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**Aleksandra Bartseva et al.**

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CIE Central Bureau  
Babenbergerstrasse 9  
A-1010 Vienna  
Austria  
Tel.: +43 1 714 3187  
e-mail: [ciecb@cie.co.at](mailto:ciecb@cie.co.at)  
[www.cie.co.at](http://www.cie.co.at)

## MUSEUM LIGHTING IN RUSSIA: STATE OF THE ART

**Bartseva, A.**<sup>1</sup>, Boos, G.<sup>2</sup>, Chernyak, A.<sup>1</sup>, Kuznetsova, A.<sup>1</sup>, Rozovski, E.<sup>1</sup>

<sup>1</sup> Russian lighting research institute named after S.I. Vavilov (VNISI), Moscow, RUSSIAN FEDERATION

<sup>2</sup> National Research University "Moscow Power Engineering Institute" (MPEI), Moscow, RUSSIAN FEDERATION

bartseva@vnisi.ru

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### Abstract

The report contains the analysis of answers given by 90 leading Russian museums to questions related to their lighting, as well as the results of the survey and measurements of lighting parameters (average illuminance on exhibits, correlated colour temperature, colour rendering index and luminance distribution in the field of view). It was found that in general the lighting of museums in the Russian Federation meets currently valid requirements and recommendations, and only in a few cases there is a need for radical changes. Many museums already use LED light sources and are ready to switch over to entirely solid state lighting. At the same time, as the main problem museums (primarily small ones) name the absence of modern standards and regulations in the field of museum lighting as the main problem.

Keywords: museum lighting, lighting in museums of the Russian Federation, illuminance, correlated colour temperature, colour rendering index, standards for museum lighting.

### 1 Introduction

In early 2018 VNISI initiated a research, the ultimate goal of which was the development of modern requirements and recommendations for museum lighting that could guide museum staff in their work. One of the directions of these studies was to obtain a complete picture of the current state of museum lighting on the basis of the results of the museums survey and measurements of lighting parameters made in a number of museums in Moscow and St. Petersburg.

### 2 The results of the survey

To get a complete picture of the real state of museum lighting in the Russian Federation, VNISI with the participation of the State Hermitage Museum, the State Tretyakov Gallery and the State Research Institute of Restoration (Gosniir) developed a questionnaire, which was sent to 168 museums in June 2018.

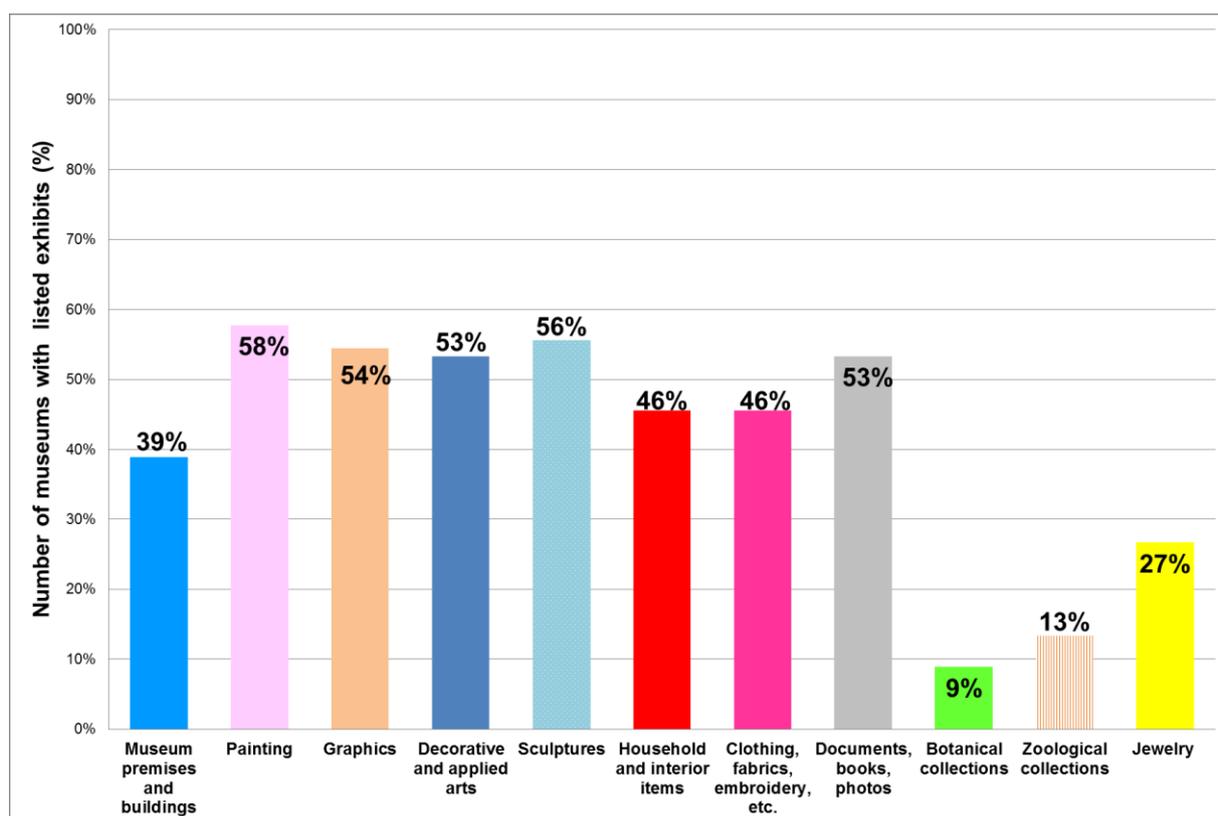
The questionnaire consisted of 13 questions aimed at museum experts with a certain level of technical knowledge such as chief curators and engineers, and due to the lack of a relevant regulatory framework in the field of museum lighting in the Russian Federation the museums responses were evaluated according to values given in the CIE 157: 2004 [1] and in several obsolete Russian documents released in 1988 [2] and 1992 [3]. The museums were asked to provide the following information:

