Current status, problems and prospects of the metrological support of brightness measuring instruments

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Introduction

Currently, the brightness measuring instruments (MI) are in the center of focused attention from the quality services, product certification bodies, expert and laboratory centers, occupation and safety monitoring services. Therefore, the demand for these MI tends to constant growth. Most brightness meters are registered in the State Register of measuring instruments and subject to verification (calibration). However, metrological support of brightness MI is a quite difficult task. Despite the fact that the developed methods of verification (calibration) quite clearly describe the procedure itself, instrumental implementation and various technical design of brightness MI, in particular angle of "view" of the photometric head lead to apparent discrepancies in the transition from an ideal Lambertian surfaces to real objects. This paper highlighted the key issues arising from brightness meter calibration and brightness measurement. It is shown that the attachable brightness meter angle of "view" is one of the essential factors affecting the accuracy of readings. The methods to account for this factor are provided.

Brightness is a physical quantity that is numerically equal to the ratio of luminous intensity of the surface element to its projected area perpendicular to the direction in question. Another definition: brightness is a ratio of illuminance in the point of plane perpendicular to the source direction to the elementary solid angle that encloses the flux creating this illuminance. The unit of the brightness in the SI system is the cd/m^2.

Of all the luminous quantities the brightness is most directly linked with visual sensations since the illuminance of object images on the retina is proportional to the brightness of these objects. Brightness in the photometry is determined by brightness meters, the most common among them are the photoelectric brightness meters that implemented the principle of conversion of the photocurrent into the detectable electrical signal.

The brightness meters may be divided into two types by the measuring method: attachable and projection. In the case of attachable brightness meter, when measuring the photometric instrument head is positioned close to the measured object. This method is useful in measuring the brightness of extended self-luminous objects such as light boards, display screens and cathode ray tubes. The projection brightness meters include the instruments for measuring the brightness of objects located far enough from the operator. Such instruments in contrast to the first type instruments can be used for measuring the brightness of both self-luminous and non-self-luminous objects. Most commonly, the projection brightness meters are used to measure the brightness of distant and non-self-luminous objects: signal lights, lanterns, cinema screens, etc. This type brightness meters are generally provided with imaging device for display of the measured object and measured brightness values.

Today the following attachable brightness meters are the most widely used in Russia (according to our sources, more than 90% market coverage): Argus-02, Argus-12 (FSUE VNIIOFI, Moscow), luminance meter TKA-PKM model 02 and TKA-04/3 (STP TKA LLC, St. Petersburg) and multi-channel measurement systems Ekolight and Ekofizika (Ekosfera LLC, Moscow). These measuring instruments are registered in the State Register of MI and have similar metrological characteristics: brightness measuring range 10 to 200,000 cd/m^2, relative error ±10%. Due to their relative simplicity and ease of use these instruments have found wide application in all areas of the economy.

Despite the similarity of the technical and metrological characteristics of the brightness meters and their areas of application, the design of the photometric instrument heads of different manufacturers differ significantly. In particular such an important parameter as the angle of "view", which characterizes the spatial angle of ray collection, can vary quite widely: from ~180 to 8 degrees. As a result the readings of such measuring instruments for a variety of objects of practical importance (LCD monitors, negatoscopes, etc.) can be significantly inconsistent with each other. For example, the readings of brightness meters Argus-02 and Ekolight successfully passed verification when measuring the brightness of the LCD monitor screen (and this is one of the main measurement objects for these instruments) may differ 1.5-2 times depending on the type of monitor. The difference between the readings of instruments manufactured by company STP TKA LLC and the brightness meter Argus-02 is less significant but in some cases it can exceed the error of these instruments. The difference between readings of different types of MI was repeatedly reported by the users of brightness meters. It stands to reason that this problem is of methodological nature and is associated with features of both the instruments and the measurement objects.

Let us consider in more detail the design features of various types of brightness meter, their process of verification and the characteristics of some self-luminous objects.

GOST 8.665-2009 “State system for ensuring uniform measurement. Light meters and photoelectric brightness meters. Verification technique.” is the main regulatory document establishing the methods and verifying instruments of photoelectric brightness meters (and light meters). The technique for verification (calibration) of the brightness meters used as working MI uses the photometric bench as the main installation consisting of the photometric lamp (emission source) and photometer separated by an opaque screen, in the hole of which is fixed a "milk" glass (light diffuser) bounded by a circular aperture (Fig. 1).

SIS type lamp (1) illuminates the "milk" glass (2) creating a uniform brightness field on the opposite side of the glass. If the aperture diameter is *d* then the reference photometer must be placed at a distance

$$r_2 > 10d \qquad (1)$$

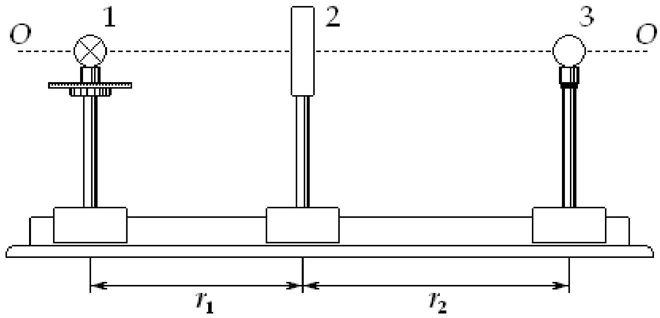

Fig.1. Installation for the brightness meter verification on the photometric bench: 1 - SIS type emission source; 2 - opaque aperture with "milk" glass, the center of which coincides with the axis OO′; 3 - reference photometer

