Light & Engineering
Vol. 3, No. 1, pp. 19-23, 1995
UDC 535.247:681.327.12

Svetotekhnika
No. 1, pp. 7-9, 1995

MICROCOMPUTER-CONTROLLED SPIRAL PHOTOMETER FOR MEASURING THE LUMINOUS FLUX AND LUMINOUS INTENSITY DISTRIBUTION OF LAMPS AND LUMINAIRES

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The luminous flux of lamps and luminaires is determined by microcomputer-controlled electronics of integration. For this reason, up to 16200 measuring values of illumination are evaluated by a light sensor rotating spirally around the light source. Variable mechanic scanner systems are explained and possible measurements of the curves of intensity distribution are shown.

Principally, two methods of luminous flux measurement can be applied.

1. Measurement with an integrating sphere according to Ulbricht. Measuring can be performed relatively fast. The exact determination of the luminous flux - measuring error <5% - is problematic, since normal luminous flux lamps having a relative spectral energy distribution that is as uniform as possible and nearly the same spatial intensity distribution as the light sources to be measured are necessary. It is another disadvantage that measuring errors may occur due to the selectivity and non-uniform reflexion of coatings, and the absorption of the light source and the screen. Measurement is complicated by aging of the sphere paint as well as soiling. It is an essential disadvantage that the luminous flux cannot be measured absolutely but only in relation to the luminous flux of expensive separately calibrated normal lamps.

2. Determination of the luminous flux from the luminous intensity or illumination distribution. In this case, the surface of an imaginary sphere around the light source is scanned with a light-sensitive sensor. Generally, the following applies for the luminous flux:

$$\Phi = r^2 \int_{\vartheta=0}^{\pi} \int_{\varphi=0}^{2\pi} E(\varphi, \vartheta) \cdot \sin\vartheta \cdot d\varphi d\vartheta. \qquad (1)$$

In the case of true light sources, the luminous flux integral according to equation (1) cannot be resolved completely since $E(\phi, \vartheta)$ is no analytical function. Numerical integration e.g. can be performed with the aid of the following approximation equation

$$\Phi \approx 4\pi r^2 \cdot \sin\frac{\Delta\vartheta}{2} \sum_{m=1}^{k} \sin\vartheta_m \cdot \frac{1}{n} \sum_{i=1}^{n} E(\varphi_i, \vartheta_m). \qquad (2)$$

Scanning of the surface of intensity distribution is mostly carried out discontinuously on parallel circles (lateral areas of a cone). Expensive computer-controlled positioning systems for both axes of rotation with digital encoders are necessary - cf. computerized rotating mirror systems [1].

The spiral photometer [2] combines the advantages of the methods mentioned - high accuracy and short duration of measurement - by passing the light sensor continually around the light source on a spiral course. This procedure requires a simultaneous direct or virtual rotation of the receiver around two axes intersecting at a right angle with constant angular speed.

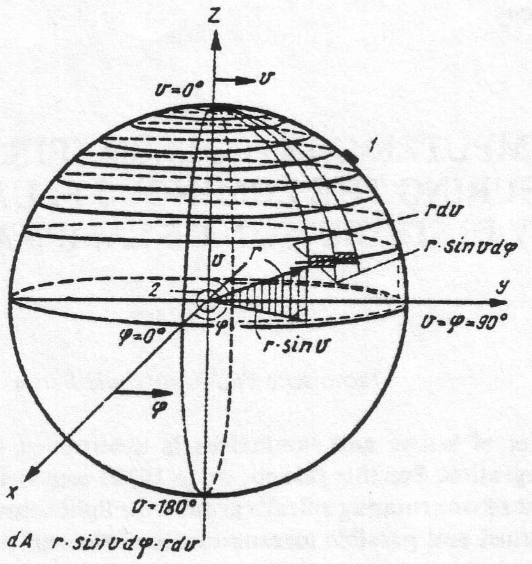

Fig. 1. Principle of spiral scanning: 1) photodetector; 2) light source.

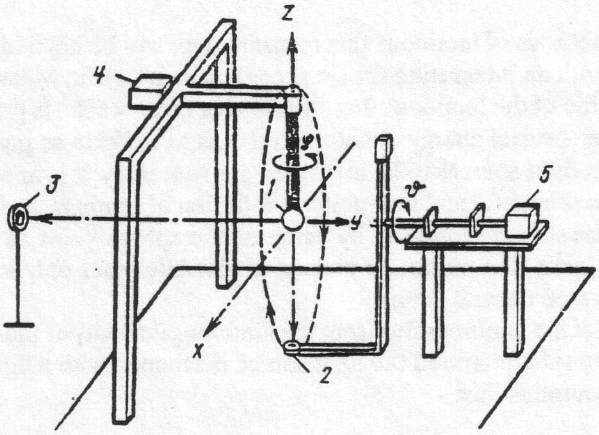

Fig. 2. Structural diagram of a photometer with rotary light source: 1) light source; 2) photocell for light flux measurement; 3) photocell for luminosity measurement in planes C or B; 4) LS rotation drive (measurement of the coordinate φ); 5) rotation drive of photocell 2 (measurement of the coordinate ϑ).

