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An apparatus for measurement of photoelectric receptor parameters

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A laboratory device for the measurement of photoelectric receptor parameters was used to obtain the receptor current characteristics, such as: functions of load resistance, illumination ranges, dimensions and position of light spot on receptor surface. The above measurements are carried out to choose the type of the receiver and to define its working regime for particular applications. The device constructed on the basis of light flux summation has an optical system which eliminates scattered light and provides uniformity of illumination and flexibility of changing light spot dimension.

1. Introduction

Radiometric properties of photoelectric radiation receivers depend on the way of their application in measurement device. In particular, they depend on load resistance, illumination range, uniformity of surface illumination, dimension of light bunch and the position of the detector surface; but not all the above data are given by the producer. In general, radiation detectors comply with radiometric requirements in limited scopes, so before an application they should be investigated to choose the range of application and to make the necessary corrections of the error.

Among the methods for investigations of photodetector luminous characteristics [1], that is, electric current response of photodetector vs. illumination level, summation of light flux is a fairly common one. In construction of the equipment used in this method some difficulties can occur connected with elimination of scattered light, with keeping a uniform illumination of detector surface, as well as with the regulation of light spot area on the detector surface, etc.

The worked out way of light flux summation allows us to avoid these difficulties. A model of relevant measurement apparatus was made.

2. Construction of the apparatus

The summation was performed by using a patented optical arrangement [2] positioned between an illuminant (8) with sources of component light and a photoelectric detector (4) under investigation.

The optical arrangement (Fig. 1) consists of an objective (1), diaphragm (2), convergent lens (3), a nest (9) for an optical filter and a grip (6) for the detector investigated (4). The arrangement provides a uniform light spot at the exit plane (4), independently of the degree of uniformity of luminance distribution on the light source surface and of its distance from the objective (1), provided that it is greater than the distance defined by objective focal length.

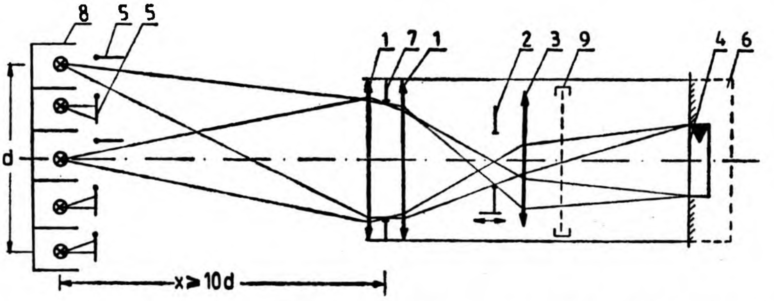

Fig. 1. Scheme of the apparatus for measurement of photoelectric receptor parameters. 1 – objective, 2 – adjustable diaphragm for limiting the field of view of optical arrangement, 3 – concentrating lens, 4 – plane of the receptor under measurement, 5 – shielding plates, 6 – adjustable grip for the receptor investigated, 7 – adjustable entrance diaphragm, 8 – illuminant, 9 – nest for an optical filter

The operation of this arrangement consists in the fact that the opening of the whole aperture diaphragm (7) is uniformly illuminated in its cros-section by a light source positioned in front of it. That should be equally true for the separate light source of the illuminant (8) and for all the sources emitting the light simultaneously. It is known [3] that at the distance from an incandescent noncollimated light source exceeding more than 7 times its diameter, the relative deviation from uniformity of the illuminance results in error lower than 0.5%. At the same time the nonuniformity of the illumination originating from the particular light source shifted from the axis by maximum 3.57 degree is lower than 0.8%. The error of nonuniformity can be reduced by increasing the axial distance between light source and the optical arrangement. The lens (3) gives the image of the uniformly illuminated diaphragm (7) in the plane of investigated detector surface.

The diameter of the diaphragm (7) image (i.e., the diameter of light spot on the investigated detector) can be controlled by changing the diameter of this diaphragm. Diaphragm (2) mounted in the image plane of the objective (1) limits the field of view of the device, thus the scattered light originating from behind the illuminant does not reach the detector surface. This diaphragm can be replaced by the mask with holes in places of image of light sources. It further diminishes the scattered light from the illuminant (8).

The light spot on the detector surface is shifted by mounting the detector in a grip of an adapted microscopic *cross table*.

