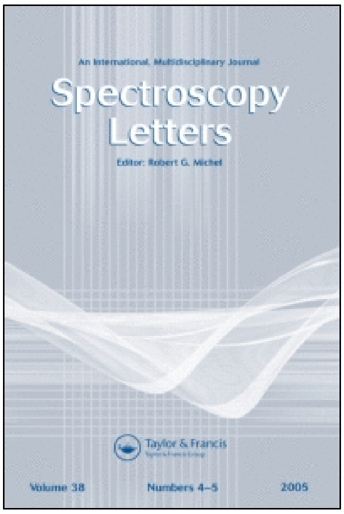

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REGISTRATION OF LOW INTENSITY SPECTRAL LINES WITH FABRY PEROT INTERFEROMETER BY PHOTON COUNTING METHOD

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ABSTRACT

A simple photon counting system for measuring very low optical spectral lines is described. It is of interest the cooling housing for its low cost and easy implementation. A comperison between the standard d.c registration system and the photon counting one is given.

INTRODUCTION

As it is well known the method of pulse counting is widely applied in radiometry. A single photon spectrum can be recorded when a photon causes a pulse. It is so called photon counting method in this case.

The equipment is the same but a more of details is to be discussed. The PMT comes the first. In order to achieve greatest sensibility a PMT with a single photon maximum is choosen. For choosen such a PMT an amplitude analisis must be carried out (fig. 1). Curve 1 shows the shape of dark current characteristic of the suitable for photon counting PMT, and curve 2 shows the shape of dark current characteristic of the conventional one with nearly the same range of the total dark current. It is evident that the plateau shall raise if an accidental beam falls onto the photocathode while the exponent shall remain nearly on the previous statistical level. This feature of the dark current characteristic provide the main advantage

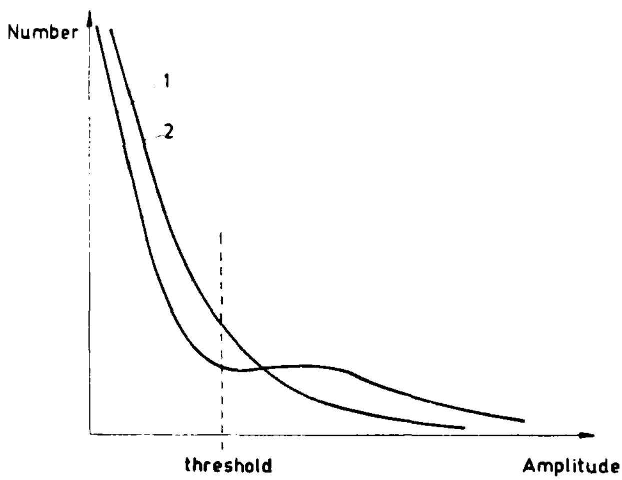

Fig. 1

A typical amplitude analyses of the dark current of suitable for photon counting photomultiplier (1) and of a standard one (2).

in the photon counting method. If a threshold is applied to suppress the main part of the dark current pulses, which manifest themselves in the exponent, the sensibility shall depend on the hight of the plateau.

It is of great importance to design and make the PMT housing and the registrating part well for maximum realization of the photon counting method. For instance[1], the single photon maximum requires higher than usual voltage and special care must be taken when the dynode chain is made -the wiring should be very carefully done with short connected wires. The whole system must be hermetically insulated if possible. If cooling is applied because of the possible scintilation of the additionally inserted materials (as the glass of special duar, for instance) there should be taken still other measures to insulate the PMT optically.

The electrostatic protection of the PMT is an important problem and must be most carefully carried out, and a special permalloy shield must be used (as those produced by EMI for example) when no magnetic field is applied to reduce the dark current. A hygroscopic material might be placed in to avoid sweating of the window[2]. In case of sweating the minimum intensity of the signal grows up so reducing the sensibility of the system.

A general block diagram of the apparatus is consist of PMT, amplifoer discriminator and data counter. The total gain factor of the electric system is about 10^9. The gain of the PMT is about 10^6 in photon counting and the pulse amplifier must have a factor of gain about 10^3. A band of 100 MHz is quite sufficient for all the registration equipment. To fix accurately the single photon maximum a descriminator with easy thresholds should be used. A 2 kV high voltage supply is suitable for a serial PMT (as an EMI one, FEU-79-USSR etc.).

EXPERIMENTAL

Fig. 2 shows a block diagram of experimental set- up UFPS-1 by Carl-Zeiss Jena is used as a source of interference atomic spectrum. It is d.c registrated by a recorder (channel 1-standard equipment) or by photon counting (channel 2).