The reference photometer measures an illuminance *E*, created by a luminous "milk" glass disc at the point (3). The actual value of the brightness of the surface of the "milk" glass is calculated by the formula (1):

$$L = 4\,E\,r_2^2 / \pi d^2 \qquad (2)$$

It should be noted that this technique has certain limitations as it allows to determine the brightness of the "milk" glass only in the direction of the photometer that collects light from an angle less than 6 degrees in accordance with the condition (1). Brightness of the "milk" glass in other directions may differ significantly from the front brightness measured using this method. To prevent this from happening the GOST 8.665-2009 recommends to use as a "milk glass" the glass with the light scattering characteristics close to the ideal Lambertian ones, e.g. MS-13 grade glass 2-3 mm thick or a spherical integrator, a special device allowing to receive brightness indicatrix close to ideal.

According to [1], all brightness meters are adjusted before release using such "ideal" source of brightness and thus work quite well for objects with the light scattering characteristics close to ideal. However, an even distribution of brightness is rather the exception. In actual practice, the object brightness is largely dependent on the direction, in particular in the case of extended self-luminous objects such as a various screens, displays, scattered light sources i.e. just those objects, the brightness of which is to be measured using the attachable brightness meter. For example Fig. 2 shows typical brightness indicatrices of the "milk" glass MS-13 (1), LCD monitor (2) and the domestic "milk" glass (3) obtained by etching the surface of ordinary glass.

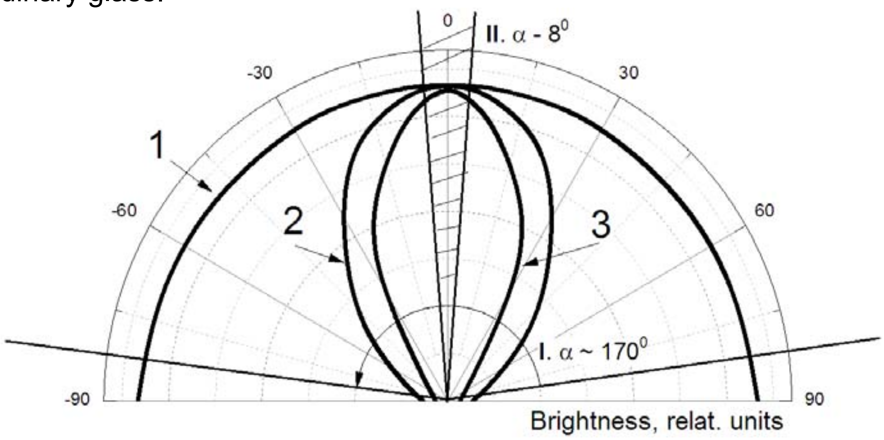

Fig.2. Typical brightness indicatrices of: 1 - Lambertian light source (brightness does not depend on the direction), 2 - surface of LCD monitor, 3 - poor quality "milk" glass. Roman numerals indicate the angles of view of the brightness meter types: I - Argus-12, Ekolight, II - Argus-02.

The sectors I and II in the same figure designate the angles of "view" of the different type brightness meters. This significant difference in the angles of view is due to design features of their photometric heads. Argus-12 and Ekolight type brightness meters uses the light meter photometric head having an angle of view of about 180 degrees as a brightness meter sensor according to GOST 8.665-2009. In fact, these instruments measure not the brightness but illumination near the surface of a self-luminous object. Their operation is based on the fact that in the case of an infinite uniformly luminous plane, the brightness of which does not depend on the angle of view, the following formula holds true [2]:

$$L = E/\pi, \qquad (3)$$

However, this formula for the majority of real objects does not work because their brightness indicatrix differs significantly from the ideal (Fig. 2, curves 1 to 3). Thus, the scope of application of these instruments is substantially limited, however, this restriction is not specified in their operational and technical documentation.

The brightness meters of STP TKA have a slightly larger angle of view (10 to 15 degrees; this characteristic is not specified in the operational and regulatory documentation and calculated approximately on the basis of the geometry of photometric head) that in the case of a narrow direction pattern at the light source may result in significant additional error.

Argus-02 type brightness meters among the brightness meter models considered here to the maximum extent corresponds to the brightness measurements of the reference photometer according to the diagram in Fig. 1 regardless of the type of diffuser used as a source of brightness because they have the smallest angle of view of 8 degrees according to the data sheet.

In our opinion, the optimal angle of view for the attachable brightness meter shall be about ~6 to 8 degrees as this angle to the maximum extent corresponds to the method of determining the maximum brightness with a reference photometer. A further decrease of the angle of view is not justified since it would lead to a substantially increased design complication and additional cost of the brightness meter (lens use is required).

Since GOST 8.665-2009 is a fundamental regulatory document for verification of photoelectric brightness meter to solve the above referenced problems it seems appropriate to amend it as follows:

1) to introduce a concept of attachable brightness meter;
2) to set the optimum angle of view for these MI;
3) to add a control of photometric head angle of view as a mandatory procedure for initial verification.

The existing verification (calibration) procedure developed by individual brightness MI manufacturers shall be also revised similarly to GOST 8.665-2009.

Thus, the angle of view of the brightness meter is an important parameter for the proper measurement of brightness of the self-luminous extended objects and shall be indicated in the operational and technical documentation and obligatorily taken into account when registering the MI in the State register and during verification (calibration).

References

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