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A Self-Quenching Light Meter

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A description is given of a self-quenching light meter and the special characteristics of meters with platinum, aluminum and magnesium photocathodes.

1. THE photon meter[1], which at this time is the most sensitive instrument for the measurement of ultraviolet light, is used successfully in many investigations that require the precise determination of low intensity light. The mass production of this instrument is impeded by the large number of rejects. A considerable number of these rejects suffer from too steep counting characteristics and instability. A long aging process is required to make them acceptable. Stabilization of counting characteristics may be achieved by the use of quenching (gas) mixtures of the type used in self-quenching meters[2].

In this paper we describe a self-quenching photon meter with very stable counting characteristics and good sensitivity that can be used industrially. Tests on the production of self-quenching meters under laboratory conditions indicate that if the proper technical production methods are used, one may expect perfect output and good reproducibility of meter characteristics.

We made and tested about 40 such self-quenching meters. Their utilization in the laboratory and under field conditions over a period of several years indicates good stability and working dependability. Cases of changes in the properties of properly used meters were not observed.

Figure 1 shows the scheme we used for our self-quenching meter. Other similar circuits are possible. Three batteries connected in series served as a source of voltage. The voltage could be varied between 600 and 900 volts by means of a two megohm potentiometer. This interval was sufficient to cover the requirements of all of our light meters. An electrostatic voltmeter was used to measure the working potential. The output terminals of the meter circuit were connected either to an oscillograph or to a counting circuit. The magnitude of the pulses put out by the meter circuit was of the order of one volt.

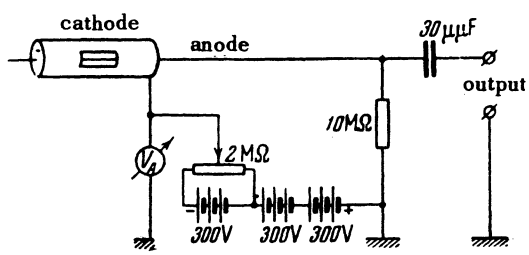

Fig. 1. Circuit diagram of the meter

2. The meter is of cylindrical form. The body consists of a tube, the mid part of which is made of quartz and the ends of molybdenum glass. The two are joined together by means of transition glass. The cathode material is chosen to satisfy the spectral requirements of the meter. We used platinum, aluminum and magnesium. The tube is filled with 85% argon and 15% methyl or ethyl vapor to a pressure of 65 to 70 mm of Hg. The entire tube is then encased in a metal setting and provided with a two prong socket.

3. The magnitude that correctly and uniquely describes the light sensitivity of the meter is the ratio of the number of impulses in the meter circuit produced by the incident light to the corresponding number of photons. This magnitude ϵ_λ is given by

$$\epsilon_\lambda = n_\lambda / N_\lambda \qquad (1)$$

where N_λ is the intensity of light in quanta per second, that is, the number of quanta of a given wavelength that pass through the cell window per second, and n_λ is the difference in the number of pulses per second when light shines on the meter and the number of pulses per second in the dark (due to background radiation). The magnitude ϵ_λ may be identified as a measure of photoelectric emission only if the meter is 100% efficient, that is, if each photoelectron is counted.

The magnitude ϵ_λ will now on be called the *spectral sensitivity* of the meter. The determination of ϵ_λ in absolute units depends on the determination of N_λ, a difficult measurement, particularly

[1] S. F. Rodionov and A. I. Shal'nikov, J. Exper. Theoret. Phys. USSR 5, 160 (1935)

[2] H. F. Neuert and K. A. Lauterjung, Reichber Phys. 1 17, (1944)

in the ultraviolet region. It is not convenient in this connection to use light sources of known spectral energy distribution (such as models of black body radiators, or incandescent lamps), because the changes in the emission characteristics of ordinarily used emitters (tungsten, for example) leads to large and unknown errors, particularly in the ultraviolet and infrared regions. To test the sensitivity of our meters, we used light sources whose spectral characteristics were determined in absolute units by means of sensitive thermal (radiation) detectors. (This method, previously described by one of the authors[3], was reconfirmed in the present work.) Then, with the same experimental arrangement and a fixed attenuation of the source, the meter was substituted for the thermoreceptor and its sensitivity in the corresponding spectral region was measured.