We reched the required gain factor of about 1000 for the whole electronic system by adding a 10 gain preamplifier to the single channel analyser 20026. The appropriatelly choosen input and output resistances of the preamplifier allow good co-ordination between the PMT and the single channel analyser. Some insignificant changes in the single channel analyser enables its effective application in our photon counting system. The multichannel analyser of the type AI-128-2 (USSR) makes the amplitude analysis of the dark current pulses, linearly

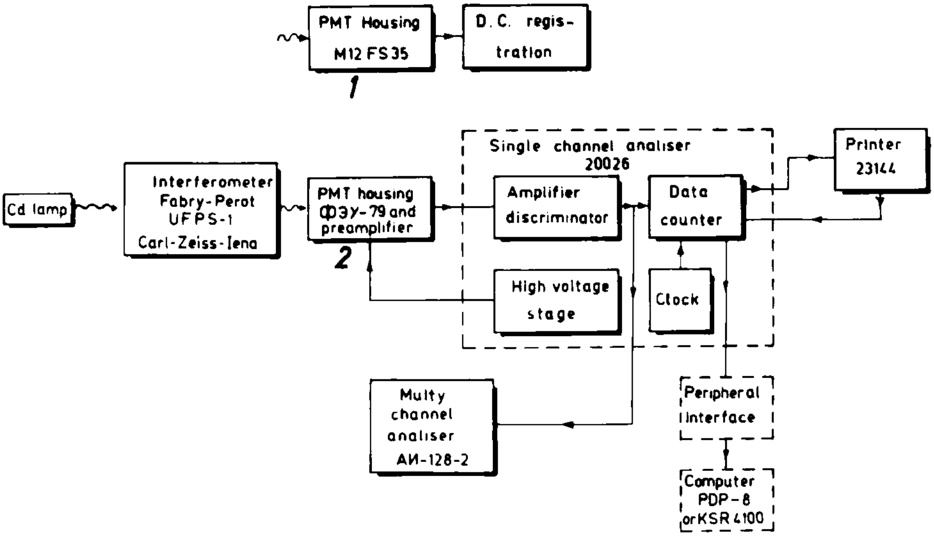

Fig. 2

Standard d.c registration system (1) and the photon counting system we have used (2).

amplified by the amplifier of the single channel analyser. The multichannel analyser is cut out when the single photon maximum is achieved and the registration is performed by the data counter of the single channel analyser. The printer records the data of the measurements in each channel and then clear and start impulses sent to the data counter so that the registration of the next spectrum channel could begin. Thus for a scanning interval Δt per channel the data are recorded by the printer or are fed into a computer for mathematical processing.

Particular attention is paid to the PMT housing. Fig. 3 shows the diagram of the PMT housing we made it. The PMT of the type FEU-79 (USSR) (4) is encircled by a cooling aluminium cylinder (3), thermally connected to a liquid nitrogen duar (1) by means of a cooling rod (2). The PMT is thermally insulated by a styrofoam cushion(7) and optically protected by a black screen (8). The electrostatic protection is assigned to the housing (6), encircling the preamplifier as well. (5) is a silica gel ring. (9) is the base of FEU-79.

The cooling system is of interest in this case, because of its fairly simple implementation and low cost.

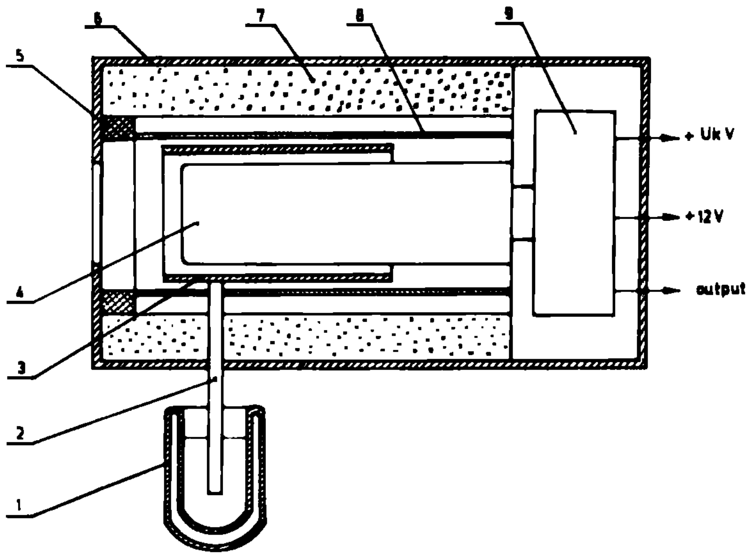

Fig. 3

Cooling PMT housing.

