The proximity focused hybrid photodiode detector

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LAPP-EXP-94.04
MARCH 1994
SW 9415

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Contribution to the Worshop on Scintillating Fibre Detectors, SCIFI 93,
October 24-28, Notre Dame, IN 46456, USA

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ABSTRACT

A new type of light detector, the Proximity Focused Hybrid Photodiode Detector, has been constructed and its properties have been studied. The main features of the new device are: a gain of up to a few thousand varying linearly with the applied high voltage, a large dynamic range, a low sensitivity to magnetic field, a power comsumption close to zero and a multipixel capability.

The Proximity Focused Hybrid Photodiode Detector (PFHPD) is a new type of photodetector which was proposed by the RD1 Collaboration at CERN and developped with the DEP company* to cope with the limitations of the conventional photomultipliers (PMT) at a competitive cost. The PFHPD, whose first prototype is shown on Fig. 1, comprises two active components:

- a glass or fiber-optics input window on which a semi-transparent photocathode is deposited, just as in a conventional PMT,
- an output disk equipped with a reversed biased silicon detector (anode), placed in close proximity (≅ 1.5 mm) to the photocathode, which acts as an electron detector.

Those components are vacuum sealed to both ends of a ceramic cylinder. A large electrical field, HV, with a strength of about 10 kV, is applied between the two electrodes.

* Delft Electronische Producten, Postbus 60, 9300 AB Roden (Dr) Holland.

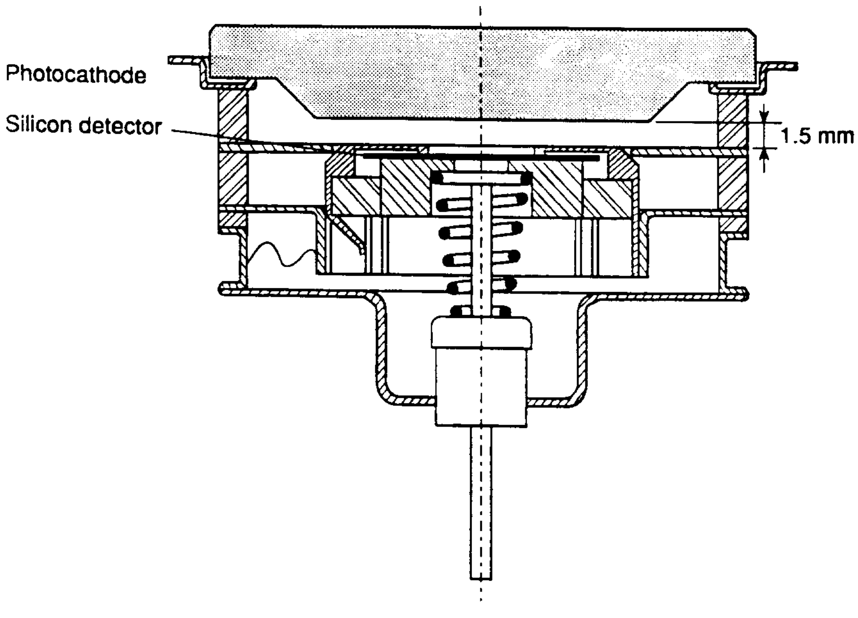

Fig. 1
The first DEP prototype of the Proximity Focused Hybrid Photodiode Detector (PFHPD)

The photoelectrons produced in the photocathode are channelled (proximity focused) by the large electrical gradient (7 kV/mm), parallel to the tube axis, into the silicon detector 1.5 mm away, where electron-hole pairs are produced. There is a thin passivation dead layer on top of the silicon which causes a mean voltage loss HF = 2 kV of the photoelectrons without pair creation. The remainder of the photoelectron energy produces 1 electron-hole pair per 3.62 eV. The electron gain of the device, G = (HV - HF) / 3.62, is therefore about 2000 at 10 kV.

The power consumption is dominated by the silicon diode reverse current. As an example, for a current of 10 nA and 100 V bias voltage the power consumption is only 1 μW.

