ISSN 0020-4412

Vol. 29, No. 5, Part 2, September-October, 1986

April, 1987

INETAK 29(5) 1111-1238 (1986)

INSTRUMENTS AND EXPERIMENTAL TECHNIQUES

ПРИБОРЫ и ТЕХНИКА ЭКСПЕРИМЕНТА

(PRIBORY I TEKHNIKA ÉKSPERIMENTA)

TRANSLATED FROM RUSSIAN

CONSULTANTS BUREAU, NEW YORK

The principal parameters of the apparatus and the measurement error were determined in experiments with tungsten and graphite electrodes, whose emission properties have been well-studied to a temperature of 4000°K [4]. Comparison of the obtained results with other available [4] has shown that the apparatus permits determination of the monochromatic emissivity of arc electrodes with an absolute error of 5%. Spectral emissivity in the wavelength range of 0.4-1.1 μm is measured with an error of 7% for discharge currents of 50-200 A.

LITERATURE CITED

1. M. F. Zhukov, N. P. Kozlov, A. V. Pustogarov, et al., Electrode Processes in Arc Discharge [in Russian], Nauka, Novosibirsk (1982).
2. D. A. Svet, Objective Methods of High-Temperature Continuous-spectrum Pyrometry [in Russian], Nauka, Moscow (1968).
3. A. Yu. Bashirin, A. V. Kirillin, and M. A. Sheindlin, Teplofiz. Vys. Temp., 22, No. 2, 131 (1984).
4. V. I. Zavidei, A. V. Pustograov, and D. Yu. Pakhomov, Teplofiz. Vys. Temp., 18, No. 6, 1252 (1980).

CHARACTERISTICS OF SYSTEM OF THREE MICROCHANNEL PLATES

M. A. Gruntman and A. A. Demchenkova

UDC 539.1.074

The characteristics of a detector based on three spaced standard microchannel plates with direct channels are studied for counting of ultraviolet photons, energetic neutral particles, and ions. An amplification factor of $\gtrsim 10^8$ with an amplitude resolution of 0.4 for photons and 0.15 for particles. The critical loads are also determined.

Microchannel plates (MCP) — a type of secondary multiplier — are widely used in physics research for detection of various particles (ultraviolet and x-ray photons, electrons, ions, and energetic neutral particles) [1-4]. Two MCPs with direct channels in a herringbone configuration are used most often for particle registration in the count mode [3-5]. Typically, such MCP systems have an amplification factor $K_a \simeq 10^7$ and an amplitude resolution R = 1.0 (for example, [5]).

A number of applications, for example, coordinate-sensitive detectors based on MCPs [6-8], require an increase in amplification with a simultaneous improvement in amplitude resolution. This can be achieved by increasing the number of MCP stages — for example, to three. In detectors with three MCPs, the plates are usually installed without spacers or supply electrodes with direct contact of the surfaces of adjacent plates [9-11], which improves the amplitude resolution somewhat but does not allow an amplification factor of $>(1\text{-}3)10^7$ to be obtained.

We have built and studied the characteristics of detectors with three MCPs with small gaps between the plates. Some preliminary results were published earlier [12].

The detector unit was made of up to three MKP-28-10 MCPs with direct channels with solid framing. The MCP's had a diameter of 28 mm, the microchannel diameter was 10 μm, the structure spacing was 12 μm, the MCP thickness was 0.44 mm, and the angle between the channel axis and the normal to the plate surface was 6°. The channels of the individual MCPs were greatly offset axially. The spacings were 0.6 mm between the first and second plates (numbered from input to collector), 0.1 mm between the second and third, and 8 mm between the third and the collector.

The MCP unit was installed in a vacuum of $2 \cdot 10^{-6}$ torr. The resistance of the plates in vacuum was 60-100 MΩ. The MCP unit was supplied by a voltage divider, but the detector

---

Institute of Space Studies, Academy of Sciences of the USSR, Moscow. Translated from Pribory i Tekhnika Eksperimenta, No. 5, pp. 146-149, September-October, 1986. Original article submitted June 5, 1985.

