2010. V32, #12, pp. 128–132.

2. Ding Jun, Wang Yang. The discussion of intelligent LED lighting system design process. Electrotechnical Application, 2011. V30, #06, pp. 36–39.

3. Han Donglin, An Qiang, Ji Lingyan. Design of LED intelligent lighting control system. Information Technology, 2012. V36, #01, pp. 167–168+172.



Qiang MAI,
Master of Microelectronics and Solid-state Electronics, Lecturer. Graduated from Sun Yat-Sen University of China

Light & Engineering
Vol. 24, No. 3, pp. 14-19, 2016

Svetotekhnika
No. 5, 2016

A NOVEL HIGH EFFICIENCY LED DRIVER WITH A HIGH POWER FACTOR AND LOW OUTPUT RIPPLE

Xiaoqiang ZHANG[1, 2, *] and Weiping ZHANG[2]

[1]School of information and Electronics, Beijing Institute of Technology, Beijing, 100081China;
[2] School of Electronic and Information Engineering, North China University of Technology, Beijing, 100144 China;
**Email: zxq@ncut.edu.cn*

ABSTRACT

In order for the light emitting diode (LED) used in lighting to be successful, they must be inexpensive, small, and have a high power factor (PF). A driver with a primary-side feedback constant-current control that is capable of power-factor correction (PFC) is proposed in this paper. The principles of primary-side constant-current control under the PFC are analyzed and the process to realize soft-switching under the quasi-resonance working mode are deduced. To reduce low-frequency current ripples, a linear regulator to filter is put forward for filtration of such ripples. An LED driver prototype with an output of 33 V/ 300mA is built to verify the proposed theory. The experiments showed that it has greater than 86% efficiency, 0.95 PF, and less than 3% ripple within the full voltage range, proving its high application value in low-power LED lighting applications.

Keywords: LED lighting, PFC, primary-side feedback

1. INTRODUCTION

In recent years, LED technology has experienced rapid development. It has numerous advantages over filament lamps, fluorescent lamps, and high-voltage gas discharge lamps, such as environmental protection, long service life, quick response, and energy conservation [1]. As a type of diode that is able to emit light, the LED also has the characteristics of a general semiconductor diode, namely unilateral conduction and nonlinearity. Its light intensity and driving current have a linear relationship. In the normal operating zone, the LED voltage and current have a relationship similar to an exponential function, where subtle changes of the forward voltage may generate drastic fluctuations in the LED current. If the current is higher than the rated value, the LED service life can be reduced and may even lead to permanent, severe damage. Conversely, if the current is lower than the rated value, the output luminous power drops along with the decrease in the current, though the LED does not suffer damage. Generally, the requirements for LED lighting sources can be summarized into the following. First, a constant current can be output regardless of any fluctuation in its input voltage, temperature, or driving voltage. Second, the output current ripple remains within an acceptable range under any circumstance.

Presently, classic LED drivers are categorized into passive drivers and switched-mode drivers based on whether or not they perform high-frequency switching operations. Passive drivers are simpler and more reliable because no high-frequency switching operations are involved. However, they suffer from large losses or from being bulky, and are incapable of providing output current regulation, which limits their applications [2–3].

Switched-mode LED drivers take advantage of high frequency operation and active switch control so that the small ballast size and precise out-

put current regulation can be achieved in order to meet different application standards. Switched-mode drivers can also be divided into single-stage and two-stage drivers. Single-stage drivers typically contain only one active switch in its circuit [4–6]. Since it is necessary to concurrently perform both PFC and output current regulation functions through one power processing stage, it is often difficult to assure good performance such as high efficiency, good PF, and constant current output simultaneously. In two-stage drivers, the PFC circuit and the DC/DC converter are independent of each other, and each circuit can be optimized independently. Good input current waveforms, a long service life, high reliability, easy light adjustment, and better safety control can be more easily realized with two-stage circuits [7–8], but their cost and size are a disadvantage in comparison with their system performance.

A two-stage circuit for a low-power LED driver is proposed in the paper. The first-stage circuit performs the PFC and DC/DC functions by utilizing a flyback converter and the second-stage circuit performs the filtration of the low-frequency current ripples. To increase efficiency, the primary-side feedback and a quasi-resonance flyback converter were used to realize soft-switching to reduce switching losses and noise. In order to reduce low-frequency current ripples, a linear adjustment was adopted to filter out low-frequency current ripples.

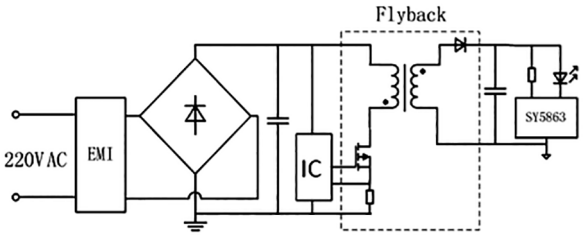


Fig.1. Proposed main circuit

2. MATERIALS AND METHODS

The structure of the proposed main circuit is shown in Fig.1. The circuit consists of two stages. The first stage is a PFC flyback converter that differs from a traditional single-stage PFC in its adoption of the primary-side feedback control and constant current control. The second-stage circuit uses a linear circuit to filter out low-frequency current ripples.

2.1. *Proposed Primary Side Feedback and Constant Current Control*

The primary-side control was adopted to reduce the number of circuit components and lower the cost. The operating principles of the primary-side feedback to realize the PFC are shown in Fig.2. The detection circuit performed the detection via the auxiliary winding, calculated the output current I_o, and took it as an input of the multiplier after making a comparison with the reference signal. The oth-

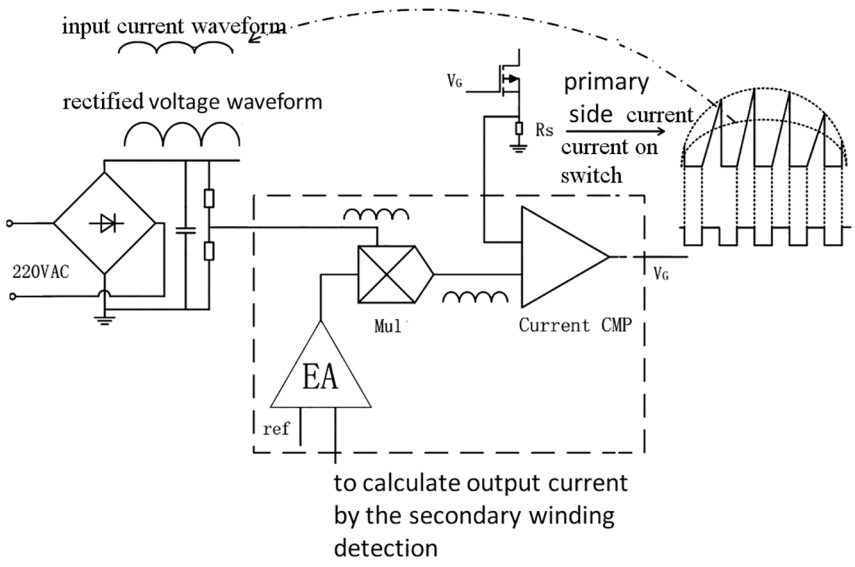


Fig.2. Operation principles of the PFC

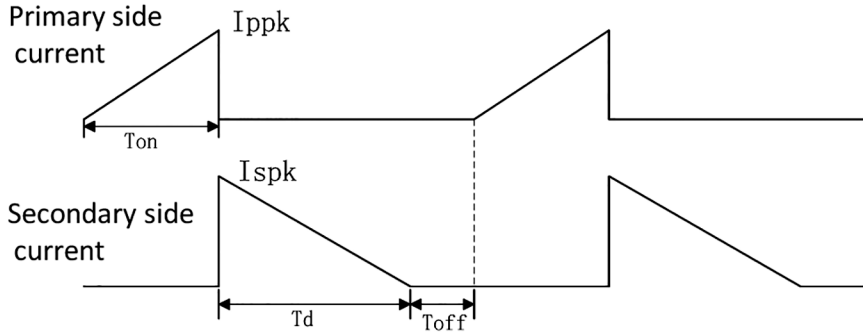


Fig.3. The current waveforms of the transformer

er input of the multiplier came from the rectified pulse-shaped half-sinusoid. Therefore, the output of the multiplier was also a pulse-shaped half-sinusoid. Current samples of the MOS were compared with the half-sinusoidal output from the multiplier; the envelope curve of the peak current was converted into a sinusoidal shape through the control of the constant-on-time peak current so that the average input current followed the sinusoidal waveform of the input voltage, both in shape and in phase, to further realize the high PF. The principle of primary-side feedback to realize constant current control was analyzed with DCM. The current waveforms of the transformer are shown in Fig.3. N_p, I_{ppk}, N_s, and I_{spk} are the flyback transformer's primary winding number, primary peak current, secondary winding number, and secondary peak current, respectively, which satisfy

$$I_{ppk} / I_{spk} = N_s / N_p. \quad (1)$$

The output current is the average value of the secondary current, which is

$$I_o = I_{spk} T_d / 2T, \quad (2)$$

where, T is the cycle time and T_d is the time it takes for the secondary current to drop to zero. Based on eq. (1), the expression of I_{spk} can be obtained

$$I_{spk} = N_p I_{ppk} / N_s. \quad (3)$$

By putting the value from eq. (3) into eq.(2), the expression of I_o can be obtained

$$I_o = I_{ppk} N_p T_d / 2(N_s T). \quad (4)$$

Eq. (4) shows that the current limitation precision of the primary peak current can be guaranteed; a comparatively high-precision output current can be obtained.

2.2. *Quasi-resonant Single-stage Circuit*

The circuit structure of the quasi-resonant flyback converter is shown in Fig.4(a), where L_m and L_p are the primary magnetizing inductance and leakage inductance, respectively, C_d is the stray capacitance of the MOS, and R_p is the equivalent resistance of the primary winding. The drain-source voltage waveform of the MOS is shown in Fig.4 (b), whose working process can be summarized as:

(1) Stage 1 (t_0~t_1): Q is on, D is off, and the primary winding stores energy. The energy of the load is provided by the output capacitance.

(2) Stage 2 (t_1~t_2): Q is turned off, and the leakage inductance L_p and C_d start to resonate. During the process, D is on and the energy stored by the primary winding is transmitted to the secondary side. The drain of Q generates an extremely high voltage peak. During the process, the voltage across C_d is

$$u_C(t) = U_S[1 - \omega_0 e^{-\alpha t} \cos(\omega_d t - \theta) / \omega_d], \quad (5)$$

where U_s is the sum of the DC converter's input voltage, U_{in}, and the transformer's reflected voltage. $\alpha = R_P / 2L_P$; $\omega_0 = \sqrt{\alpha^2 + \omega_d^2} = 1/\sqrt{L_p C_d}$; $\omega_d = \sqrt{1/L_P C_d - (R_P / 2L_P)^2}$; and $\theta = Arctg\ (\alpha / \omega_d)$.

(3) Stage 3 (t_2~t_3): Q is off, D is on. The resonance of L_p and C_d is completed; the drain voltage of Q remains constant at the moment. The primary winding inductance is demagnetized and the magnetic core is reset.

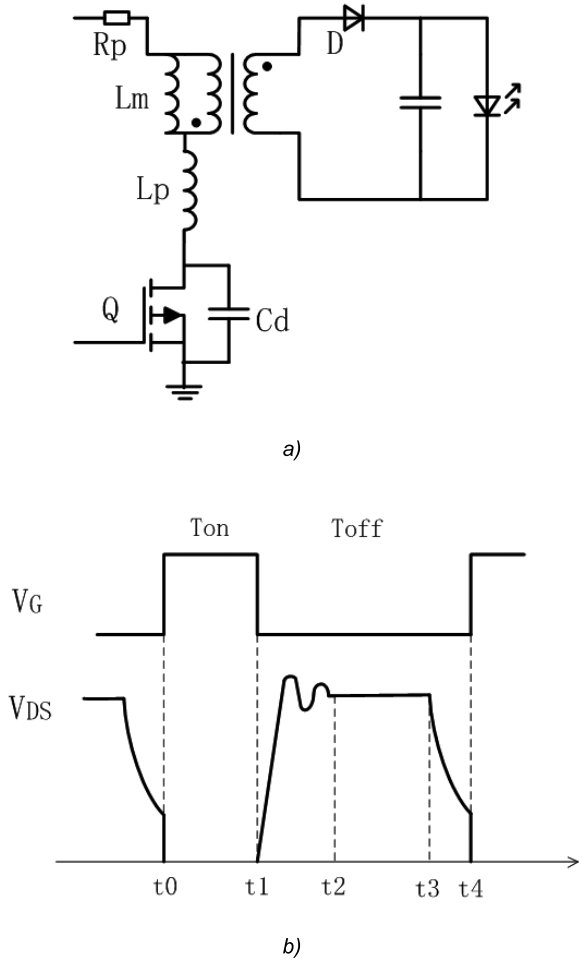


Fig.4. (a) Quasi-resonant Flyback Converter; (b) Drain-source Voltage Waveform of the Switch

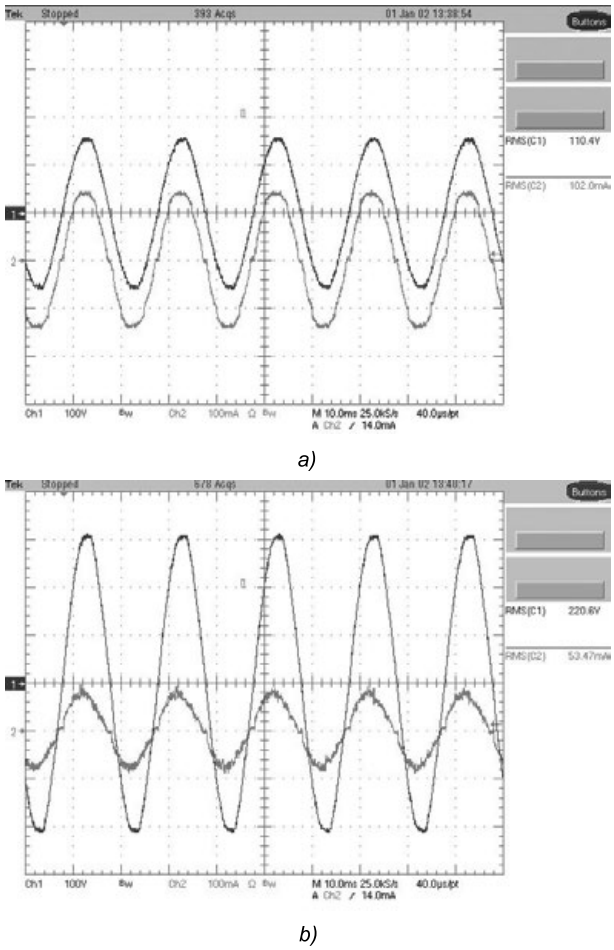


Fig.5. Input current waveforms:
(a) 110Vac Input; (b) 220Vac Input

(4) Stage 4 (t_3~t_4): Q is off; the current of D drops to zero. L_m, C_d, and R_p form the RLC resonance circuit to generate a damped resonance on the primary-side of the transformer. When the resonance lasts until the lowest switching voltage, the MOS is turned on to realize zero-voltage switching. During the process, the voltage on C_d is

$$u_C(t) = U_{in} + (U_s - U_{in})e^{-\alpha t}\cos(\omega_d t). \quad (6)$$

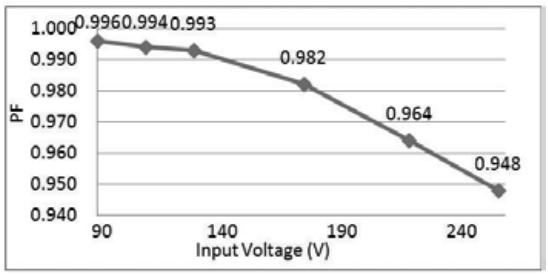
The quasi-resonance technology is able to, under any output load and any input voltage conditions, lower the drain-source voltage of the MOS to the minimum by postponing the off time of the MOS.

2.3. Linear Adjustment and Control Circuit

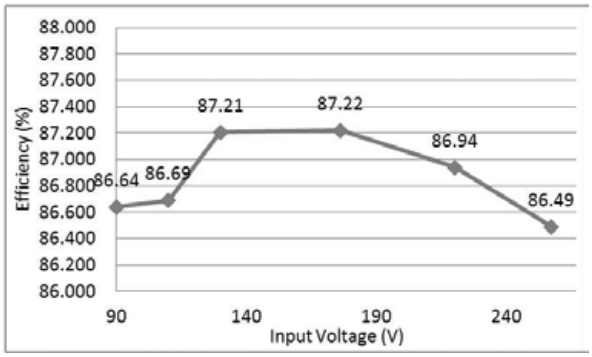
The method usually applied to reduce output current ripples at the output end is to add another stage with a DC/DC converter, or to use a ripple reduction circuit, such as the active ripple current filter. The serial connection of linear voltage regulating modules is typically adopted to substantially reduce the output current ripples, but this type of circuit suffers from a high cost and large energy losses. The SY586X series chips produced by Silergy Corporation are self-adaptive filtering chips designed exclusively for the LED output end, and are able to effectively filter out low-frequency current ripples. Datasheets show that this series of chips incurs a loss of less than 1.5% from the system. Therefore, the SY5863 chips can be successfully used to filter output current ripples.

3. RESULTS

An LED driver with a voltage of 90–265 VAC and an output of 33V/300mA is built to verify the correctness of our design. Fig.5 shows the waveforms of the input voltages vs. input current with

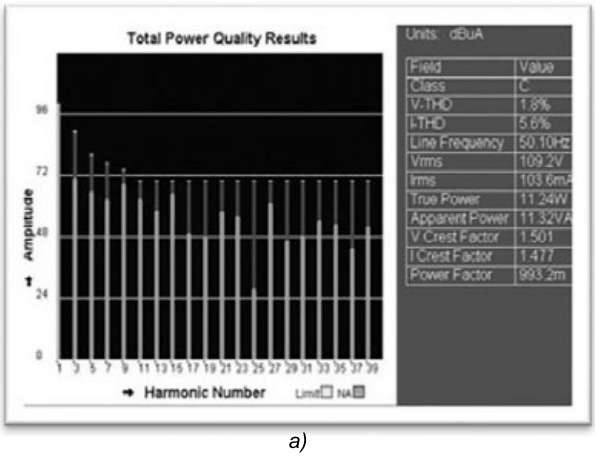


a)

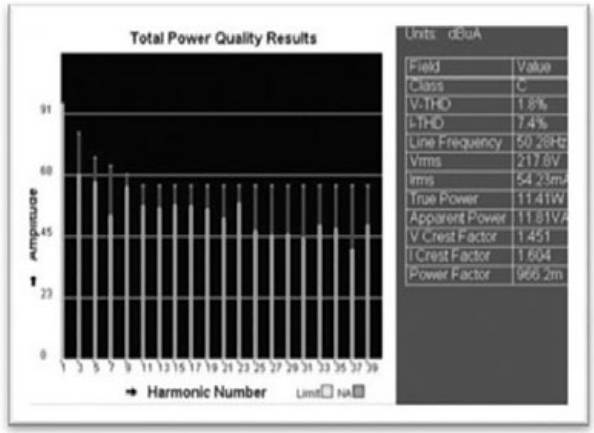


b)

Fig.6. (a) PF vs. Input Voltage;
(b) Efficiency vs. Input Voltage

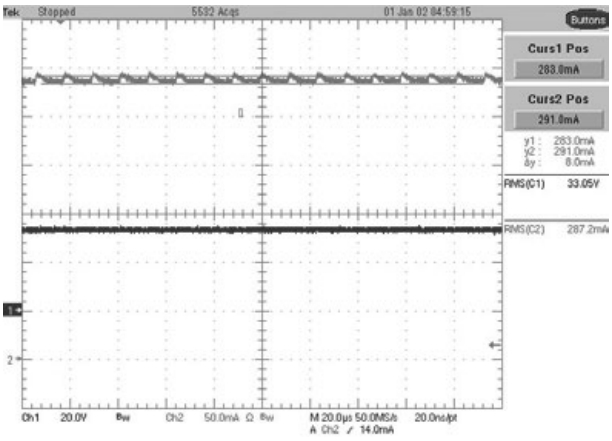


a)

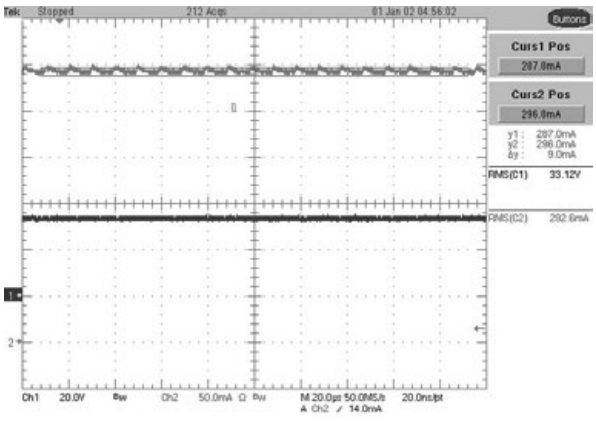


b)

Fig.7. Harmonic testing results:
(a) 110Vac Input; (b) 220Vac Input



a)



b)

Fig.8. Output current waveforms:
(a)110 Vac Input; (b) 220 Vac Input

different input voltages. The input current is almost the same as the sine wave from Fig.5. Fig.6 shows the curves of the PF and efficiency with different input voltage. Fig.6 (a) shows that with the increase of the input voltage, the PF drops, but this value remains larger than 0.94 across the full voltage range. The efficiency remains higher than 86% at the full voltage input from Fig.6 (b). Fig.7 shows the results of the harmonic standard testing, which indicated that the harmonic input current can reach the EN61000–3–2, Class C standard with an input voltage of 110V or 220V. Fig.8 shows the waveforms of the output current with input voltages of 110V or 220V. It also shows that the output current ripple is less than 3%.

4. CONCLUSIONS

To satisfy the need for a small, low cost, and high PF LED that does not suffer from low-frequency current ripples, an LED driver with prima-

ry-side feedback constant-current control is proposed. The conclusions are as follows.

(1) The principle of a primary-side constant-current control under the PFC was analyzed. The process was deduced in order to realize soft-switching under the quasi-resonance working mode.

(2) A linear adjustment method was put forward to reduce the output ripple current.

(3) To verify the proposed theory, an LED driver prototype with an output of 33 V/300mA is built. The experiment results showed that the high-performance low-power LED driver was able to meet the requirements for low output ripples and a high PF; the prototype was also highly efficient, relatively inexpensive, small, and could operate in electrical isolation. It also met the harmonic current standard.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the National Natural Science Foundation of China (No.51277004).

REFERENCES:

1. Mukhtar, O., Golam, S.M., Liu, E. Development of high-rate control system for LED based general lighting applications. International Symposium on Power Line Communications and Its Applications, 2005. pp. 417–421.

2. Kim, H., Lee, B. Passive LED driver compatible with rapid-start ballast. IEEE ECCE, 2011. pp. 507–514.

3. Alonso, J. M., Gacio, D. A study on LED retrofit solutions for low-voltage halogen cycle lamps. IEEE Trans. on Industry Applications, 2012.V48, # 5, pp.1673–1682.

4. Qu, X., Wong, S. C., Tse, C.K. Resonance-assisted buck converter for offline driving of power LED replacement lamps. IEEE Trans. on Power Electronics, 2011. V26, # 2, pp. 532–540.

5. Alonso, J., Vina, J. Analysis and design of the integrated double buck–boost converter as a high-power-factor driver for power-LED lamps. IEEE Trans. on Industrial Electronics, 2011.V59, #4, pp. 1689–1697.

6. Ma, H., Lai, J., Fang, Q. A novel valley-fill SEPIC-derived power supply without electrolytic capacitor for led lighting application. IEEE Trans. on Power Electronics, 2012.V27, #6, pp. 3057–3071.

7. Qu, X., Wong, S.C., Tse, C.K. No cascading structure for electronic ballast design for multiple LED lamps with independent brightness control. IEEE Trans. on Power Electronics, 2010.V25, #2, pp. 331–340.

8. Arias, M., Lamar, D. G., Diallo, A.A. High efficiency LED driver without electrolytic capacitor for street lighting. IEEE Trans. on Industry Applications, 2013. V49, #1, pp. 127–137.

Xiaoqiang ZHANG,
M.S. of Electrical Engineering, Assistant Professor. Graduated from North China University of Technology in 2007

Weiping ZHANG,
Doctor of Power Electronics, Professor. Graduated from Zhejiang University in 1998. Fellow of IEEE

Light & Engineering
Vol. 24, No. 3, pp. 20-23, 2016

Svetotekhnika
No. 5, 2016

PROGRESS OF WIRELESS NETWORK SIGNAL TRANSMISSION TECHNOLOGY BASED ON LED VISIBLE LIGHT COMMUNICATION TECHNOLOGY

Hao YANG[1,2], Jianan ZHAO[1,2], Wenhao ZHU[3], Yingtong DOU[1,2], and Jianguo YU[4*]

[1]*International School, Beijing University of Posts and Telecommunications, Beijing, 100876, China*
[2]*School of Electronic Engineering & Computer Science Queen Mary University of London, London, UK*
[3]*Department of Electrical Engineering, Tonggji University, Shanghai 201804, China*
[4]*School of Electronic Engineering, Beijing University of Posts and Telecommunications, Beijing, 100876, China*
E-mail: jianguoyubupt87@126.com

ABSTRACT

In this study, the network architecture for wireless network convergence of light-emitting diode (LED) visible light is theoretically analyzed, along with transmission technologies for network convergence of various visible light communication systems. Research is conducted on a communication system based on radio-over-fiber (ROF) technology. Then, the quadrature phase-shift keyed signal is observed and demodulated via a constellation diagram. This study adopts the transmission technologies of single-sideband filtering and carrier suppression. In addition, the experiment shows that the vector signal of a demodulated signal cannot fulfill the requirements of a communication system that is characterized by long-distance transmission for signal quality through ROF.

Keywords: LED Visible Light Communication, Wireless Networks, QPSK

1. INTRODUCTION

Voice transmitted via wireless communication has transitioned from unitary to integrated. At present, transmission has entered a multi-service period. Simultaneously, the development of wireless services has accelerated given the advancement of terminal technology [1]. In this case, copper access has gradually lagged behind and cannot satisfy current demands. The capability of copper networks to satisfy broadband demands and their communication capacity have reached their limits. Indoor visible light communication (VLC) is an emerging wireless communication technology that applies light-emitting diode (LED) visible light, which is also used for lighting, to transmit signals [2]. Tatu et al. divided a channel into two parts: direct and reflection channels. Indoor LED lighting can be used as the communication base to transmit information wirelessly [3]. Compared with traditional radio frequency communication and other forms of wireless communication, VLC exhibits the following advantages. First, visible light is safe for humans. Second, rich resources of visible light are available. Third, the transmitted power of VLC is huge and it does not require the radio frequency spectrum. Fourth, electromagnetism does not interfere with VLC [4]. Consequently, VLC has considerable potential. It can provide optical communication with new access to high-speed data, and thus, has elicited the attention of researchers [5]. In this study, we aim to prove that LED lighting has made wireless communication possible. Integrating wireless communication into LED lighting has become a trend [6]; what is more, optical wireless communication can provide access to a network.

The second part of this paper describes the current situation of related studies in detail. The third part introduces the transmission characteristics of the single-sideband filtering of a communication system based on radio-over-fiber (ROF) technology. In the fourth part, the feasibility and validity are verified. The last part provides the conclusions and implications of this study.

2. STATE OF THE ART

From 2001 to 2004, the International Telecommunication Union (ITU) started its research on the next-generation network (NGN). The ITU proposed a standard draft for NGN in 2003. The architecture of NGN includes the service, control, transmission, and access planes. All these planes are interconnected and provide multiple accesses to clients. In addition, the softswitch is the core of NGN architecture. It separates access from the bearing of the control.

NGN adopts the Internet Protocol (IP) as its core. It is an open network that supports various services, including voice, data, and multimedia. Compared with current network systems, the establishment of NGN integrates different networks and connects various business systems. The IMS (IP Multimedia Subsystem) is gradually being adopted for supporting multimedia services. As a new IP technology, IMS is highly inclusive. It combines various multimedia services, gains access to networks, and provides improved service to clients. At present, IMS technology is not only regarded as a key technology of NGN but also as an efficient scheme that supports fixed and mobile convergence as well as various multimedia services. Many international telecom operators have gradually adopted the scheme in which the core network based on IMS technology is used as the convergence network.

In indoor LED VLC, the method used for source encoding and the adopted modulation mode directly determine the performance of the communication system. A VLC system is consistently designed as an ID or DD system given its simple implementation. The Manchester encoding and the on–off keying (OOK) modulation mode are used. The binary OOK encoding can only transmit 1 bit via the optical link. In addition, transmission speed is slow. The Manchester encoding reduces the code error rate, but requires a wideband. The modulation bandwidth for LED that emits "white light" based on the blue photostimulable phosphor is insufficiently wide. Therefore, we should study new encoding and modulation modes. Orthogonal frequency-division multiplexing is widely used because of the following advantages. First, its spectral efficiency is high. Second, its expandability is strong. Third, it avoids multipath fading. Fourth, it enables the flexible allocation of spectrum resources. In addition, the channel of indoor LED VLC for transmitting signals is random. The wavelength of LED visible light approximates the sizes of dust and gas molecules in a room. Thus, creating dispersion is easy but receiving signals is difficult. LED lighting in different locations and backgrounds, including sunlight, also affect the system. To ensure the normal operation of a random channel, further research should be conducted on LED visible light. An appropriate indoor transmission model should also be built.

3. METHODOLOGY

Transmission Characteristic of a Single-Sideband Communication System Based on ROF

At present, the ROF system based on external modulation technology has three working modes: double-sideband, single-sideband, and carrier-suppressed modulations. The technology of double-sideband modulation is adopted in transmitting signals via long-haul optical networks because the single-mode optical fiber exhibits the dispersion effect problem. A phase difference exists in the double sideband, and thus, the signals at the receiving ends can be eliminated and microwave power is attenuated. In addition, as signal frequency transmission increases, the dispersion effect will become increasingly evident. Thus, the influence of the fiber dispersion effect on microwave power limits the distance of microwave signal transmission to a large extent. To address this defect, this study adopts single-sideband transmission technology. The optical filter can eliminate one sideband of the double-sideband signal. Then, the signals of only one sideband can be produced in signal transmission. During the transmission process of a single-sideband signal, only one beat signal occurs. Consequently, the dispersion effect problem caused by a double-sideband signal can be resolved and microwave signal quality is improved. Single-sideband modulation is a refinement of am-

Table 1. Output microwave signal spectrum

Frequency in MHZ	4860	4900	4940	4980	5020	5060	5100	5140
Spectrum in dBC	-45	-57	-52	-55	-60	-50	-60	-53

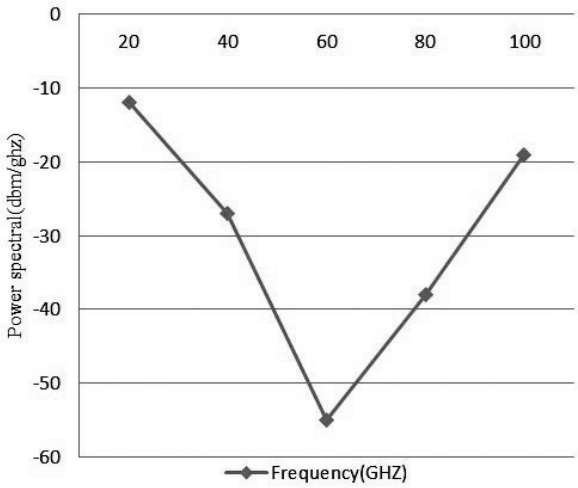


Fig.1. ROF Information System

plitude modulation that uses transmitter power and bandwidth more efficiently. Single-sideband modulation is closely connected with the vestigial sideband. The bandwidth of the modulation signals that are outputted via amplitude modulation is twice as much as that of the source signals. Single-sideband modulation technology can avoid doubling the broadband. It can also prevent wasting power on a signal carrier. However, cost is increased under this technology because of the required complex equipment. An ROF communication system based on the single-sideband transmission technology eliminates the effects of dispersion and increases the distance of signal transmission. Furthermore, only a narrow broadband is required. Therefore, this study builds an ROF communication system, and subsequently tests and analyzes its transmission performance (Fig. 1).

Microwave signal created by a radio frequency source

When intensity is modulated, the microwave signal created by the radio frequency source can be loaded on the light carrier output by the tunable laser through the $LiNbO_3$ electro-optical modulator. The light signals at the output ends of the modulator can be amplified through the erbium-doped fiber amplifier. The signals outputted by the filter retain a part of the signals of the partial sidebands after transmitting over a long distance in the fiber. A spectrum analyzer can be used to analyze these signals. Another section of the signals can be tested using a photo detector and analyzed using a frequency spectrum analyzer.

4. RESULT ANALYSIS AND DISCUSSION

In the experiment, we use an external modulator laser and a $LiNbO_3$ electro-optical modulator. An Agilent E826 is applied as the signal source and an Agilent E485 is used as a frequency spectrum analyzer. The vector signal analyzer application is Agilent 658. Table 1 shows the spectra of the received signals. This study adopts the carrier-suppressed modulation technology. Consequently, the signal frequency at the receiving ends is 12 GHz. This receiving frequency is twice the input frequency. The vector signal is modulated from eight phase-shift keying to quadrature phase-shift keying (QPSK). In the ROF communication system, the format of signal modulation is changed during the process of modulating signal carrier frequency. The QPSK signal can be observed in the four quadrants output of the constellation diagram. The observation shows that the error vector magnitude index value of the vector signal is 8.87% after the transmission technologies of single-sideband filtering and carrier suppression are adopted. This result indicates that single-sideband transmission can satisfy communication requirements.

5. CONCLUSION

The ROF communication system based on LED VLC and characterized by signal transmission over wireless networks demonstrates desirable performance. The popularity of such a system in fiber transmission is gradually increasing. In the rapid innovation of technologies, a mobile terminal dominates the market share. Under this background, the wireless-optical broadband access network technology emphasizes its considerable advantages. This study analyzes signal transmission over wireless networks based on LED VLC and conducts a contrast experiment on single-sideband and double-sideband transmissions. The obser-

vation of the QPSK signal in the four quadrants of the constellation diagram shows that when the transmission technologies of single-sideband filtering and carrier suppression are adopted, the error vector magnitude index value of the vector signal is 8.87% after optical transmission reaches a distance of 9.86 km. This result indicates that single-sideband transmission satisfies communication requirements. Signal transmission over wireless networks based on LED VLC will provide a new transmission mode for an intelligent network of terminals. Such transmission can also promote the development of the telecommunication business in China. Although this study makes certain achievements, room for improvement remains considerable. For example, we will conduct further research on the easy operation and intuitive performance of signal transmission over wireless networks based on LED VLC.

ACKNOWLEDGEMENT:

This work was supported by the national natural science foundation, key projects "Theory and technology of amorphous flattening self-organization wireless network". The project number: 61531007. The application code is F0104.

REFERENCES:

1. Zhu X, Murch R D Performance analysis of maximum likelihood detection in a MIMO antenna system. Communications, IEEE Transactions on, 2002, V50, #2, pp. 187–191.

2. Krongold B S, Jones D L PAR reduction in OFDM via active constellation extension. Broadcasting, IEEE Transactions on, 2003, V49, #3, pp. 258–268.

3. Tatu S O, Moldovan E, Wu K, et al A new direct millimeter-wave six-port receiver. Microwave Theory and Techniques, IEEE Transactions on, 2001, V49, #12, pp. 2517–2522.

4. Sekine K, Kikuchi N, Sasaki S, et al 40 Gbit/s, 16-ary (4 bit/symbol) optical modulation/demodulation scheme. Electronics Letters, 2005, V41, #7, pp. 1.

5. He L, Ge H A new full-rate full-diversity orthogonal space-time block coding scheme. Communications Letters, IEEE, 2003, V7, #12, pp. 590–592.

6. Sathya P, Natarajan R. Solar PV powered energy efficient LED lighting system for a class room. Journal of Engineering Science and Technology Review, 2014, V7, #4, pp. 34–39.

Hao YANG,
Undergraduate of Beijing University of Posts and Telecommunications. He is Major in Telecommunication Engineering with Management

Wenhao ZHU,
Doctoral student of Department of Electrical Engineering, Tonggji University, Graduated from WuHan University. He is a Senior Engineer in smart grid intelligent system on the user side

Jianguo YU,
professor, Ph. D, he graduated from Beijing University of Posts & Telecommunications (BUPT) in 1997. He is now a professor and doctoral advisor of Beijing University of Posts and Telecommunications (BUPT)

Jianan ZHAO,
Undergraduate of Beijing University of Posts and Telecommunications. He is Major in Telecommunication Engineering with Management

Yingtong DOU,
Undergraduate of Beijing University of Posts and Telecommunications. He is Major in the Internet of Things

Light & Engineering
Vol. 24, No. 3, pp. 24-27, 2016

Svetotekhnika
No. 5, 2016

APPLICATION OF LED-BASED VISIBLE LIGHT COMMUNICATION IN LOGISTICS TRANSPORTATION

Dan LIU, Renqiang XIE, Xiaozhen JIANG*, and Jie ZHU

Department of Economics and Trade, Fuzhou University of International Studies and Trade, Fuzhou 350202, Fujian, China
**E-mail: jiangxiaozhen894@sina.com*

ABSTRACT

Despite its great development, the logistics industry in China exhibits a low level of overall inefficiency. This paper proposes a logistics transportation system using LED-based visible light communication technology. An open WDM system designed with dense wavelength division multiplexing (DWDM) technology; this system adopts the official bytes within the optical monitoring channel of DWDM for official communication. Results indicate that this system shows high efficiency in applications such as traffic route management, location management of transport vehicles, and loading of running vehicles.

Keywords: optical fibre communication technology, dense wavelength division multiplexing (DWDM), logistics transportation system, OTU

1. INTRODUCTION

Logistics is a process in which products, equipment, and cargo are transporting from one location to another within a certain time. At present, China's logistics system is developing in the direction of modernization, intelligence, and informatization. In 2008, Chen et al. [1] proposed a management system model comprehensively utilizing FRID, GPS, and GIS, which could automatically acquire information and perform real-time tracking and monitoring for the logistics processes of hazardous articles, including production, storage, operation, transportation, destruction, [2]. Xu et al. designed service-oriented and component-based four-layer architecture by using a GIS logistics system in 2010 [3]. In 2011, Yang et al. designed a tracing model of the logistics of agricultural products, which systematically realized the rapid acquisition and process tracing of distribution process information [4]. Qu et al. proposed a remote monitoring system of logistics transport vehicles on the basis of wireless sensor networks and GPRS communication in 2013 [5]. Ma proposed a logistics temperature control system of meat cold chains using RFID technology for continuous, dynamic, accurate, and reliable temperature control of meat products. Wang et al. integrated GPS and GIS to realize real-time recording and planning through mobile communication to improve the dynamically adaptive capacity of logistics distribution systems. Despite these developments, the systems and logistics centres of most logistics enterprises remain mutually independent, which generates high costs, is not conducive to management, and causes waste of allocated resources.

To solve these problems and establish a high-efficiency, low-cost logistics system, this paper utilizes DWDM technology to design a logistic transportation system on the basis of optical fibre communication technology. The second section introduces the basic principle of DWDM technology and the development of modern logistics systems integrated with advanced communication technology. The third section illustrates the design of an official communication system, a network management system, and the optical fibre wiring of

a DWDM system. The fourth section describes testing of the transmitting optical power of a wavelength division system. The fifth section draws some conclusions.

2. STATE OF THE ART

Optical fibre communication technology

Optical fibre communications use light as an information carrier and transmit it through optical fibre for communication. The capacity of optical fibre communication is higher than that of microwave communication. This is mainly because that the optical wave frequency of carriers in an optical fibre system is higher than the frequency of electric waves. Furthermore, the loss caused by the fibre transmission medium is lower than that caused by cables or guided wave tubes. As the ground loop, optical fibres made of glass, which is an insulator. In addition, since optical fibre communication technology utilizes optical waves to carry out transmission, its advantage is that it will not be tapped, which ensures the security of communication. Finally, optical fibre is mainly composed of optical fibre cables of a small diameter and volume. Therefore, it will not cause the congestion of the underground pipeline and difficulty during installation. These aspects have caused optical fibre communication technology to be widely adopted.

Basic principle of DWDM technology

Dense wavelength division multiplexing (DWDM) technology is an optical fibre communication technology, which can transmit a large degree of electrical information concurrently to realize system expansion. Based on the optical fibre's bandwidth and low loss, the carrier wave of DWDM adopts multiple wavelengths, and different carrier channels can be transmitted simultaneously in one optical fibre, which reduces the quantity of optical fibres. In addition, there is no association between the protocol of DWDM and transmission speed. Thus, the networks adopting DWDM can transmit different data flows in the same laser channel at different speeds.

Logistics system integrated with advanced communication technology

The construction of modern logistics systems requires intelligence, digitalization, and automation of logistics equipment, which is mainly composed of logistics management, information technology, and control systems. Reasonable and effective logistics information systems can automatically collect process information for analysis, which could be further disposed and analyzed to guide the overall logistics activity. The efficiency and quality of management can be improved so, that the risk in logistics activity process could be avoided.

3. METHODOLOGY

Opening WDM system

The proposed logistics transportation system based on LED visible light communication technology adopts an opening system. The wavelength converter is placed in front of the wavelength division multiplexer, and nonstandard wavelength of SDH is converted to standard wavelength, which is suitable for long-distance transmission light sources. Opening WDM systems can utilize a G.957 interface, rather than the exclusive G.692 interface, meaning different SDH systems of logistics enterprises can be operated in the same WDM system. This saves significant equipment resources and controls enterprise costs, improving economic efficiency.

Official communication in DWDM system

Signals in the proposed system are transmitted across the same cable over several channels. At the receiver, the signal in each channel is filtered through a band-pass filter based on various carrier frequencies. The light wave is taken as the carrier wave of the signal, according to the different frequencies of light waves in various channels. Additionally, the design presented in this paper adopts the wavelength division multiplexer for the sending end to integrate signal light carrier waves with different wavelengths to transmit in the same optical fibre.

DWDM network management system

This paper considers a system which utilizes the existing DWDM network management system to manage the new DWDM system, which is responsible for the performance, fault, configuration, and security management of erbium optical fibre amplifier (EDFA), optical transform unit (OTU), optical terminal multiplexer (OTM), optical add drop multiplexer (OADM), and monitoring channel of each network element. The network

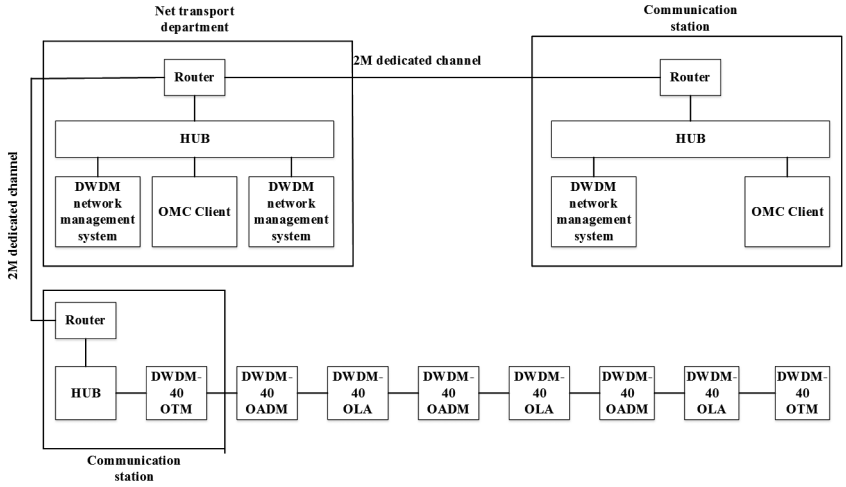


Fig. 1. DWDM network management system

management system transmits data through OSC and 2M/s private channel as a transmission and protection channel. The DWDM network management system is shown in Fig. 1.

Optical fibre distribution

Optical fibre connections in DWDM devices are mainly between the DWDM and SDH equipment, the disks, the optical channel sub-frame, and the optical amplification sub-frame. The fibre jumper requires the joint loss to be less than 0.5 dB, and return loss must be greater than 40 dB. The optical fibre connection between the DWDM and SDH devices has two parts. The first is the optical fibre connecting the output port of the STM transmitter and the input port of the wavelength converter of the DWDM device. The second is the optical fibre connecting the output port of the wavelength dividing device with the input port of the STM optical receiver. The optical cables of each disk on the optical channel sub-frame are correspondingly connected between the OTU disk and the OMU disk of the combiner.

4. RESULT ANALYSIS AND DISCUSSION

The transmitting optical power of the wavelength division system was tested to verify the effectiveness of the proposed system. The OTU configured in this paper was LWC. The test of OTU should close FEC, according to the instrument. The test was carried out according to the actual configuration of the project, using an optical power meter. For a test carried out at point s, a measurement error of less than 0.5dB was allowed, while testing on an ODF frame allowed attenuation less than 1.0 dB to be introduced. The test assumed one OTM in the 10^{th}, 12^{th}, 14^{th}, 15^{th}, 24^{th}, and 30^{th} waves of node configuration of OTM. Test data are shown in Table 1.

Experimental results showed the system is highly efficient in plan management of route, delay, accidents and other emergency contact information, location management of transport vehicles distributed in each terminal, loading conditions of running vehicles, and operating instruction information.

Table 1. OUT (LWC) transmit optical power

Work serial number	Nominal centre wavelength (nm)	Transmit optical power (dBm)	Conclusion
10	1551.72	-6.84	Pass
12	1500.12	-7.18	Pass
14	1548.51	-7.94	Pass
15	1547.72	-7.42	Pass
24	1540.72	-7.6	Pass
30	1535.82	-6.36	Pass

5. CONCLUSION

The rapid development of information, machinery, electronics, and other technologies has made logistics a technology, which integrates mechanical design, information technology, management, and communication control technology. This paper presents a design of a logistics transportation system based on optical fibre communication technology by utilizing DWDM technology. The system adopts the device light of DWDM to monitor official bytes in the channel in order to realize official communication. Furthermore, it utilizes the existing DWDM network management system to manage new DWDM systems. This system shows high efficiency in location management of logistics transportation vehicles, loading conditions of operating vehicles, and operating instructions. Contradictions, such as delayed logistics periods, complex processes, increased cost, and tedious inventory management are avoided, further enhancing competitiveness of logistics service. However, the author's major limits understanding of the overall logistics system formed by upstream and downstream industry chains. Hence, the solution proposed in this paper can be further expanded.

ACKNOWLEDGEMENT:

The work presented in this paper is supported by two research project. One is Social Science Planning Program for the Youth of Fujian Province, The Comparison Analysis of Construction Experience Between Fujian FTA and Shanghai International Shipping Centre (FJ2015C129), the other is An Analysis of Fujian FTA Harbor Logistics Competitiveness -Wisdom Logistics (FJ2015C131) Colleges and Universities Exceptional Young Scientific Research Talents Plan (Fujian Education Science Issue No.2015[54]).

REFERENCES:

1. Chen Yuan, Zhang Jing. Research on the model of dangerous goods logistics system based on RFID. technology GPRS packaging engineering, 2008. V29, #5, pp. 78–80.

2. Xu Shengli, Wang Shiqing. Design of logistics information system based on GIS technology. computer engineering and design, 2010. V31, #6, pp. 1259–1263.

3. Yang Xinting, Qian Jianping. Intelligent distribution system of agricultural product logistics process. Journal of agricultural machinery. 2011. V42, #5, pp. 125–130.

4. Wu Xuejun. Research on remote monitoring system of logistics transport vehicle based on wireless sensor network. logistics technology, 2013. V31, #12, pp. 426–428.

5. Ma Jiang. Research on temperature control system of meat cold chain logistics. technology RFID logistics technology: equipment edition, 2014. #7, pp. 69–72.

Dan LIU,
Master of Logistics Engineering, Lecturer, Graduated from Fuzhou University, Employer: Fuzhou University of International Studies and Trade

Xiaozhen JIANG, Master of International Business, Lecturer/ Intermediate Economist Title, Graduated from Grenoble Graduate School of Business (France) Employer: Fuzhou University of International Studies and Trade

Renqiang XIE,
Master of Public Management, Associate Professor, Graduated from Fujian Agriculture and Forestry University Employer: Fuzhou University of International Studies and Trade

Jie ZHU,
Master of Logistics Engineering, Associate Professor, Graduated from Fuzhou University Employer: Fuzhou University of International Studies and Trade

Light & Engineering
Vol. 24, No. 3, pp. 28-31, 2016

Svetotekhnika
No. 5, 2016

EXTRACTION OF CHARACTERISTIC OF FREQUENCY RESPONSE CURVES IN LED VISIBLE LIGHT COMMUNICATION SYSTEMS

Yancheng JI, Junma LI, Guoan ZHANG*, and Zhanghua CAO

School of Electronics and Information, Nantong University, Nantong, Jiangsu, China
**E-mail: guo_anzhang639@126.com*

ABSTRACT

In recent years, visible light communication technology has been developed well as an emerging wireless optical communication technology. This study investigates the characteristic curves of the frequency response in a light-emitting diode (LED) visible light communication system to improve its frequency response and expand its bandwidth. This study adopts the square-wave pulse modulation method to test the frequency response characteristics of the sample. After comparing the frequency response curves and bandwidths of the device under different bias currents, the step-shaped electron blocking layer LED is found helpful in improving the density of carrier injection in the active area and LED response characteristics.

Keywords: LED, frequency response, square-wave pulse modulation, visible light communication system

1. INTRODUCTION

In optical fibre communication, semiconductor light-emitting diode (LED) is one of the most commonly used light sources suitable for short-distance and low-capacity systems. With the rapid development and wide application of LED in recent years, experts and scholars have focused increasing attention and efforts on research on fluorescent LED response characteristics to explore the new function of fluorescent LED through LED response characteristics. Chen [1] conducted a sinusoidal modulation of incident infrared radiation intensity in 1985. He recorded the signal voltage from the detector and performed normalization. The relative frequency response characteristics of the detector were then obtained. Wang studied forward electrical and luminous characterization in 2006. Yang investigated the frequency response of white-light LED. He analyzed the effects of intrinsic modulation bandwidth and parasitic parameter on bandwidth, which improved the modulation response characteristics of resonant-cavity LED. Tan et al. [2] calculated the frequency response of the communication channel through the channel impulse response (CIR). He used numerical methods to conduct simulation on indoor CIR and frequency response. The results showed that the widest bandwidth could be found at the centre of the room. Yang measured the frequency response characteristic curve of LED using a spectrometer. However, inductive effects occurred in the traditional electron blocking layer (EBL) and led to band bending, which could not effectively prevent the spill of electron. A large boundary defect could easily occur. In addition, the radiation recombination efficiency of the electron hole pair decreased because of the uneven distribution of carrier injection, which eventually affected the response time and radiant power of the LED.

The present study investigates the characteristic curves of frequency response in a LED visible light communication system to improve the frequency response of fluorescent LED and increase its bandwidth. The second section introduces several characteristics of LED and its luminous mechanism. The third section uses the square-wave pulse modulation method to test the response characteristics of two samples and further compares the 3 dB fre-

quency response curves and bandwidths of the device under different bias currents. In the fourth section, a simulation verification and analysis of fluorescent LED are performed, and the conclusion of the study is presented.

2. STATE OF THE ART

Visible light communication system

Visible light communication technology is used to transmit information through the invisible, high-speed flashing light emitted from a fluorescent tube or LED. The technology connects a high-speed Internet cable to lighting devices to ensure that the device will work when the plug is used. A visible light communication system has bright prospects in terms of its development because its range covers indoor lighting.

Characteristics of LED

In Volt–Ampere characteristic, the current flowing through the *p–n* junction is changed with voltage, which can be directly reflected on the oscilloscope. Complete Volt–Ampere curve has forward and reverse characteristics [3]. In general, the current index will increase when voltage reaches a certain threshold. The Volt–Ampere characteristic curve is frequently described using three parameters: reserve breakdown voltage, reserve current, and forward voltage.

P–I characteristic: The I–V characteristic of LED indicates that the current changes with voltage, which is similar to the curve of a common diode [4]. At the beginning, current is absent when voltage is low, and the forward voltage is less than a certain value. The forward current increases with voltage and light glows when the voltage is larger than a certain value. I–V curve is not linear after the break over. Therefore, the forward voltage cannot be excessively high; otherwise, the large current will significantly increase heat and damage the diode.

Modulating characteristic, in which the electric signal becomes an optical signal when it is loaded into the LED light source. The modulating characteristic of LED has two problems: one is linearity and the other is bandwidth [5]. The nominal output power can be represented by the following formula:

$$p(w) = \frac{p(0)}{\sqrt{1+(w\tau)}}. \qquad (1)$$

Frequency response

The frequency effect characteristic of LED is an important part of a visible communication channel. It determines the effective bandwidth of the signal and influences the transmission performance of a visible light communication system. Frequency response describes the capability of an amplifying circuit under different frequency sinusoidal signals. That is, the amplitude of the input signal is constant, whereas signal frequency is changing. The changes in the amplitude of the output signal and the phase position are investigated. This method is known as the frequency domain method. In circuit amplification, coupling and bypass capacitors on the sign form the high-pass circuit. At this time, the signal can be passed without any loss. However, a pressure drop will occur on the capacitive reactance of the clamped capacitance when the signal frequency is sufficiently low, which results in a small amplification value and a phase shift. In addition, contrary to the coupling capacitor, a low-pass circuit is formed by the inter-electrode capacitance and the distributed capacitance of the semiconductor tube, which indicates that no impact occurs in the low-frequency signal and the circuit. However, the shunt of the inter-electrode capacitance will reduce amplification and phase shift when the signal is sufficiently high.

3. METHODOLOGY

Test methodology

This study uses a square-wave pulse modulation method to test the response characteristics of LED, which adds a certain direct current bias to a small sinusoidal signal. The testing devices include an AFG3101 function signal generator, a TSD2040 oscilloscope, a TCP312 100 MHZ high-frequency current probe, a New Focus 16011 GHz high-speed photoelectric detector, a ZFBT-4R2GW+0.1–4.2 GHz bias, and an LWD-QGS PS303PM direct current bias power supply.

LED frequency response characteristics

This study compares the 3 dB response curves and widths of the devices under different bias currents to obtain the response characteristics of fluorescent LED. The influence of the internal capacitance of the device is reduced because of the pre-bias. Fig. 1 presents the response curves of the conventionally structured LED and the step-

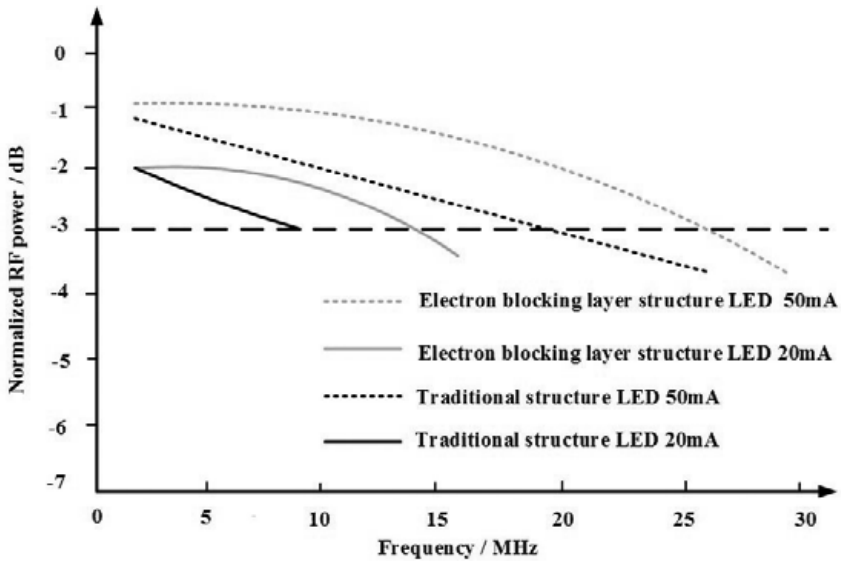


Fig. 1. Response curve of the traditional structure LED and the step shape electronic barrier structure LED

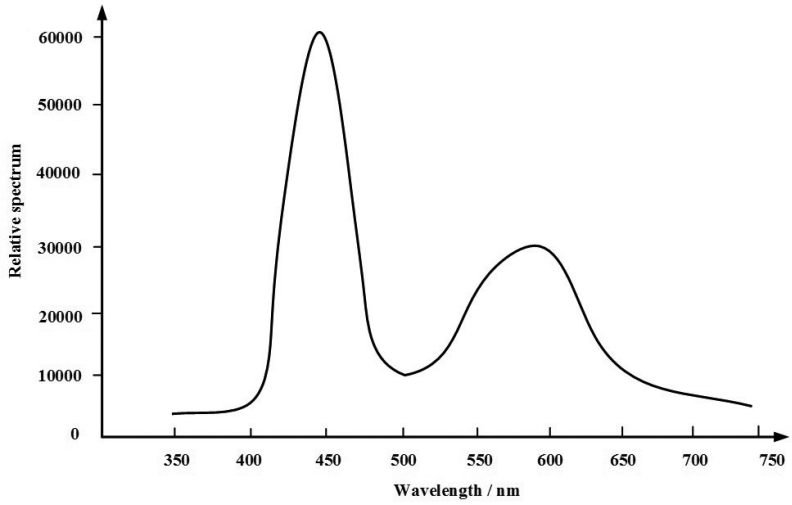


Fig. 2. Spectra of commercial white LED lamp

shaped EBL under 20mA and 50mA. The latter is flatter than the former in terms of frequency range, thereby indicating that the step-shaped EBL outperforms the traditionally structured LED in terms of frequency characteristics.

The corresponding bandwidth of the step-shaped EBL LED under 20–50mA bias current is higher than that of the traditionally structured LED. The step-shaped EBL LED can improve the hole injection rate to obtain a higher hole injection density under the same current in the active area. Meanwhile, it effectively limits electron overflow and ensures a relatively large bias injection current density under a high bias current in the active area. At this time, the corresponding bandwidth is higher. In the comparison of the optoelectronic characteristics between the traditionally structured LED and the step-shaped EBL LED, the latter is found more effective in improving the density of the injection carrier in the active area. The step-shaped EBL LED does not only improve the response characteristics of the fluorescent LED, but also increases its optical power output.

4. RESULT ANALYSIS AND DISCUSSION

This study performs an experiment on fluorescent LED. The testing equipment includes an AvaSpec-2048-USB2 spectrograph, an Ocean Optics HR2000 spectrograph, and a commercial white LED lamp. During the experiment, the commercial fluorescent white LED was initially turned on. Then, its light source was ensured to be oblique to the light probe of the AvaSpec-2048-USB2 spectrograph. Subsequently, the distance between the light source and the probe was adjusted. Then, the spectrum on the computer was observed, and data were recorded. The spectrum is presented in Fig.2.

As shown in Fig. 2, the two peaks of the commercial white LED lamp are 450 nm and 560 nm. Accordingly, the commercial white LED lamp is composed of a blue LED chip coated with YAG yellow phosphor, which is a common practice. Therefore, white light can be used as a lighting

source, although a significant difference with the sun still exists.

5. CONCLUSION

The frequency response characteristic of LED is an important part of the visible channel of information. It obtains the effective signal bandwidth while determining the minimum pulse width of the high-speed pulse light, thereby affecting the transmission performance of the visible light communication system. This study adopts a square-wave pulse modulation method to test the frequency response of traditional EBL fluorescent LED, improve its frequency response, and enlarge its bandwidth. The 3 dB response curves and bandwidths of the devices are compared under different bias currents. The result shows that both the step-shaped EBL LED and the traditional LED exhibit improvements in terms of luminous power and response characteristics. The EBL step-shaped LED is more helpful in improving the density of carrier injection in the active area than the traditionally structured LED. It improves response characteristics while increasing optical power output. Optimizing EBL and improving carrier injection characteristics are evidently effective means to improve fluorescent LED response characteristics. However, this study has limitations, and fluorescent LED applications still require further research.

REFERENCES:

1. Chen Rujun. The frequency response of infrared detector using infrared light emitting diode is infrared technology, 1985. V5, #8.

2. Tan Jiajie, evergreen. Analysis of channel characteristics of indoor polycyclic. LED Journal of system simulation, 2013. V25, #12, pp. 2906–2911.

3. Wang Y, Wang Y, Chi N, et al. Demonstration of 575-Mb/s downlink and 225-Mb/s uplink bi-directional SCM-WDM visible light communication using RGB LED and phosphor-based LED. Optics express, 2013. V21, #1, pp. 1203–1208.

4. Almeida P S, Bender V C, Braga H A C, et al. Static and dynamic photoelectrothermal modeling of LED lamps including low-frequency current ripple effects. Power Electronics, IEEE Transactions on, 2015. V30, #7, pp. 3841–3851.

5. Bialic E, Nguyen D C, Vaufrey D. LED dynamic electro-optical responses and light-fidelity-application optimization. Applied optics, 2014. V53, #31, pp. 7195–7201.

Yancheng JI,
Doctor of communication and information system, Graduated from the Xidian University. He is currently an Associate professor at the School of Electronics and Information, Nantong University

Junma LI,
Master Candidate of Information and Communication Engineering. Graduated from Nantong University

Guoan ZHANG,
Doctor of communication and information system, Graduated from the Southeast University. He is currently a Professor at the School of Electronics and Information, Nantong University

Zhanghua CAO,
Doctor of Mathematics, Graduated from the Yangzhou University. He is currently an Assistant Professor at the School of Electronics and Information, Nantong University

Light & Engineering
Vol. 24, No. 3, pp. 32-35, 2016

Svetotekhnika
No. 5, 2016

DESIGN OF A NOVEL UAV BASED ON SHORT-DISTANCE LED VISIBLE LIGHT COMMUNICATION TECHNOLOGY

Wei LIAO[1,*] and Yan XU[2]

[1] Shanghai University of Engineering Science, Shanghai 201620, China
[2] College of Applied Science, Jiangxi University of Science and Technology, Ganzhou 341000, Jiangxi, China
**E-mail: weiliaosr235@163.com*

ABSTRACT

The existing UAV search methods are affected by the environment and algorithms, associated with high costs and complex operation. For these reasons, this paper presents a design of designs a new type of UAV based on short-distance LED visible light communication technology. The Egli model is selected as the model of wireless communication. In addition, an MSP430F149 chip is the main control chip, and an RFC33A module with low power consumption is utilized as the wireless communication module. The results show that this system can accurately locate a person in distress, and return the information to the ground station in real time, so as to greatly improve the rescue efficiency.

Keywords: unmanned aerial vehicle (UAV), wireless communication, whip antenna, optical fibre communication

1. INTRODUCTION

With the development of science and technology, UAVs have rapidly risen as an emerging industry. By virtue of their features of unmanned operation, portability, small size and low requirements for climate conditions, as well as rapid takeoffs and landings, UAVs have been widely utilized in search and rescue operations. The utilization of UAV search systems can greatly improve search scope and capability, while also reducing search costs. Liu Gequn designed the hardware of a small UAV flight controller on the basis of an 80C196KC single chip microcomputer and a programmable microcontroller peripheral device PSD813F1 in 2013 [1]. Zang et al. introduced the composition of remote sensing system and designed the technological process of a remote sensing monitoring of micro UAV in 2010 [2]. Yue Jilong et al. analyzed the key technologies of the micro electro mechanical system, nonlinear system modelling and flight control in 2010 [3]. In 2011, Luo Qiufeng et al. utilized integrated instrument technology and anti-interference technology to successfully develop an automatic detection system based on a PXI bus. Wang Jian et al. designed a real-time video surveillance system based on WiFi in 2015 [4]. However, the existing airborne detector is mainly depending on infrared imaging, image recognition and aerial photography and other optical equipments. The search method is also influenced by the environment and its own algorithm. Most systems exhibit the shortcomings of high cost, large volume of locator beacon in danger, and complex operation. UAVs are characterized by unmanned operation, portability, small size and low lost [5]. Satellite positioning technology and wireless communication technology are less seriously affected by environment. Therefore, this paper designs a new type of UAV based on short-distance LED visible light communication technology, by utilizing electronic information technology and short-distance wireless communication technology. This study provides a new method and way of thinking for the design of airborne equipment of

technique in searching for persons in outdoor distress by unmanned air vehicle in China.