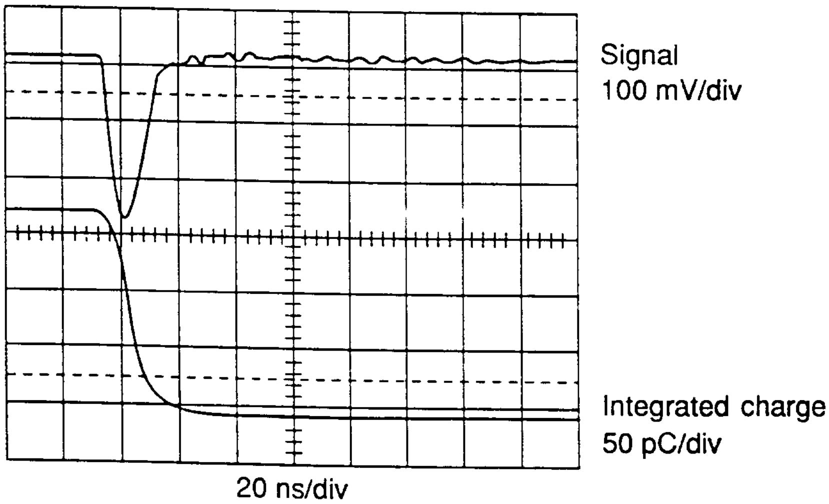

Fig. 2
The ouput pulse and the integrated signal of the PFHPD.

Prototypes (Fig. 1) were built with available Ø = 6 mm and Ø = 8 mm silicon detectors, and the properties of the device were studied (Ref. 1). A typical output pulse with a risetime of 5 ns and the corresponding integrated charge are shown on Fig. 2.

The relevant properties of the device reported in Ref. 1 are summarized below:

- linearity of the response within ± 2% over a dynamic range > 10^4 for the input pulse.
- insensitivity to axial magnetic field measured up to 2 Tesla and low sensity to transverse magnetic field: < 10% at 0.15 Tesla.
- gain up to 2000, linear with the applied voltage.
- power consumption close to zero.

With the first prototype the gain at a fixed applied voltage decreased by a factor 1/e for an integrated output charge of 1 C/cm^2. Most of that loss appeared to be due to ions emitted by the silicon detector causing damage to the photocathode. At DEP that effect was shown to be very much reduced by a better preparation - scrubbing with an electron beam - of the silicon detector.

Based upon the results obtained with the prototypes, a larger hybrid photodiode detector equipped with a Ø = 25 mm silicon was built (Fig. 3). The gain of the detector as a function of the high voltage is shown on Fig. 4. An increase of the output pulse risetime was expected due to the larger size of the silicon detector. As shown by Fig. 5 the risetime is still adequate, 7.5 ns for a bias of 100 volts.

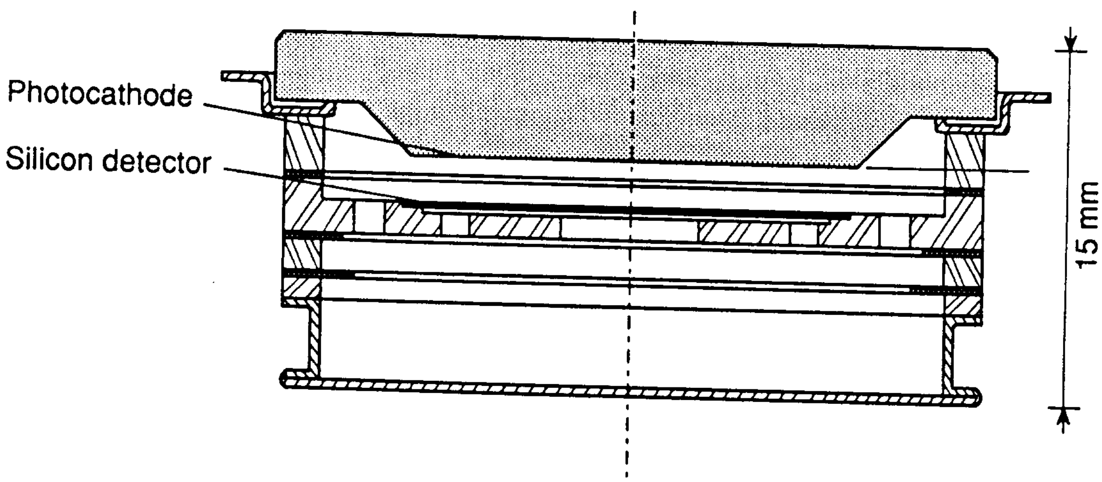

Fig. 3
The new PFHPD with a Ø = 25 mm silicon detector, intended for large quantity production by DEP.