 0020-4412/86/2905-1144$12.50

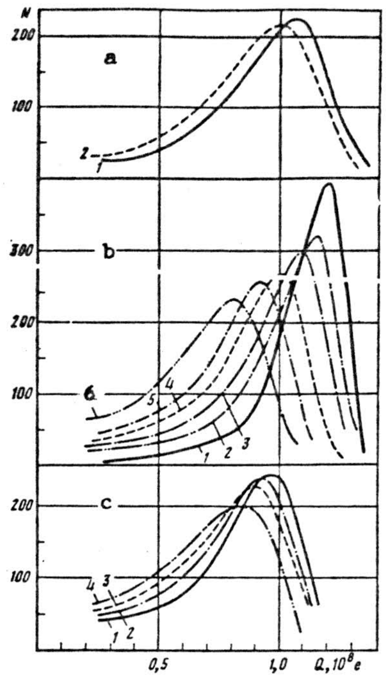

Fig. 1. Distributions of pulses N (number of counts) with respect to amplitudes Q (charge of electron avalanche): a) dependence on flux density I (1 – $1.6 \cdot 10^{-2}$, 2 – $5 \cdot 10^{-2}$/channel/sec) of Xe atoms (E = 1.5 keV), U = 3.04 kV, amplitude resolutions R = 0.46 (1) and 0.54 (2); b) dependence on voltage U (1 – 3.04, 2 – 2.96, 3 – 2.92, 4 – 2.88, 5 – 2.84, 6 – 2.80 kV) for registration of Xe^+ ions (E = 4.5 keV, I = $2 \cdot 10^{-3}$ channel/sec); c) dependence on voltage U (1 – 3.04, 2 – 3.00, 3 – 2.96, 4 – 2.92 kV) for registration of ultraviolet photons.

characteristics were studied only as functions of the total supply voltage U. The ratios of the voltages supplied to the plates were constant: $U_1:U_{1,2}:U_2:U_{2,3}:U_3:U_{3,c}$ = 8:1.5:10:0:10:1.5, where U_i is the potential difference at the i-th plate and $U_{i,j}$ is the potential difference between the i-th and j-th plates or collector ($U_{3,c}$). The relatively low voltage on the first MCP reduced the noise count, which did not exceed 2 sec^{-1}. Since the collector was at ground potential while the input of the first MCP was at ~ –3000 V, the electrons that were knocked out by the particles being registered from the interchannel spaces of the MCPs were not drawn into the channels and were not detected.

The characteristics of the unit were studied n the count mode for registration of ultraviolet photons with a wavelength of 147 nm (which allowed the single-electron characteristics of the detector to be obtained [13]), neutral He and Xe atoms with energies of 1500 and 3000 eV, and He^+ and Xe^+ ions with energies (with allowance for additional acceleration by the field at the input surface of the first MCP) of 4500 and 6000 eV. The detector pulses were amplified by a charge-sensitive amplifier and measured by a 10-bit analog–digital converter. The amplitude distributions of the pulses were stored in microcomputer memory and used to determine K_a and R; all amplitude distributions were normalized for "area," i.e., for the total number (10^4) of accumulated pulses. It should be noted that the pulse amplitudes (for a 50-Ω load) directly from the detector could reach hundreds of millivolts, which allows the detector to be used as an effective time marker without preamplification.

We did not study the dependence of the detector parameters on the total count rate for a particle flux that uniformly distributed over the entire sensitive surface of the detector. The cross-sectional diameters of the fluxes of registered particles were <3 mm, and the total count rate was $<10^4$ sec^{-1}. The characteristics of the MCP unit are greatly dependent on the load, which is understood as the "count rate density" of the detector, i.e., the product of the registration efficiency multiplied by the flux density of particles arriving at the detector input. The flux density is conveniently measured in units of arriving-particle counts per channel of the input MCP per unit time. For the MCPs used, $1/\text{channel}\cdot\text{sec} \approx 10^6/\text{cm}^2\cdot\text{sec}$.