2. STATE OF THE ART

Short whip antenna

As one of the main components of wireless communication, antennas play an important role in the communication performance of wireless communication. High gain antennas can increase the communication distance without the need for additional transmitted power or transmission loss. The common short wave or ultra short wave portable radio antennas are all whip antennas. Whip antennas are basically single-stage antennas, which evolved from symmetric dipole antennas. A single-stage antenna, with a length of h, can be mirrored as a symmetric oscillator. The field of the upper half space of the single-stage antenna is the same as that of the symmetric oscillator. The field intensity of the lower half space is zero, and the electric field intensity of the single-stage antenna is as follows:

$$\begin{cases} E(\Delta) = j\dfrac{60 I_M \cos(kh\sin\Delta) - \cos kh}{\cos\Delta} e^{-jkr}, \\ E(\Delta) = 0, -\pi < \Delta < 0 \\ 0 \le \Delta \le \pi \end{cases} \quad (1)$$

where I_M is the oscillator current, r is the distance, and k=2π/λ. Δ represents the horizontal elevation of the test point. h is the length of antenna single stage. Supposing that r is a constant, the unnormalized direction function (Δ) can be obtained as follows:

$$f(\Delta) = \frac{|E(\Delta)|}{\dfrac{60 I_M}{r}} = \frac{\cos(kh\sin\Delta) - \cos kh}{\cos\Delta}. \quad (2)$$

According to the above formula, the normalized pattern function of F(Δ) is:

$$F(\Delta) = \frac{f(\Delta)}{f_M}, \quad (3)$$

where f_M is the maximum value of $f(\Delta)$.

The purpose of a short whip antenna is mainly to shorten the length of the whip antenna. At the same time, an inductor is added at the base of whip antenna to compensate for the capacitive reactance. Inductance can be achieved by means of the coil of the whip antenna. Therefore, a short whip antenna possesses the same performance as a whip antenna. In addition, short whip antennas are widely used for their low price and ease of purchase.

Egli Model

The Egli model is mainly suitable for ultra short wave mobile communication, as well as VHF and UHF communication. When the communication distance is less than 30 km, the frequency is between 40 and 450 MHz. As the frequency is less than 1 GHz, the Egli model can more accurately predict the field strength of hilly and mountainous terrain.

$$L_M(dB) = 88 + 401gd + 201gf - \\ - 201g(H_t \times H_r) - Kh. \quad (4)$$

Where L_M is the median path loss, d is the distance between the receiving and transmitting antennas, and f is the operating frequency of short-range wireless communication. H_1 is the transmitting antenna height of the transmitter, H_r is the receiving antenna height of the receiver, and Kh is a topographic correction parameter factor.

With the increase of communication distance, the path loss of each frequency will increase. Higher operating frequency will lead to greater path loss. As can be seen from the comparison, the Egli model can better conform to the actual needs of field communication.

RFC33A Module

The RFC33A module is embedded with an nRF905 single-chip RF transceiver chip. The nRF905 chip is internally installed with various functional modules, such as a frequency synthesizer, power amplifier, crystal oscillator and modulator. In this paper, the RFC33A module is equipped with a power amplifier circuit based on an original nRF905 peripheral circuit, to improve the transmitting power, and the actual communication distance reaches up to 2000 m.

Formula (5) can be obtained from Formula (4) as follows:

$$L_M(dB) = 33dBm - (-100dBm) = \\ = 88 + 401gd + 201gf - 201g(H_t \times H_r) - Kh. \quad (5)$$

Table 1. Communication distance between the wave airborne detector and the ground station

Times	1	2	3	4	5	6	7
d/m	8.0	9.0	9.5	9.7	10.0	10.3	10.5
Signal	Great	Great	Great	Great	Good	Good	Bad

As an RFC33A module is utilized in this paper, the MSP430 mainly exchanges data through the serial peripheral interface SPI and RFC33A wireless communication module. In addition, considering the influence of antenna gain on communication distance, a 430 MHz short whip antenna is adopted.

3. METHODOLOGY

System hardware design

The hardware equipment in the UAV search system mainly includes the airborne detector and rescue beacon. The system diagram of the UAV search system is shown in the Fig.1.

The airborne detector mainly includes the master control module, wireless module and power module. The master control module adopts an MSP430F149 chip. The wireless communication module utilizes an RFC33A module with an nRF905 chip, and carries out communication through the SPI interface and MSP430. The power module utilizes a voltage stabilizing circuit and voltage reduction circuit, and the power supply rechargeable lithium polymer batteries continue to provide a 5V voltage. For the power supply a rechargeable lithium polymer battery is adopted, which can continuously provide a 5V voltage. The hardware design of the beacon mainly includes the master control module, wireless communication module, positioning module, beacon module and power module. The master control module adopts an MSP430F149 chip, an RFC33A module is purchased for the wireless communication module, the positioning module utilizes a GPS module with GSl5-C, and the power module adopts voltage stabilizing circuit and circuit, among which a rechargeable lithium battery is utilized for the battery.

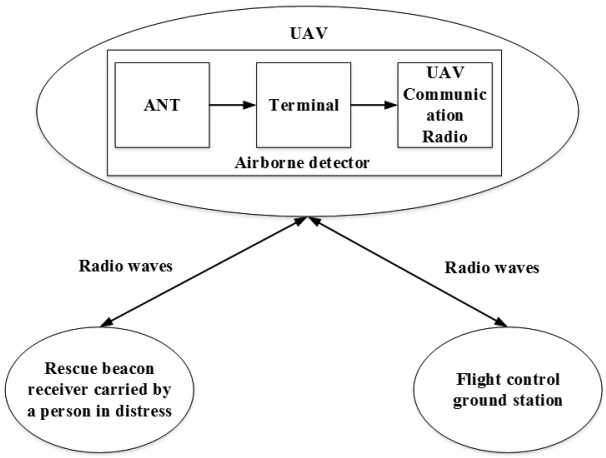


Fig. 1. System diagram of the UAV search system

System software design

The airborne detector and the rescue beacon machine transmit and exchange information through a wireless module. Therefore, the communication protocol between the two should be controlled to carry out information transmission.

The airborne detector is equipped with two serial ports. First, the communication is realized by sending the module and flight control ground station to obtain the configuration information of the search system and identification code range. Second, when the search is carried out, the rescue beacon machine carried by the person in distress is activated by transmitting the activation information through radio waves, so as to carry out data interaction. Afterwards, the obtained data are analyzed to extract the relevant data. Finally, the receiving module is transmitted to the UAV Communication Station, and is eventually passed on to the flight control ground station.

4. RESULT ANALYSIS AND DISCUSSION

In order to verify the effectiveness of the system, this study carried out an experiment under indoor temperature. The adopted output voltage was 11.1~12.6V, and a battery with a capacity of 1500 mA·h was utilized to supply power for the eight tests. The test results are shown in the Table 1.

Table 1 shows the communication distance between the airborne detector and ground station in the open field test. As can be seen from the results, the index test and field test indicate that

the airborne detector achieved the target design requirements. It was able to accurately locate the person in distress and send the information to the ground station in real time, so that the rescuers could quickly reach the distress area. This design improves the deficiency of low research efficiency and the poor results of existing search and rescue systems, and achieves the purpose of searching for persons in field distress.

5. CONCLUSION

The vigorous development of outdoor adventure and mountaineering leads to frequent accidents. Most of the existing search methods for persons in field distress rely on human ground search, with additional general aviation eye observation. There is great difficulty in search and rescue, and the rescue results are not ideal. Therefore, this paper designed a new type of UAV based on short-distance wireless communication technology. The rescue beacon in the system realizes automatic mode conversion function, simple and practical input- output interface, and ease of operation. In addition, the design airborne detector resolves the problems of ambiguous location information of the search target, as well as the missed and erroneous judgments obtained through human eye observation. The design improves the deficiency of low research efficiency and poor results of existing search and rescue systems, and achieves the purpose of searching for persons in field distress. However, since wireless communication is affected by terrain factors, further research must be carried out to improve the communication distance between the airborne detector and ground station.

ACKNOWLEDGEMENT:

The research is supported by Science and technology research project of the Education Department in Jiangxi Province in 2015(GJJ151521).

REFERENCES:

1. Liu Gequn. Hardware design of flight controller for small UAV. computer measurement and control, 2003. V11, #2, pp. 144–146.

2. Zang ke, sun YH, Li Jing, et al. Miniature UAV remote sensing system in Wenchuan earthquake application. Natural disasters journal, 2010. V19, #3, pp. 162–166.

3. Yue Jilong, Zhang Qingjie, Zhu Huayong. Research progress and key technologies of Micro Four rotor UAV. electro optic and control, 2010. V17, #10, pp. 46–52.

4. Qiu Feng Luo, Qian GUI Xiao, Yang Liuqing. UAV automatic detection system design and implementation. Chinese Journal of scientific instrument, 2011. V32, #1, pp. 126–131.

5. Liu M, Wang H. Research on Agriculture Survey and Evaluation UAV Navigation System. INMATEH – Agricultural Engineering, 2013. V41, #3, pp. 31–38.

Wei LIAO
received D.E. degrees from East China Normal University, Shanghai, China, in 2007 and 2010, both in communication and information system. She currently works as a Lecturer at School of Electric and Electronic Engineering, Shanghai University of Engineering Science, Shanghai, China. Her research interests include wireless communication networks and biomedical EMC

Yan XU
received the D.E. degrees in photoelectric information engineering from Huazhong University of Science and Technology, Wuhan, China, in 2012. She currently works as a Lecturer at College of Applied Science, Jiangxi University of Science and Technology, Ganzhou, China. Her research interests include laser precision measurement, computer simulation, and data processing

Light & Engineering
Vol. 24, No. 3, pp. 36-39, 2016

Svetotekhnika
No. 5, 2016

DESIGN OF LED VISIBLE LIGHT REAL-TIME VIDEO TRANSMISSION SYSTEM BASED ON FPGA

Yu JING* and Yaan LI

School of Marine Science and Technology, Northwestern Polytechnical University, China
**E-mail: yujingnp537@sina.com*

ABSTRACT

This study aims to establish a FPGA-based Light Emitting Diode (LED) visible light real-time video transmission system through the combined functions of white-light LED illumination and communication. AGC circuits and amplitude limiting were used to enhance the dynamic range of the system, thereby ensuring the stability of audio frequency transmission. Array reception was applied to ensure sensitivity, and a front low-noise high-gain amplifier was designed. Experimental results proved the feasibility of the new FPGA-based system to provide undistorted performance for visible light audio frequency transmission.

Keywords: visible light communication, white light LED, video transmission

1. INTRODUCTION

With the popularization of WiFi in modern society, wireless communication has become a new focus of research. One of the hot topics of wireless communication research is information transmission using illumination LED lights as a communication base [1]. White light LED exhibits high brightness, long service life, and low energy consumption; these light sources are small, environment friendly, and very sensitive and adjustable to signal [2]. Hence, LED light can be used for lighting and wireless light information transmission, the latter has become a popular wireless technology [3]. Our study uses LED visible white light for indoor short-distance audio transmission. These lights were chosen for their large divergence angle and security in large-range transmission. LEDs are also highly adjustable, making it possible to modulate audio signal into LED visible light for transmission. Such transmission is not reliant on infrastructure, which effectively reduces the operating costs and time for construction of infrastructure. Additionally, electromagnetic radiation to the surroundings can be minimized. This system exhibits high speed, good reliability, excellent security, and low energy consumption and is thus suitable to achieve "Green Communication."

2. BACKGROUND TO THE SYSTEM

The theoretical foundation of visible-light communication systems is the use of LED visible white light as the light and signal source. Spherical wave approximation is conducted for LED visible white light in accordance with the transmission rules of visible light in the atmosphere. The Maxwell equations are then used to establish the following expression for spherical light wave transmission [4]:

$$E(r,t) = \frac{E_0}{r}\exp\left[j\left(kr - \omega t\right) + \Psi_0 \right]. \qquad (1)$$

In this expression, the wave source electric field intensity is E_0; the angular frequency of the light wave is ω ($\omega = 2\pi v$, $v > 0$); time is t; the wave vector (or wave number) in the direction of light transmission is k ($k = 2\pi / \lambda$); the space coordinate is r; and the initial phase is Ψ_0. The equation implies

that an increase in the divergence angle can facilitate light signal reception. If the transmission signal is heavily weakened and the wave length of the light wave is very short, visible light will scatter, resulting in signal loss.

According to the Rayleigh scattering law, the attenuation coefficient of the incident light wave can be calculated as [5]:

$$a_m(\lambda) = \frac{8\pi^3}{3} \times \frac{\left(n^3 - 1\right)^2}{N\lambda^4} \times \frac{6+3\sigma}{6-7\sigma} \qquad (2)$$

In equation (2), λ is the wave length of the incident light; N is the molecular number in unit volume; n is the refractive index of the particle; and σ is the polarization factor.

The scattering consists of two patterns: forward scattering and back scattering. Each pattern occupies half of the total scattering. The coefficient obtained with the above equation is in reverse proportion to λ^4, which will result in heavy loss of short-wave visible light, thereby considerably decreasing the quantity and capacity of communication [6]. Therefore, related technological methods should be adopted to reduce the influence of Rayleigh scattering and background light to improve the communication performance of the system.

3. METHODOLOGY

System components

The short-distance white LED visible light audio transmission system is composed of an LED visible white light source, a visible light transmitting module, a photoelectric detector, and a visible light reception module. The transmitting module circuit transfers the candidate audio signal to the visible light. The electric signal is transformed into light signal through the drive circuit in the LED light; the light signal is then transmitted into the atmosphere as a light beam, which is received by the aforementioned detector; the received light signal is then transformed back into the electric signal, which can be reinterpreted into audio information by using a series of processes, such as amplification and shaping of the electric signal [7].

Design of the visible light transmitting module

The transmitting module of visible light can produce a specific kind of pulse signal (namely, PWM pulse), which is adjustable. In the present study, the brightness of LED visible white light is modified and stabilized through these PWM pulse signals. One advantage of this design is that the light switches are controlled in line with the space occupation of different frequencies; that is, when the frequency reaches a certain level, the LED will be switched on to work with sufficient current. If the frequency is insufficient, the LED will be switched off and no current flows through it [8]. The frequency of PWM is set to 100 kHz to reduce audible noise surrounding the LED driver caused by output capacitance. When the frequency of the audio signal is conversed and the tone is modified, the interaction between pulse and constant current is applied to ensure transmission stability.

Design of visible light reception module

The operating principle of the reception module is as follows. The reception module recovers and utilizes information from the light signal transmitted to the receptor through wireless technology based on the premise of minimum noise and distortion. The reception module should be designed with emphasis because the reception affects the function of the entire system. The reception module is made of many components, including the photoelectric detector [9].

Photoelectric detector is the core component of the reception module. For light signal reception, the photoelectric receptor needs to receive a signal with the specific properties of White light LED. Various properties of LED light should be considered when selecting a photoelectric detector. The detector should have sufficient spectrum range and scope to cover the range wavelengths of the transmitted white light [10].

Preamplifier restores the transformed light signal into electric signal through a diode. The level of the amplifier determines whether the signal can pass through the final output terminal. In designing the preamplifier, noise should be minimized and the amplifier should be capable of providing sufficient transmission gain within a certain bandwidth. According to the En-In noise model of the amplifier, the internal noise source of the reception module can be converted into the equivalent noise source of the preamplifier input terminal for further analysis. The noise coefficient F can be expressed as:

Fig.1. Audio and video transmission between two computers connected with a network cable

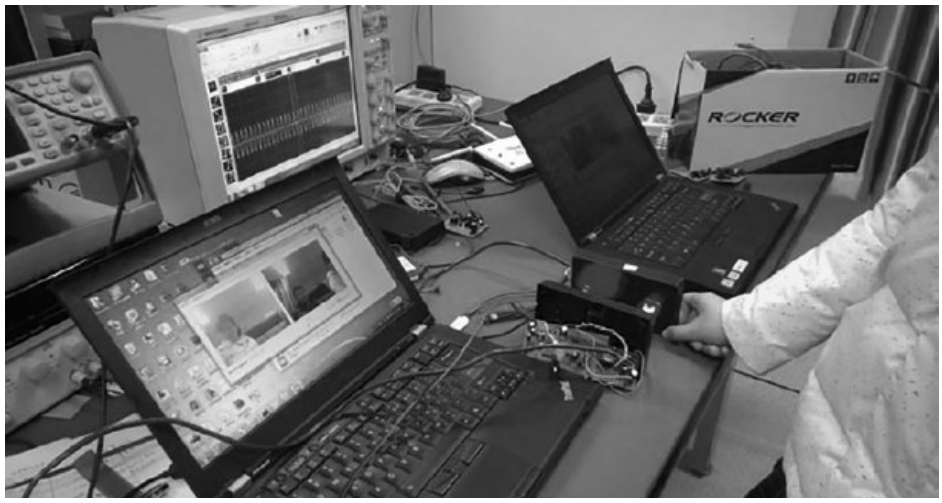


Fig.2. Two computers are connected by visible light module

$$F = \left(E_n^2 + I_n^2 R_S^2 + 4KTR_S \Delta f \right) / 4KTR_S \Delta f, \qquad (3)$$

where R_S is the internal resistance of the equivalent signal source; E_n and I_n are the noise voltage and current of the equivalent input terminal, respectively; K is the Boltzmann constant; T refers to absolute temperature; and Δf is the bandwidth of the noise. The derivative dF / dR_S of Equation (3) is calculated to obtain $R_{S0} = E_n / I_n$ and ensure optimal source resistance. This formula reveals that in the surrounding region of the optimal source resistance, the value of F is small, and can be regarded as the basis for selecting proper source resistance.

The photoelectric detector can be equivalent to the signal source of extremely high source resistance and should be matched to high impedance load resistance to produce maximum gain. When the trans-impedance preamplifier reaches $R_{S0} \approx R_S$, the amplifier is ready for direct coupling. After coupling, new resistance will be created in the input and output port; this resistance is called the trans-boundary feedback resistance. The emergence of this resistance will lead to a connection negative feedback, which could produce voltage for stabilizing the circuit, facilitating bandwidth expansion, and increasing its own range of signal transmission. Trans-impedance amplification is obtained by an integrated operational amplifier. In this case, sufficient output voltage is produced to reduce the noise caused by electricity inductance in the second half of the transmission circuit.

4. RESULT ANALYSIS AND DISCUSSION

Connection with network cable

The key to network cable connection is to install an FPGA program on computers A and B, which are connected with the same network cable. The computers are then placed in the same

workgroup, with the IP address of computer A set to 192.168.1.134 and that of computer B is set to 192.168.1.134. The computers are then tested through the PING command to check their connection. When operating the preset transmitting program on computer A, the IP address of computer B is typed and "Start" is clicked to obtain the transmitting effect, Fig. 1. "End" is pressed to terminate the communication.

Computer–computer communication

As shown in Fig. 2, two visible light modules are inserted into the RJ45 connection slots of the computer and maintained aligned. When the two computers simultaneously operate the FPGA program, parameters should be set according to the above operation method. "Start" is clicked to begin communication. When the computers are connected by visible light modules based on internet interfaces, the transmitted video and audio progress is stable with good signal and no delay; this phenomenon is consistent with the network cable connection.

5. CONCLUSION

A short-distance transmitting system perfectly transmits videos through visible white-light LEDs. LED lights can realize high-speed broadband at low energy cost and provide a new solution for the insufficient transmission ability of limited broadband infrastructure. This solution can be also recommended for transmission of wide ranges and large frequencies of visible light. However, high-speed and undamaged light communication must be further investigated.

REFERENCES:

1. Grobe L, Paraskevopoulos A, Hilt J, et al. High-speed visible light communication systems. Communications Magazine, IEEE, 2013, V51, #12, pp. 60–66.

2. Yeh C H, Liu Y L, Chow C W. Real-time white-light phosphor-LED visible light communication (VLC) with compact size. Optics express, 2013, V21, #22, pp. 26192–26197.

3. Jovicic A, Li J, Richardson T. Visible light communication: opportunities, challenges and the path to market. Communications Magazine, IEEE, 2013, V51, #12, pp. 26–32.

4. Khalid A M, Cossu G, Corsini R, et al. 1-Gb/s transmission over a phosphorescent white LED by using rate-adaptive discrete multitone modulation. Photonics Journal, IEEE, 2012, V4, #5, pp. 1465–1473.

5. Cossu G, Khalid A M, Choudhury P, et al. 3.4 Gbit/s visible optical wireless transmission based on RGB LED. Optics express, 2012, V20, #26, pp. B501-B506.

6. Rajagopal S, Roberts R D, Lim S K. IEEE 802.15. 7 visible light communication: modulation schemes and dimming support. Communications Magazine, IEEE, 2012, V50, #3, pp. 72–82.

7. Wang Y, Wang Y, Chi N, et al. Demonstration of 575-Mb/s downlink and 225-Mb/s uplink bi-directional SCM-WDM visible light communication using RGB LED and phosphor-based LED. Optics express, 2013, V21, #1, pp. 1203–1208.

8. Rufo J, Rabadan J, Delgado F, et al. Experimental evaluation of video transmission through LED illumination devices. Consumer Electronics, IEEE Transactions on, 2010, V56, #3, pp. 1411–1416.

9. Yeh C H, Liu Y F, Chow C W, et al. Investigation of 4-ASK modulation with digital filtering to increase 20 times of direct modulation speed of white-light LED visible light communication system. Optics Express, 2012, V20, #15, pp. 16218–16223.

10. Wang Z, Yu C, Zhong W D, et al. Performance of a novel LED lamp arrangement to reduce SNR fluctuation for multi-user visible light communication systems. Optics express, 2012, V20, #4, pp. 4564–4573.

Yu JING,
Ph.D., University Lecture. Graduated from the Xidian University in 2010

Yaan LI,
Ph.D., Professor. Graduated from Northwestern Polytechnical University

Light & Engineering
Vol. 24, No. 3, pp. 40-43, 2016

Svetotekhnika
No. 5, 2016

STUDY OF AN ATMOSPHERE DETECTION MODEL BASED ON LED VISIBLE LIGHT ARRAY INFORMATION TRANSMISSION TECHNOLOGY

Feng JIANG* and Yunqing LIU

College of Electronic and Information Engineering, Changchun University of Science and Technology, Changchun, Jilin, China
**E-mail: yujingnp537@swina.com*

ABSTRACT

In recent years, air pollution has gained considerable attention from researchers. To conduct accurate monitoring of atmospheric aerosol and provide reference data for studies on atmospheric pollution, this study constructs an atmospheric sounding model based on LED visible light array information transfer technology. An atmospheric sounding model is constructed by utilizing modular structure to design software structure and simulation flow of simulation system. Experimental results show that this model can realize long-time and continuous observation, and achieve safety and stability.

Keywords: LED visible light array information transfer technology, atmosphere, extinction coefficient, aerosol

1. INTRODUCTION

As one of the elements of earth atmospheric composition, the rise in particle concentration of aerosol has had a significant impact on environmental pollution and health conditions. This impact has gained much attention in recent years. Therefore, studying spatial and temporal distribution of atmospheric aerosol optical parameters and understanding the mechanism for research of environmental pollution and climate change are necessary. Recently, Chinese and international experts and scholars have put forward various methods to detect atmospheric aerosol. In particular, research relevant to laser radar system has progressed. Zhou Jun et al. proposed an equation solution and data processing method for the detection of atmospheric aerosol in 1998 [1]. The structure and main technical parameters of two laser radar systems of L625 and L300 were presented. The achievements provided a theoretical basis for later research on laser radar detection. Qiu Jinheng et al. designed the multi-wavelength laser radar and applied the technology to the detection of high-level cloud and aerosol in the troposphere in 2003 [2]. The results indicated that the multi-wavelength laser radar had certain reliability for the detection of tropospheric aerosol. Pan Hao et al. utilized pulsed laser radar to detect dust-haze in Shanghai. In the detection, laser radar data inversion was adopted to obtain data on aerosol extinction coefficient in 2010 [3]. The practical results showed that pulsed laser radar could accurately detect aerosol with relatively high applicability. Jiang Haijiao et al. proposed that the discrete distribution of the laser radar ranging data was inversely proportional to the signal to noise ratio, and provided a calculation method for ranging accuracy [4]. The results indicated that this method could more accurately characterize the density of data. Zhang Chaoyang et al. utilized aerosol particle spectrum distribution and refractive index products obtained in aerosol monitoring sites, and adopted the aerosol lidar ratio calculated through Mie scattering method in 2013. Their study provided a theoretical guide for solving

the problem, in which the micropulse laser radar could not obtain the laser radar independently [5]. Bai Guangyu et al. adopted the dual-wavelength laser radar to obtain aerosol extinction coefficient, wavelength index, and moisture absorption growth factor in 2014 [6]. The results showed that laser radar could effectively collect haze aerosol parameters, and had broad application prospects. However, because of the strong scattering property of atmospheric aerosol particles in the visible light band, the radar is sensitive to the detection of such particles. At present, most radar systems are only suitable for continuous observations of short duration, and are unable to carry out continuous atmospheric observations for longer periods. Furthermore, the radar could only identify certain hazards. High cost also limits the application of radar.

To conduct accurate monitoring of aerosols in the atmosphere and provide data reference for the study of atmospheric pollution, this paper constructs an atmospheric sounding model based on LED visible light array information transfer technology. In the second section, the theory and technology of atmospheric sounding are introduced. The third section describes the design and implementation process of the atmospheric sounding model based on LED visible light array information transfer. In the fourth section, this model is simulated and tested. Finally, the fifth section provides the conclusions.

2. STATE OF THE ART

Atmospheric sounding, also known as meteorological observation, refers to the process and method of conducting individual, systematic, or continuous observation and measurement of meteorological elements or weather phenomena that represent atmospheric conditions and their changing processes, and to collate obtained records [7]. As an important branch of atmospheric science, atmospheric sounding detects the mystery of the atmosphere. Atmospheric sounding played a significant role in the development of atmospheric science and is considered a foundation of the field. It provides routine data for weather forecast, climate analysis, scientific research, and national economy. Atmospheric sounding is divided into surface meteorological observation, high-altitude meteorological observation, and professional meteorological observation.

Surface meteorological observation refers to watching closely and measuring atmospheric conditions on near-surface layer through vision or instruments. These phenomena include clouds, visibility, weather, pressure, temperature, humidity, wind, precipitation, evaporation, radiation energy, sunshine duration, depth of permafrost, snow cover, wire icing, among others.

High-altitude meteorological observation uses balloons, radio sounding detector, weather reconnaissance aircraft, meteorological rocket, meteorological radar, and satellites. These devices detect pressure, temperature, humidity, wind, and other elements of free atmosphere.

Professional meteorological observation is conducted based on the needs of the research, such as atmospheric pollution monitoring and agricultural meteorological observation.

The development of science and technology has allowed atmospheric sounding to achieve remarkable progress, which is indicated in the increased detection and rapid improvement of automation levels. Furthermore, more attention has been given to observation methods, design of observation network, and observation instruments. Direct detection and remote sensing technology coexist and exploit respective advantages through comprehensive utilization.

3. METHODOLOGY

LED visible light array information transfer

Based on the various principles of atmospheric scattering and absorption to laser, LED visible light array information transfer analyzes the echo signal of laser in the atmospheric transmitting process. This feature detects related information and characteristics of the atmospheric environment. LED visible light array information transfer plays a significant role in the study of atmospheric environmental monitoring because of its characteristics of high laser brightness, narrow pulse width, as well as similar wavelength and aerosol particle size. The working life of the device is longer than the traditional laser radar, which guarantees continuous operation of long-time atmospheric observation. Furthermore, its low energy ensures safety and stability of the observation equipment during operation, and realizes automatic operation of the system. Hence, better signal to noise ratio is achieved.

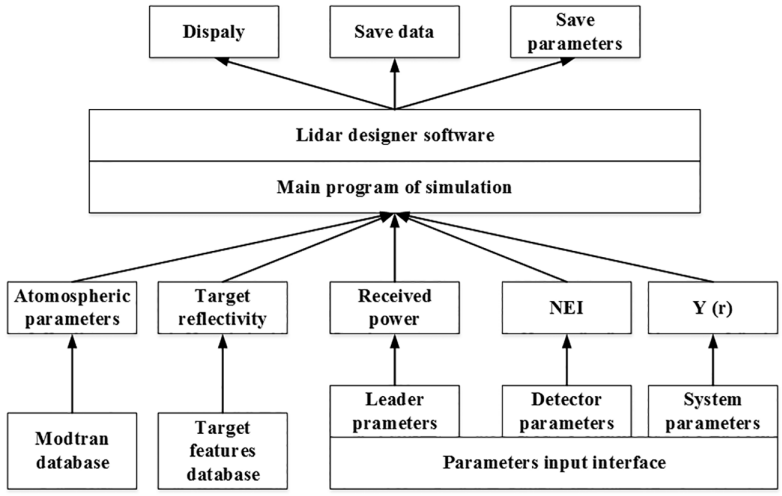


Fig. 1. Software structure of atmospheric detection model based on LED visible light array information transfer technology

Software structure design

Based on the characteristics of this model, this paper utilizes a stand-alone database-computing model to design the software structure. Atmospheric transmission adopts MODTRAN model database, and program development platform is C++Builder 5.0 and MATLAB6.1. The software structure of this system is shown in Fig. 1.

The program receives input system parameters according to noise and geometric overlap factors as well as the type of target and the parameters of the atmospheric environment. Then, the system utilizes the Modtran database and the target scattering characteristic database to obtain atmospheric attenuation and scattering coefficients. Through these coefficients, the main program adopts the Monte-Carlo method to simulate the received signal to noise ratio, detection probability, and intensity distribution of received signal after each laser emission.

4. RESULT ANALYSIS AND DISCUSSION

To verify the validity of this model, this study adopted an atmospheric sounding model based on LED visible light array information transfer. The device was used in conducting the detection experiment for regions within the third ring of the Chengdu urban area. The detected data were inversed, and the experimental results are shown in Fig. 2.

The figure shows that the extinction coefficient of the areas within the third ring in Chengdu began to increase gradually from 0300 hours and reached the maximum value at 1500 hours and then the extinction coefficient gradually reduced, and reached the minimum value at 2100 hours. The effects of sunlight on the surface of the earth caused the geothermal temperature to be relatively high, but surface heat begins to dissipate at night. In addition, according to the experiment presented this paper, the extinction coefficient of atmospheric aerosol was inversely proportional to the altitude of the detection area. That is, the extinction coefficient decreases with the increase in altitude. In this experiment, the aerosol extinction coefficient presented two peaks at the high altitude of 500 and 1000 m. The peak of the extinction coefficient at 500 m is affected by urban dust and tall buildings, which increased fine particles content in the air. The peak at 1000 m is caused by convection and transfer of aerosols at detected areas.

5. CONCLUSION

As one of the elements of the earth atmospheric composition, the rise in particle concentration of aerosol has a significant effect on environmental pollution and health conditions. Therefore, this study constructed an atmospheric sounding model based on LED visible light array information transfer technology and carried out simulation experiments. This model could realize all-weather automatic observation. The model is portable because of its small volume. The modular structure makes the system more compact, which ensures the stability of the system and the reliability of the detected data. Low reflection energy solves the safety problem in the operation of the detecting equipment,

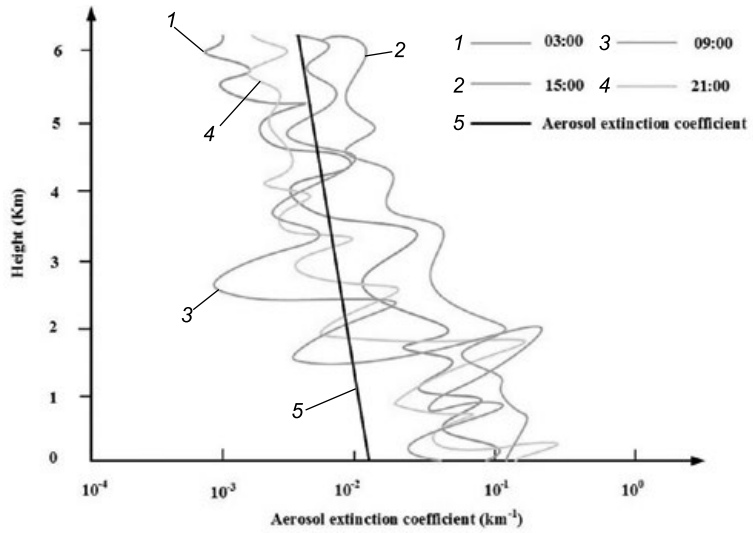


Fig. 2. Extinction coefficient of the average of 4 times a day in August 2015

which decreases the cost of atmospheric observation and improves its applicability and expansibility. However, because emission and reception share the same optical path, other problems might be caused, such as post pulse correction and determination of near-end filling function of the detector. Hence, future studies will aim to improve and perfect the model in view of these elements.

REFERENCES:

1. Zhou Jun, Yue Guming, Qi Fu, etc.Lidar detection of atmospheric aerosol optical properties. Chinese Journal of quantum electronics, 1998, V15, #2, pp. 140–148.

2. Qiu Jinhuan, Zheng Siping, Huang Qirong, et al. Laser radar for the detection of cloud and aerosol in the middle and upper troposphere of Beijing area. atmospheric science, 2003, V27, #1, pp. 1–7.

3. Pan Hu, Geng Fuhai, Chen Yonghang. Using the pulse laser radar analysis of a haze in Shanghai. 2010.

4. Jiang Haijiao, to build, Wang Chunyong, et al. Research on the characteristics of the laser range finder. China laser, 2011, V38, #5, pp. 229–235.

5. Zhang Zhaoyang, Su Lin, Chen Liangfu.Höfle B, Hollaus M, Hagenauer J. Urban vegetation detection using radiometrically calibrated small-footprint full-waveform airborne LiDAR data. ISPRS Journal of Photogrammetry and Remote Sensing, 2013, V67, pp. 134–147.

6. Bo Guangyu, Liu Dong, Wu Decheng Chioukh L, Boutayeb H, Deslandes D, et al. Noise and sensitivity of harmonic radar architecture for remote sensing and detection of vital signs. Microwave Theory and Techniques, IEEE Transactions on, 2014, V62, #9, pp. 1847–1855.

7. Brydegaard M, Gebru A, Svanberg S. Super Resolution Laser Radar with Blinking Atmospheric Particles——Application to Interacting Flying Insects. Progress In Electromagnetics Research, 2014, V147, pp. 141–151.

Feng JIANG,
Master, lecturer, Changchun University of Science and Technology, School of Electronics and Information Engineering, Changchun, Jilin, China

Yunqing LIU,
Professor, Changchun University of Science and Technology, School of Electronics and Information Engineering, Changchun, Jilin, China

Light & Engineering
Vol. 24, No. 3, pp. 44-47, 2016

Svetotekhnika
No. 5, 2016

STUDY ON THE INFORMATION ACQUISITION FROM STEREO IMAGES BASED ON A NOVEL CSS3D LIGHTING SYSTEM

Hongmei ZHU* and Yan PIAO

School of Electronics and Information Engineering, Changchun University of Science and Technology, Changchun, Jilin, 130022, China
**E-mail: hongmeizhu937@yeah.net*

ABSTRACT

As an advanced type of optical imaging technology, Stereo Imaging Technology has been applied in various fields. To obtain stereo imaging information in real time, this paper proposes a stereo imaging information acquisition method based on the CSS3D lighting system. The extraction principle of stereo imaging information was analyzed to ensure accurate extraction, and a full-frame sensor in black and white and designed with a doublet structure was adopted in this paper. Results show that this system improves image definition and resolution, and allows real-time acquisition of stereo imaging information.

Keywords: CSS3D lighting system, stray light, optical system, stereo imaging information extraction

1. INTRODUCTION

As a new type of optical imaging technology, stereo imaging technology can obtain multifaceted information of objects in the space. The development of this technology earlier started in Western countries where it was more mature. It has been widely used in pipeline detection, aerospace exploration, virtual simulation, and in other fields. In China, some achievements have been made in recent years, and they have been applied to many fields. Bai et al. [1] achieved dynamic panoramic digital image processing by using the systemic prototype based on the omnidirectional targeting imaging principle completed in a one-time effort. Zhao et al. proposed an ultra-high resolution panoramic optical annular imaging system, which allows swift correction of high-pixel panoramic annular images. Niu et al. replaced the traditional monolithic panoramic lens with the doublet structured lens and designed a new panoramic optical annular imaging system. Lu et al. [2], addressing the stray light problem of the panoramic annular lens, proposed a method to suppress the stray light reflected from the transmission plane. This method has high universality. Yao designed a PAL system by using free-form surface. Results showed that the system not only expanded the field of view but also greatly reduced the volume and weight of the system. Zhou et al. [3] employed the Q-type to design a non-spherical panoramic optical system that could run on visible light wave band. Results show that the detection accuracy of the system was effectively improved. However, a blind spot exists for the majority of optical imaging systems in the process of acquiring information: it is easily influenced by stray light and prone to distortion. Therefore, errors are present in most of the acquired information. Other disadvantages are also seen in the system. For example, the real-time monitoring can't be achieved, and the operation is difficult because of its heavy weight.

On the basis of the literature, this paper proposes a stereo imaging information acquisition method based on the CSS3D lighting system to obtain a wide panoramic image field of view and to gain real-time access to stereo imaging information. Section 2 is introducing the extraction principles for stereo imaging information and extraction accuracy. Section 3 details the design process of stereo imaging information acquisition method based on the CSS3D light-

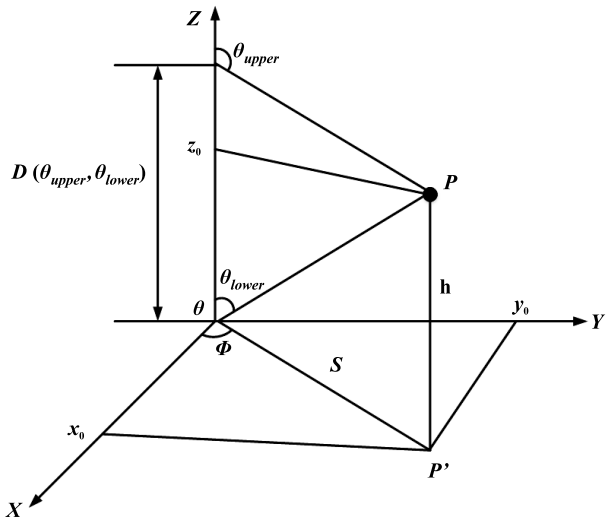


Fig.1. Point coordinates of the object by the use of triangulation method

ing system. Section 4 presents the simulation experiment of the system. Section 5 summarizes the paper.

2. STATE OF THE ART

Principle and accuracy of extracting stereo imaging information

In the process of extracting stereo imaging information, the system needs to be calibrated first to minimize error. Then, the interpolation method can be applied to process the image. Finally, the stereo imaging information can be extracted [4]. A simplified diagram of the system is shown in Fig. 1. The origin of a coordinate axis represents the entrance pupil of the annular lens imaging system unit [5]. Φ is the azimuth of P, θ_{upper} and θ_{lower} are the angles of field of view. S, h, and Φ represent the polar coordinate parameter. S and h can be calculated by the following formula:

$$\begin{cases} s = d\left(\theta_{upper}, \theta_{lower}\right) \cdot \dfrac{\sin\theta_{upper} \cdot \sin\theta_{lower}}{\sin\left(\theta_{upper} - \theta_{lower}\right)} \\ h = d\left(\theta_{upper}, \theta_{lower}\right) \cdot \dfrac{\sin\theta_{upper} \cdot \cos\theta_{lower}}{\sin\left(\theta_{upper} - \theta_{lower}\right)} \end{cases}. \quad (1)$$

Space coordinate $\left(x_0, y_0, z_0\right)$ can be calculated by

$$\begin{cases} x_0 = s \cdot \cos\phi \\ y_0 = s \cdot \sin\phi \\ z_0 = h \end{cases}. \quad (2)$$

As mentioned in the previous section, θ is the angle of field of view, $\triangle d\left(\theta\right)$ is the entrance pupil excursion, $r\left(\theta\right)$ is the radius, s is the distance between the space object and the optical axis of the system, and S0 represents the distance between a point on the space object and the optical axis of the system. In Fig. 2, S_1 and S2 are assumed to be two different boundary points. Then, the reciprocal of the distance between S2 and S1 can represent the spatial resolution of the system [6].

S1 and S2 can be represented by $S_1\left(\theta'_{upper}, \theta'_{lower}, d'\right)$ and $S_2\left(\theta'_{upper}, \theta'_{lower}, d'\right)$. The parameters of the two points can be calculated with the following formula:

$$\begin{cases} \theta_{upper}' = \theta_{upper} + d\theta_{upper} \\ \theta_{lower}' = \theta_{lower} - d\theta_{lower} \\ d' = d_0 + \triangle d\left(\theta_{upper}', \theta_{lower}'\right) \\ \theta_{upper}'' = \theta_{upper} - d\theta_{upper} \\ \theta_{lower}'' = \theta_{lower} + d\theta_{lower} \\ d'' = d_0 + \triangle d\left(\theta_{upper}'', \theta_{lower}''\right) \end{cases}. \quad (3)$$

Through the calculation of S_1 and S_2, the spatial resolving power $R\left(\theta_{upper}, \theta_{lower}\right)$ can be calculated as follows:

$$R\left(\theta_{upper}, \theta_{lower}\right) = \frac{10}{S_2 - S_1}. \quad (4)$$

3. METHODOLOGY

In the study of the stereo imaging information acquisition based on the CSS3D lighting system, this paper adopts the full-frame sensor SVSl6000 in black and white with the spectrum in the visible light band. The doublet structure is used in the design of the system.

Design of reverse system of imaging system machine

To control the stray light caused by the reflection from different refractive surface, this study traced the retrodirected ray of several imaging rays. The optimization function was written in ZEMAX merit function, and then image quality was optimized. A doublet structure was used in the system. In the reverse design of the bottom imaging system,

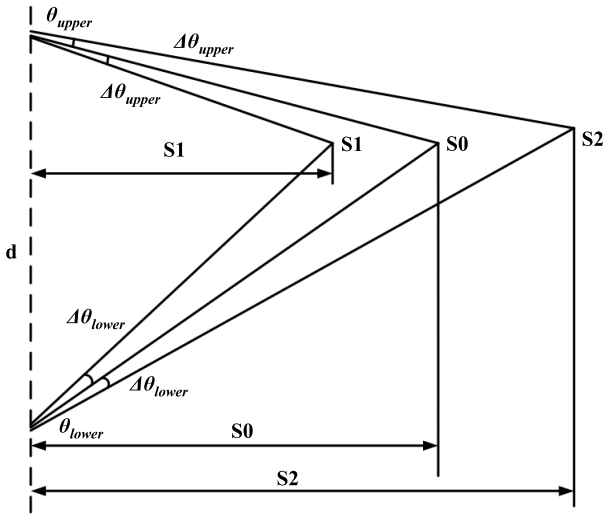


Fig.2. Spatial resolution error due to pixel size

this study placed groups of lenses before the images to ensure that the imaging surfaces connect smoothly. This approach ensures a consistently telecentric image pace and uniform illumination. It also makes the virtual image surface smoother (which ensures imaging clarity) and reduces the pressure of aberration correction during unit combination optimization. This approach has two notable aspects. First, placing groups of lenses in front of the image allows control of the image size and numerical aperture. Given the unknown effect of the fusion between the reverse system and the front imaging system, the problem of image distortion correction can be solved by placing a few lens groups in front of the image. Second, the system baseline distance has a decisive influence on the resolution of the imaging, and the length of the baseline is proportional to the spatial resolution, that is, a long baseline corresponds to a high resolution. In addition, because of the limited volume of the system, the placement of the lens group in front of the image can increase the length of the baseline to improve the spatial resolution of the system. In this part of the design, this paper's proposed method adds the lens group on the second reflective surface.

Design of the above imaging system

In the design of the imaging system units, the specific design method is consistent with the imaging system and is therefore not repeated here. However, the design of the imaging system unit has one vital point; namely, the size of the image surface should fit the reverse structure of the image surface and the telecentricity in the image space. In addition, the design in this study simplifies the structure of the system as much as possible. However, because the image surface below is larger than that above, the design of the system structure does not need to use the glued construction. Moreover, to make the entire system more compact, the design of this part does not need to optimize the stray light.

Combination of the imaging systems

This part of the design combines the lens group in the previous two parts and then optimizes the combination. In the optimization process, to ensure the imaging of the two parts in the same image plane, the two images must have a high resolution, and the

Table 1. Experimental results of distance measuring panoramic stereo imaging system

Test point	Real distance/cm	Computed distance/ cm	Error/cm	Error rate/%
S1	50	48.24	-1.76	-3.52
S2	80	76.86	-3.14	-3.92
S3	110	106.15	-3.85	-3.5
S4	140	145.5	5.5	3.9
S5	170	164.74	-5.26	-3.09
S6	200	208.9	8.9	4.45
S7	230	220.04	-9.96	-4.33
S8	250	240.93	-9.07	-3.62
S9	280	265.56	-14.44	-5.15
S10	300	287.96	-12.04	-4.01

image boundaries cannot overlap. With the configuration parameters of the system below kept constant, the parameters of each configuration of the additional lens group and the system above are optimized separately, and the image quality of the combined system is optimized. In addition, because the combination of the system contains and even amplifies both systems' own distortion characteristics, the imaging system distortion curve needs to be optimized, thereby marking the completion of the design of the whole system.

4. RESULT ANALYSIS AND DISCUSSION

This study conducted a simulation experiment to verify the effectiveness of the system in obtaining stereo imaging information. In this experiment, objects at a distance of five meters were used to adjust the incorrect aspects of the surface structure of the system; these incorrect aspects reduce image quality. Results are shown in Table 1.

As shown in Table 1, the proposed stereo imaging information acquisition method based on the CSS3D lighting system can ensure the accuracy of the stereo imaging information. However, this system needs to be further optimized and improved to meet the needs of stereo image information extraction of long-distance spatial objects.

5. CONCLUSION

As a new type of optical system, stereo imaging not only obtains a 360° field of view, but it can also acquire stereo imaging information of the space object in real time. This technology has been applied to various fields. On the basis of this technology, this paper adopted the doublet structure method and designed a PAL unit imaging system, which combined the imaging systems, and optimized their combination. Thus, the problem of blind area in the traditional imaging system was solved. Stray light was effectively suppressed, thereby optimizing the image quality. In addition, the doublet structure design simplified the system structure and reduced the size and weight of the system. Experimental results showed that this system expanded the field of view and effectively improved the clarity and resolution of the imaging system. It achieved real-time acquisition of stereo imaging information and has high applicability and scalability. However, it has certain limitations, therefore, further improvement and optimization is also required in stereo imaging information extraction of distant space objects.

REFERENCES:

1. Bai Jian, Niu Shuang, Yang Guoguang, et al. Panoramic staring imaging technology. infrared and laser engineering, 2006, V35, #3, pp. 331–335.

2. Lu Tianxiong, Bai Jian, Huang Zhi, et al. Analysis and suppression of stray light of. optical panoramic imaging system, 2013, #5, pp. 96–104.

3. Zhou Xiangdong, Bai Jian. Design of non spherical small distortion panoramic optical system Q-Type. optical journal, 2015, #7, pp. 291–297.

4. Seo H J, Jo J H. Catadioptric Omnidirectional Optical System Using a Spherical Mirror with a Central Hole and a Plane Mirror for Visible Light. Korean Journal of Optics and Photonics, 2015, V26, #2, pp. 88–97.

5. Zhou X, Bai J, Wang C, et al. Comparison of two panoramic front unit arrangements in design of a super wide angle panoramic annular lens. Applied Optics, 2016, V55, #12, pp. 3219–3225.

6. Genovese K, Lee Y U, Lee A Y, et al. An improved panoramic digital image correlation method for vascular strain analysis and material characterization. Journal of the mechanical behavior of biomedical materials, 2013, V27, pp. 132–142.

Hongmei ZHU,
Master, Technician,
School of Electronics and Information Engineering,
Changchun University of Science and Technology,
Changchun, Jilin, China

Yan PIAO,
Ph.D., CAS Changchun Institute. Professor,
School of Electronics and Information Engineering,
Changchun University of Science and Technology.
Research interests are digital image processing, digital signal processing and 3D imaging technology

Light & Engineering
Vol. 24, No. 3, pp. 48-51, 2016

Svetotekhnika
No. 5, 2016

MONITORING THE CREEP RUPTURE OF FRACTURED COAL-ROCK MASS WITH CRACK EXPANSION BASED ON THE LED VISIBLE LIGHT SIGHT DISTANCE MEASUREMENT

Donghai JIANG[1,*], Chang LIU[2], and Wenqiang MA[1]

[1] School of Mining and Safety Engineering, Shandong University of Science and Technology, China
[2] School of Resources and Safety Engineering, China University of Mining and Technology (Beijing), China
**E-mail: jiangdonghai735@163.com*

ABSTRACT

A system of aiming and ranging LED visible light exhibits satisfactory effects on monitoring the fracture extension of rock and soil masses. Basing our research on the working principle, system composition, system arrangement of aiming and ranging a system of LED visible light, we analyzed the observation data from the monitoring of coal–rock mass deformation in a specific coal field. The results show that the protected coal and rock layers rapidly expand when the working face of the coal–rock seam is advanced to 90 m. At the same time, the maximum hole deformation is 22.31%. Finally, a basis for determining damages to coal and rock seams is established.

Keywords: aiming and ranging, LED visible light, coal and rock mass, monitoring

1. INTRODUCTION

The creep of coal and rock seams is an important rock characteristic and used as one of the important indicators of rock mass damage. Modern monitoring equipment is used to reduce the creep damage of coal and rock mass in a coal mining course [1]. In long-term practice, the system of aiming and ranging LED visible light is widely recognized because of its high precision, stability, and reliable performance of advanced vacuum visible technology [2]. The system can serve engineering applications with high requirements for precision and stability through improvements for many years. Currently, the success of other deformation monitoring systems has not been compared [3–4]. Monitoring of the deformation of coal and rock mass requires excellent precision and accurate calibration technology to satisfy technical requirements. Thus, this paper introduces the damage mechanism of crack propagation and creep damage of coal and rock masses, as well as the working mechanism of aiming and ranging of LED visible light. These mechanisms are then applied to monitor an actual coal seam.

2. COAL AND ROCK MASSES

Fracture evolution of coal and rock mass

Coal and rock masses, which belong to anisotropic rock masses, are filled with irregular cracks. Human activity causes primary and secondary fissures in coal and rock mass to become extended. In coal seam excavation, gas pressure increases and is pumped because of blast in the coal and rock stratum with high-gas content and low permeability; this phenomenon causes not only the pressure of coal and rock seams but also fracture extension of coal seams. However, the law of increase

and attenuation of gas drainage remains unclear because of the effect of rheological properties of coal and rock mass on generation and development of a coal seam fracture. The development of fractures in coal and rock seams leads to the creeping deformation of coal and rock mass, leading to the instability of coal and rock seams. The combination of this technique with modern monitoring systems is advantageous to analyze crack evolution and guide coal seam excavation.

Creeping instability of coal and rock mass

Creeping of coal and rock seams is a nonlinear and dynamic process because of the state of unbalanced force in rock mass. Coal and rock mass creep exists in each stage of rock mass because of the interaction among several factors, such as tectonic forces and human disturbance. The fracture development of coal and rock mass is inconsistent with that under the three axis tests of conventional rock mass; this development is one-way but nonlinear. The coal and rock mass itself, these influencing factors, and the external action systems exhibit complex energy relations. In practice, accidents that occur in coal and rock seams could be due to complicated mechanical behaviour and internal stress release in rock mass. Generally, crack extension of coal and rock seams cannot be sustained to maintain its stability. With continuous coal mining, the occurrence of crack extension in coal and rock seams under stress also increases, resulting in coal mining accidents.

3. METHODOLOGY

Working principles

The system of aiming and ranging of LED visible light is called zone plate system, Fig. 1.

LED visible light is sent from the Transmitting Terminal 1 to the receiver of rock seams to allow the light to pass through the zone plate setup in coal and rock seams. Meanwhile, diffraction appears in the zone plate, and light diffraction forms Spot 4 in the receiver. When Zone Plate 2 in the measuring point position shows point displacement with measuring point in coal and rock seams, the position of the light spot changes. The degree of coal and rock seams' displacement can be calculated from these; the calculation formula is shown as follows:

$$X = X_m \cdot Ln / L, \quad (1)$$

where X is the value of the measured displacement; X_m is the observation value of receivers; Ln is the distance from transmitters to the zone plate; and L is distance from transmitters to receivers.

System compositions

The main components of system of aiming and ranging of LED visible light include: visible light emitter, measuring point equipment, light-spot detection equipment, and end-point displacement monitoring equipment. The main functions are as follows:

Visible light emitter is the light source of the system for aiming and ranging of LED visible light and basic monitoring condition;

Equipment for measuring points is mainly used to place the zone plate in coal and rock mass;

Light-spot detection equipment is mainly placed in the receiving terminal and is the most important detecting instrument in the system of aiming and ranging of LED visible light; the proposed instrument mainly detects position and length of light spot, finally calculating displacement amount;

End-point displacement monitoring equipment monitors the position of visible light-emitting devices and light-spot detection equipment to determine plane coordinates of quasi-straight line.

System arrangement

Visible light transmitting terminal is arranged in the observation room of coal mine, which is equipped with permanent power, light-spot detection equipment, visible light generator, and three-dimensional inverse plumb line. The receiving terminal is set at the position of coal seams in coal mine, where creep deformation is more serious. In addition, the length of the vacuum pipe is set to 600 m. Seamless steel pipe welding is used

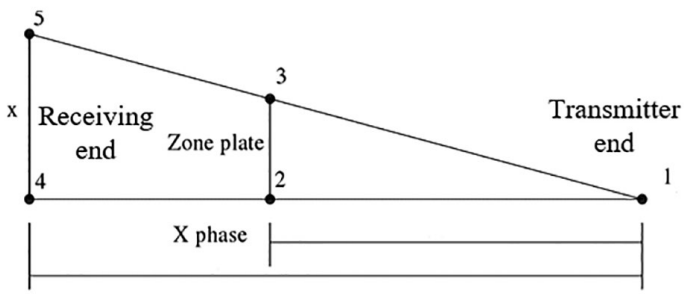


Fig. 1. Zone plate alignment principle diagram

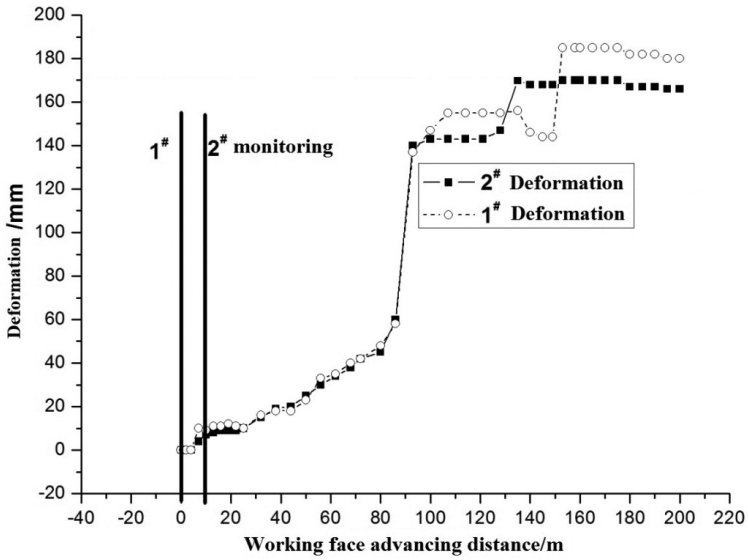


Fig. 2. The deformation trend of protected layer

in the connection points of vacuum pipes arranged on the upper side of coal and rock seams. An electric heater can be installed in the vacuum pump to ensure smooth monitoring.

System management software

Software of the system of aiming and ranging of LED visible light is developed based on Windows operating system. In the system, monitoring status can be set and automatically generate creep and crack extension curve of coal and rock mass according to monitoring or artificial data. The corresponding report is generated.

4. RESULT ANALYSIS AND DISCUSSION

Project introduction

The mine field in this project is located in Jinzhong City, Shanxi Province, whose average length from east to west, average slope length from south to north, and area are about 10 kilometres, 6.5 kilometres, and 43 square, kilometres respectively. The overall structure of coal-bearing strata is asymmetric anticline, in which the eastern part seems plunging and an axis moves from north to west; stratum gradient from south wing's southern tendency to that in north wing's north eastern tendency, and the slope angle is considerably low, generally at 7° to 10°.

The 11–2 coal bed is more unstable, and the inclination of coal seam is 163°–190° and dip angle is 3–10°. The 11–2 coal is black, massive, and semi–bright, half-dark briquette. The coal seam thickness is 1.88–2.98 m, which gradually thickens from west to east, and its average thickness is 2.36 m. The direct roof comprises sandy mudstone, mudstone, and 11–3 coal. Old roof is fine sandstone, and direct bottom is sandy mudstone. False roof of 11–2 coal seam does not develop generally and composes of composite roof with 11–3 coal; the old top is fine sandstone; and the old bottom is fine sandstone and siltstone.

The 13–1 coal exhibits an unstable coal seam. The thickness of this specimen is 0.7–4.9 m, and the average thickness is 3.28 m. This type of coal has a simple structure, which generally has one to two layers of gangue and located at the top or bottom of the coal seam. The lithology of 13–1 coal is carbonaceous mudstone and mudstone; the top plate is mainly shale and a small amount of sandstone, and the bottom plate is shale.

In recent mining process of underground coal seams, the characteristics of the creep slope of coal and rock mass have been discovered and are mainly concentrated in 13–1 and 11–2 coal seams. Thus, this paper applies aiming and ranging of LED visible light to monitor coal and rock mass.

Monitoring arrangement

The plane arrangement is shown in Fig. 2. Three boreholes with a 5 m interval are arranged to determine deformation. The pressure measuring holes are divided into three groups. Borehole measuring directions are arranged in two rows to ensure that the data measured are effective; most lateral boreholes for measuring pressure are designed according to field requirements. A borehole is first constructed in the upper tank, and the other one is constructed on the bottom of the tank. Similarly, inclined boreholes are arranged in two rows for inspection. However, construction position is unclear and should be evaluated under the existing conditions.

Analysis of monitoring results

As shown in Fig 2, during the time when the working surface is promoted from 20 m to 80 m, the deformation amount measured by deformation holes increases slowly. The protected layer be-

gins to expand and be misshapen because of artificial mining. The protection effect is not fully reflected before the cracking of the key strata overlying the protected layer. When the working surface is increased to 90 m, the key strata drops at the first time and the protected layer expands rapidly; thus, the maximum deformation of Deformation Hole 1 is 22.31‰. The location of deformation hole 3 is closer to the dryer, and the wire rope used to fasten the levelling hammer is eroded in wet air for a long time; hence, this hole is rusted and broken along the orifice when the working surface of the protected layer is promoted to about 120 m. Therefore, the deformation measurement of deformation hole 3 stops. According to deformation index of deformation holes 1 and 2, deformation rate in the investigated region is higher than 3‰.

5. CONCLUSION

Coal and rock seams must be monitored because the creep damage of the seams caused by crack expansion will lead to serious coal mine accidents. Application of the system of aiming and ranging of LED visible light to monitor coal and rock seams is tested in field. The following conclusions are drawn. The protected layer of coal and rock seams expands and becomes out of shape because of the influence of artificial disturbances, leading to further development of the fracture of coal and rock seams and the occurrence of creeping in the rock layers. The protection effect is not fully reflected before cracking of the key strata overlying the protected layer. The maximum deformation can reach 22.31‰ when the disturbed working surface of coal and rock seams is increased to 90 m and the protected layer fracture is completely expanded. Hence, coal and rock seams will be destroyed at any time. Accordingly, this paper recommends establishing sufficient time for pressure relief to eliminate danger in the region. The creep damage of coal and rock seams begins as a microscopic damage; thus, the accuracy of the system of aiming and ranging of LED visible light must be improved.

ACKNOWLEDGEMENT:

The authors are grateful for the Emphasize Research and Development Project of Shandong Province (2015GSF116012).

REFERENCES:

1. Lu T, Yu H, Zhou T, et al. Improvement of methane drainage in high gassy coal seam using water jet technique. International Journal of Coal Geology, 2009. V79, #1, pp. 40–48.

2. Khater M A. Trace detection of light elements by laser-induced breakdown spectroscopy (LIBS): Applications to non-conducting materials. Optics and Spectroscopy, 2013. V115, #4, pp. 574–590.

3. Lee J R, Shin H J, Chia C C, et al. Long distance laser ultrasonic propagation imaging system for damage visualization. Optics and Lasers in Engineering, 2011. V49, #12, pp. 1361–1371.

4. Cicchi R, Kapsokalyvas D, Troiano M, et al. In vivo non-invasive monitoring of collagen remodelling by two-photon microscopy after micro-ablative fractional laser resurfacing, Journal of biophotonics, 2014. V7, #11–12, pp.914–925.

Donghai JIANG,
Dr. read, Shandong University of Science and Technology

Wenqiang MA,
Dr. read, Shandong University of Science and Technology

Chang LIU,
Dr. read,
China University of Mining and Technology(Beijing)

Light & Engineering
Vol. 24, No. 3, pp. 52-55, 2016

Svetotekhnika
No. 5, 2016

FLATNESS DETECTION OF ASPHALT PAVEMENT MAINTENANCE BASED ON LED VISIBLE LIGHT SIGHT DISTANCE MEASUREMENT

Yingmei YIN*, Ronghui ZHANG, and Huiqing LV

School of Civil and Transportation Engineering, Guangdong University of Technology, Guangdong 510006, China
**E-mail: yingmeiyingd845@126.com*

ABSTRACT

Based on a one-fourth real size car model and with the aim of addressing the inaccurate measurement of pavement flatness caused by pavement roughness, the present paper proposes a pavement flatness detection method based on LED visible light sight distance measurement. The method provides the computational formula of pavement flatness and realizes synchronous collection and combined processing of multiple data. The researchers conducted a flatness detection experiment on an actual road. Results show that this method has high accuracy. The pavement flatness detection method based on inertia standard provides a perspective on the detection of pavement flatness. The method can also be applied in practical engineering.

Keywords: flatness of bituminous pavement, LED visible light sighting distance measurement, error

1. INTRODUCTION

Pavement flatness refers to the index of pavement flatness measurement as well as one an evaluation standard for pavement construction and maintenance. Nowadays, pavement flatness can be measured using LED visible light sighting distance measurement equipment to detect the relative elevation of a pavement while driving. We also use the formula to work out the flatness index. In actual application, the quantitative value detected by the LED visible light sighting distance measurement equipment is the bump displacement value of the car caused by pavement unevenness, which adds to the pavement flatness displacement value. This value cannot ensure an accurate detection result. Eliminating the bump displacement value is one of the major research needs in flatness detection [1]. Koch and others introduced inertia standard apparatus and an acceleration sensor into the detection system to detect the bump displacement value of the car caused by pavement unevenness, which provides precise detection for the car [2]. In studies from China on flatness detection, we rarely use the inertia standard apparatus because of the high cost of introducing foreign technology. Thus, the present paper proposes the flatness detection method for bituminous pavements based on a measurement of LED visible light sighting distance. The method also realizes detection on actual roads and determines the detection precision.

2. STATE OF THE ART

From the appearance of the first professional equipment for detecting pavement flatness, many foreign scholars have exerted considerable effort to improve this kind of equipment, and thus they have accumulated large amounts of experience and have obtained nearly perfect equipment [3]. The pavement flatness detection equipment made in the early days in various countries has been widely popularized and applied in multiple fields [4]. However, because such equipment can only be

placed on a bituminous pavement and the detection equipment may affect pavement flatness, the flatness value from the detection has an error. The detection speed is slow, and the difficulty of detection is increased.

With the advancement of society and technology, and the popularization and wide use of photoelectric technology, the flatness of bituminous pavement can now be detected without contact. This non-contacting detection equipment has become a hot research topic in recent years [5]. This type of equipment uses laser, ultrasonic wave, and radar as a means of detection. The equipment can work out the flatness of the road by reanalyzing the information. China began to research bituminous pavement qualities quite late, and only began research on its detection methods from the 1990s. Most of our research focuses on distance detection of the laser time-of-flight method. Because the propagation distance of light is fixed, the distance can be worked out by measuring the time difference between sending and receiving LED visible light [6]. However, further improving measurement accuracy by detecting the propagation time through digital devices can be difficult. Thus, the key point of research on detection systems for measuring the flatness of bituminous pavement is to improve the measurement accuracy and measurement speed; in short, the choice of sensor.

3. METHODOLOGY

Optical sighting distance measurement

Optical sighting distance measurement is conducted using an optical sighting telescope, which is composed of an objective lens, erector tube, and ocular lens. An objective lens is used mainly in light concentration. The larger the objective lens, the ampler the light concentration. Furthermore, the objective lens transfers optical fibers to ensure that they are in parallel, that the eyes can focus, and that sufficient view is provided. An erector tube processes images in an objective lens for the image to be in the right position. The tube also has the function of adjusting magnification. Good sighting equipment should have over nine lenses. Through this lens, we can have a better view [7].

