SINGLE-CHANNEL PHOTOELECTRONIC ATTACHMENT FOR MEASURING THE LOGARITHM OF THE INTENSITY RATIO OF TWO SPECTRAL LINES

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Paper [1] describes a single-channel photometer for measuring the logarithm of the intensity ratio of two light fluxes. The logarithmic operation is performed by means of a vacuum diode, severe requirements being imposed on it with respect to the insulation of the heater cathode. Computation of the light fluxes in the photometer is performed with the help of a rotating mirror, in consequence of which the design is considerably complicated. In this photometer, moreover, both of the imput leads of the recording device (ÉPP-09) prove to be under pulsed potential relative to the earth, which diminishes the stability and accuracy of the recording operation of the device.

The above-mentioned defects are absent in the present photoelectronic attachment. Its theoretical circuit diagram is shown in Fig. 1a. It operates in the following manner. Spectral lines with intensities I_1 and I_2 pass through slits 1 and 2 of optical commutator 3. The optical commutator alternately lets them pass to the cathode of photoelectronic multiplier 4 (FÉU-31 A). The FÉU load is the small array 5 of two logarithmically operating diodes of type D-310. Signals from the logarithmically operating array, which are in linear dependence on the logarithms of intensities I_1 and I_2, enter amplifier 6 and then cathode follower 7. From the cathode follower they proceed to integrating arrays 8 and 9, whereupon the signal from the spectral line that has passed through slit 1 enters one array, and the signal from the line through slit 2 enters the other. This is accomplished by means of switch 10, which operates synchronously with the optical commutator. The potential difference from the integrating arrays, proportional to $\ln(I_1/I_2)$, passes through divider 11 into the recording device (ÉPP-09).

The optical commutator consists of shadow-mask 12 with slits 1 and 2 and disk 13 with slots 14 and 15 cut out in it. As it rotates, they uncover first one and then the other slit. The width of the slits is identical and somewhat greater than that of the spectral lines. The lengths of the slits, l_1 and l_2, are chosen on

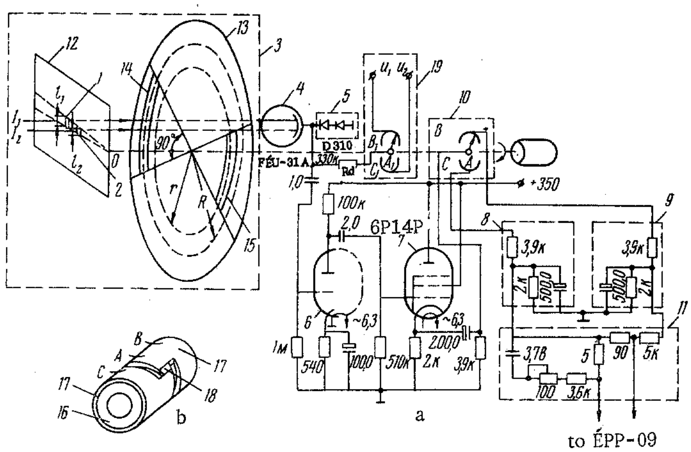

Fig. 1. Theoretical circuit diagram of photoelectronic attachment (a) and design of synchronous switch (b).

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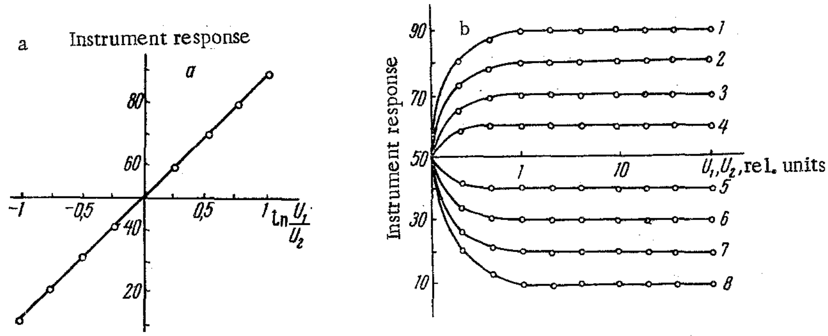

Fig. 2. Characteristics of the computing device of the attachment: a) calibration curve; b) dependence of the response of the device on the quantities U_1 and U_2: 1) $\ln(U_1/U_2) = 1$; 2) 0.75; 3) 0.5; 4) 0.25; 5) −0.25; 6) −0.5; 7) −0.75; 8) −1.