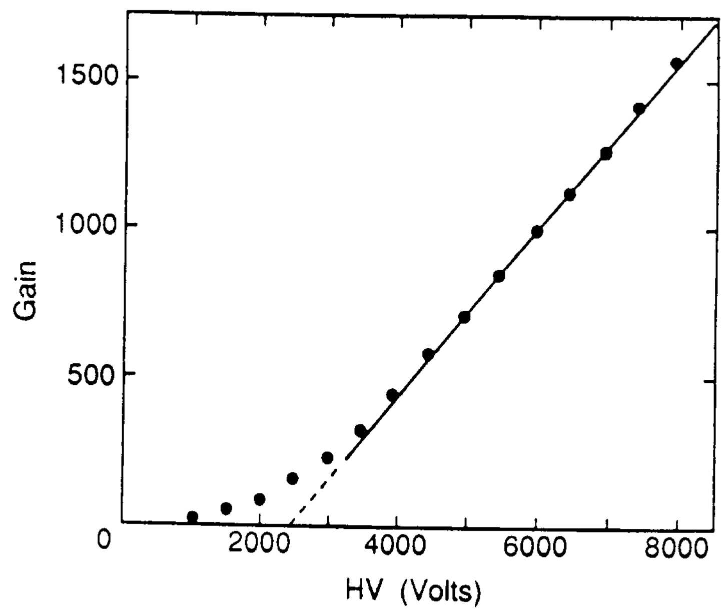

Fig. 4
Gain versus high voltage for the new tube.

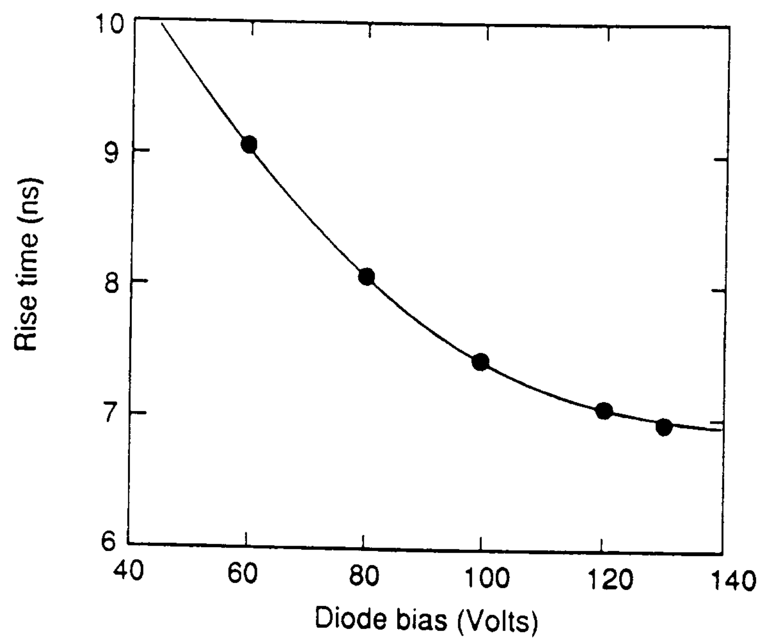

Fig. 5
Risetime of the output pulse versus the bias applied to the silicon detector.

Other properties of the larger tube are presently under study and a commercial version should become available in the near future

REFERENCE:

1. S. Basa, J-C. Clemens, M. Commerçon, D. Sauvage, S. Tisserant and J-M. Gaillard, NIM A 330 (1993) 93.