Detection principle

A one-fourth car model is shown in Fig.1. From Fig.1, we can work out this formula as follows:

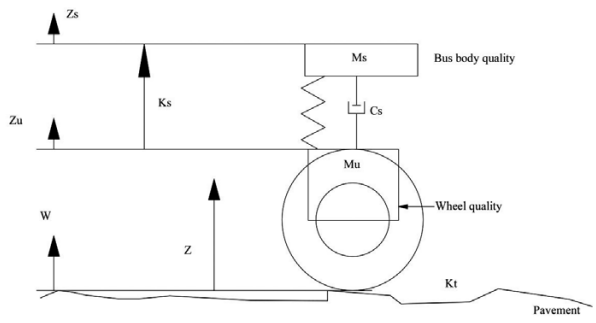


Fig. 1. 1/4 vehicle model

$$M_s\ddot{Z}_s + C_s\left(\dot{Z}_s - \dot{Z}_u\right) + K_s\left(Z_s - Z_u\right) = 0. \quad (1)$$

$$M_u\ddot{Z}_u - C_s\left(\dot{Z}_s - \dot{Z}_u\right) - K_s\left(Z_s - Z_u\right) + K_t Z_u = K_t W. \quad (2)$$

In the formulas, Z_s represents the displacement of the car, m; Z_u represents the displacement of the wheels, m; $\dot{Z}_s$ is the speed of the car, m/s; $\dot{Z}_u$ refers to the speed of the wheels, m/s; $\ddot{Z}_s$ stands for acceleration of the car m/s^2; and $\ddot{Z}_u$ stands for acceleration of the wheels, m/s^2. C_s refers to the damping coefficient, N·s/m; M_s refers to the mass of the car, kg; M_u is the mass of the wheels, kg; K_s stands for the elastic deformation coefficient of the spring, N/m; K_s stands for the elastic deformation coefficient of the wheels, N/m. W indicates the height of road profiling, which is composed of two parts and represents the measured displacement value w_1 and the revised displacement value w_2 after w_1 goes through a double integral with acceleration.

$$w_1 = Z_s - Z_u. \quad (3)$$

$$w_2 = \iint a(t)\,dtdt. \quad (4)$$

Combining Formulas (3) and (4), we work out the following formula:

$$W(i) = w_1(i) - \int_{T(i)}^{T(i-1)} \iint a(t)\,dtdt, \quad (5)$$

where $W(i)$ is the height of road profiling at $T(i)$ moment; $w_1(i)$ is the displacement value at $T(i)$ moment; and $a(i)$ is the acceleration at vertical direction at $T(i)$ moment.

To obtain the specific value of the pavement's IRI (International Roughness Index), the LED vi-

Table 1. Results of flatness measurement

Section	IRI, m/km		Rate of error, %
	Laser flatness detection system	Precision level	
1	1. 42	1.45	-2.11
2	2.52	2.56	-1.59
3	2.66	2.57	3.37
4	3.56	3.40	4.49
5	3.98	4.15	-4.27
6	4.62	4.77	-3.25
7	4.27	4.40	-3.04
8	5.00	5.22	-4.40
9	2.84	2.75	3.17
10	1.66	1.74	-4.82

sible light distance detection equipment is needed to obtain w_1, displacement; the acceleration sensor can be used to obtain the acceleration, a. Then, a is used to obtain w_2; add w_1 and w_2 to obtain the measurement of the road profiling height, W; then work out the detected pavement's IRI value form, W.

Information collection

w_1 and w_2 are collected using the LED distance measurement equipment and acceleration sensor, respectively. When the car travels a certain distance, the car will trigger the distance sensor, which will trigger the aforementioned equipment to start data collection. The distance sensor requires the installation of a specific sensor and magnetic steel at the front wheel of the detected car to work properly [8]. When the detected car drives on a bituminous pavement, the magnet in the car will come into contact with the sensor because of the movement, and the frequency of the sensor is changed with the change of the car's speed. Thus, the collection frequency of w_1 and w_2 is affected by the speed of the detected car. These two factors have a proportional relation. We conducted a sample collection when the car moves in integral multiples of 5cm.

We enlarge the piezoelectric effect and build a new type of sensor, which is called piezoelectric acceleration sensor. This equipment is composed of multiple parts. Compared with other sensors, the equipment has many advantages, such as good corresponding effect, small size, and so on [9].

Data processing

Because pavement flatness detection is conducted under field operations, the work environment is relatively harsh and many interfering sources, such as environmental temperature, electric field, magnetic field, can be found. To reduce or even eliminate the error caused by the external environment and improve the system's stability, we conduct filter processing on the data collected during flatness detection. We introduce the Butterworth filter into the data processing module of this system. This filter has a balanced performance in linear phase, attenuation slope, and loading characteristics.

In the system's data processing, the system itself does not change to its own response. Instead, the system changes the simulative filter into the digital filter. Thus, we design the filter system to correspond to the Butterworth filter, which means that through the algorithm of this system, we process the data to improve the system's reliability, reduce or eliminate the noise signal to ensure the accuracy of the data processing result [10].

In data processing, integral computation of the output signal often exists, which leads to the overflow of the result. This phenomenon results in accelerated error in the restoration of the transmission signal. Thus, we often use software to process data. At first, this software stores the transmission signal, and sets this signal as the initial point. After the software processes the data, it subtracts the initial point from the output data. The final data are the output signal of the sensor.

4. RESULT ANALYSIS AND DISCUSSION

This plan chooses the simulation experiment to analyze the system's utility. First, the plan detects the pavement of a 300-meter-long road. The detection places the leveling instrument every 250 mm to detect the elevation. Finally, the plan summarizes and calculates the IRI of the pavement. We conduct detection in the bituminous pavement between Nanjing to Shanghai. The result is shown in Table.1

Table 1 shows that compared with the level of precision, the error of the laser pavement flatness detection system is below 5%, and the average relative error is 4%.

5. CONCLUSION

The present paper proposes the flatness of bituminous pavement detection method based on LED visible light sighting distance measurement. For the flatness detection, we propose the pavement flatness detection method using LED visible light sighting distance measurement equipment based on inertia standard because pavement unevenness leads to inaccurate measurement. We conduct flatness detection on an actual road. Results show that compared with the precision level, the error of the pavement flatness detection system based on the inertia standard is below 5% and the average relative error is 4%. The flatness detection system of bituminous pavements improves the efficiency of all fronts of pavement detection and promotes the development of pavement detection activities. Although the laser pavement flatness detection system used in the present paper has a high accuracy, some errors remain. The reduction of the error is the key point of future studies.

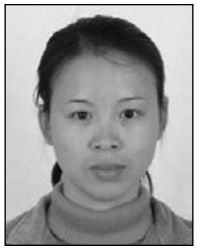
REFERENCES:

1. Tsai Y C J, Li F. Critical assessment of detecting asphalt pavement cracks under different lighting and low intensity contrast conditions using emerging 3D laser technology. Journal of Transportation Engineering, 2012, V138, #5, pp. 649–656.

2. Koch C, Brilakis I. Pothole detection in asphalt pavement images. Advanced Engineering Informatics, 2011, V25, #3, pp. 507–515.

3. Wang W, Yan X, Huang H, et al. Design and verification of a laser based device for pavement macrotexture measurement. Transportation Research Part C: Emerging Technologies, 2011, V19, #4, pp. 682–694.

4. Bitelli G, Simone A, Girardi F, et al. Laser scanning on road pavements: a new approach for characterizing surface texture. Sensors, 2012, V12, #7, pp. 9110–9128.



Yingmei YIN,
Doctor of road engineering, lecturer. Graduated from the South China University of Technology.
Staff member of School of Civil and Transportation Engineering, Guangdong University of Technology of PR China

Huiqing LV,
Doctor of Mechanical Engineering (road direction), lecturer. Graduated from the Guangdong University of Technology.
Staff member of School of Civil and Transportation Engineering, Guangdong University of Technology of PR China

Ronghui ZHANG,
Bachelor of road engineering, Professor. Graduated from the Guangdong University of Technology.
Staff member of School of Civil and Transportation Engineering, Guangdong University of Technology of PR China

Light & Engineering
Vol. 24, No. 3, pp. 56-60, 2016

Svetotekhnika
No. 5, 2016

APPLICATION STUDY ON DATA MINING TECHNOLOGY IN THE IMAGE TRANSMISSION BASED ON LED VISIBLE LIGHT

Dong LIANG*, Zhaojing ZHANG, Huahua XIE, and Hao JIN

Key Laboratory of Universal Wireless Communication, Beijing University of Posts and Telecommunication, Beijing 100876, China
**E-mail: dongliangbupt745@163.com*

ABSTRACT

On the basis of the limitations of LED visible light image (LED-VLI) extraction methods, the relationship of the satellite LED-VLI information and the ground substance and structure spectrum is analyzed to form a space angle model. The limitations of existing algorithms on LED-VLI data processing are also analyzed. The mathematical performance of the space angle-based algorithm in LED-VLI processing is evaluated through computer simulation and experiments, thereby providing useful information for the selection of mathematical processes and data mining tools, which can facilitate further development and research of LED-VLI.

Keywords: high resolution, optical LED-VLI data, data mining, lithologic information

1. INTRODUCTION

Data are the carrier of the primary information of a substance. The objective of data mining and knowledge discovery (MD & KDD) is to explore useful information from a vast database and to establish knowledge – based multi – stage advanced processing [1]. Zhang L. studied the automatic registration of visible light image on the basis of Scale-invariant feature transform (SIFT); findings revealed that images with small deformations can accurately match the features of vast data, but this type of matching pattern is simple [2]. According to rational function models, Wen-Sheng M. A. established the approximate epi polar equation, which adopted the approximate one-dimensional image matching of the projection track-based epi polar constraint; however, this method has the disadvantages of low data extraction accuracy and computational complexity [3]. Miao Z. presented a method to correct a database in accordance with the data same name-based automatic matching algorithm and the triangle subdivision technology; however, this method has a low level of accuracy, which barely met the requirements [4]. Yang B. presented a simple matching rule by extracting homonymy points based on SIFT; this method needs no manual interpretation, but the accuracy is still unsatisfactory.

To explore the LED-VLI data analysis method in line with LED visible light multidimensional angle transmission, an evaluation method based on multidimensional LED visible light data field is presented in this research. Using the mercury mine zone of western Hunan and eastern Guizhou in China as a case study, an experimental simulation was conducted to analyze the ore-bearing bedrock, thereby providing foundations for future geological exploration survey. The second section of this research initially includes an introduction to high spatial resolution LED-VLI. Then, the existing LED visible light extraction methods are discussed. In the third section, a multidimensional LED visible light data field angle decomposition model is presented. In the fourth section, quantified simulation verification and analysis are conducted for the statistical data of the multichan-

nel LED visible light data angle transmission. Finally, conclusions are made based on the experimental results and findings.

2. STATE OF THE ART

High spatial resolution LED-VLI refers to the LED-VLI technology whose resolution to the ground is more than 5 m. High spatial resolution LED-VLI has vast information content and high definition, comparing with the LED-VLI of other resolutions. It can clearly present the slight changes in the ground, thereby enabling the detection of the ground surface changes in immense sizes. Therefore, high spatial resolution LED-VLI has become the preferred data source of high spatial resolution satellite image applications (e.g., spatial data production and the detection of underlying surface changes). Henceforth in this paper, high spatial resolution optical satellite image will be referred to as high resolution satellite image or high resolution LED-VLI. High resolution LED-VLI has many disadvantages in practical applications mainly because of the detection of excessive data. In addition, some of the interference factors exert negative effects on the LED-VLI, thereby causing difficulties for the automatic extraction of the related ground objects. Currently, information extraction is primarily achieved through manual interpretation and decoding. Moreover, traditional LED-VLI processing technology is facing new challenges.

In recent years, multi-scale image classification for objects has been presented to improve the accuracy and efficiency of high resolution LED-VLI processing. The basic principle of this idea is to predefine the ground boundary or image segmentation to generate image objects with rich attributes information in any size. In this method, image object is regarded as the basic spatial unit; the attribute information (e.g., spectral feature, texture feature, and shape feature) of each image object is used to achieve the automatic extraction of classified information.

3. METHODOLOGY

High spatial resolution LED-VLI data scan the ground surface through wireless signals in which data are collected and stored through digital signals. The traditional data collection patterns, data transmission, and data storage barely fulfil the requirements of high spatial resolution LED-VLI and obtain unsatisfactory results. Hence, a multi-dimensional LED visible image data field angle decomposition model is introduced in this research. Then, the multi-factor step-by-step orthogonal transformation is analyzed.

Multi-dimensional LED-VLI data field angle decomposition model

The pixel gray value recorded by one waveband LED-VLI data can be seen as the one-dimensional vector of the pixel. The pixel vector dimension of multiple wavebands LED-VLI data is multidimensional; the pixel vector can be expressed as

$$DN_{ij}^{[k]} = \left[DN_{ij1} DN_{ij2} \cdots DN_{ijk} \right]^T = \begin{bmatrix} DN_{ij1} \\ DN_{ij2} \\ \vdots \\ DN_{ijk} \end{bmatrix}. \quad (1)$$

In Formula (1), i and j refer to the position subscript of the pixel; and k stands for the dimensionality, which is also known as the number of wavebands. The data of the entire waveband can be treated as a vector, which is

$$DN_{k}^{[p]} = \left[DN_{k1} DN_{k2} \cdots DN_{kp} \right]^T = \begin{bmatrix} DN_{k1} \\ DN_{k2} \\ \vdots \\ DN_{kp} \end{bmatrix}. \quad (2)$$

In Formula (2), p is the pixel number of the entire image. If the size of the image is $M \times N$, then $p = M \times N$; k is the number of wavebands.

The base vector of the one-dimensional pixel vector differs from that of the multidimensional pixel vector. If an image is seen as a vector, then the number of images can be regarded as the number of vectors. For the k-dimensional vector of the pixel, a set of base vectors is a unit matrix; as stated, k stands for the dimensionality. In this research, a matrix that represents the relationship between pixels and waveband vectors is established in accordance with vector spatial transformation, which realizes the selection of LED-VLI data attributes and data processing. In linear space, additive operation and scalar multiplication of vectors can be conducted, allowing for identification of the correlations of the vector, the rank of vector sets, and the

base of linear space. However, measurement and quantitative analysis of the vector should be conducted in inner product space where the length, distance, and orthogonality of the vector can be defined and the standard orthogonal basis of the space can be established.

Multi-factor step-by-step orthogonal transformation

Multi-factor step-by-step orthogonal transformation is matrix diagonalization decomposition, which conducts multiple steps of rotations to the multi-waveband LED-VLI data variance covariance matrix A. The rotation feature axis of each step refers to a different angle; in this way, the separation of target information can be realized.

$$C = p_1 \times p_2 \times p_3 \cdots p_n, \tag{3}$$

where C is the orthogonal matrix; $CTT=C\text{-}1$. In this equation, C can be divided into a series of simple orthogonal matrix's products, in which

$$P_i = Up_q. \tag{4}$$

$$\begin{bmatrix} 1 & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\ 0 & 1 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & 1 & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cos\vartheta & \cdots & \sin\vartheta & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & 1 & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & -\sin\vartheta & \cdots & \cos\vartheta & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 1 & 0 \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 0 & 1 \end{bmatrix}, \tag{5}$$

In Equation (5), the omitted element on the diagonal in the matrix is 1; the omitted element in the off-diagonal is 0, which then leads to

$$\begin{aligned} b_{pp} &= a_{pp}\cos^2\vartheta - 2a_{pq}\sin\vartheta\cos\vartheta + a_{qq}\vartheta\sin^2\vartheta \\ b_{qq} &= a_{pp}\sin^2\vartheta + 2a_{pq}\sin\vartheta\cos\vartheta + a_{qq}\vartheta\cos^2\vartheta \\ b_{pq} &= b_{qp} = (a_{pp} - a_{qq})\sin\vartheta\cos\vartheta + a_{pq}(\cos^2\vartheta - \sin^2\vartheta) \\ b_{pj} &= a_{pj}\cos\vartheta - a_{qj}\sin\vartheta \qquad j \neq q \\ b_{qj} &= a_{pj}\sin\vartheta + a_{qj}\sin\vartheta \qquad j \neq p \\ b_{ij} &= a_{ij} \quad i, j \neq p, q \end{aligned} \tag{6}$$

To make the off-diagonal element 0

$$\begin{aligned} &u_{pp} = u_{qq} = \cos\vartheta, u_{pq} = -u_{qp} = \sin\vartheta \\ &u_{ii} = 1,\ u_{ij} = 0 \quad i \neq j,\ B = u^T Au. \end{aligned} \tag{7}$$

In Equation (7), the function of U_{pq} matrix is to continuously increase the elements on the principal diagonal and to continuously decrease the off-diagonal elements. Each rotation will produce a maximum orthogonal axis of the two-factor variance p and q; in this case, the two new vectors p and q will be mutually independent, and the covariance will be 0. On the basis of the mutual orthogonal features of these two new vectors, iterations can be repeated until the maximum orthogonal axes of all the variances are obtained. As the variance covariance matrix is rotated to a diagonal matrix, the obtained feature values and feature vectors are the analytical results from the main components. Next, the variable load factor during the rotation process is analyzed to obtain the load distribution in different rotation positions against the primary data. Consequently, the target information can be highlighted and extracted.

4. RESULT ANALYSIS AND DISCUSSION

The mercury mine zone of western Hunan and eastern Guizhou is taken as a typical example to illustrate the image processing method of multi-factor step-by-step orthogonal transformation. In this paper, the image size of the mercury mine zone is 224 km². A total of seven wavebands exist, including a thermal infrared waveband, which is unnecessary in the multi-step rotation computation. First, data recorded by the multi-dimensional LED-VLI are analyzed. Then, the variance covariance matrices of the six non-thermal infrared wavebands are computed. The statistical results are listed in Table 1.

The third stage rotation matrix is included to produce principal component analysis, Table 2.

To visually display the performance of multi-factor step-by-step transformation on the classification of lithologic information, the factors of TM5 and 7 waveband (mainly composed of lithologic information) are selected as the principal factor axis for the load space surface. With the use of the three-dimensional coordinates (TM3-X, TM5-Y,

Table 1. Mean and covariance matrix of 6 bands

mean value					
80.768070	37.249001	40.608448	69.195240	97.684002	47.537426
covariance matrix					
53.967155	33.535265	69.660571	-15.800603	117.254421	103.295697
33.535265	23.264519	45.931809	0.750338	84.171626	69.506811
69.660571	45.931809	99.826045	-22.889488	171.121876	151.388773
-15.800603	0.7050338	-22.889488	140.418399	43.231309	-25.636412

Table 2. Principal component analysis transformation of characteristic value and characteristic vector

characteristic value					
18.966984	0.683514	2.4816441	65.986014	775.234213	7.010476
feature vector					
0.61662	-0.29996	-0.61098	-0.13063	0.23415	-0.29090
0.35896	0.91499	0.01846	-0.01323	0.16132	-0.8596
0.47192	-0.25826	0.74928	-0.18106	0.33801	0.04631
0.28453	-0.07294	-0.00455	0.91276	0.00716	0.28376
-0.41080	-0.00696	0.04012	0.28101	0.69980	-0.51078
-0.13602	0.02728	-0.25163	-0.19464	0.56136	0.75128

TM7-Z), the surface is the load distribution of the fifth factor axis on three wavebands. The peak value distribution area is the principal component load, where the lowest correlation exists. In this case, the load on TM5 is medium, Y=0.70. The lithologic information is mainly distributed in the area with a large contribution of TM5, Y=0.85. With the use of the three-dimensional coordinates (TM1-X, TM7-Y, TM5-Z), the surface is the load distribution of the sixth factor axis on three wavebands. The minimum value distribution area is the principle component load, where the lowest correlation exists. The lithologic information is mostly distributed on TM7 (Y=0.81) and the area of TM5 with large contributions (Y= –0.38).

According to the above analysis, the load factor 526 is selected to compose the factor image, which can effectively distinguish the ore-bearing bedrock and provide reliable foundations for detailed exploration in the future.

5. CONCLUSION

In this paper, the principle and theory of MD & KDD is applied to establish a multi-dimensional LED-VLI data field, with the mercury mine zone of western Hunan and eastern Guizhou taken as an example to process the LED-VLI data. According to the analytical results, the distribution information of the ore bed can be obtained, thereby providing a basis for decisions on further geological exploration. This paper proved that effective data mining methods can facilitate the acquisition of more useful information from the LED-VLI data, which is beneficial to the development of LED-VLI information and can positively contribute to various research fields (e.g. geology and oceanography). However, the depth and extent of this research require further discussion and investigation because of the limitations of the research data, imaging time, and time resolution of the LED-VLI data.

REFERENCES:

1. Fan GL, Liu YW, Tong JQ, Zhao SH, Nie ZQ. Application of K-means algorithm to web text mining based on average density optimization. Journal of Digital Information Management, 2016, V14, #1, pp.41–46.

2. Zhang L, Shi Z, Wu J. A Hierarchical Oil Tank Detector With Deep Surrounding Features for High-Resolution Optical Satellite Imagery. 2015.

3. Wen-Sheng M A, Wang A C. The Application of Satellite Image-based Image Data Mining in Forest Fire Analysis. Forestry Labour Safety, 2008.

4. Miao Z, Shi W, Samat A, et al. Information Fusion for Urban Road Extraction From VHR Optical Satellite Images. IEEE Journal of Selected Topics in Applied Earth Observations & Remote Sensing, 2016, pp.1–14.

Dong LIANG,
Doctor of signal and information processing. Currently, he is with the Beijing University of Posts and Telecommunications. Fellow of big data mining

Huahua XIE,
Post graduate student of the Key Laboratory of Universal Wireless Communication, BUPT. Fellow of big data mining

Zhaojing, ZHANG,
Post graduate student of the Key Laboratory of Universal Wireless Communication, BUPT. Fellow of big data mining

Hao JIN,
Doctor of signal and information processing. Assistant Professor of the Key Laboratory of Universal Wireless Communication, BUPT. Fellow of optimization of mobile wireless

Light & Engineering
Vol. 24, No. 3, pp. 61-65, 2016

Svetotekhnika
No. 5, 2016

APPLICATION OF LED VISIBLE LIGHT COMMUNICATION TECHNOLOGY IN THE AIRBORNE PASSIVE LOCATION FOR EMERGENCY COMMUNICATION

*Hongping PU and Kaiyu QIN

School of Aeronautics and Astronautics, University of Electronic Science and Technology of China, Chengdu 611731, China
**E-mail: hongpingpu284@yeah.net*

ABSTRACT

To improve the accuracy of emergency communications, this paper addresses a method to locate unmanned aerial vehicles (UAV) using LED visible Light Communication Technology. The system can also transmit passive location to an airborne single station. The study was performed as follows: first, the algorithm of the calculating phase difference was established to conduct UAV positioning. The method of detecting the intensity of the received optical signal was applied to UAV positioning. Then, the phase difference was measured by using the two-dimensional Fourier transform method. Finally, simulation technology was used to analyze the feasibility of the LED visible light system. This research promotes the development of LED visible light technology and its application in emergency communications.

Keywords: airborne passive location, LED visible light communication technology, emergency communications

1. INTRODUCTION

In emergency communications, passive location technology is used for rapid positioning and accurate identification to enable remote monitoring of tactical situations and attack planning. Passive location technology can ensure that secret acceptance of signals cannot be easily traced by the enemy and is effective at a long distance; therefore, it has become one of the important directions in future developments [1].

At present, scholars are actively attempting to develop passive location technology without using other auxiliary platforms to simplify the system [2–4].

Consequently, passive location technology has recently been receiving much attention among engineers and researchers, unmanned aerial vehicles (UAVs) use passive location systems to detect and observe targets. This paper proposes the application of LED visible light communication technology in UAVs and determines the feasibility of the application of passive location systems in UAV through analysis, research, and use of driving environment simulation experiments. In the plan design, the phase difference measurement method of the two-dimensional Fourier transform is applied to analyze the algorithm of passive location. Conclusions are drawn from the analysis of the simulation experiment.

2. STATE OF THE ART

Visible light communication technology

Two popular positioning systems are used nowadays. The first one is GPS positioning, which is mostly used in outdoor environments; because it is radio based, it has low accuracy because of electromagnetic interference in many places. With GPS, transmission and communication quality will become poor when users share their location with

each other. Moreover, GPS is unusable in aircrafts and other places with harsh electro-magnetic interference requirements. The current direction of research and development is the use of LED visual light for positioning. Positioning is divided into two types, one that needs imaging and the other that needs to display the target coordinates of the location only. For the positioning system that does not require imaging, the traditional positioning method can be used to locate the objects via the communication mode with multiple points. The indoor positioning that needs imaging should use the VLC system. Thus, the indoor positioning system required for imaging will become the mainstream topic of future research.

UAV observation platform model

$O'-X'Y'Z'$ coordinates are built by using the state [5, 6*]. Intersection hypothesis: The intersection point O' is the intersection point of the wing axis of the aircraft and the axis of the lower part, and the punching head of the fuselage direction is the axis direction $O'X'$. The wing axis toward the left side is the axis $O'Y'$. The $O'Z'$ axis uses the right rule for the direction perpendicular to the plane $O'X'Y'$ and pointing above. The azimuth angle of the i time target relative to the observation platform is β_i, and the pitch angle is ε_i. An antenna should be placed on the left wing and fuselage tail axis, and its value should be three standard units. Hence, it forms two interferometers that are orthogonal to each other.

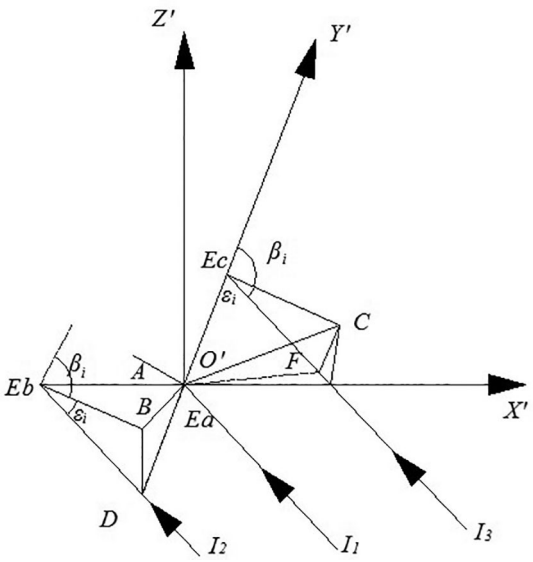


Fig.1. UAV platform to receive the target LED visible light sketch map

According to Fig.1 the two unit elements of the interferometer are E_a and E_b, and the distance between the two unit elements is dx. The two unit elements mounted on the wings' phase interferometer are Ea and Ec. The distance between the two unit elements is dy; l_1, l_2. and l_3 are the directions of the target LED visible light that are received by E_a, E_b, and E_c, respectively. Too much distance exists between the observation target and the UAV, and it far exceeds dx and dy. Thus, the error that is generally considered $l_1 // l_2 // l_3$ can be ignored. EaB, EbB, and EcC are projections of l_1, l_2 and l_3, respectively, on the $O'X'Y'$ plane. Therefore, the wave and path difference of the top two unit elements is E_bD when receiving visible light, and the wave and path difference of the last two unit elements is E_cF. Thus, the phase difference of two unit elements E_a and E_b of body axis phase interferometer that receives the target LED visible light at the i time is:

$$\phi_{xi} = \omega_T \times \Delta t_x = 2\pi f_T \times \times \frac{d_x}{c} \sin\beta_i \cos\varepsilon_i = k_x f_T \sin\beta_i \cos\varepsilon_i, \quad (1)$$

$$k_x = \frac{2\pi d_x}{c}.$$

The change rate of corresponding phase difference is:

$$\phi_{xi}' = k_x f_T \left(\beta_i' \cos\beta_i \cos\varepsilon_i - \varepsilon_i' \sin\beta_i \sin\varepsilon_i\right). \quad (2)$$

The phase difference of the two unit elements E_a and E_c of the wings' phase interferometer that receives LED visible light is:

$$\phi_{yi} = \omega_T \times \Delta t_y = 2\pi f_T \times \frac{d_y}{c}\left(-\cos\beta_i \cos\varepsilon_i\right) = = k_y f_T \cos\beta_i \cos\varepsilon_i, \quad (3)$$

$$k_y = \frac{2\pi d_y}{c}. \quad (4)$$

The change rate of corresponding phase difference is:

$$\phi_{yi}' = k_y f_T \left(\beta_i' \sin\beta_i \cos\varepsilon_i - \varepsilon_i' \cos\beta_i \sin\varepsilon_i\right). \quad (5)$$

In all the above formulae, the wave angular frequency of reaching the observation platform is ω_T on average, the wave frequency is f_T, and the time difference of wave reaching E_a and E_b is presented by Δt_x, and the speed of light is c.

The geometric relationships at i moments have the following information:

$$\beta_i' = \frac{\left(x'_{Tgi} - x'_{Ogi}\right)\left(y_{Tgi} - y_{Ogi}\right) - \left(x_{Tgi} - x_{Ogi}\right)\left(y'_{Tgi} - y'_{Ogi}\right)}{r_i \cos\varepsilon_i}, \quad (6)$$

$$r_i = \frac{\left(x'_{Tgi} - x'_{Ogi}\right)\cos\beta_i - \left(y'_{Tgi} - y'_{Ogi}\right)\sin\beta_i}{\beta_i \cos\varepsilon_i}. \quad (7)$$

In the formula, the radial distance from the target to the observation platform at i time is presented by r_i, and then formula (8) is used to obtain the current position of the observation target.

$$\begin{aligned} x_{Tgi} &= x_{Ogi} + r_i \cos\varepsilon_i \sin\beta_i \\ y_{Tgi} &= y_{Ogi} + r_i \cos\varepsilon_i \cos\beta_i . \\ z_{Tgi} &= z_{Ogi} + r_i \sin\varepsilon_i \end{aligned} \quad (8)$$

In accordance with the aircraft coordinates $O'X'Y'Z'$, the azimuth of the target can be calculated by the above formula. Navigation equipment in an UAV can determine the relative position and relative velocity between itself and a fixed observation target on the ground. The observed data can be used to calculate the specific location of the fixed observation target.

3. METHODOLOGY

LED visible light communication technology

This paper proposes a new positioning system that has the same aspects as current popular methods but places more emphasis on optical signal communication. When receiving the positioning signal, the positioning is carried out according to the strength of the received signals; this approach is called the VLC positioning method. The component that tests the strength of signals is a photoelectric detector. The principle of this method is similar to that of RSSI. Thus, this method is convenient for mixed uses. This positioning method has two types: one is parameterized positioning, and the other is non-parameterized positioning. In this paper, parameterized positioning is used. In the parameterized VLC positioning system, when only line links are present in the positioning system, the information transmission in the positioning system has only two methods: direct or reflection. The arriving power reaches its maximum when it is direct, and it occupies the largest percentage of the total power. Hence, we studied direct transmission.

The mathematical expression of DC gain of direct distance from LED to the receiving side is

$$H(0) = \begin{cases} \frac{(m+1)A}{2\pi d 2}\cos^{\mathrm{m}}(\phi) T_s(\phi) g(\phi)\cos(\phi), & 0 \le \phi \le \phi_c \\ 0, & \phi > \phi_c . \end{cases} \quad (9)$$

In the formula, the photoelectric detector's receiving area is A; the distance between the transmitting terminal and the receiving side is d; the angle of incidence is ϕ; the launch angle is also ϕ; the optical filter gain is $T_s(\phi)$; the light condenser gain is $g(\phi)$; the receivers' perspectives are ϕ_c; and the light source radiation pattern is m. The equation for m is

$$m = \frac{\ln 2}{\ln\cos\Phi_{1/2}}. \quad (10)$$

In the formula (10), the half-angle light power is $\Phi_{1/2}$, which means that the value of central power is twice the power generated by the angle. The value of m is related to the direction of the emitted light. When the m is larger, the probability that all the photons in the light will fly toward the target direction is greater. Generally, the value of m is set at 1. Size determines the direction of the beam, and a greater value corresponds to better direction of the beam. Usually, we take m to be equal to 1. The distance between the point of light source and the point required positioning can be obtained by using the above equation and the obtained data. Moreover, in indoor short-distance positioning, the light source that can be received by the point required positioning is excessive (> 3). Thus, this point that can be located by three sides originally can be located by establishing a set of equations to solve and

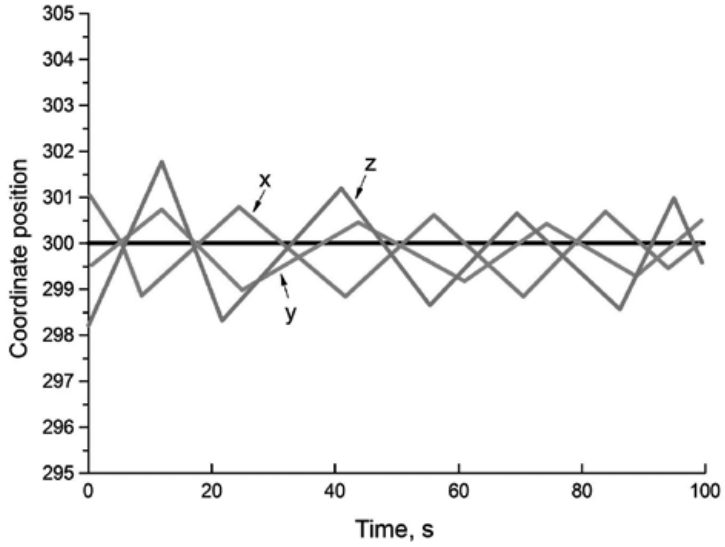


Fig. 2. Testing value of the object in three dimensions

estimate them at this time. Finally, the coordinates of the location of the point can be confirmed more accurately.

Phase difference measurement method based on two-dimensional Fourier transform

The precision of the phase difference measured by a phase interferometer with element antenna directly affects the final positioning accuracy. However, the use of two-dimensional Fourier transform to measure can effectively remove the external clutter in the target LED visual light. However, the measurement method requires the spectral information of sampling signals to measure signal phase. Taking the sine signal as an example, the sampling value is

$$x(n)=\sin\left(\frac{2\pi}{N}q*n\right). \tag{11}$$

In Formula (11), q is an integer $(q=0,1,\cdots,N-1)$. Its discrete Fourier transform is

$$X(k)=\sum_{n=0}^{N-1}x(n)W_N^{kn}\,(k=0,1,\cdots,N-1). \tag{12}$$

Among this,

$$x(n)W_N^{kn}=\frac{1}{2}j\cdot\exp\left[-j\frac{2\pi}{N}(q+k)n\right]- -\frac{1}{2}j\cdot\exp\left[-j\frac{2\pi}{N}(q-k)n\right]. \tag{13}$$

Thus, $X(k)$ should be

$$X(k)=\frac{1}{2}j\sum_{n=0}^{N-1}\left\{\begin{array}{l}\exp\left[-j\frac{2\pi}{N}(q+k)n\right]-\\ -\exp\left[-j\frac{2\pi}{N}(q-k)n\right]\end{array}\right\}. \tag{14}$$

Two sinusoidal signal sequences are

$$\begin{aligned}x_1(n)&=\sin\left(\frac{2\pi}{N}qn+\varphi_1\right),\\ x_2(n)&=\sin\left(\frac{2\pi}{N}qn+\varphi_2\right).\end{aligned} \tag{15}$$

Two-dimensional Fourier transform uses the phase difference measurement method, in which many computations use Fourier transformation, and the FFT real-time processing computer is used to receive signals. This measuring method satisfies the measuring requests of UAV.

4. RESULT AND DISCUSSION

This paper verifies the operability and performance of the UAV search and rescue system through an experiment of simulated reality. We set the fixed target location on the ground beyond 1km, as required by the application. The simulation reality is to set the coordinates of the fixed target to be measured, and the specific value of the fixed coordinate system is (300, 300, 300) m. $f_T=5\times10^{14}$ Hz

is the target radiation frequency; the initial point of the UAV platform is (20, 20, 100) m, whose flight speed is $100\times\left(\cos_{\eta_i}\cos_{\gamma_i},\cos_{\eta_i}\sin_{\gamma_i},-\sin_{\eta_i}\right)$ m/s and the separate baseline length of two phase interferometers arranged over the head is *dx* equal to 10 m and *dy* equal to 5 m. In the simulation experiment, θ_i is the orientation angle of aircraft gesture, η_i is the angle of pitch, and γ_i is the yaw angle. Their change rates are

$\theta_i = 0.075°/s, \eta_i = -0.075°/s, \gamma_i = -0.00125°/s$

According to the phase difference measurement method introduced in this paper, we conducted simulation and Monte Carlo simulation experiment 100 times. The simulation results of target coordinates x, y, z are shown in Fig. 2.

Through the experiment of simulated reality, we can conclude that under certain restrictions, the positioning function of the system can acquire the target location in the coordinate system with a deviation of generally less than 1 m, and the coordinate difference of *z* direction is less than 2m, which can meet the application requirements.

5. CONCLUSION

In this study, a passive location system was used to locate the UAV accurately. The UAV was used as an observation platform to locate the observation object. First, we analyzed the model algorithm of the UAV passive location system, and we used the method of phase difference change rate to locate. Then, two-dimensional Fourier transform was applied to signal measurement, and we explained the composition and design of LED passive location in actual applications. Finally, computer simulation experiment results show that the LED passive location system can be used in emergency communication. This study provides a perspective for future research on the UAV advanced positioning system.

REFERENCES:

1. Dawidowicz B, Kulpa K S, Malanowski M, et al. DPCA detection of moving targets in airborne passive radar. Aerospace and Electronic Systems, IEEE Transactions on, 2012, V48, #2, pp. 1347–1357.

2. Lee W S, Alchanatis V, Yang C, et al. Sensing technologies for precision specialty crop production. Computers and electronics in agriculture, 2010, V74, #1, pp. 2–33.

3. Moll F, Horwath J, Shrestha A, et al. Demonstration of high-rate laser communications from a fast airborne platform. Selected Areas in Communications, IEEE Journal on, 2015, V33, #9, pp. 1985–1995.

4. Stamatiadis S, Taskos D, Tsadila E, et al. Comparison of passive and active canopy sensors for the estimation of vine biomass production. Precision Agriculture, 2010, V11, #3, pp. 306–315.

Hongping PU,
Ph.D. Student in the University of Electronic Science and Technology of China. Research field: Passive Location System, Navigation

Kaiyu QIN,
Ph.D. professor, UESTC. Research field: Passive Location System, Communications

Light & Engineering
Vol. 24, No. 3, pp. 66-69, 2016

Svetotekhnika
No. 5, 2016

ROCK SLOPE MONITORING TECHNIQUES BASED ON SEMICONDUCTOR LIGHT SOURCE APPLICATION

Zhenyang FENG[1*], Dongyan LIU[1,2], Zhengwei ZHU[1], and Haifeng DING[3]

[1]School of Civil Engineering, Chongqing University, Chongqing, China,400030;
[2] School of Civil Engineering and Architecture, Chongqing University of Science and Technology, Chongqing, China,401331;
[3] China Overseas Real Estate Corporation Ltd., Harbin, Heilongjiang, China, 150000;
**E-mail:1516740442@QQ.COM*

ABSTRACT

This thesis explores the key problems in the stress transfer rule of mortar based materials of composite optical fibre devices. Issues in the monitoring of side slope deformation are also investigated. An indoor direct shear test is adopted to study the correspondence between fibre loss and slippage displacement, as well as the stress transfer rule of mortar base materials, on the basis of theoretical analysis. Results indicate that foam as the base material reaches the maximum stroke under the optimal mortar proportion of 1:5 and that PVC reaches its maximum stroke under the optimal mortar proportion of 1:9. Then, the corresponding curves and relational expressions between optical loss and slippage displacement under the optimal mortar proportions are established. The results indicate that the former is highly sensitive because of its monitored maximum displacement of 49.7mm.

Keywords: light source, optical time domain reflection (OTDR) technology, rock slope, slope monitoring

1. INTRODUCTION

Optical time domain reflection (OTDR) technology based on semiconductor light sources was invented in the 1970s [1], when scholars started to study the application of this technology to rock slope monitoring because of its advantages, which include convenience, safety, low cost, and remote use [2]. Subsequently, Chinese scholars began exploring the same research area. Tianguo Tang and Yiwen Zhua et al. [3] buried bare fibre into a cylinder of C40 concrete and then simulated rock slippage via triaxial compression. The authors primarily verified the feasibility of using the OTDR technology with fibre as the sensor in distributed landslide monitoring, but the measured maximum stroke of fibre is 3.6mm, and the dynamic range is 0–3.3mm. Dongyan Liu and Zhengwei Zhu et al [4] developed a composite fibre device for monitoring slope deformation. The device is buried through drilling and grouting and deforms together with the slope. The monitored maximum stroke is 23.6mm, and the maximum dynamic range is 0–21.1mm. The same authors studied other aspects, including monitoring theory, laboratory simulations test, and field applications.

Although previous scholars have achieved impactful results in OTDR, further research is needed. The thesis of this study is a theoretical research based on a composite optical fibre device. By simulating rock slippage via shearing concrete blocks, we perform a model test on the sensor of a composite optical fibre device to determine the optimal proportion of mortar under different base materials. We also establish the corresponding curves and relational expressions between fibre loss and slippage displacement.

2. DIRECT SHEAR TEST WITH COMPOSITE OPTICAL FIBRE DEVICE

The grouting material is the bridge that transfers the load of rock and earth mass around the drilling hole to the composite optical fibre device. The combination of different grouting materials and the composite optical fibre device with different materials present different phenomena. To effectively apply the OTDR technology based on semiconductor light sources to slope engineering monitoring, the optimal grouting proportion should be determined. As for the working conditions in this experiment, three factors are mainly considered: base materials, cross-sectional areas of base materials, and mortar proportions.

Types of base material: PVC tube and foam;

Sectional dimensions of base material: 25mm, 45mm;

Mortar proportions:1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8, 1:9.

We set four 1mm capillary steel tubes at the central axis outside the base material of the composite optical fibre device and cover them with 2mm capillary steel tubes to prevent adhesion between the mortar and the 1 mm capillary steel tubes outside the base material. The bottom parts of the steel tubes are attached to the surface of the base material as indicated in Fig. 1.

Loading. Push the jacks up to 2mm each time, and record the reading of the OTDR instrument. When the bowknot point at the top of the device can be read or is broken, end the loading, and measure the deformation of the fibre. Then, analyze the relationship between the displacement at the shearing surface of the composite optical fibre device and the reflection coefficient on the OTDR instrument on the basis of the measured deformation. The shear deformation of the composite optical fibre device is illustrated in Fig. 2.

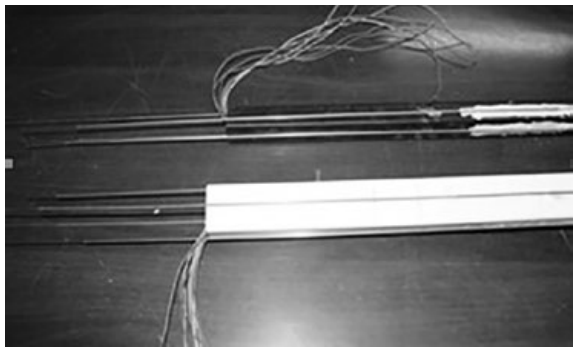


Fig.1. Composite optical fibre device

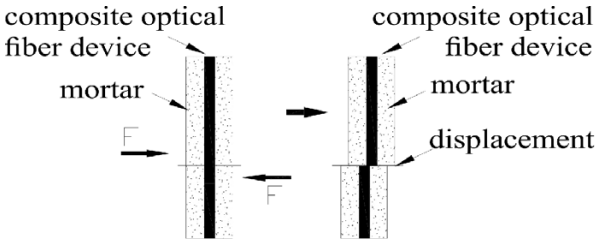


Fig.2.Schematic diagram of shear deformation of composite optical fibre device

3. ANALYSIS OF TEST RESULTS

3.1. Optimal cement–mortar ratio under different base materials

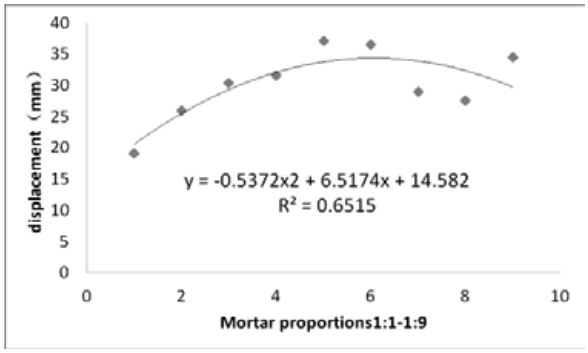
We analyzed the change rule of the maximum sliding displacement of the model under different base materials and different cement–mortar ratios. Subsequently, we experimentally obtained the change curve of the maximum sliding displacement, as shown in Fig. 3.

(1) The maximum sliding displacement of the composite optical fibre device with foam as the base material, the side lengths of which are 25mm and 45mm, is observed at the cement–mortar ratio of 1:5. This result indicates that the maximum measuring range of the composite optical fibre device appears at this moment. In other words, the cement–mortar ratio of 1:5 is the optimal ratio of the composite optical fibre device with 25 mm × 25 mm foam as the base material.

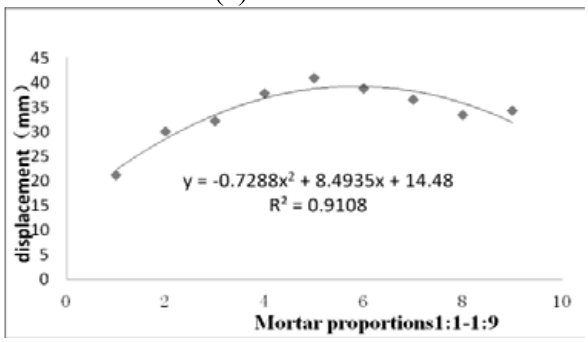
(2) The maximum sliding displacement of the composite optical fibre device with PVC as the base material, the side lengths of which are 25mm and 45mm, increases with a decrease in the cement–mortar ratio. Hence, the change curve shows that the maximum sliding displacement of the composite optical fibre device with PVC as the base material occurs when the cement–mortar ratio is 1:9. That is, the cement–mortar ratio of 1:9 is the optimal ratio of the composite optical fibre device with 25 mm × 25 mm PVC as the base material.

3.2. Response relationship between fibre energy consumption and displacement curve at load point

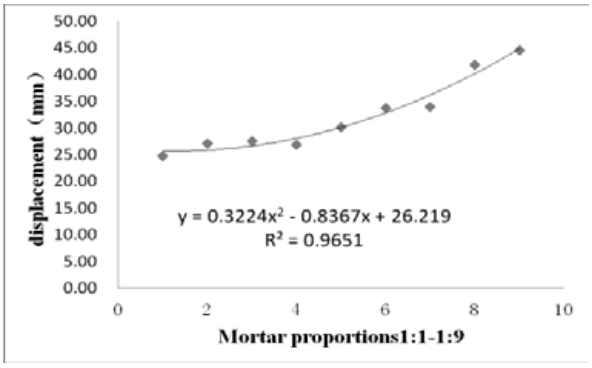
The fibre losses of the composite optical fibre device under different cement–mortar ratios in-



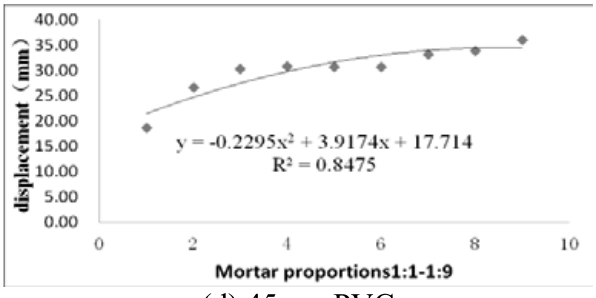
(a) 25mm foam



(b) 45mm foam



(c) 25mm PVC



(d) 45mm PVC

Fig. 3. Relationship curve between maximum sliding displacement and cement–mortar ratio under different base materials

crease with an increase in the displacement of the load point. If the displacement is small, then the amplitude of the increase is relatively small. As the displacement of the load point rises, the amplitude of the increase in fibre loss also increases and reaches the peak value at the cement–mortar ratio of 1:1.

Table 1. Values of coefficients in relational expression between fibre loss and sliding displacement

Coefficient	*a*	*b*	*c*	*d*
25 mm ×25mmPVC	0.339	–3.514	15.894	2.673
45 mm ×45mmPVC	0.979	–10.18	32.912	1.992
25 mm ×25mm foam	0.630	–6.907	25.173	1.764
45 mm ×45mm foam	0.436	–5.366	22.838	1.644

3.3. Relational expression between fibre loss and sliding displacement

The values of different sliding displacements and fibre losses under the optimal cement–mortar ratio are used for fitting to obtain the relational expression between the fibre loss and the sliding displacement of the composite optical fibre device with different base materials. The curves, formulas, and relevant coefficients obtained through fitting based on experimental data are shown in Figure 7. The squared value of the relevant fitting coefficients is between 0.9906–0.9946. Thus, the correlation of the fitting formulas is relatively good. The fitting formulas are all cubic polynomials, and thus, the relational formula between the fibre loss and the sliding displacement of the composite optical fibre device with different base materials can be synthetically written as

$$y = ax^3 + bx^2 + cx + d,$$

where y is the sliding displacement (mm); x is the value of fibre loss, db; and a, b, c, and d are the coefficients, the values of which are shown in Table 1.

4. CONCLUSIONS

(1) Through direct shear test, the micro bend loss of semiconductor light sources during optical fibre transmission can be determined with OTDR technology. This technology can accurately reflect the fibre loss caused by the deformation of the opti-

cal fibre sensing device. Thus, applying the OTDR technology based on semiconductor light sources to slope monitoring is feasible.

(2) The analysis of the results of the direct shear test reveals the corresponding curve and empirical correlation between fibre loss and sliding displacement. The data collected with the OTDR technology can infer the deformation state of the sliding surface of rock slopes and may thus serve as basis for the issuance of primary warnings on safety.

This research reveals that OTDR technology based on semiconductor light sources presents broad prospects in rock slope monitoring. However, the relational expression in this work is based on a single sliding surface in laboratory model experiments. Therefore, other factors should be considered in the future research.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the National Natural Science Foundation of China (No. 51478066 and 51178488).

REFERENCES:

1. Lines M E. Scattering losses in optic fibre materials. 2. Numerical estimates. Journal of Applied Physics, 1984. V55, pp.4058–4063.

2. F. Cappa, Y. Guglielmi, S. Gaffet, H. Landon, L Lamarque. Use of in situ fibre optic sensors to characterize highly heterogeneous elastic displacement fields in fractured rocks, International Journal of Rock Mechanics and Mining Sciences, 2006.V43,#4, PP. 647–654.

3. Tang Tianguo, Zhu Yiwen. Optical Fibre Sensing Monitoring Principle of Rock Stratum Sliding. Rock Mechanics and Engineering Journal, 2006.V25, #2, pp.340–344.

4. Zhu Zhengwei. Research on Technology Progress of Slope Stability Monitoring. Chongqing University of Science & Technology (Natural Science Edition), 2008. V10, #3, PP.31–34.

Zhenyang FENG,
Doctoral Candidate of Civil Engineering, Studying in Chongqing university, pursuing his studies in Geotechnics, Geohazards and etc

Dongyan LIU,
Doctor of Civil Engineering, Professor, Doctoral Supervisor, mainly engaged in environmental pollution and geo hazards research

Zhengwei ZHU,
Doctor of Civil Engineering, Professor. Graduated from the CQU. Mainly engaged in environmental pollution and geo hazards researches

Haifeng DING,
Graduated from the Heilongjiang Institute of Technology, pursuing his studies in project management and engineering technology

Light & Engineering
Vol. 24, No. 3, pp. 70-73, 2016

Svetotekhnika
No. 5, 2016

APPLICATION OF A NEW LED LIGHT IRRADIATION TECHNOLOGY IN THE RESIN REPAIR OF DENTAL FLUOROSIS

Jialing LI[1*], Min HUANG[2], Penghao LIANG[1], and Lige ZHENG[1]

[1]*Stomatological Hospital of Southwest Medical University, Luzhou, China*
[2]*Nanchong Central Hospital, Nanchong, China*
**E-mail: lijialingshsm837@yeah.net*

ABSTRACT

This paper evaluates the application prospects of a new type of LED irradiation technology in oral cavity aesthetic repair by comparing its clinical effect and that of traditional halogen irradiation technology in the repair of dental fluorosis resin. One hundred cases of mild dental fluorosis (TFI=1–3) receiving treatment in our hospital from February 2014 to February 2015 are selected and divided into two groups. The new type of LED light curing lamp bluephase® 20i and irradiation composite resin Z350 is applied for 10 s in 50 cases in Group A. The traditional halogen lamp ALC-50 and irradiation composite resin Z350 is applied for 40 s in 50 cases in Group B. We then evaluate the clinical effect of the two groups one year after treatment. Group A obtained better results with a success rate of 86% and a patient satisfaction rate of 88%. By contrast, the success rate of Group B is only 74%, and patient satisfaction rate is 70%. The gap between the two results is statistically significant ($P < 0.05$). This paper concludes that the new type of LED irradiation technology can more effectively improve the success rate of the dental fluorosis resin repair compared with the traditional halogen lamp. Furthermore, its irradiation time is short and easy to handle, thereby explaining its high clinical application value.

Keywords: LED; dental fluorosis, halogen lamp, composite resin

1. INTRODUCTION

Four types of light curing lamps currently exist, based different light sources, namely, quartz-tungsten-halogen light curing lamp, LED light curing lamp, argon laser light curing lamp, and plasma electric arc lamp. Among these lamps, the plasma electric arc lamp and argon laser light curing lamp are complicated, expensive, and infrequently applied in clinical cases. In recent years, with the development of LED technology, the LED light curing lamp has attracted increasing attention from many clinicians. Unfortunately, the first and second generations of the LED irradiation technologies have significant defects in the application of oral aesthetic repair despite their fast light curing speed, small light thermal radiation, and a light and handy design [1–3].

First, their spectrum is too narrow and can cure only light-cured materials with camphorquinone as the initiator [4]. Such technology is incompatible with Lucirin TPO, a common initiator in aesthetic repair materials. Therefore, despite the several defects of the traditional halogen lamp, such as its long operating time, slow light curing speed, high optical radiation heat production, and bulb burn-in, the lamp is still widely used in composite resin aesthetic repair of dental fluorosis. The third generation of LED irradiation technology has been developed, which possesses all the advantages of the previous two generations and perfectly resolves the defects of narrow spectrum and short duration. This paper applies both the new type of LED light cur-

ing lamp and the traditional halogen lamp in the repair of dental fluorosis resin. Their clinical effects are compared and analyzed, and the clinical application value of the new type of LED irradiation technology in the treatment of dental fluorosis is evaluated [5].

Materials

The light-cured resin is ESPE Filtek Tm Z350 (3M ESPE, St. Paul, MN, USA), and its colour includes A1, A2, and A3. The LED light curing lamp is bluephase®20i (Ivoclar Vivadent, Schaan, Liechtenstein), which has an output power of 1200 mW/cm ^{2}, as shown in Fig.1. The halogen lamp is ALC-50, which has an output power of 500 mW/cm^2 and is produced by Aosuo Medical Apparatus and Instruments in Hangzhou, China.

Experimental Subject

We select 100 dental fluorosis patients in the stomatologic hospital of the Southwest Medical University from February 2014 to February 2015. Among these patients, 57 are males and 43 are females. Their ages range from 17 to 58 with an average age of (33.1±7.9). These patients are informed about the content of this experiment, and their consent is obtained before they are divided into two groups. We adopt the new type of LED light curing technology for the 50 patients in Group A and the traditional halogen light curing technology for the 50 patients in Group B.

Method of repair for light-cured resin

All the patients are treated by the same doctor. First, the surface of the teeth is washed. Then, the teeth colour under the natural light (less than 5s) is compared. Afterwards, resin repair materials with a similar colour are chosen. We wash the teeth surface by using the regular procedure and then polish and desiccate them. Acid etching is conducted with a cotton ball with 37% phosphoric acid for 1 min. The enamel surface is washed with running water from the air gun for 10 s to 15 s. After acid liquor and chippings are removed, the teeth are desiccated with compressed air. Afterwards, we can see that the acid-etched surface is white. Enamel adhesives are sprayed and light cured for 15 s. The light-cured composite resin is sprayed, and moulding solidity is conducted in different layers. We adopt blue phase® 20i in Group A to conduct light curing for 10 s, and ALC-50 is applied in Group B to conduct light curing for 40 s to restore the normal physiological anatomic form of the teeth. Finally, we adjust the occlusion, examine the high spot, and polish the teeth.

Therapeutic evaluation

Subsequent clinical visits were conducted one year after the resin repair treatment and the clinical effects were evaluated, including repair effects and the self-assessment of satisfaction rate of the patients. Among these patients, 57 are males and 43 are females. Their ages range from 17 to 58 with an average age of (33.1±7.9). For repair effects, the same doctor conducts routine oral inspection and adds dental pulp vigour test when necessary. The doctor evaluates the dummy colour, margin discrepancy, loosening or falling off of the teeth, periodontal conditions, dental pulp conditions, and secondary caries in accordance with the Modified Ryge Criteria. When the six indicators are normal, the repair is deemed successful. The repair is considered to have failed if any one of the six indicators is abnormal. As for the satisfactory rate of patients, this hospital conducts a survey of the two groups of patients with its own questionnaire, which includes three aspects, namely, good appearance, occlusion function, and psychological status; the total is 10 points, with each aspect accounting for 4 points, 3 points, and 3 points, respectively. The patients mark their response according to their own impressions after the light-cured resin repair. A high score corresponds to a high satisfaction rate. Scores of 9–10 are deemed excellent, scores of 7–8 are good, and scores of 6 and below are poor. The satisfaction rate is the ratio of the total number of patients who provided an excellent or good remark of the repair to the total number of patients.

Statistical analysis

We apply SPSS19.0 (SPSS, Chicago, USA) to conduct χ^2 analysis of the experimental results. The gap ($P < 0.05$) indicates statistical significance.

3. RESULTS

Light-cured resin repair effects

Among the 50 patients of dental fluorosis in Group A there were four cases of dummy colour changing, two cases of poor margin discrepancy, one case of dummy loosening, thereby indicating a repair success rate of 86%. Among the 50

patients of dental fluorosis in Group B there were five cases of dummy colour changing, four cases of poor margin discrepancy, three cases of dummy loosening, one case of secondary caries after repair, thereby indicating a repair success rate of 74%. Results are shown in Table 1. We apply SPSS19.0 to conduct interblock χ^2 analysis ($P < 0.05$), which demonstrates that the new type of LED irradiation can achieve far better clinical effects than the traditional halogen irradiation in terms of dental fluorosis resin repair.

Fig. 1. New type of LED light-cured bluephase® 20i lamp

Evaluation of the satisfaction rate of patients

Among the 50 patients in Group A, 31 report an "excellent" satisfaction level, 13 provide a "good" mark, and 6 provide a "poor" mark. The total satisfaction rate is 88%. Among the 50 patients in Group B, 24 reported an "excellent" satisfaction level, 11 provided a "good" mark and 15 provided a "poor" mark. The total satisfaction rate is 70%. Results are shown in Table 2. We apply SPSS19.0 to conduct interblock χ^2 analysis ($P < 0.05$) and found that the new type of LED light curing method can achieve a better patient satisfaction rate.

4. DISCUSSION

LED has many clear advantages over the traditional halogen lamp, thereby enabling its ideal adaptation to light curing of oral biological materials. First, the ray of light has a small thermal radiation with no other lights being generated thereby suggesting that little extra heat is generated when the LED light curing lamp is operating. A lower tendency of damage to the teeth and the power of the cooling fan are expecting. Such lowering of risk will not only be conducive to the teeth but will also reduce noise when working. Second, the operating life of LED is longer than that of other light sources. It is sturdy, durable, small in size, and stable in terms of light beam concentration. Some scholars have found that the LED lamp is superior to the traditional halogen lamp after comparing the light-cured surface strength, abrasive resistance, and solidity depth obtained by the two light sources.

Despite the numerous advantages of the previous LED light curing lamp, using it in resin aesthetic repair treatment is still not possible. This finding can mainly be explained by the light-cured composite resin possibly being classified into fill-

Table 1. Comparison of the Clinical Effects between the New Type of LED Group and the Traditional Halogen Lamp Group

Group	Number of cases	Colour changing	Poor margin	Loosening	Periodontal diseases	Secondary caries	Dental pulp diseases	Successful cases	Repair success rate, %
led group	50	4	2	1	0	0	0	43	86
traditional halogen lamp	50	5	4	3	0	1	0	37	74

Table 2. Comparison of the Satisfaction Rate of the Patients in the New LED Group and the Traditional Halogen Lamp Group

Group	Number of cases	Excellent	Good	Poor	Satisfaction rate, %
LED group	50	31	13	6	88
Traditional halogen lamp	50	24	11	15	70

ing resin and aesthetic repair resin in accordance with its application method and two different types. The most widely used photoinitiator, camphorquinone, of the filling resin can absorb the wave crest of 468 nm, which is extremely close to that of the old type LED lamp (435–485) nm. Therefore, it has the high initiation efficiency. However, dental fluorosis aesthetic repair adopts the initiator of the light-cured composite resin, which requires the wavelength of the light source to be less than 430 nm. As a result, the first and second generations of LED light curing lamp have poor light curing effects in resin repair of dental fluorosis. The current third-generation LED irradiation technology has ideally resolved the above problems. This lamp has three blue light LED emitters and one short purple light LED light wave emitter. These light wave emitters can generate more than two different narrow waves whose wavelength ranges exceed that of the traditional halogen lamp and can rapidly cure all the light-cured composite resin in the current clinical application. The new LED light curing lamp improved its output power with a maximum of 2200 mW/cm^2. This result has significantly reduced the time required in clinical light curing, which is not only conducive for doctors to operate but also reduces the possibility of oral contamination. To obtain a better evaluation of the clinical effects of the new LED light curing lamp and provide data support for its clinical promotion, this experiment applies a clinical experiment, compares its clinical effects with that of the traditional halogen lamp, and demonstrates that the third generation of the LED light curing lamp is superior to the traditional halogen lamp in dental fluorosis resin repair.

5. CONCLUSION

Compared with the traditional halogen irradiation technology, the new type of LED irradiation technology is more effective in dental fluorosis resin repair; it not only reduces the clinical operational time but also significantly improves treatment effects and satisfies patients' needs. Therefore, LED technology has high clinical application value.

REFERENCES:

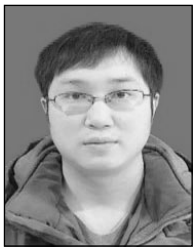
1. Jandt KD, Mills RW. A brief history of LED photopolymerization. Dent Mater. 2013, V29, #6, p.605.

2. Pettemerides AP, Sherriff M, Ireland AJ. An in vivo study to compare a plasma arc light and a conventional quartz halogen curing light in orthodontic bonding. Eur J Orthod. 2004, V26, #6, p. 573.

3. Moon HJ, Lee YK, Lim BS, et al. Effects of various light curing methods on the leachability of uncured substances andhardness of a composite resin. J Oral Rehabil, 2004, V31, #3, pp. 258–264.

4. Shortall AC. How light source and product shade influence cure depth for a contemporary composite. J Oral Rehabil, 2005, V32, #12, pp. 906–911.

5. Price RB, Labrie D, Rueggeberg FA, et al. Irradiance differences in the violet (405 nm) and blue (460 nm) spectral ranges among dental light-curing units. J Esthet Restor Dent. 2010. V22, #6, p.363.