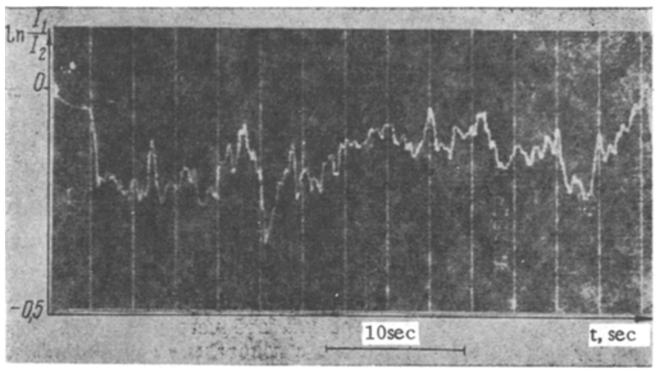

Fig. 3. Graph of the logarithm of the intensity ratio of two spectral lines of copper ($\lambda_1 = 5153$ Å; $\lambda_2 = 5105$ Å).

the basis of the correlation

$$l_1/l_2 = R/r,$$

that is, the angular lengths of the slits should be the same if observed from point 0 (point 0 lies in the same plane as the slits). With the fulfillment of this condition, the current pulses being received at the FÉU load from spectral lines with intensities I_1 and I_2 are obtained equal in duration and identical in shape. However, due to the fact that when $I_1 = I_2$ the amplitude of the current pulses is not equal (the ratio of their amplitudes is equal to l_1/l_2), there appears a constant error, the absolute value of which is equal to $\ln(l_1/l_2)$. Consequently, a correction in the measurements must be made by this amount.

Switch 10 (Fig. 1) consists of insulating bushing 16 with metallic collars 17 mounted on it. There are notches in the collars. The switch is mounted on the same shaft as the optical-commutator disk. With the rotation, contact A closes circuit successively with contact B and contact C, contacts AB or AC closing earlier and opening later than the uncovering and covering of the respective slits (1 or 2). In order that, at the moment of the passage of contact A from one collar to the other, there be no circuit closing, insertions 18 of laminated Bakelite insulation (micarta) are mounted between the collars.

Calibration of the circuit is carried out from special imitator 19 which generates rectangular current pulses with duration equal to that of the photocurrent pulses obtained by means of the photoelectronic attachment. These pulses are fed into the logarithmically operating diodes. The imitator operates synchronously with switch 10 (it is mounted on the same shaft) and is of a similar design. The angular sizes of the uncut parts of the collars are equal to the sum of the angular sizes of the slit and optical-commutator slot. When calibrating the circuit, electrodes B_1 and C_1 are supplied with voltages negative with respect to the earth, and the logarithm of their ratio can be measured by means of instruments of the required accuracy. With the rotation of the shaft, electrode A_1 will receive rectangular pulses of voltage, and the logarithm of the ratio of their intensities will also be known. These pulses are fed through supplementary resistance (instrument range multiplier) R_d (much greater than the direct resistance of the logarithmically-operating array) into the logarithmically-operating array and, as a result, rectangular current pulses with a known logarithm of their amplitude ratio will flow through it. Upon ascertaining the different voltages at electrodes B_1 and C_1, we can determine the dependence of the response of the recording-instrument on the logarithm of the ratio of these voltages, that is, the calibration curve (Fig. 2a). The response of the instrument does not depend (beginning with a certain value) on the magnitude of these voltages, but only on the logarithm of their ratio (Fig. 2b). The fact that rectangular current pulses are used for imitation, and not trapezoidal (as occurs in the operation of the photoelectronic attachment), should not lead to error of imitation (bearing in mind that the logarithmic operation is ideal).

Among the shortcomings of the photoelectronic attachment we may regard the dependence of its response on the ambient temperature. This in turn is due to the temperature dependence of the parameters of logarithmically-operating diodes. For this reason it is desirable to thermostabilize them. The latter is not absolutely necessary if we bear in mind the relationship

$$A = A_0 \frac{T}{T_0},$$

where A is the response of the instrument at an ambient temperature T; and A_0 is the response of the instrument at an ambient temperature T_0.

The photoelectronic attachment under consideration can find application in the measurement of plasma temperature according to the relative intensity of spectral lines (it is well known that, to determine the temperature of a plasma by this method, it suffices to know the value of $\ln (I_1/I_2)$). The isolation of the lines can be accomplished by any standard spectral instrument (for example, UM-2, ISP-51, etc.).

With the help of the above-described attachment, we have measured the temperature of a nitrogen plasma jet generated by a linear plasmatron. The investigation was conducted with a mixing chamber having a gas consumption of 2 g/sec. We used the radiation of the jet along a cross-sectional axis at a distance of 3.5 cm from the shear of the nozzle. The copper lines $\lambda_1 = 5153$ and $\lambda_2 = 5105$ Å were selected for measurement. From Fig. 3 it is evident that the quantity $\ln (I_1/I_2)$ fluctuates randomly about a mean value. A comparison of the mean value of the temperature found with the attachment and the temperature as measured by the spectroscopic method for the same time (≈40 sec) showed that they practically agree (with an error not exceeding 2%).

LITERATURE CITED

1. V. I. Dianov-Klokov and G. D. Turkin, Prib. i Tekh. Éksperim., No. 6, 169 (1965).