The appropriately choosen cooling rod provides a quite sufficient temperature of abcut -20°C with adequate stability and riliability. If desired a plain replacement of the cooling rod could secure the same cooling stability and riliability by means of other cooling mixtures (as cryogen, for instance), dry ice etc.

RESULTS

We have not applied magnetic fied to reduce the number of dark pulses because of the sharp elevation of their level, probably due to the construction of the PMT. In the cases of a PMT, produced by EMI good results are achieved.

Fig. 4 shows the blue line of cadimium registrated by standard equipment (a) and by our photon counting system (b). The line is reduced by the diaphragms of UFPS-1 to the potentialities of the standard equipment. The isotopic structure of the line is clearly seen in case (b). Some measurement characteristics are shown. The improvement of signal to noise ratio in our photon counting case is about 10^4. The width of channel in case (b) is determined by the free spectral range and the halfwidth of the line so that it becomes evident that the number of channel per order must be equal to the finess of the Fabry-Perot etalon. Thus, by means of the value of the time per cha-

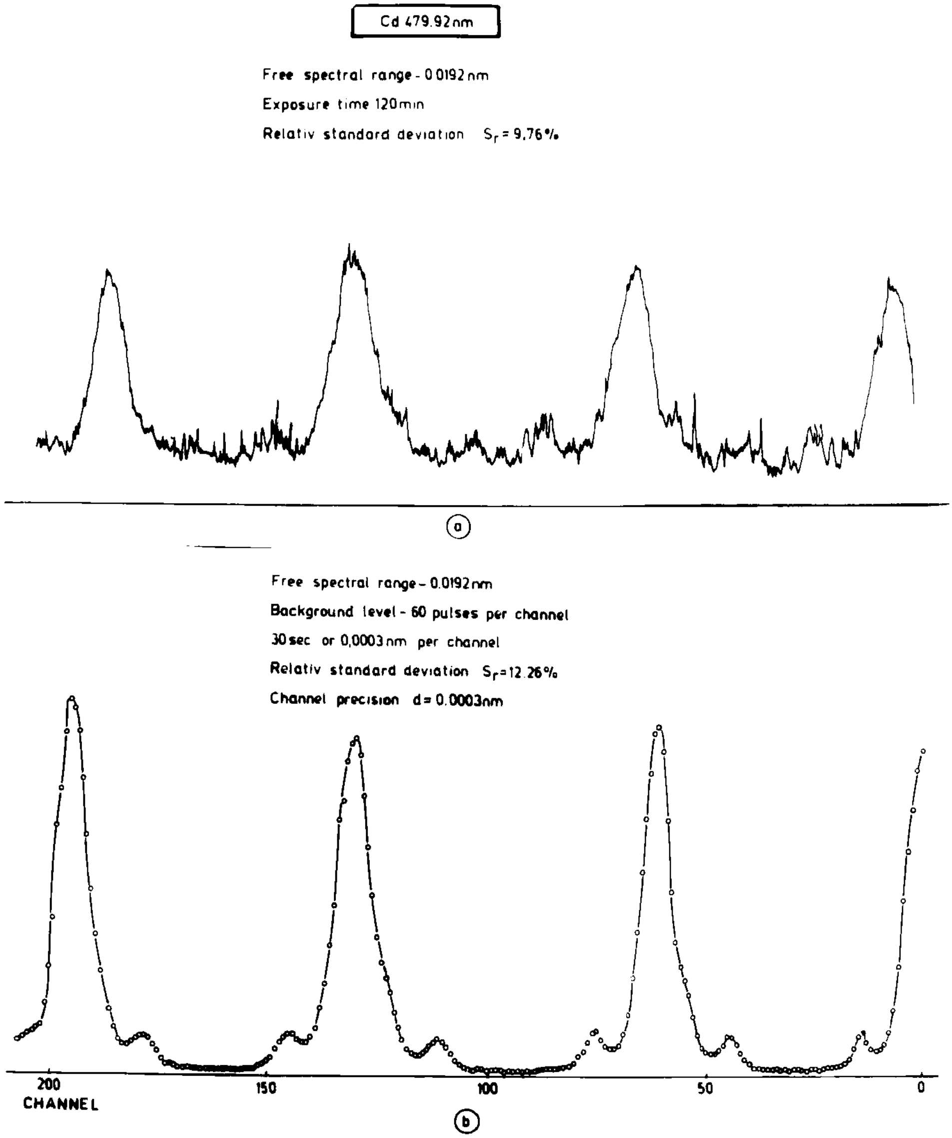

Fig. 4

Isotopic structure of Cd 479.92 nm, (a) standard d.c system, (b) photon counting system.

nnel we can calculate a time of exposure to provide an optimal statistical level.

