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LEDS IN MUSEUMS: NEW OPPORTUNITIES AND CHALLENGES

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ABSTRACT

The national and international requirements for the lighting of museum pieces are presented based on the results of researches carried out in the second half of the 20th century and which should be actualized in connection with the introduction of LED lighting into the museums. In addition, the spectrum diversity of the LED sources needs to address the issue of changing the approach to the assessment of museum lighting, in particular, the transition to the new colour rendering indices (Fidelity Index and Gamut Index) according to the CIE, and the use of energy and/or photonic values in addition to light values.

Keywords: museum lighting, preservation of museum pieces, perception of exhibited items, LED lighting, colour rendering indices, light, energy, and photonic values

Light plays a primary role in human life and activity: at present, the functions and goals of light have gone far beyond ensuring visibility and related safety. In our opinion, the theme of lighting of museums in recent decades has been unfairly ignored by the lighting engineers. Thus, in the Svetotekhnika journal – without exaggeration, the main print medium on lighting engineering in Russia – in the last ten years no more than five articles, one way or another concerning the museum lighting and mainly telling about the experience of lighting design (e.g. [1]) have been published. A number of articles by foreign authors, in particular [2, 3], consider the theoretical principles of lighting the museum items focusing on the issues of colour rendering and visual perception of paintings.

Display of museum pieces, as well as their storage in museum collections, necessarily involves the certain light environment created by daylighting and/or artificial lighting. The museum light environment has several essential functions: provision of the opportunity to see the exhibited items for museum visitors, provision of working conditions with the exhibition and museum collection for the staff. In addition, the museum light should be as safe as possible for museum pieces, while playing an informational and artistic role in the exhibition, as well as ensuring the safety of visitors and museum staff. The inquiry of museum custodians conducted in 2014th by Pacific Northwest National Laboratory of the United States has shown that in the case of LED lighting, while energy efficiency is an important criterion in the choice of the light source, ensuring the preservation of museum pieces and exhibition aesthetics [4] have an unconditional priority.

Creating a light environment in the museum space is a complex and demanding challenge, since it is necessary, on the one hand, to ensure the full viewing and perception of the museum pieces and the creation of a sufficient level of visual adaptation and light comfort for people, and on the other hand, to minimize the harmful effects of optical radiation on museum pieces. At present, in fact, three aspects are involved in the search for the optimal solution for creating a light environment. These are:

– The museum custodian or other museum staff responsible for both the preservation of museum pieces and the lighting of the hall and exhibited

items in terms of the role of light in exhibition perception, accents, etc.;

– Lighting designer, who is responsible for ensuring the performance of artistic, navigational, and informational tasks set by the museum custodian, with the existing technical capability;

– Lighting engineer, who should be focused on the principle of "do no harm" and the compliance of technical parameters of the lighting installation with regulations and requirements to ensure its safe and effective operation.

Undoubtedly, the priority opinion should be the opinion of the museum representatives, and that is why the key aspect of the concept preparation of creating the light environment in the museum is the constant interaction of lighting designer with the customer, the search for common ground. In turn, the task of the lighting designer and the design engineer is to develop a lighting installation complying both with aesthetic requirements of the customer and safety requirements including physicochemical safety of museum pieces using modern technical means and lighting techniques.

The essential attribute of a high-quality lighting installation in the museum is the largest possible prevention of harmful and sometimes destructive effects of optical radiation, both ultraviolet and infrared, and visible, on museum pieces. In Russia, in terms of sensitivity to the effects of optical radiation, the museum pieces are divided into three categories, which are listed in Table 1. In accordance with these categories, lighting requirements are established, which are currently non-regulatory. At the same time, if we talk about Russia, most of these recommendations were developed in 1980–1990s years, and in principle, the known Russian regulations on the lighting of museums are very few [5–8]. The most cited publication on this subject prepared by the CIE was issued in 2004 [9], and given the pace of development of lighting (first of all, LED) technology in recent years, it can be assumed that the recommendations do not fully correspond to the modern possibilities of lighting engineering. The lighting requirements contained in these documents, which are compared in Table 1, make it possible to estimate the levels of lighting that provide not only the opportunity to exhibit museum pieces but also the relative safety of these pieces.

These documents were developed quite a long time ago, and all of them, including the CIE publication, considered as a light source mainly traditional lamps (incandescent lamps and, in part, fluorescent lamps and high-pressure lamps) and practically did not consider the LED sources.