- General information about the museum.
- Exhibited objects.
- Light sources used.
- Electrical lighting illuminance maintained level.
- The tone of the background (walls) when exhibiting museum objects.
- Background illuminance (as compared to exhibits illuminance).
- What methods of daylighting control and shielding are used in the museum?

- What lighting meters are used in the museum?
- What standards and/or recommendations are used while establishing the lighting in the museum? Evaluate their practical value according to 10-point scale.
- Do current requirements for maximum permissible lighting levels provide adequate perception and preservation of museum objects?
- What would you like to change in your museum lighting?
- Rate the need for the development of listed regulatory documents on the lighting of exhibition spaces and depositories.
- Name your wishes for museum lighting standardization.

From the museums responses it follows that:

1. Most of the museums do not have lighting professionals whose duties are mostly assigned to electricians who do not have a special lighting engineering education. At the same time, even such specialists are available only in 53 % of the museums that answered the questions.
2. In some museums, the collections are systematized on a territorial basis, and in the storage rooms and exhibition halls there is no separation of objects by light sensitivity, so that an integrated storage mode is maintained in all rooms with museum objects in them (Fig.1).



**Figure 1 – The presence of various objects in the museum collection (in % of the number of respondents)**

3. Museums use warm white LEDs (CCT 2700-3200 K) and linear and compact fluorescent lamps for general lighting of exhibition halls, and white LEDs (CCT 3200-4200 K), tungsten halogen lamps and linear fluorescent lamps (LFL) for accent lighting of museum objects. In storage facilities they prefer to use LFLs, mainly white (CCT 3200-4200 K) for general lighting and LEDs, tungsten halogen lamps or LFLs for accent lighting. The restoration workshops use white LEDs (CCT 3200-4200 K), LFLs and LEDs for general lighting and white CFLs (CCT 3200-4200 K), LEDs and LFLs for accent lighting. As for quantitative