As a source of light we used a 25 watt hydrogen tube especially prepared for us. In some measurements we also used the Mercury-Argon tube PRK-2. The optical system consisted of a double quartz monochromator that was built up from two quartz monochromators of equal angular dispersion. The diagram of the optical system is shown in Fig. 2. The light source was placed directly in front of the input slit *I*. The light receptors, the thermal indicator of our meter, was placed after the output slit *III*.

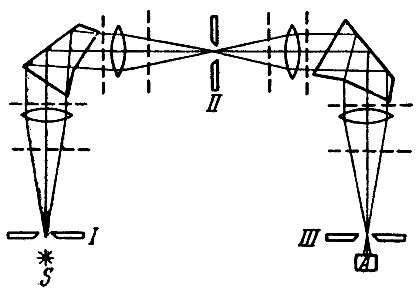

Fig. 2. Schematic diagram of the optical system for the measurement of meter sensitivity.

To determine the absolute intensity of the source, we used calibrated thermoelements and thermopiles with quartz windows followed by photoelectric amplification of the thermocurrent. A similar system has recently been brought to a high state of perfection by Kozyrev[4]. The thermoelement or thermopile was connected to a galvanometer. The light reflected from the mirror of this galvanometer impinges on a compensated photoelectric system having a second galvanometer in its output. The ratio of the current in the second galvanometer to that in the first represents the amplification of the photoelectric-optical system (the current amplification factor). A special check was made of the linear dependence of this ratio on the current in the first galvanometer.

Special measurements were made to ascertain the spectral nonsensitivity of the thermal elements. The results of these measurements are shown in Fig. 3. This figure represents, in relative units, the energy spectrum of the hydrogen tube, measured under similar conditions, using as receptor *1)* the thermopile FAI, *2)* the Kipp thermopile and *3)* the thermoelement LETI[4]. As is seen from the diagram, the third receptor proved selective because, as was shown later, its surface blackening was defective (the reflection coefficient in the region 2100 to 2900 Å was too large). The coincidence of the curves obtained from the first two receptors was checked by means of controlled measurements on their surface reflectivities. The results fully justified the interchange of data obtained by means of the first two receptors.

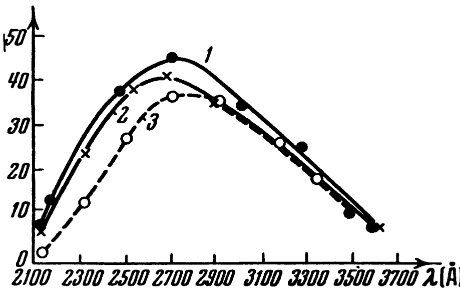

Fig. 3. Energy distribution in the hydrogen spectrum.

Table 1 represents a summary of the data on the distribution of energy in the hydrogen spectrum in absolute units. These were obtained with the aid of the photo-optical amplifier.

If n_T is the current measured by the second galvanometer in the photo-optical system (expressed in scale divisions); I_λ the light intensity in ergs per second that emerges from the slit system *I, II, III*; $d_I = d_{II} = 0.2$ mm and $d_{III} = 0.4$ mm; it follows that:

$$I_\lambda = n_T (R_T + R_r) \alpha / \beta\gamma \qquad (2)$$

where α = the sensitivity of the first galvanometer

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[3] S. F. Rodionov, J. Exper. Theoret. Phys. USSR **10**, 294 (1940)

[4] B. M. Kozyrev, Usp. Fiz. Nauk **44**, 173 (1951)