At the same time, lighting devices (LD) with LEDs have already firmly entered all spheres of our life, where they are widely used. The museum lighting was not an exception, where the LEDs are being implemented, although it concerns more the foreign museums. Thus, according to the above-mentioned survey [4], in 46 museums surveyed in only two years (2009–2011) the share of the used LED devices increased from 0 to 40 %. However, more than a half (51 %) of museums surveyed still use incandescent lamps as the main lighting source. Nevertheless, the trend of increasingly intensive use of LEDs in museum lighting is undeniable and explained by the possibilities offered by LEDs. By allowing to vary not only the illuminance level, as it happens, for example, when using halogen incandescent lamps (however, with changes in the correlated colour temperature), but also spectral distribution of lighting, the LED devices can significantly facilitate the performance of exhibition and aesthetic tasks at a constant level of illuminance, which affects both the perception of museum pieces and their safety.

It should be noted, however, that it is now widely felt that in the case of LED sources the quality of lighting can no longer be measured only by traditional indicators, including correlated colour temperature and general colour rendering index. In our days, the CIE consider the introduction of new colour rendering indicators: the *Fidelity Index* and the *Gamut Index* [10]. The value of these new criteria for colour rendering evaluation was confirmed, inter alia, by a study conducted by the Technical University of Ilmenau and *OSRAM Opto Semiconductors*, which showed that there is a strong correlation between the Fidelity Index and the perceived colour difference and colour shift, and between the Gamut Index and the colour saturation [11].

Another topical issue related to the introduction of LED into museum lighting is the need for a more adequate quantitative assessment of the optical radiation effect on museum pieces. So far, light values have been used for such an assessment, which was explained by the relative immutability of the spectral distribution in the museum lighting.

Thus, today it is necessary to estimate the following light values:

Fig. 1. General view of Hall No. 277 "Art of France of the 17th century" (a) and luminance distribution across the room (b)

- Illuminance;
- Exposure;
- Colour rendering;
- Luminance distribution in the view field.

The corresponding surveys of the halls of the State Hermitage and the State Tretyakov Gallery were carried out by the VNISI named after S.I. Vavilov, as a result of which the levels of illuminance and luminance distribution were measured [12] (Fig. 1).

At the same time, the diversity of possible spectra of light sources used in museums makes it possible to remember that light values do not allow to judge the effect of radiation on the material of museum pieces. For this, obviously, it is necessary to use energy or even photonic values, such as the radiation flux in W, irradiance in W/m^2, the photon flux of radiation in photons per second, and photon illuminance or photon flux density in photons per second per m^2. The introduction of additional metrics for the evaluation of museum lighting is a controversial issue and requires both rethinking the available data and additional research.

As a result, the regulation of the museum lighting, which, in addition to the mandatory exclusion of UV and IR radiation, is currently limited to non-regulatory requirements to the lighting in lx and to exposure in lx·hour, should be supplemented by the requirements for both other photometric and colourimetric lighting parameters (correlated colour temperature and colour rendering indices) and for energy or photon parameters (energy or photon illuminance in $W \cdot m^{-2}$ and energy or photon exposure in $J \cdot m^{-2}$) and possibly spectral distribution of radiation. The relevant requirements will have to be introduced into the standards for luminaries, possibly developing a separate standard or a preliminary standard GOST R60598–2-… "Luminaries. Part 2. Specific requirements. Luminaries for museum lighting".

It is necessary to take into account the fact that in addition to the objective (quantitative) assessment of lighting there is also its qualitative assessment based on the perception of illuminated items by people, which in terms of museum items is crucial. In this part, LED devices provide unique opportunities that have already been used in many museums. As an example, the lighting of Leonardo da Vinci's painting "Mona Lisa" in the Louvre, which was developed by Faros-Alef LLC experts led by L.G. Novakovsky [13], and the lighting of the Sistine Chapel in the Vatican [3]. It was suggested that the light should display the colours of the paintings, which, as far as possible, are similar to the original ones. This means that since most paintings created before the end of the 19th century were created in daylight, the spectral distribution of the light source with T_c of 3,500 K, which is usually preferred by museum custodians, should be optimized so that the colours of the paints illuminated by the light source are similar to those of the paints illuminated by the light source with T_c of 6,500 K. The best approach, in our opinion, would be to create a standard series of LED luminaries with colour temperatures, in the range between 3,000 and 6,500 K, and to use a luminaire with adjustable colour temperature to choose the most suitable lighting for a particular exhibited item. Moreover, the museum custodians should have the last word.