Jialing LI,
Oral Postgraduate, Practicing Physician, Graduated from Southwest Medical University. Doctor of Stomatological Hospital of Southwest Medical University

Min HUANG,
Clinical Medicine Undergraduate, Practicing Physician, Graduated from Southwest Medical University. Doctor of Nanchong Central Hospital

Penghao LIANG,
Oral Postgraduate, Practicing Physician, Graduated from Southwest Medical University. Doctor of Stomatological Hospital of Southwest Medical University

Lige ZHENG,
Oral Undergraduate, Professor, Graduated from Sichuan University. Doctor of Stomatological Hospital of Southwest Medical University

Light & Engineering
Vol. 24, No. 3, pp. 74-78, 2016

Svetotekhnika
No. 5, 2016

NUMERICAL SIMULATION OF LIGHT PULSE TRANSMISSION IN ATMOSPHERIC TURBULENCE

Bin REN[1,2*] and Chunyi CHEN[1]

[1] School of Computer Science and Technology, Changchun University of Science and Technology, Jilin, Changchun, 130022 China;
[2] School of Computer Technologies and Engineering, Changchun Institute of Technology, Jilin, Changchun, 130012 China;
**Email: renbin_ccit@126.com*

ABSTRACT

Light pulse spreading time caused by atmospheric turbulence results in the shape variation of pulse time and an increase in bit error rate. This study used a split-step transmission method under weak turbulence across a horizontal path to conduct a numerical simulation calculation of collimating ultra-short pulse transmission with a two-frequency mutual coherence function. Then, the results are compared with the numerical analysis results of 100 groups of data. Under weak turbulence and narrow-band assumptions, numerical simulation results of the two-frequency mutual coherence function for the first 20 groups of data were identical with the numerical analysis results. The results also demonstrated that as the difference in value between the two frequencies increased, the degree of coherence that could be maintained was reduced.

Keywords: atmospheric turbulence, light pulse, split-step transmission, two-frequency mutual coherence function, numerical simulation

1. INTRODUCTION

Free-space optical communication can acquire a considerably higher transmission rate than traditional wireless communication; hence, it has been extensively applied to the fields of laser and LED light communication. However, free-space optical communication is easily influenced by atmospheric turbulence, which causes distortion phenomena such as light pulse spreading and signal attenuation, among others. Hence, there is a need to comprehensively study the distortion factors of a light pulse in atmospheric turbulence.

In recent years, numerous scholars have focused studies on light pulse transmission. Andrews et al. [1] studied pulse spreading based on the two-frequency mutual coherence function. Young et al. [2] conducted a numerical analysis of arrival time fluctuations of space–time Gaussian pulses in weak turbulence. Chen et al. [3] completed a numerical analysis of the two-frequency mutual coherence function of the transmission of Gaussian pulses in anisotropic turbulence. Although the two-frequency mutual coherence function plays a significant role in studies on the transmission characteristics of light pulses in atmospheric turbulence, most studies are numerical analyses based on the two-frequency mutual coherence function, whereas only a few are numerical simulation studies.

Hence, the current study conducted a numerical simulation of the two-frequency mutual coherence function of the horizontal transmission of Gaussian pulses in turbulence using weak turbulence theory and collimated light beam transmission theory. Then, the correlation of the results with the results of a numerical analysis was analyzed.

2. NUMERICAL SIMULATION MODEL FOR LIGHT PULSE TRANSMISSION IN ATMOSPHERIC TURBULENCE

To conduct a numerical simulation of light pulse transmission in atmospheric turbulence, an algorithm and model for numerical simulation should be initially established before verification can be conducted.

Atmospheric Transmission Model for Light Pulse

The output expression form of a light pulse through atmospheric transmission is [4]

$$v_0(r,L;t) = \\ = \frac{1}{2\pi}\int_{-\infty}^{\infty} V_i(\omega)U(r,L;\omega+\omega_0)e^{-i\omega t}d\omega, \quad (1)$$

where $V_i(\omega)$ is the Fourier transform of the input pulse amplitude, and $U(r,L;\omega+\omega_0)$ is the transmission function of a pulse in the atmosphere.

Two-Frequency Mutual Coherence Function

The two-frequency mutual coherence function was used to calculate and analyze an ultra-short pulse in the frequency domain; this function could describe the coherence degree of optical waves after passing through a random medium. The calculation formula is as follows [4]:

$$\Gamma_2(r_1,r_2,L;k_1,k_2) = \left\langle U(r_1,L;k_1)U^*(r_2,L;k_2)\right\rangle \\ = U_0(r_1,L;k_1)U_0^*(r_2,L;k_2) \\ \left\langle \exp[\psi(r_1,L;k_1)+\psi^*(r_2,L;k_2)]\right\rangle \\ = \Gamma_2^0(r_1,r_2,L;k_1,k_2)M_2(r_1,r_2,L;k_1,k_2). \quad (2)$$

3. VERIFYING THE REASONABILITY OF PARAMETER SELECTION IN THE NUMERICAL SIMULATION

Selection of the Verification Model

To verify the reasonability of parameter selection in a numerical simulation under weak turbulence, a group of specific parameters is used to conduct sampling. The numerical simulation program is operated, and a normalized scintillation variance in single-frequency transmission is obtained and compared with the prediction results of weak turbulence theory. If the difference is minimal, then the sampling parameter setting is considered reasonable.

The normalized scintillation variance formula is as follows:

$$\sigma_I^2 = \frac{< I >^2}{< I^2 >} - 1. \quad (3)$$

The predictor formula of weak turbulence theory is as follows Eqn. 4, [4] :

In formulas (3) and (4), the outer scale influencing factor is $Q_o = {Lk_o^2}/{k}$, whereas the inner scale influencing factors are $Q_m = {35.05L}/{kl_o^2}$, $\sigma_R^2 = 1.23C_n^2k^{7/6}L^{11/6}$, $k_o = {2\pi}/{L_o}$,

$\varphi_1 = \tan^{-1}\left[\frac{(1+2\Theta)Q_m}{3+2\Lambda Q_m}\right]$, and $\varphi_2 = \tan^{-1}\left[\frac{2\Lambda}{1+2\Theta}\right]$.

Verification Results

The wavelength of light used in the test is 800 nm, the structure constant C_n^2 of the atmospheric refractive index is 1×10^{-16}, the transmission distance is 3 km, the inner scale of the atmospheric turbulence is 0.003 m, the outer scale is 0.2 m, the

$$\sigma_I^2(r,L) = 3.93\sigma_R^2\Lambda^{5/6}[(\frac{\Lambda Q_m}{1+0.52\Lambda Q_m})^{1/6} - 1.29(\Lambda Q_o)^{1/6}]\frac{r^2}{W} \\ +3.86\sigma_R^2\left\{\begin{array}{l} 0.40\dfrac{[(1+2\Theta)^2+(2\Lambda+3/Q_m)^2]^{11/12}}{[(1+2\Theta)^2+4\Lambda^2]^{1/2}} \\ -\sin(\dfrac{11}{6}\varphi_1+\varphi_2) \\ -\dfrac{6\Lambda}{Q_m^{11/6}[(1+2\Theta)^2+4\Lambda^2]} - \dfrac{11}{6}(\dfrac{1-0.31\Lambda Q_m}{Q_m})^{5/6} \end{array}\right\}. \quad (4)$$

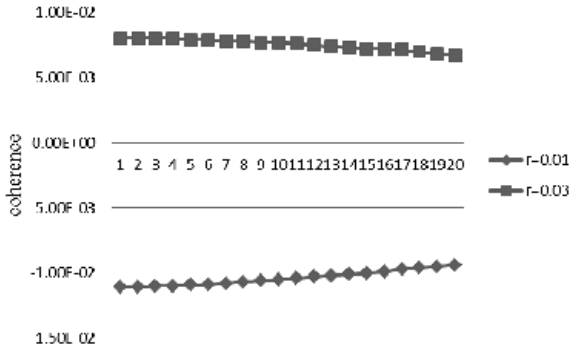


Fig.1. Calculation results of the variation of different r values with k variation of the first 20 groups

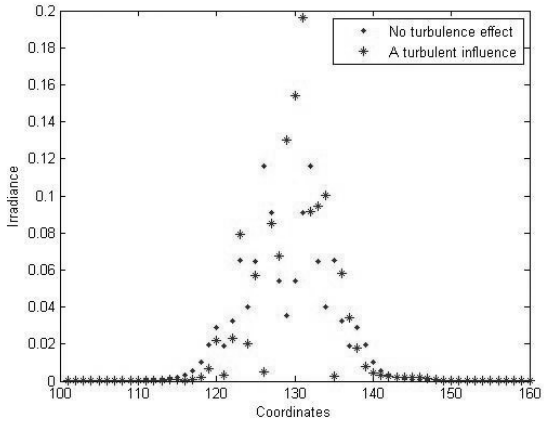


Fig.3. Average light intensity of k_1 when C_n^2 is 1×10^{-14}

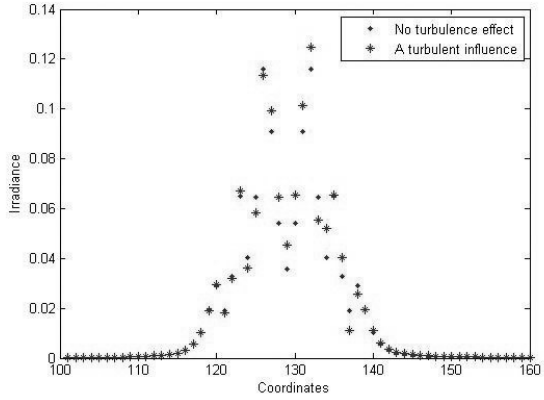


Fig.2. Average light intensity of k_1 when C_n^2 is 1×10^{-16}

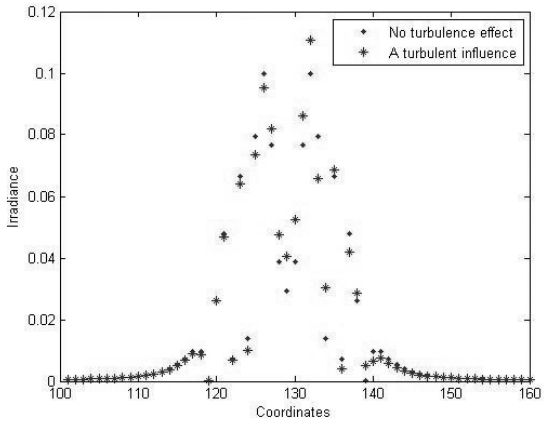


Fig.4. Average light intensity of k_2 when C_n^2 is 1×10^{-16}

waist radius of the Gaussian beam is 0.01 m, and the Rytov variance is 0.03. The scintillation variance obtained by sampling the aforementioned group of specific parameters is 0.048, which is nearly identical to the prediction results of the theory. Hence, the sampling parameters can satisfy the test under weak turbulence.

4. COMPARISON BETWEEN THE NUMERICAL SIMULATION RESULTS AND THE NUMERICAL ANALYSIS RESULTS

Numerical Simulation Results

The sampling parameters and the conditional constraints determined by the verification model were used to complete the numerical simulation at points $r = 0.01$ and 0.03. The simulation results are calculated using the following formula:

$$\Gamma_2(r,r,L;k_1,k_2) = \left\langle U(r,L;k_1)U^*(r,L;k_2)\right\rangle. \qquad (5)$$

The values of k_1 and k_2 during the numerical simulation are as follows:

$$k_1 = k_c + {k_d}/{2} \text{ and } k_2 = k_c - {k_d}/{2}, \qquad (6)$$

where the k_d value is considered according to a 1% variation of the wavelength. The calculation results of the first 20 groups of the two-frequency mutual coherence function with k_d variation are presented in Fig.1

The Fig.1 shows that as the difference in value between the two frequencies increases, the degree of coherence that can be maintained is reduced.

To analyze the influences of the atmospheric turbulence parameters on an average pulse waveform, the influences are verified through a numerical simulation of the average light intensity per pulse. The verification results are presented in Figs.2–5.

In these figures, the dots denote lack of turbulence influence, whereas the asterisks denote the

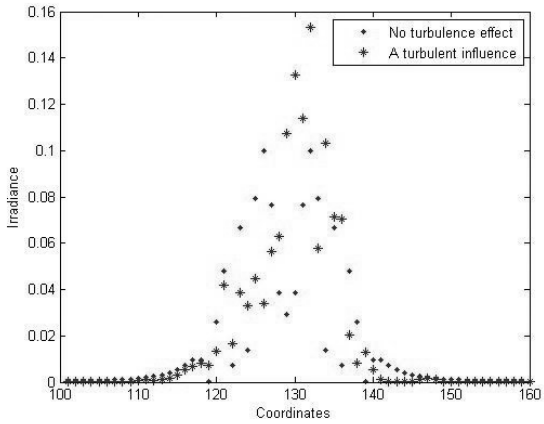


Fig.5. Average light intensity of k_2 when C_n^2 is 1×10^{-14}

presence of turbulence influence. The influences of the atmospheric turbulence parameters of k_1 under strong and weak turbulence conditions on an average pulse waveform are shown in Figs.2–3, whereas the influences of the atmospheric turbulence parameters of k_2 under strong and weak turbulence conditions on an average pulse waveform are shown in Figs.4–5. The comparison shows that the concurrence between an average pulse waveform under strong turbulence influence and that under no turbulence influence is relatively low. By contrast, the concurrence between an average pulse waveform under weak turbulence influence and that under no turbulence influence is high.

Selection of Numerical Analysis Model and Calculation Results

Weak turbulence is assumed to be approximated with a narrow band. For a collimated Gaussian pulse ($\Theta_0 = 1$), when $\Lambda_{0m} \gg 1$ and $\omega_d^2 \ll \omega_c^2$, the far-field approximation of the pulse, and the two-frequency mutual coherence function formula of (r_1=r_2=r, t_1=t_2=t) on the same axis is as follows Eqn. 7, [4],

where $a_1 \cong \dfrac{0.39C_n^2 Lk_o^{-5/3}}{c^2}$, $\Lambda_{0m} = \dfrac{2L}{k_m W_0^2}$, $\Theta_0 = 1$,

and $\omega = kc$.

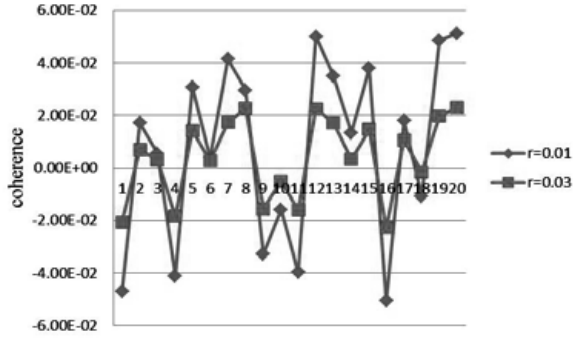


Fig.6. When $\omega_d^2 \ll \omega_c^2$, the calculation results of the first 20 groups as different r values change with the k variation

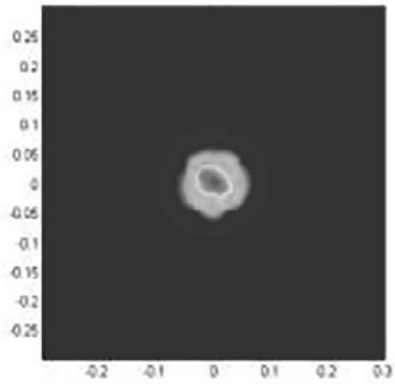


Fig.7. k_1 = 7.89E+06

This study used far-field approximation to conduct a numerical analysis according to the sampling parameters and conditional constraints determined by the verification model. The numerical analysis results of the first 20 groups are presented in Fig.6.

COMPARISON OF RESULTS

Under weak turbulence and narrow-band assumptions, transmission distance is set at 3 km, light beam wavelength at 800 nm, number of samples at 256, number of phase screens at 12, grid spacing of phase screens at 0.01 m, and the structure constant C_n^2 of the atmospheric refractive index as 1×10^{-16}.When the numerical simulation results and the numerical analysis results of the first

$$\Gamma_2(r,r,L;\omega_1,\omega_2) = \Gamma_2(r,r,L;\omega_0+\omega_c+\frac{1}{2}\omega_d,\omega_0+\omega_c$$
$$-\frac{1}{2}\omega_d) \cong (\frac{W_0^2}{2Lc})^2(\omega_0+\omega_c)^2 \times \exp[-\frac{1}{2}(\frac{W_0 r}{Lc})^2(\omega_0 \qquad (7)$$
$$+\omega_c)^2] \times \exp[i(\frac{L}{c}+\frac{r^2}{2Lc})\omega_d - a_1\omega_d^2],$$

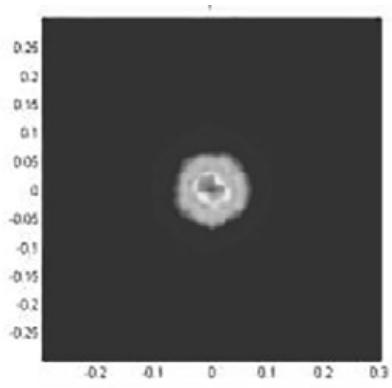


Fig.8. k_1 = 7.15E+06

20 groups are compared after a collimated Gaussian pulse is transmitted across 3 km, the correlation coefficient is obtained at 0.56, which indicates that the proposed method can complete the numerical simulation of a two-frequency mutual coherence function after an optical pulse is transmitted through atmospheric turbulence. Furthermore, when the results of different k values are compared, the transmission results become increasingly poor as k values change, Figs.7–8.

5. CONCLUSIONS

This study combines the split-step transmission method, weak turbulence theory, and far-field transmission model to propose a numerical simulation method for the two-frequency mutual coherence function after a collimated ultra-short pulse is transmitted across a horizontal path with weak turbulence. The results obtained using this method are then compared with the numerical analysis results of 100 groups of data. The comparison indicates that when $\omega_d^2 \ll \omega_c^2$, the numerical simulation results of the two-frequency mutual coherence function of the first 20 groups are identical with the numerical analysis results, which proves the feasibility of the proposed numerical simulation method.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the National Natural Science Foundation of China (No. 61275080).

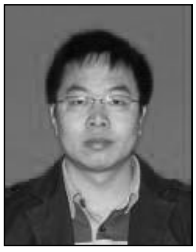
REFERENCES:

1. L. C. Andrews, R.L. Phillips, R. Crabbs, and T. Leclerc. Deep turbulence propagation of a Gaussian-beam wave in anisotropic non-Kolmogorov turbulence. Proc. SPIE, 2013. V8874, p.887402.

2. Cynthia Y. Young, Larry C. Andrews, and Akira Ishimaru. Time-of-arrival fluctuations of a space-time Gaussian pulse in weak optical turbulence: an analytic solution. Applied Optics, 1998. V37, #33, pp. 7655–7660.

3. Chunyi Chen, Huamin Yang, Shoufeng Tong, Bin Ren, and Yanfang Li. Characterization of temporal pulse broadening for horizontal propagation in strong anisotropic atmospheric turbulence. Optics Express, 2015. V23, #4, pp. 5797–5799.

4. Larry C. Andrews, and Ronald L. Phillips. Laser beam propagation through random media. Proc. SPIE, 2005. pp. 737–749.



Bin REN,
Ph. D. candidate at
Changchun University
of Science and Technology

Chunyi CHEN,
Doctor of Physical
Electronics, Assistant
Professor. Graduated from
Changchun University
of Science and Technology

Light & Engineering
Vol. 24, No. 3, pp. 79-82, 2016

Svetotekhnika
No. 5, 2016

APPLICATION OF LED-BASED ARRAY SIGNAL TRANSMISSION TECHNOLOGY IN THE INFORMATION TRANSMISSION OF BIOLOGICAL TISSUE

Xiaohua JIN

Suzhou Polytechnical Institute of Agriculture, Jiangsu, China
E-mail: xiaohuajin_spi986@163.com

ABSTRACT

The transformation of biological information plays an important role in biological information research and the present paper is based on the understanding of relevant research results in China and abroad. This study applies biological information in transmission technology of light emitting diode array signals to transform biological information. The study further proposes the transmission technology of visible light dynamic parallelism and reconfigurable computing method for bioinformatics. Experimental data show that the technical scheme is feasible and the performance indicators meet user requirements.

Keywords: LED, array signal transmission, transformation of biological information

1. INTRODUCTION

In 2016, Brunner D.O. [1] determined that light emitting diode (LED) had the characteristics of energy conservation, environmental protection, long life, low power consumption, and is strong, reliable, and easy to maintain and adjust. LED is a fourth generation light source that can be used in all kinds of applications, display, adornment, back light, general lighting, and other fields. In 2010, Chiu H.J. [2] studied the development of industry and technology breakthrough, and found that the luminous efficacy was improved and had a lower price. A newly combined pipe core technology also increased the power of a single module. In 2014, Chaigne T. [3] determined that the single situation of LED products had a further turn and that the improvement of control software for LED lighting has made them more convenient. These studies show that LED has wide applications. Kilappa V. [4] stated that the absence of a message resulted in being unable to have normal life activities. A previous study conducted in 2013 observed the significance of the transformation of information in adjusting the relationship between organisms' populations and maintaining the stability of ecological systems. In 2015, Koonin E.V. [5] determined that the study of transformation of biological information can help control harmful biology phenomena and improve the production level of farming and animal husbandry.

The present article studies the application of transmission technology of LED array signals to transform biological information on the basis of the understanding of relevant research results in China and abroad. In Section 2, we study the application technology of transformation of biological information. In Section 3, we propose the dynamic parallelism of the visible light transmission technology and reconfigurable computing method for bioinformatics. In Section 4, we analyze the experimental data and research. Finally, in Section 5, we summarize the processes and results.

2. BACKGROUND

LED

LED is a type of semiconductor diode that can convert electric energy to light energy. LEDs and normal diodes both have unidirectional conductiv-

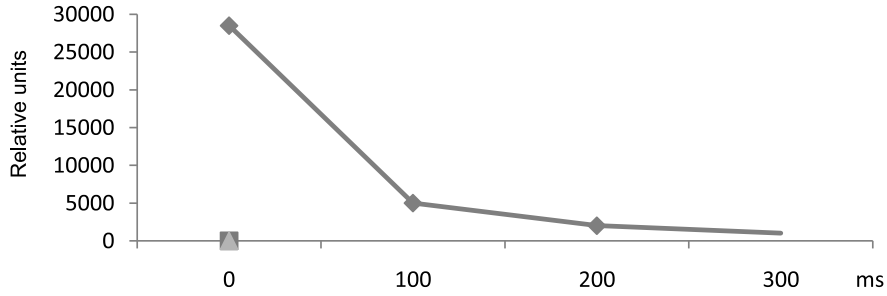


Fig.1. Schematic diagram of delayed luminescence of samples

ity and are composed of *p*-*n* junctions. In loading the forward voltage, electrons from the *p* area to *n* holes or from *n* area into *p* area will be in several micrometers within the *p*-*n* junctions and compound with the electrons in *n* area and holes in the *p* area, respectively. Through spontaneous emission of visible light from electroluminescence, LEDs can be used to create indicator lights and lighting sources [6]. Compared with incandescent light bulbs and neon, LED has high efficiency, long life, low work voltage and electric current, good impact resistance, good seismic performance, high switching speed, and reliability, which other traditional light sources do not have [7]. LEDs can also be divided into ordinary monochromatic, high brightness, colour changing, flicker, voltage control, infrared and negative resistance types, such as persistence and constant pressure, which represent two kinds of control modes, and perform a variety of dimmer methods. Most LEDs have constant current control, which is intended to maintain current stability and prolong service life [8].

Transformation of biological information

Information refers to the ways that various new media communicate with each other, which contains information output, information transmission, and information acceptance. Biological information has significant effects upon organisms and contains a wide range of information. The genetic material, nerve impulses, hormones, voice, odour, colour, and behaviour of living organisms belong to biological information [9]. Basic biological information can be divided into physical information, chemical information, and behavioural information. Physical information means that a message is transferred by physical process, such as voice. Chemical information means that creatures in the life activities of chemicals can convey information, such as animal's sexual pheromones. Behaviour information means that numerous plants and animals can convert some kind of special behavioural information, such as "Bees can dance." The transformation of information widely exists in ecosystems. Biological normal life activities and the maintenance of population and ecosystem must be implemented by sending and receiving information [10].

3. METHODOLOGY

Transmission techniques of parallel communication of visible light

The basic idea of parallel communication of visible light is that after launching modulated information loading on display array and observing array emission signals with high speed observational system, parallel communication restores the original information content through the corresponding image and information processing. QR (Quick Response Code) has a high recognition rate, large information capacity, error correction ability, and all-around read capacity. The present paper applies to an array of communication and provides a dynamic display of QR code information. The machine obtains QR code images that will be processed and decoded. The scheme has good adjustability, large volume, high resource utilization, application flexibility, and so on.

The QR code symbol is composed of a series of modules and a two-dimensional array, which is divided into detection patterns, positioning graphics, separator, and function graphics, which are used to hold data in an encoded data area of the two parts. Function graphic symbols are used to determine the location, size, and slope. QR does not have starting and terminal operators. To detect the position of the bar code, the bar code must use the characteristics of the location where the graphics is being detected. To satisfy the QR, the QR code symbols of the characteristics of high speed read

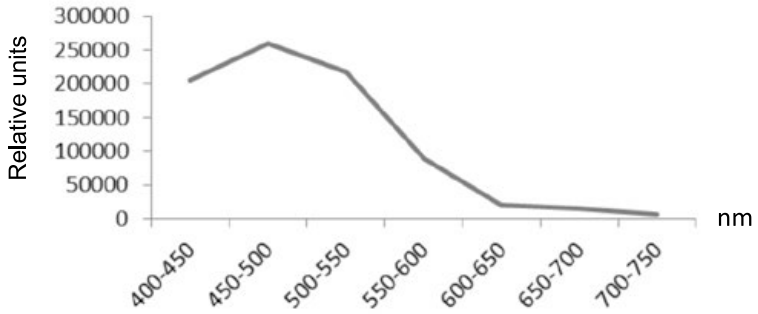


Fig.2. Delayed luminescence spectra

and all-round read can use QR codes to detect the characteristics of the position detection pattern. By focusing on the scale features, we have three thresholds for processing whole images, and have rotation correction for sloping images by using vertical and horizontal scanning.

Reconfigurable computing method of information biology

League matching is a process wherein more than one symbol sequence are compared with each other and reflect the process of the similarities and differences between them**.** With the rapid growth of biological information data, the demand of the large-scale analysis method for biological information has become increasingly urgent. During the long-term evolution of organisms, the same sequences differ for various reasons. Thus, organisms cannot fully complete the exact match but a certain similarity exists. On the basis of combining the actual demand and with the editing distance, which can significantly measure the similarity of two sequences, we can obtain an editing distance algorithm, which is a global sequence matching algorithm.

Editing distance algorithm is computed by the degree of similarity of the matrix dynamic programming algorithm, which can yield the editing distance of two sequences. This method usually does not require outputting each point score, and only requires the final score matrix at the right corner of bottom. This value is the editing distance between two sequences. We need to determine the function score in the process of calculation according to the matching biological significance. When calculating the editing distance, the inserting and deleting scores can be set as 1 and replacing score as 2 because replacing is equivalent to deleting and inserting. This calculation is in line with the significance of the editing distance in biological practice that the probability of replacement is less than the possibility of insertion and deletion. In this case, each point's score in the matrix will be equal to the horizontal or vertical direction's adjacent points score plus or minus 1. The calculation can be simply proved through mathematical induction.

4. RESULT ANALYSIS AND DISCUSSION

A delayed luminescence, which does not place any filter cases, is shown in the Fig. 1.

The sample's delayed luminescence trends to 1 ms and then becomes smooth and late data adulterate noise effects. The light attenuation in front of the apparent phase is a typical biological photons relaxation time. At this stage, biological photons carry most biological information. We provide a numerical summation to the corresponding band of the photon to delay luminescent emergent light spectra value, as shown in Fig. 2.

The experimental analysis shows that the transmission technique of parallel communication of visible light has a message capacity. The equipment is also small in size, which enables the equipment to achieve higher linking gain, better information transmission quality, and can be implemented in large capacity and low array signal transmission distortion. Reconfigurable editing distance algorithm has a large amount of data. The algorithm is relatively simple and the parallelism is high. Hence, the type of operation is simple and has strong repeatability.

5. CONCLUSION

Visible light communication refers to the development of newly developing wireless optical communications based on the light response of the de-

vice used in high speed. The present paper seeks to understand the Chinese and foreign related research results, discusses some relevant concepts and principles, points out the transmission technique of dynamic parallelism of visible light and reconfigurable computing method faced in information biology, and conducts experiments to verify the correctness of the theory and the feasibility of the scheme. Results show that the technical scheme is feasible and the performance indicators rapidly, accurately, and effectively meet the requirements of using the biological message content. However, to strengthen the application research of optical communications requires making optical communications richer, ensuring perfect information perception, and gathering technological means, which will bring about significant research value and development space.

REFERENCES:

1. Brunner D. O., Pruessmann K.P. SVD analysis of Array transmission and reception and its use for bootstrapping calibration. Magnetic resonance in medicine, 2016.

2. Chiu H. J., Lo Y.K., Chen J.T., et al. A high-efficiency dimmable LED driver for low-power lighting applications. Industrial Electronics, IEEE Transactions on, 2010. V57, #2, pp. 735–743.

3. Chaigne T., Gateau J., Katz O., et al. Light focusing and two-dimensional imaging through scattering media using the photoacoustic transmission matrix with an ultrasound array. Optics letters, 2014. V39, #9, pp. 2664–2667.

4. Kilappa V., Xu K., Moilanen P., et al. Assessment of the fundamental flexural guided wave in cortical bone by an ultrasonic axial-transmission array transducer. Ultrasound in medicine & biology, 2013. V39, #7, pp. 1223–1232.

5. Koonin E.V. The meaning of biological information. Phil. Trans. R. Soc. A, 2016. V374, #2063, pp. 20150065.

6. Metildi C. A., Kaushal S., Luiken G.A., et al. Fluorescence laparoscopy with an LED light source enables fluorescence-guided resection of pancreatic cancer, labeled with fluorophore-conjugated antibodies, in mouse models. Cancer Research, 2013. V73, #8, pp. 4138–4138.

7. Chakrabarti M., Thorseth A., Jepsen J., et al. Monte carlo analysis of multicolour LED light engine. Proc. of 28th CIE Session, 2015.V 526.

8. Atta M., Idris A., Bukhari A., et al. Intensity of blue LED light: a potential stimulus for biomass and lipid content in fresh water microalgae Chlorella vulgaris. Bioresource technology, 2013. V148, pp. 373–378.

9. Buikema Jr. A. L., Niederlehner B.R., Cairns Jr.J. Biological monitoring. Biological monitoring in water pollution, 2013. V239.

10. Koch M.A., German D.A. Taxonomy and systematics are key to biological information: Arabidopsis, Eutrema (Thellungiella), Noccaea and Schrenkiella (Brassicaceae) as examples. Front Plant Sci, 2013. V4, pp. 267.

Xiaohua JIN,
Master of Agriculture, Lecturer. Graduated from Nanjing Agricultural University. At present, she is in staff of Suzhou Polytechnic Institute of Agriculture

Light & Engineering
Vol. 24, No. 3, pp. 83-86, 2016

Svetotekhnika
No. 5, 2016

DESIGN OF PERIODICAL LIGHT COMPENSATION EQUIPMENT FOR LETTUCE IN GREENHOUSE COMBINING LED LIGHTS

Li WANG[1,*], Hongjian HUANG[1], Peitao TAN[1], and Xiaowei ZHANG[2]

[1]Xinhui Forestry Science Institute, Guangdong, China
[2]Huazhong Agriculture University, Hubei, China
**E-mail: liwangxfsi836@126.com*

ABSTRACT

The rapid development of greenhouse technology has attracted increased attention to research on greenhouse supplementary lighting. To improve performance of supplementary lighting system in lettuce greenhouses, this study uses the combination of blue and red light LEDs to design a new model of intelligent periodic supplementary lighting system for the lettuce greenhouse. Researchers used solar power to provide electricity for the system to improve energy efficiency. Results indicated that this system provides periodic supplementary lighting to the greenhouse, demonstrating a high degree of applicability and expandability.

Keywords: lettuce greenhouse, supplementary lighting system, LED, micro-controller

1. INTRODUCTION

Lighting plays an important role in the growth rate and quality of crops. With the development of greenhouse crop growing, research on supplementary greenhouse lighting has also increased. In recent years, experts and scholars in China and abroad have conducted significant research on this front. Compared with foreign research, domestic research in China in this area started late and is not sophisticated enough, but has indicated progress. In 2001, Hu Guangyong [1] and others put forward the idea of artificial supplementary lighting equipment in greenhouses. This method delivers supplementary lighting in greenhouses to a certain extent. However, the study has a low degree of intelligent design and expandability. In 2006, Xu Zhiru [2] and others designed an intelligent measurement and controlling system for the greenhouse environment based on a micro-controller. This system could operate stably and achieved intelligent management of the greenhouse. In 2011, Zhang Haihui [3] and others proposed a comprehensive self-adapting precise supplementary lighting system. This system produced a high degree of reliability in the performance of the supplementary lighting system and improved energy utilization rate. In 2013, Liu Xiang [4] and others presented an intelligent greenhouse supplementary lighting system based on expert's rule. The result indicated that this system realized intelligent supplementary greenhouse lighting and improved the quality of crops. In 2015, Li Zhengming and others designed a combination of LED lighting used in the supplementary lighting of greenhouses. The results showed that this system achieved an ideal supplementary lighting effect and had a high degree of applicability and expandability. However, most supplementary lighting systems currently adopt single fixed light intensity, which cannot achieve precise supplementary lighting. The system also has a high degree of energy consumption, high degree of error, and a slow response speed.

Based on the above studies and to improve the performance of the system, this paper designed a periodically supplementary lighting system in lettuce greenhouses based on LED light. The second chapter provides an analysis of the conditions and

demand for supplementary lighting system in greenhouses in China. The third chapter explains in detail the design and research process of periodic supplementary lighting equipment in lettuce greenhouses based on LED lights. The fourth chapter describes the experiment and research. Finally, the fifth chapter is the summary of the paper.

2. TECHNOLOGY BACKGROUND

The quality and rate of growth as well as the photosynthesis and material metabolism of lettuce cannot be achieved without lighting. Different light intensities and qualities have different effects on the growth of lettuce. At present, in agriculture, fluorescent and incandescent lights are used as light sources. However, these light sources incur high costs and have high energy consumption. Thus, such lights are not convenient for daily maintenance and control. Moreover, the lights cannot achieve precise supplementary lighting. While most supplementary lighting systems adopt single fixed light intensity, such a system cannot achieve precise supplementary lighting. In addition, the system uses a lot of energy and presents a high degree of error and slow response speeds. Further, given that the system prevents reasonable adjustment according to growth conditions and demand of crops, it is not beneficial to ensure quality and efficiency of crop growth. To address this gap, we need to develop an intelligent greenhouse supplementary lighting system with low energy consumption and high degree of performance. In recent years, with the development of semiconductor technology, light-emitting diodes (LED) have been used in greenhouse supplementary lighting system because of their high reliability, low energy consumption, wavelength characteristics, and other features.

3. METHODOLOGY

Overall design of the system

According to the above analysis, this study establishes periodic supplementary lighting equipment based on LED light in a lettuce greenhouse. The overall structure of the system is shown in Fig. 1.

In Fig. 1, the testing module adopted temperature and light intensity sensors to conduct real time monitoring of information, such as temperature and light intensity in the lettuce greenhouse. The core processor of the intelligent controlling module uses a STC12C5A60S2 micro-controller, which is responsible for data collection, data storage, information output, management and dispatch, and other tasks in the system. The power module adopted solar energy to provide electricity with voltage of 5 V and 12 V to the entire system. The supplementary lighting module used two Pulse Width Modulation (PWM) drive circuits to control the red and blue LEDs to realize supplementary lighting in the greenhouse. The user interaction module is composed of an LCD and keyboard. The function of the former is to realize the display of system data, whereas the latter is responsible for input and alteration of relevant system data.

HARDWARE DESIGN

Power module

The power module consists of a solar panel, accumulator, and control circuit. The solar power is stored in the accumulator through the control circuit. The power module needs to provide 5 V power supply to the testing and user interaction modules and 12 V power supply for supplementary lighting module. Given that we used MIC29302 voltage stabilization and voltage transformation module, the accumulator could only provide both 12 V and 5 V power supply after adjustment.

Controlling module

The controlling module is powered up by 5 V stabilized power supply. In the design of this paper, the core processor of the intelligent controlling module was equipped with a STC12C5A60S2 micro-controller, which has 1280B Static RAM, 56K Flash memory space, A/D port, and PWM output port. The module is responsible for data collection, data storage, information output, management, and dispatch, as well as other tasks in the system.

Testing module

To conduct real time monitoring on temperature and light intensity in the lettuce greenhouse, we used temperature and light intensity sensors to conduct real time monitoring on temperature and light intensity and other information. The information was sent to the micro-controller for data processing. The testing module included temperature and light intensity testing modules. Temperature testing module realized data collection of temperature in the greenhouse through tempera-

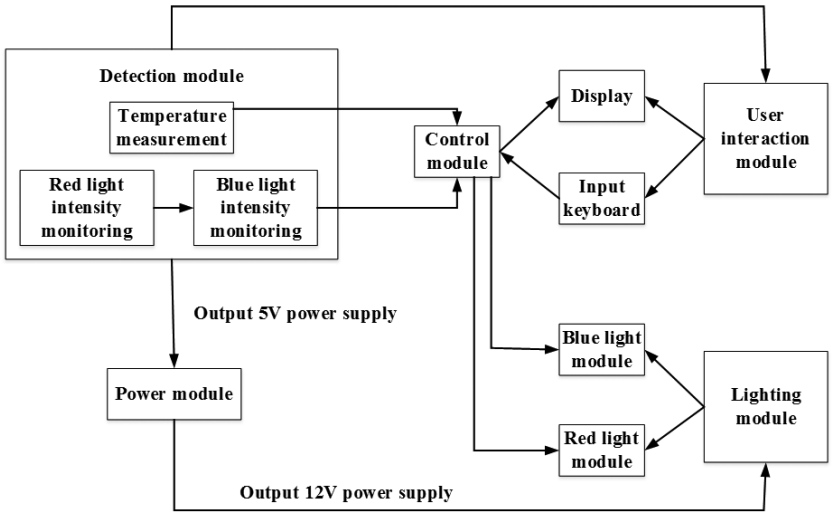


Fig. 1. Overall structure of the system

ture sensor and connection to the micro-controller through data line. Detected elements of the light intensity-testing module are composed mainly of silicon photocells to conduct tests on light intensity of the red and blue lights.

Supplementary lighting module

In the design of supplementary lighting module, we designed two parts, namely, the LED lighting set and driving circuit. In the design of the LED lighting set for blue and red lights, we adopted a narrow-band blue light LED array with 450 nm central wavelength and narrow-band red light LED array with 660 nm central wavelength. The design of the driving circuit adopted PT4115 driving modular circuit. We realized periodical supplementary lighting in the lettuce greenhouse through PWM signal from micro-controller connecting the controlling ends of the red and blue light modules. This step realized quantitative supplementary lighting of the LED lighting set.

User interaction module

The user interaction module is composed of an LCD and keyboard. The function of the former is to realize the display of system data, whereas the latter is responsible for input and alteration of relevant system information.

Software design

In the software design of the system, we devised an analytic program for the sensor, a data parameter setting program, a signal control program, and a data display program. The designs of these parts were intelligently controlled. To realize real time monitoring of the temperature in the lettuce greenhouse, maintain suitable temperature for crop growth in the greenhouse, and realize real time adjustment of supplementary lighting, we set the threshold values of temperature and light intensity. When temperature was within threshold value, we monitored light intensity of the blue and red lights. If the light intensity were within threshold value, then the system will conduct precise supplementary lighting.

4. RESULT ANALYSIS AND DISCUSSION

To test the effectiveness of the system, this paper conducted simulation experiments at the greenhouse of a case study farm. During the experiment, according to the acreage of the greenhouse, we positioned proportionately the blue light LED with threshold value of 3500 lx and red light LED with threshold value of 1000 lx in the greenhouse. We then set the temperature range from 15 °C to 35 °C, which is the most suitable temperature. The results of the experiment are shown in Fig. 2.

Fig. 2 shows that the light intensity of red and blue lights remained unchanged during the day. Except for noon, light intensities at other times were within the threshold value. At noon, because of the angle of illuminance, the system automatically stopped supplementary lighting. The result of the experiment showed that the system could achieve periodic precise supplementary lighting.

5. CONCLUSION

With the development of semiconductor technology, LED has been used in greenhouse supplementary lighting system. Lettuce requires different supplementary lighting in different growth cycles. Hence, based on the testing technology of light intensity, intelligent technology, and information technology, this study designed a new type of periodic supplementary lighting system based on red and blue LED lights for the lettuce greenhouse. The proposed system could provide peri-

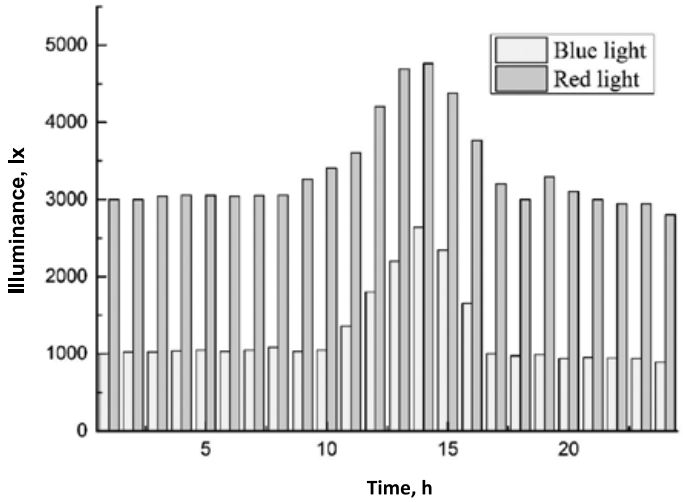


Fig. 2. Diurnal variation curve of light intensity

odic quantitative supplementary lighting for the growth of lettuce. Solar energy used by the system to provide electricity improved energy efficiency and reduced the operating costs of the greenhouse. The results of the experiment showed that a periodic supplementary lighting system based on red and blue LED lights in lettuce greenhouse had a fast response speed, low rate of data error, and achieved periodically precise supplementary lighting. However, this study has limited expertise and this system has yet to undergo sufficient practice. In the next phase, we will expand our research on comprehensive LED combination supplementary lighting system.

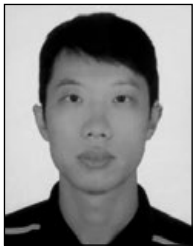
REFERENCES:

1. Hui Hu Yongguang, Li Pingping. Effect of artificial lighting in greenhouse research and fill light source configuration design. Jiangsu and University of Technology: Natural Science Edition, 2001, V22, #3, pp. 37–40.

2. Cui Jiren, Xu Zhiru. Design of intelligent measurement and control system for greenhouse based on single chip microcomputer. sensor and micro system, 2006, V25, #5, pp. 52–54.

3. Hai Hui Zhang, Yang Qing, Hu Jin, et al. Precision controllable LED brightness plant adaptive fill system. Agricultural Engineering Journal, 2011, V27, #9, pp. 153–158.

4. Liu Xiang, Hu, Fan Hongpan. Based on expert rules of greenhouse intelligent lighting system design. Agricultural Mechanization Research, 2013, V35, #12, pp. 174–177.



Li WANG,
received his MSC degree in university of Leeds. At present, he is a biotechnology engineer in Xinhui Forestry Science Institute. His current research interests include biodiversity & conservation and forest breeding

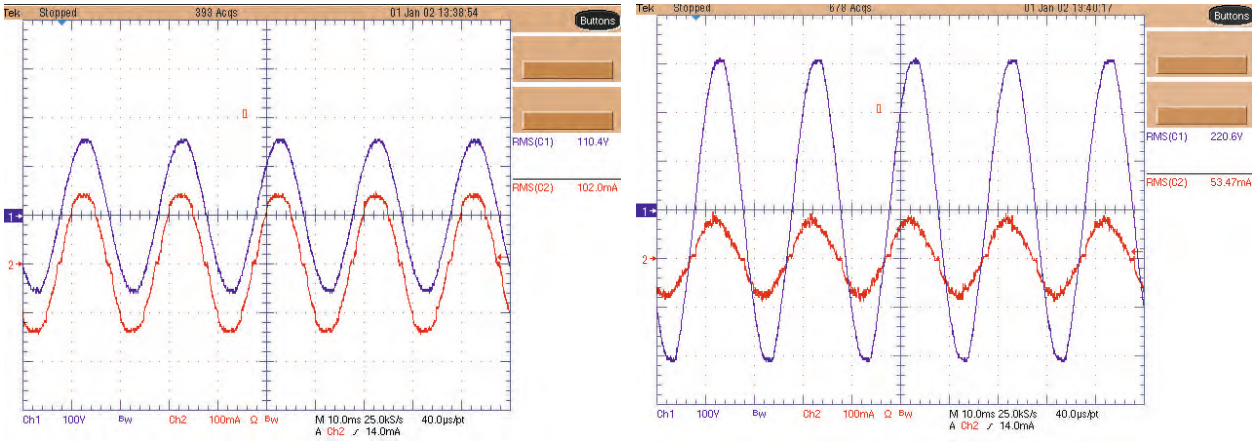
Peitao TAN,
received his Bachelor degree in South China Agricultural University, At present, he is a forestry Engineer in Xinhui Forestry Science Institute. His current research interests Landscape architecture

Hongjian HUANG,
received his Bachelor degree in Beijing Normal University. At present, he is a Senior forestry Engineer in Xinhui Forestry Science Institute. His current research interest is landscape architecture

Xiaowei ZHANG,
received her MAG degree in Huazhong Agricultural University. At present, she is an assistant agronomist in Noberfun (China) Chemical Co. Ltd. Her current research interests include plant protection and plant diseases

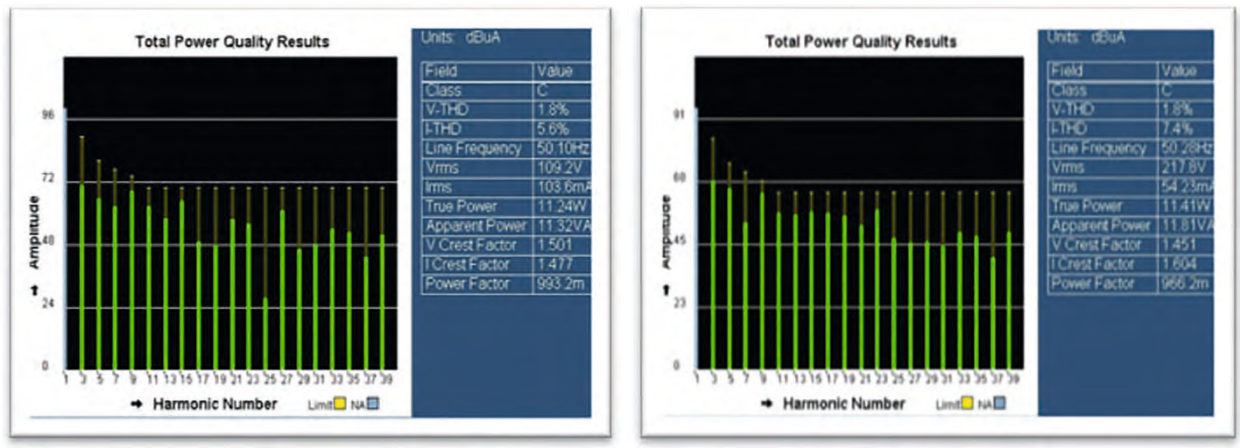
Fig.1. Obelisk

Fig. 2. Square street lamp



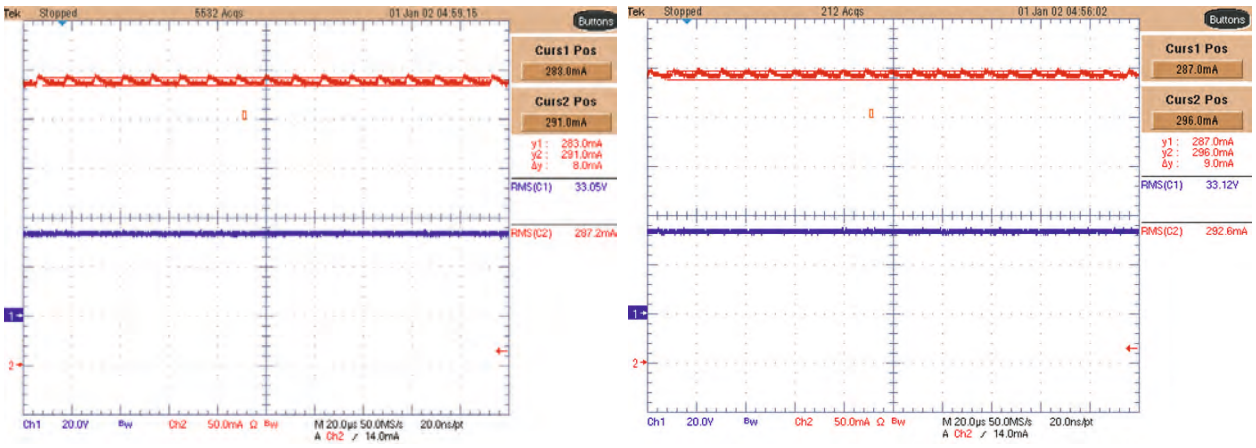
a) *b)*

Fig.5. Input current waveforms: (a) 110Vac Input; (b) 220Vac Input



a) *b)*

Fig.7. Harmonic testing results: (a) 110Vac Input; (b) 220Vac Input



a) *b)*

Fig.8. Output current waveforms: (a)110 Vac Input; (b) 220 Vac Input

Fig.1. Audio and video transmission between two computers connected with a network cable

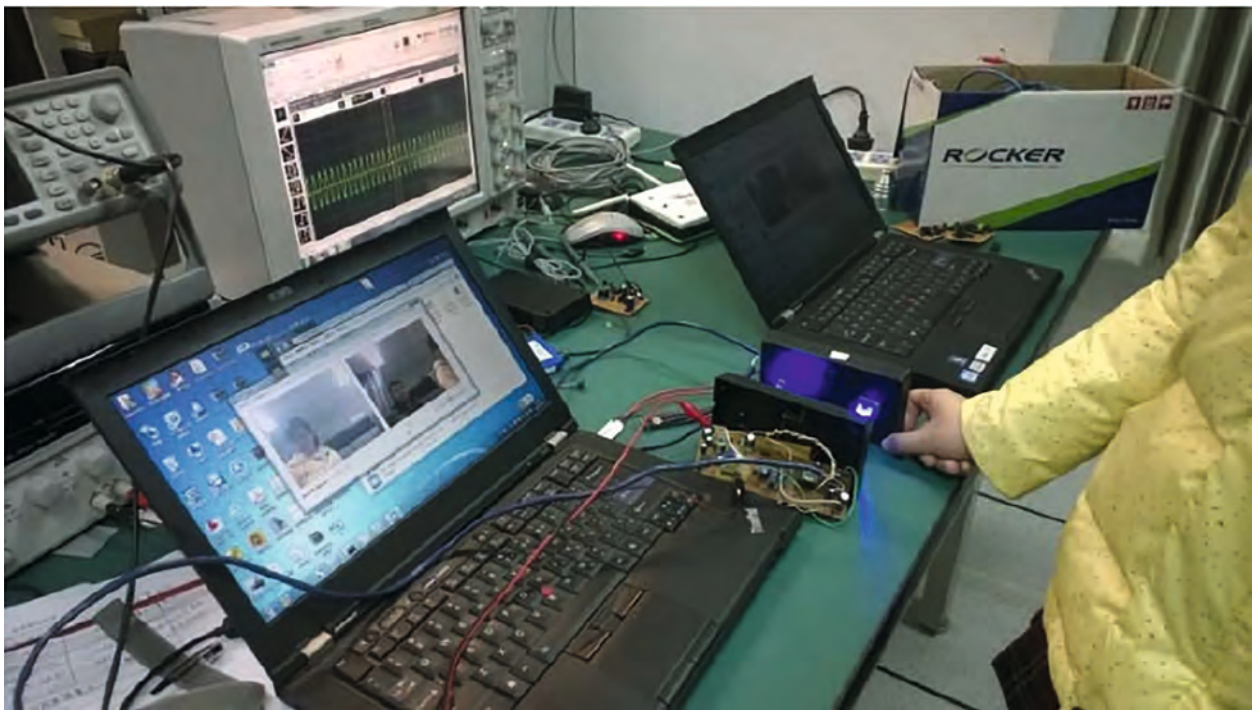


Fig.2. Two computers are connected by visible light module

Zhenyang FENG, Dongyan LIU, Zhengwei ZHU, and Haifeng DING

Rock Slope Monitoring Techniques Based on Semiconductor Light Source Applications

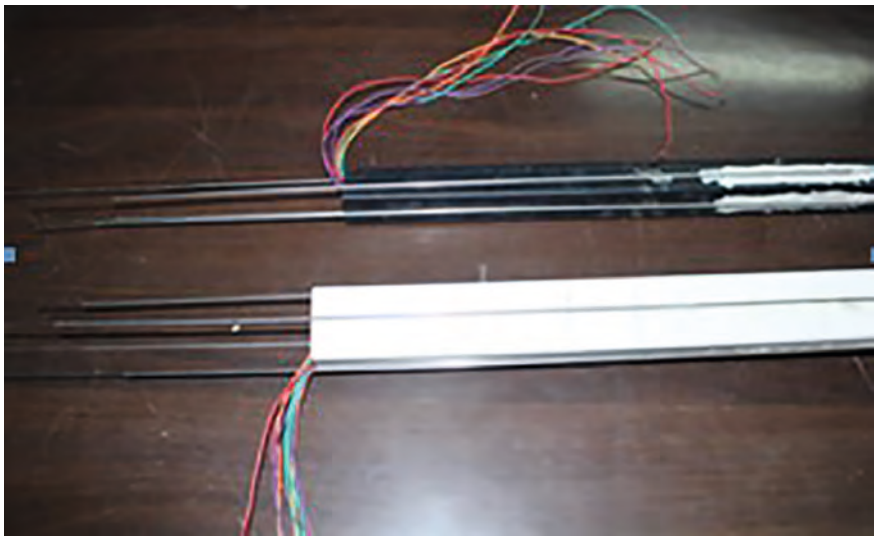


Fig.1. Composite optical fibre device

Yanping LIU

The Development Status and Countermeasures of Photovoltaic-Ecological Agriculture in China

Fig.1. Solar Greenhouse

Light & Engineering
Vol. 24, No. 3, pp. 91-94, 2016

Svetotekhnika
No. 5, 2016

THE DEVELOPMENT STATUS AND COUNTERMEASURES OF PHOTOVOLTAIC-ECOLOGICAL AGRICULTURE IN CHINA

Yanping LIU

College of Economics and Management, Shanxi Agricultural University, Shanxi, China
E-mail: liuanpingsau743@126.com

ABSTRACT

An analysis of the current status of China's photovoltaic ecological agriculture indicates a small agricultural economy in the overall scale. Moreover, photovoltaic projects are not closely connected to agricultural production, power is wasted, and technology is immature. Corresponding measures are proposed in this paper. This paper analyzes pilot photovoltaic ecological agriculture projects of three areas and proves that good use of photovoltaic agricultural economy can promote the long-term development of China's agricultural economy. The annual growth rate of agricultural economy in Shouguang, Shandong, and Zhongwei, Ningxia, has reached more than 20%, thereby providing decision making guidance for the development of the agricultural economy.

Keywords: photovoltaic ecological agriculture, development status, countermeasures

1. INTRODUCTION

The agricultural economy is the top priority of China's economy. Agriculture, as the basic industry of our country, is the industry on which mankind depends the most. Thus, sustainable development of the agricultural economy is important for our country. In the thirty years since reform and opening up, China's agricultural economic development has progressed rapidly and established the foundation for its economic development [1]. In the development of the agricultural economy, a series of problems have emerged, such as environmental pollution, inadequate utilization of resources, and ecological imbalance, which restrict the development of an ecological agricultural economy [2]. Developing the manufacturing technology of thin-film solar panels can support China's ecological agriculture economy; transparent solar photovoltaic thin-film is used for reasonable utilization of solar radiation, which can be divided into light energy required for plant photosynthesis and for solar power [3]. This process not only provides the necessary light for the normal growth of plants but also achieves photoelectric conversion, thereby realizing low-cost power generation [4]. In recent years, the application of China's solar film has developed rapidly. Demonstration buildings have been established in many areas in China, and parts of the completed thin-film photovoltaic solar greenhouses are connected to the local power grid to achieve energy utilization [5], Fig.1. How-

Fig.1. Solar Greenhouse

ever, several problems exist in the application of photovoltaic ecological agriculture, such as the high cost in the early stage and the immaturity of key technology related to crop production. Accordingly, this paper analyzes the development status of the traditional photovoltaic ecological agriculture, proposes corresponding countermeasures, and analyzes photovoltaic ecological agricultural economy pilot projects.

2. STATE OF THE ART

Small overall scale of the agricultural economy

The concept of economy applies when developed countries achieve a sufficiently high overall economic level to resolve ecological imbalance and resource shortage caused by development [6]. Unlike in developed countries, agricultural development in China is in a period of transition from the primary to the secondary level. Transitional development is characterized by weak economic strength. However, entering the agricultural economy as soon as possible is highly beneficial for China. Technical problems of photovoltaic products mean that such products have a high cost and are nearly unaffordable for ordinary farmers or small businesses.

At present, production lines of the amorphous silicon thin-film photovoltaic solar panel mostly come from foreign countries because domestic enterprises cannot grasp the core technology of solar panel manufacturing. The price of raw materials has increased in recent years, and China's solar panels also have high production costs. Most thin-film photovoltaic solar demonstration greenhouses that have been completed or are under construction are reportedly funded by the government or financially strong enterprises. Therefore, without financial support from the government, successfully developing photovoltaic ecological agriculture can be difficult [7].

The photovoltaic industry is not closely combined with agricultural production

More than 20 thin-film photovoltaic solar greenhouses of different sizes have been built in many provinces of China, but most are conceptual pilot projects. An investigation of the pilot sites of Shandong, Jiangxi, and other places shows that most of the completed thin-film photovoltaic solar greenhouses failed, that they have exhausted their possible usage, and that they have grown only a few crops or none at all [8]. Currently, the thin-film photovoltaic solar greenhouse is still at the theoretical research and development stage and still not closely integrated with actual agricultural production; the same situation is true with solar power. This finding is unfavourable to the development of the agricultural economy.

Wasted solar energy power

The thin-film photovoltaic solar panel can use excess solar energy to generate electricity for the greenhouses and other corresponding facilities, such as heat preservation facilities. However, in many cases, the power supply of thin-film photovoltaic solar panel is inconsistent with that of agricultural electricity demand [9]. The solution is to connect to the local grid, but this option is high cost and has difficult requirements. For example, Hangzhou requires a generation capacity of 200000 kW before a facility can be connected to the local power grid. This demand results in solar energy wastage, thereby affecting the development of the economy.

Immaturity of key technology

Most of the current thin-film photovoltaic solar agricultural greenhouses are only pilot projects. Thus, no corresponding agricultural production facilities exist, such as cooling and heating facilities. The four distinct seasons in most parts of China are characterized by a high temperature in summer and a low temperature in winter. If installing thin-film photovoltaic solar greenhouses fails with the corresponding equipment, then normal production of crops in summer and winter cannot be guaranteed [10]. Furthermore, the daily maintenance of solar panels cannot be ensured. Thus, their operating effect after the completion of the greenhouses cannot be guaranteed. Therefore, the application effect of most of the current completed thin-film photovoltaic solar greenhouses is far from ideal.

3. METHODOLOGY

Enhancement of the government's financial support for developing thin-film photovoltaic solar greenhouses

Thin-film photovoltaic solar greenhouses have recently started up in China with only pilot sites in a few provinces. Research on foreign thin-film

photovoltaic solar greenhouses should be strengthened. Moreover, cooperation among government departments should be encouraged. To better promote the development of thin-film photovoltaic solar greenhouses in our country and boost the development of the photovoltaic ecological agricultural economy, the government should enhance its support for photovoltaic agriculture.

Prioritization of funding for joint relevant research by enterprises or research institutes

The thin-film solar intelligent stereo agriculture is a new model and a new path to explore in the development of modern agriculture. Thus, this type of agriculture requires the government's vigorous support, as well as the cooperation and common development of related enterprises and research institutes. The key technology of thin-film solar panels is to improve the utilization efficiency of solar energy, which involves multiple disciplines of industry and agriculture, and requires significant investment and joint research. We should encourage agricultural enterprises or agricultural research institutes to strengthen their cooperation with photovoltaic solar energy enterprises in conducting preliminary technological research and feasibility studies for large-scale application.

Strengthening links with the power sector and providing grid technology support for large-scale application of thin-film photovoltaic solar greenhouses

The generating capacity of thin-film photovoltaic solar greenhouses fails to correspond with their power demand, and it exceeds their power demand during ordinary periods. The support and cooperation of the local power departments should be gained through communication, and the local power grid should be combined with the greenhouse grid to improve profits.

4. RESULT ANALYSIS AND DISCUSSION

To compare the influence of photovoltaic ecological agriculture on economic development, this paper selects three regions, namely, Shouguang in Shandong, Chengde in Hebei, and Zhongwei, in Ningxia as the case studies. Shouguang and Chengde belong to the first group of photovoltaic ecological agriculture pilot projects established by the Chinese government. The agricultural economy of these northern cities is developed and occupies a large proportion of the local economy. After three years of pilot research on the photovoltaic ecological agricultural economy, the thin-film photovoltaic solar greenhouses in Chengde Hebei are mostly idle. Three years of data on agricultural economic development also demonstrate that the agricultural economy has not developed substantially in the last three years. By contrast, with the support of the local government, the thin-film photovoltaic solar greenhouses in Shouguang and Zhongwei have a high planting rate. Furthermore, these locations have also developed a new area for ecological agriculture and significantly contributed to the agricultural economy in only three years, Table 1.

Table 1 shows that the annual growth rate of the agricultural economy in Shouguang, Shandong, and Zhongwei, Ningxia, reached 22.79% and 21.37%, respectively, after a three-year development of photovoltaic ecological agriculture. The photovoltaic ecological agriculture in Chengde, Hebei, is hindered by many factors, thereby slowing its agricultural development.

5. CONCLUSION

Photovoltaic ecological agriculture is an important part of sustainable development in China. An analysis of the photovoltaic ecological agriculture

Table 1. The state of the agricultural economy in three regions in 2012–2015 (Unit: Million Yuan)

	2012	2013	2014	2015	Annual growth rate
Shandong Shouguang	1274.35	1452.85	1739.25	2359.43	22.79%
Chengde Hebei	1459.25	1485.27	1530.32	1566.72	2.40%
Zhongwei Ningxia	2382.36	2853.46	3563.59	4259.53	21.37%

pilot projects in three regions of China shows that the annual growth rate of the agricultural economy in Shouguang, Shandong, and Zhongwei, Ningxia, reached 22.79% and 21.37%, respectively, after three years of developing the photovoltaic ecological agriculture. By contrast, the photovoltaic ecological agriculture in Chengde, Hebei, is hindered by many factors, and its agricultural economic growth rate reached only 2.40%. Good use of the photovoltaic ecological agriculture can promote the long-term development of the agricultural economy in China. The current problems in the photovoltaic ecological agriculture economy are significantly worse than proposed in this paper. Mobilization of people's enthusiasm and division of different functions in the photovoltaic agricultural areas are specific efforts that can be applied to address practical agricultural problems; these efforts require further investigation.

ACKNOWLEDGEMENT:

The authors are grateful for the Humanities and Social Sciences base project in Shanxi Province: Shanxi Modern Ecological Agricultural Development Mode Research (2013316); Shanxi Province Philosophy and Social Science Project: Research on Measurement and Impact Factors of Shanxi Province Agricultural Products Circulation Efficiency(201512); Shanxi Province Federation of Social Sciences project: Research on Training Problems of New Kind Vocational Farmers under the Background of Modern Agricultural Development in Shanxi Province (SSKLZDKT2014079).

REFERENCES:

1. Feng Y, Guo Y, Yang G, et al. Household biogas development in rural China: On policy support and other macro sustainable conditions. Renewable and Sustainable Energy Reviews, 2012, V16, #8, pp. 5617–5624.

2. Li JY. Study on the relationship between agricultural economic growth and agricultural nonpoint source pollution in Inner Mongolia Autonomous Region of China. Nature Environment and Pollution Technology, 2016, V15, #2, pp. 471–476.

3. Moiceanu G, Voicu Gh, Paraschiv G, Dinca M, Chitoiu M, Vldut V. Mechanical properties of energetic plant stems – review. INMATEH – Agricultural Engineering, 2015, V45, #1, pp. 149–156.

4. Wang Y, Song Q, He J, et al. Developing low-carbon cities through pilots. Climate Policy, 2015, V15, #1, pp. S81-S103.

5. Ghisellini P, Protano G, Viglia S, et al. Integrated Agricultural and Dairy Production within a Circular Economy Framework. A Comparison of Italian and Polish Farming Systems. Journal of Environmental Accounting and Management, 2014, V2, #4, pp. 372–391.