The illuminant arrangement consists of five separated light sources (two sets are used alternatively — an incandescent lamps, set I, or a water cooled tungsten-halogen lamp, set II) mounted in a housing, each of the sources being screened separately with shielding plates (5). The housing with the sources being mobile allows a continuous adjustment of the illumination level at the exit surface (4) of optical arrangement in the range 1 : 25. Step regulation is done by replacement light source set by using grey filters mounted in grip of the optical arrangement. It is possible to use an additional monochromatic source realized by SPM-2 monochromator with incandescent illuminant or by a wedge interference filter with high intensity incandescent source.

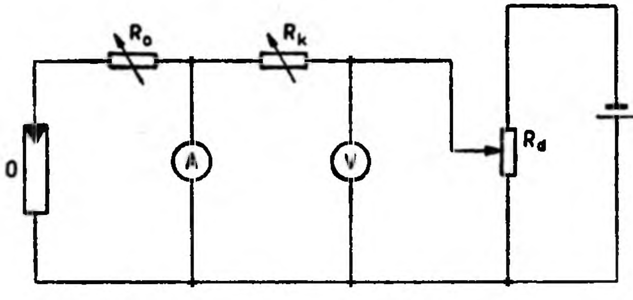

Fig. 2. Scheme of circuit for measuring the photoelectric receptor current. R_0 — load resistance, R_k — compensating current resistance, R_d — tension divider, B — high capacity battery, A — ammeter, V — voltmeter, O — receptor to be measured

Electric circuit for measuring the current of the detector is a compensating system (a scheme is presented in Fig. 2).

3. Parameters achieved

i) *General data* — range of illumination: 0.2–600 lx, diameter of light spot: 3–50 mm, supply stability: 0.1 %, accuracy of positioning light spot on the detector surface: 0.1 mm.

ii) *Illuminant data*:

— sources, set I — calibration: colour temperature 2850 K or equal intensity of each source,

— sources, set II — calibration: colour temperature 2350 K or 3150 K, cooling with running water,

— option with a monochromatic source (operating together with set I): a. SPM-2 monochromator with incandescent illuminant, b. Carl Zeiss wedge interference, Jena, WG17 filter with lamp.

iii) *Measuring circuit data*: R_0 — 0–10 kOhms, R_k — 0–1.111 MOhms, R_d — 10 kOhms, compensating current — 10^{-8}–10^{-3} A.

4. Results of photoelectric receiver investigations

The model of the apparatus presented in Figure 3 is employed mainly to control the quality of selenium photovoltaic cells used in manufacturing of optical radiation meters. The following features of these detectors are to be investigated: i) linearity of luminous characteristics, ii) luminous sensitivity,

iii) spectral sensitivity. For example, selenium Sangana-Weston photocells, used in our investigation, having the diameter of active area $\varnothing = 40$ mm, retain, in general, linearity of luminous characteristics within photocurrent range of 0–100 μA, although in some photocells the deviation from linearity exceeds 5%. The same type of electrocell receivers does not retain linearity of their

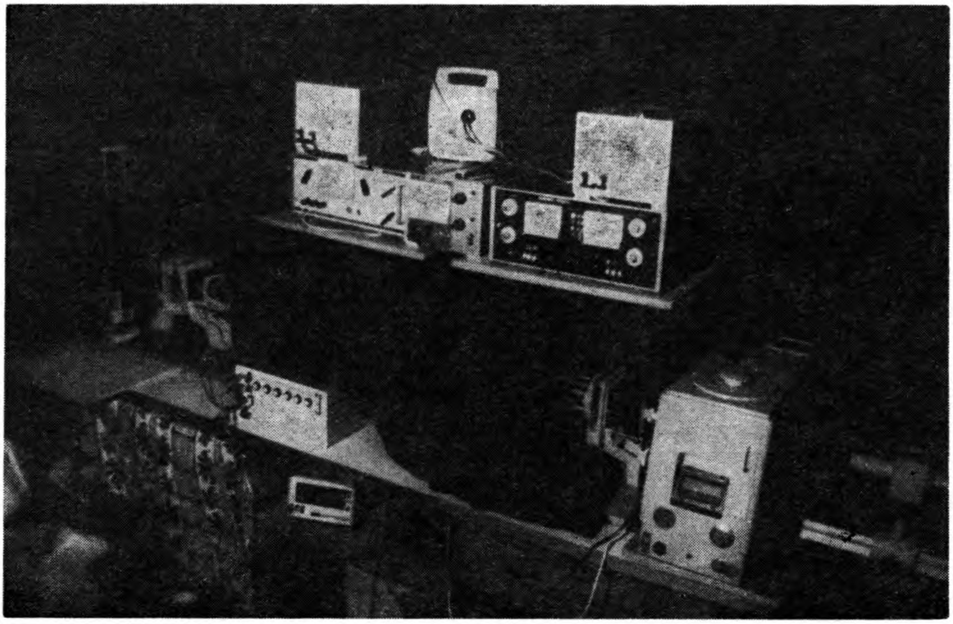

Fig. 3. A model of apparatus for measurement of photoelectric receptor parameters