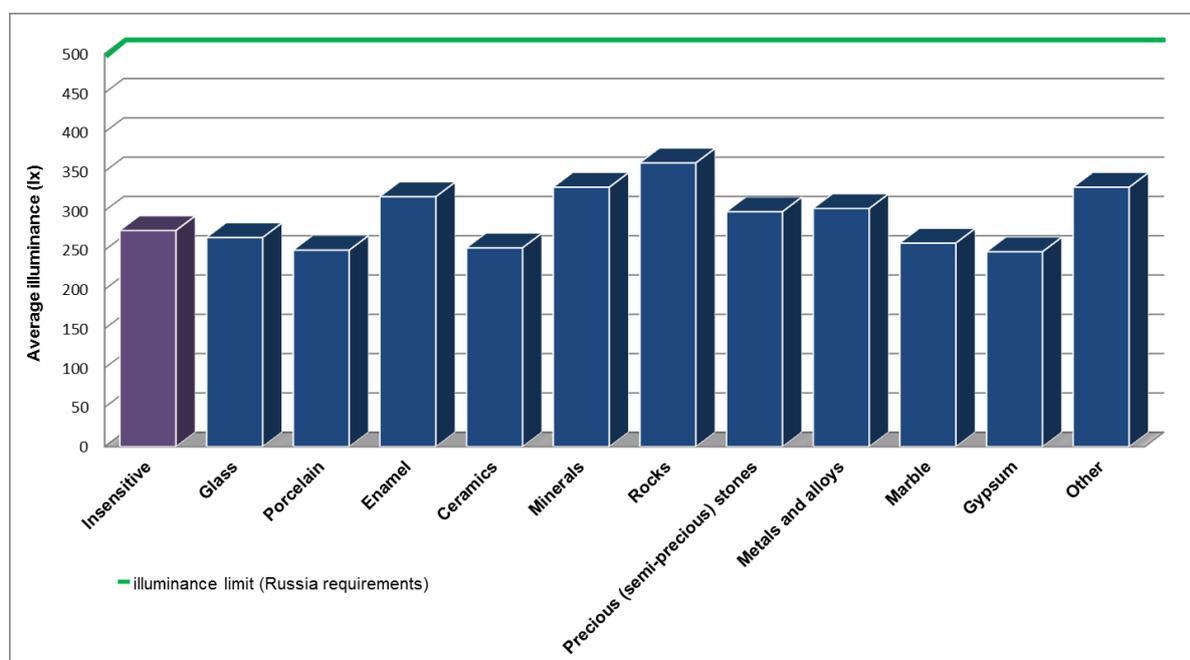
indicators of SSL introduction into museum practice, LED light sources are already to some extent used for general and accent lighting in respectively 77 and 61 % of the museums surveyed. At the same time, there are practically no museum exhibition spaces where there is no daylight, which is dangerous for works of art with high sensitivity to light. The same applies to restoration workshops and storage facilities.

4. Museum objects maintained illuminance levels were cited in relation to the classification of museum objects materials according to light sensitivity adopted in the Russian Federation, which consists of three groups:
- Group 1 (low sensitivity (high light resistance), which roughly corresponds to group I as per CIE 157:2004);
  - Group 2 (medium sensitivity (medium light resistance), which roughly corresponds to group II as per CIE 157:2004);
  - Group 3 (high sensitivity (low light resistance), which roughly corresponds to groups III and IV as per CIE 157:2004).

With regard to this classification, it follows from the answers of the museums that the recommendations for maximum permissible levels of museum objects lighting currently accepted in the Russian Federation are met in most museums, and international recommendations, less stringent for material of the 2nd group, are met almost always (Tables 1-3, Fig. 2-4).

**Table 1 – The number of museums maintaining the specified illuminance value (% of the total number of museums that answered the relevant question) and the average illuminance values (lx) for materials belonging to group 1 by light sensitivity**

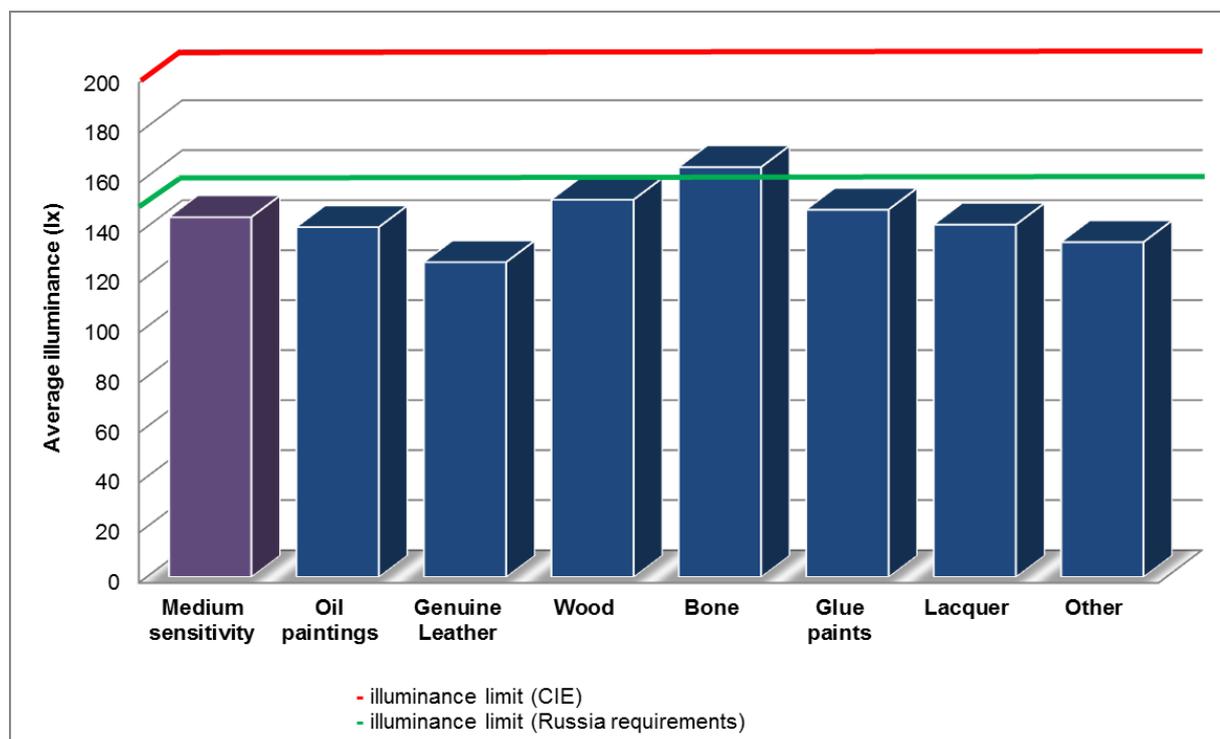
Illuminance, lx	Number of the museums, %						Average illuminance, lx
	0-100	100-200	200-300	300-400	400-500	> 500	
Group as a whole	19	27	21	9	23	1	275