If the flux density of the registered particles is below a particular value I_{cr} (which corresponds to the critical load), the shape of the amplitude distributions will be independent of the load. For loads that are greater than critical, the distributions are shifted in the direction of lower amplitudes and broadened, i.e., the detector characteristics are impaired. A typical graph of amplitude distribution as a function of load is shown in Fig. 1a, where curve 1 corresponds to a critical load. It was found that for He atoms, I_{cr} was $1.0\cdot10^{-2}$/channel·sec for a particle energy of 1500 eV and $3.5\cdot10^{-3}$/channel·sec for an energy of 3 keV. For Xe atoms, $I_{cr} = 1.6\cdot10^{-2}$/channel·sec (1500 eV) and $1.1\cdot10^{-2}$/channel·sec (3000 eV). The critical loads that correspond to different parameters of the registered particles agree with one another; the higher the amplification factor, i.e., the higher the average charge of an electron avalanche, the lower I_{cr}. Note also that the detector characteristics are not sharply impaired when the critical load is exceeded. For example, when I_{cr} is exceeded by a factor of 3, K_a is decreased by 5-8% and R is increased by 10%.

Typical pulse amplitude distributions for various supply voltages U for particles (Xe^+ ions with an energy of 4500 eV) and ultraviolet photons are shown in Figs. 1b and 1c. It is apparent that, as U is increased, the amplitude distributions are shifted in the direction of higher amplitudes and become narrower. The upper limit of the supply voltage is governed by the fast rise in the noise-count rate when U > 3100 V. All distributions of Fig. 1 indicate that the MCP unit operates under saturation conditions. Graphs of the amplification factor and amplitude resolution as functions of voltage U for Xe^+ ions and photons are shown in Fig. 2. It is apparent that the amplification factor is practically flat as U is increased, i.e., saturation has occurred. A plateau is not observed for the function R(U); this provides a basis for assuming that a further increase in U (using less noisy plates) could result in a decrease in R. The obtained values $K_a \gtrsim 10^8$ and $R \simeq 0.4$ for photons and R < 0.15 for particles (He atoms with an energy of 3 keV; Fig. 3) greatly exceed the characteristics of a unit of two MCPs and can be improved by optimum selection of the ratios of the voltages in the plates and between them (especially $U_{2,3}$) and of the spaces between the MCPs. For the MCPs in the described unit, the spaces were based on structural considerations; a special study of their effect on the detector characteristics was not performed. A difference in the spacing between plates can be partially compensated for by changing the voltage between them.

The amplitude distributions are functions of the energy and mass of the registered particles. It is obvious that the atom with the higher energy in a collision knocks out the greater number of secondary electrons. The number of secondary electrons is also a function of particle mass. Amplitude distributions obtained in registration of atoms with different energies are shown in Fig. 3. It is apparent that K_a for He (Xe) atoms with an energy of 3 keV exceeds by 10% (15%) the value of K_a for atoms with an energy of 1.5 keV. Registration of He atoms also corresponds to a higher value of K_a than is the case with Xe atoms.

Use of the described three-MCP detector has made it possible to obtain K_a and R values that greatly exceed those of two-MCP units as well as those of three-MCP units with direct contact of adjacent plate surfaces. For a total supply of 3 kV, $K_a > 10^8$, and the amplitude resolution is improved to 0.4 for photon registration and 0.15 for particle registration. The use of three MCPs allows reduction (as compared with two MCPs) of the supply voltage on each MCP and a relatively lower voltage to be fed to the first plate, which reduces detector noise. The obtained characteristics of the MCP unit make it highly effective to use coordinate-sensitive detectors for its construction.