luminous characteristics even at low photocurrents, while their sensitivity incerases with illuminance up to the point, where this increase is compensated by the fatigue effect. Similar compensation can be achieved in a given measurement range by selecting the best load resistance. This is illustrated in Fig. 4, where the deviation from linearity is shown for two illumination levels of about 2 lx and 90 lx.

The deviation was computed from the formula

$$\delta = \frac{a_i - \sum_{k=1}^{i} a_{i,k}}{\sum_{k=1}^{i} a_{i,k}} 100\,\%, \qquad i = 1, 2, \dots, 5$$

where a_i — indication reading of photocurrent for i sources illuminating detector simultaneously,

$a_{i,k}$ — indication reading for a k-th simple source illuminating detector.

For both illumination levels applied at short-circuit current ($R_0 = 0$ Ohms) the deviation from linearity occurs in positive direction (increase of sensitivity

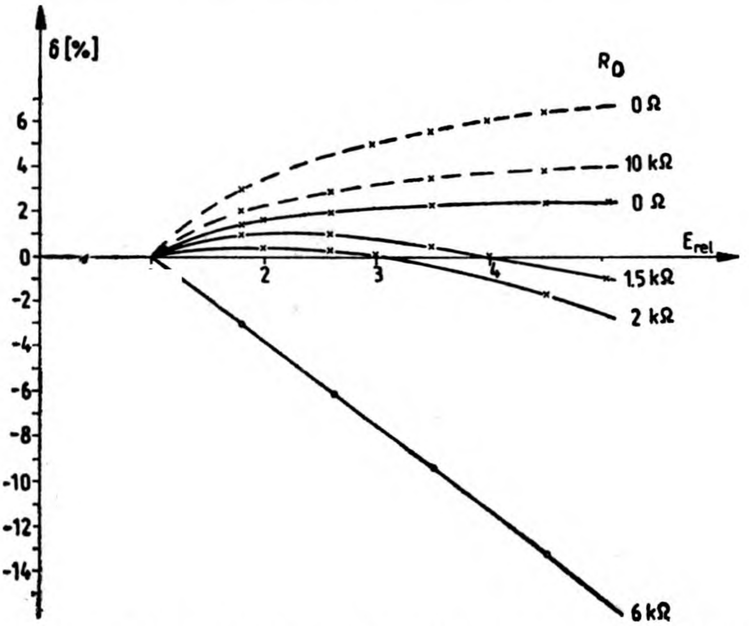

Fig. 4. Percentage deviation (δ) from linearity vs. relative illumination (E_{rel}) of selenium photoelectric cell at two illuminant levels: about 2 lx — dashed curves, about 90 lx — continuous curves (R_0 — load resistance)