**Figure 2 – Illuminance values for materials of the group 1 by light sensitivity (averaged over all respondents). The green line shows the maximum permissible illuminance level according to Russian recommendations (500 lx). As per CIE 157:2004, the illuminance is not limited for this group**

**Table 2 – The number of museums maintaining the specified illuminance value (% of the total number of museums that answered the relevant question) and the average illuminance values (lx) for materials belonging to group 2 by light sensitivity**

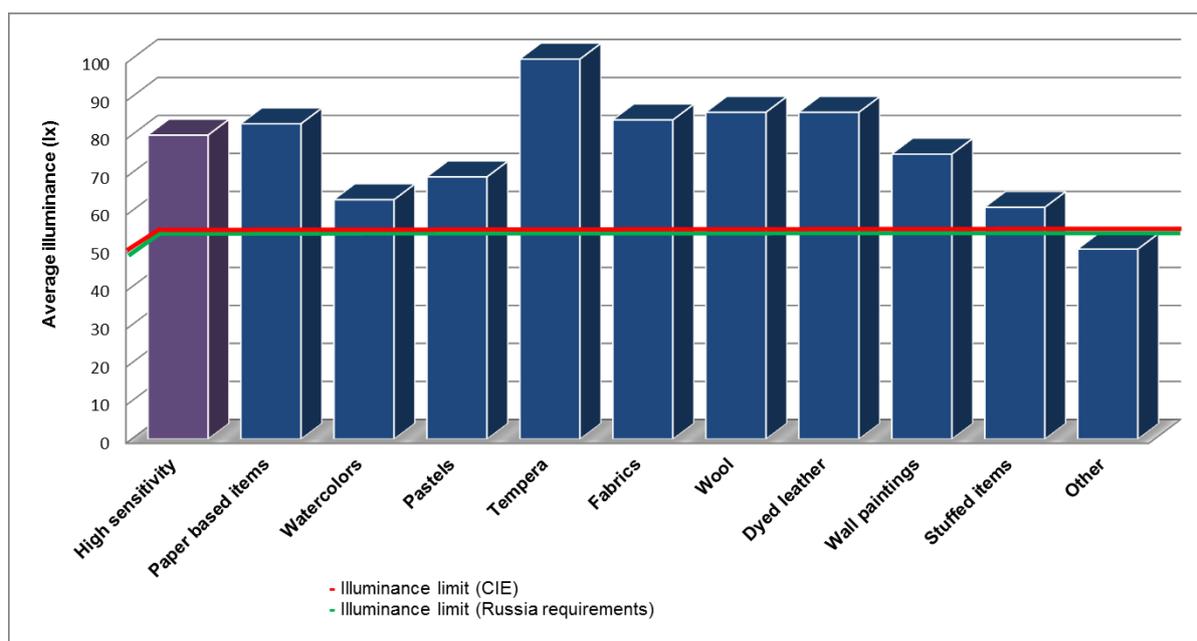
Illuminance, lx	Number of the museums, %						Average illuminance, lx
	0-100	100-150	150-200	200-300	>300	0-200	
Group as a whole	32	40	24	4		96	144



**Figure 3 – Illuminance values for materials of the group 2 by light sensitivity (averaged over all respondents). Green and red lines show maximum permissible illuminance levels according to Russian recommendations (150 lx) and to CIE 157:2004 (200 lx)**

**Table 3 – The number of museums maintaining the specified illuminance value (% of the total number of museums that answered the relevant question) and the average illuminance values (lx) for materials belonging to group 3 by light sensitivity**