6. Schuetze T, Lee J W, Lee T G. Sustainable urban (re-) development with building integrated energy, water and waste systems. Sustainability, 2013, V5, #3, pp. 1114–1127.

7. Davidescu A A M, Paul A M V, Gogonea R M, et al. Evaluating Romanian Eco-Innovation Performances in European Context. Sustainability, 2015, V7, #9, pp. 12723–12757.

8. Pan J, Liu J, Zhu C. Budgeting carbon for urbanization in China. Wiley Interdisciplinary Reviews: Energy and Environment, 2015, V4, #5, pp. 406–409.

9. Wang H, Li C, Zheng Y. Space expression of industry status using GIS and SWOT analysis. Wuhan University Journal of Natural Sciences, 2015, V20, #5, pp. 445–454.

10. Song M, An Q, Zhang W, et al. Environmental efficiency evaluation based on data envelopment analysis: a review. Renewable and Sustainable Energy Reviews, 2012, V16, #7, pp. 4465–4469.

Yanping LIU,
Educational background: Ph.D. in Economics, Associate Professor, graduated from Shanghai University of Finance and Economics. At present, she is working at the College of Economics and Management, Shanxi Agriculture University

Light & Engineering
Vol. 24, No. 3, pp. 95-99, 2016

Svetotekhnika
No. 5, 2016

ANALYSIS OF THE ACCESS SYSTEM OF PHOTOVOLTAIC POWER STATION BASED ON PHOTOVOLTAIC POWER/AGRICULTURAL PLANTING HYBRID

Ya BI[1,2*] and Cunfa WANG[3,4]

[1]*College of Public Administration of Huazhong University of Science & Technology, Wuhan, Hubei, China*
[2]*School of Logistics and Engineering Management, Hubei University of Economics, Wuhan, Hubei, China*
[3]*School of Management, Wuhan University of Technology, Wuhan, Hubei, China*
[4]*An-Fa new energy Co., Ltd., Wuhan, Hubei, China*
**E-mail: biyahz426@yeah.net*

ABSTRACT

This study conducts a feasibility analysis on the photovoltaic power generation project based on the agriculture–photovoltaic hybrid approach in Anlu City, Hubei Province. The article considers policy orientation, implementation model, technology, resource conditions, and economic benefits. This paper mainly reports the characteristics of the sites and the superiority of adopting the agriculture–photovoltaic hybrid approach, equipment selection, as well as regional demand for electricity and solar energy resources, which are important factors that affect the implementation of the project. Finally, results of electric power balance in Anlu after the implementation of the project are discussed based on the actual conditions of the project.

Keywords: agriculture–photovoltaic hybrid, photovoltaic power generation, solar energy resources, feasibility analysis

1. INTRODUCTION

The problems of a substantial increase in energy consumption and the trade-off between energy and environment constraining sustainable development will become increasingly serious as the economy of China rapidly develops. Therefore, the extensive development of solar energy, wind energy, geothermal energy, and other renewable energy sources is an important measure to reduce environmental pollution. Such development will be an inevitable choice for China to ensure the security of its energy supply and its sustainable development [1]. Among renewable energy sources, solar power is one of the most promising technologies [2]. Following the "Twelfth Five-Year Plan of Renewable Energy Development," the photovoltaic power generation capacity of China is projected to reach 900 million kW by the end of 2015. The Chinese solar market will immediately open with the formal implementation of the "Renewable Energy Law in the People's Republic of China" and a series of supporting policies. Solar photovoltaic power will gradually enter the electricity market and partially replace conventional energy sources [3]. Therefore, solar power is highly significant in terms of both environmental protection and as an energy strategy.

2. INTRODUCTION OF THE AGRICULTURE–PHOTOVOLTAIC HYBRID POWER GENERATION SYSTEM IN ANLU, HUBEI

(1) Agriculture–photovoltaic hybrid

The agriculture–photovoltaic hybrid power project is implemented in Muzi Township, Anlu

Table 1. Summer power balance in Anlu (unit: MW)

Projects	2016		2017		2018		2020	
	Peak load	Moderate load	Peak load	Moderate load	Peak load	Moderate load	Peak load	Moderate load
A. System capability	195	156	211.8	169.4	235.9	188.7	281.1	224.9
1. Maximum load	185.7	148.6	201.7	161.4	224.7	179.8	267.7	214.1
2. Load reserve	9.3	7.4	10.1	8.1	11.2	9.0	13.4	10.7
B. Electric power capacity	90	90	90	90	90	90	90	90
1. Water, thermal power	0	0	0	0	0	0	0	0
2. Photovoltaic	60	60	60	60	60	60	60	60
3. Others	30	30	30	30	30	30	30	30
C. Available capacity	66	21	66	21	66	21	66	21
1. Water, thermal power	0	0	0	0	0	0	0	0
2. Photovoltaic	45	0	45	0	45	0	45	0
3. Others	21	21	21	21	21	21	21	21
D. Surplus electricity	-129	-135	-145.8	-148.4	-169.9	-167.7	-215.1	-203.9

City. This project covers an area of approximately 1,200 acres and the planned total installed capacity is 2 MWp × 20 MWp. The site is a rehabilitated hill with an undulating terrain and an elevation drop of over 50 m. Several PV modules are installed on the terraced steep terrain. The project adopts the agriculture–photovoltaic hybrid mode, which combines photovoltaics and high-efficiency agriculture, for three-dimensional development to fully utilize land resources. In this hybrid mode, the upper part consists of photovoltaic power generation, whereas the lower part comprises farming [4]. Compared with the traditional fixed mode, this mode can significantly improve solar conversion efficiency and crop yield for a multi-purpose plot of land. The project provides clean energy and simultaneously uses the land under the photovoltaic panels to cultivate an expensive medicinal plant, i.e., *Dendrobium*, in an area of approximately 900 acres. This technology does not only considerably improve the use of land resources and solar energy, but also provide nearly 200 jobs to achieve mutually beneficial economic and social benefits.

(2) Equipment selection

The PV array installation adopted in this project is fixed; and 300 Wp modules of polycrystalline silicon solar cells are used. The PV power plant directly uses a 0.27–35 kV step-up mode, a 40 kW inverter, one station with a capacity of 1000 kVA, 35/0.27 kV, 20 sets of transformers (1000 kVA), and 35/0.27 kV × 35 kV cable for the power distribution bus means. Five sets of 35 V box transformer substations are located parallel to a joint unit in the high side and two units access the switching station on the 35 kV bus side. Simultaneously achieving maximum power output is nearly impossible for the PV module because of the unevenness of solar radiation, and thus, the output power of the PV array is lower than the sum of the nominal power of the individual components. In addition, the coefficient of the factors of the mismatch between the PV modules and the connection loss of the plates, which affects solar panel power output, is 0.95. Grid-connected PV power plant efficiency considers the mounting angle after the conversion factor reaches 0.88; hence the actual power generation efficiency (η) is 79.8% [5].

Table 2. Winter electricity balance in Anlu (unit: MW)

Projects	2016		2017		2018		2020	
	Peak load	Moderate load	Peak load	Moderate load	Peak load	Moderate load	Peak load	Moderate load
A. System capability	136.5	95.5	148.3	103.8	165.1	115.6	196.7	137.7
1. Maximum load	130	91	141.2	98.8	157.3	110.1	187.4	131.2
2. Load reserve	6.5	4.5	7.1	4.9	7.9	5.5	9.4	6.6
B. Electric power capacity	90	90	90	90	90	90	90	90
1. Water, thermal power	0	0	0	0	0	0	0	0
2. Photovoltaic	60	60	60	60	60	60	60	60
3. Others	30	30	30	30	30	30	30	30
C. Available capacity	66	21	66	21	66	21	66	21
1. Water, thermal power	0	0	0	0	0	0	0	0
2. Photovoltaic	45	0	45	0	45	0	45	0
3. Others	21	21	21	21	21	21	21	21
D. Surplus electricity	-115.5	-29.5	-127.3	-37.8	-144.1	-49.6	-175.7	-71.1

3. FEASIBILITY STUDY ON THE PHOTOVOLTAIC POWER SYSTEM BASED ON THE COMPLEMENTARY PRODUCTION OF AGRICULTURAL PRODUCTS AND PHOTOVOLTAIC POWER IN ANLU, HUBEI

(1) Requirement analysis

Secondary industries are dominant in Anlu and electricity consumption accounts for a large proportion. From 2010 to 2014, the average growth rate of the largest electricity consumer in Anlu was 6.2%, whereas the average growth rate of the entire city was 13.3%. The "13th Five-Year Plan of Electric Distribution Network in Anlu" projects that the maximum power load in Anlu will reach 224.69 MW in 2018 and electricity consumption will reach 997 million kWh. Furthermore, the maximum power load is expected to reach 267.68 MW in 2020 and electricity consumption will reach 1.186 billion kWh. During the period covered by the "13th Five-Year Plan," the average annual growth rate of the maximum load in Anlu is 8.8%. Therefore, given the development of the economy and the society, as well as the continuous improvement of living standards of people in recent years, the per capita electricity consumption exhibits a sharply rising trend every year.

The peak load of the Anlu power grid usually occurs in July or August. During winter, the peak load typically happens in February. The lowest load usually occurs in April and October. The typical daily load every summer presents the same variation trend, which is substantially a peak between two troughs. The peak appears at around 14:00. Its trends are described as follows. The load remains low and flat from 01:00 to 05:00. After 05:00, the load begins to rise gradually. At around 08:00, the load reaches a small peak and continues to grow. At around 14:00, a peak appears, after which, the load drops to the second trough. After 18:00, the load increases again, and the evening peak appears at around 20:00. The winter typical daily load curve presents the following trend: a peak, a trough, and a level segment. From 01:00 to 05:00, a low load operation is consistent. Then, the load begins to rise slowly at around 10:00 until it reaches a level segment and remains stable. At 16:00, the load be-

gins to rise rapidly, and the highest peak appears at around 20:00. Subsequently, the load gradually declines

(2) Analysis of solar resources

The solar energy resources in this region can be divided into four levels according to the annual solar radiation. A: Extremely rich, B: Very rich, C: General D: Poor.

The preceding calculations indicated that in the last 10 years, the total annual radiation in Anlu was 5826.5 MJ/m², which classified as very rich category "B". The monthly average total amount of radiation reaches the maximum value in July, amounting to 549.1MJ/m². The minimum value is recorded in December, with 282.3 MJ/m², RW = 282.3/549.1 = 0.51, which is under the "stable" rating.

In addition, the solar resources in Hubei Province are divided into three main areas. In the first available area, sunshine hours last between 1900 h and 2100 h, and the number of sunny days is between 155 days and 180 days. In the second available area, sunshine occurs between 1400 h and 1900 h, and the number of sunny days is 130 days to 150 days. In the third available area, annual solar radiation is low and less sunshine is available. In addition, more sunny days occur in August and rarely in other months. Anlu belongs to the first available area.

(3) Analysis on annual changes in solar radiation

The solar radiation data have important guiding significance to ensure the authenticity and reliability of the PV system output efficiency. The monthly total radiation in Anlu demonstrates a sharp increase in March. The peak is reached in July, and then radiation rapidly declines in September. During winter (December, January, and February), total radiation reaches its minimum value. From April to September, the total measured radiation reaches over 400 MJ/m². In July, its value reaches 549.1 MJ/m², which is the highest total monthly radiation. Sunshine hours increase dramatically from the beginning of March, reach a peak in July, and slightly decline in October. During winter (December, January, and February), sunshine hours reach a minimum value. From March to October, monthly sunshine hours are over 100. In July, the recorded hours reach 152.5; hence, July is the month with the longest sunshine throughout the year. Thus, the variations in sunshine and solar radiation in Anlu are the same.

4. RESULTS OF POWER BALANCE AFTER THE IMPLEMENTATION OF THE PROJECT IN ANLU

With the establishment of the photovoltaic power plant, the installed grid capacity of Anlu is projected to increase significantly from 2016 to 2020. In 2016, the total installed PV capacity in Anlu accounts for 32% of the maximum load. By 2020, it will account for 22% of the annual maximum load. Thus, the Anlu photovoltaic power generation project can serve as a useful complement to the grid in Anlu. The power shortage situation in Anlu can then be alleviated to a certain extent. The specific conditions are provided in Tables 1 and 2.

5. ANALYSIS AND DISCUSSION

(1) Among renewable energy sources, photovoltaic power generation is an important technology that receives full governmental support, and thus, it demonstrates considerable prospects for development.

(2) The agriculture–photovoltaic hybrid approach for photovoltaic power generation can guarantee solar conversion efficiency and considerably improve land productivity and crop utilization. This mode is extremely efficient for developing photovoltaic power generation projects in mountainous and hilly areas. It provides employment for local laborers, and has high economic and social benefits.

(3) Nearly no large-scale thermal power or hydropower project has been established in Anlu, and thus, it mainly depends on the main grid for its power supply. The photovoltaic power generation project can serve as a useful complement to the Anlu grid to alleviate the electricity shortage in Anlu to a certain extent. However, with the increasing growth in electricity load, vacancies will continue to increase in the future.

ACKNOWLEDGEMENT:

This work was financially supported by the China's Post-doctoral Science Fund (2015M580648) and Hubei Logistic Development Research Project (2016A03).

REFERENCES:

1. Information Industry Department of Electronic Science and Technology Committee. Research Report on the development strategy of solar photovoltaic industry. China integrated circuit, 2008. V17, #6, pp. 10–24.

2. Liu Fei. The present situation and Prospect of solar photovoltaic power generation. modern economic information. 2015, #22, pp. 331–332.

3. Abdelkader Gourbi, Imen Bousmaha, Mostefa Brahami, Amar Tilmatine. Numerical Study of a Hybrid Photovoltaic Power Supply System. Journal of Power Technologies, 2016, V96, #2, pp. 137–144.

4. Wei Xiaobo. distributed photovoltaic power generation have a brilliant future in the poverty alleviation work in northern economy. 2016, #3, pp. 39–41.

5. Li Peiqiang, Zeng Xiaojun, Huang Yuan, Tong Ying, Zhang Xiaomin, Zhang Li. For comprehensive load of grid connected photovoltaic power generation system equivalent modeling. Automation of electric power systems.2016, V40, #8, pp. 43–49.

Ya BI, Ph.D.,
college of Public Administration of Huazhong University of Science & Technology, Associate professor, Hubei University of Economics.
Research field: Optimization algorithm

Cunfa WANG,
Master, School of management, Wuhan University of Technology Research field: Management Optimization

Light & Engineering
Vol. 24, No. 3, pp. 100-104, 2016

Svetotekhnika
No. 5, 2016

OPTIMAL DESIGN OF SOLAR PHOTOVOLTAIC POWER GENERATION SYSTEM

Zhiming XU[1], Tieliu JIANG[1,2,*], and Yong LI[1]

[1] *The College of Energy and Power Engineering in Northeast Dianli University, Jilin, China*
[2] *The College of Energy and Mechanical Engineering in North China Electric Power University, Beijing, China*
**E-mail: JiangTie_liu@163.com*

ABSTRACT

In this paper, solar concentrator mass and wind factor are used as objective functions. The coupling effect of function factors is combined with the adaptive chaos optimization algorithm for multi-objective optimization. The multi-objective function of a dish solar concentrator is obtained using weighting factors. Flow field and quality are then compared before and after the optimization of the dish solar concentrator. The optimized dish solar concentrator exhibits reduced quality but improved flow, stress, and pressure fields at varying degrees.

Keywords: dish solar concentrator, multidisciplinary design, chaos optimization algorithm

1. INTRODUCTION

Solar thermal technology is promoted by environmental policies. Dish solar thermal power systems have been widely used because of their satisfactory performance [1]. For example, heat transfer efficiency is high and the overall stability is good. The dish solar thermal power system easily becomes unstable under external loads; hence, the solar thermal power generation system reflects the surface damage that occurred [2, 3]. At high wind speed, the aerodynamic force of the solar thermal power system is high [4]. The cavity absorber is the main energy source of a dish Stirling solar thermal power generation system. Heat loss is high in the entire system, thus any reduction in heat loss will contribute to the efficiency of the power generation system. The inlet structure and shape of the cavity absorber is the main structure of the system. In the past few years, many scholars from various fields have proposed optimization schemes but failed to consider the coupling effect of the cavity absorber system. Thus, the there are still optimizations to be made for the inner radius and condenser thickness.

2. MATERIALS AND METHODS

The maximum positive wind resistance of a condenser related to aerodynamic characteristics is used as the optimization goal to form a multi-objective optimization problem; the target function includes condenser weight $f_1(X,Y)$ and wind factors $f_2(X,Y)$, $f_3(X,Y)$, and $f_4(X,Y)$.

Structure of dish solar concentrator

The power generation efficiency of dish solar thermal power is mainly affected by condenser concentration ratio, and the geometric characteristics determine the flow field characteristics. The cross-sectional shape obtained with a plane-parallel direction cutting is shown in Fig. 1, which is the maximum cross-sectional diameter.

In Fig.1, t is the concentrator thickness, and L is the cross-sectional diameter or the maximum diameter of the cross section; for the condenser reflection plane, the R_1 of the curvature is the inner

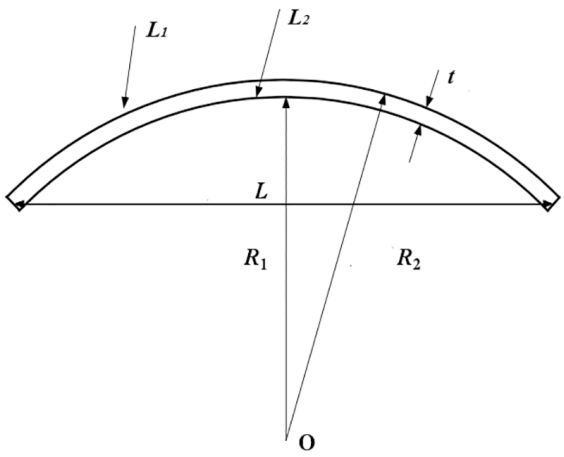


Fig.1.
The geometric parameters of condenser

diameter, and R_2 is the outer diameter. The curvature affects the flow field characteristics of the condenser, stress, and the strain concentration ratio; the inner and outer diameter size, thickness, and material affect the condenser's weight.

Mathematical model for design optimization of dish solar concentrator

Considering the factors of the aerodynamic performance, quality, and size and according to the MDO (Multidisciplinary Design Optimization) design ideas, the mathematical model of the multidisciplinary design optimization of the dish solar concentrator can be described as:

$$\min f(X,Y), \tag{1}$$

$$s.t.g_i(X,Y) \le 0 \quad i = 1,2,\cdots,\mathrm{n}. \tag{2}$$

Establishing and solving multi-objective function of dish solar concentrator

Two design goals of positive resistance and quality are selected. Assuming the blade-cross section is divided into *n* sections, the optimization variables are each section of inner radius R1 and thickness t.

Finite element analysis is used to calculate unit weight. All units are placed together to determine concentrator weight.

$$f_1(X,Y) = \sum_{i=1}^{N} G^i, \tag{3}$$

where N is the unit sum, and G^{i} is the weight of each unit N.

The forced direction of the dish solar concentrator can be decomposed into three directions x, y, and z. When the dish solar concentrator is in some space, the wind force from x, y, and z directions are:

$$F_x = C_{F_x}(X,Y)\frac{\rho v^2 A}{2}, \tag{4}$$

where $C_{F_x}(X,Y)$ is the resistance coefficient; ρ is the air density, kg/m$^{3;}$ v is the constant wind velocity, m/s; and A is the condenser frontal area, m^2.

$$F_y = C_{F_y}(X,Y)\frac{\rho v^2 A}{2}, \tag{5}$$

where $C_{F_y}(X,Y)$ is the lateral force coefficient.

$$F_z = C_{F_z}(X,Y)\frac{\rho v^2 A}{2}, \tag{6}$$

where $C_{F_z}(X,Y)$ is the lift coefficient.

$$f_2(X,Y) = C_{F_x}(X,Y) = \frac{\rho v^2 A}{2F_x}. \tag{7}$$

$$f_3(X,Y) = C_{F_y}(X,Y) = \frac{\rho v^2 A}{2F_y}. \tag{8}$$

$$f_4(X,Y) = C_{F_z}(X,Y) = \frac{\rho v^2 A}{2F_z}. \tag{9}$$

For optimization of the design variables, the following constraint conditions are used:

$$\begin{cases} R_{\mathrm{l}_{\max}} \ge R_{\mathrm{l}_1} \ge R_{\mathrm{l}_2} \cdots \ge R_{\mathrm{l}_i} \ge \cdots \ge R_{\mathrm{l}_n} \ge R_{\mathrm{l}_{\min}} \\ t_{\max} \ge t_1 \ge t_2 \ge \cdots \ge t_i \ge \cdots \ge t_n \ge t_{\min} \end{cases}, \tag{10}$$

where $R_1^{\min}$ is the least value of the optimization design of concentrator, $R_1^{\max}$ is the highest value of the optimization design of concentrator, $t_{\min}$ is the least value of the thickness of the optimized condenser, and $t_{\max}$ is the highest value of thickness of the optimized condenser.

In the process of the unified target function *f(X, Y)*, this paper uses a weighting factor method to make each target function close to the optimal values at various target points:

$$f(X,Y)=\sum_{i}^{q} w_i f_i(X,Y)^{\rightarrow} \min, \tag{11}$$

where w_i is the weighting factor of the i^{th} target function $f_i(X,Y)$, and w_i is a real number, which is more than *0* and less than *1*. The size of weighting factor depends on the number level and the important level of each target function $\sum_{i}^{q} w_i = 1$.

The process of seeking weighting factors in weighting factor method is a process of determining the optimal solution. An adaptive chaos optimization algorithm can be used to solve weighting factors.

Adaptive chaos optimization algorithm

The value range of weighting factors, namely, w_1, w_2, w_3, w_4, is determined. The adaptive chaos optimization algorithm is used to solve global optimization in Formula (2). Weights w_1 and w_2 are the minimum values of the global optimization. When the chaotic function in Formula (11) is used as the chaotic model to generate chaotic factors, the times of coarse and fine iterations are represented by K1 and K2, respectively.

$$\begin{cases} x_{n+1}=\sin(2/x_n) & n=1,2,\cdots,n \\ -1\le x_n\le 1 & x_n\neq 0 \end{cases}. \tag{12}$$

The steps of chaos optimization algorithm of adaptive mutative scale are as follows:

Step 1: Initialization. Make $K_1 = 1$, $K_2 = 1$, $N_1 = 1{,}000$, and $N_2 = 1{,}000$, then place the randomly generated x_0 in the chaos model in Formula (12). Finally, generate the chaos variable $x_{i,n+1}^{'}(i=1,\cdots,M)$.

Step 2: Rough conversion of chaos variables. Using Formula (13), change the value range of the i^{th} chaos variable from $[-1,1]$ to design the optimization of the variable range $[a_i,b_i]$.

$$x_{i,n+1}^{'}=a_i+(b_i-a_i)x_{i,n+1}. \tag{13}$$

Step 3: Coarse iteration research. Make $x_i(K_1)=x_{i,n+1}^{'}$. Calculate the optimal solution $f_i(K_1)$. Then, make $x_i^{*}=x_i(0)$ and $f_i^{*}=f_i(0)$.

If $f_i(K_1)<f_i^{*}$, then $f_i^{*}=f_i(K_1)$, and $x_i^{*}=x_i(K_1)$; if $f_i(K_1)>f_i^{*}$, then abandon $x_i(K_1)$. If $K_1 \prime\prime N_1$, enter the next iteration, $K_1=K_1+1$; if $K_1>N_1$, end the coarse iteration.

Step 4: Shrinking the search region. Assume:

$$\begin{cases} a_i^{'}=x_i^{*}-\phi(b_i-a_i) \\ b_i^{'}=x_i^{*}+\phi(b_i-a_i) \end{cases}, \tag{14}$$

where ϕ is shrinkage factor, $\phi\in(0,0.5)$.

Ensure that the search range will not be cross range when it shrinks, as follows:

If $a_i^{'}<a_i$, then $a_i^{'}=a_i$; if $b_i^{'}>b_i$, then $b_i^{'}=b_i$.

Therefore, in the new range $[a_i^{'},b_i^{'}]$, do the reduction process for x_i^{*}. Then, determine y_i^{*} by formula (9):

$$y_i^{*}=\frac{x_i^{*}-a_i^{'}}{b_i^{'}-a_i^{'}}. \tag{15}$$

Step 5: Fine conversion of chaos variables.

After Step 3, f_i^{*} remains unchanged. Using formula (15), take the linear combination of y_i^{*} and $x_{i,n+1}$ as new variables to search:

$$x_{i,n+1}^{'}=(1-\beta_i)y_i^{*}+\beta_i x_{i,n+1}, \tag{16}$$

where β_i is adaptive control coefficient, $0<\beta_i<1$.

For adaptive control coefficient β_i use the following method for adaptive control:

$$\beta_i=1-\left(\frac{K_2-1}{K_2}\right)^{m}, \tag{17}$$

where *m* is a non-negative integer. Here, make *m=2*.

Table 1. Related parameters of MDO optimization objective

Variable name	Initial value	Optimization results	Improvement degree%
Condenser resistance system C_{Fx}	1.55	1.19	-20.3
Condenser side force system C_{Fy}	-0.98	-1.17	19.3
Concentrator lift system C_{Fz}	-0.84	-0.77	6.2
Concentrator M /103kg	7.4	7.6	-4.2

An adaptive control coefficient is introduced in the early stage of fine iteration search because $(x_1, x_2, \cdots, x_n)$ changes often and needs to choose larger β_i. In the search process, this parameter gradually approaches the optimal point, and small β_i should be selected. Then, search in a smaller range of $(x^*_1, x^*_2, \cdots, x^*_n)$ becomes convenient.

Step 6: Fine iteration search. Make $x_i(K_2) = x^*_{i,n+1}$, and calculate the optimum solution $f_i(K_2)$. If $f_i(K_2) \le f^*_i$, then $f^*_i = f_i(K_2)$, and $x^*_i = x_i(K_2)$. If $f_i(K_2) > f^*_i$, then abandon $x_i(K_2)$. If K_2 " N_2, enter the next iteration, $K_2 = K_2 + 1$; if $K_2 > N_2$, end the fine iteration.

Through the above process, $w_1 = 0.4$, $w_2 = 0.2$, $w_3 = 0.2$, and $w_4 = 0.2$ are known. Thus, the multi-disciplinary design objective function of dish solar concentrator is:

$$F(X,Y) = 0.4 f_1(X,Y) + 0.2 f_2(X,Y) + \\ + 0.2 f_3(X,Y) + 0.2 f_4(X,Y). \quad (18)$$

3. RESULTS

Written programs are needed to set up the parametric model of a dish solar concentrator to achieve the optimal design of the concentrator and analyze flow, stress, and pressure fields.

This paper takes dish solar concentrator as the optimization object. The basic design parameters of the concentrator are shown in Table 1. A 420 parallel is taken to the axial sectional design optimization. In Formula (6), n = 420, $R_{1\min}$= 30 m, $R_{1\max}$= 120 m, and t = 0.027 m.

The optimization carries out flow field simulation for 30° height angle and 30 m/s constant wind speed; the process evaluates change trends of the dish solar concentrator C_{Fx}, C_{Fy}, and C_{Fz}, with changes in azimuth before and after the optimization. Values in Table 1 are the average value of the wind power coefficient of six azimuth angles.

From Table 1, the drag coefficient of the dish solar concentrator is decreased by 20.3%. The lateral force and lift coefficients increase by 19.3% and 6.2%, respectively, whereas the mass decreases by 3.7%. This finding proves that the resistance, lateral force, and lift force of the optimized dish solar concentrator become smaller than the former and the mass is reduced in the environment of 30° condenser height angle and 30 m/s wind speed. Thus, in this paper, the concentrator implements multi-disciplinary optimization.

4. CONCLUSION

This paper establishes a multi-objective function and a multi-disciplinary optimization design model of a dish solar concentrator. Flow field performance and quality of dish solar concentrator are compared before and after the optimization. In the environment of 30° condenser height angle and 30 m/s wind speed, the dish solar concentrator drag coefficient and the mass decreases by 20.3% and 3.7% respectively, whereas the lateral force and lift coefficients increases by 19.3% and 6.2%, respectively. The resistance, lateral force, and lift force of the optimized dish solar concentrator become smaller than the former, and the mass is reduced. Multi-objective function multi-disciplinary approach is used to optimally design the dish solar concentrator. This approach lays the foundation for further optimization of dish solar concentrator design while promoting the development of solar photovoltaic power generation system. Although the dish solar concentrator is optimally designed, it will suffer from various external load applications, including sand impact, in the long-term operation. Thus, dust

impact reduction should be the focus of future research. In addition, this paper only considers the condition of condenser elevation angle at 30°; hence, further simulation analysis must be performed under different conditions.

ACKNOWLEDGEMENT:

The authors are grateful for the NSFC (NO.51376041).

REFERENCES:

1. Lovegrove K, Burgess G, Pye J. A new 500m 2 paraboloidal dish solar concentrator. Solar Energy, 2011. V85, #4, pp. 620–626.

2. Biyanto Totok R, Alhikami Akhmad F, Nugroho G, et al. Thermal energy storage optimization in shopping center buildings. Journal of Engineering and Technological Sciences, 2015, V47, #5, pp. 549–567.

3. Ali Tofighi. Performance Evaluation of PV Module by Dynamic Thermal Model. Journal of Power Technologies, 2013. V93, #2, pp. 111–121.

4. Li Z, Tang D, Du J, et al. Study on the radiation flux and temperature distributions of the concentrator–receiver system in a solar dish/Stirling power facility. Applied Thermal Engineering, 2011. V31, #10, pp. 1780–1789.

Zhiming XU,
Professor, graduated from the Xi'an Jiaotong University. Work Unit: Northeast Dianli University

Tie-liu JIANG,
Doctorial Degree, graduated from the North China Electric Power University. Work Unit: Northeast Dianli University

Yong LI,
Professor, graduated from the Southeast University. Work Unit: Northeast Dianli University

Light & Engineering
Vol. 24, No. 3, pp. 105-108, 2016

Svetotekhnika
No. 5, 2016

THE DEVELOPMENT OF THE PHOTOVOLTAIC INDUSTRY IN SICHUAN PROVINCE, CHINA: HUMAN CAPITAL INVESTMENT AND KNOWLEDGE INNOVATION

Jun SHI

Southwest Petroleum University, China
E-mail: junshi774@yeah.net

ABSTRACT

This paper analyzes the development trajectory of the photovoltaic industry in the context of an innovation drive; it then studies the causes of technological talent aggregation in the photovoltaic industry in Sichuan province, based on the actual situation. The paper is analyzing the promotion of technological talent aggregation. The innovation drive is in fact a talent drive. The development of the Sichuan photovoltaic industry cluster should rely on the knowledge and technology spillover effect caused by technological talents aggregation. To promote the technological talents aggregation of Sichuan photovoltaic industry, we should start from highlighting the dominant role of technological talent in photovoltaic enterprises, enhancing the macro-control of the government on technological talents management, improving the coordination of photovoltaic associations in technological talent management, and maximizing the advantage of technological talents cultivated by colleges and research institutes.

Keywords: technological talents, aggregation, innovative drive, path

1. STATE OF THE ART

Sichuan province established China's first polysilicon production project, with an output capacity of more than 1,000 tons in 2007 and 14,000 tons in 2009, becoming an important polysilicon production base. In 2009, the solar cell module attained capacity 100 MW. In May 2010, Chengdu became the "National High-tech Industry Base of the New Energy Industry." In October 2012, Chengdu Shuangliu Economic Development Zone was recognized as the "Innovation Base of New Energy and Reinvigorating Trade through Science and Technology." The Sichuan photovoltaic industry has formed a complete industrial chain.

Policies driving the development of the Sichuan photovoltaic industry are mainly based on the national renewable energy policy system framework and *The 12th Five-year Development Program of the Solar Photovoltaic Industry*. Local policies of Sichuan province include the *Development and Construction Plan of Sichuan Photovoltaic Industry*, initiated in 2010, and the *12th Five-year Energy Development Plan of Sichuan Province*, 2011. In addition, the *13th Development Plan of Sichuan Province*, to be instigated in 2016, also stresses the need to promote the development of clean energy industry, and establish large-scale concentrated utilization and small-scale distributed utilization new energy utilization system by focusing on distributed energy, smart micro-grid and electric car charging infrastructure. These policies created the general environment that supports development of the Sichuan solar photovoltaic industry [1, 2].

2. MECHANISM OF SICHUAN PHOTOVOLTAIC DEVELOPMENT UNDER AN INNOVATION DRIVE

Driving innovation is strategically important for promoting economic development and transformation raised by Chinese government. The es-

sence of an innovation drive is to use human capital to accumulate knowledge and improve technology, and use knowledge and technological innovations to advance productivity [3]. As a new energy industry, the photovoltaic industry is strategically important to the "12th Five-year" and "13th Five-year" plans of Sichuan. As a large labour province with abundant fossil energy, Sichuan is facing an important issue, which is resolved would transform the economy and promote the great-leap-forward development of the photovoltaic industry. Hence, this part will focus on the mechanism of Sichuan photovoltaic development in the context of an innovation drive, and study its motive mechanism [4].

The Sichuan photovoltaic industry is a strategic emerging industry which should be preferentially developed. Currently, there are enterprises distributed across the production chain: upstream, midstream and downstream of the photovoltaic industry in Sichuan province. Sichuan has formed a complete industry chain. Upstream enterprises mainly produce polysilicon, monocrystalline silicon, silicon ingots and wafers, etc. Midstream enterprises mainly produce photovoltaic cells and photovoltaic components. Downstream enterprises mainly produce solar photovoltaic power generation and photovoltaic application products, etc. All of these enterprises should use technological innovation to create competitive advantages. The basis of technological innovation is related knowledge innovation. Compared with technological innovation, the process of knowledge innovation is more stable, which has particular certainty. However, technological innovation has larger uncertainty. In Sichuan province, many colleges and research institutions have high optical engineering research levels, including Sichuan University, University of Electronic Science and Technology of China, and Southwest Petroleum University.

According to industry cluster theory, industry cluster is an economic body and a knowledge complex. In the Sichuan photovoltaic industry cluster, knowledge flows from colleges and scientific research institutions to enterprises but also flows from individuals to enterprises, from enterprises to individuals, or between individuals in the industry cluster. Optimization of Sichuan photovoltaic industry chain is promoted by the knowledge flow in the cluster, which is realized through communication and sharing of information among individuals, enterprises, and individuals with enterprises. The flow of knowledge among technological talents indirectly promotes cluster development in the photovoltaic industry.

The conceptual model of the mechanism of Sichuan photovoltaic industry development under innovative drive is shown in Fig. 1.

3. MOTIVES OF TECHNOLOGICAL TALENTS AGGREGATION OF SICHUAN PHOTOVOLTAIC INDUSTRY WITHIN THE INDUSTRY CLUSTER

Industry clusters result from market resource allocation, and industry clustering is the process of industry talent aggregation. Technological talent aggregation in the Sichuan photovoltaic industry leads to technical advancement and scale expansion of the industry cluster. This talent aggregation is produced by the combined action of multiple factors.

Regional factor of marginal income difference

According to economic theory, economic factors flow from lower marginal income regions to higher income regions (e.g., the migration of the labour force from central and western regions to eastern regions over 30 years after the reform and opening policy of China). As a special economic factor, technological talents adhere to the flowing rule of economic factors and flow from lower marginal income regions to higher income regions. As such, the Chengdu-Chongqing economic zone in the southwest of China is the most active region in the economic development of the whole southwest region, which also has a complete photovoltaic industry chain. As the Chengdu-Chongqing economic zone has a fast urbanization process, high economic growth and abundant economic elemental resources, the marginal income of technological talents of the photovoltaic industry is higher than in other provinces and regions. Hence, the talent aggregation of the Sichuan photovoltaic industry is realistic. Of course, from the angle of the whole country, the marginal income of technological talent in the Sichuan photovoltaic industry is lower than that in the eastern areas, but this difference can be compensated in other aspects.

Structure of the industry cluster

The structure of the industry cluster mainly consists of the scale of the cluster, horizontal com-

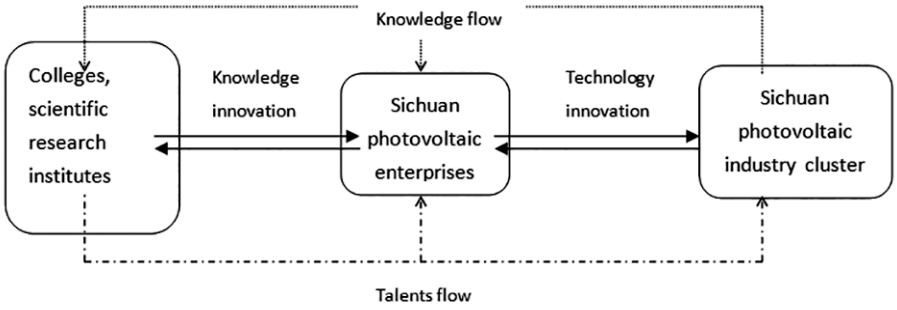


Fig.1. Mechanism model of Sichuan photovoltaic industry development in the context of an innovation drive

petition between enterprises, vertical labour and cohesion or division of enterprises, and the cluster's social network. Sichuan has a complete photovoltaic industry chain, with a reasonable distribution of enterprises upstream, midstream, and downstream, a cooperative relationship among enterprises, colleges, and scientific research institutions, and smooth contact and cooperative channels among enterprises. Technological talent can flow in freely and reasonably through market resource allocation, while enterprises and the government create reasonable policies to attract talent, making it convenient for talent to flow from colleges, scientific research institutions, and other institutions to the Sichuan photovoltaic industry cluster. Hence, the gradual aggregation of technological talents in the Sichuan photovoltaic industry is formed with the expansion of the cluster. Talent aggregation also provides the driving force for innovation in the Sichuan photovoltaic industry development.

Technological talent environment

From the perspective of human resource management, one of the important factors influencing technological talent flow is the working and living environment. Working and living conditions within the Sichuan photovoltaic industry are more comfortable than those in eastern regions. First, in the aspect of policy environment, Sichuan has policies which promote development of the photovoltaic industry, including industry investment and development, as well as introduction and management of technological talent, which create a preferred policy environment for workers. Second, from the aspect of the internal environment of enterprises, currently most enterprises in the photovoltaic industry chain in Sichuan are supported or owned by well-known enterprises in China. These enterprises have standard management systems and high profitability, and provide favourable working environments. Additionally, there are two 985 universities, five 211 universitie s, and many other universities with majors related to photovoltaic in Sichuan. These universities provide training and promote opportunities for students, which can help their self-development. Finally, from the aspect of the living environment, the famous Chengdu Plain in Sichuan province is famously known as "The Land of Abundance." The Chengdu–Chongqing economic zone has a high economic development level, with beautiful natural scenery and a comfortable climate, which are very attractive to talented workers from fast-paced areas.

4. A PRACTICAL PATH OF PROMOTING TECHNOLOGICAL TALENTS AGGREGATION OF SICHUAN PHOTOVOLTAIC INDUSTRY

Highlight the dominant role of technological talents in photovoltaic enterprises

The essence of an innovation drive is talent drive. Hence, we need to adhere to a people-oriented policy, highlight the dominant role of technological talents in enterprises, and further optimize the introduction, management, and flow of technological talent. Specifically, enterprises should consider this from three aspects. First, positively introduce scientific and reasonable talent evaluation systems, promotion systems, and other incentive systems that conform to market rules, to attract an excellent technological talent flowing into the cluster and provide sufficient intellectual support for the development of the industry cluster. Second, optimize the talent flow system to promote reasonable flow of talent inside the cluster to activate the current population of technological talent, and tap their

potential and establish competitive mechanisms. Third, create an enterprise culture, which respects knowledge and innovation, and further highlight the importance of talented workers in the development of photovoltaic enterprises.

Enhance the macro-control of the government on technological talent management

The formation of the Sichuan photovoltaic industry development cluster owes to both the market resource allocation and the policy support of the government. Hence, in the cluster development of Sichuan photovoltaic industry, the promotion of technological talent flowing into the cluster can be realized by strengthening the macro-control of the government on technological talent management. Related departments of the Sichuan government can increase macro-control through the following actions. First, improve the technological talent management system, including hiring, dismissal, and resignation of talent; standardize mutual legal rights of workers and enterprises, including working rights, labour remuneration, social security, intellectual property protection, etc. Second, use economic methods to balance the allocation of talents in each segment of the industry chain, avoid the centralization of talents, and promote the healthy development of the whole chain. Finally, standardize the behaviour of market players and market operation to assure a healthy and reasonable flow of talent into and out of the photovoltaic industry, and promote the appreciation of human capital in the Sichuan photovoltaic industry.

Take full advantage of college and research institution cultivation of technological talents.

Colleges and research institutions are the main sources of high-level technological talent, and are the upstream part of technology conversions. Positive cultivation of talent can provide abundant intellectual resources for the Sichuan photovoltaic industry cluster. While we should take advantage of these resources to continuously educate talents, we should also encourage cooperation among colleges, research institutions, and enterprises, in order to realize the connection of technology conversions. We should also use these resources to enable lifetime learning for workers, promote appreciation of human capital, and improve the competitiveness of the Sichuan photovoltaic industry cluster.

5. CONCLUSION

Technological talent flow in the industry cluster can not only increase the cluster's and region's human capital but also promote cluster innovation because of technology and knowledge spillover during the flow and re-allocation of human capital. In the context if an innovation drive, the development of the Sichuan photovoltaic industry is largely due to talent drive. In order to further improve the competitiveness of the Sichuan photovoltaic industry, we should promote the knowledge and technology spillover effects brought by technological talent aggregation. To promote talent aggregation in the Sichuan photovoltaic industry, we should highlight the dominant role of technological talent in photovoltaic enterprises, enhance government macro-control of technological talent management, improve the coordination of photovoltaic associations regarding technological talents management, and take full advantage of colleges and research institutions' cultivation of talent.

REFERENCES:

1. Bianchi N, Bolognani S, Zigliotto M, et al. Innovative remedial strategies for inverter faults in IPM synchronous motor drives. IEEE Transactions on energy conversion, 2003. V18, #2, pp. 306–314.

2. Hicks D, Breitzman T, Olivastro D, et al. The changing composition of innovative activity in the US – a portrait based on patent analysis. Research policy, 2001. V30, #4, pp. 681–703.

3. Holdren J P, Ehrlich P R. Human Population and the Global Environment: Population growth, rising per capita material consumption, and disruptive technologies have made civilization a global ecological force. American scientist, 1974. V62, #3, pp. 282–292.

4. Knowles S, Owen P D. Health capital and cross-country variation in income per capita in the Mankiw-Romer-Weil model. Economics Letters, 1995. V48, #1, pp. 99–106.

Jun SHI,
Doctor of Petroleum engineering management, lecturer. Graduated from Southwest Petroleum University, China

Light & Engineering
Vol. 24, No. 3, pp. 109-113, 2016

Svetotekhnika
No. 5, 2016

TECHNOLOGICAL INNOVATION AND POLICY SYSTEMS FOR THE PHOTOVOLTAIC INDUSTRY OF SICHUAN PROVINCE, CHINA

Liang LIN* and Xintong WU

Southwest Petroleum University, China
**E-mail: linliangsp829@163.com*

ABSTRACT

The current situation of the photovoltaic industry in China has been evaluated using the structure, conduct, and performance (SCP) analysis paradigm. Results show that the industry presents evident industrial chain differentiation characteristics in its market structure, enterprise market conduct, and market performance. Thus, the policy system framework is based on SCP, and the industrial chain is established. Policy advice is proposed to promote the development of the photovoltaic industry in China along financial, fiscal, technical, trade, and industry measures.

Keywords: photovoltaic industry, industrial chain, policy system

1. INTRODUCTION

The development trend of the energy industry is moving away from high energy consumption and high pollution solutions. New renewable energy sources have received increased attention. Solar energy exhibits the highest potential, especially in China where solar energy resources are abundant. But the development of the photo voltaic (PV) industry is influenced by the inertia of the traditional energy industry. Since the 1990s, Chinese researchers have focused on actively developing its PV industry. *The decision of accelerating the fostering and development of strategic emerging industries* proposed in 2010 incorporated the PV industry into emerging strategic industries; in 2012, *the "Twelfth Five-Year" development plan of the solar photovoltaic industry* determined the national strategic position of the PV industry.

The PV industry in China presents excess periodic production capacity through its rapid development from 2010 to 2012. Yu believed that the expansion and excess production capacity of the PV industry in China seriously affected global PV industry policy and caused anti-dumping investigation [1]. Considering the future development of the PV industry, Ling-Chin carried out life cycle analysis on marine PV industry development to formulate an industrial technological development framework [2]. Yang believed that building integrated PVs exhibits high potential for development and realization of long-term benefits [3]. In view of the role of government policy in the development of the PV industry, Zhao summarized the policy system of China's renewable energy power generation from 2006 to 2015 and studied the positive influence of the national policy on PV industry development [4].

This study posits that the development of China's PV industry is affected by the Chinese market structure and the international market environment. The market and management behaviour of PV enterprises in China is restricted by macro policy to a certain extent. Thus, the roles of autonomy and flexibility are difficult to assume, thereby influencing the market performance and industrial development. Therefore, this study adopts the structure–conduct–performance (SCP) analysis paradigm to study the development path of China's PV industry; and establish a corresponding policy system to promote long-term and sustainable development of the industry.

2. DATA AND METHODS

Based on the theoretical framework of SCP paradigm and empirical analysis, this paper considers the topic from three aspects, namely, market structure, behaviour, and performance in every link of China's PV industry chain; acquires the status and future development path of China's PV industry in terms of SCP; and proposes policy recommendations a for differentiated development of the industrial chain.

Market structure of China's PV industry

The market structure is the comprehensive embodiment of market competition and price. This research takes market concentration ratio (CR4) as the main index for measurement and carries out the discussion by combining industrial technical barriers.

According to the Bain classification method, when CR4 is not less than 30%, the industry belongs to the definition of an oligopoly industry. This study classifies the PV industry chain and records market CR of four production processes, including silicon material, silicon wafer, PV cells, and PV components (Fig. 1; missing data are estimated through power function).

1. The market concentration of each production link of PV industry is considerably high. This finding is related to the surge in demand for the PV industry in 2010 and the installed capacity expansion of the PV power station worldwide. Influenced by the international PV industry development, China's small- and medium-sized PV enterprises have expanded their production, reducing the market share of leading enterprises in the industry.

2. The market concentration degree of each production link of the PV industry shows a clear downward trend. The installed capacity of the global PV market has reached 18.2 GW with a year-on-year growth of 139%. Market demand has stimulated investment in the PV industry; thus, a large number of investors and businesses enter into the PV market, reducing the market concentration degree.

3. The market concentration degree and decreasing trend of each production link of the PV industry have great differences. PV battery production process has the lowest market concentration degree with the most obvious decreasing trend before; and now it has decreased below 30%, which is close to the competitive market, showing that PV battery market in the link is the fiercest competition. This is related to technical requirements and barriers of different production processes. Silicon refining is a typical technology intensive production process; while PV cell production has low technical requirements, being a labour intensive production process.

4. Technical barriers and policies have a great impact on industry concentration. In the silicon material production link, core technologies, which are special raw silicon material and high-purity silicon, is mainly imported; independent research and development is difficult; and purchase of patent technology needs a large amount of money. All of which makes it difficult for new enterprises to develop in PV industry upstream. The development advantage of China's PV industry mainly lies in the middle stream manufacturing sector because of low-technical threshold and cheap labour.

Market conduct of the China's PV industry

China's PV industry installed capacity during 2006 to 2015 has surged from 80 MW to 16,600 MW. The entire industry shows a momentum of capacity expansion and is faced with upstream and downstream imbalances of the industrial chain. The main raw material of PV power generation – polycrystalline silicon relies on imports; and PV industry terminals with extremely low utilization rate are mainly responsible for high-energy consumption, high-pollution manufacturing. Therefore, installed capacity surge leads to obvious capacity surplus and excessive expansion of domestic markets.

PV price shows a slow downward trend. PV cells and main components in China are exported through processing trade; so export is influenced more by PV cell price and their components. In general, PV product price falls considerably fast, and PV products rely on main competitiveness of price advantage, leading to lower profits for the industry overall.

Market performance of China's PV industry

Gross profit and capacity utilization are used to measure market performance of China's PV industry.

The PV industry does not follow a U-curve form. Instead, it shows a decreasing trend along the industrial chain. The market structure of different links in the industry chain determines prof-

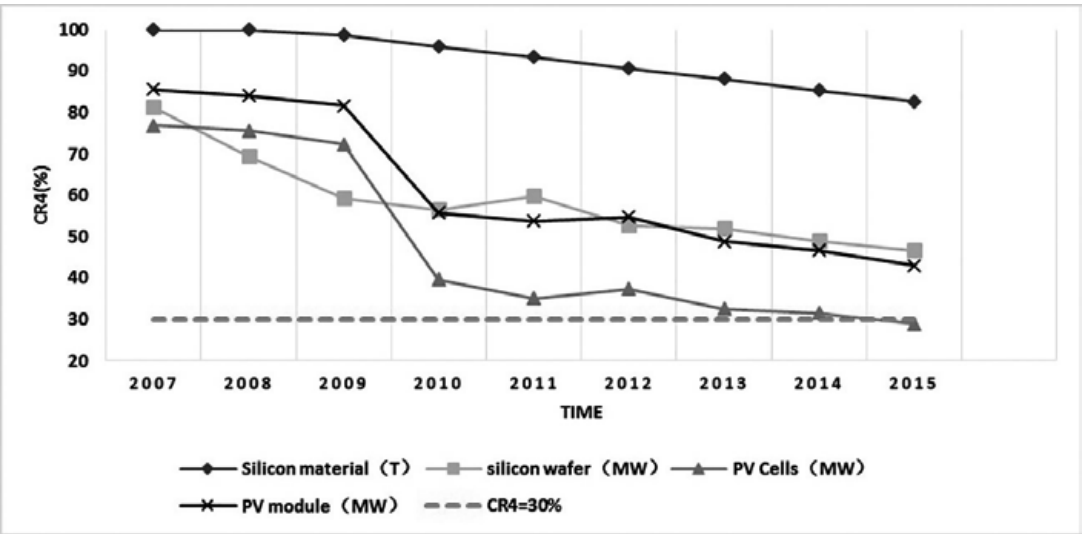


Fig.1. Market concentration of the China's PV industry chain in 2007–2014

itability. In terms of gross profit margin, the gross margin of production and packaging of PV cells and PV components is less than 10%. With all industries gradually transferring from monopolies to competition structures, and with import and export prices of polycrystalline silicon declining, price war at downstream production enterprises is exacerbated, leading to further decline in gross margin. The economic performance of enterprise decreases with industrial chain extension.

With regard to capacity utilization, China's PV industry has been falling behind the global average level in various aspects for a long time. Capacity utilization is directly related to social performance by measuring the efficiency of the whole industry and social resources. In the silicon material production process, global profit margins for average capacity are about 70%, whilst in China it is about 50% with an upward trend.

3. RESULTS ANALYSIS

Based on SCP analysis paradigm and framework, we have obtained the development status of China's PV industry.

1. The market structure gradually transforms from a monopoly to competition structure, with the industrial chain from top to bottom, but it is influenced by macroeconomic policy, international market, and technical barriers.

2. Installed capacity is increasing annually, and the industry demonstrates overcapacity. Also, PV product price falls rapidly, and industry profit is low.

3. Capacity utilization is catching up with the global average level, but the industrial chain is mainly concentrated in the middle and lower sections with low margins, leading to low-economic performance of enterprises.

4. Industrial chains of China's PV industry have obvious difference in market SCP, which shows obvious link characteristics with different industry chains. Thus, industrial development policy should be differentiated according to different production processes. Main policy framework is shown in Fig. 2.

Industry chain and development policy

Setting installed capacity target should not only be aimed at the middle stream manufacturing link, but also at PV power network and terminals (number and proportion of power network; quantity and proportion of electricity consumption), taking advantage of the PV industry products to alleviate contradiction between supply and demand of energy, reduce environmental pollution, adjust energy structure, and transform economic development mode.

Specific development measures are as follows:

1. Financial measures: At industry upstream, preferential policies, including financial support, financing convenience, and low tax, should be provided. In the downstream, networking and use of PV electricity should be promoted by stimulating terminal demand mainly through market mechanism, including subsidies on price and energy consumption.

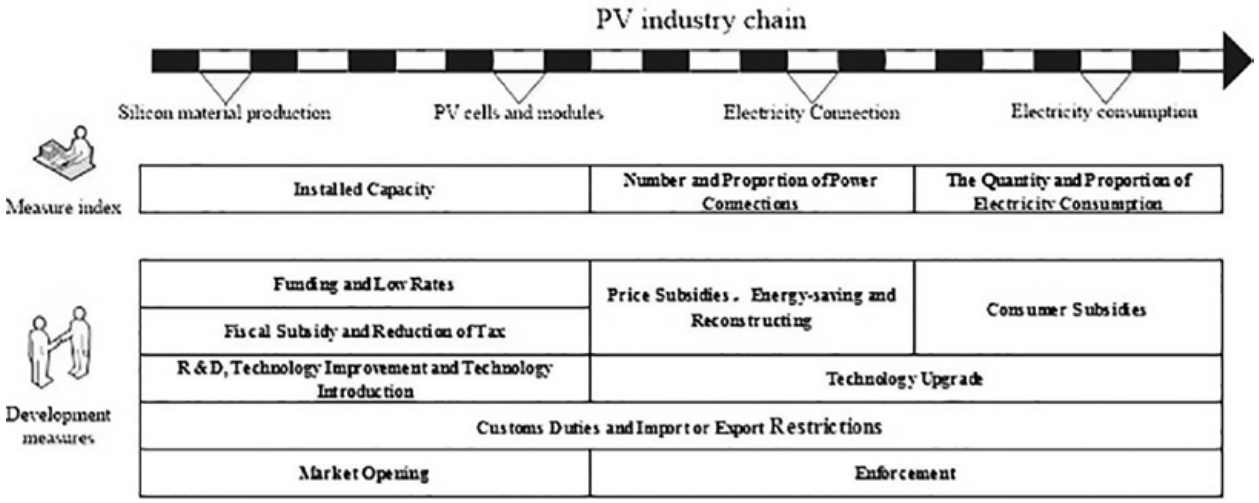


Fig. 2 Development policy framework of China's PV industry

2. Fiscal measures: Financial subsidies and tax incentives can be used in the upstream industry; and market mechanism is used in the downstream to stimulate demand, which can refer to subsidies for new energy automobile by directly giving subsidies to sales links of PV power generation system or products.

3. Technical measures: Grants for research and development and technology introduction can be carried out in the upstream industry to encourage technological innovation, cut upstream technical barriers, and eliminate dependence on international market and international large-scale PV enterprises. At the middle and downstream, technology update and conduct technological improvements should be emphasized to reduce costs based on existing power grid and power consumption mode.

4. Trade measures: It is necessary for government restriction by taking measures of environmental taxes or special tariff. Preferential tariff policy can be used to adjust import and export. For international market development, excessive dependence on overseas market should be discouraged. Instead, domestic consumer market should be encouraged, and technological innovation of domestic enterprises in upstream production should be promoted.

5. Industrial measures: Industry upstream and midstream encourage market opening, so the main role of the government is to establish a market environment for fair competition, clear industrial planning, and strict market access conditions. Mandatory measures can be taken to formulate power network policies, forcing some large and state-owned enterprises to use PV power resources.

Market conduct and excess capacity

The China PV industry presents significant excess capacity, but it should be critically viewed in the context of global economic downturn. Production decisions and the overcapacity phenomenon are largely influenced by installed capacity target stipulated in PV industry development goals, which are results of government's macroeconomic regulation and control. Therefore, periodical excess capacity is the process of industry transformation from monopoly to competition modes, but it cannot spontaneously achieve equilibrium; thus, industry competition should be further promoted and market and price mechanisms should be assumed.

4. CONCLUSIONS

The PV industry chain is integral, complex, and hierarchical, and the competition environment of the upper, middle, and lower reaches transits from monopoly to competition with value distribution showing a descending trend. The development of the PV industry in China is concentrated in the low-end part of the industry value chain, so the industrial base is weak; an enterprise innovation system is absent; enterprise financing is difficult; industry development lacks planning and management; and structural imbalances exist, such as capacity imbalance between supply and demand, technical bottlenecks, financing chain deficiency

and development disorders. China's PV industry has been in a periodic dilemma.

Due to obvious industry chain characteristics of market SCP of the China's PV industry, the policy system framework should be established based on SCP and industrial chain in the process of policy making; and policies according to sequence of industry chain, including measures of financial, fiscal, technical, trade, and industry, should be formulated.

ACKNOWLEDGEMENTS:

The study was supported by Open Fund (PLN1423) of State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation (SWPU), Sichuan Science and Technology Program (2015SZ0227) and Development Research Centre of Oil and Gas, Sichuan (SKB14–10).

REFERENCES:

1. Sarti D, Einhaus R. Silicon feedstock for the multi-crystalline photovoltaic industry. Solar energy materials and solar cells, 2002. V72, #1, pp. 27–40.

2. Yang H, Wang H, Yu H, et al. Status of photovoltaic industry in China. Energy Policy, 2003. V31, #8, pp. 703–707.

3. Wu C Y, Mathews J A. Knowledge flows in the solar photovoltaic industry: Insights from patenting by Taiwan, Korea, and China. Research Policy, 2012. V41, #3, pp. 524–540.

4. Marigo N. The Chinese silicon photovoltaic industry and market: a critical review of trends and outlook. Progress in photovoltaics: research and applications, 2007. V15, #2, pp. 143–156.

5. Zhang HP. An Agent-based Simulation Model for Supply Chain Collaborative Technological Innovation Diffusion. International Journal of Simulation Modelling, 2015. V14, #2, pp. 313–324.

Liang LIN,
Master, Associate Professor. Graduated from the SWPU. Fellow of Economics and Management

Xintong WU,
Doctor. Graduated from the SWPU. Fellow of Economics and Management

Light & Engineering
Vol. 24, No. 3, pp. 114-117, 2016

Svetotekhnika
No. 5, 2016

ANALYSIS OF ENVIRONMENTAL REGULATION REGARDING THE POLLUTION CAUSED BY PHOTOVOLTAIC INDUSTRIES

Yan LI[1,2,*], Taozhen HUANG[3], Qiaoliang ZHANG[2], and Minghao BAI[1]

[1] *Business School, Hohai University, Nanjing, Jiangsu, China*
[2] *School of Economics and Management, Lanzhou University of Technology, Gansu, China*
[3] *School of Public Administration, Hohai University, Nanjing, Jiangsu, China*
**E-mail: liyan_hohai67@163.com*

ABSTRACT

This study analyzes the dilemma of the development of the photovoltaic industry in China and its consequent pollution. It mainly aims to determine how environmental regulations can be implemented while simultaneously developing the photovoltaic industry. The paper is written based on a review of two literatures. First, the literature on the effect of environmental regulations for photovoltaic industry pollution is classified into five categories, as follows: intensity, threshold, time, spatial heterogeneity, and contagion effects. Second, the literature on solutions for environmental regulations of pollution caused by the photovoltaic industry pollution is classified into environmental regulation, regulation effect, regulation area difference, and foreign investment. Finally, lessons learned from environmental regulations for photovoltaic industry pollution in China are presented.

Keywords: environmental regulation, photovoltaic industry pollution, economic growth

1. INTRODUCTION

The development and use of new energy sources is becoming a key issue in the long-term planning of the energy revolution in China, considering the anticipated energy shortage in the future [1]. Solar energy is the cleanest, most reliable, and most secure energy source for the future. The photovoltaic industry generates clean and green solar energy. However, the development of this industry is controversial because of the possible pollution problem that can result from it. The problem lies in whether the byproduct polycrystalline silicon production, i.e., silicon tetrachloride, can be properly treated and recycled. The current production technology for polycrystalline silicon is called the modified Siemens process. In this process, 10 to 20 tons of silicon tetrachloride is generated to produce a ton of polycrystalline silicon. If a production enterprise has a low levels of control, then harmful substances such as silicon tetrachloride, hydrogen chloride, and chlorine are likely to spill, thereby leading to high potential danger and high recycling cost [2]. However, controlling pollution requires considerable investment, which poses a challenge to certain enterprises. International market competition is fierce, and thus, the key is to upgrade the technology of production. However, most enterprises lack the motivation to do so considering the high cost of such an upgrade; hence, external pressure can push enterprises to include technological improvement in their strategy. Consequently, enterprises should search for technologies and methods that can improve the resource utilization rate to reduce waste or find means to turn waste into useable products to reduce production cost [3]. To achieve such technology, enterprises must be guided to innovate under appropriate environmental regulations. Thus, the key to the development of the photovoltaic industry is enterprise cost and external regulation, which also drive healthy industrial development [4].

2. LITERATURE REVIEW ON THE EFFECT OF ENVIRONMENTAL REGULATIONS ON POLLUTION IN THE PHOTOVOLTAIC INDUSTRY

Intensity effect: The effect of regulations varies for different intensities of pollution by producers

A Kuznets U-type curve is formed for the relationship between the intensity of environmental regulation and technological innovation. The Porter hypothesis can only be realized when the former reaches a certain threshold. Enterprises can be classified according to their scale of pollution into seriously, moderately, and mildly polluting. The key is to determine whether these enterprises break the inflection point of the U-type curve under different intensities of environmental regulations [5]. When the intensity of an environmental regulation is reasonable, the rate of green total factor productivity, technological innovation, and efficiency improvement of the industry can be promoted.

Threshold effect: The threshold of economies of scale must be suited to small enterprises

The level of economic development remains the main factor that influences technological innovation. Testing through the threshold effect indicates that strict environmental regulation is effective only when a country or a region reaches a certain economic level. Such a scenario is the necessary condition for the Porter hypothesis. Certain economic scales cannot be realized through inefficient economic growth. Instead, they should be realized via technological innovation and a new type of industrial development when considering the degree of economic development.

Period effect: Environmental regulation has short- and long-term effects

Research on production efficiency indicates that environmental regulation will increase production costs and exert a crowding-out effect on productive investment. In the short term, enterprises fulfill their environmental obligation under environmental regulations, turn external cost into internal cost, and increase their production costs. However, faced with uncertainty about the effectiveness of reform, environmental regulations influence the technological innovation of enterprises and indirectly affect their production efficiency. By contrast, other studies have shown that environmental regulations have a hysteretic quality toward economic development and technological advancement. These studies demonstrate that production rate will increase gradually over time when environmental regulations adjust to technological innovation.

Spatial heterogeneity effect: Enterprises can choose spatial transference for different environmental regulations

The adverse effect of environmental regulations on the competitiveness of enterprises may cause them to lose market share; the effect may also prompt enterprises to invest in countries and regions with relaxed environmental regulations. If certain countries or regions implement strict environmental regulation standards, then producers must reduce environmental pollution, internalize pollution cost, and increase relevant investment. Such changes increase production cost in that country or region, which may also comprise the funds of other projects with potential revenues. Compared with countries and regions with relaxed environmental regulations, those with strict environmental regulations will influence the production efficiency and competitiveness of similar industries, thereby decreasing the competitiveness of enterprises in the international market.

Contagion effect: Technological innovations and structural changes in an industrial development model are enforced by environmental regulations

Individual enterprises encounter increasing difficulties in realizing mutually beneficial results between environment protection and competitiveness as environmental treatment cost increase. The government forces enterprises to implement environmentally responsible strategies through environmental regulations. To obtain maximum profit, enterprises adopt technological innovations to improve their competitiveness. Environmental regulations exert a contagion effect, which leads to structural changes in an industrial development model.

3. LITERATURE REVIEW OF ENVIRONMENTAL REGULATIONS FOR PHOTOVOLTAIC INDUSTRY POLLUTION

Environmental regulations aim to force technological advancement once enterprises cross the threshold

Can environmental regulations promote technological advances? The relationship between environmental regulation and technological advances in China can be described by a U-type curve, which indicates that when the intensity of an environmental regulation increases, technological advancement will initially decrease, and then increase. The strength of environmental regulations in China is located in the declining part of the U-type curve, which is far below the inflection point. Environmental regulations have an inhibiting effect on technological innovation, thereby indicating that the intensity of environmental regulations remains at a low level. Increasing the intensity of government environmental regulations for enterprises can promote the sustainable development of technological innovation. Simultaneously, different forms of environmental regulations influence the amplitude of variation and the inflection point of the U-type-curve relationship between environmental regulation and technological advancement. The spatial heterogeneity effect of different regions demonstrates that the influence of the intensity of environmental regulations on technology lies in geography. The relationship between the intensity of environmental regulation and technological innovation in eastern and central China conforms to a U-type curve, whereas the U-type curve relationship in western China is insignificant. The intensity of environmental regulations in all the regions is below the inflection point. However, the intensity of environmental regulations in eastern China is higher than the national average level, whereas that in central China is lower.

