

1.12 Photon counting in atomic collision experiments

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A photon counting method is developed in order to measure cross-sections for excitation of atoms by electron impact. If a monoenergetic electron beam of the order of  $10^{-8}$  A traverses the investigated gas at pressure of  $10^{-4}$  torrs, one gets approximately  $10^3$  monochromatic photons per second per 1 cm. of electron

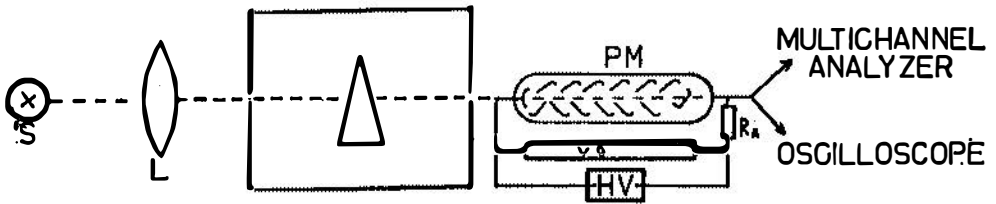


Fig. 1

path and per unit solid angle, assuming the cross-section for emission of certain atomic line to be of the order of  $10^{-20}$  cm<sup>2</sup>. The real photon flux reaching the photocathode of the photomultiplier detector is 1 to 10 photons/s. Such a low light flux

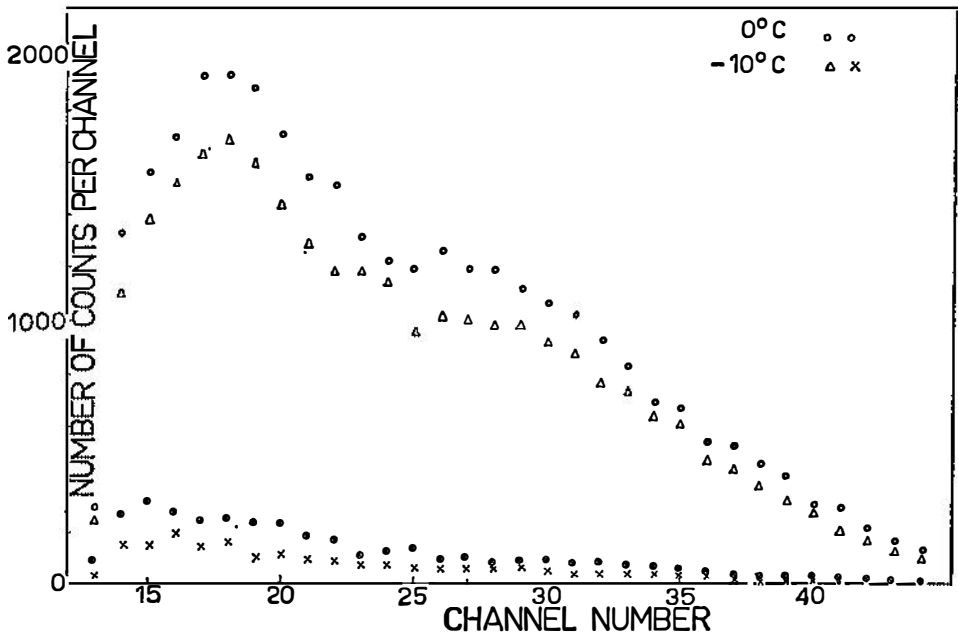


Fig. 2

can be measured only by counting individual photons. The problem of optical photon counting has been treated since 1963<sup>1)</sup>, but at present it does not seem to be solved completely.

In this work EMI 6256 S photomultipliers, placed in a refrigerator, have been used. The diagram of experiment is shown on Fig. 1. The light from tungsten lamp focused by the lens falls on the slit of the monochromator and after passing it, falls on the cathode of the photomultiplier. The voltage source was ORTEC Model 446. In carefully designed voltage divider, a Zener-diode was put between cathode and first dinode to keep constant voltage drop of 150 volts. The pulses formed on 2 k $\Omega$  resistor (the pulse duration being 2  $\mu$ s) were directly fed into a multichannel analyser (Nuclear Data, Model 2200). The shape of pulse height