Illuminance, lx	Number of the museums, %						Average illuminance, lx
	0-50	0-75	75-100	100-150	150-200	>200	
Group as a whole	51	16	16	9	6	2	80



**Figure 4 – Illuminance values for materials of the group 3 by light sensitivity (averaged over all respondents). Green and red lines show maximum permissible illuminance levels according correspondingly to Russian recommendations (50 lx) and to CIE 157:2004 (also 50 lx)**

5. In museums there are medium-tone, light and dark backgrounds, and museums would prefer backgrounds having medium, light or, to a lesser extent, dark tone. As far as preferences in the illuminance of the background and exhibit are concerned, at present the background illuminance is for the most part approximately equal to or less than the exhibit illuminance, and this relationship is considered preferable by museums.
6. Some of the survey questions were related to methods of daylight regulation and shielding, as well as methods for light measurements. From the museum responses it follows that practically all known methods are used to regulate and shield the daylight, including curtains, roll-up curtains, louvers and protective glazing. Lighting control is mainly carried out with the help of illuminance meters, with which 34 % of the total number of museums surveyed are equipped. UV meters, colorimeters and spectroradiometers are used by, respectively, 4, 3 and 2 % of museums, and only one museum has a centralized lighting monitoring system. At the same time, it is noted that the lack of necessary gaged meters is due to limited funding.
7. As far as lighting is concerned, museums mainly use a practical manual issued by the State Research Institute of Restoration in 1995 (38 % of museums) and the already inactive Order of the Ministry of Culture of the Russian Federation of December 8, 2009 (33 % of museums). The practical value of these documents was evaluated according to a 10-point scale as 9.3 and 8.3, respectively. Most of the museums surveyed believe that the existing requirements for the maximum permissible levels of illuminance provide adequate perception and preservation of museum objects in the exhibition halls, restoration workshops and depositories. However, about half of the respondents either found it difficult to judge whether current requirements for maximum permissible lighting levels provide adequate perception and preservation of museum objects or believe that they don't provide it, which indicates the need to make changes in existing requirements.
8. Museums expressed the following wishes for changes in the existing lighting systems:
  - 40% of museums want to replace electric light sources that provide general and accent lighting in exhibition premises with LEDs. They are also in need of linear LED light sources with individually tailored hues and high luminous efficacies.
  - 11% of museums want to exclude natural light in the exhibition premises.

- 30% of museums want to replace electric light sources providing general lighting in depositories with LEDs.
- 18% of museums want to replace electric light sources that provide accent lighting in depositories with LEDs.
- 4% of museums want to exclude natural light in depositories.
- 26% of museums want to replace electric light sources providing general lighting in restoration workshops with LEDs.
- 19% of museums want to replace electric light sources that provide accent lighting in restoration workshops with LEDs.
- Almost all museums suggest to rate not only the illuminance, but also the annual exposure for different materials.
- Some museums expressed the need for a training seminar on lighting for chief curators.

In addition, the surveyed museums pointed out the necessity of developing a number of documents that would contain requirements and recommendations in the field of museum lighting, namely:

- A standard "Museum lighting. General specifications".
- A standard "Museum lighting. Methods of measurement of lighting parameters".
- Guidelines for the use of LED light sources and luminaires in museums.

The development of the documents listed above should begin with the development of a unified system for measuring lighting characteristics and criteria for the selection of the necessary equipment that meets the realities of the modern world. As part of this work, it is necessary to conduct experimental studies to obtain objective data for modernization of the museum lighting requirements.

### **3 Measurement results**

To clarify the picture of the current state of museum lighting in the Russian Federation, overviews of lighting and measurements of lighting parameters were carried out in the State Hermitage Museum, the State Tretyakov Gallery, the State Museum of Fine Arts named after A.S. Pushkin, the State Historical Museum, the Museum of the Patriotic War of 1812 and the Alexander Shilov Gallery, as well as in the St. Nicholas Church in Tolmachy, which is a temple-museum and the State Tretyakov Gallery's home church, and in the All-Russian Art Research and Restoration Center named after Academician I.E. Grabar (Moscow).