It should also be noted that already today modern photometric equipment allows us to measure all parameters of lighting devices necessary to make a decision on whether to use a particular or another

Table 1. Lighting Requirements

Items	Source		
	[5]	**[8]**	**[9]***
Items insensitive to light: metal products, ceramic products; minerals (except photosensitive), jewels, glass, enamels	Illuminance is not standardized (rarely more than 300 lx required) UV and IR are not standardized (general comment on inadmissibility)	(200–500) lx UV: (20–300) μW/lx IR: (30–40) mW/lx	< 200 lx Annual exposure < 600,000 lx·hour UV and IR are not standardized (general comment on the inadmissibility of UV and the need to limit IR)
Painting works, varnishes, wood, ivory, glue paint	< 150 lx Paintings annual exposure < 650,000 lx·hour UV and IR are not standardized (general comment on inadmissibility)	(75–150) lx UV: (20–50) μW/lx IR: (30–70) mW/lx	< 50 lx Annual exposure < 150 lx·hour UV and IR are not standardized (general comment on the inadmissibility of UV and the need to limit IR)
Items especially sensitive to light: watercolours, drawings, fabrics, clothing, manuscripts, zoological and botanical collections	< 50 lx UV and IR are not standardized (general comment on inadmissibility)	(30–50) lx UV: (20–30) μW/lx IR: (30–120) mW/lx	< 50 lx Annual exposure < 15 lx·hour UV and IR are not standardized (general comment on the inadmissibility of UV and the need to limit IR)

* The CIE classification involves the separation of materials into four groups of light resistance (insensitive, low-sensitive, medium-sensitive, and high-sensitive), with the last two of the Russian classification forming a group of especially sensitive to light museum pieces

device in the museum. Modern measuring devices ensure the monitor the required parameters of museum lighting devices, namely:

- Luminous flux and luminous intensity distribution;
- Spectrum of radiation;
- Correlated colour temperature;
- Colour rendering index;
- Other photometric, colourimetric, and electrical parameters of the lighting device.

In addition, progress in measuring instruments and telecommunications allows us to provide the most significant museum pieces, and in the long run all of them, with illuminance/irradiance sensors, with their readings transferred to a single centre for monitoring the illuminance/irradiance, and exposure levels, and taking timely measures to ensure the preservation of museum pieces.

Unfortunately, few museums in our country have engineering and technical personnel with the necessary knowledge and experience to organize such monitoring, so there is a certain risk for the museums to get lighting products of inadequate quality, and even unsafe.

It is obvious that even having the necessary instruments to monitor the lighting parameters, the requirements for which are enshrined in the current (though obsolescent) regulations, today it is impossible to make an adequate evaluation of lighting installations with LED in museums, and the existing guidelines and recommendations require extensive analysis and possible revision, both in the part of the exhibition illuminance level, and in the part of the permissible exposure for a certain period of time.

In addition, it is necessary to organize a systematic survey and monitoring of the museum lighting parameters during the operation of the lighting installation, which, in our opinion, should include:

- Periodic measurement of the level of UV radiation falling on museum pieces, E_{UV}, μW/m^2;

• Periodic measurement of the level of IR radiation falling on museum pieces, E_{IR}, mW/m^2;

• Periodic measurement of the illuminance level of museum pieces, E_{LI}, lx;

• Estimation of the light exposure of museum pieces, $E_{LI} \cdot t$, lx·hour.

Knowledge of the levels of irradiance and illuminance of the E_{UV}, E_{IR}, and E_{LI} will allow us to take measures to reduce the corresponding parameter (replacement of UV or IR filters, reduction of illuminance level), and the knowledge of the light exposure will allow us to make a reasonable decision on limiting the time of display of museum pieces.

Moreover, it is worth noting that the monitoring of these parameters should be carried out strictly in accordance with the measurement methods, which are not currently standardized, not allowing to give a "legal" opinion on the condition of a facility, even when the necessary equipment and the experience of measurement operators are available.

Proceeding from this, we see as a priority the development and release of a modern regulatory document: an industry standard for lighting engineering or an appropriate guide for museum custodians, taking into account the introduction of modern light sources and technologies and incorporating techniques for lighting parameters measuring. Within the conference "Light in the Museum" held in April 2018 in St. Petersburg the representative of the Ministry of Culture of the Russian Federation declared the intention of the government to create an appropriate regulatory framework.

This task will be facilitated by the R&D "Analysis of current regulatory documents studies in order to develop the standard for the museum lighting. Basic procedure setting and research work program on the standard development", which is currently being conducted under the authority of the Ministry of Culture. The data obtained from a detailed analysis of the modern scientific and technical base will help to identify controversial and poorly studied areas, to determine the feasibility and areas of new research necessary to obtain a complete picture of the museum lighting and its peculiarities, in order to develop a standard or recommendations containing scientifically sound, modern, and adequate regulatory requirements for museum lighting.

The underlying rationale of the research is:

• Diversity of LED sources in terms of photometric, spectral, and colourimetric characteristics;

• Insufficient knowledge of the of visible light effect (as well as UV and IR radiation) on the preservation of museum pieces;

• Lack of national and interstate standards on lighting and exposure of museum pieces;

• Lack of research into existing museum lighting systems and their lighting characteristics.

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