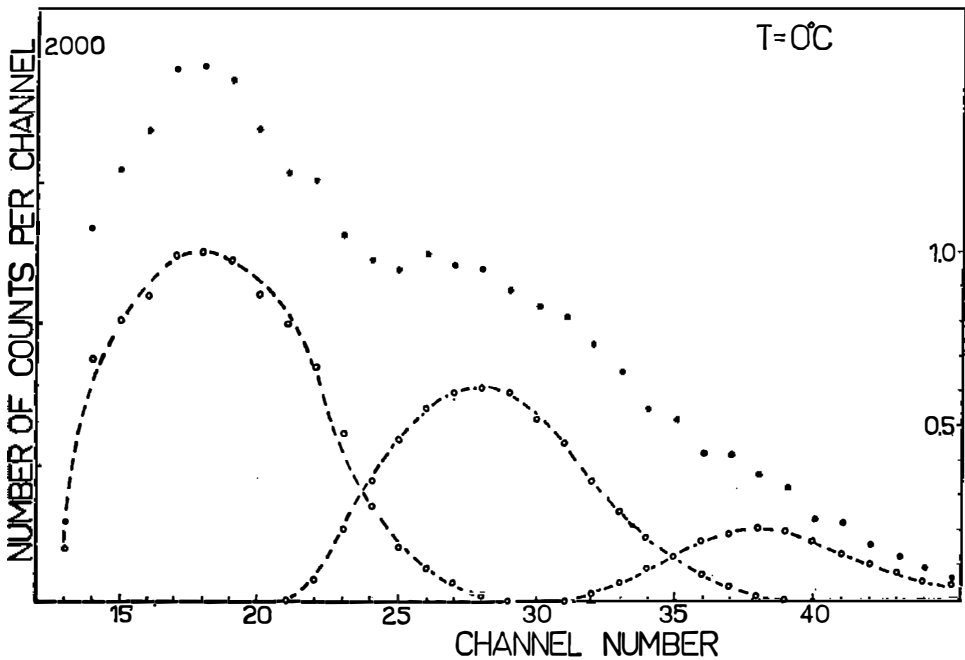


Fig. 3

distribution curves at 1900 volts and two different temperatures for dark count and signal + dark count is shown on Fig. 2. In all cases one can see a big maximum followed by two less intensive equidistant peaks, which can be graphically separated as it is shown on Fig. 3. (At lower voltages the 2<sup>nd</sup> and 3<sup>rd</sup> peaks are not so clearly visible, but the 2<sup>nd</sup> maximum exists on dark count curves even at 1700 volts, for all photomultiplier samples investigated). The first peak probably represents a single electron response. The origin of other two peaks is under consideration.

By using ORTEC standard counting equipment (preamplifier Model 113, amplifier Model 485, single channel analyzer Model 406A and scaler Model 484), the first maximum falls into electronic noise and cannot be seen.

The overall quantum counting efficiency (number of pulses per 1 photon) can be estimated to be 1 — 5% at wavelength of maximum sensitivity for this type of photomultiplier. We calculated the real values using known light fluxes from standard tungsten lamps<sup>2)</sup> and they are represented on Fig. 4. As it can be seen, the overall counting efficiency is about 1% at wavelength of maximum sensitivity. The cooling of photomultipliers from 20°C to —20°C gives a diminution of dark counts by a factor of 10, following the Richardson law (Fig. 5). Further cooling is practically without effect. It seems that the quantum counting efficiency is also slightly affected by cooling.

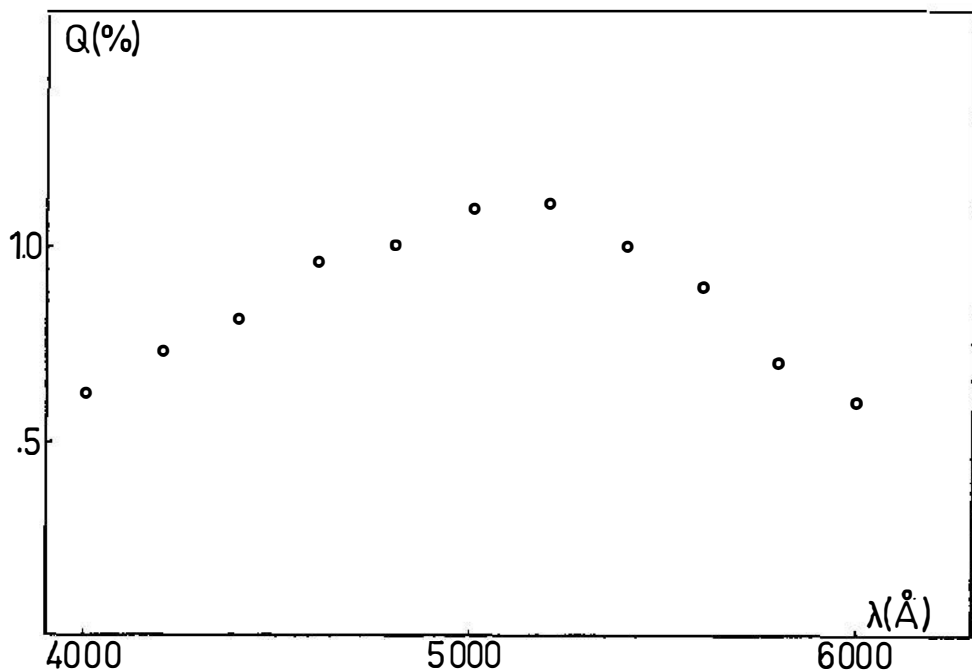


Fig. 4

The integrated net signal counts at 1700 volts and 1900 volts are practically the same, indicating the existence of a rather large plateau in photon counting versus voltage.

The square root of number of counts depends linearly on duration of measurements, which indicates random distribution of pulses from photomultiplier (Fig. 6). The deviation from linearity, i. e. from Poisson distribution of pulses, is practically negligible.

For accurate measurements the voltage on the photomultiplier must be kept at least 24 hours before reading, and the stability of voltage source, as well as of the photomultiplier and ambient temperatures, should be as high as possible.