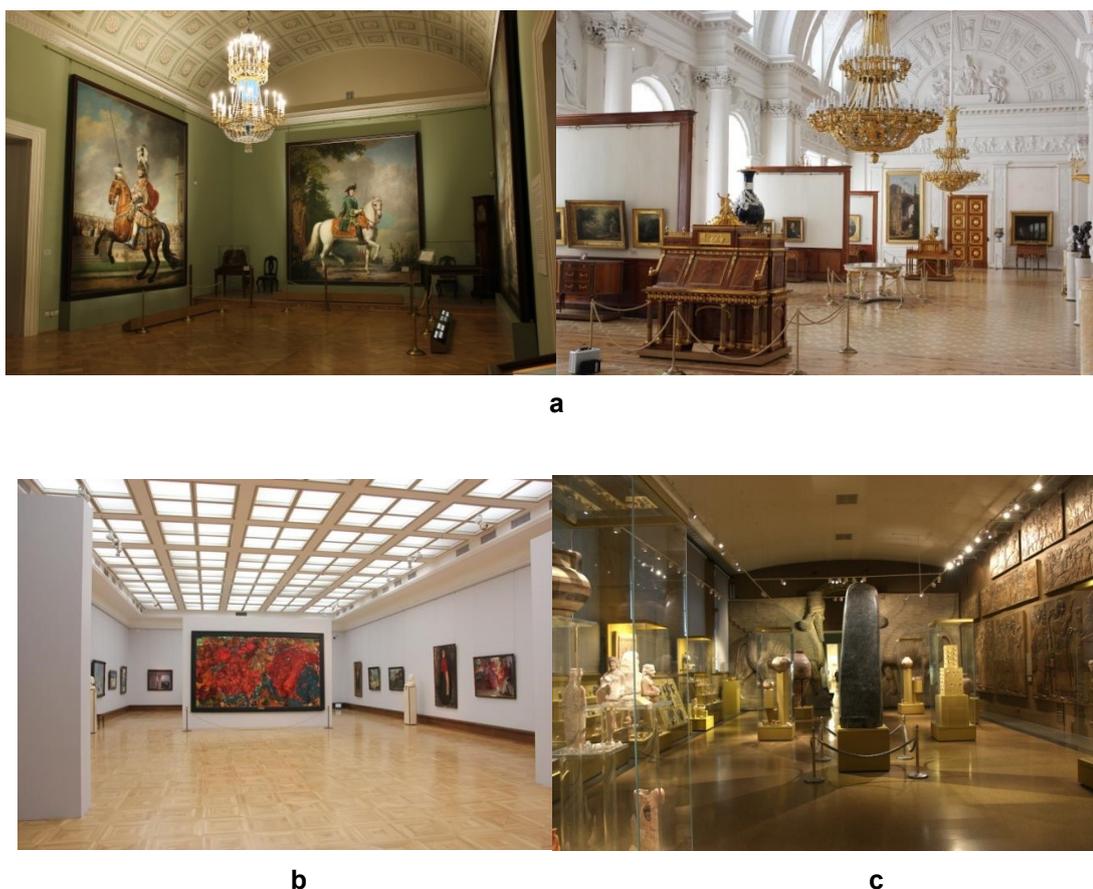
The following parameters were measured:

- average illuminance on the exhibits and in the halls;
- illuminance uniformity;
- correlated colour temperature;
- colour rendering index;
- luminance distribution in the field of view of the observer.

At the initial stage, in addition to photometric quantities measurements, we measured UV radiation levels and temperature distributions over paintings surfaces that show the degree of paintings heating due to irradiation. Later these measurements were not carried out because of infinite small differences between paintings temperatures and the ambient temperature and negligible levels of UV radiation as a result of the presence of protective films on the windows and relevant choice of electric light sources.

The museums where the survey was conducted differ significantly from each other in the interiors of the premises for the demonstration of artworks, mainly paintings and drawings, and accordingly in their lighting systems. For example, the State Hermitage Museum is a complex of palace halls, outstanding in architecture and decor, and therefore it is a work of art by itself, whereas the State Tretyakov Gallery, the State Historical Museum and the Alexander

Shilov Gallery are specially created to demonstrate painting and graphics, and natural light is significantly limited or absent in them (Fig. 5, a-c).



**Figure 5 – Examples of lighting in the State Hermitage Museum (a), the State Tretyakov Gallery (b) and the State Museum of Fine Arts (c)**