Using a high angular resolution, the scanning period can hereby be reduced to a few minutes; computer-controlled systems of positioning and angular measuring are dispensable [3].

MECHANIC SYSTEMS FOR SPIRAL SCANNING

Device to move the luminaire: Rotation of the sensor around the horizontal y axis and the light source around the vertical z axis. Outside the photometric limit distance in the x or -x direction or -y direction, the luminous intensity distribution in the C and B planes can be measured with special luminaire adapters, whereby, generally, the admissible operating position will be observed. Thus, this system is especially suitable for manufacturers of luminaires offering an extraordinarily economic alternative to the expensive computer-controlled rotating mirror systems.

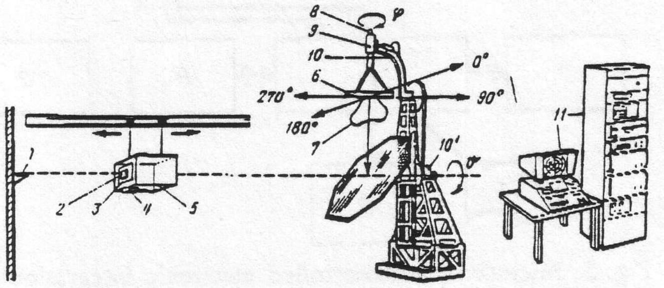

Fig. 3. Design diagram of a photometer with a rotary mirror: 1) adjustment laser (He-Ne); 2) photo cell with a thermostat; 3) iris diaphragm; 4) light current amplifier; 5) tube; 6) light source; 7) LC; 8, 8′) sensors of rotation angles of the light source and the mirror; 9) assembly changing the light source position height; 10, 10′) electric drives with generators; 11) microcomputer control system.

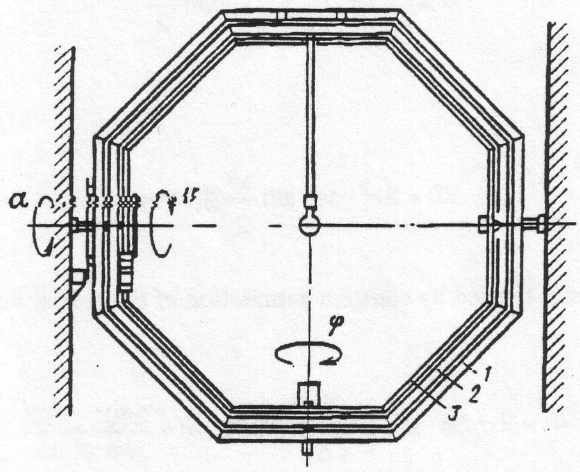

Fig. 4. Cardan goniometer.

Rotating mirror system: Rotation of the mirror around a horizontal axis, simultaneous rotation of the light source around the horizontal and vertical axis. Fixed light sensor. The mechanism is very well suited for manufacturers producing large luminaires. The technical expenditure is considerable, a high room (>6 m in height) is necessary.

Cardan goniometer: This mechanic system offers the chance of performing the spiral scanning of a spatial light source by Cardanic suspension of the photocell [4]. Furthermore, the exterior rotating frame permits the adjustment of the operating position desired, i.e., all lamps with defined operating positions can be measured correctly. A transmission of the lamp current by collecting rings is not necessary.

The rotating frame 1 is used for the adjustment of the operating position. Spiral scanning is effected by the rotating frames 2 and 3 fixed by Cardanic suspension. This design is particularly suited for lamp manufacturers and governmental laboratories (the PTB goniophotometer in the Federal Republic of Germany is operating according to this principle).

MICROCOMPUTER-CONTROLLED ELECTRONIC INTEGRATION

For the area of a spherical zone limited by the elevation angles ϑ_1 and ϑ_2 the following applies

$$A_Z = r^2 \cdot 2\pi(\cos\vartheta_1 - \cos\vartheta_2) = \\ = r^2 \cdot 4\pi \cdot \sin\vartheta_1 \cdot \sin\frac{\Delta\vartheta}{2}, \tag{3}$$