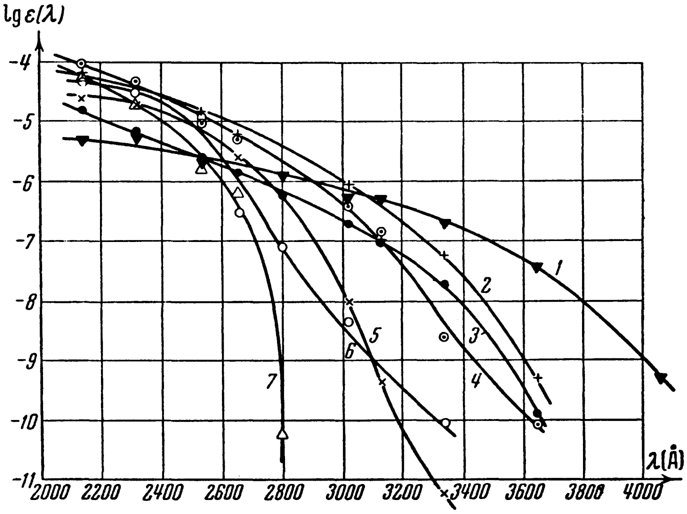

Fig. 4. Spectral sensitivity of self-quenching light meters. 1 – M-1, 2 – A-4, 3 – A-3, 4 – A-6, 5 – P-6, 6 – P-7, 7 – P-10.

TABLE I. Current in the tube was 25 ma

λ in Å	n_T in scale divisions	I_λ ergs/second	$N_\lambda \times 10^{-10}$ quanta/second
2145	11	0.123	1.32
2318	43	0.480	5.60
2537	76	0.850	10.80
2655	82	0.920	12.20
2803	80	0.842	12.60
3022	64	0.715	10.80
3130	52	0.580	9.07
3340	32	0.358	6.20
3650	12	0.134	2.43
4000	8	0.089	1.78

β = the current amplification of the photo-optical system

R_T = the resistance of the thermopile or the thermoelement

R_r = the internal resistance of the first galvanometer

γ = the sensitivity of the thermopile or thermoelement in volts/erg.

The constants for one of our systems, using the FAI thermopile, are: $\alpha = 0.5 \times 10^{-3}$ amperes per scale division, $\beta = 580.5$, $R_T = 30$ ohms, $R_r = 35$ ohms and $\gamma = 10^{-3}$ volts per erg.

Having ascertained in absolute units the energy distribution of our source, we could then attenuate it a known amount and measure it with our meter. That is, we could establish the value of ϵ_λ in Eq. (1).

As light attenuators we used thin metal screens (mesh), whose attenuation was measured very carefully. They were placed in the optical system so that the width of the light beam was considerably larger than the cell size of the screen (see Fig. 2). Such neutral attenuators, as was previously shown[3], give excellent results. In this way we established the linearity of our meter (that is, the dependence of n_λ on light intensity) to a sufficiently high degree.

The spectral characteristics of our self-quenching meters with photocathodes of different metals are shown in Fig. 4, where we plot Log ϵ_λ vs. λ in Å.

The use of platinum cathodes (meters P-6, P-7 and P-10), aluminum cathodes (meters A-3, A-4 and A-6) and magnesium cathodes (meter M-1), allow, as is seen from Fig. 4, the rather sharp separation of three spectral regions, 2100 to 2800 Å, 2100 to 3500 Å and 2100 to 4000 Å, where it is particularly convenient to use the meters of the described type as integrating photometers. The results shown in Fig. 4 indicate that the sensitivity of the tested meters compare well with previous measurements[3] and are normal for the photoeffect from clean metal surfaces. At the wavelength of 2000 Å, this sensitivity is of the order 10^{-4} electrons per quantum or about 7×10^{-5} coulombs per calorie.

The typical working characteristics of self-quenching light meters are shown in Fig. 5. The lower curve corresponds to the dark background activity, the upper curve was obtained with some illumination. There is a good plateau over the range of about 100 volts.