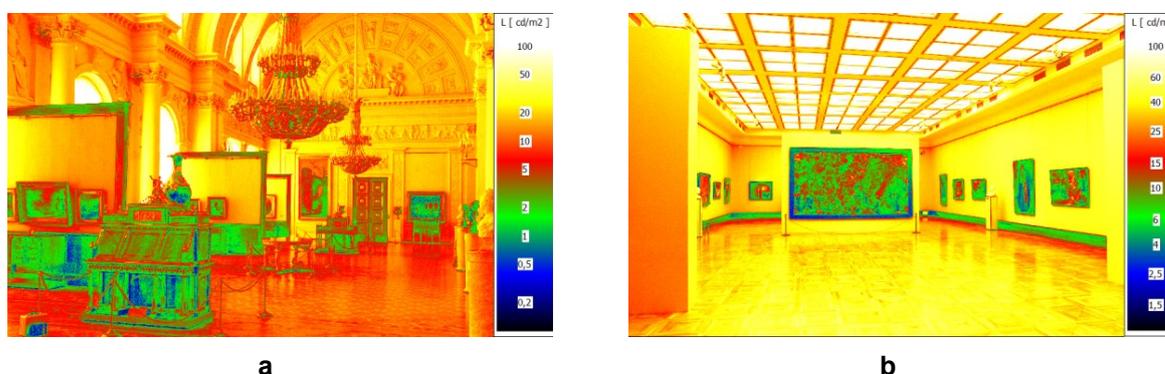
As a result of the survey, it was found that the use of luminaires with tungsten halogen lamps prevails in museums, followed by linear and compact fluorescent lamps. At the same time, there is a tendency to switch to LEDs. For example, in the State Hermitage Museum, which is the leader in the perfection of lighting systems, the transition to such light sources has already been carried out for more than 15,000 (25 %) light points.

When measuring the average illuminance on the painting surface, the classical method of measuring the illumination at different points of the picture with an illuminance meter was used (Fig. 6). It should be noted that when measuring the illuminance levels on museum exhibits, especially paintings, it is very important to determine the zones and levels of possible local "overexposure". This requires measuring light at as many points as possible, which can be quite difficult and does not always guarantee that the "dangerous" area will not be missed. It is especially difficult to fix the maximum value of illuminance for the upper part of large-size paintings and paintings suspended high above floor level (Fig. 6,a). Therefore, quite an urgent task is the use of measuring equipment and measurement methods, allowing to obtain the distribution of light over the illuminated area of the museum exhibit at once. The emergence of new measuring instruments – imaging luminance meters – makes it possible to solve this problem but requires the development and approval of new methods of measurements.



**Figure 6 – The process of measuring the average illuminance by the classical method in the State Hermitage Museum (a) and the location of control points on the picture (b)**

The results of the measurements showed that exhibits average illuminance values do not exceed the recommended levels in the most of the surveyed museums, and that the overall luminance distribution in the field of view of observers is good enough (Fig. 7). At the same time, in the State Tretyakov Gallery there is an excess of illumination of certain parts of some paintings due to uneven lighting, while in The State Hermitage Museum and the State Historical Museum some paintings are illuminated insufficiently. In the Museum of the Patriotic War of 1812 with its solely LED lighting there were identified local overexposures of exhibits and cases of significant, up to thirty-fold, differences in luminance in the field of view of the observer. In the State Museum of Fine Arts exposition lighting is fully consistent with the requirements, although in some cases the level of illumination is intentionally set too high for a better perception of the paintings by viewers.



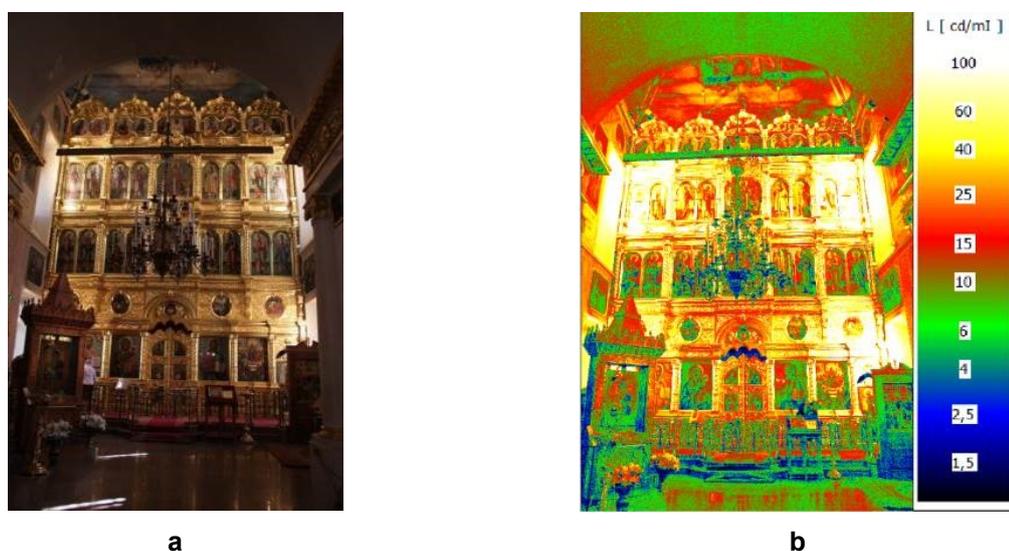
**Figure 7 – Luminance distribution (in pseudo colors) in the halls of the State Hermitage Museum (a) and the State Tretyakov Gallery (b)**

It should be noted that the diversity of museum collections often greatly complicates the installation of lighting. As an example we can mention the showcases of the State Hermitage Museum's hall No. 223 one of which contains glass and bronze items (exhibits that are not sensitive to light), and the other – openwork fabrics (exhibits that are highly sensitive to light with rated illuminance less than 50 lx). These showcases are placed opposite each other and have very different lighting levels.