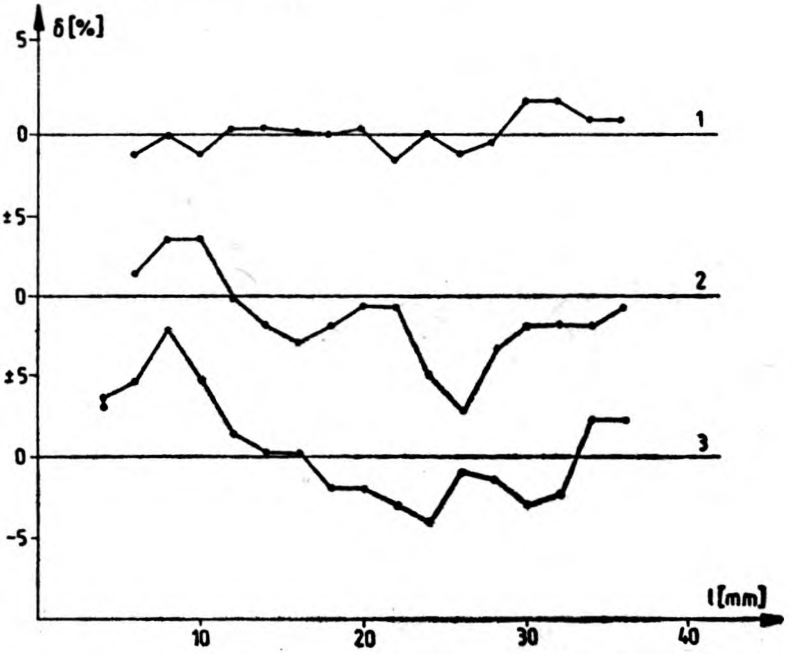

Fig. 5. Relative local luminous sensitivity distribution of selenium photocell (percentage deviation δ from the mean value) vs. the distance from the receptor edge, for three measurement lines: 1 — 4 mm above the horizontal diameter, 2 — along the horizontal diameter, 3 — 4 mm under horizontal diameter

with the increasing illumination). Increasing load resistance produces the deviation in negative direction, which allows a linearization of luminous characteristics by selecting a proper load resistance for each range of illumination. It follows from the graph (Fig. 4) that for the illumination level of 90 lx the most advantageous resistance is 1.5 kOhms.

A surface distribution of local luminous sensitivity, expressed in terms of percent deviation from the mean value measured for this type of photocell, is presented in Fig. 5.

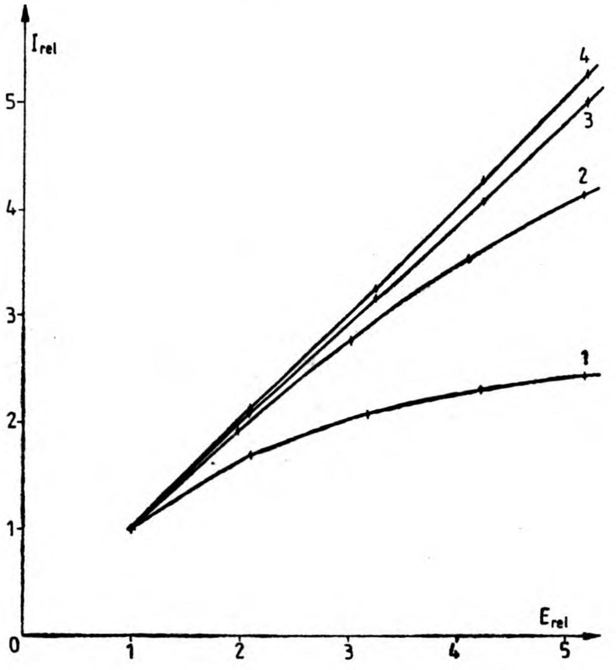

Fig. 6. Relative photocurrent (I_{rel}) of silicon photocell vs. relative illumination (E_{rel}) for different load resistance (R_0) and area illuminated. 1 — R_0 = 10 kOhms, Ø = 20 mm, 2 — R_0 = 10 kOhms, Ø = 10 mm, 3 — R_0 = 2.5 kOhms, Ø = 20 mm, 4 — R_0 = 0 Ohms, Ø = 20 mm

Linearity of luminous characteristics of silicon photoelectric cell proved to depend on both the area illuminated and on the load resistance (for results see Fig. 6). With the higher load resistance the higher nonlinearity increases. At the same illumination and resistance values, the linearity improves with diminution of the area illuminated.

5. Conclusions

To avoid serious measurement errors in applications of photoelectric receivers to the measuring devices, the receivers should be investigated in conditions possibly most similar to those of their real application (the way of surface illumination, load resistance, range of illumination).

It has been observed in such investigations that the use of optical arrangement for summation of light bunches described above, is particularly advantageous. It allows us to measure linearity of luminous characteristics in different conditions of surface illumination, load resistance, and to measure distribution of local luminous sensitivity and spectral luminous sensitivity at different levels of illumination. In such a way, the best work conditions for desired scope of application can be selected.

References

[1] Sanders C. L., Appl. Opt. 1 (1962), 207.
[2] Mańk A., Patent PRL No. 61389, 1968.
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Прибор для измерения параметров фотоэлектрических приемников

Лабораторный прибор для измерения параметров фотоэлектрических приемников предназначен для определения токовых характеристик приемника в зависимости от резистанции нагрузки, пределов освещенности, а также геометрических размеров и позиции светового пятна на поверхности приемника. Эти измерения проводятся с целью выбора типа приемника и определення условий работы для данного применения. Прибор, использующий принцип суммирования световых потоков, имеет оптическую систему, которая исключает рассеянный свет и обеспечивает однородную освещенность светового пятна, а также дает возможность регулировкн размеров пятна.