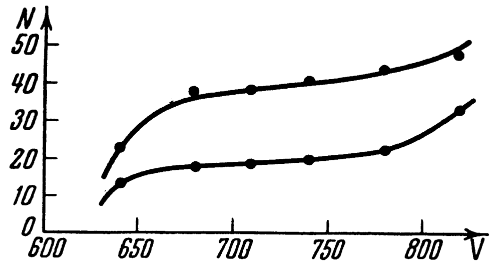

Fig. 5. Working characteristics of the meter.

The dark background count of different meters varies between 3 and 15 counts per minute. The magnitude of this background activity depends, of course, on the size of the meter. If the working volume of the meter is a cylinder 1.0 cm in diameter, 2.5 cm high, the background count is about 9 pulses per minute.

In this study we did not undertake the detailed study of self-quenching light meters. One may expect that the meters described in this paper will have characteristics similar to those of ordinary self-quenching meters of the type used in measuring hard radiation.

Some of our meters that have been in use for a long time already show signs of aging and fatigue, due no doubt to the exhaustion of the quenching components of the gas mixture. It may also be that the photocell itself shows the effects of aging.

Unfortunately, our experience to date is not enough for a more detailed judgement. We hope to return to this subject when more experience is gathered on the utilization of the self-quenching light meters.

The design and construction of the self- quenching meters was done at the Institute for Physical Problems, Academy of Science of the USSR, by A. I. Shal'nikov and M. S. Khaikin. The measurements of the spectral sensitivity of the meters were done at the Institute of Physics, Leningrad State University, by F. Rodionov.

Translated by M. M. Kessler
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Additional footnote:

S. F. Rodionov and E. N. Pavlova, Doklady Akad. Nauk SSSR 79, 961 (1951)

ERRATA

	reads	should read
Rodionov et al, Soviet Phys. JETP 1, 64 (July, 1955)		
p. 64, column 2, line 19	methyl or ethyl	methylal or ethylal
Bogoliubov and Zubarev, Soviet Phys. 1, 83 (July, 1955)		
p. 88, column 1, line 6	omits	is taken over
p. 88, col. 1, 4th line from bottom	appears in	are
Grametitskii et al, Soviet Phys. JETP 1, 562 (November, 1955)		
p. 562, title	"fissions"	"disintegrations"
p. 562, paragraphs 1 and 2 (3times)	"fissions"	"disintegrations"
p. 563, column 1, 5th line from bottom	"fissions"	"disintegrations"

Index to J. Tech. Phys.
p. 374
Our apologies to Academician Abram Fedorovich Ioffe for interpreting his anniversary biography as an obituary. Like the report of Mark Twain's demise, it was a great exaggeration.

ANNOUNCEMENT

Beginning with the next issue (August, 1956), Soviet Physics JETP will appear monthly. Volume 3 (August, 1956-January, 1957) will contain translations of all articles appearing in Volume 30 of the Journal of Experimental and Theoretical Physics of the USSR (January-June, 1956). Volume 4 (February-July, 1957) will be a translation of Volume 31 (July-December, 1956) of the Soviet Journal.

Subscribers to Soviet Physics JETP for the calender year 1956 will receive Volume 3 as the completion of their subscription. For new subscribers (beginning with Volume 3) the subscription price will be $60.00 per year (two volumes, twelve issues) in the United States and Canada, $64.00 per year elsewhere. The single issue price will remain at $6.00.

Beginning in either July or August, 1956, the American Institute of Physics will commence translations of the Journal of Technical Physics of the USSR, the Acoustics Journal of the USSR and the physical sciences portions of Doklady. Price schedules for these journals are given below. Subscriptions should be addressed to the American Institute of Physics, 57 East 55 Street, New York 22, N. Y.

Soviet Physics—Technical Physics

A translation of the "Journal of Technical Physics" of the Academy of Sciences of the U.S.S.R. Eighteen issues per year, approximately 4,000 Russian pages. Annually, $90.00 domestic, $95.00 foreign.

Soviet Physics—Acoustics

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Soviet Physics—Dokaldy

A translation of the "Physics Section" of the Proceedings of the Academy of Sciences of the U.S.S.R. Six issues per year, approximately 900 Russian pages. Annually $25.00 domestic, $27.50 foreign.