Fig. 5 shows a blue calcium line from a hollow-cathode lamp in magnetic field and all the characteristics of the measurement accomplished by the standard equipment (a) and our photon counting system (b).

CONCLUSIONS

On the basis of our work we can make the following widely vallid conclusions:

1. The cooling system applied is expensive and is easily implemented. It provides a stable temperature of about -20°C which is sufficient for reducing to the minimum the number of dark pulses from an antimony-cesium cathode such as the cathode of PMT FEU-79 (USSR).

2. It is evident that the sensibility of our photon counting system is higher than the sensibility of the standard equipment with d.c system. Very week light beam of about 100 photon per second can be registrated. The avarage rate of signal to nois ratio is over 10^4 in our photon counting case.

3. It is quite easy in our case to apply a computer for a large range of mathematical processing of the data. For example: processing of the shape of the lines, correction by means of the apparatus function; direct plasma

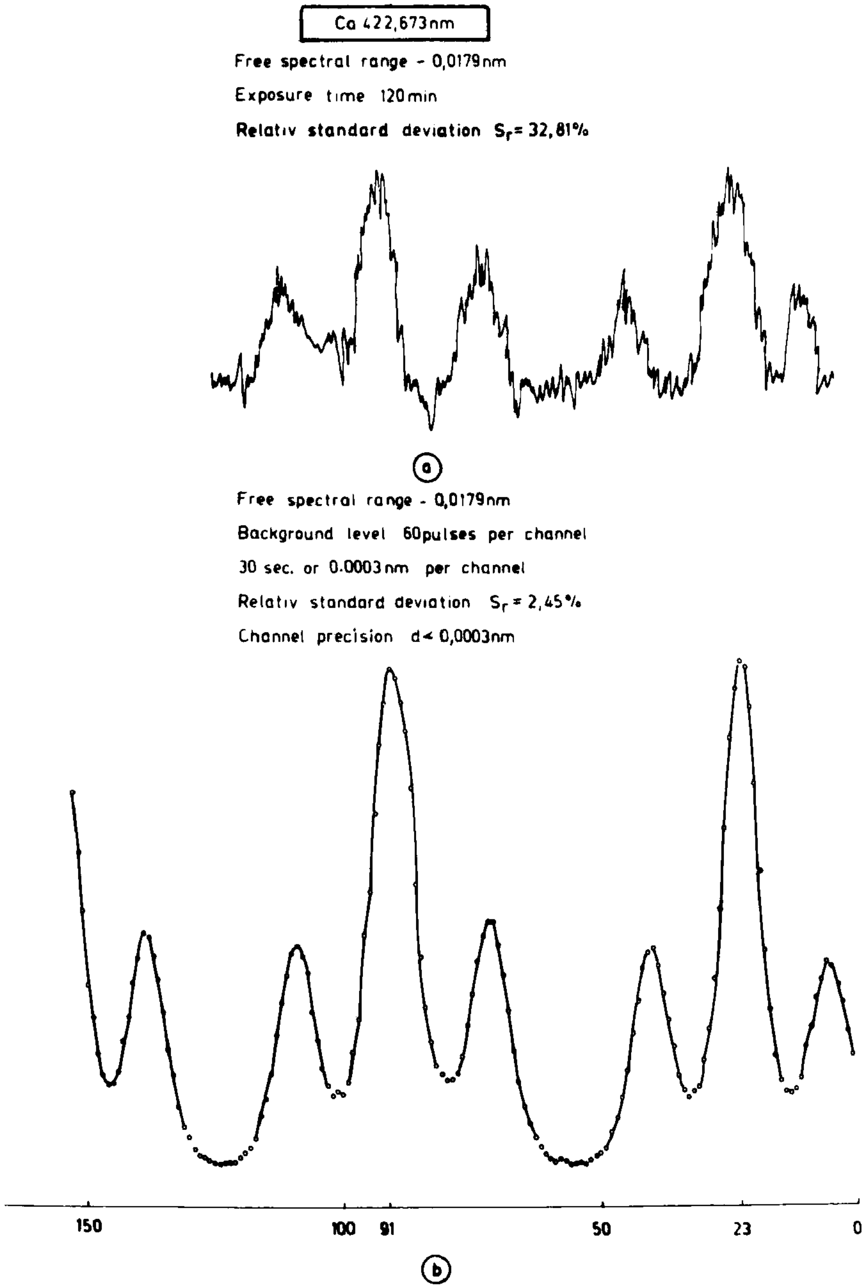

Fig. 5

Zeeman spliting of Ca 422.67 nm line: (a) standard d.c system, (b) photon counting system.

diagnostics on very precise registration of the line profiles; structural analysis of very low isotopic concentrations; precise analysis of laser lines and so on.

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