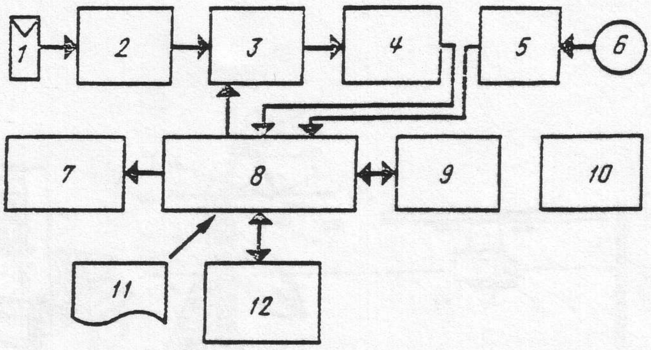

Fig. 5. Microcomputer-controlled electronic integration of luminous flux. 1) Sensor; 2) Input amplifier; 3) Sample and Hold circuit; 4) Analog/Digital Converter; 5) I/O; 6) Positioning indicator; 7) Printer; 8) Microcomputer; 9) Rapid arithmetic processor; 10) Power supply; 11) Programme; 12) Monitor with keyboard.

where $\vartheta_1 = (\vartheta_1 + \vartheta_2)/2$ and $\Delta\vartheta = \vartheta_2 - \vartheta_1$.

An element of area of a spherical zone situated between two meridians will then be

$$\Delta A_Z = 2r^2\,\Delta\varphi\cdot\sin\vartheta_i\cdot\sin\frac{\Delta\vartheta}{2}, \tag{4}$$

and its partial luminous flux

$$\Delta\Phi = 2r^2\cdot\Delta\varphi\cdot\sin\frac{\Delta\vartheta}{2}E_i\sin\vartheta_i. \tag{5}$$

The total luminous flux is formed by constant summation of the partial luminous fluxes along the spiral course.

$$\Phi = 2r^2\,\Delta\varphi\cdot\sin\frac{\Delta\varphi}{2}\sum_{i=0}^{M}E_i\cdot\sin\vartheta_i\,;\; M = \frac{360^\circ}{\Delta\varphi}\cdot\frac{180^\circ}{\Delta\vartheta}. \tag{6}$$

The microcomputer-controlled electronic integration is illustrated by means of the block diagram: The photoelement is supplying a short-circuit current proportional to the illumination. This current is converted with an amplifier into an open-circuit voltage which arrives at an Analog/Digital Converter (ADC) over a Bessel low-pass filter and a Sample and Hold circuit. This ADC is functioning according to the principle of successive approximation (14 bit). At the outlet of the photocurrent amplifier, a signal proportional to the illumination - and/or outside the photometric limit distance to the luminous intensity - is available. The control and the numerical integration of the luminous flux of the spiral photometer are performed by the microcomputer-controlled system with a Motorola processor 6809, 4 kByte EPROM, 2 kByte RAM, arithmetic processor AMD 9511, PIA 6821, ACIA 6551 and TIMER 6840. The Motorola Assembler language is used for the software. The translated machine code requires a storage capacity of approx. 4 kByte. The goniometric scanning pattern is adjustable over a range of $\Delta\phi = \Delta\vartheta = 2° ... 20°$. A maximum of 16200 measuring points can be evaluated per total integration. Nearly 200 measuring points per second can be processed. The arithmetic processor used has the capacity of a scientific-technical pocket calculator with batch processing. The accuracy of measurement of the floating point operations amounts to at least 7 digits. Operation of the new spiral photometer is performed in the interactive mode by way of a terminal. The following is displayed on the screen:

System status, illumination measuring range, impulse start/stop operation, measuring value for ADC,

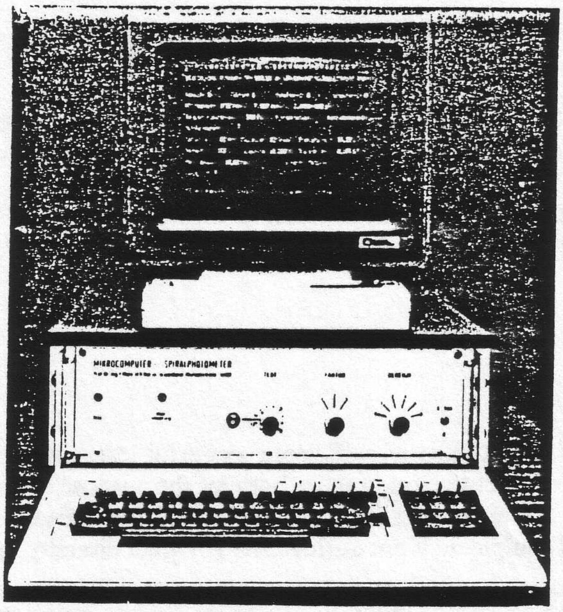

Fig. 6

illumination, spherical radius, goniometric scanning pattern, measuring time, measuring period, number of measuring points, rotational speed of light source and receiver, total luminous flux.

Four computer controlled modes can be performed:

a) Modification of measuring parameters (P);
b) Measuring (M);
c) Calibration (C);
d) Error deletion (D).

The system can be operated very simply by an implemented menu technique. The photo (Fig. 6) illustrates the new measuring system.

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