The values of CCT of museums electric lighting did not exceed 4000 – 4200 K, while the values of CRI were usually more than 90.

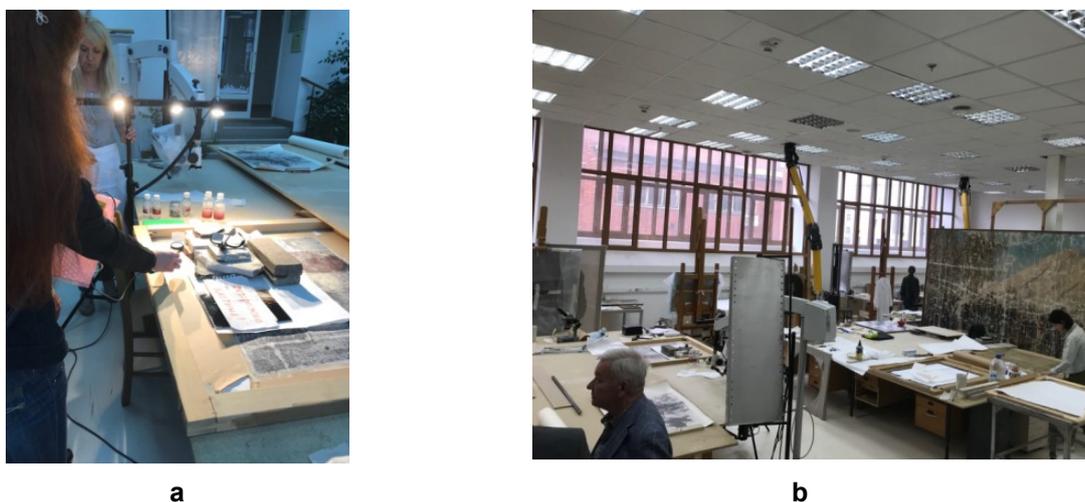
Only the St. Nicholas Church in Tolmachy stands apart from the generally auspicious picture – premises with high ceilings and unshielded windows without protective UV-films. Electric lighting of the interior, certain icons and the iconostasis is carried out by floodlights with

tungsten halogen lamps with power up to 500 W, and in the daytime when the daylight and electric light act simultaneously there is a significant overexposure of icons with the formation of glare (Fig. 8). Currently the church lighting is under reconstruction, including the transition to LEDs.



**Figure 8 – Lighting of the iconostasis of the St. Nicholas Church in Tolmachy: photo (a) and luminance distribution in pseudo-colors (b)**

Daylight is widely used in the restoration rooms of the All-Russian Art Research and Restoration Center and the State Hermitage Museum for a more accurate colour rendition and perception of museum exhibits under restoration. In the restoration center the work with objects having different light sensitivities is done under different light sources, including LEDs, which create the lighting necessary for accurate work and comfortable for restorers (Fig. 9). When working with paintings the light levels do not exceed 300-400 lx.



**Figure 9 – Lighting of the restorer's desktop (a) and general lighting of the room for restoration work (b) in the All-Russian Art Research and Restoration Center**

#### 4 Conclusion

Many museums already use LEDs as light sources and are ready to switch entirely to LED lighting. At the same time, the main problem of most museums is the lack of modern standards in the field of museum lighting, taking into account the emergence of new light sources (LEDs) and luminaires.

Accordingly the main task based this survey and research work is the modern standard for museum lighting development including LED-luminaries and lamps. In order to solve this task we need:

1. To investigate the influence of the spectral composition and the level of LED lighting on the perception of museum objects (oil painting).
2. To conduct an experimental study of the effect of the spectral composition of LED lighting on the deterioration of museum objects.
3. To study the ways of practical usage of imaging luminance meters for measuring the illuminance distribution on museum exhibits.

The results of the work and the proposed areas of research were discussed by the Scientific and Technical Council of the Russian Lighting Industry NTS "Svetotechnika", which includes representatives of both leading Russian scientific, educational, industrial and trade organizations in the field of lighting and the largest Russian museums, and received a positive assessment.

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