BRIEF COMMUNICATIONS

AN OPEN CATHODOLUMINESCENT SHORTWAVE ULTRAVIOLET RADIATION RECEIVER

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At the present time there is no sufficiently reliable and sensitive ultraviolet receiver capable of operating in a low vacuum and able to retain its characteristics after exposure to air. A secondary-electron multiplier (SEM) of the open type, for example, can only operate normally in a vacuum of not less than 1 cmHg and becomes less sensitive if exposed to air. The scintillation receiver recently described in [1] is close in sensitivity to an open SEM, but also requires a high vacuum and a high input voltage (15-25 kV); because it employs a closed photomultiplier it is characterized by a high dark current.

Our receiver begins to operate stably at 1 cmHg with a relatively low input voltage (~600 V). At 2000 V its sensitivity reaches that of an open SEM. This receiver is based on the principle of photoelectric conversion. Ultraviolet radiation illuminates the cathode and knocks electrons out of it. The beam consisting of these electrons enters the field of an immersion objective, consisting of a series of diaphragms, which accelerates and focuses the electrons into a spot on the cathode luminophor. The electrons cause the luminophor to luminesce, and this luminescence is picked up by a photomultiplier. The acceleration of the electrons in the converter is such that the energy of each is sufficient to excite in the luminophor enough light quanta to knock out at least one electron from the photomultiplier cathode. The luminophor is applied directly to the end face of the light conductor and acts both as a "reflector" and as a transmitter.

An essential difference between this radiation receiver and a scintillation receiver is that the former uses efficient luminophors and does not have an aluminum coating on its cathode luminophor. In a scintillation counter the aluminum layer serves to separate the scattered light from the electrons and to discharge the screen; it also acts as a mirror which increases the amount of scintillator light received by the photomultiplier. In our case the electrons are separated from the scattered light through an appropriate choice of their trajectories, and the screen is discharged by secondary electron emission from its surface. The absence of an aluminum coating and the use of efficient cathode luminophors enabled us to reduce the accelerating voltage to 1-2 kV. The average electron trajectory in our receiver is 8.5 mm. Reducing the trajectory length is equivalent to reducing the probability of collisions between the electrons and the residual gas molecules; this allows the receiver to operate with a relatively low vacuum. The receiver focuses the electrons into a spot with a maximum diameter of 2 mm. Focusing of the electrons makes it possible to use a light conductor of small diameter (5 mm) with a profiled collector head and a photomultiplier with a 5 mm diameter cathode as well as a reflecting mirror to improve the collection of luminescence light. The use of a photomultiplier with a small-diameter cathode endows the receiver with a dark current of the same order as that of an open photomultiplier.

A diagram of the radiation receiver is shown in Fig. 1. The converter is a cylindrical brass housing (1) 35 mm in diameter and 30 mm high which contains the focusing rod (2). A plastic mounting unit supports the control electrode (3), the focusing diaphragm (4), and the anode (5). The spherical inner surface of the anode is polished. The cathode (6) is mounted on the control electrode (3) opposite the radiation entrance hole in the housing.

The light collection device consists of a spherical reflecting surface affixed to the anode (5) and of the light conductor (7). The light conductor is made of high-quality plastic. Together with the reflector it collects 70% of the light radiated by the luminophor, and the end face is coated with the luminophor (8). On emerging from the light conductor the luminescence light is picked up by an FEU-64 or FEU-36 photomultiplier (9).

The converter is compact and can be readily mounted in a small vacuum chamber. The photomultiplier can be
situated outside the vacuum chamber, from which the light conductor can be led out readily (with a seal around it to prevent light entering the housing). The receiver can also operate without a light collector, in which case the light conductor is omitted and the photomultiplier is located immediately after the cathode luminophor coating on a flat quartz plate. The receiver can be disassembled, which permits the replacement of the cathode and luminophor, and the cathode is made of a material similar to those used in open photomultipliers. Also the receiver can operate with several types of cathode luminophors presently used in vacuum-type electronic instruments. The luminophor is applied to the light conductor end face by spraying with a suspension in ethyl alcohol (coating density is 2 mg/cm²). The receiver is powered from a stabilized rectifier (voltage: 600–5000 V).

The receiver described is characterized by a linear dependence of the photocurrent on the luminous flux. Its sensitivity depends on the voltage applied to the converter electrodes. The receiver sensitivity as a function of the pressure of the air + helium mixture for several converter voltages is shown in Fig. 2. At about 2000 V the sensitivity of the receiver is equivalent to that of an open SEM; at still higher voltages it exceeds the latter. The converter operates stably in the 600–5000 V range but the receiver gain depends not only on the voltage applied to the converter anode, but also on the voltage applied to the control electrode (by "gain" we mean the ratio of the photocurrent from the photomultiplier cathode to the current from the converter cathode). To saturate the converter completely it is sufficient to apply a voltage equal to 0.1 of the anode voltage to the control electrode.

The use of various types of cathode luminophor endows the receiver with a number of new capabilities. The FS-IV luminophor, for example, affords the maximum gain, but at the expense of time resolution. Use of the L-30 cathode luminophor preserves the time resolution to within 3 x 10⁻⁷ sec. Willemite transforms the receiver into a light integrator with a time constant τ = 2 x 10⁻². This makes it possible to employ the receiver for recording pulsed luminous fluxes in the presence of accompanying strong electrical interference. The reason for this is that the pickup can be shut off for the duration of the interference. The amount of light lost during the off-duty time is

\[ \tau I_1 (1 - e^{-\frac{t}{\tau}}) = I_2, \]

where \( I_1 \) is the total luminous flux; \( I_2 \) is the unsensed (unregistered) luminous flux; \( \tau \) is the luminophor constant; \( t \) is the off-duty time.

In using the receiver in the 100–15 nm range we usually made use of a platinum cathode. Other cathode materials tried out were the metals Cu, Au, Al, In, Zr, Ti, Sn, Ta, Nb, W, Ni, and Fe, as well as dielectric layers of certain oxides, fluorides, sulfides, and other substances. The receiver described was used in an investigation of the relative spectral dependence of the quantum yields of the photoelectric effect for the above materials. The highest quantum yields in the indicated portion of the spectrum were exhibited by LiF, SrF₂, and CsI cathodes. The maximum photosensi-

### Properties of Cathode Luminophors

<table>
<thead>
<tr>
<th>Brand</th>
<th>Formula</th>
<th>Time of de-excitation to 5% (sec)</th>
<th>Luminescence color</th>
<th>Examples of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS-IV</td>
<td>ZnS–Ag</td>
<td>10⁻³</td>
<td>Light blue</td>
<td>Recording of constant and pulsed luminous fluxes without loss of time to data</td>
</tr>
<tr>
<td>L-30</td>
<td>Ca₂⁺–Mg⁺–WO₄⁻</td>
<td>5.10⁻⁷</td>
<td>Blue</td>
<td>Recording of pulsed luminous fluxes</td>
</tr>
<tr>
<td>Willemite</td>
<td>Zn₂SiO₄⁺–Mn⁺</td>
<td>2.10⁻²</td>
<td>Green</td>
<td>Recording of pulsed luminous flux against a strong electrical interference background</td>
</tr>
</tbody>
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