Effect of environmental regulation transmission mechanism: Innovation compensation and technology overflow

Does the indirect technological advancement of an environmental regulation have an evident effect on technological overflow? The effect of overall environmental regulation on technological advancement in China cannot fully benefit from technological overflow because of the uncertainty in the cost effect and the Porter hypothesis that follow technological advancement. In terms of the structural effect, the consumption structure cross item is negative, which indicates that environmental regulations in China cannot enforce the upgrade of industrial structures at present. Instead, the industrial reverse elimination effect occurs because of industrial transference. The capital-intensive characteristic of the photovoltaic industry leads to an unapparent effect of element investment structure on the energy-saving effect from environmental regulations. The future trend of energy consumption structures is oriented toward energy conservation. When the energy consumption structure is adjusted, environmental regulations produce an apparent energy-saving effect and huge potential for more sustainable development.

Regional regulation strategies vary at different development stages in various regions

Do evident differences exist in regional economic development models? The economic development model for coastal areas is transforming, driven by the total productivity factor. By contrast, no improvement occurs from relying on considerable element investment in inland areas, and thus, the development model for inland areas is inefficient. The relatively strict environmental regulations in coastal provinces lead to the innovation compensation effect. However, inland provinces are more likely to encounter the paradox of resources because of their rich resources and unique industrial structures. By contrast, photovoltaic industry regulation in coastal provinces strongly promotes an increase in total green productivity factor. Moreover, interaction already occurs between environmental regulation and technological advancement. In regional relationships, different regions can connect with one another via the environmental medium, which results in the issue of environmental decisions in certain regions influencing the economic decisions of another region.

Environmental regulations require comprehensive design and implementation given a combination of environmental policy tools that consider the optimization of differences in the environmental regulations in various regions and their feedback interaction. Simultaneously, we should also consider the coordination between the interaction and benefit of environmental regulations in different regions.

Environmental regulations and foreign investment: Environmental access regulation and environmental technological overflow regulation

Do different combinations of environmental access regulation and technological overflow regulation have the same effect? Research shows that when environmental access regulation is lacking,

foreign investment can lead to environmental pollution. Similarly, when technological overflow regulation is lacking, foreign investment will find it difficult to realize technological overflow. When environmental access regulations increase foreign investment cost, foreign investors can either conduct green innovation activities to decrease cost and increase revenue or transfer to areas with less environmental access regulations. However, if all the regions implement environmental access regulations, then foreign investors can only conduct green innovation activities. Similarly, when technological overflow regulations increase foreign investment cost, foreign investors can either promote technological overflow to reduce cost and increase revenue or transfer to areas with less technological overflow regulation. Evidently, the effect of a regulation will vary considerably with different intensities.

4. CONCLUSION

The literature review on environmental regulations for photovoltaic industry pollution in China indicates that such regulations have an intensity effect. For the photovoltaic industry, which has varying pollution intensities, the issue of matching intensity with environmental regulations arises. Only when environmental regulation intensity reaches a certain threshold level can environmental regulations promote technological innovation in the photovoltaic industry. The period effect is observed, which indicates that environmental regulations for photovoltaic industry pollution can reduce the production efficiency of an enterprise in the short term. The spatial heterogeneity effect also occurs, which refers to the negative effect of environmental regulations on the competitiveness of photovoltaic enterprises, thereby prompting enterprises to invest in countries and regions with relaxed environmental regulations. The contagion effect, which leads to structural changes in industrial development models, also exists.

REFERENCES:

1. Yang YF. A study on the relationship among fossil energy consumption, air pollution, and economic development in Hebei Province. Nature Environment and Pollution Technology, 2016, V15, #1, pp. 269–275.

2. Collatz G J, Ball J T, Grivet C, et al. Physiological and environmental regulation of stomatal conductance, photosynthesis and transpiration: a model that includes a laminar boundary layer. Agricultural and Forest Meteorology, 1991, V54, #2, pp. 107–136.

3. Jaffe A B, Palmer K. Environmental regulation and innovation: a panel data study. Review of economics and statistics, 1997, V79, #4, pp. 610–619.

4. Kaldellis J K, Kokala A. Quantifying the decrease of the photovoltaic panels' energy yield due to phenomena of natural air pollution disposal. Energy, 2010, V35, #12, pp. 4862–4869.

5. Hoppmann J, Peters M, Schneider M, et al. The two faces of market support – How deployment policies affect technological exploration and exploitation in the solar photovoltaic industry. Research Policy, 2013, V42, #4, pp. 989–1003.

Yan LI,
Doctor of Business Management, in Hohai University. Associate Professor. Fellow of Lanzhou University of Technology of China

Taozhen HUANG,
Doctor of Business Management, Professor. Graduated from Hohai University. Fellow of Hohai University of China

Qiaoliang ZHANG,
Master of Business Management, Professor, CPA. Graduated from Lanzhou University. Fellow of Lanzhou University of Technology of China

Minghao BAI,
Doctor of Business Management, in Hohai University

Light & Engineering
Vol. 24, No. 3, pp. 118-122, 2016

Svetotekhnika
No. 5, 2016

REVIEW OF EQUIVALENT CIRCUIT MODEL FOR PHOTOVOLTAIC AND LI–ION CELLS

Xiaoqiang ZHANG[1, 2 *], and Weiping ZHANG[2]

[1]School of information and Electronics, Beijing Institute of Technology, Beijing, 100081China;
[2] School of Electronic and Information Engineering, North China University of Technology, Beijing, 100144 China
**E-mail: zxq@ncut.edu.cn*

ABSTRACT

To build proper photovoltaic (PV) and Li-ion cells models are essential in predicting behaviors under various operating conditions, avoiding unsafe operations, and developing proper control algorithms and maintenance strategies. This paper analyzes the equivalent circuit and kinematic theory for extracting parameters, along with their respective advantages and limitations, for modeling PV cells. In addition, this paper presents a comprehensive review and discussion of Li-ion cell modeling methods, mechanisms, and characteristics. Partnership for a New Generation of Vehicles (PNGV) model can easily be obtained and is most widely used in cell management systems.

Keywords: PV cell, Li-ion cell, model

1. INTRODUCTION

With widespread applications of proper photovoltaic (PV) power generation and micro-grid systems, PV cell and Li-ion cell models have been the topic of much research [1]. Studies have shown that the nonlinear features of the PV cells output are influenced by light intensity, ambient temperature, and workloads. Under certain light intensities and ambient temperatures, PV cells operate at different output voltages. However, only at a certain value of output voltage, the output power can reach its maximum value. The real output power-generation devices vary with changes in light intensity; during the daytime, when light intensity is the strongest, the power-generation devices output the highest power, whereas, during the nighttime, in the absence of light, power output is nearly zero. Thus, apart from equipment failure, power output is affected by natural factors such as sunlight, weather, seasons, and temperature. Therefore, it is highly necessary to study the characteristics of PV cells, particularly output characteristics [1–3].

Most studies on Li-ion cell models analyze usage and management rather than design and production. As such, the equivalent circuit model is generally studied through the application of circuit and mathematical methods and, therefore, has become the most widely adopted Li-ion cell model. Reference [4] introduces several typical equivalent circuit models and presents a universal cell model. Reference [5] develops a modified equivalent circuit model based on the typical ones.

In this review, numerous PV and Li-ion cell equivalent circuit models are introduced in detail along with their advantages and disadvantages.

2. MODELS UNDER ANALYSIS

2.1. models of PV cells

At present, the models of PV cell are mainly classified into two categories, namely, the external characteristic model and the flat parabolic motion model. The external characteristic model obtains an equivalent model circuit on the basis of

operation output characteristics. A diode and a current source are used to build a primitive model of a PV cell, as shown in Fig.1(a). The main parameters in this model are I_{ph}, the photo-current; I_D, the dark current; I_L, the load current of the PV cell; U_{oc}, the open circuit voltage of the PV cell; and R_L, the load. When current flows through PV panels, it causes series loss inside the PV panels, which is represented by series resistance, R_s. A parallel resistance, R_{sh}, represents the leakage current effect. Thus, as shown in Fig.1 (b), a more accurate equivalent circuit model of PV cells is evolved.

According to the PV cell model shown in Fig.1(b), the mathematical model of the current and voltage of the equivalent circuit can be established directly,

$$I_D = I_0\left[\exp\left(qU_D / AkT\right)-1\right]. \quad (1)$$

$$I_L = I_{ph} - I_0\left[\exp\left(qU_D / kT\right)-1\right]- -U_D / R_{sh}. \quad (2)$$

$$U_D = U_{OC} + I_L R_S. \quad (3)$$

$$I_{SC} = I_0\left[\exp\left(qU_{OC} / AKT\right)-1\right]. \quad (4)$$

$$U_{OC} = AkT\ln\left(I_{SC} / I_0 +1\right)/q, \quad (5)$$

where, I_0 is the reverse saturation current of the internal equivalent diode of the PV cell and is regarded as a constant; I_{SC} is the internal short-circuit current of the PV cell and is defined as the current flowing through the output terminal under the condition of output short circuit (R_L=0) when the PV cell is subjected to irradiation of a standard light source.

Some studies note that I_{ph} equals I_{SC} in the equivalent circuit model, which is an approximation that ignores the reverse-leakage current that flows through the diode at the time of the output short circuit of the equivalent circuit; q is the electron charge, and $q = 1.6 \times 10^{-19}C$; k is the Boltzmann constant; T is the ambient temperature for the PV cell; and A is the internal P–N junction curve of PV cell. R_S decreases to 0 under the ideal condition, whereas R_{sh} increases to infinity.

A PV cell can be depicted as a nonlinear DC source and is regarded as a constant current source approximately before it reaches the maximum power point and as a constant voltage source after the maximum power point. The characteristic curve of a PV cell is greatly similar to that of the trajectory curve of flat parabolic motion of particles [6]. As shown in Fig. 2, the V–I characteristic curve of a PV cell and the trajectory curve of flat parabolic motion of particles are plotted in the same coordinate system and can be divided into three sections on an abscissa, with each section in a different gravity field. The assumption that the particle is thrown horizontally from the short circuit current point (0, I_{sc}), and then this action can induce a curve similar to that of a real characteristic curve.

On the basis of kinematic theory, it can be deduced, see Eqn. 6-7.

Where, V is the output voltage; I_o is the output current in the interval $0 < V \leqslant \lambda V_m$; I_1 is the output current in the interval $\lambda V_m < V \leqslant V_m$; and I_2 is the output current of a PV cell in the interval $V_m < V \leqslant V_{oc}$. Even when environmental conditions change, the location points through g_0 and g_1 adjust automatically. Therefore, these conditions could also ensure that the curves are well fitted for the dyna-

$$\begin{cases} g_1 = \dfrac{2\left(I_{SC} - I_m\right)}{\left(V_m - \lambda V_m\right)^2} \\ g_2 = \dfrac{2\left[I_m\left(V_m - \lambda V_m\right) - 2\left(I_{SC} - I_m\right)\left(V_{OC} - V_m\right)\right]}{\left(V_{OC} - V_m\right)^2\left(V_m - \lambda V_m\right)} \end{cases}, \quad (6)$$

$$\begin{cases} I_0 = I_{SC} \\ I_1 = I_{SC} - \dfrac{1}{2} g_1\left(V - \lambda V_m\right)^2 \\ I_2 = I_m - \dfrac{1}{2} g_2\left(V - V_m\right)^2 - g_1\left(V - V_m\right)\left(V_m - \lambda V_m\right) \end{cases}. \quad (7)$$

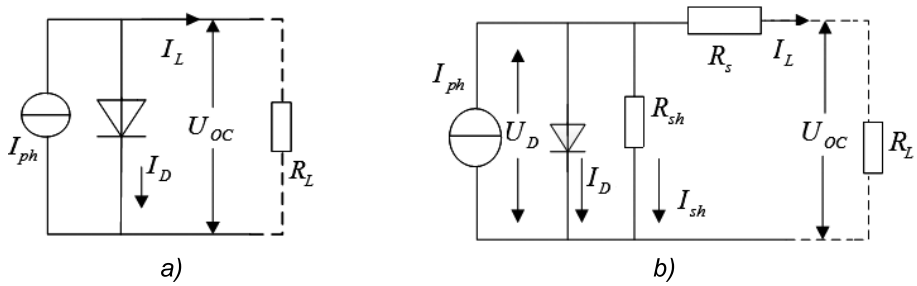


Fig.1. (a) Simple model of a PV cell; (b) an equivalent circuit model of a PV cell

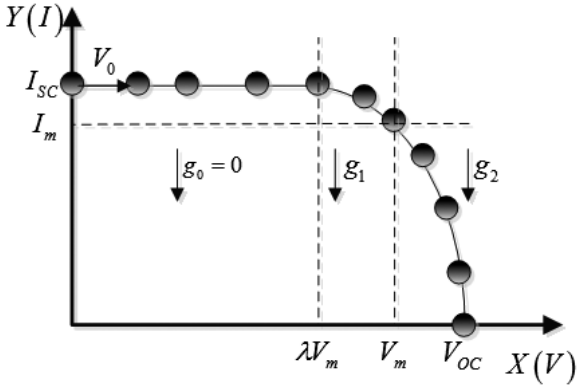


Fig. 2. Dynamic model of a PV cell

mic model and the theoretical model near the maximum power point.

2.2. Models of Li-ion cells

Li-ion cell equivalent circuit models are used to describe the working characteristics of a Li-ion cell through a circuit based on cell working principles. This review focuses on the RC, Thevenin, and Partnership for a New Generation of Vehicles (PNGV) models [7].

An RC model consists of two capacitances and three resistances, as shown in Fig. 3(a) [8]. Large capacitance, C_b, describes the ability of a Li-ion cell to store electric charges; capacitance C_s represents the surface capacity and diffusion effect of the Li-ion cell; R_t is the terminal resistance; R_s is the surface resistance; and R_e is the end resistance. Voltages, V_{Cb} and V_{Cs}, at both ends of the two capacitances are the status variables; terminal current, I_L, is the input variable; and terminal voltage, V_L, is the output variable. The *RC* model state-space equation is deduced based on Kirchhoff's law as follows, see Eqn. 8.

The Thevenin model, depicted in Fig. 3(b), is a commonly used model [9]. This model describes the Li-ion cell open-circuit voltage (OCV) through an ideal voltage source and uses a series resistance R_o and an *RC* parallel network to predict the response of the Li-ion cell to the instantaneous load at a certain state of charge (SOC). Voltage V_{Cp} at both ends of capacitance C_p is the state variable, terminal current I_L is the input variable, and terminal voltage V_L is the output variable. According to Kirchhoff's law, the Thevenin model state-space equation is deduced.

$$\begin{aligned} \dot{V}_{C_P} &= -\frac{1}{R_P C_P} V_{C_P} + \frac{1}{C_P} I_L \\ V_L &= V_{C_P} + R_O I_L + OCV \end{aligned} \tag{9}$$

The PNGV model is obtained by adding a capacitor C_o to the Thevenin model as depicted in Fig. 3(c) [10]. This model is of distinct physical significance in which the ideal voltage source *OCV* indicates the Li-ion cell's *OCV*, resistance R_o is the cell's ohmic internal resistance, resistance R_p is the polarization internal resistance, capacitance C_p is the polarization capacity, I_L is the

$$\begin{aligned} \begin{bmatrix} \dot{V}_{C_b} \\ \dot{V}_{C_s} \end{bmatrix} &= \begin{bmatrix} -\frac{1}{(R_e+R_s)C_b} & \frac{1}{(R_e+R_s)C_b} \\ \frac{1}{(R_e+R_s)C_s} & -\frac{1}{(R_e+R_s)C_s} \end{bmatrix} \begin{bmatrix} V_{C_b} \\ V_{C_s} \end{bmatrix} + \begin{bmatrix} \frac{R_s}{(R_e+R_s)C_b} \\ \frac{R_e}{(R_e+R_s)C_s} \end{bmatrix} I_L \\ V_L &= \begin{bmatrix} \frac{R_s}{R_e+R_s} & \frac{R_e}{R_e+R_s} \end{bmatrix} \begin{bmatrix} V_{C_b} \\ V_{C_s} \end{bmatrix} + \left(\frac{R_e R_s}{R_e+R_s} + R_t\right) I_L \end{aligned} \tag{8}$$

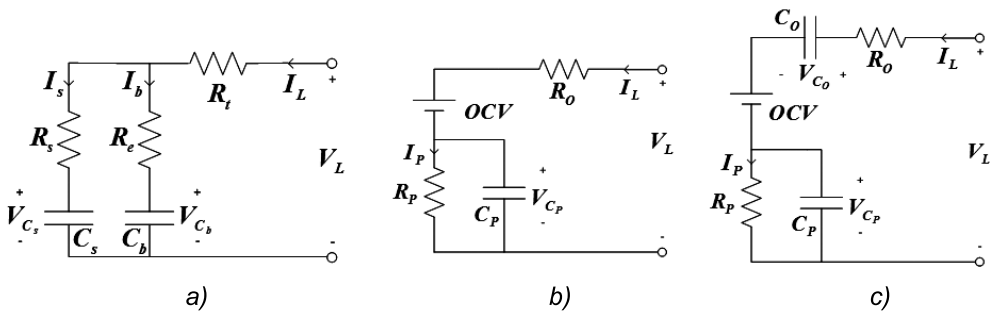


Fig. 3. (a) RC Model; (b) Thevenin Model; and (c) PNGV Model

load current, I_p is the polarization current, V_L is the terminal voltage, and capacitance C_o refers to the changes in *OCV* caused by the timely integration of load current I_L. When the Li-ion cell is at a charging or discharging state, the accumulation of its current with time changes the SOC, which in turn further changes the cell's OCV shown as voltage changes on capacitor C_o. In this model, capacitance C_o represents not only the capacity of the Li-ion cell but also its direct current response, thereby compensating for the deficiencies of the Thevenin model.

Voltage, V_{Co}, at both ends of capacitance C_o and voltage V_{Cp} at both ends of capacitance C_p, are the state variables; terminal current, I_L, is the input variable; and terminal voltage, $V_{L,}$ is the output variable. The PNGV model state-space equation is deduced on the basis of Kirchhoff's law. The PNGV model is the Li-ion cell model introduced by USA PNGV and Freedom CAR hybrid electric vehicles, which has a number of significant influences.

$$\begin{bmatrix} \dot{V}_{C_O} \\ \dot{V}_{C_P} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -\dfrac{1}{R_P C_P} \end{bmatrix} \begin{bmatrix} V_{C_O} \\ V_{C_P} \end{bmatrix} + \begin{bmatrix} \dfrac{1}{C_O} \\ \dfrac{1}{C_P} \end{bmatrix} I_L \qquad (10)$$

$$V_L = \begin{bmatrix} 1 & 1 \end{bmatrix} \begin{bmatrix} V_{C_O} \\ V_{C_P} \end{bmatrix} + R_O I_L + OCV.$$

3. RESULTS

A comparison of the various models of PV and Li-ion cells shows the following results. In the equivalent circuit model of a PV cell, each parameter has a clear physical meaning. However, the parameters and equations include so many multiple logarithmic and exponential operations that computations for CPUs can be challenging. Compared with the circuit model of a PV cell, the dynamic model requires only the relevant cell data from the cell manufacturer and provides a universal formula for the calculation for a more convenient method for reproducing the output characteristic curve under different conditions. With the help of the dynamic model, computation time is cut by half, which can facilitate the controlling devices to speed up the real-time response during the calculation. Whereas, the Li-ion cell RC model fails to describe the relationship between the OCV and SOC of the cell, it can be used to establish an extended Kalman filter and develop a sliding mode controller for the Li-ion cell SOC estimation [11]. The Thevenin model is simple and extensively used. However, if the OCV does not change with the SOC, then the model can only be used to describe the temporary responses of the Li-ion cell at a certain SOC. Therefore, it cannot be used to predict operation duration and charge and discharge management. Compared with the RC and Thevenin models, the PNGV model clearly describes the physical significance of the cell, and parameter identification experiments can be performed easily with high accuracy. As such, this model is among the most popular.

4. CONCLUSIONS

Proper models of PV and Li-ion cells are essential for simulating their behaviours and characteristics. This review collects equivalent circuit models of PV and Li-ion cells. In particular, the models are thoroughly described and their respective advantages and disadvantages are analyzed. The main results are as follows:

– In the equivalent circuit model of a PV cell, the physical meaning of each parameter is clear; however, its parameters and equations include loga-

rithmic and exponential operations. Therefore, this model is not suitable for computation.

– The parameters of a dynamic model for a PV cell are easily obtained, and its equations are simple. Therefore, this model is suitable for computation.

– In the Li-ion cell model, the PNGV model clearly describes physical significance of cell and parameter identification experiments and can be performed easily with high accuracy. Therefore, this model is one of the most popular.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the National Natural Science Foundation of China (No.51277004).

REFERENCES:

1. Marin-Comitre U, Mulero-Diaz AA, Garca-Cuevas MTM. Feasibility Analysis of Photovoltaic Facilities for Household Electricity Self-Consumption in Extremadura. Dyna, 2014, V89, #4, pp. 413–421.

2. de Cisneros-Fonfria JJJ, Orduz-Marzal R, Parrado-Calzado RC, Perez-Higueras PJ, Martos-Lara C, Gomez-Vidal P. Experimental Prototype of an Inclined Simple-Axis Solar Photovoltaic Tracker Integrated on a Parking Car Canopy. Dyna, 2015, V90, #3, pp. 324–330.

3. Benda Vitezslav. Crystalline silicon cells and modules in present photovoltaics. Journal of Engineering Science and Technology Review, 2014, V7, #2, pp.7–15.

4. Chengtao, Lin., Bin, Qiu., Quanshi, Chen. Comparison of Current Input Equivalent Circuit Models of Electrical Vehicle Cell. Chinese Journal of Mechanical Engineering, 2005, V 41, #12, pp. 76–81.

5. Haifeng, Dai., Xuezhe, Wei., Zechang, Sun. An Inner Resistance Adaptive Model Based on Equivalent Circuit of Lithium-ion Batteries. Journal of Tongji University, 2010, V38, #1, pp. 98–102.

6. Wang, Fu., Lin, Zhou. Research on Engineering Analytical Model of Solar Cells. Trans. Of China Electrotechnical Society, 2011, V26, #10, pp211–216.

7. Chengtao, Lin., Bin, Qiu., Quanshi, Chen. A Comparative Study on Power Input Equivalent Circuit Model for Electric Vehicle Cell. Automotive Engineering, 2006, V28, #3, pp. 229–234.

8. Vasebi, A., Partovibakhsh, M., Bathaee, S. A novel combined cell model for state-of-charge estimation in lead-acid batteries based on extended Kalman filter for hybrid electric vehicle applications. Journal of Power Sources, 2007, V174, #1, pp. 30–40.

9. Lee, S., Kim, J., Lee, J. State-of-charge and capacity estimation of lithium-ion cell using a new open-circuit voltage versus state-of-charge. Journal of Power Sources, 2008, V185, #2, pp. 1367–1373.

10. Idaho National Engineering and Environmental Laboratory. FreedomCAR Cell Test Manual for Power-Assist Hybrid Electric Vehicles [EB/OL].2003. http://avt.inel.gov/cell/pdf/freedomcar_manual_04_15_03.pdf.

11. Kim, I. Nonlinear State of Charge Estimator for Hybrid Electric Vehicle Cell. IEEE Trans on PE, 2008, V 23, #4, pp. 2027–2034.

Xiaoqiang ZHANG,
M.S. of Electrical Engineering, Assistant Professor. Graduated from North China University of Technology in 2007

Weiping ZHANG,
Doctor of Power Electronics, Professor. Graduated from Zhejiang University in 1998. Fellow of IEEE

Light & Engineering
Vol. 24, No. 3, pp. 123-127, 2016

Svetotekhnika
No. 5, 2016

MEASUREMENT AND ANALYSIS OF INNOVATION EFFICIENCY IN CHINA'S PHOTOVOLTAIC INDUSTRY

Xiang DENG

School of Finance, Zhongnan University of Economics and Law, Wuhan,430073China
E-mail: xdeng@zuel.edu.cn

ABSTRACT

The photovoltaic industry in China has exhibited remarkable growth in recent years, ranking first in production volume, yet its production efficiency remains low. We analyzed 34 listed photovoltaic firms in China and found that their R&D investment efficiencies are significantly below the efficient frontier. Shortage of R&D staff and insufficient R&D expenditure are the key issues responsible for this phenomenon. We posit that the efficiency of Chinese photovoltaic firms can be improved by innovation the existing technology, developing downstream business, and introducing new products.

Keywords: Photovoltaic Industry, Photovoltaic Firm, Innovation Efficiency

1. INTRODUCTION

The photovoltaic industry in China began to flourish in the 1970s, and its productivity has been demonstrating unprecedented growth since 2007. Since then, the annual total production of Chinese photovoltaic enterprises has constantly ranked first worldwide. However, these photovoltaic firms are facing problems relating to heavy energy-consumption, heavy pollution, and high production cost. Moreover, many of these enterprises focused more on innovation investments, such as expanding the R&D investment scale, consequently neglecting their innovation efficiency, which is essential for the sustainable growth of such firms. Numerous scholars have focused on solar energy conversion efficiency and photovoltaic technology innovation, financing efficiency, financial and business performances, and competitiveness of photovoltaic enterprises [1–3]. However, few studies have been conducted on the innovation efficiency of photovoltaic firms. Therefore, in view of the lack of resources for innovation, the study of innovation efficiency is important for enhancing the development of China's photovoltaic industry.

In this paper, we focus on the photovoltaic firms listed in the Chinese Stock Market and analyze their innovation efficiencies by constructing an innovation efficiency index based on Data Envelopment Analysis (DEA). Our empirical results reveal that the majority of these companies show poor innovation efficiencies. To determine the causes of this, we evaluate the firms' efficiencies and use return to scale analysis and projection analysis. We then offer several conclusions and suggestions on how to improve firm efficiency.

2. EVALUATION INDEX AND RESEARCH METHODOLOGY

2.1. Evaluation index

Many innovation efficiency evaluation index systems have been established. For innovation input indices, most scholars choose R&D staff quantity and R&D expenditure. However, scholars tend to choose different output indexes. Some consider quantity of patents granted as part of the output, whereas others use the number of patent applications.

We believe that the number of patent applications outweighs the number of patent granted, because patents granted indicate the firm's past innovation capability, whereas patent applications verify the present innovation potential of a company. New product revenue is another output index used by scholars [4]. However, in the real production scheduling process, a time lag is present between the current R&D investment input and new product output. For example, if a new product creation process lasts for many years, the current year's investment and the new product output may not be in the same fiscal year. Therefore, we choose total product revenue as our innovation output index.

Table 1. Innovation efficiency evaluation index

Primary index	Secondary index	Tertiary index
Innovation input	Labour force input	R&D staff
	Funding input	R&D cost
Innovation output	Product output	Product revenue
	Patent output	No. of Patent application

We construct an innovation efficiency evaluation index based on characteristics of photovoltaic firms, as shown in Table 1. This innovation efficiency evaluation index includes innovation input and output variables. The innovation input index is composed of labour force input and funding input, which are represented by R&D staff and R&D cost, respectively. Product revenue and number of patent applications indicate a firm's product and patent output, which consist of innovation output.

2.2. Research methodology

Efficiency is measured by parametric and non-parametric methods, represented by Stochastic Frontier Analysis (SFA) and DEA, respectively. Compared with parametric method, DEA is more flexible for handling models containing multiple output and input variables, and this technique does not impose an explicit function form on the efficient frontier. Thus, DEA is more appropriate for evaluating photovoltaic firm innovation efficiency in China. C^2R and BC^2 are two widely used models in DEA. For n to be evaluated decision-making units each has m input and n output variables. The equation for final results is as follows:

$$h_i = \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{mn} v_i x_{ij}$$
$$i = 1,2,\ldots m; r = 1,2,\ldots s; j = 1,2,\ldots n,$$

where x_{ij} is the i^{th} input variable of DMUi, and $x_{ij} > 0$; y_{rj} is the j^{th} output variable of DMUj; and $y_{rj} > 0$; v_i is the weight of i^{th} input variable, and u_j is the weight of j^{th} output variable.

Taking the efficiency index of the DMUj0 as the objective number and all indexed efficiency as constraints, C^2R can be expressed as follows:

$$\begin{cases} \max h_{j_0} = \sum_{r=1}^{s} u_r y_{rj_0} \Big/ \sum_{i=1}^{m} v_i x_{ij_0}, u \geq 0, v \geq 0 \\ s.t. \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \leq 1, j = 1,2,\ldots n \end{cases} . \quad (1)$$

The Charnes-Cooper (1978) [5] conversion is used to convert Equation (1). Then, by introducing a slack variable s+ and a residual variable s^-, the inequality constraint can be transformed into the following equality constraint:

$$\begin{cases} s.t. \sum_{j=1}^{n} \lambda_j x_j + s^+ = \theta x_0 \\ \sum_{j=1}^{n} \lambda_j y_j - s^- = y_0 \\ \lambda_j \geq 0, j = 1,2,\ldots n \\ \theta \text{ unconstrained } s^+ \geq 0 \; s^- \leq 0 \end{cases} . \quad (2)$$

The efficiency status can be evaluated by using the optimal solutions of Equation (2), namely, θ^0, λ^0, s^{0+}, s^{0-}.

First, given the uncertainty of the marginal revenue of innovation in photovoltaic firms, the C^2R model is used to calculate photovoltaic firm innovation efficiency. Then, $\Sigma\lambda j=1$ is plugged into the C^2R model to derive the B^2C model, which measures innovation technical efficiency. After which, innovation efficiency is decomposed into pure technical efficiency and scale efficiency. On the basis of the results, return to scale can be constant, increasing, or decreasing.

3. EMPIRICAL ANALYSIS

3.1. Data source

Eighty photovoltaic enterprises are listed in the Chinese Stock Market in 2015. After their annual reports and daily announcements are examined, only 34 companies are considered appropriate for the empirical study, because 12 firms had only been involved in the photovoltaic business that year, and the other 34 firms did not report any information on patent applications.

Table 2 shows the input and output data for the period of study used to derive efficiency scores. The minimum value of R&D personnel is 93, and the maximum can be 20 times as large as the minimum. The minimum of R&D expenditure is CNY11.8 million, and the maximum is approximately CNY1.3 billion. The minimum of product revenue is CNY31.79 million, and the maximum is CNY22.52 billion. The minimum of patent applications is 1, the maximum is 177. All of these figures illustrate that the listed photovoltaic firms in China have tremendously diverse input/output range.

Table 2. Chinese photovoltic enterprise innovation output and input data descriptive Statistics in 2015

Index	Min.	Max.	Mean
R&D staff	93	1956	511
R&D cost	1180	129443	17632
Product revenue	3179	2251813	353525
No. of Patent application	1	177	54

Note: R&D cost unit and product revenue unit are CNY10 thousand. Staff unit is person, and No. of patent applications is piece.

Table 3. China's photovoltic enterprise innovation efficiency evaluation in 2015

Efficiency Name	Mean	Firms
Innovation efficiency	0.513	16
Technical efficiency	0.685	18
Scale efficiency	0.724	20

Note: "Firms" represent the number of firms whose efficiency value is larger than the mean.

3.2. Efficiency evaluation

The input-oriented C2R and BC2 models are used to derive the innovation efficiency, technical efficiency, and scale efficiency values through the DEAP 2.1 software. The average efficiency values of the sample firms are shown in Table 3.

The innovation efficiency value is equal to the technical efficiency value multiplied by the scale efficiency value. In Table 3, the mean value of innovation efficiency (0.513), innovation technical efficiency (0.685), and innovation scale efficiency (0.724) is less than 1, indicating that the innovation activities of these firms proceed inefficiently. The relatively low result of innovation efficiency comes from the small value of innovation technical efficiency, and the innovation scale efficiency is closer to the efficient frontier. These findings reflect that Chinese photovoltaic firms are depending on large-scale investment, rather than technical breakthroughs, to facilitate innovation progress.

Table 4. Enterprise innovation efficiency classification

Efficiency			1	0.8–1	0.4–0.8	0.2–0.4	>0.2
Innovation efficiency	Firms		6	2	11	7	8
	Pro.(%)		17.7	5.9	32.4	20.6	23.5
Technical efficiency	Firms		12	3	12	6	1
	Pro.(%)		35.3	8.8	35.3	17.7	3.0
Scale efficiency	Firms		6	11	10	5	2
	Pro.(%)		17.7	32.4	29.4	14.7	5.9

Note: Valuation of efficiency value being 1 is "Good", the valuation for 0.8–1is "Fair", the valuation for 0.4–0.8 is "Average", the valuation for 0.2–0.4 is "Poor", and the valuation for value below 0.2 is "Bad".

In Table 3, the last column indicates that around half of the total firms' innovation efficiency values are less than the mean.

Table 4 illustrates that the innovation efficiency of six firms are on the efficient frontier and the value is 1, but more than 80% of the firms are innovation inefficient. Approximately one-third of photovoltaic enterprises have technical efficiency values of 1, and the rest are technical inefficient. Nearly half of the firms' scale efficiency values are approximately close to the scale efficient frontier.

3.3. Return to scale analysis

Table 5 show that among 34 photovoltaic companies, six firms have constant return to scale; that is, 18% of total companies can be found at the point of optimum scale efficiency.

Twenty-three companies exhibited an increasing return to scale, indicating that firms are under investing in innovation, thereby keeping scale efficiency low. Expanding the scale of investment is the only solution to this problem.

3.4. Projection analysis

By scanning and comparing the redundancy rate of each variable, the factors causing companies to be non-DEA-efficient can be identified through projection analysis. Moreover, solutions to these issues can be posited based on the analysis.

Table 6 illustrates the redundancy rate of the sample firms. As shown, 21 and 20 firms currently suffer from redundancy of R&D staff and R&D cost, respectively. The main factor causing DEA inefficiency is redundancy in both R&D staff and R&D cost. Inefficiency in scale efficiency value is caused by the same reason found in the return to scale analysis. As for the technical efficiency value, the redundancy indicates the insufficient quantity of R&D personnel.

Table 5. Innovation return to scale analysis

Return to scale	Firms	Pro.
Constant	6	18%
Increasing	23	68%
Decreasing	5	14%

Table 6. Projection analysis

Projection distribution		Firms	Pro.
Input surplus	R&D staff	21	62%
	R&D cost	20	59%
Output scarcity	Product revenue	9	26%
	No. of patent application	0	0%

4. CONCLUSION

In the photovoltaic industry, nearly all companies are boosting their investments in the photovoltaic business, but not everyone is reaching the efficiency frontier. As discussed, although most photovoltaic companies have difficulty realizing efficiency in the innovation technical aspect, they remain focused on manufacturing products instead of technology breakthroughs. Although the increasing demand is promising for the future of the photovoltaic industry, a negative influence is beginning to emerge from the decreasing return to scale because of the mismatch between the unceasingly expanding production size and the corresponding market demand. In addition, photovoltaic companies in China mainly are centred on the upstream, such as photovoltaic device components and photovoltaic battery manufacturing. However, the downstream is more profitable, where companies can transmit the power gathered by photovoltaic devices to households, factories, etc. As a result, companies should consider moving their resources to the downstream and expand their size there to enjoy profits from increasing return to scale.

The study can be summarized with some conclusions and suggestions. Chinese photovoltaic firms should exert more effort on developing technological breakthroughs. At present, prices of photovoltaic products have become low. Without further improvements and technology innovation, companies may no longer profit from the photovoltaic business. The photovoltaic core technology and material for Chinese firms are imported from European and US markets, and the main consumers of photovoltaic products are from Europe and the US. Firms in China can readjust the size of upstream development and add resources to support downstream growth, i.e., "create internal demand". They can also consider introducing new technologies, and they can vary photovoltaic product types and introduce wider selections.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the Soft Science Research Project of Technology Innovation Specific Funds in Hubei Province (Research Approach on Newly Financial Service System for Science and Technology within the Industry Chain Responding to "Made in China 2025" Strategy in Hubei Province).

REFERENCES:

1. Pandey, R., Chaujar, R. Rear contact SiGe solar cell with SiC passivated front surface for >90% external quantum efficiency and improved power conversion efficiency. Solar Energy, 2016. V135, pp.242–252.

2. Larrouturou, F., Caliot, C., Flamant, G. Influence of receiver surface spectral selectivity on the solar-to-electric efficiency of a solar tower power plant. Solar Energy, 2016. V130, pp.60–73.

3. Li, Y.Q., Liu, G., Liu, X.P., Liao, S.M. Thermodynamic multi-objective optimization of a solar-dish Brayton system based on maximum power output, thermal efficiency and ecological performance. Renewable Energy, 2016. V95, pp.465–473.

4. Chiu, Y.H., Huang, C.W., Chen, Y.C. The R&D value-chain efficiency measurement for high-tech industries in China. Asia Pacific Journal of Management, 2012. V29, #4, pp.989–1006.

5. Charnes, A., Cooper, W.W., Rhodes, E. Measuring the Efficiency of Decision Making Units. European Journal of Operational Research, 1978. V2, #6, pp. 429–444.

Xiang DENG,
Ph.D. in Economics, Lecturer. Graduated from the Zhongnan University of Economics and Law. Fellow of the School of Finance at Zhongnan University of Economics and Law

Light & Engineering
Vol. 24, No. 3, pp. 128-131, 2016

Svetotekhnika
No. 5, 2016

THE ROLE OF THE GOVERNMENT IN THE DEVELOPMENT OF THE LED INDUSTRY

Wei WU[1,2]

[1]*School of Economics & Business Administration, Chongqing University, Chongqing, 400044, China;*
[2] *School of Finance & Economics, Chongqing City Management College, Chongqing, 401331, China*
E-mail:38633165@qq.com

ABSTRACT

Existing literature has not yet reached a consensus on whether or not government policies can promote industrial development. In this study, we combed the government's industrial policies in the light-emitting diode (LED) industry of major countries and regions, and then analyzed their positive and negative effects on the development of this industry. Government support of the LED industry is not conducive to its healthy development. The influence should be divided between the government and the market in accordance with their comparative advantages. The government should comply with and assist the market as well as aim toward a dynamic division of the industrial chain between regions based on their comparative advantages.

Keywords: light source, LED, industrial policies, government failure, market mechanism

1. INTRODUCTION

Light-emitting diodes (LEDs) were introduced in the 1960s. Given the potential market value of the LED industry, it is not only favoured by investors but also identified as a strategic high-tech industry by governments in many countries. This industry has also received substantial support in forms of technology research, patent protection, market development, and tax incentives.

This paper is organized as follows. Section 1 briefly describes LED and presents the research questions. Section 2 discusses LED industrial policies in major countries and regions. Section 3 analyzes the functions of these policies. Section 4 defines the role of the government based on the comparative advantages and dynamic division of the industrial chain of the LED industry. Section 5 concludes the paper.

2. LED INDUSTRY POLICIES IN MAJOR COUNTRIES AND REGIONS

The LED industry is mainly concentrated in the US, Japan, the European Union (EU), South Korea, and China [1].

2.1. LED industry policy in the US

The US Department of Energy (DOE) launched The National Research Program on Semiconductor Lighting with a budget of $500 million as early as 2000. Afterward, the DOE introduced a Five Year Solid-State Lighting Commercialization Support Plan in 2007 to promote the market development of LED. The US government also launched an energy-saving appliances subsidy program worth up to $300 million in early 2009. In 2014, the US government implemented a new scheme that prohibits the production and import of incandescent lamps.

2.2. LED industry policy in Japan

In 1998, the Japanese government launched the 21st Century Light Plan with a budget of 6 billion yen. Japan also revised its Energy Conserva-

tion Law and launched the "leader" program. From 2004 to 2009, the Japanese government launched a white LED treatments and application program. The Japanese government also shouldered half of the R&D costs for the program installing LED technology in railway signal lights.

2.3. LED industry policy in South Korea

The South Korean government implemented the Photonics Industry Development Plan as early as 2000, which aimed to promote its photonics industry into one of the top five photonic industries in the world by 2008. The South Korean government then allocated an additional $100 million to support its LED industry from 2004 to 2008. In 2006, the South Korean government aimed to use LED in 30% of the country's overall lighting by 2015. In 2011, the South Korean government introduced the Green LED Lighting Popularization and Development Program and the LED Lighting 2060 Plan.

2.4. LED industry policy in the EU

Between 2000 and 2003, the EU implemented the Rainbow Project, establishing a manufacturing base for certain types of LED. In 2005, the EU issued a directive on formulating the framework of the eco-design requirements of energy-using products. In 2007, the UK launched the Novel Efficient LED Lighting Solution Program. After the completion of the OLLA project, the EU launched the special OLED100.eu program.

2.5. LED industry policy in China

The LED industry policy of China is divided into two levels, namely, central and local governments. In the late 20th century, the central government launched the 863 Program, which aims to fund the research and development of LED technology. In 2006, semiconductor lighting was explicitly defined as an "industrial energy saving" theme and was prioritized for development. In 2009, the Chinese government launched the "10 cities 10,000 lights" semiconductor lighting pilot demonstration project. In 2011, the Chinese government issued plans to phase out incandescent lamps. Similar policies have been adopted by local governments. The LED industry policies of China are characterized by their complexity and formulation by different departments.

3. THE ROLE OF LED INDUSTRIAL POLICY

The rapid development of the LED industry has been significantly and positively correlated with the aforementioned industrial policies. However, does a causal relationship exist behind such correlation? Are these supportive policies economically efficient?

3.1. Positive effects of the LED industrial policy

3.1.1. Support for basic research

Given that basic research has more uncertainties than application research, market participants are generally uninterested in basic research. However, basic research activities may have a groundbreaking role in technological innovation and revolution, which may be a result of the government's support for scientific research as a part of their LED industrial policies.

3.1.2. Offset of negative factors

The market mechanism may be disturbed by many unfavourable factors. For example, the minimum wage system has effectively increased the operating costs of enterprises. Government measures, such as subsidies, tax breaks, and financial support to LED manufacturers, can help companies reduce their operating costs.

3.1.3. Reduced transaction costs

The government can help the market reduce information costs and help market participants in their decision-making through continuous monitoring of the LED market. The government also establishes alliances with different agencies, such as enterprises, research institutes, and universities, to promote mutual cooperation. The government may also represent a country or region by encouraging collaboration or forming industry links with other countries and regions.

3.2. Negative effects of LED industrial policies

3.2.1. Blindness in selecting a funded object

Current typical LED enterprises are mostly established before the government started to provide supportive policies. For example, Nichia was founded in 1956, the US-based Cree was founded in 1987 [2], Toyoda Gosei was founded in 1949, Lumileds was established in 1999, and its predecessor, the Optoelectronics Division of Hewlett–

Packard, was established 40 years before that. These firms remained in the market by surviving competition instead of relying on government subsidies or support. This suggests that the government may be blindly funding LED businesses.

3.2.2. Possible disruption to the market mechanism

When competition among companies results in bankruptcy, the market may consolidate its resources through mergers. If the government provides subsidies to a losing enterprise, but the enterprise cannot restore its vitality, the large amount of subsidies provided by the government is rendered useless. Government subsidies may also lessen the dedication of market players to searching for novel technologies or reducing their costs.

Government support for research in LED technology may not increase the value of a patent. This situation happened to China. Many R&D organizations in this country do not directly participate in market competition and are not sensitive to the market value of technology because they are owned by the state. This situation is the reason the patent has poor conversion rate in the Chinese market [3].

Some governments formulate standards of product quality in the LED industry. Improving product quality will increase the costs of enterprises. Faced with competitive pressures in the market, companies naturally strive to improve their product quality.

3.2.3. Difficulty in deciding on the best support

The government provides a handsome amount of funding in its policies as shown in the determination of the amount of government funding summarized previously. Determining such amount does not follow any criteria, calculation methods, or research procedures. The Chinese government particularly shows these characteristics. The policies in the Chinese LED industry are formulated by multiple organizations and cannot be easily optimized as a whole. Difficulties also exist in determining how long the government's support for the LED industry should last.

3.2.4. Social cost of the LED industrial policy

If the government delivers its resources to the LED industry through administrative means, then the resources that the other industries can obtain will be reduced. Although the development of the LED industry may be very visible, Other industries are forced to reduce the development opportunities.

4. THE DYNAMIC DIVISION OF THE INDUSTRIAL CHAIN AND THE GOVERNMENT'S ROLE BASED ON COMPARATIVE ADVANTAGES

Given the integration of several economies, the market must be understood from a global perspective. The LED industry chain can be divided into three links. The upstream and midstream sectors account for more than 70% of the profits in the whole industry chain. Geographically, Cree and Lumileds in the US, Nichia and Toyoda Gosei in Japan, and Osram in Germany monopolized the high-end product market [4]. Despite this progress, no company has dared relax its pace of technological R&D. The reduced patent concentration in the LED industry shows that competition in the market remains very intense [5]. The accumulation of technologies is most advantageous for leading LED manufacturers. Given that newcomers will have to pay a huge amount for technology research, they focus instead on the downstream sectors of the LED industry.

The division of the industrial chain should proceed from a comparative advantage. If the government ambitiously promotes its enterprises to become global leaders in the LED industry, this ambition probably goes against the choice of the market.

This situation raises the following question: If all governments are indifferent to the LED industry, will newcomers have the opportunities to develop the LED industry? The answer to this question is yes. Different levels will evolve from the same industry, and these levels set different requirements for the nature of resources of the country or region. This may help expand the concept of division of labour within the industry to a global context. The competitive ability of different countries and LED enterprises continues to change with their labour costs and research abilities. Transfer within the LED industry embodies the inherent requirements of these factors.

5. CONCLUSIONS

The paper has analyzed the positive and negative effects of LED industrial policies by compar-

ing the government LED industrial policies of major countries and regions. Given the lack of information, the government cannot function as well as the market mechanisms in efficiently solving problems related to labour division, distribution of the industrial chain, industrial upgrading, technological development, and promotion of product quality. The government's intervention or support to the LED industry is not conducive to the healthy development of this industry. The government should respect, safeguard, and assist the market, improve the patent system, and protect property rights.

REFERENCES:

1. National Lighting Test Centre, Beijing semiconductor lighting science and Technology Promotion Centre. Analysis on Solid State Lighting Industry: Policies and Standards, China Machine Press, 2012. 7.

2. Jia-xiu Luo. The U.S. patent analysis in LED field of Nichia and Cree. China Integrated Circuit.2011. V20, #11, pp.82–87.

3. Tao Zhang, Guang-han Fan, Yi-qin Xu, Long-fei He, Jian-yong Xiong. Patent Information Analysis of Guangdong LED Packaging Industry. Science and Technology Management Research, 2015.V35, #4, pp.122–126,136.

4. Yu Chen. Patent analysis of semiconductor lighting lamps in Ningbo and suggestions for its industrial development. Science & Technology Progress and Policy, 2009. V26, #15, pp.57–59.

5. Xiao-dong Yuan, Jing Chen. The co-operation relationship of LED manufacturers based on patent information analysis. Science Research Management.2013. V34, #7, pp.78–86.

Wei WU,
Doctoral student of Chongqing University, lecturer in Chongqing City Management College. Research fields: quantitative economics and contract economics

Light & Engineering
Vol. 24, No. 3, pp. 132-135, 2016

Svetotekhnika
No. 5, 2016

FINANCIAL SYSTEM INNOVATION OF LARGE-SCALE LED ENTERPRISES IN CHINA WITHIN THE INTERNET ECONOMY

Yunzhe CHEN

China Youth University of Political Studies, Beijing, China
E-mail: yunzhechen349@sina.com

ABSTRACT

The development of an Internet economy provides an opportunity for many medical laser enterprises to grow rapidly. However, unbalanced development could lead to devastating consequences for the companies. Thus, this article analyzes several efficiency growth methods of medical laser enterprises in the Internet economy, and proposes reasonable suggestions for financial planning in the development process of large LED enterprises. Research results show that internal growth rate and sustainable growth rate are important forecasting tools for the financial planning of medical laser enterprises as well as LED enterprises within the context of an Internet economy.

Keywords: internet, medical laser enterprises, financial planning

1. INTRODUCTION

Today's science and technology are changing rapidly. The development and spread of the Internet and the appearance of interactive Web applications result in the surging tide of e-commerce. Internet technology is rapidly changing the traditional form of the industrial economy, resulting in the gradual formation of a new economic form, the Internet economy [1]. Internet economy is a type of economic activity that can accomplish the circulation of production, circulation, exchange, and distribution by means of network and digital technology [2]. The traditional concept of wealth and value, and the environment of financial planning and management have changed along with the emergence of the Internet economy [3]. The maturity of related technologies has promoted the development of laser medicine, and the development of laser medicine promoted the rise of medical laser manufacturing companies. The emergence of the Internet economy has enabled numerous medical laser enterprises to grow rapidly. However, rapid growth consumes a large amount of resources. Foreign research data show that the number of bankrupt enterprises has increased due to rapid growth or growth recession. Therefore, companies require rational financial planning and must maintain reasonable growth rates by taking appropriate measures to achieve a balanced and sustainable growth [4].

2. MEDICAL LASERS

The development of medical laser technology and equipment complements the development of laser medicine [5]. With the advent of the ruby laser in 1960, the laser used for retinal detachment surgery created in 1962 [6]. Such laser technology gave rise to the development of laser medicine, thereby promoting the gradual improvement of medical laser equipment [7]. The strategic importance of the area of medical equipment has been widely recognized by countries around the world, and has become one of the most important signs of the modernization of national economies and the modernization of health services [8].

Financial planning is the concrete embodiment of corporate strategic planning. Financial planning

is not only a series of compiled budget tables, but also rather a scheme that requires detailed business initiatives and plans to guide business activities of enterprises, achieve business objectives at different stages, and prevent companies from deviating from the strategic direction [9]. Financial planning includes scheme of operations and financial budgets, and involves every aspect of business activities from market sales, production management to cost control, cash flow management and control, and from brand management to human resources configuration. Each link is interrelated within an organic system [10].

3. METHODOLOGIES FOR FINANCIAL PLANNING

Growth mode of medical laser enterprises in the Internet economy

The growth mode of medical laser enterprises has three types. The first type promotes the enterprises' growth, mainly by relying on issuing shares to absorb equity investment or obtaining external funds by external loans. However, depending on this method of achieving growth, it is generally difficult to maintain. The second type relies solely on internal funds. The difficulties in borrowing money or when some enterprises do not want to borrow, can cause laser enterprises to foster growth through the use of internal funds. Internal growth rate (IGR) means that enterprises achieve the maximum growth rate that is not dependent on external financing and reflects the potential growth of the enterprise that relies on internal funds under the condition of IGR without any new debts and all assets related to sales. The third type is balanced growth, which is also known as balanced growth or sustainable growth. To maintain balanced development, enterprises use the growth of internal retained earnings to access external debt growth according to a certain proportion. In addition, enterprises cannot only maintain the company sales growth, but also the synchronization of financial resources growth.

Financial planning advice to medical laser companies within the Internet economy

We assume that financial planning uses the same operational efficiency and financial policy with that of last year on the premise of enterprises' successful sales of new products, and the actual growth rate of the current year is the same as that of the IGR or SGR of the previous year. Under the Internet economy, the medical laser enterprises' development status requires the growth state, which is a balanced growth that can be sustained development continuously through money.

If the statistics on the number of financial ratios have one or more numerical rise, the real growth would have been more than that of the IGR or SGR of the previous year. Furthermore, this extraordinary growth is not because the maintenance of operational efficiency and financial policy in the past, but a result of changes in financial ratios. On the basis of its status, the enterprise can choose different financial planning management measures by themselves and want to increase the equity capital or secondary offerings, LED enterprises can make the secondary offerings as specific financial planning management measures and utilize newly raised funds to fill the funding gap through rapid sales growth. Laser enterprises can also raise money by improving the liabilities ratio and increasing the debt, which is used to fill the funding gap through rapid sales growth. Laser companies can also improve the retention ratio and reduce corporate dividend bills, which will not only fill the funding gap of the LED enterprise, but also enhance the anti-risk ability of enterprises and make the next step in laying down a foundation. However, when we find the enterprise sales growth rate is actually greater than sustainable growth rates (SGRs); laser enterprises can seek for internal potential to improve the funding gap because of operating efficiency. In addition, to improve the asset turnover ratio and consequently improve the SGR, laser enterprises can outsource the production of laser products to other companies, which will release homemade funds.

Typically, after supernormal growth, a lower development period would be inevitable. If the financial ratios under more than one decrease, the actual growth rate will be lower than the number of the IGR or SGR of the previous year. If laser enterprises even exceed the extended cash surplus in a period, then the laser can consider these financial planning management measures. First, the enterprise can fully utilize surplus cash for new product research and development or upgrade the old products or adjust product structure, which stimulates the sales growth in the period, and can search for new sales growth points. Second, when the la-

Table 1. ABC Company

Net sales rate	5.90%	4.80%	3.90%	2.70%
Asset turnover	3.1	3.3	3.2	3.5
Percentage of earnings retained	0.5	0.5	0.5	0.5
Early shareholders' equity	2.2	2.4	2.8	3.1
Sustainable growth rate	20.12%	19.01%	17.47%	14.65%
Real growth rate	23.26%	25.71%	28.52%	24.39%

ser enterprises have a large number of surplus cash but are unable to find investment projects with high returns, enterprises can increase the returns to shareholders through dividends and compensate for losses sustained during the growth period, which is a type of rational practicing. High debt ratios cause an increase in financial risk for companies. At this point, the enterprises can decide to reduce the debt proportion after reaching the maturity period. The enterprises can also pay off some debts to achieve debt structure adjustment and control the financial risk.

4. RESULT ANALYSIS AND DISCUSSION

In the present paper, we use two medical laser enterprises as instances and elaborate further on the main points of the medical laser enterprises' financial planning under Internet economy. The LED companies actual growth rate and SGR data are investigated. Results are shown in the following table.

The chart shows that the company's actual growth rate is significantly greater than the SGR. Thus, the laser companies need to obtain external funding to support operation. The table also shows that the companies fill the gap by borrowing. This method is not the optimal choice. The company should improve its price and control cost to adjust the sales' net interest rates. The method can also increase its profit retention rates by reducing dividend spending.

5. CONCLUSION

The rapid development of the Internet economy has enabled numerous medical laser companies to grow rapidly. Based on the analysis of growth modes of medical laser enterprises in the era of Internet economy, the paper proposes reasonable suggestions for financial planning. The IGR and SGR are important prediction tools for financial planning of LED enterprises under the Internet economy too. These rates embody a concentrated reflection of the comprehensive strength of the medical laser companies and the ability to use financial policy to weigh the benefits and risks in the context of an Internet economy. LED business should be based on its own strengths as well as its own risk management ability and the ability to access to external resources. These companies should also have dynamic plans for development speed. In addition, real-time analysis of the difference and the causes of differences with real growth and IGR or SGR should be conducted. Guidance for the next step of enterprise management planning should be provided. However, the present article only proposes some suggestions for medical laser enterprises under the Internet economy, which can be used in LED industry. Nevertheless, more research is necessary, especially on the enterprise management process.

REFERENCES:

1. Schulmeister K, Jean M. The risk of retinal injury from Class 2 and visible Class 3R lasers, including medical laser aiming beams. Medical Laser Application, 2010. V25, #2, pp. 99–110.

2. Pierce J S, Lacey S E, Lippert J F, et al. Laser-generated air contaminants from medical laser applications: a state-of-the-science review of exposure characterization, health effects, and control. Journal of Occupational & Environmental Hygiene, 2011. V8, #8, pp. 447–66.

3. Hornby P. The Design of a Medical Laser Laboratory. Archives of Environmental Health An International Journal, 2013. V10, #3, pp. 493–497.

4. Gallo E. The Young Adult: Financial Education, Social Networking, and Internet Security. Journal of Financial Planning, 2011.

5. Snider, Joanne. Success Factors of Small Business Owners of Independent Financial Planning Firms. Dissertations & Theses – Gradworks, 2015.

6. Cohn M. Survey: Many CPAs Have Only Loosely Embraced Financial Planning. Financial-planning.com, 2013.

7. Agarwal S, Amromin G, Ben-David I, et al. Financial literacy and financial planning: Evidence from India. Journal of Housing Economics, 2015.

8. Smith H, Finke M, Huston S. The Influence of Financial Sophistication and Financial Planners on Roth IRA Ownership. Journal of Financial Service Professionals, 2012.

9. Cordell D M, Grange E V, Langdon T P. Useful Financial Planning Concepts from Academic Research. Journal of Financial Service Professionals, 2012.

Yunzhe CHEN,
Lecturer, graduated from University of New South Wales. Work Unit: China Youth University of Politics

Light & Engineering
Vol. 24, No. 3, pp. 136-140, 2016

Svetotekhnika
No. 5, 2016

DYNAMIC PRICING OF LED COMPONENTS BASED ON STRATEGIC CONSUMER BEHAVIOUR WITHIN A COMPETITIVE ENVIRONMENT

Dejie SUN[1,2], Wenyuan LIU[1,2,*], and Jie ZHANG[1]

1. School of Information Science and Engineering, Yanshan University, Qinhuangdao, HeBei, China
2. The Key Laboratory for Computer Virtual Technology and System Integration of HeBei Province, Qinhuangdao, HeBei, China
**E-mail: wenyuanliu994@126.com*

ABSTRACT

The traditional pricing system of light-emitting diode (LED) components can no longer satisfy the requirements of diverse customer behaviours. In this regard, we propose a dynamic pricing game model for two vendors to sell LED devices by considering different customer choices, in which potential customers are divided into three types. From a case study on the pricing of multi-cycle LED components, we draw the conclusion that the probability of purchase is higher for customers with high loyalty to the seller, which increases the corresponding price with the expected revenue of the seller.

Keywords: optical LED devices, dynamic pricing, customer strategic behaviour, competitive environment

1. INTRODUCTION

When purchasing goods, some customers refer to the prices provided by several retailers to have a reasonable expectation for the products to be purchased, and then choose the appropriate time to purchase the commodity in its dynamic changes to achieve maximum benefits. Such customers are known as strategic customers. Strategic customers exist because the price of optical components fluctuates heavily over time and the dynamic pricing strategy of retailers will directly affect the utility of the purchase during different periods [1]. Any instruments or devices that form an optical path or are related to optics are optical light-emitting diode (LED) components, such as lenses, optical fibers, plane mirrors, gratings, optical isolators, and beam splitters. Optical LED devices significantly change over time. When dealing with strategic customers, retailers should consider the effect of their pricing on the market demand for optical LED devices and the effect of the waiting period of customers on the existing price. A unilateral consideration of one factor will adversely influence the marketing effect of optical LED devices [2]. Therefore, we should consider the relationship between retailers and the purchase behaviour of strategic customers in building a decision model, which can make the pricing of manufacturers reasonable, and thus, improve their income [3]. Therefore, studying how dynamic pricing can be implemented in the case of strategic customer behavior is significant. This paper discusses the dynamic pricing of LED components based on strategic customer behaviour within a competitive environment. A dynamic pricing game model for alternative products by two sellers that considers different customer choice behaviours is then proposed.

2. BACKGROUND

A dynamic pricing mechanism is one of the important factors that influences enterprise income. The current literature on dynamic pricing of optical components shows that optical components are

priced by large monopolized enterprises according to their high precision requirements. Thus, research on the pricing system of optical components is related to a monopoly environment. However, increasingly fierce competition in the product market poses considerable challenges for the application of a dynamic pricing technology within a traditional monopoly environment. A dynamic pricing mechanism can guide the decision-making process of enterprises, and decisions that disregard market environment and strategic customer behaviour are unsuccessful [4]. Price determines the competitive capability of a product in a fiercely competitive business market. The popularity of information dissemination tools in modern society leads to the complexity of factors that affect the purchase intention of consumers. Consequently, enterprises cannot consider the competitive conditions of the market alone when pricing products.

Researchers have found that both competition among enterprises and consumer evaluation of a product significantly influence the pricing of a product; however, previous studies have researched on these two factors individually instead of combining them. The pricing of optical LED components is dynamic, and pricing enterprises mostly have a monopoly position. The pricing model should be based on the transmission behaviour of customers in a competitive business community. Studies on multi-cycle dynamic pricing based on customer behaviour under a competitive environment are rare because of the complexity of computation and the two-week cycle of both factors.

3. METHODOLOGY

Building the model

The model simulates the process in which two dealers distribute LED components within N weeks when the stock is certain and the number of consumers satisfies the predetermination. We suppose that only one strategic customer participates in every period, and the probability of customer participation in cycle $t\left(t=1,2,\cdots,N\right)$ is represented by λ_t. When the strategic customer appears, his/her purchasing power is limited to one unit of the product or possibly nothing.

Customer classification and their choice behaviour

Purchasers in a commercial market are divided into three categories. The first group comprises product-oriented customers who are likely to choose both sellers 1 and 2. The second group consists of customers who are satisfied only with the products of seller 1, and thus, the products of seller 1 will be bought as long as these customers intend to make purchases. The third group is composed of customers who are satisfied only with the products of seller 2, and thus, the products of seller 2 will be bought as long as these customers intend to make purchases. $\lambda_{it}\left(i=1,2,3\right)$ is used to represent the probability of ith customer in cycle T, and thus, $\lambda_t=\sum_{i=1}^{3}\lambda_{it}$. $P_j\left(p_{1t}\left(t\right),p_{2t}\left(t\right)\right)\left(j=0,1,2\right)$ represents the probability for the third type of customers buying product j when the prices of dealers 1 and 2 are p_{1t} and p_{2t}, respectively. $P_0\left(p_{1t},p_{2t}\right)$ represents the probability for the third type of customers to give up purchasing.

$$U_i=\alpha_i-\beta p_i+\varepsilon_i, i=1,2. \tag{1}$$

The unity with no purchase behaviour is $U_0=\varepsilon_0$, $\alpha_0=p_0=0$. $p_0\left(p_1,p_2\right)$ is recorded. When seller i sets the price of the product as p_i, the customer gain maximum utility to buy the product. That is, if customers buy the product of seller i only when they can gain maximum utility, then the probability for each potential customer to buy the product is

$$\begin{aligned} q_i\left(p\right)&=P\left\{U_i=\max_{j=0,1,2}\mathrm{U_j}\right\}= \\ &=e^{\alpha_i-\beta p_i}\Big/\left(1+\sum_{j=1}^{2}e^{\alpha_j-\beta p_j}\right)\left(i=1,2\right). \end{aligned} \tag{2}$$

The probability that a customer will not buy any product is

$$q_0\left(p\right)=1\Big/\left(1+\sum_{j=1}^{2}e^{\alpha_j-\beta p_j}\right), \tag{3}$$

where $p_j\left(p_{1t},p_{2t}\right)=q_j\left(p_{1t},p_{2t}\right),\left(j=0,1,2\right)$.

The dynamic pricing game model for alternative products is described as follows.

Single cycle model: At this point, N is equal to 1 and the product is in the final sales cycle. The payoff function is

$$\pi_i\left(p\right)=p_i d_i\left(p\right). \tag{4}$$

$$p_i\left(\lambda_1+\lambda_3\frac{e^{\alpha_i-\beta p_i}}{1+e^{\alpha_i-\beta p_i}+e^{\alpha_j-\beta p_j}}\right),i,j= \quad (5)$$
$$=1,2 \text{ and } i\neq j.$$

The objective is to find p_1 and p_2 that simultaneously satisfy $\partial\pi_i(p)/\partial p_i=0$ and $\partial\pi_i(p)/\partial p_j=0(i,j=1,2,i\neq j)$.

Multi-cycle model

(x_1,x_2) represents the stock level of sellers 1 and 2. When purchase behaviour is absent, $x_i(t)=x_i(t-1)$ (seeEqn. 6-7).

The boundary conditions are $V_{i,0}(x)=0$ and $V_{1t}(0,x_2)=V_{2t}(x_1,0)=0$. optimal price p_{it}^* is selected to maximize the expected return.

Nash equilibrium price

Nash equilibrium price assumptions: a Nash equilibrium strategy occurs in each cycle of the game process of the multiple-cycle pricing mechanism of sellers when the payoff function is determined from the price of a seller and that of the competition. A Nash equilibrium price assumption has been proven to exist in the dynamic pricing of LED components based on strategic customer behaviour within a competitive environment.

Equilibrium price is an optimized reflection formed by the response of each customer within a certain period. The realization of this type of equilibrium price does not indicate that the prices of the two parties are fixed because an equilibrium state is produced through the competition between two parties and the influence of the competition. The equilibrium price does not indicate the optimal state that can be achieved by the two sides. However, only the best response can produce an equilibrium environment. Therefore, a slight competition difference instead of an excessively large response gap can realize this equilibrium environment. One or more equilibrium environments will exist during the competition of two parties, but only one will exist during prisoner's dilemma (A special game between two prisoners, which explains why it is difficult to maintain cooperation even when cooperation is beneficial to both parties.).