The shortcomings of the three-MCP detector as compared with a two-MCP unit include a higher total supply voltage (up to 3 kV) and higher sensitivities to the load and to the total number of registered particles, since the MCP properties are also determined by the total charge carried from the walls of the microchannels by electron avalanches. This is

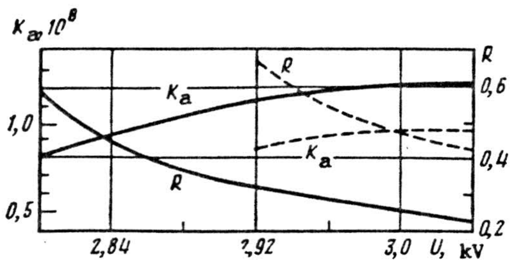

Fig. 2

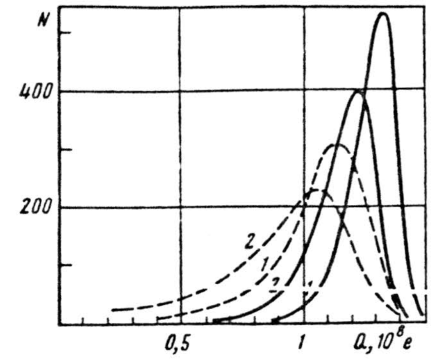

Fig. 3

Fig. 2. Amplification factor K_a and amplitude resolution R as functions of voltage U in registration of Xe^+ ions (solid curves; E = 4.5 keV, I = $2 \cdot 10^{-3}$/channel/sec) and ultraviolet photons (dashed curves; I = $8 \cdot 10^{-3}$/ channel/sec).

Fig. 3. Distributions of pulses N (number of counts) with respect to amplitudes Q (charge of electron avalanche) as functions of energy E (1 – 3, 2– 1.5 keV) of registered He atoms (solid curves; I = $3 \cdot 10^{-3}$/ channel·sec) and Xe atoms (dashed curves; I = $5 \cdot 10^{-3}$/channel·sec); U = 3.04 kV. Amplitude resolutions R for He: 1) 0.15; 2) 0.19; for Xe: 1) 0.3, 2) 0.46.

an important factor in the case of prolonged use of the detector and requires additional study.

The authors thank V. B. Leonov for constant interest, discussion, and support, and also M. Lampton, discussion with whom in many ways stimulated formulation of the problem.

LITERATURE CITED

1. W. E. Baumgartner and W. K. Huber, J. Phys. E, 9, No. 5, 231 (1976).
2. J. L. Wiza, Nucl. Instrum. Methods, 162, No. 1-3, Pt. 2, 587 (1979).
3. M. R. Ainbund and B. V. Polenov, Open-Type Secondary-Emission Multipliers and Their Use [in Russian], Énergoizdat, Moscow (1981).
4. V. D. Dmitriev, S. M. Luk'yanov, Yu. É. Penionzhkevich, and D. K. Sattarov, Prib. Tekh. Éksp., No. 2, 7 (1982).
5. M. A. Gruntman and A. P. Kalinin, Prib. Tekh. Éksp., No. 4, 175 (1980).
6. M. Lampton, Proceedings of International Astronomical Union Colloquium 40, Meudon Observatory, France (1977), p. 32/1.
7. R. W. Wijnaendts van Resandt and J. Los, Proceedings of Eleventh International Conference on Physics of Electron and Atomic Collisions, North-Holland, Amsterdam (1980), p. 831.
8. M. A. Gruntman, Prib. Tekh. Éksp., No. 1, 14 (1984).
9. J. G. Timothy and R. L. Bybee, Appl. Optics, 14, No. 7, 810 (1975).
10. D. H. Ceckowski, E. Eberhardt, and E. Carney, IEEE Trans. NS-28, No. 1, 677 (1981).
11. C. C. Lo and B. Leskovar, IEEE Trans., NS-28, No. 1, 698 (1981).
12. M. A. Gruntman and A. A. Demchenkova, Preprint IKI AN SSSR, No. 921, Moscow (1985).
13. M. A. Gruntman, Prib. Tekh. Éksp., No. 1, 144 (1985).