This method can be applied also in other physical experiments where very low light fluxes are to be measured, such as some plasma experiments, collisions of heavy particles with solids, astrophysics, astronomy, scattering of light, etc.

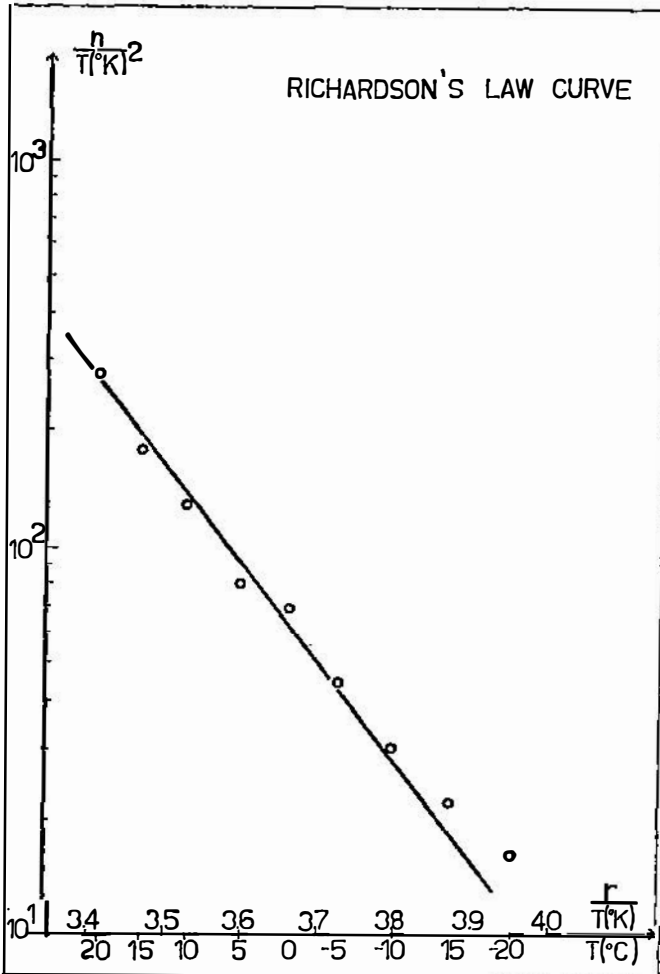


Fig. 5

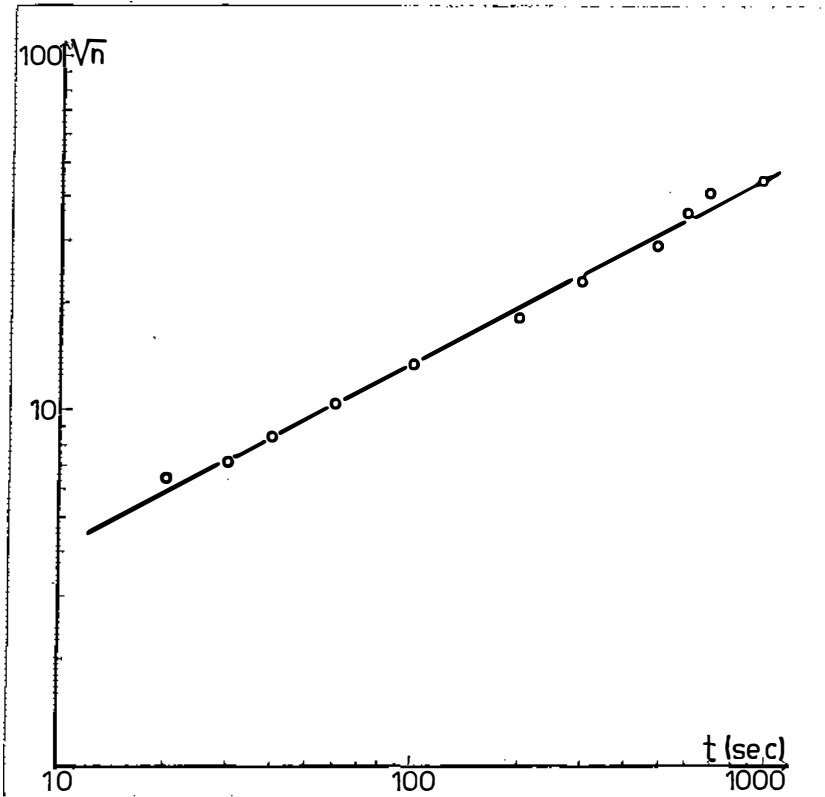


Fig. 6

## References

- 1) L. P. Rodman and H. J. Smith, *Appl. Opt.* **2** (1963) 181; G. A. Morton, *Appl. Opt.* **7** (1968) 1; R. Foord & Associates, *Appl. Opt.* **8** (1969) 1976; A. И. Перцев и соавторы, *ПТЕ*, **2** (1965) 146; A. И. Перцев, А. И. Писаревский, *ПТЕ* **4** (1967), 5;
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### 1.13 Electron energy spectra calculations from homogeneous, cylindrical and spherical electronic field dispersing elements

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