4. RESULT ANALYSIS AND DISCUSSION

We suppose that sellers 1 and 2 are selling LED components. The customers arrive with probability $\lambda_t=\lambda=0.6$. loyal to sellers 1 and 2 arrive with the respective probabilities λ_{1t} and λ_{2t}. general customers arrive with probability λ_{3t}. Provided $\alpha_1=8$, $\alpha_2=5$, $\beta=1$, t = 10, $\lambda_{1t}=\lambda_1=0.1$, and $\lambda_{2t}=\lambda_2=0.2$, when $x_1=5$ is given, the corresponding equilibrium prices of different values of x_2 are p_1^*: $x_2=1$, $p_1^*=23.40$; $x_2=2$, $p_1^*=23.60$; $x_2=3$, $p_1^*=25.25$; $x_2=4$, $p_1^*=26.70$; $x_2=5$, $p_1^*=24.50$; $x_2=6$, $p_1^*=23.80$; $x_2=7$, $p_1^*=23.80$; $x_2=8$, $p_1^*=24.45$; and $x_2=9$, $p_1^*=24.45$.

The preceding data shows that when x_2 constantly increases, the value of p_1^* also continues to increase. Thus, $x_1>x_2$, which indicates that seller 2 is a greenhand newcomer when he/she enters the component market. However, when X2 becomes greater than X1, the value of p_1^* begins to decrease. Subsequently, we examine the influence of the probability λ_{1t} of customers who are highly loyal to seller 1 on equilibrium price and the expected return of the two retailers by assuming $\lambda_t=\lambda=0.6$, $\lambda_{3t}=\lambda_3=0.4$, and $x_2=5$, t = 10.

$$\begin{aligned}&V_{1t}(p_i)=\max\lambda_{1t}\left[p_{1t}+V_{1(t-1)}(x_1-1,x_2)\right]+\\&\lambda_{3t}\begin{Bmatrix}q_1(p_i)\left[p_{1t}+V_{1(t-1)}(x_1-1,x_2)\right]+\\q_2(p_t)\left[V_{1(t-1)}(x_1,x_2-1)+\right]+q_0(p_i)V_{1(t-1)}\times(x_1,x_2)\end{Bmatrix}\\&+(1-\lambda_{1t}-\lambda_{3t})V_{1(t-1)}(x_1,x_2).\end{aligned} \quad (6)$$

$$\begin{aligned}&V_{2t}(p_i)=\max\lambda_{2t}\left[p_{2t}+V_{2(t-1)}(x_1-1,x_2)\right]+\\&\lambda_{3t}\begin{Bmatrix}q_1(p_i)V_{2(t-1)}(x_1-1,x_2)+\\q_2(p_t)\left[p_{2t}+V_{2(t-1)}(x_1,x_2-1)+\right]+q_0(p_i)V_{2(t-1)}\times(x_1,x_2)\end{Bmatrix}\\&+(1-\lambda_{1t}-\lambda_{3t})V_{2(t-1)}(x_1,x_2).\end{aligned} \quad (7)$$

Table 1. The equilibrium prices and expected revenues of sellers with different x_2

λ_1	λ_2	p_1^*	p_2^*	$V_{1,10}(3,5)$	$V_{2,10}(3,5)$
0.00	0.16	17.3000	27.5000	16.3216	56.2315
0.04	0.12	12.2000	29.000	19.2654	40.2536
0.08	0.08	413.200	21.4300	31.5623	27.2457
0.12	0.04	33.1000	30.1000	21.2365	13.4569
0.16	0.00	27.1000	20.3000	64.3214	10.6752

Table 2. The equilibrium prices of both sellers with different remaining time

x	t	p_1^*	p_2^*	t	p_1^*	p_2^*
(3,5)	1	27.21	24.56	6	27.56	26.47
	2	21.24	23.45	7	23.15	21.57
	3	24.56	27.54	8	29.54	23.62
	4	23.45	24.57	9	23.48	27.89
	5	24.5	19.34	10	27.31	27.54
(5,9)	1	25.68	24.57	6	24.56	24.57
	2	21.54	28.21	7	23.45	19.34
	3	28.26	19.48	8	24.5	24.10
	4	21.57	16.54	9	25.68	25.32
	5	23.54	23.47	10	24.56	26.24

Table 1 shows that p_1^* and $V_{1,10}(3,5)$ increase with λ_{1t}, whereas p_2^* and $V_{2,10}(3,5)$ decrease with the increase in λ_{1t}. When $\lambda_1 = \lambda_2 = 0.1$, p_1^* and p_2^* are close to each other, and the expected returns are approximately equal. Evidently, achieving the probability equilibrium price and the expected revenue are extremely significant to loyal customers. We further investigate the relationship between the equilibrium price and the remaining time t of the two sellers (Table 2). Given $x = (3,5)$ and $x = (5,9)$ for sellers 1 and 2, respectively; $\lambda_t = \lambda = 0.6$, $\lambda_{1t} = \lambda_1 = 0.1$, and $\lambda_{2t} = \lambda_2 = 0.2$.

Table 2 shows that the equilibrium price of the two sellers fluctuates over time. However, the equilibrium price is found to be generally higher when $x = (3,5)$ than when $x = (5,9)$ after comparing the initial inventory.

5. CONCLUSION

The pricing mechanism of optical LED devices is extremely important to the profits of enterprises, which apply adjustments according to market supply relationship to obtain optimal income. In this study, we establish a dynamic pricing model for LED components based on different customer purchasing behaviours in a competitive environment. The following conclusions are drawn through research on the multi-cycle pricing of optical LED devices. Customers with high loyalty have high purchasing probability, and the corresponding price will be higher, along which, the expected revenue of the seller will increase. The equilibrium price of the LED components of retailers is positively correlated to the inventory level of their rivals to a certain extent, and the relationship be-

tween equilibrium price and remaining time exhibits significant fluctuations. The dynamic pricing strategy of LED components based on customer behaviour within a competitive environment can guide sellers in setting a reasonable price to ensure optimal income. In real life, the theoretical dynamic pricing of optoelectronic devices may encounter problems because of information asymmetry, which will be the focus of future research.

ACKNOWLEDGEMENT:

This work is supported in part by the National Natural Science Foundation of China under grants 61272466, 61303233 and the Natural Science Foundation of Hebei Province under grant F2014203062.

REFERENCES:

1. Helfat C E, Winter S G. Untangling dynamic and operational capabilities: Strategy for the (N) everchanging world. Strategic Management Journal, 2011. V32, #11, pp. 1243–1250.

2. Livengood R S, Reger R K. That's our turf! Identity domains and competitive dynamics. Academy of Management Review, 2010. V35, #1, pp. 48–66.

3. Ren C R, Hu Y, Hu Y, et al. Managing product variety and collocation in a competitive environment: An empirical investigation of consumer electronics retailing. Management Science, 2011. V57, #6, pp. 1009–1024.

4. ElMaraghy W, ElMaraghy H, Tomiyama T, et al. Complexity in engineering design and manufacturing. CIRP Annals-Manufacturing Technology, 2012. V61, #2, pp. 793–814.

Dejie SUN,
Doctor of Computer Science, Senior Project Engineer. Graduated from the Yanshan University. Fellow of the ACM

Jie ZHANG,
Master of Communication Engineering, Experimentalist. Graduated from the Harbin Engineering University

Wenyuan LIU,
Doctor of Computer Science, Professor. Graduated from the Harbin Institute of Technology. Fellow of the IEEE and ACM

Light & Engineering
Vol. 24, No. 3, pp. 141-144, 2016

Svetotekhnika
No. 5, 2016

ANALYSIS OF THE MICRO-BLOG MARKETING METHOD BY THE INDUSTRIAL AND COMMERCIAL BANKS OF CHINA FOR LARGE-SCALE LED ENTERPRISES

Shizhang PANG*, Xiaofeng JU, and Hualong YANG

School of Management, Harbin Institute of Technology, China
**E-mail: pangshizhang539@126.com*

ABSTRACT

With the emergence of network platforms in recent years, the competition between large-scale LED enterprises has become increasingly fierce. Taking four commercial banks in China as examples, this paper analyzes the marketing situation and micro-blog contents of large-scale LED enterprises. Results indicated that the micro-blog marketing method of commercial banks has a simple structure, a rigid pattern, less micro-blog interaction, but cater more to zombie fans, deficient in communication with branches, and absent in a complete marketing system. Therefore, countermeasures are proposed in this paper with respect to micro-blog marketing for commercial banks.

Keywords: Commercial bank, micro-blog marketing, large-scale LED enterprises

1. INTRODUCTION

After nearly 20 years of vigorous development, large-scale LED enterprises in China have made great progress in the LED business. However, in recent years, the number of domestic and foreign producers has increased and a brutal price war was immediately launched, resulting in fierce market competition. Hence, promoting large-scale LED enterprises with the help of online platform became necessary to enhance sales. Meanwhile, the micro-blog is a platform for information sharing and communication with many impressive advantages [1]. Today, many companies have established their own micro-blog certified public accounts to improve marketing effectiveness through interaction with users or fans via micro-blog [2]. Enterprises achieve the purpose of promoting themselves through sharing the image and dynamics of the company with fans on the micro-blog platform [3]. In recent years, micro-blog marketing has become a new marketing tool for commercial banks [4]. This study uses commercial banks that have opened official micro-blogs on Sina, for example, to explore the micro-blog marketing model of China's commercial banks and the promotion of large-scale LED enterprises. The study puts forward corresponding suggestions as well.

2. MATERIALS AND METHODS

Marketing status

We surveyed the application status of the micro-blog of Bank of Beijing, Bank of Chongqing, Chengdu Bank, and China Minsheng Bank. The following are their application situation on the Sina micro-blog platform. Bank of Beijing has 14832 micro-blogs with 6423000 fans and 838 concerned; Bank of Chongqing has 838 micro-blogs with 3866000 fans and 87 concerned; Bank of Chengdu has 7649 micro-blogs with 2027000 fans and 57 concerned; and China Minsheng Bank has 6323 micro-blogs with 2748000 fans and 74 concerned.

To study the effectiveness of the micro-blog marketing of the four commercial banks based on the promotion of large LED enterprises this

Table 1. Micro-blog's basic situation of banks

Bank name	Total monthly micro-blog	Total forwarding times	Total review times	Point of praise
Bank of Beijing.	114	3249	1953	2948
Bank of Chong Qing	163	13723	2486	1702
Bank of Chengdu	123	1832	643	183
Minsheng Bank	127	9274	7024	684

paper presents the statistics on micro-blogs on the promotion of large LED enterprises released by the four banks during March 1, 2016 and April 1, 2016. The results are as shown in Table 1.

Table 1 show that Minsheng Bank has the most micro-blogs related to large LED companies, and the number of the other three banks is almost similar. As for the number of fans, the Bank of Beijing has the most fans, but its micro-blogs are forwarded less in number, which indicates a large number of fans are zombie fans [5].

Analysis of the micro-blog contents of the bank

To analyze the micro-blog content on the promotion of large LED enterprises, we categorized the content into LED life information, LED bank advisory, LED public information, and LED newsletters. LED life information is related to entries about LED usage and application. LED bank advisory includes the series of LED promotions launched by banks with the cooperation large LED enterprises, such as preferential credit and the service publication of LED. LED public information presents public welfare activities and events jointly launched by large LED enterprises and commercial banks, such as the free LED network upgrade in a community. LED newsletters mainly involve investment information and national policy changes in LED strategy.

Table 2 shows that the most popular type of micro-blog among the released data of the Bank of Beijing is LED life information followed by LED bank information. Meanwhile, micro-blogs on LED newsletters and LED public information, especially the latter, are few in number. Therefore, the Bank of Beijing needs to pay more attention to such information on its micro-blog.

The micro-blogs on LED bank information by Bank of Chongqing are more popular with fans. Therefore, the Bank of Chongqing could increase publicity in these areas or integrate other business into this type of information to win the attention of fans. This step would achieve successful promotion of LED to followers.

All types of micro-blogs of Chengdu Bank in March in 2016 enjoyed interaction with the fans, among which the LED bank advisory boasts the most significant response from the fans. Hence, fans pay most attention to LED bank information, and thus, Chengdu Bank should enhance the promotion in this aspect.

The LED bank information of Minsheng Bank has the best interactive effect, but has fewer types of information including LED life information, newsletters, and public information. Therefore, Minsheng Bank should enhance the marketing of LED bank information on the micro-blog and serve for the profits of large LED enterprises.

Analysis of micro-blog marketing by commercial banks

Through analyzing the micro-blog marketing situation of the four commercial banks aiming at the promotion of large-scale LED enterprises, we found the following problems.

The micro-blog is simple in structure and rigid in mode. The micro-blog contents of the four commercial banks are the same and mainly involve the promotion of LED for credit card users, promotion and delivery of LED network, gifts for business, and a series of activities held to pay back the community. These activities are not integrated with the characteristics of the large LED enterprises, leading to low influence of the micro-blog marketing.

The micro-blogs of the banks lack interaction with more zombie fans. The acceptance of micro-blog fans determines its marketing effectiveness. Therefore, for the micro-blog of commercial banks aiming to promote large-scale LED enterprises, the purpose is to interact with the public through micro-blogs, thereby promoting the

Table 2. Micro-blog content analysis of commercial banks

	Bank of Beijing.			Bank of Chong Qing		
	Total number of praise	Total review times	Total forwarding times	Total number of praise	Total review times	Total forwarding times
Optical bank information	2424	2099	998	937	724	493
Fiber optic life information	6824	4720	3824	424	307	204
Optical fiber information	1825	1640	608	320	153	100
Fiber optic information	592	352	149	425	228	175
	Bank of Chengdu			Minsheng Bank		
	Total number of praise	Total review times	Total forwarding times	Total number of praise	Total review times	Total forwarding times
Optical bank information	1038	702	592	1572	836	472
Fiber optic life information	777	592	309	1148	592	320
Optical fiber information	304	210	149	620	432	274
Fiber optic information	264	164	85	492	391	263

large-scale LED enterprises. Most followers begin to follow the micro-blog during LED promotions. However, the praise, forwarding, and comments are small in number because the followers have no desire to learn about large LED enterprises. If the bank fails to respond to the comments on the official micro-blog in a timely manner, developing loyalty among users to the enterprises is difficult.

The branches of the banks lack communication on the micro-blog and a complete marketing system. Nowadays, the branches of most banks will register the official micro-blog and the credit card centre. However, their public accounts do not have good mutual interaction, which would reduce the effects of publicity of the large LED enterprise and thereby minimizing the effects of LED marketing.

3. RESULTS

Establish micro-blog marketing awareness

The micro-blog is a major change in the Internet communication platform in recent years. Usage of the micro-blog presents an opportunity and a challenge for commercial banks and large LED companies. Micro-blogs could also lead large LED enterprises to gain advantages of network marketing, and commercial banks could earn mutual benefits. Hence, commercial banks should first establish a sense of micro-blog marketing, comprehend the development trend of micro-blog marketing, and promote the products of large LED enterprises on the micro-blog platform. These steps could then promote their own development as well.

Encourage the management department of micro-blog to form a micro-blog marketing system

Commercial banks can establish a network marketing department, utilize the existing micro-blog resources by overall planning, and make up deficiencies to form a complete micro-blog marketing system. In the process of micro-blog building, the micro-blog contents should be integrated with the large LED enterprises, involving information on LED bank products, services, and ac-

tivities. The significant preferential information of large LED enterprises should be appropriately disclosed to attract people's attention. Therefore, commercial banks should establish a long-term micro-blog marketing plan through analysis and planning to form a sound marketing system.

Increase communication with the fans and achieve mutual benefit and win-win situations

Managers of banks using micro-blog should properly guide the topic of the micro-blog, issue topics that address the interest of users, and include timely updates on such interests. These strategies could enhance user enthusiasm. Using micro-blog marketing for promotion of large LED enterprises, requires the bank to reply promptly to user questions on the micro-blog. Promptness in replying could establish a good responsible image. For negative feedback, commercial banks should clarify the message on time to prevent the loss of trust of the users.

4. CONCLUSION

Enterprises adopt micro-blog marketing model for individual release or provide information through the micro-blog platform to meet people's needs. Using micro-blogs promote enterprises. This paper analyzes a micro-blog marketing model of four Chinese commercial banks based on the promotion of large LED enterprises. We conclude that LED bank data are topics that concern the fans of the four commercial banks. LED life information of the Bank of Beijing enjoyed the highest interaction with fans, and the interactions of the remaining three commercial banks enjoyed relatively less attention. LED newsletters and public information had low degrees of interaction among the four commercial banks. In view of the problems above, this paper proposes corresponding suggestions to enhance the promotion of large-scale LED enterprises. The paper conducted the study only on four kinds of micro-blog topics, and thus, future research could be conducted on a variety of topics to improve comprehensiveness.

REFERENCES:

1. Ghauri M T K, Maqsood F. Incorporating social media into integrated marketing communications-The case study of Warid. Marketing Management, 2011, V36, #8, pp. 1046–56.

2. Bai H, Yu G, Tain XY. Study on the classification of negative sentiment Weibo messages in the post-disaster situation. Journal of Digital Information Management, 2016, V14, #2, pp. 136–142.

3. Kaplan A M, Haenlein M. The early bird catches the news: Nine things you should know about micro-blogging. Business Horizons, 2011, V54, #2, pp. 105–113.

4. Wei J, Bu B, Liang L. Estimating the diffusion models of crisis information in micro blog. Journal of Informetrics, 2012, V6, #4, pp. 600–610.

5. Kim A J, Ko E. Do social media marketing activities enhance customer equity? An empirical study of luxury fashion brand. Journal of Business Research, 2012, V65, #10, pp. 1480–1486.

Shizhang PANG
is a Ph.D. candidate in the business administration at the School of Management, Harbin Institute of Technology. His current research interests include social media, e-service and technology innovation

Hualong YANG
is a Ph.D. candidate in the Management Science and Engineering at the School of Management, Harbin Institute of Technology. His current research interests include online health community, e-word of mouth, and e-service

Xiaofeng JU
is Professor of Information Systems at the Harbin Institute of Technology. His current research focuses on e-health and IT enabled innovation

Light & Engineering
Vol. 24, No. 3, pp. 145-148, 2016

Svetotekhnika
No. 5, 2016

THE INCENTIVE EFFECT OF MODES OF GOVERNMENT SUBSIDIES ON TECHNOLOGICAL INNOVATION OF LED LIGHTING ENTERPRISES IN CHINA

Xilong DENG

School of Economic & Management, Lanzhou University of Technology, Lanzhou, China
E-mail: dengxi; onglz634@yeah.net

ABSTRACT

The rapid development of China's economy has increased the demand for lighting quality. A serious conflict exists between this demand and the relatively stable energy supply. This paper reviewed the government subsidies for LED lighting businesses in several major countries. In accordance with Vroom's expectancy theory, this paper proposed corresponding suggestions toward three relationships in the government subsidies, namely, efforts and performance, performance and rewards, and rewards and satisfaction of the demand, with the aim to identify an effective method that the government can use to stimulate technological innovation in the LED lighting industry.

Keywords: government subsidies, led lighting businesses, technological innovation, effective incentive

1. INTRODUCTION

The accelerated urbanization process in China has constantly increased the demand of residents for lighting quality. The demand for lighting in public facilities and services has strengthened with economic development [1]. However, a serious conflict exists between this growing demand and the relatively stable energy supply. If the government continuously and extensively increases the energy supply in response to such demand, then environmental pollution and ecological damage will be aggravated, which will seriously affect the sustainable development of China's economy [2]. Considering such conflict combined with the overall background of global energy, which is energy conservation and environmental protection, the Chinese government began to increase financial subsidies for energy efficient LED products [3]. However, people who are familiar with economic principles are aware that tax and financial subsidies from the government will result in the loss of social welfare. Moreover, the "publicity" and "externalization" of some products may lead to market failure, which may further lead to a greater loss of social welfare and even the collapse of the market system. If negative effects are inevitable, then pursuing the lesser option is recommended; if the benefits are discretionary, then the greater option is chosen. Taxes and subsidies were chosen as the optimal approach for the government to prevent market failure. On the basis of these objectives, this paper focuses on the influences of different forms of government subsidies on the technological innovation of LED lighting industry. This paper theoretically attempts to find a desirable mode of government subsidy through financial subsidies to accelerate the technological innovation of LED lighting businesses, thereby helping the LED lighting companies to return to compete in the market as soon as possible.

2. LITERATURE REVIEW OF GOVERNMENT SUBSIDIES OF LED LIGHTING BUSINESSES

Review and analysis of overseas government subsidies of LED lighting businesses

The LED lighting industry subsidy policy is implemented in the United States and Canada,

where consumers directly enjoy the subsidy price as long as they purchase LED products that are consistent with the standard defined by the subsidy policy. This process is a direct subsidy to consumers. From the perspective of economics, although the total loss of social welfare remains the same with subsidies to enterprises or to consumers, direct subsidies to consumers can convince them that the government is willing to encourage such consumption.

The Japanese government uses incentives, such as tax breaks, to encourage enterprises and the public to buy and use LED lighting products. However, large energy consuming enterprises are forced to use energy-saving products because of punitive taxation and even administrative punishment. In Japan, many local governments provide subsidies to businesses and people who use LED lighting products and other local energy-saving products according to their circumstances. The government specifically merges the LED product subsidies in other energy-saving products. They make the products share the same subsidy program and fail to delineate the subsidies for LED products and other energy-saving products. This finding shows that the Japanese government's market intervention is relatively small. The government is only concerned with the energy saving levels of businesses and people rather than with what "energy saving" means. If the LED lighting businesses want to survive and prosper, they have to exert all effort to cater to the demand from energy-saving markets and continuously pursue technological innovation to reduce costs or to conduct industrial restructuring to meet the consumer demand.

Review and analysis of Chinese government subsidies to LED lighting businesses

In 2012, the National Development and Reform Commission Office, the Office of the Ministry of Finance, and the Office of the Ministry of Science and Technology of China jointly issued a notice on Organizing and Carrying Out the 2012 Annual Subsidies for the Promotion of Semiconductor Lighting Products. Since then, many local governments have also introduced local subsidies for the LED lighting industry. Undoubtedly, the financial subsidies have stimulated the research, development, and manufacture of LED lighting products, as well as promoted the development of the LED industry. To achieve the goal of semiconductor lighting in the 12th Five-Year Plan, the government proposed two subsidy policies in 2012. One is the 2012 Semiconductor Lighting Products Financial Subsidies Promotion Project. In this subsidy, the government initially selects several enterprises and their LED lighting products through bids. Then, financial subsidies to the selected enterprises are provided, and they are asked to sell LED lighting products to hospitals, schools, commercial office buildings, village committees, and other institutions at a price equal to the bid price minus subsidy price. Essentially, such process indirectly provides financial subsidies to the abovementioned institutions for purchasing LED lighting products. The other policy is the Energy-Saving Products Subsidy Policy, in which the State Council set a budget of RMB36.3 billion for subsidies to four types of energy-saving products.

The Chinese government's approach in subsidizing LED products indicates that the government not only wants to promote energy consumption among consumers but also to encourage LED lighting enterprises to improve technological innovation to reduce costs and compete in the market again. Therefore, in the process of subsidizing LED products, the government chooses the double subsidy mode. In other words, the government offers subsidies for both the LED lighting businesses and the consumers. This mode introduces an obvious subsidy incentive effect, and the subsidy is larger than those of other countries and government intervention in the LED product market. The direct result of such intervention is the production of a framework of supply and consumption of LED products in the shortest time. Furthermore, the cost of trial and error is reduced to shorten the time in forming the market framework.

3. ANALYZING THE ACTS OF GOVERNMENT ON THE EFFECTIVE INCENTIVE OF LED LIGHTING BUSINESS TECHNOLOGICAL INNOVATION

As reflected by the subsidies for LED products by different governments, two goals mainly exist to gain incentives. First, the government offers subsidies to the consumers to encourage the market to adopt energy-saving practices. Second, the government offers subsidies to the LED manufacturer to encourage the technological innovation of LED

lighting businesses to decrease the cost and return to the market. When the LED lighting enterprises improve the technological level and reduce the production cost, the traditional lighting products will be forced out of the market, and LED lighting will have absolute advantage. Eventually, the government will no longer need to offer subsidies to guide the market. Hence, the logic behind the government offering subsidies to the LED lighting businesses is that they are "offering subsidies today to remove subsidies tomorrow." The foundation of realizing such an objective does not encourage energy-saving consumption. Instead, its aim is to encourage businesses to constantly pursue technological innovation. The issue then becomes simple. The government can achieve its goal by effectively stimulating the LED lighting businesses' technological innovation through financial subsidies. According to Vroom's expectancy theory [4], effective encouragement requires agreeable handling of three relationships, namely, efforts and performance, performance and rewards, and rewards and satisfaction of the demand. An effective stimulation must deal with the three relationships.

Government's behaviour regarding the relationship between businesses effort and performance

A study of the relationship between LED lighting businesses' effort and performance should be the primary criterion for the government to choose the object of incentive. According to Vroom's expectancy theory, the object of the organization's motivation must be the members who attain their performance through their own efforts. This aim is the universal requirement of organizational value, because only such value is helpful in acquiring a sustainable performance among the members of the organization. The government should also comply with the principles above in offering incentives to LED lighting enterprises. The government should focus more on offering subsidies or incentives to the companies that pursue independent innovation and make commendable technological achievements. Specifically, the government can deduct the cost of technological innovation of the enterprises from the taxation, and the magnitude of deduction can be based on the total amount of sales of the LED lighting companies. The calculation method is similar to the progressive ladder for personal income tax calculation. The cost deduction of technological innovation of the enterprise reflects the government's positive attitude and recognition of the companies' efforts in technically developing the LED lighting industry. The progressive deduction approach based on the amount of sales of the LED lighting business reflects the relationship between the efforts of the enterprises and the performances. Such approach also indicates that the government is more willing to motivate enterprises that work hard and achieve good performance.

Government's behaviour regarding the relationship between businesses performance and government subsidies

In the previous sections, this paper discussed that the object of the government incentives should be the companies who make significant efforts in technological innovations. However, hard work does not necessarily or sufficiently result in good performance. Different performance levels will constantly exist among hardworking companies. The government's limited subsidies or incentives should first be allocated to the companies with the best performance in terms of technological innovations. Accordingly, the government conforms to the principle of optimal resource allocation. Nevertheless, this procedure does not mean that subsidies should be offered only to the companies with the best performance because doing so is unfair and does not maximize the efficiency. Thus, how to deal with the companies who make the same efforts but perform differently is a problem for the government, which requires scientific and cautious treatment. This paper argues that the government should follow a scientific and quantitative principle in dealing with the problem, that is, the principle of equal marginal benefit of the government subsidies. This simply means that the government should seek an equal effect between the subsidies on technological innovation toward different companies with different performance levels. In other words, the financial subsidies on the last unit of the companies' technological innovation from the government should be equal regardless of the performance of the companies. On the basis of this finding, the government should initially establish an evaluation system for the technological innovation performance of the LED lighting businesses. On the basis of this evaluation system, the government should form a progressive calculation standard of subsidies according to the principle of equal marginal benefit.

Government's behaviour regarding the relationship between government subsidies and achievement of businesses demands

According to Vroom's expectancy theory, the organization's reward to the members comes into force only when it achieves the demands of the members. During the process of rewarding the individual members of the organization, considering that their most urgent demands vary according to different educational backgrounds, income levels, and positions (although the members share the same time node), the organization should use different inventive means for each individual. Fortunately, the government faces a much less complex situation in offering incentives to LED lighting businesses to reward their technological innovations compared with the organization toward their members. This condition occurs because LED lighting businesses have a relatively concrete and clear target and objective, which is to maximize their profit. The difference lies mainly in whether it is a long-term or a short-term profit. The LED lighting industry has a natural demand for capital recovery and a desire to quickly grab market share. Furthermore, decreasing the cost is required (including the internal management cost and the external cost, such as tax and the cost of administrative approval). Accordingly, the government should consider the demands of different LED lighting businesses and adopt the suggestions from this paper to address the differentiation of demands in different means of subsidies. Such a move tends to ensure that the incentives have the best effects on the LED lighting industry. To improve understanding of the different demands of the companies, the government should allow and invite LED lighting businesses with excellent technological innovation performance to set standards for products. The government should also offer corresponding subsidies to the enterprises that participate in the promotion activities in line with the standard.

4. CONCLUSION

This paper reviewed and analyzed the means of government subsidies for LED lighting businesses in different countries. In the analysis, two main purposes of the government subsidies are identified: (1) to gradually develop energy-saving habits among consumers by guiding them in lighting consumption; and (2) to encourage additional LED lighting businesses to strengthen technological innovation and decrease the cost of the manufacturing to help LED businesses return to the market. A relationship exists between energy-saving consumption and the LED market supply. On the one hand, the energy-saving consumption stimulates the market supply of related products. On the other hand, constant technological innovation significantly decreases the manufacturing cost, which significantly lessens the market share of high energy-consuming products and further consolidates the energy-saving consuming habits in the market. To determine the best use of such limited government subsidies and identify how the best effect on the LED lighting industry can be achieved, the government should deal with three groups of relations, namely, efforts and performance, performance and rewards, and rewards and satisfaction of the demand. Under this principle, an effective incentive for the technological innovation of the LED lighting industry will be achieved with the introduction of differentiated subsidy programs.

REFERENCES:

1. Shen Junchao, Qi Libo. From "Functional Lighting and Land Scape Lighting" Towards "Green Lighting and Featured Lighting": Thoughts Over Nanjing Urban Lighting Specialized Plan. City Planning Review, 2011, V34, #1, pp.93–96.

2. Dou Linping. Discussion on LED Lighting Application in China. Zhaoming Gongcheng Xuebao, 2011, V22, #6, pp.51–58.

3. Dai Kaicheng. For the first time in China by means of fiscal subsidies to support the promotion of efficient lighting products. China finance, 2008, #9, p. 26.

4. Victor H. Vroom. Work and motivation. Industrial Organization Theory & Practice, 1964, #2, pp. 2–33.

Xilong DENG,
Doctor of Management, associate professor.
Graduated from the Southwest Jiaotong University.
A teaching staff member of School of Economics & Management, Lanzhou University of Technology

Light & Engineering
Vol. 24, No. 3, pp. 149-152, 2016

Svetotekhnika
No. 5, 2016

ANALYSIS OF THE CURRENT SITUATION AND DEVELOPMENT TRENDS OF THE LED LIGHTING INDUSTRY IN CHINA

Jian JIN[1] and Jianxiang WANG[2]

[1]College of Economics, Hebei University, Baoding,071000 China;
[2]Safety Work Department, Hebei University, Baoding, 071000 China
E-mail: wangjianxiang626@163.com

ABSTRACT

General developments in the LED lighting industry in China are described in this paper. The industry is analyzed by evaluating in detail the scale and status of industry chain, from the upstream epitaxial chip, through midstream packaging, and to downstream application of the LED lighting. Based on an analysis of the entire situation and the advantages of this industry, a development trend is predicted. Results show that as LED product prices decrease, the product sales of the LED lighting industry continue to increase and thus have good prospects in China

Keywords: LED lighting industry, epitaxial chip, packaging, application

1. INTRODUCTION

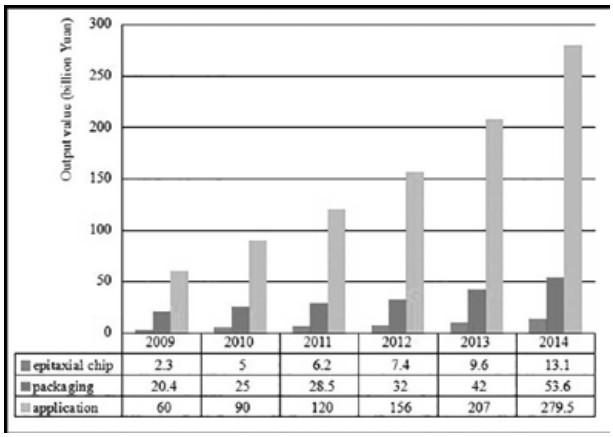
Light-emitting diode (LED) lighting, uses a solid semiconductor chip as its luminescent material, promotes composition that occurs via carrier in a semiconductor, provides excess energy, causes photonic emission, and directs red, yellow, blue, green, bluish-green, orange, purple, and white lights. As a fourth-generation lighting source, LED has many merits, such as energy efficiency, long life, large luminous efficacy, rich colours, anti-earthquake stability, safety and reliability, fast response, and intelligent control. These advantages mean that LED is widely used in indicator light, signal light, display screen, landscape lighting, and other areas. With the continuous development of the research on semiconductor luminescence materials in recent years, the continuous advancement of the LED manufacturing process and development, and the application of new materials, multicoloured LED with ultra-high brightness have made a significant breakthrough. The most important part is the introduction of ultra-high brightness white LED, which makes the application of the LED to high-efficiency light-source market possible.

Given the advantages of an LED source compared with a traditional lighting source and the extensive application of LED, many studies have been conducted on it, such as the future development of the LED industry of China [1], the development course of the LED lighting technology and the principles and features of LED luminescence, the key technology of LED lighting, and the development tendencies of LED lighting technology [2].

Based on the scale analysis of the upstream epitaxial chip, midstream packaging, and downstream application of the LED lighting industry chain, this study predicts the future development trend of the LED lighting industry.

2. CURRENT STATUS

The LED lighting industry chain can be classified into three sectors, namely, chip manufacturing, packaging, and application. After a merger and the acquisition boom of the entire industry in 2014, LED lighting industry agglomeration is occurring, which also promotes technology advancement, reduces costs, and accelerates the LED lighting in-



	2009	2010	2011	2012	2013	2014
epitaxial chip	2.3	5	6.2	7.4	9.6	13.1
packaging	20.4	25	28.5	32	42	53.6
application	60	90	120	156	207	279.5

Fig.1. Output of the three sectors of the LED lighting industry chain in 2009–2014

dustry permeation. The scale of the LED lighting industry of China is expanding rapidly, and the overall growth in 2014 was higher than that in 2013. In 2014, the overall scale of the LED lighting industry of China reached 346.2 billion Yuan, which is a 33% increase compared to 258.6 billion Yuan in 2013. The development of the three sectors of the LED lighting industry chain in 2009–2014 is shown in Fig. 1.

In 2014, the LED lighting industry kept going forward, the industrial chain structure relatively matured, large enterprises steadily developed, and the external attentiveness of the industry obviously decreased compared with the previous two years. Corporate profitability is beginning to stabilize along with light efficacy improvements, price decline for LED lighting products, rapid growth in sales, and price and cost decline in downstream products.

Current situation of the upstream epitaxial chip stage of the LED lighting industry

In 2014, the scale of upstream epitaxial chip sector was up to 13.1 billion Yuan, which increased by 33% compared with the 9.6 billion Yuan in 2013. From 2009 to 2014, influenced by the rapid growth in demand for chips, the upstream epitaxial chip sector was expanding. An increase of 4.7 times was observed, that is, from 2.3 billion Yuan in 2009 to 13.1 billion Yuan in 2014. Owing to the significant improvement in the capacity utilization of most enterprises, production of the epitaxial chip increased by 69%, which is far greater than the output growth. The production of *GaN* chip accounts for 60%, that of *InGaAIP*-dominated quaternary system chip accounts for nearly 28%, and that of other chips, such as *GaAs,* accounts for approximately 12%.

Some leading companies producing LED upstream epitaxial chips in China include Sanan Optoelectronics, Hangzhou Silan Azure, Shanghai Epilight, China Fangda Group, Shanghai Rainbow, Shandong Inspur Huaguang Optoelectronics, Dalian Lumei, Jiangxi Lianchuang Optoelectronic, Shenzhen Century Epitech Photonics, Pooium Photonics, and Yangzhou Dare Win Chip. In 2014, some chip makers, such as HC SemiTek, Nanojoin, Kaistar Lighting, and Aucksun, amplified metal organic chemical vapour deposition (MOCVD) equipment, and the MOCVD equipment ownership in China had more than 1290 sets, which indicated an increase of approximately 200 sets compared with the 1090 sets in 2013. MOCVD equipment has been centralized to large enterprises, of which 11% of enterprises installed more than 50 sets, 45% between 10 and 50 sets, and 44% less than 10 sets. Enterprises with less equipment are at a disadvantage in terms of scale.

Current situation of the midstream packaging stage of the LED lighting industry

In 2014, the output value of the midstream packaging of the LED lighting industry of China reached 53.6 billion Yuan, which increased by 27% compared with the 42 billion Yuan in 2013, accounting for 54.4% of the global output value of LED packaging. The LED packaging market is divided into two parts. The first part is the private enterprises for LED packaging in the mainland, and the market mainly focuses on mainland China. The second part is the enterprises in Taiwan and some foreign enterprises for LED packaging in the mainland, and the market is mainly for export.

Major packaging enterprises include Foshan Nation Star Optoelectronics, Xiamen Hualian Electronics, Ningbo Aimida, and Jiangxi Lianchuang Optoelectronic. In product specification, mid-power (0.2–1 W) device becomes a mainstream application on the market. More than 70% of light sources for medium- and small-power lighting fixtures, such as lamp, bulb, panel lights, ceiling lamp, and ceiling lights, comes from mid-power packaging devices. The packaging enterprises have been shifting from keeping up with high-power devices to enlarging the proportion of mid-power devices. In 2014, the production of mid-power devices accounted for more, than 55% that of high-pow-

er devices accounted for less than 15%, and the remaining was for small-power (less than 0.2 W) devices. Mid-power device became the mainstream.

Present situation of the downstream application scale of the LED lighting industry

In 2014, the scale of the downstream application of the LED lighting industry of China reached 279.5 billion Yuan, which increased by 35% compared with the 207 billion Yuan in 2013. From 2009 to 2014, the scale had been obviously increased by 3.66 times, that is, from 60 billion Yuan in 2009 to 279.5 billion Yuan in 2014. The downstream enterprises of the LED lighting industry mainly include Shanghai Sansi, QSTECH, and Leyard Optoelectronic.

The gap between the key technology of the LED lighting industry of China and that of international levels is constantly narrowing. In 2014, the industrial lighting efficiency of power white LED reached 1401 m/W, and the industrial lighting efficiency of silicon-based power LED chips with independent intellectual property rights reached 1401 m/W. Nanosphere-patterned sapphire, epitaxial high-quality AlN, and deep-UV LEDs are the first breakthrough in the world. The wavelength of deep-UV LED is 293 nm, and its output power is over 4 mW under 20 mA current. The lighting efficiency of LED devices reaches 97 lm/W and the life-time is more than 10,000 h.

LED is currently mainly used for backlight, colour screen, and indoor lighting. Among these, backlight applications occupy an important position. However, under the influence of a new round of bans on the sale of incandescent lamps across the globe, indoor lighting will replace backlight and become the fast growing area of LED in the future.

3. DEVELOPMENT TREND OF THE LED LIGHTING INDUSTRY

The development of the LED lighting industry of China has many advantages, which can be observed from three aspects: resources, technology, and market environment. In terms of resources, China is great nations that are rich in resources, with an enormous variety of non-ferrous metals, which will make the development of LED occupy obvious advantages in resources. From the perspective of technology, the LED lighting industry of China has a good research foundation because many units are involved in research, including the Institute of Semiconductor of the Chinese Academy of Sciences (CAS), the Institute of Physics of the (CAS), the Tsinghua University, the Peking University, and other famous universities and enterprises. From the market environment, China will become the main driving force of the global LED lighting market development and is gradually becoming the global LED lighting industry base, and its market is large at home.

In all LED fields of application, the LED lighting market has always been considered the most important and the most promising one. The macro environment is generally beneficial to the development of LED lighting applications, which is mainly represented as follows: (1) energy saving and emission reduction have become a hotspot of global concern and been promoted actively; (2) traditional light sources develop slowly in technology and meet bottlenecks in their development; (3) with the advancement of technology and the increasing reduction in cost, the developmental problems of the LED lighting market are decreasing slowly in the long term.

The scales of upstream epitaxial chips, midstream packaging, and downstream applications are all showing a growing trend in recent years. LED lighting is expected to maintain a high growth trend, and it will provide considerable opportunities for commercial lighting. The output value of each part of the LED lighting industry chain will keep growing in the future. The downstream LED lighting market will start rapidly. LED lighting products have a high technical content and a long service life, and its economic benefits are reflected in the energy-saving effect. Leading enterprises of upstream epitaxial chips and midstream packaging, as well as domestic suppliers of core materials, also will accelerate the localization process of key materials and improve the cost performance of products.

China generally has a number of benefits for the development of the LED lighting industry, and the LED lighting industry has good prospects. Although some differences remain between China and developed countries in terms of advanced technology and production scale, the LED industry in China will have an excellent developing trend along with the greater importance attached to the LED industry from the government and the continuous breakthrough of technology.

4. CONCLUSIONS

The characteristics of LED lighting were described. The development status of the LED lighting industry has been analyzed in general. The current situation of the LED lighting industry was described in three aspects, namely, the upstream epitaxial chip, midstream packaging, and downstream application of the industry chain. Based on the analyses of its development situation, the development trend of the LED lighting industry of China in the future is predicted. The conclusion is that the LED lighting industry has a good prospect in China. Those studies predict the development trend of the LED lighting industry by merely observing data, and do not use professional statistical method to carry out a deeper analysis. Some improvement needs to be conducted in future studies.

ACKNOWLEDGEMENT:

The study was supported by the Humanities and Social Sciences Planning Fund of the Ministry of Education of China (11YJA910005), the National Planning Office of Philosophy and Social Science of China (12BTJ012), and the Technology Foundation for Selected Overseas Scholars in Hebei Province (C201400103).

REFERENCES:

1. Xueyu, W. Analysis on the development of LED lighting industry in China. Advanced Materials Industry, 2012. V218, #1, pp.27–31.

2. Wenjun, W., Dan, Z. LED lighting technology development status and future trends. Chinese Lighting Forum – LED Lighting Product Design, Application and Innovation Forum, 2015. V3, #4, pp.37–45.

Jian JIN,
Ph.D. in Economics, Professor of College of Economics, Hebei University. Graduated from the Dongbei University of Finance & Economics, China

Jianxiang WANG,
Bachelor of Economics, Intermediate Economist of Safety Work Department, Hebei University. Graduated from the Hebei University, China

Light & Engineering
Vol. 24, No. 3, pp. 153-156, 2016

Svetotekhnika
No. 5, 2016

COMPETITIVE STRATEGY CHOICE OF LED OPTICAL FIBRE COMMUNICATION ENTERPRISES IN CHINA: PURE OR HYBRID STRATEGY

Bingyun ZHENG* and Sui LI

College of Management Science and Engineering Anhui University of Finance and Economics Anhui, Bengbu, 233030, China
**E-mail: engzh519@163.com*

ABSTRACT

LED optical fibre communication enterprises in China have ushered in a new round of opportunities for development. At the same time, the production cost rapidly increases, mainly affecting the business of optical fibre communication enterprises. Therefore, these enterprises should develop appropriate competitive strategies to gain advantage. This study extends previous research on the relationship of competitive strategy and performance. Results show a significant difference in the performance of different strategies of LED optical fibre communication enterprises and demonstrate that a hybrid strategy is the best one to implement.

Keywords: LED optical fibre communication enterprise, competitive strategy, variance analysis

1. INTRODUCTION

With the intense promotion of "Broadband China" and "Internet Plus" as both a national strategy and a top design idea in the industry, LED optical fibre communication enterprises in China have ushered in a new round of opportunities for development. China's market has become an important force in promoting the development of the global LED optical communication industry. According to the Competitiveness Report for Optical Communication Enterprises 2015[1], LED optical fibre communication enterprises have maintained a good state of development. From 2007 to 2015, the overall competitiveness of the LED optical fibre communication enterprises in China exhibited an upward trend. The development was rapid and led to gratifying achievements, especially in the past two years. At the same time, the report highlights that production costs have increased equally fast, which has become the main factor affecting the business of LED optical fibre communication enterprises. Shortage of high-level talent has also become one of the bottlenecks for the development of the industry.

In this situation, LED optical fibre communication enterprises should develop an appropriate competitive strategy to gain advantage in the international market.

Porter's generic business level strategies, overall cost leadership, differentiation, and focus have become a dominant paradigm in the business policy literature [2]. According to Porter, each of these models represents "a fundamentally different approach to creating and sustaining a competitive advantage. Usually, a firm must make a choice between them or it will become stuck in the middle." Moreover, Porter stressed that "achieving cost leadership and differentiation are usually inconsistent because differentiation is usually costly."

Several researchers have found empirical support for Porter's assertion that overall cost leadership and differentiation cannot be simultaneously pursued successfully. However, others have argued that cost leadership and differentiation strategies are not mutually exclusive and that they can be

pursued simultaneously [3]. Nevertheless, few empirical studies have specifically compared the effect of simultaneous pursuit of generic strategies (i.e., hybrid strategy) and pure generic competitive strategy on firm performance.

In the LED optical fibre communication industry, San'an Optoelectronics Co. Ltd. adopted a hybrid strategy and gained advantage. However, a number of LED optical fibre communication enterprises applied a pure strategy and gained relative advantage. This study intends to make a careful distinction and examine the performance of a hybrid competitive strategy over a single generic strategy using data from a transition economy in China. The Chinese economy is in transition and industry characteristics differ in many aspects, which affect the competitive strategy and performance of LED optical fibre communication enterprises. This study contributes to the debate on the competitive strategy–performance relationship based on data from the LED optical fibre communication industry in China.

2. HYPOTHESES

According to Porter (1985), each of the three generic competitive strategies is a completely different approach to create a sustainable competitive advantage. A firm must select between cost leadership and differentiation strategies or it will become stuck in the middle.

Empirical evidence on the subject is inconclusive. For instance, Hambrick did not find any firms that followed hybrid strategies within the mature industries he examined [4]. The findings of Dess and Davis were generally consistent with Porter's contention that commitment to at least one generic strategy results in higher performance compared with being stuck in the middle [5]. Others, however, found that firms combining low cost with differentiation were among the highest, if not the highest performers [6–7]. Mas clearly indicated that the cost leadership, differentiation, and hybrid strategies have been implemented successfully worldwide. The successful implementation of cost leadership and differentiation strategies has been proven on occasion. However, the hybrid strategy, which has only been recently implemented successfully, is a new trend for a company to compete in the industry [8]. Mika examined the achievability and performance of a hybrid strategy compared with a single strategy as firms internationalize in the high-technology market; hybrid strategies mediate these contextual factors and thus contribute to superior financial performance [9].

A hybrid competitive strategy simultaneously involving high levels of emphasis on both cost leadership and differentiation strategies should be distinguished from a "stuck in the middle" strategy in which an LED optical fibre communication enterprise fails to successfully pursue both cost leadership and differentiation strategies. Thus, we posit that LED optical fibre communication enterprises emphasizing the hybrid strategy will experience an increase in performance. However, those that pursue the hybrid strategy can achieve a significantly higher level of performance than those that pursue a single strategy. Moreover, LED optical fibre communication enterprises that pursue either the single strategy or the hybrid strategy will experience a significant performance benefit over those that are "stuck in the middle."

Therefore, the study presents the following hypotheses:

Hypothesis 1: LED optical fibre communication enterprise performance differs according to strategy types.

Hypothesis 2: LED optical fibre communication enterprises that implement a hybrid strategy outperform enterprises that adopt a pure cost leadership strategy.

Hypothesis 3: LED optical fibre communication enterprises that implement a hybrid strategy outperform enterprises that adopt a pure differentiation strategy.

Hypothesis 4: LED optical fibre communication enterprises that implement a hybrid strategy outperform enterprises that are stuck in the middle.

3. METHODS

Sample and data

The data for this study were collected from 260 respondents who are high-level managers in LED optical fibre communication enterprises and their branches. After several visits and communication with the companies, we received a total of 206 responses. However, only 156 of the survey instruments presented complete data on all questions, yielding a usable response rate of 75.73%.

Firm performance

Return on assets (ROA) has been used in many studies to examine the performance effects of corporate strategies. This measure is appropriate. ROA reflects the primary objective of most LED optical fibre communication enterprises in a rapidly growing industry. Furthermore, financial indicators are the most useful measures of organizational performance at the macro organizational level. Respondents were asked to indicate the performance of their company relative to that of competitors over the past three years in terms of the variables. They used scales ranging from 1 ("much worse'") to 7 ("much better"). Furthermore, the three-year period minimizes the influence of short-term variations on the reported LED optical fibre communication enterprise performance.

Identifying a competitive strategy

The 19 strategy variables used in this study to identify strategic groups reflect the multifaceted nature of the strategy construct. They include variables related to product development, manufacturing, and marketing. We chose variables that appeared frequently in the literature and seemed theoretically appropriate. Each item uses a scale ranging from 1 ("much less") to 7 ("much more"). To ensure that the items measuring competitive strategy represented the underlying constructs, we conducted factor analysis.

We reduced the 19 variables to two factors that reflect Porter's generic strategies: cost leadership and differentiation. We named them as cost leadership and differentiation factor. The composite scores of the LED optical fibre communication enterprise on the two factors can then be calculated.

If the composite scores of an LED optical fibre communication enterprise only on factor 1 are greater than the sample mean of the respective competitive strategies, then the enterprise implements a differentiation strategy. If the composite scores of the LED optical fibre communication enterprise only on factor 2 are greater than the sample mean value, then the enterprise implements cost leadership strategy. If the composite scores of the LED optical fibre communication enterprise on both factors 1 and 2 are greater than the sample mean value, then the enterprise implements a hybrid strategy. If the composite scores of the LED optical fibre communication enterprise on both factors 1 and 2 are equal to or less than the sample mean value, then the enterprise implements the stuck-in-the-middle strategy.

Method of analysis

Analysis of variance is conducted to test for performance differences resulting from the strategic orientations of LED optical fibre communication enterprises.

4. RESULTS

We reduced the 19 variables to two factors that accounted for 81.2 percent of the total variance. The two factors reflect Porter's generic strategies: cost leadership and differentiation. Factor 1 consists of 13 variables with factor loadings that are higher than 0.40. This factor is called cost leadership factor because it mainly reflects the characteristics of cost leadership strategy that Porter proposed. Factor 2 consists of 9 variables with factor loadings above 0.40. A special feature of this factor is that it emphasizes high quality, new product development, and innovation; thus, it is called differentiation factor. We subsequently use the factor scores of these two factors rather than the 19 strategy variables to develop the taxonomy of strategic groups.

Table 1 shows the results of analysis of variance. These results indicate significant differences in the performance of optical fibre communication enterprises that pursue different strategic types. Therefore, Hypothesis 1 is supported.

From the second line of Table 1, the F-test for significant differences among the groups on the performance measure shows that the mean value for the hybrid strategy group is significantly greater than that for the cost leadership strategy group ($p=0.062$). Although the significant level is higher than 0.05, it remains lower than 0.10. Thus, Hypothesis 2 is supported. Similarly, the third and fourth lines imply that LED optical fibre communication enterprises that adopt the hybrid strategy significantly outperform those that adopt the differentiation and stuck-in-the-middle strategies. Thus, Hypotheses 3 and 4 are supported. LED optical fibre communication enterprises pursuing the successful hybrid strategy enjoyed superior performance in terms of ROA, whereas enterprises stuck in the middle ranked at the bottom. These results suggest that a coherent strategy is beneficial for LED optical fibre communication enterprises to achieve superior performance.

Table 1. Analysis of variance results of performance

H	Degree of freedom	Sum of squares	Mean squares	Degree of freedom	Sum of squares	Mean squares	F-statistic	P-value
H1	3	16.9	5.6	152	226.9	1.5	3.8	0.012
H2	1	5.3	5.3	92	137.1	1.5	3.7	0.062
H3	1	4.7	4.7	78	66.2	0.9	5.5	0.021
H4	1	5.9	5.9	56	27.3	0.5	12.0	0.001

(Note: column 2, 3, and 4 are from treatments; column 5, 6, and 7 are from error.)

5. CONCLUSIONS

This study empirically investigates the relationship of competitive strategy and performance with the data from LED optical fibre communication enterprises in China. The results demonstrate that a hybrid strategy is the best one for LED optical fibre communication enterprises to implement, as San'an Optoelectronics Co. Ltd. has shown. When these firms develop a competitive strategy, they must consider technology innovation to obtain differentiation advantage. Simultaneously, they should explore other means to achieve low cost advantage.

ACKNOWLEDGMENT

The authors are grateful for the support provided by the National Social Science Foundation (Grant No. 15BGL018), Anhui Provincial Natural Science Foundation (Grant No. 1308085MG112), and Anhui Province College Natural Science Foundation (Grant No. KJ2013A004), and for Outstanding Young Talents Project (Grant No. gxyqZD2016095).

REFERENCES:

1. Network telecom information institute. Competitiveness report for optical communication enterprises 2015. http://www.networktelecom.cn/dianxin/2015/baogao/cn/index.html.

2. Porter ME. Competitive advantage: creating and sustaining superior performance. New York: Free Press, 1985.

3. Hill C. Differentiation versus low cost or differentiation and low cost: a contingency framework. Academy of Management Review,1988. V13, #3, pp. 401–412.

4. Hambrick D. High profit strategies in mature capital goods industries: a contingency approach. Academy of Management Journal, 1983. V26, #4, pp. 687–707.

5. Dess G. and Davis P. Porter's generic strategies as determinants of strategic group membership and organizational performance. Academy of Management Journal, 1984, V27, #3, pp. 467–488.

6. Spanos Yiannis E, Zaralis George and Lioukas Spyros, Strategy and industry effects on profitability: evidence from Greece, Strategic Management Journal, 2004.V25, #2, pp. 139–165.

7. Hall WK, Survival strategies in a hostile environment. Harvard Business Review, 1980.V58, #5, pp. 75–85.

8. Mas Bambang Baroto, et al. Hybrid Strategy: A New Strategy for Competitive Advantage, International Journal of Business and Management, 2012.V7, #20, pp.120–133.

9. Mika Gabrielsson, et al. Realizing a hybrid competitive strategy and achieving superior financial performance while internationalizing in the high-technology market, Industrial Marketing Management, 2016.V54, #4, pp. 141–153.

Bingyun ZHENG,
Doctor of Management,
Assistant Professor.
Graduated from Nanjing University of Aeronautics and Astronautics

Sui LI,
Doctor of Management,
Assistant Professor.
Graduated from Nanjing University of Aeronautics and Astronautics

Light & Engineering
Vol. 24, No. 3, pp. 157-160, 2016

Svetotekhnika
No. 5, 2016

CURRENT MARKET DEVELOPMENT STATUS AND MARKETING STRATEGY OF CHINESE LED OPTICAL FIBRE ILLUMINATION ENTERPRISES

Mina GE[1,2*] and Jun FAN[1]

[1]*College of Business Administration Institute, University of Zhejiang Gongshang Hangzhou, 310018 China;*
[2]*Research Centre of Zhejiang Tourism Development, Tourism College of Zhejiang Hangzhou, 311231 China;*
**E-mail:176443578@qq.com*

ABSTRACT

China is the world's production base of equipment for LED optical fibre illumination (LED illumination hereinafter). The country is also the technology development centre of the industry and has the largest market and consumption of LED illumination lamps. In recent years, Chinese LED illumination enterprises have obtained substantial development in scale and performance. Expanding their markets has been suggested by marketing strategists to enhance the shares of these enterprises in the competitive international environment. In this study, the following aspects of the Chinese LED illumination enterprises were analyzed: their current development status in domestic and overseas markets, the realistic and potential local and international demand for the enterprises, and the related marketing theories. Accordingly, new marketing strategies were proposed for the LED illumination enterprises in the country. Analysis results show that the investigated enterprises have a large market development scale, the optical network of the industry is gradually completed, and the number of LED illumination enterprises in the country increases rapidly. Moreover, Chinese LED illumination enterprises face large market demand, which is increased further by technological advancement and reduced prices. These enterprises can effectively improve their core competitiveness by marketing means of intensifying market planning, cultivating an export market, and enhancing R&D innovation. The study provides full understanding of the current development status of Chinese LED illumination enterprises, and proposes these enterprises to investigate the demand of optical fibre market and effectively elevate their global competitive strength and status.

Keywords: LED optical fibre illumination, optical fibre enterprise, marketing strategy

1. INTRODUCTION

The application of LED optical fibre illumination (LED illumination hereinafter) in communication systems has been fundamentally studied in China since the 1970s. Technological progress and increasing market demand have increased the reliance of modern society on communication systems, and emphasized the importance of the reliability of networks. Developments in communication and changes in operating environments have also imposed high requirements for optical fibre communications. Current pump priming policies in China constantly consider the light industry and optics illumination technology as key development industries.

2. MARKETING CAPACITY ANALYSIS OF THE CHINESE LED ILLUMINATION MARKET

(1) Market Development Capacity

Although an annual 20% increasing momentum is maintained by the Chinese LED illumination industry, the momentum is highly distributed. Given that a conventional routine has been pursued, the LED illumination industry has low entry barriers with low technological content and thousands of enterprises flock together and join in tangled warfare in a low-end product market. Meanwhile, few enterprises can truly integrate LED illumination and drive brand promotion. The growth of LED illumination enterprises is marked by their proactivity in studying and creating new market demands for the industry and meeting consumption psychology. LED illumination enterprises should initiate in analyzing their advantages and opportunities to form a commensally and self-enhanced organization, and take a leading role in new market competition. Society has entirely entered the information technology age, thereby increasing the market competition faced by LED illumination enterprises while minimizing commercial opportunities. Hence, these enterprises should not only meet the business requirements of existing customers, but also initiate in investigating the market demand of potential customers and creating industry demands.

(2) Technological Innovation and Product R&D Capabilities

Technological innovation is important to gain a competitive advantage. This concept facilitates sustainable enterprise growth and is an important means for products to achieve sound marketing practices. The histories of economic development in developed countries and regions, such as America, Europe, Japan, and Korea, have demonstrated that rapid economic development and improved survival and development capability of enterprises are impossible without technological innovation. Currently, nearly all Fortune 500 enterprises have been grown from small-sized enterprises by relying on technological innovation. Technological innovation of enterprises has shifted from passive innovation toward initiative innovation. Chinese LED illumination enterprises of small and medium sizes are still centred on imitating and plagiarizing the products of others. This practice has caused adverse effects on marketing campaigns and the development of the entire industry. Faced with competition from international LED illumination giants such as OSRAM, GE, and Philips, continued adoption of such practices to catch up with rivals, placing less emphasis on technological innovation will sooner or later result in the dismissal of Chinese LED illumination enterprises from the market. The innovation capability of successful foreign enterprises is significantly higher than that of the investigated enterprises. Therefore, technological innovation capability can guarantee the development of enterprises.

(3) Financial Management Capability

Growth histories of enterprises in various countries demonstrate that steady and prudent financial system can drive enterprises to conduct operation management continuously and evade various risks effectively, thereby facilitating unrestrained development. Chinese LED illumination enterprises at present are generally small in scale with incomplete financial system, and many of them only depend on interim financial personnel in summarizing their financial analysis. Financial management in the industry faces various problems, such as frequent occurrence of financial loopholes and capital loss. Thus, LED illumination enterprises should build sound financial system to obtain definite requirements and methods for reference, which can provide system guarantee for enhancing financial management. The organizational structure of an enterprise is concretely manifested when setting various functional departments, information transfer, department leader, and cooperating mode. Highly efficient organizational structure of LED illumination enterprises can result in steady financial system and scientific and democratic decision making. Accordingly, the internal innovation and technological reform of the enterprise can be facilitated and maintained and pace of growth can be accelerated. Therefore, LED illumination enterprises should also establish a highly efficient organizational structure [1].

3. MARKETING STRATEGY OF CHINESE LED ILLUMINATION ENTERPRISES

(1) Enhance Planning in the LED illumination Industry

The full advantages of market mechanism should be considered to enhance the guiding de-

velopment of LED illumination industry, and the low-level and disorderly competition among them at the national level should be avoided. Several LED illumination enterprises resolve into blind mass action when shortage of optical fibre and cable occurs. These enterprises are small-sized ones and have insufficient capital and difficulty in producing high-end products. China imports a large number of performs every year in such a case, thereby increasing the production cost and facilitating external control of LED illumination enterprises. The associated branches of the government should combine the basis to develop Chinese LED illumination enterprises. They should propose the development of the national LED illumination industry, accurately master technology orientation and product strategies of the enterprises in this industry, and integrate various resources on the basis of the development direction of LED illumination technology and orientation of national industrial policies. The government should organize specialized forces to formulate and issue development programs for the LED illumination industry, and to guide healthy and orderly development of the enterprises in this industry in the national level.

(2) Emphasize Cultivation of an Export Market of LED illumination Products

Apart from considering the domestic demand, Chinese LED illumination enterprises should also emphasize the cultivation of an export market of their products. At present, the market demand potential of LED illumination is large on a global scale. Specifically, countries and regions, such as India, Russia, Brazil, and Central Asia, prioritize the development of the information industry. China has only around 5% LED illumination products that can be exported currently because of high cost and backward technology. Becoming a member of the WTO has provided China with broad market prospect for the export products of the LED illumination enterprises in the country. Hence, related enterprises should be actively guided to steadily and proactively develop all kinds of LED illumination products in accordance with the features of international market and its demand. Accordingly, LED illumination products could be the important backbone of the country's national export [2].

(3) Cultivate the Core Competitiveness of LED illumination Enterprises

In the current phase, a large gap exists between national LED illumination enterprises and multinational corporations. Multinational corporations, such as Corning and Alcatraz-Lucent, have been in the LED illumination industry for more than 30 years. In their 30 years of development, they have acquired an abundant economic and technological base, rich management experience, and mature marketing channels. These corporations enjoy an excellent reputation on the international market, and their global sales volumes reach tens of billions of dollars. Some Chinese LED illumination enterprises have been on the scene for 10 years or even less. These enterprises have the following characteristics: their brand and reputations have not been fully established, their scales are still small with weak technological strength, their sales scope is usually restricted to the domestic market, and their market shares in the domestic market are relatively small with annual sales volumes generally being from tens of millions of yuan to billions of yuan. To catch up with multinational corporations in such a competitive environment, Chinese LED illumination enterprises should form their core competitiveness as soon as possible to obtain more rapid development than that of the international communication giants. They should also introduce advanced technologies to provide more and better products that those of their competitors, and establish powerful marketing network to occupy a wider range of markets, unlike their multinational counterparts.

(4) Intensity Cultivation and Introduction of Talents Specialized in LED illumination

Human resources are the most important production factor that decides the survival and success of enterprises. Talent competition is the final analysis is the common form of competition among enterprises. Talent is an important wealth for enterprises, and an excellent enterprise has an assembly of outstanding talent. Employing many talents means owning important resources for an enterprise. Given that LED illumination industry is a technology-intensive industry, technological talents are criticize, especially those specialized in R&D and test of LED illumination equipment and product development. Whether LED illumination enterprises can own first-rate professional and technical personnel is directly related to their

success in fierce market competition. The introduction of professionals in LED illumination industry should be increased, especially those who have studied abroad and have rich experience in the prime of their life from overseas markets. A favourable environment for work, study, and living for these professionals should be provided, as well as support in human resources for the LED illumination enterprises in China. Carrying out various academic exchange activities and cultivating the existing professional and technical talents by means of the concept of "go abroad and introduce in" should be pursued.

4. CONCLUSION

With the development of strategic emerging industry, Chinese LED illumination enterprises have also rapidly developed and the chain of the industry has formed. Faced with increasingly fierce international competition, the overall strength of Chinese LED illumination enterprises still needs further elevation. In this study, the current market development status of Chinese LED illumination enterprises was investigated and new marketing strategies for these enterprises were proposed. This study proposes how Chinese LED illumination enterprises can improve their global competitiveness.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the Natural Science Foundation of Zhejiang province, "The innovation atmosphere of customer participating in online service and its impact on customer creativity research" (Grant No.LY15G020004); The annual National Social Science Foundation Project, "The research on customers to participate in new service development online under the perspective of knowledge co-creation" (Grant No.14BGL197).

REFERENCES:

1. Dulhai G. The 5S strategy for continuous improvement of the manufacturing processes in auto car exhaust. Management and Marketing, 2008. V3,#4, pp.115–120.

2. Geng J., Xu J., Wei G. The development of brillouin scattering distributed optic fibre sensor. Journal of Test and Measurement Technology, 2002. V16, #2, pp.87–91.

Mina GE,
Doctor of Business administration, lecturer. Graduated from Zhejiang Gongshang university school of business administration, Hangzhou, Zhejiang, China. Specialized in service marketing and service innovation

Jun FAN,
Doctor of Business administration, professor. Graduated from Zhejiang university of China. Specialized in Knowledge management, customer participation and service innovation

Light & Engineering
Vol. 24, No. 3, pp. 161-165, 2016

Svetotekhnika
No. 5, 2016

EVALUATION OF THE OPERATIONAL EFFICIENCY OF LISTED LED LIGHTING INDUSTRY OF CHINA BASED ON DEA MODEL

Yongbo YU[1], Yunchao DU[2*] and Yuan GAO[3]

[1] School of Economics and Management, Hubei University of Technology Hubei, Wuhan, 430070 China;
[2] School of Management, Wuhan University of Technology Hubei, Wuhan, 430070 China;
[3] Global Institution, King's College London
London, WC2R2LS UK
**E-mail: hbdyc1990@126.com*

ABSTRACT

As one of the important emerging national strategic industries in China, the LED lighting industry promotes the rapid development of other industries. The paper selects 20 listed companies in the LED lighting industry in China as examples, chooses fixed assets, operating costs, intangible assets, administrative expenses and government subsidies as input indicators, with revenue and net profit as output indicators, and uses the DEA model to evaluate their operational efficiency. The result shows that operational efficiency in 60% of samples is DEA efficient. For non-DEA efficient samples, the paper suggests relevant strategies to improve operational efficiency.

Keywords: operational efficiency, LED lighting industry of China, DEA

1. INTRODUCTION

LED (Light Emitting Diode) is a semiconductor consisting of Ga, As, P, N and other chemical compounds, which is able to convert electric energy to light energy. It does not rely on heating by filaments and phosphor to glow, but it can use the energy produced during recombination process to launch a cold light source from LED through the recombination between electron and electron hole. Compared with traditional filament lamps, fluorescent lamps, HID lamps, the LED is more energy efficient, environmentally friendly, durable and safe. The innovation of LED is regarded as the third revolution in the industry after filament lamps and fluorescent lamps, which has historic meaning. As one of the important emerging national strategic industries in China, LED lighting industry has strong industrial linkage.

Although there is much strong research on input-output efficiency in many other fields, the research about the LED lighting industry is quite limited. Chia et al. (2014) have researched the evaluation system of the current LED lighting industry in Taiwan. They estimate the performance of 10 listed enterprises and production efficiency in the industry between 2003 and 2009 by DEA and malmquist index [1–2]. Meanwhile. Wu et al. (2014) also take the DEA method to examine domestic listed companies' scale efficiency in the industry, and the result indicates the scale efficiency of domestic listed LED firms has a better performance than their pure technology efficiency [3].

Research on LED lighting is quite mature in China and abroad. But from the perspective of efficiency, few studies have evaluated the input-output efficiency of listed companies in the LED lighting industry in China. Referring to evaluations of input-output efficiency in other fields, this study attempts to evaluate operational efficiency of listed companies in the LED lighting industry in China using a quantitate method, which has practical and theoretic value.

2. EVALUATION MODEL DESIGN

Sample selection and indicator design

According to the industry classification by the China Securities Regulatory Commission, the study considered following factors when selecting suitable listed companies from LED lighting industry in China:

1) Listed companies which have no net profit, negatively impacting the assessment results, and have no comparability, are excluded; 2) Based on the requirements of DEA model, the study tried to consider twice as many companies as input and output indicators. Finally, 20 listed companies were selected from the LED lighting industry in China, which are modeling of decision making units (DMU).

Referring to relevant scholars, five input indicators were selected: fixed assets (x_1), operating costs (x_2), intangible assets (x_3), administrative expenses (x_4) and government subsidies (x_5). Among these, fixed assets and operating costs reflect the situation of fixed capital and working capital in the sample companies. Intangible assets and government subsidies reflect the characteristics of the LED lighting industry as a high-tech and strategic emerging industry. Intangible assets reflect the company's R&D expenditure. Administrative expenses reflect employee compensation. The enormous economic and social benefits which the LED lighting industry can bring, not only prompt national and local governments to formulate development plans, but also promote regional R&D investment and continue to strengthen efforts to promote the rapid development of the LED lighting industry. Revenue(y_1) and net profit(y_2) are selected as output indicators. A good level of revenue, is the foundation of enterprise survival and sustainable growth, reflecting the company's profitability. Under the circumstances of the certain cost in companies, until the companies ensure good revenue, it is impossible to achieve improved levels of corporate profits.

The indicator data are from the Wind database. Data of fixed assets, intangible assets come from the corresponding subjects in the balance sheet of sample companies in 2015. Data of operating costs, administrative expenses, revenue and net profit come from the corresponding account in the income statement. Government subsidies are from the non-operating revenue account in the income statement.

DEA model

Since 1978, Charnes, Cooper, and Rhodes put forward the method of data envelopment analysis (DEA, Data Envelopment Analysis), the DEA method has been widely used in many fields like objective decision making, efficiency analysis, theoretical system and application levels. The first DEA model, called the C^2R model, mainly used to analyze and evaluate the relative effectiveness of the decision-making unit. The second model is called BC^2 DEA model, proposed by Banker, Charnes and Cooper in 1984, is primarily used to determine the corresponding point in the decision-making unit of the production function image [4].

The method hypothesizes that if there is a decision-making unit (DMU), each DMU in value creation has m kinds of input and s types of output. The value creation input vector of the j[th] decision-making unit (DMU_j) is $x_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T > 0$. The value creation output vector of the j[th] decision-making unit (DMU_j) is $y_j = (y_{1j}, y_{2j}, \ldots, y_{sj})^T > 0$. And their weight vectors respectively are $v = (v_1, v_2, \ldots, v_m)^T$ and $u = (u_1, u_2, \ldots, u_s)^T$. The efficiency rating index of the j[th] decision-making units (DMU_j) is:

$$h_j = \frac{u^T y_j}{v^T x_j} = \frac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}}. \quad (1)$$

Suppose the optimal solution for the dual programming $D^I_{BC^2}$ is λ^*, s^{-*}, s^{+*} and ρ^*, when $\rho^* = 1$ and $\hat{e}^T s^{-*} + e^T s^{+*} = 0$, DMU is DEA efficient; when $\rho^* = 1$ and $\hat{e}^T s^{-*} + e^T s^{+*} > 0$, DMU is weak DEA efficient; when $\theta^* < 1$, DMU is not valid. Let the overall efficiency θ^*, scale efficiency s^*, technical efficiency ρ^*, the overall efficiency:

$$\theta^* = s^* \cdot \rho^*. \quad (2)$$

Having a non-Archimedean infinitesimal ε BC2 model of the dual form (variable returns to scale) is

$$(D^{I}_{BC^2})\begin{cases}\min[\rho-\varepsilon(\hat{e}^T s^- + e^T s^+)] \\ \sum_{j=1}^{n} x_j\lambda_j + s^- = \rho x_0 \\ \sum_{j=1}^{n} y_j\lambda_j - s^+ = y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0, j = 1,2,\cdots,n \\ s^- \geq 0, s^+ \geq 0\end{cases} . \quad (3)$$

3. OPERATIONAL EFFICIENCY EVALUATION

The raw data of input and output indices of the 20 samples were entered into the DEAP2.1 software and the parameter of the boot file were set up: with the DMUs set at 20 and the interval set at 1 year, the input-leading mode chosen with 2 output indicators and 5 input indicators, 0=INPUT ORIENTATED, 1=VRS, 0=DEA (MULTI-STAGE). Table 1 shows the evaluation outcome of the operational efficiency of listed companies in the LED lighting industry in China based on the BCC model.

From Table 1, it can be seen that the mean technical efficiency of 20 listed companies in the LED lighting industry in China is 0.94, the mean pure technical efficiency is 0.98, and the mean scale efficiency is 0.96. The operational efficiency of 12 listed companies is DEA efficient.

The specific explanations are as follow:

1) The operational efficiency of 12 listed companies is DEA efficient, which means that with fixed amounts of input and proper output, operational efficiency reaches optimization. Besides, DEA efficient companies account for 60% of the total while the rests account for 40%, which means most LED companies in the sample have good operational efficiency.

2) From the eight non-DEA efficient companies, Kingsun, Ledman, and Elec-Tech International have a pure technical efficiency of 1.00, while scale efficiencies are 0.91, 0.88 and 0.73 respectively; the rest of the companies have pure technical efficiencies and scale efficiencies below 1.00, which shows Kingsun, Ledman, and Elec-Tech are in need of expanding scale to improve operating efficiency, while the rest need to not only expand scale but also improve pure technical efficiency.

3) Four listed companies are both in increasing returns to scale and in decreasing returns to scale, and 12 companies are in constant returns to scale. This shows the reason that some companies' returns to scale remain unchanged or decreasing because of increasing input and expanding scale caused by upgrading of technology, widespread of application and expanding market. For the remaining four amongst increasing returns to scale companies, it may be caused by fierce competition in the market.

The input and output slack values of operational efficiency of the listed companies in LED lighting industry in China are shown in Table 1. Taking Country Star Power as an example, its operational efficiency of the production frontier projected point is (87422.34, 122119.50, 9894.27, 15430.6, 73676.39) and (24764.73, 183851.56). Therefore, when improving its operational efficiency, it is recommended to respectively reduce 657.43 million yuan of fixed assets (x_1), 201.43 million yuan of operating costs (x_2), 23.17 million yuan of intangible assets (x_3), 25.45 million yuan of administration expenses (x_4), and 25.45 million yuan of government subsidy (x_5). In this case, operating income (y_1) can be increased by 93.52 million yuan. Input and output efficiency adjustment of other listed companies follows that revelation. The enlightenment is that although the greater output listed companies in LED lighting industry of China invest, the greater output they gain, still have more to optimize its input indicators. Reasonable investment can ensure effective output, focusing on fixed assets, terms of operating costs, administrative expenses and other adjustments to achieve a reasonable goals of inputs and outputs based on the corresponding improvement strategies.

3. CONCLUSIONS

The global economy has brought many opportunities to the development of the Chinese economy, and promoted the development of China's various industries. With the growing levels of consumption, LEDs are applied more and more widely. Following this, the number of listed companies in the LED lighting industry in China becomes greater, but the current economic situation seriously affects the development of listed companies in the LED

Table 1. DEA evaluation result of operational efficiency of 20 listed companies in the LED lighting industry in China

DMU	Technical Efficiency	Pure Technical Efficiency	Scale Efficiency	Input Slacks					Output Slacks	
				s_1^-	s_2^-	s_3^-	s_4^-	s_5^-	s_1^+	s_2^+
DMU1	0.73	1.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU2	0.85	0.86	0.99	44056.44	0.00	588.79	0.00	0.00	9352.60	0.00
DMU3	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU4	0.91	1.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU5	0.93	0.95	0.98	18483.59	0.00	11248.58	0.00	0.00	3894.30	0.00
DMU6	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU7	0.88	1.00	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU8	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU9	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU10	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU11	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU12	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU13	0.90	0.92	0.97	56407.06	0.00	4875.27	722.06	0.00	3400.26	0.00
DMU14	0.90	0.94	0.96	2168.01	792.57	763.62	0.00	0.00	0.00	0.00
DMU15	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU16	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU17	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU18	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMU19	0.79	0.90	0.88	37318.67	0.00	0.00	16530.23	3123.12	22683.53	0.00
DMU20	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.94	0.98	0.96	7921.69	39.63	873.81	862.61	156.16	1966.53	0.00

lighting industry, its operational efficiency has become the focus of attention. This study adopts the DEA model to evaluate the operational efficiency of listed companies in the LED lighting industry and the results show that operational efficiency of the majority of listed companies in the LED lighting industry is DEA efficient. Some listed companies suffer reducing operating costs due to fixed assets, intangible assets, excessive operating costs and other reasons. It is suggested that operating costs and administrative expenses should be controlled, fixed assets and intangible assets managed, as well as other steps taken to effectively enhance the operational efficiency of listed companies in the LED lighting industry of China.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the National Social Science Foundation of China (15BJY065).

REFERENCES:

1. Chungwon Woo, Yanghon Chung. The static and dynamic environmental efficiency of renewable energy:

a Malmquist index analysis of OECD countries. Renewable and Sustainable Energy Reviews, 2015. V47, #3, pp.367–376.

2. Chia Chi Sun, Shihua Li. Assessing the relative efficiency and productivity growth of the Taiwan LED industry: DEA and Malmquist indices application. Mathematical Problems in Engineering, 2014. V14, #5, pp.1–13.

3. Sanderson, W. Light emitting diodes and the lighting revolution: the emergence of a solid-state lighting industry. Research Policy, 2014. V43, #8, pp.1730–1746.

4. Marco-Serrano, F. Monitoring Managerial efficiency in the performing arts: a regional theatres network perspective. Annals of Operations Research, 2006. V145, #1, pp.167–181.

Yongbo YU,
Doctor of Manage- ment Science and Engineering, Lecturer. Graduated from Wuhan University of Technology. Hubei University of Technology

Yunchao DU,
Doctoral Student of Management Science and Engineering, Doctoral Student of Wuhan University of Technology

Yuan GAO,
M. Sc, Graduated from King's College London

Light & Engineering
Vol. 24, No. 3, pp. 166-169, 2016

Svetotekhnika
No. 5, 2016

DECISION GAME MODEL OF SUPPLY CHAIN CONSIDERING NON-DECEPTIVE LED LIGHTING COUNTERFEITS

Chuantao WANG[1,2*], Xiaofei CAI[1,2], and Hua QIN[1,2]

[1]School of Mechanical-electronic and Automobile Engineering, Beijing University of Civil Engineering and Architecture, Beijing, 100044 China;
[2]Beijing Key Laboratory of Performance Guarantee on Urban Rail Transit Vehicles, Beijing, 100044 China;
**E-mail: wangchuantao@bucea.edu.cn*

ABSTRACT

To identify the impact of counterfeit light-emitting diode (LED) lighting on the supply chain, a decision game model of the supply chain is constructed consisting of an LED lighting brand company, a LED lighting counterfeiter, and a retailer. The pricing decision of the decision game model is discussed. Afterwards, the impacts of the quality improvement of the authentic LED lighting products and the non-deceptive LED lighting counterfeits on the wholesale price, retail price, market share, and profit of the supply chain is analyzed through comparative static analysis. The conclusion is verified by numerical examples.

Keywords: supply chain, counterfeit, game

1. INTRODUCTION

China is in the reformative acceleration period of the social economic structure, and enterprise systems, industrial structures, and business patterns are frequently changing. At the same time, counterfeits have quietly formed the scale in China and have gained a wider influence on normal socio-economic development.

Counterfeits are also prevalent in the light-emitting diode (LED) lighting industry. Some well-known domestic and foreign LED lighting companies have suffered from counterfeiting. For example, in April 2015, OPPLE lighting found up to 5672 counterfeit products in the northern region, more than 700 counterfeit bath heaters and flat lamps in the western region, 1900 counterfeit integrated ceilings and flat lamps in the eastern region, and 337 counterfeit bath heaters and flat lamps in the southern region [1].

Several scholars have studied counterfeiting. For instance, Grossman et al. divided counterfeits into non-deceptive and deceptive counterfeits. A non-deceptive counterfeit is a product that consumers know with certainty to be a counterfeit at the time of purchase, whereas a deceptive counterfeit is a product that is unknowingly counterfeit and purchased by consumers [2]. Zhang et al. used the distinction between deceptive and non-deceptive counterfeits as a basis, determined the condition behind the general channel support for counterfeits, and analyzed the optimal supply chain structure, the attitude of consumers to the risk of counterfeits, and the loyalty of consumers on certification shops [3]. Soo-Haeng et al. compared two types of counterfeiters: deceptive and non-deceptive. Their analysis reveals that the effectiveness of these strategies critically depends on whether a brand company faces a non-deceptive or deceptive counterfeiter [4]. Peggy et al. investigated recent counterfeiting trends in the international marketplace and discussed the various labeling techniques that have been developed to distinguish between "real" and "fake" products [5]. Martin et al. reviewed a number of existing studies on the

determinants of the consumers' intention to purchase counterfeit products [6]. Existing studies have only considered deceptive counterfeits and not the non-deceptive counterfeits. This paper will study decision game problem of supply chain considering non-deceptive LED lighting counterfeits.

The rest of this paper is arranged as follows: Section 1 provides the basic model; Section 2 studies the game model of the supply chain, which consists of a LED lighting brand company, a LED lighting counterfeiter, and a retailer; Section 3 illustrates numerical examples; and Section 4 provides the conclusion.

2. BASIC MODEL

The model considers two companies producing similar LED lighting products in the market: a brand LED lighting company and a LED lighting counterfeiter. The retailer buys from both companies and then sells the authentic LED lighting products and the non-deceptive LED lighting counterfeits to consumers, assuming that the retailer sells without cheating. Consumers can decide whether to purchase the authentic LED lighting products (choice a, authentic) or the LED lighting counterfeits (choice f, counterfeits) from the retailer. Here, p_i is the price of product i, which the retailer sells to consumers ($p_i > 0$).

We assume that $q_i > 0$ is the quality level of the LED lighting product ($i = a, f$), $w_i > 0$ is the whole sale price of the product that the retailer buys, $c_i > 0$ is the cost of product i $c_i = k_i q_i^2$, and $k_i > 0$ is the cost coefficient. Given that the cost of the authentic LED lighting products includes production cost, design cost, advertising cost, and so on, and the cost of the counterfeits on design and advertising, among others, are almost zero, the cost of the authentic products is greater than the cost of the counterfeits, that is, $k_a > k_f$. In addition, $\phi_i(p_a, p_f)$ is the market share of i product. A market share is similar to that reported by Zhang et al [3]. For any (p_a, p_f), the market share of the authentic LED lighting products is $\phi_a(p_a, p_f) = 1 - \dfrac{p_a - p_f}{q_a - q_f}$, and the market share of the LED lighting counterfeits is

$$\phi_f(p_a, p_f) = \frac{p_a - p_f}{q_a - q_f} - \frac{p_f}{q_f},\ 0 < \frac{p_f}{q_f} < \frac{p_a - p_f}{q_a - q_f} < 1.$$

The profit of the retailer is expressed as

$$\pi_r = (p_a - w_a)\cdot\phi_a(p_a, p_f) + \\ +(p_f - w_f)\cdot\phi_f(p_a, p_f). \quad (1)$$

Assuming that the probability found by the relevant department about the LED lighting counterfeiter selling the counterfeit is u, $u \in (0,1)$, and assuming that the damage award is r times as its cost, then $rc_f = rk_f q_f^2$, where r is the penalty coefficient.

Thus, the profit of the brand name company is given by

$$\pi_a = w_a \cdot \phi_a(p_a, p_f) - c_a. \quad (2)$$

The expected profit of the LED lighting counterfeiter is expressed as

$$\pi_f = (1-u)(w_f \cdot \phi_f(p_a, p_f) - c_f) - urc_f. \quad (3)$$

3. SUPPLY CHAIN GAME

From Equation (1)-(3), we can we can obtain the wholesale price of the authentic LED lighting products can be expressed as

$$w_a^* = \frac{2q_a(q_a - q_f)}{4q_a - q_f}. \quad (4)$$

The wholesale price of the retailer buying the LED lighting counterfeits can be obtained through the following equation:

$$w_f^* = \frac{q_f(q_a - q_f)}{4q_a - q_f}. \quad (5)$$

The price of the authentic LED lighting products, which the retailer sells to consumers, through the equation

$$p_a^{**} = \frac{6q_a^2 - 3q_a q_f}{8q_a - 2q_f}. \quad (6)$$

The price of the LED lighting counterfeits sold by the retailer to consumers can be obtained by using the equation below

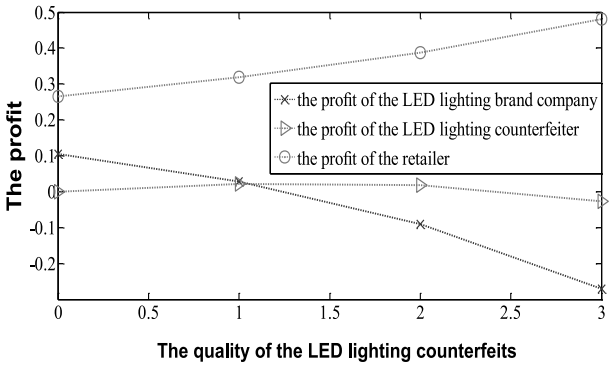


Fig.1. Impacts of the quality improvement of the LED lighting counterfeits on the LED lighting brand company, the LED lighting counterfeiter, and the retailer

$$p_f^{**} = \frac{5q_a q_f - 2q_f^2}{8q_a - 2q_f}. \quad (7)$$

The profit of the LED lighting brand company, the LED lighting counterfeiter and the retailer are

$$\pi_a^{**} = \frac{2q_a^3 - 2q_a^2 q_f}{(4q_a - q_f)^2} - k_a q_a^2, \quad (8)$$

$$\pi_f^{**} = (1-u)\left[\frac{q_a^2 q_f - q_a q_f^2}{2(4q_a - q_f)^2} - k_f q_f^2\right] - urk_f q_f^2, \quad (9)$$

$$\pi_r^{**} = \frac{4q_a^3 + 5q_a^2 q_f}{4(4q_a - q_f)^2}, \quad (10)$$

respectively.

From Equations (4)-(10), we can obtain the following correlative conclusions:

Conclusion 1: The higher the quality of the authentic LED lighting products q_a, the greater the wholesale price of the retailer buying the authentic LED lighting products w_a^*. The higher the quality of the LED lighting counterfeits q_f, the lower the w_a^*. The higher the value of q_a, the greater the wholesale price of the retailer buying the LED lighting counterfeits w_f^*.

Conclusion 2: The higher the quality of the authentic LED lighting products q_a, the greater the price of the retailer selling the authentic LED lighting products to customers p_a^{**}. The higher the quality of the LED lighting counterfeits q_f, the lower the p_a^{**}. Finally, the higher the values of q_a and q_f, the greater the price of the retailer selling the LED lighting counterfeits to customers p_f^{**}.

Conclusion 3: The higher the value of q_a, the smaller the market share of the authentic LED lighting products p_a and the LED lighting counterfeits p_f. Furthermore, the higher the value of q_f, the greater the values of p_a and p_f.

Conclusion 4: The higher the value of q_f, the lower the profit of the LED lighting brand company π_a^{**}. Meanwhile, the higher the value of q_a, the greater the expected profit of the LED lighting counterfeiter π_f^{**}.

4. NUMERICAL EXAMPLES

Assuming that the cost coefficient of the authentic LED lighting products is $k_a = 0.03$ and the cost coefficient of the LED lighting counterfeits is $k_f = 0.003$.Assuming that $u = 0.3$ and $r = 2$, the impacts of the quality improvement of the LED lighting counterfeits and the authentic LED lighting products on the LED lighting brand company, the LED lighting counterfeiter, and the retailer are respectively analyzed.

Assuming that the quality of the authentic LED lighting products $q_a = 3$, the figure below shows the profit changes of the LED lighting brand company, the LED lighting counterfeiter, and the retailer, when the quality of the counterfeit LED lighting improves.

Fig. 1 shows that the higher the quality of the LED lighting counterfeit, the lower the profit of the LED lighting brand company becomes. The profit of the LED lighting counterfeiter shows a trend from an increase to a decline along with the quality improvement of the LED lighting counterfeits. The higher the quality of the LED lighting counterfeit, the greater the retailer's profit would be.

The quality of the LED lighting counterfeits is $q_f = 1$, when the quality of the authentic LED lighting products improves. Fig. 2 shows the changing conditions of the LED lighting brand company, the LED lighting counterfeiter, and the retailer.

As shown in Fig. 2, the profit of the authentic LED lighting products shows a trend from an increase to a decline along with the quality improvement of the LED lighting counterfeits. The higher the quality of the authentic LED lighting products is, the greater the profit of the LED lighting counterfeits would become. The profit of the retailer shows a trend from decline to rise along with the quality improvement of the LED lighting brand company.

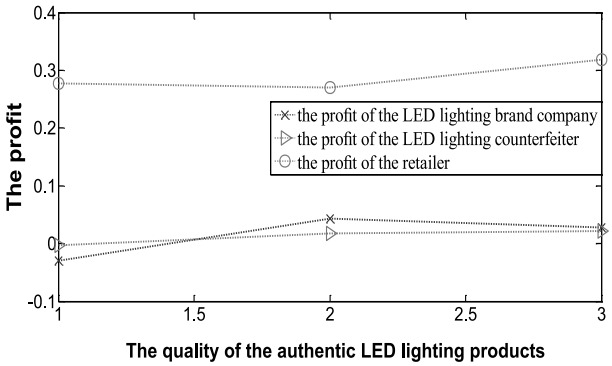


Fig.2. Impacts of the quality improvement of the authentic LED lighting products on the LED lighting brand company, the LED lighting counterfeiter, and the retailer

5. CONCLUSIONS

In this paper, we consider two LED lighting companies producing similar products in the market: a LED lighting brand company and a LED lighting counterfeiter. Assuming that the retailer sells without cheating, the retailer buys from them and then sells the authentic LED lighting products and the non-deceptive LED lighting counterfeits to consumers. The game model is established for the optimal solution. Afterwards, the situation of the LED lighting counterfeiter discovered by relevant parties is analyzed, resulting in the identification of the optimal wholesale price of the retailer buying productions.

In terms of its limitation, this paper only considered the impacts of quality improvement on the wholesale price of the retailer buying productions, price of the retailer selling to consumers, market share, and company profit under the market circumstance, which includes a single LED lighting brand company and a single LED lighting counterfeiter. However, this paper has not considered the condition of the retailer selling deceptive counterfeits. Thus, the multi-stage LED lighting supply chain that sells deceptive counterfeits is also worthy of further discussion.

ACKNOWLEDGEMENT:

The authors are grateful for the support provided by the National Science & Technology Supporting Program of China (2014BAH23F01, 2014BAK01B01) and Scientific Research Project of Beijing Educational Committee (SQKM201610016016).

REFERENCES:

1. http://www.optochina.net/html/zx/scfx/44714.html.

2. Grossman, G., Shapiro, C. Counterfeit-Product Trade. American Economic Review, 1988. V78, #1, pp.59–75.

3. Zhang, J., Zhang, R. Supply chain structure in a market with deceptive counterfeits. European Journal of Operations Research, 2014. V240, #2015, pp.84–97.

4. Soo-Haeng, C., Xin, F., Sridhar, T. Combating strategic counterfeiters in licit and illicit supply chains. Manufacturing & Service Operations Management, 2015. V17, #3, pp.273–289.

5. Peggy, C., Michael, W. An assessment of the impact of counterfeiting in international markets: the piracy paradox persists. Columbia Journal of World Business, 1996. V31, pp.34–48.

6. Martin, E., Pakize, S. Explaining counterfeit purchases: a review and preview. Academy of Marketing Science Review, 2006. V2006, #12, pp.1–22.

Chuantao WANG,
Doctor of System Engineering, Assistant Professor. Graduated from Beijing Jiaotong University

Xiaofei CAI,
Bachelor of Human resource management, Master candidate of Beijing University of Civil Engineering and Architecture

Hua QIN,
Doctor of Industrial Engineering, Associate Professor. Graduated from Tsinghua University

Light & Engineering
Vol. 24, No. 3, pp. 170-173, 2016

Svetotekhnika
No. 5, 2016

PSYCHOLOGICAL TRAINING PROGRAMMES FOR YOUNG EMPLOYEES IN CHINA'S NEW ENERGY INDUSTRIES: A PHOTOVOLTAIC INDUSTRY CASE STUDY

Qiaoxia SUN

Baotou Light Industry Vocational Technical College, Inner Mongolia, China
E-mail: sunqiaoxia664@163.com

ABSTRACT

This study determines the current psychological state of young employees in new energy industries by obtaining real data, which provide important bases for analyzing problems and exploring solutions, through a questionnaire, interviews, and informal discussions that focus on the photovoltaic industry. Young employees are generally facing considerable pressure, depression, loneliness, and other psychological problems because of work factors, such as safe production, working environment, and labour intensity, as well as family factors, such as burden from family and difficulties in finding a spouse. Companies should place importance on the psychological status of employees, establish a comprehensive psychological archive, provide employees with regular psychological exercises, and develop a five-in-one mental health awareness mechanism.

Keywords: new energy industry, psychological training, young employees, photovoltaic industry

1. INTRODUCTION

The World Health Organization Charter defines a "healthy state" as a state that is not only free from diseases or physical disabilities, but also characterized by good mental condition. In modern society, both work and life rhythms are fast-paced. Individuals are facing fierce competition in the labour market, which increases pressure in life. The information age is gradually accelerating along with the modernization of power grid enterprises. Work pace, standards, duties, and pressures are gradually increasing, which significantly influences the employees of power generating enterprises. Employees become more prone to anxiety, irritability, and other negative emotions, which considerably affect their work efficiency and quality [1]. Therefore, comprehensively studying the psychological state of employees in energy enterprises, strengthening psychological training and counselling, and establishing a scientific and reasonable regulation mechanism are particularly important.

2. PSYCHOLOGICAL PROBLEMS OF YOUNG EMPLOYEES IN THE PHOTOVOLTAIC INDUSTRY

The upstream enterprises of the photovoltaic industry are frequently located in mountainous areas with abundant silicon resources. Meanwhile, downstream enterprises are frequently located in areas where the duration of sunlight is long. The photovoltaic industry is generally located in regions with relatively harsh environments, where employees are more prone to psychological problems than those working in urban areas. Six manifestations of psychological problems are observed among employees in the photovoltaic industry: (1) physical discomfort with various typical occupational diseases; (2) psychological loneliness and emptiness, and low self-esteem, judging one's ability and self-worth; (3) lack of passion and spirit, which they possessed before working, and irri-

tability and anger, many are suffering from depression, autistic spectrum disorders, among others; (4) a general feeling that the work they are doing is meaningless, low efficiency or self-evaluation of low competence or unsuitability for the current work, which leads to high turnover; (5) poor interpersonal relationship characterized by indifference and lack of sympathy; and (6) aggressive behaviour towards others. Employees suffer from many interpersonal frictions. In extreme cases, fights or self-destructive behaviours may occur [2]. Power grid enterprises have higher health and safety requirements than other industries. They regard safety as their lifeblood. These problems have become "time bombs" in Chinese power grid industries. They can "explode" any time and considerably affect safe production, social security, and industrial stability [3].

3. ANALYSIS OF PSYCHOLOGICAL PROBLEMS OF YOUNG EMPLOYEES IN THE PHOTOVOLTAIC INDUSTRY

This study uses a questionnaire survey to gather information from 100 young employees in the photovoltaic industry and to determine their actual psychological state.

Psychological stress caused by occupational factors

Safety is the lifeblood of the photovoltaic industry. At present, the Chinese government has placed considerable importance on the issue of safe production. Accident rate is an important index to evaluate enterprise development and performance. Most young employees work on the frontline. Therefore, they work hard to ensure safety. The considerable pressure of ensuring safe production remains with young employees. Eventually, they become highly stressed. Under such pressure, employees with obsessive–compulsive disorder (OCD) are compelled to calculate data and conduct cross-checks repeatedly. The results of the survey indicate that the closer the position is to the core, the more important the task, and the more intense the working pressure. That is, staff members working at the frontline experience more pressure than staff members working in the office. This situation will inevitably lead to the adverse psychological state of young employees who easily develop OCD.

The photovoltaic industry is an emerging industry. Primary enterprises are facing a serious contradiction between the supply and demand of talents. The primary sectors of the photovoltaic industry are located far from urban areas, where resources are more abundant. Young people have a psychological resistance to such areas, which causes a serious brain drain phenomenon. Simultaneously, both the management and first-line technical staff are required to work in shifts; that is, working overtime has become a normal condition, which results in various degrees of anxiety among many young employees and seriously affects their psychological health. The survey results indicate that the proportions of young employees who frequently, sometimes, and seldom suffer from psychological anxiety are 27%, 62%, and 11%, respectively.

In general, both the upstream and downstream enterprises of the photovoltaic industry are located in mountainous areas, where the working environment is harsh. Young employees who work in such environments and far from vivacious cities and their homes, coupled with incidents of gender discrimination in companies, experience difficulties in searching for a spouse. They find life boring and dull, easily feel weary, and have unhealthy psychological states. In particular, facilities are incomplete and unsound in some early projects in the photovoltaic industry. Employees lack access to channels of communication with the outside world. The survey results indicate that 53% of young employees claim that they have to bear the pressure alone. Only 27% talk to their family and friends, and only 9% talk to the management and supervisors. The remaining 21% vent pressure through the Internet or by engaging in sports. The considerable pressure exerted by the working environment causes employees to experience a high level of psychological anxiety, which cannot be solved in the absence of a suitable outlet. Consequently, employees are prone to depression. Some companies use simple and boring training methods that drain the enthusiasm from young employees. These methods do not only fail to fulfill the purpose of training, but also restrict individual ability and quality. The restriction of personal development also increases psychological pressure on employees.

Stress from family factors

The family planning policy (one-child policy) has been implemented in China for over 30 years. The proportion of only-child young employees is large. Many families belong to the "421" pattern,

where "4" represents the four elderly parents of the couple, "2" represents the couple, and "1" represents the child. Young employees from such families are inevitable mainstays who are under the heavy burden of family. The survey results show that 39% of young employees feel themselves under a heavy family burden, particularly those belonging to the 30–35 year age group. These employees are married and have children. They need to consider both work and family. In addition to working hard in their job, they have to support their elderly parents and raise their children, which require a considerable time and effort.

At present, most young employees were born during the 1980s and 1990s. These people have grown up after the Reform and Opening up Eras. They have active minds, are more romantic, and have more demands in marriage than those from previous generations, which aggravates the difficulties in searching for a spouse. Male employees are not the only ones to experience difficulties because of their small social circle and working environment, some female employees also experience difficulty in finding a match because of working factors and the lack of men who meet their expectations. Some female workers find themselves unworthy of men with a higher status, but are unwilling to accept men with a lower status. Accordingly, female employees who are of marrying age but are still single are common. In recent years, living standards have rapidly improved with rapid economic development. The cost of living has continued to increase, particularly housing prices. Young employees are under relatively high pressure to purchase an apartment. This factor leads to high salary expectations. The survey results show that 68% of young employees are encountering or have encountered difficulties in searching for a spouse. Moreover, 52% believe that such difficulty is caused by their small social circle, whereas 30% reckon that it is because of their low salary that does not satisfy their expectation. The rest believe that other factors cause their difficulty in searching for a spouse.

Psychological stress caused by social factors

China is in a transition period of economic development. It is still at the primary stage of socialism and is developing toward being a comprehensively well-off society. During this period, social ideologies easily change, while psychological factors that may affect young employees have gradually increased. Young employees in the photovoltaic industry have apparently higher expectations than the older generation. Their values are more diverse. New media, represented by the Internet, have become the main channel for young people to obtain information, particularly with the rapid popularization of the Internet and mobile smartphones. On the one hand, such media make communication convenient. On the other hand, they make disseminating negative ideas easy. Young people are weak in terms of discrimination. They are easily provoked and confused.

As the economy develops, the demands of people from work and life are no longer limited to material interests, but have diversified to include spiritual, democratic, and other interests. For example, young employees in photovoltaic enterprises do not only expect monetary benefits from work, but also expect personal development in their career, participation in enterprise management, and democratic rights to express themselves. However, the job sequence is typically singular and development is restricted in the photovoltaic industry, which result in psychological problems among young employees. They feel hopeless and gradually lose their enthusiasm to work. Simultaneously, their income level cannot catch up with rapidly increasing housing prices. Young employees feel increasing pressure in both work and life. The survey results indicate that 28% of young employees deem their current income as relatively low and hope that it will increase in the coming months. Furthermore, 58% have thought about changing job, particularly during the first few years of joining the industry.

4. STRATEGIES FOR STRENGTHENING THE PSYCHOLOGICAL TRAINING OF YOUNG EMPLOYEES IN THE PHOTOVOLTAIC INDUSTRY

Comprehensively understanding the psychological situation of employees, establishing employee psychological files

Introducing various psychological theories, methods, and experiences into the daily management of photovoltaic enterprises is necessary to cope with the psychological problems of young employees. Maximizing the use of various software and hardware equipment before recruitment is important, for example, conducting psychological assessment of employees to grasp their psychologi-

cal state fully. Meanwhile, companies should conduct regular surveys among employees who have served longer to understand psychological changes among this group.

Develop targeted psychological training courses

Many psychological training methods are available, but developing a psychological course that is suitable and targeted for photovoltaic employees is necessary. First, companies should use psychological archives, conduct periodic analyses, and classify current problems. Then, targeted training courses should be designed to guide young employees in gradually grasping the self-regulation method and improving their control for all kinds of negative emotions as well as their resistance to psychological problems. Special attention should be focused on cultivating the psychological ability of managers to spot psychological problems among staff members and to find a reasonable solution.

Establish a psychological health website

Enterprises should establish a specialized psychological health website if technology and funds are available, and actively take advantage of the convenient network and the dependence of young employees on such network, for example, by uploading theories of psychological health knowledge as well as audio and video courses on the website. By doing so, employees can easily use their spare time to learn about themselves. In addition, enterprises can also offer online counselling services, which can provide online answers to questions from employees. Providing timely guidance to staff and performing psychological adjustment can also help those who have difficulty in face-to-face communication, which can effectively improve the efficiency of the psychological management of an enterprise.

Construct a five-in-one psychological promotion mechanism for employees

Psychological state is an important index for assessing staff quality. Ensuring the psychological health of employees does not only require external forces for psychological adjustment. Instead, a more effective approach is training to enhance the immunity and ability of employees to achieve self-regulation, and thus, fundamentally relieves the mental health problems of young employees in the photovoltaic industry. Therefore, establishing a scientific and comprehensive prevention security system equipped with consultation, evaluation, and monitoring facilities, and using scientific research as their basis, is necessary. The five aspects, namely, training, consultation, assessment, monitoring, and research, constitute a five-in-one employee psychological health promotion mechanism.

5. CONCLUSION

The causes of psychological problems among employees in the photovoltaic industry consist of both work and family factors. Mental health problems are not acquired in a day or two, but build up over time. Similarly, the problems cannot be solved overnight. Instead, a long-term mechanism should be established from the recruitment of employees. The psychological state of employees should be monitored and understood to enable the timely detection of problems, the analysis of problems, and the exploration of reasonable ways to solve problems. The company should place considerable importance on psychological health problems, exert efforts to help young employees establish a scientific concept of psychological health, and eliminate the influence of all forms of negative psychological problems.

REFERENCES:

1. Costuleanu CL, Dumitrescu D, Brezuleanu S, Bobitan N. Relationships between Fashion Enterprises Resilience under Market Disruption and Employees' Creative Involvement and Wellbeing Degree. Revista de Cercetare si Interventie Sociala, 2015, V48, pp. 50–59.

2. Kaplan S, Sawhney M. E-hubs: the new B2B marketplaces. Harvard business review, 2000, V78, #3, pp. 97–106.

3. Lund P D. Effects of energy policies on industry expansion in renewable energy. Renewable energy, 2009, V34, #1, pp. 53–64.

Qiaoxia SUN,
Bachelor of science. Graduated from Inner Mongolia Normal University. Associate professor, Baotou Light Industry Vocational Technical College

Light & Engineering
Vol. 24, No. 3, pp. 174-177, 2016

Svetotekhnika
No. 5, 2016

OPERATION OPTIMIZATION OF PHOTOVOLTAIC ENTERPRISES AND MICRO-GRID AGENTS WITH THE OBJECTIVE OF PROFIT MAXIMIZATION

Zhang LI

School of Electrical Engineering and Information, Xihua University, Sichuan 610039, China
E-mail: lizhangxh795@126.com

ABSTRACT

In recent years, the efficiency of photovoltaic power generation keeps rising, but the cost remains high. This paper studies the optimization process of photovoltaic enterprises and micro-grid agents with the objective of profit maximization, and builds a two-layer optimization model. Research findings suggest that the model can reduce the costs of photovoltaic enterprises and micro-grid agents and maximize their profits.

Keywords: photovoltaic enterprises, micro-grid, two-layer optimization, energy

1. INTRODUCTION

In recent years, the rapid growth of the photovoltaic industry has given rise to increasingly severe energy supply and environmental problems [1]. Developing new energy resources is a critical energy strategy of all countries. Luo *et al.* put forward a non-radiative dielectric guide volume configuration plan based on reliability and economic efficiency in 2010 [2]. In 2011, Yuan built a set of distributive, photovoltaic power generation micro-grid experimental platforms from the perspective of a distributive, photovoltaic power generation micro-grid power supply system [3]. Xu *et al.* proposed a low-carbon development goal and key objective indicator system, and put forward the realization of companies' low-carbon development [4]. In 2013, Su *et al.* devised methods of calculating the cost and efficiency of photovoltaic power generation in different operational modes [5]. High *et al.* made some effective suggestions based on the distributive, photovoltaic connected-grid and the operation of grid companies in 2013[6]. Zhang *et al.* used a global environmental multi-scale model to propose quantitative study methods of group competitiveness in 2015 [7]. Nevertheless, due to the ideas, policies, and market price, the development of the Chinese photovoltaic industry is greatly restricted. Although the Chinese photovoltaic manufacturing industry relies little on outside markets, the lower-level photovoltaic power generation sector has not been vastly improved and its successful future development is still at stake.

In order to maximize the profits of photovoltaic enterprises and micro-grid agents, this paper establishes a two-layer optimization model with the objective of profit maximization. In Section 2, the present state of photovoltaic enterprises and micro-grid systems and related problems are introduced. In Section 3, we illustrate how to use two-layer optimization planning to improve photovoltaic enterprises and micro-grid systems. Simulative verification and analysis on the two-layer optimization operating mode is given in Section 4. Section 5 summarizes the conclusions of our research.

2. CURRENT STATE OF THE INDUSTRY

Photovoltaic systems

A photovoltaic system is mainly comprised of solar power battery components, inverters, measuring instruments, power charge and discharge

controllers, computer monitoring and other electrical equipment, and storage batteries. Types of photovoltaic systems include separate power generation systems and connected-grid systems. Their major application areas include spacecraft, communication systems, microwave-radio relay communications, TV transposer stations, photovoltaic pumps, and power supplies in areas without access to or lack of local sources of electricity. Owing to the demands of technological development and global economic sustainable development, developed countries have plans to build up household, roof-mounted photovoltaic power generation systems, MW-Class centralized and large-scale connected-grid power generation systems, etc. In the meantime, photovoltaic systems are widely promoted in transportation and urban illumination.

Micro-grid

A micro-grid refers to the subsystems made up from distributive power generation devices, power storage equipment, and load in a certain topological structure so as to reduce the adverse impact of a distributive power supply with high permeability on the main grid. A micro-grid offers electric energy and heat to users. Its internal systems can transform different kinds of energy via electrical devices and provide the necessary control. The operational mode of microwaves is flexible and changing, so a quality micro-grid power supply service depends on the quality and stability of the controlling system. Thus, studying the controlling strategy of intelligent micro-grids is of great significance to conduct a feature study of distributive micro-grids, plug-in grids, and smart power network systems.

Two-layer planning

Two-layer planning refers to a system optimization with a two-layer hierarchical structure. These two layers have their own decision-making variables, objective functions, and constraints. Two-layer optimization studies the planning and management of the two-layer system. Upper decision-makers need to direct the lower decision-makers with their own strategies. Then, within their possible range, they can make their own decisions. Two-layer planning studies the order and non-cooperative interaction between the decision-makers with their separate functional objectives. Upper decision-makers have the priority to make decisions, while those at the lower level need to react according to the upper decision-making information.

3. METHODOLOGY

Two-layer optimization operating mode

This paper applies two-layer optimization planning to improve a micro-grid system, and establishes the two-layer optimization operation model with the objective of maximizing the profits of photovoltaic enterprises and micro-grid agents. The upper level is the volume optimization model and the lower level is the operation optimization model. The upper decision-making results can directly affect the objective functions and constraints of the lower level. The upper ones directly report decision-making results to the upper level, thereby promoting interaction between upper- and lower-level decision-making. The logic diagram of two-layer optimization is shown in Fig. 1.

Two-layer optimization model

The two-layer optimization model can be described mathematically as

$$\begin{cases} J_1 = \min F\left(x, y_1, y_2, \cdots, y_m\right) \\ s.t.G\left(x\right) \le 0 \end{cases}, \quad (1)$$

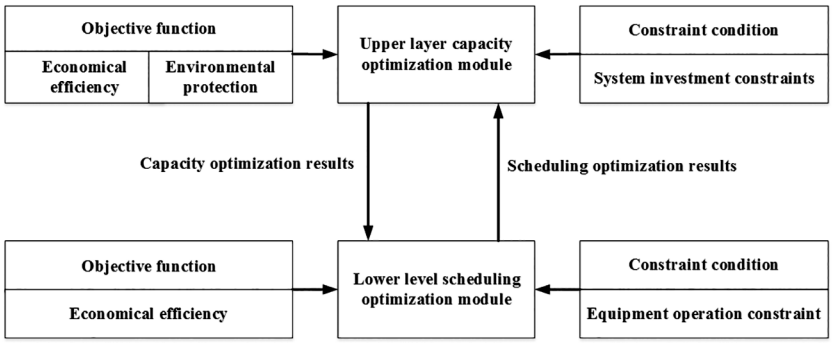


Fig. 1. Two stage optimization logic diagram

Table 1. Scheduling results for different objectives and different strategies

Combination ways	Energy cost	Depreciation cost	Environmental cost	Comprehensive cost
Combination 1	336.34	972.17	378.85	1626.1
Combination 2	312.27	1181.6	401.07	1938
Combination3	413.46	763.07	394.2	1320.5
Combination 4	412.22	737.12	394.2	1321
Combination 5	422.53	1151.3	307.62	1869.5
Combination 6	484.92	1495.4	294.37	2377.6
Combination 7	378.77	765.43	413.26	1284.8
Combination 8	377.43	763.79	413.7	1283.6

$$\begin{cases} J_2 = \min f\left(x, y_1, y_2, \cdots, y_m\right) \\ s.t.g\left(x, y_1, y_2, \cdots, y_m\right) \le 0 \end{cases}, \quad (2)$$

where F represents the objective function of upper-level optimization; f, the objective function of lower-level optimization; x, the decision-making vector of upper-level optimization; y, the decision-making vector of lower-level optimization; G, the constraint of upper-level optimization; and g, the constraint of lower-level optimization.

Upper-level volume optimization and lower-level operation optimization

During the course of upper-level volume optimization, this paper uses the Pareto best solutions set to obtain multi-objective, overall optimal solutions, thereby avoiding the weighting issue of transforming multi-objective problems into single-objective problems. Therefore, this paper uses the multi-objective genetic algorithm of the second-generation non-disposable sequencing evolution algorithm to solve the multi-objective problems. In the lower-level operation optimization, mixed-integer linear programming is an important mathematical planning issue, which can be marked with linear formulae. The mixed-integer linear programming issue is shown as follows:

$$\begin{aligned} &\min cx \\ &s.t.Ax\begin{Bmatrix} \ge \\ = \\ \le \end{Bmatrix} = b \quad . \\ &x_{\min} \le x_i \le x_{\max} \end{aligned} \quad (3)$$

In this equation, cx represents the objective function, and x_i, x_j represent continuous variables and integer variables. A denotes the simultaneous linear equation factor matrix and b is the simultaneous linear equation value.

4. RESULTS ANALYSIS AND DISCUSSION

In order to verify the results of this research, experiments were conducted to determine the combined effects of various economic operations, including recorded consumption cost, depreciation cost, environmental cost, and comprehensive cost. Experimental results are shown in Table 1.

According to Table 1, for different objective functions, a micro-grid system uses low costs to sell power to supply the grid system while meeting load demand, thereby gaining profits. Compared to the way in which the grid meets overall demand, the unit contribution of DER and operational strategy reduces environmental costs by 8.35% and 12.2%, respectively. When realizing the complementary relationship between several energy sources, the two-layer optimization model of the photovoltaic industry and micro-grid agents can improve the efficiency, power supply reliability, and power utilization rate of the entire micro-grid system, thereby reducing the cost of photovoltaic enterprises and micro-grid agents.

5. CONCLUSIONS

In recent years, the Chinese photovoltaic industry has made the best use of its advantage in supporting industries and technology costs

to gain a global competitive edge. However, problems such as stage overcapacity and incomplete supporting systems and mechanisms also exist in China's photovoltaic industry. Therefore, this paper has applied two-layer optimization to improve photovoltaic enterprises and micro-grid systems. The upper-level optimization is based on the multi-objective, genetic algorithm calculation system optimization configuration of the second generation, non-disposable sequencing evolution algorithm, while the lower level optimization utilizes the optimal operation plan of the mixed-integer linear planning algorithm. Results show that the two-layer optimization operation mode described in this paper for photovoltaic enterprises and micro-grid agents can be applied to several different sources of energy to improve the efficiency, reliability, and energy utilization rate of the entire micro-grid system, as well as to cut the costs of photovoltaic enterprises and micro-grid agents. While the two-layer optimization maximizes economic benefits in theory, application of the model in practice requires further study.

ACKNOWLEDGEMENTS:

This paper is supported by the key project of natural science of Education Department of Sichuan Province "Research on condition monitoring and fault diagnosis of large generator based on Artificial Intelligence Theory" (11ZA280).

REFERENCES:

1. Klaic Z, Fekete K, Sljivac D. Demand Side Load Management in the Distribution System with Photovoltaic Generation. Tehnicki Vjesnik-Technical Gazette, 2015, V22, #4, pp. 989-995.

2. Luo Yunhu, Wang Bingjie, Liang Xin, et al. Optimal allocation of micro grid non renewable distributed generation capacity in the electricity market environment. electric power automation equipment, 2010. #8, pp. 28-36.

3. Yuan Jianhua. Hoppmann, J., Peters, M., Schneider, M., & Hoffmann, V. H. The two faces of market support—How deployment policies affect technological exploration and exploitation in the solar photovoltaic industry. Research Policy, 2013. V42, #4, pp. 989-1003.

4. Xu Jieming, Xu Hongling, Tian Jianqiang,Lin, Chun Yueh, and Yih-Chearng Shiue. "An application of AHP and sensitivity analysis for measuring the best strategy of reverse logistics: a case study of photovoltaic industry chain." Journal of Testing and Evaluation, 2013. V41, #3, pp. 1-12.

5. Su Jian, Zhou Limei, Li Rui. Tang Y, Sun H, Yao Q, et al. The selection of key technologies by the silicon photovoltaic industry based on the Delphi method and AHP (analytic hierarchy process): Case study of China. Energy, 2014. V75, pp. 474-482.

6. High Zhengping. Hoppmann J. Vasseur, Véronique, Linda M. Kamp, and Simona O. Negro. "A comparative analysis of Photovoltaic Technological Innovation Systems including international dimensions: the cases of Japan and The Netherlands." Journal of Cleaner Production, 2013. V48, pp. 200-210.

7. Zhang Xiang, Wang Jingya, Zhou Min. Bücker S, Acker J. Spectrometric analysis of process etching solutions of the photovoltaic industry—Determination of HNO 3, HF, and H 2 SiF 6 using high-resolution continuum source absorption spectrometry of diatomic molecules and atoms. Talanta, 2012. V94, pp. 335-341.

Zhang LI,
Ph. D. in field of Electrical Power System and Automation, Lecturer. Graduated from Sichuan University

Light & Engineering
Vol. 24, No. 3, pp. 178-181, 2016

Svetotekhnika
No. 5, 2016

STUDY ON THE BEHAVIOR ORIENTED INCENTIVE MECHANISM OF LARGE LIGHTING FIXTURE MANUFACTURERS BASED ON THE GAME THEORY OF INCOMPLETE INFORMATION

Yan MAO and Yongjian LI*

School of Economics and Management, Southwest Jiaotong University, Sichuan, China
**E-mail: yongjianlisj729@163.com*

ABSTRACT

Market internationalization has led to increased competition in the lighting manufacturing industry. Large-scale lighting firms can improve their core competitiveness through employee inventive mechanisms. Based on a game of incomplete information, this study looks into the incentive mechanism of such firms. The paper proposes and tests a model to incentivize the development of the overall lighting industry and of the individual firms within the industry. The result shows that an employee incentive mechanism can effectively improve the competitiveness of firms.

Keywords: incomplete information, game theory, incentive mechanism

1. INTRODUCTION

Ziada [1] asserts that designing an employee incentive mechanism that is based on an enterprise's characteristics is beneficial to improving the enterprise's core competitiveness and promoting its sustainable development. Lin He [2] contends that the early twentieth century management practice of increasing the employees' income to boost production was the beginning of incentive theory research. Manshaei [3] believes that, according to the focus and the level of the incentive mechanism, incentive theory can be classified into content oriented incentive theory and process oriented incentive theory. Roughgarden [4] states that a human's basic needs include achievement, power and friendship, and that these needs are important elements of incentive management. Hanss [5] considers that the feeling of fairness comes not only from the absolute amount of an individual's achievement, but it is also influenced by the relative amount of that individual's achievement. Individual's compare their achievements with the achievements of others, to see whether their own achievement is reasonable. The power of the incentive is also related to the individual's expectation. This means that in a game, it is possible to strengthen or to weaken the target individual's behavior through an external factor to achieve the effect of the incentive [6].

This paper investigates the effects of an employee incentive mechanism in a high-tech industry. The study presented in this paper uses a game of incomplete information to investigate a large-scale lighting fixture manufacturing firm that is faced with increasing market competition. Section two of this paper discusses the lighting manufacturing sector, and introduces game theory. Section three uses a game of incomplete information to look at establishing an employee incentive mechanism. Section four analyzes the effect of the incentive mechanism. Finally, section five discusses the findings.

2. CURRENT SITUATION

The lighting manufacturing sector

China's lighting industry has developed rapidly in recent years, attracting large amounts of capital and many enterprises into the sector. China is

the world leader in lighting production and technology. The two main products of the lighting industry are electric light sources (i.e., incandescent lamps, gas-discharge lamps, and light-emitting diode lamps) and lighting fixtures. From a marketing perspective, China's lighting source sector has transitioned from a terminal product to an intermediate product, and the sector is gradually developing downstream. Firms that operate in the lighting fixture sector are entering light source production to cut cost and to ensure quality [7].

In the overall lighting industry, China's firms continue to build their brands. Such firms are increasing their investments in product research and development (R&D), and are focusing on the promotion of their proprietary brands in the market. Further, these firms want to tap into their internal potential and to improve their competitiveness. Accordingly, these firms are focusing on improving their internal incentive mechanisms.

Game theory

Game theory is a branch of modern mathematics. It is an important sub-discipline of operational research, and is widely used in many fields. Game theory can be used to research the competitiveness phenomenon. Game theory is also known as the theory of games because it looks at forecasting behavior, at actual behavior, and at optimizing strategies in individual games [8]. Generally, a game can be classified as cooperative or as non-cooperative. The difference lies in whether there is a binding agreement to constrain the interacting parties. The non-cooperative game can be further classified into a static game of complete information, a dynamic game of complete information, a static game of incomplete information, and a dynamic game of incomplete information. The latter corresponds to the Nash equilibrium, and has sub-games of perfect Nash equilibrium, Bayesian Nash equilibrium, and perfect Bayesian Nash equilibrium [9].

Behaviorally, games can be classified into static and dynamic games. Their main difference is whether the second mover knows the specific action of the first mover. For example, the *prisoner's dilemma* is a static game, while chess and card games are dynamic games. A game of complete information and a game of incomplete information are differentiated according to the degree that the participants understand the other participants. An incomplete information game is when the participants have an incorrect or an incomplete understanding of the other participants.

3. METHODOLOGY

Analyzing a firms' incentive mechanism using game theory

A firm's knowledge reserve can be increased through R&D. According to endogenous economic growth theory, technological innovation is the basic driving force for an industry's development, for productivity growth, and for the improvement of people's living standards. Game theory is used as a modeling tool for *external* and *non-external* research. In external research, fierce market competition leads to a large overflow effect, a large loss for the firm, and weak enthusiasm for technological innovation. In non-external research, a competitive market structure prompts the firms to increase their R&D investment levels. The competitive model extends competition into the competition stage and the product market competition stage.

By building a differential game model, we find that the over-investment caused by competition is larger than the need of an optimal society, which leads to waste. We assume that there is no overflow effect, and conduct further research using the partial equilibrium method.

If we assume that technological innovation brings an increase of net surplus to society, then the net surplus in an optimal society that is the innovative incentive is:

$$V^M = \frac{1}{r}\int_{\underline{c}}^{\bar{c}} D(C)\,dc \tag{1}$$

Assume that the competing firms use the same marginal cost technology to produce the product. If one of the firms achieves a major technological innovation to reduce its cost, and the other firms with low efficiency quit because they lose money, then the profit of the innovative enterprise that is the incentive is:

$$\begin{aligned} V^C &= \frac{1}{r} D[P(\underline{C})][P(\underline{C}) - \underline{C}] = \\ &= \frac{1}{r}\int_{\underline{C}}^{P(\underline{C})} d[P(C)]dC \end{aligned} \tag{2}$$

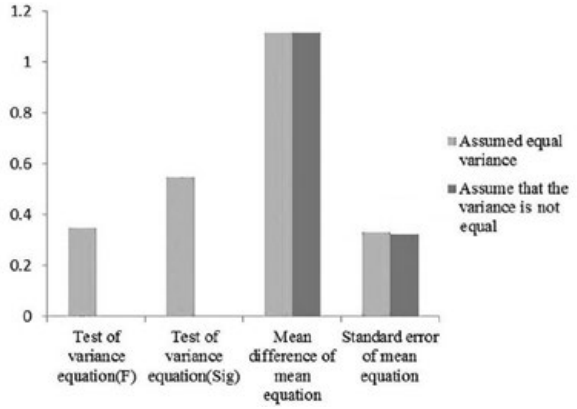


Fig. 1. Analysis on the project of enterprise incentive mechanism

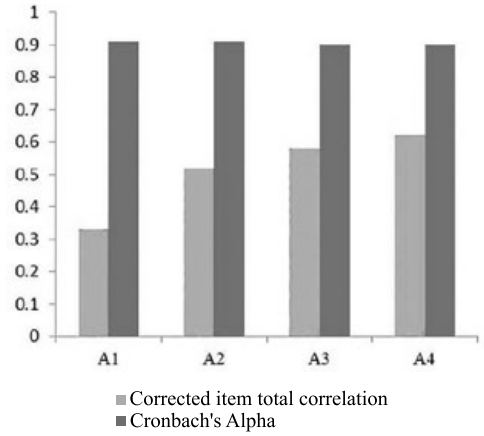


Fig 2. Analysis on the reliability of enterprise incentive mechanism

Analyzing a firms' internal incentive mechanism using game theory

An agency conflict arising from a misunderstanding of the reward mechanism can be discussed by adopting a game of incomplete information. Agency issues can be classified into two types: rebel choice and moral hazard. Rebel choice stems from ineffectively identifying and verifying the agent's information. The consignor does not know exactly the true ability of the agent, and can only make a decision based on the agent's self-justification. The accumulative skills and information of the agent is highly significant to the current consignor and to the other consignors in the competition. The agent's losses will result in significant losses to the original consignor. Moral hazard grows out of the uncertainty regarding the agent's behavior and the results of this behavior. It is difficult for the consignor to directly observe the agent's behavior; hence, it is also difficult for the consignor to make a precise prediction about the agent's behavior and the corresponding results of the behavior.

We design our theory according to the incentive mechanism. If the agent's risk is neutral, then we can transfer the relevant uncertainty risk to the agent to inhibit moral hazard. However, the agent is often assumed as a risk aversion type. To incentivize the agent, we need to choose behaviour that is beneficial to the consignor. Further, the agent must take part of the risk and receive remuneration for this. Generally, production is determined by the degree of effort and other unacceptable random factors. Under the precondition of the maximal effect of its expectation, the consignor determines the share of interest of the agent as follows.

$$\begin{aligned} &\max_{s(x)} \underset{\theta}{E}\{G[x-S(x)]\} \\ &s.t.\underset{\theta}{E}\{U[S(x)-V(e)]\} \geq u_0. \end{aligned} \tag{3}$$

If the effect accepted and obtained by the agent is no less than the received and rejected effect, then the degree of effort made by the agent to maximize his or her effect under the sharing contract is:

$$\max_{\theta} \underset{\theta}{E}\{U[S(x)-V(e)]\}. \tag{4}$$

4. RESULTS, ANALYSIS AND DISCUSSION

First, we analyze the distinction degree of the tested area. Then, we conduct a reliability analysis. Finally, through exploratory factor analysis, we test the validity of the results. The result is shown in Fig 1.

Using the same method, we repeat the experiment on the same object, and determine the reliability according to the possibility of getting the same result. The result is shown in Fig 2.

The agents in the group make different contributions and they lack enthusiasm under equalitarianism. Therefore, if the agents face an identical uncertainty, in theory, we can obtain an optimal result by using a relative performance evaluation mechanism. If the production is hard to quantify but can be compared, then we can evaluate it through a sequence competition mechanism. The incentive of the competition mechanism is no less than the observed common random factors.

5. CONCLUSION

Using an incomplete information game, this paper researches an incentive mechanism used by hi-tech firms. The paper proposes a development incentive and an internal incentive mechanism model, and conducts hypothesis verification. The verification result proves that formulating an innovative benefit distributing mechanism between the consignor and the agent (and between the members of the agent's group) is very significant: it incentivizes firms and the firm's internal personnel to undertake technological innovation and industrial upgrades, and to improve the firm's core competitiveness.

Using an incomplete information game, this paper only discusses income distribution from the perspective of an incentive mechanism. It needs further improvement.

ACKNOWLEDGEMENT:

The authors are grateful for the WR01HX1110Y16008.

REFERENCES:

1. Ziada S, Lafon P. Flow-Excited Acoustic Resonance Excitation Mechanism, Design Guidelines, and Counter Measures. Applied Mechanics Reviews, 2014, V66, #1, p. 010802.

2. Lin H, Shuhua L. Effect Mechanism of Low Quality Fly Ash in Concrete and its Excitation Mechanism. Fly Ash Comprehensive Utilization, 2015, V1, p. 15.

3. Manshaei M H, Zhu Q, Alpcan T, et al. Game theory meets network security and privacy. ACM Computing Surveys (CSUR), 2013, V45, #3, p. 25.

4. Roughgarden T. CS364A: Algorithmic Game Theory Lecture# 12: More on Selfish Routing. 2013.

5. Hanss M, Bestle P, Eberhard P. A Reproducible Excitation Mechanism for Analyzing Electric Guitars. PAMM, 2015, V15, #1, pp. 45–46.

6. Nita MA. The Importance of Image Management for a Good Society. Revista de Cercetare si Interventie Sociala, 2014, V44, pp. 308–320.

7. Xiong D R, Deng L C. A Theoretical Probe for Excitation Mechanism of Solar-like and Mira-like Oscillations of Stars. Acta Astronomica Sinica, 2013, V54, pp. 20–26.

8. Skrinjar JP, Abramovic B, Brnjac N. The Use of Game Theory in Urban Transport Planning. Tehnicki Vjesnik-Technical Gazette, 2015, V22, #6, pp. 1617–1621.

9. Huang YM, Liu L, Qi ES. Simulation on the Complementary Product Strategy Based on the Cournot-Bertrand Mixed Game Model. International Journal of Simulation Modelling, 2014, V13, #4, pp. 497–509.

Yan MAO,
she is currently working toward the Ph.D. degree in School of Economics and Management from Southwest Jiaotong University. Her research interests include human resource management

Yongjian LI,
Professor, Ph.D. Supervisor School of Economics and Management, Southwest Jiaotong University. His research interests include knowledge management, human resource management

CONTENTS

VOLUME 24 **NUMBER 4** **2016**

LIGHT & ENGINEERING

PARTNERS OF LIGHT & ENGINEERING JOURNAL

Editorial Board with big gratitude would like to inform international lighting community about the Journal Partners Institute establishment. The list with our partners and their Logo see below. The description of partner's collaboration you can found at journal site *www.sveto-tekhnika.ru*

GENERAL PARTNER

BL Group — BL GROUP holding

ITMO UNIVERSITY

PLATINUM PARTNERS

LIGHTING SOLUTIONS

enercon СОЗДАЕМ ВОЗМОЖНОСТИ

PHAROS-ALEF

ГЛОБАЛ ЛАЙТИНГ

GOLD PARTNERS

FAGERHULT

ГСТЗ г. Гагарин

ZUMTOBEL

SILVER PARTNERS

Светотехнический завод ВЛАДАСВЕТ

ВНИСИ

НИИ СП

BRONZE PARTNERS

ВНИИОФИ

TS TENZOSENSOR

СВЕТОВЫЕ СИСТЕМЫ

ЦФ

СОЛАР МАГИЧЕСКИЙ СВЕТ