RUBICON - A NEW DIODE ARRAY DETECTOR SYSTEM

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Abstract

A photon-counting system with a 512-channel parallel output digital image tube is presented. Electronics developped separately for each detector channel as well as data aquisition are optimized for low power consumption and high count rates. This detector, characterized by wide dynamic range, very low noise and high photometric accuracy, is especially suitable for spectrophotometry and calibrations.

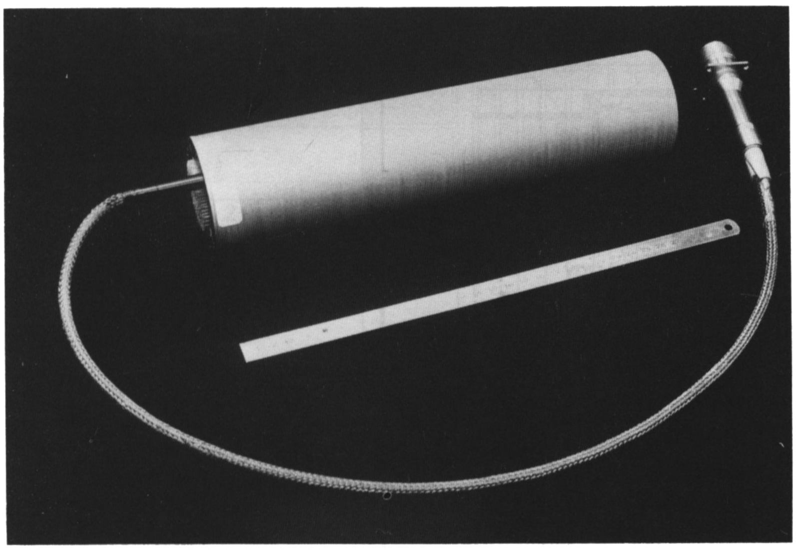

Fig. 1 The complete encapsulated tube

The potentialities of very large telescopes are fully exploited only by optimal backend instrumentation, i.e. high-sensitivity detector systems with fast exhaustive data processing. The requirements, restrictions and astronomical uses of various one- and two-dimensional detector systems have been described by Rudolph et al. (1978) and Eccles et al. (1983).

Here we present a one-dimensional, photon-counting detector system with low noise and extreme dynamic range which is especially suitable for spectroscopic work, and for absolute and relative calibrations.

This detector system is based on an imaging tube with 512 parallel-output channels. The tube has a photocathode as an electron source on one end and a one-dimensional monolithic diode array as detector on the other end. Incoming light produces electrons which are accelerated in an electrostatic field of 15 - 25 kV and magnetically focussed to the diode array. A photoelectron generates an electron-hole pair for each 3.6 eV loss of energy, producing a charge pulse of 4000 - 7000 electron-hole pairs in the semiconductor. Each diode is connected through a ceramic header to its own charge-sensitive amplifier, discriminator and counter.

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Since the whole tube gain occurs in one stage the pulse-height distribution is sharply peaked. As all photoelectrons produced by the photocathode are counted, this is a real photon-counting detector system. The sensitivity depends only on the quantum efficiency of the photocathode. The tube is characterized by a wide dynamic range (10^6), low noise level ($\lesssim 10^{-2}$ cts/sec·pix) and high photometric accuracy (< 0.1 %). The tube body design is based on the Spectracon (McGee et al. 1969). The chrome-iron backplate of this detector was replaced by a multilayer ceramic header with a diode array (Figure 2).

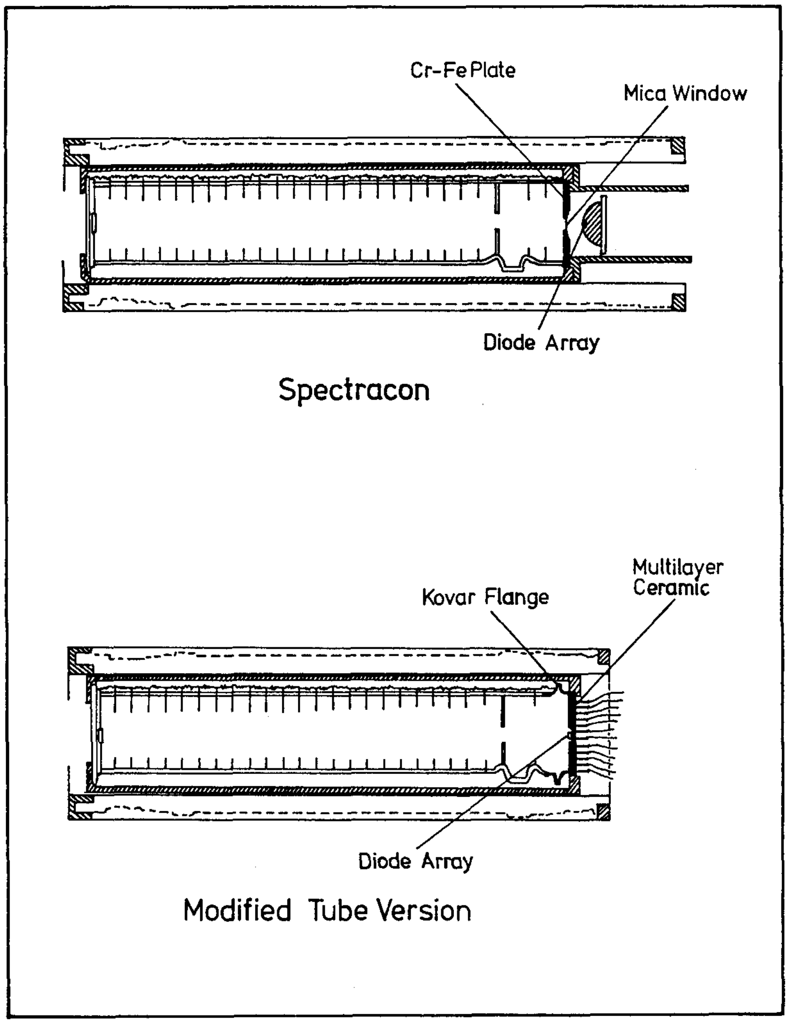

Fig.2 Tube design

Description of the Detector System

The diode array chip is 29 mm x 5 mm in size and carries a line of 512 diodes of 38 µm x 500 µm each with a center-to-center spacing of (48 ± 1) µm. Two additional diodes of 200 µm x 200 µm are positioned at each end of the array (Fig. 3). The header is a seven-layer ceramic substrate used as a tube socket. It is a vacuum tight plate of 44.5 mm diameter and 2.7 mm thickness. The array is mounted

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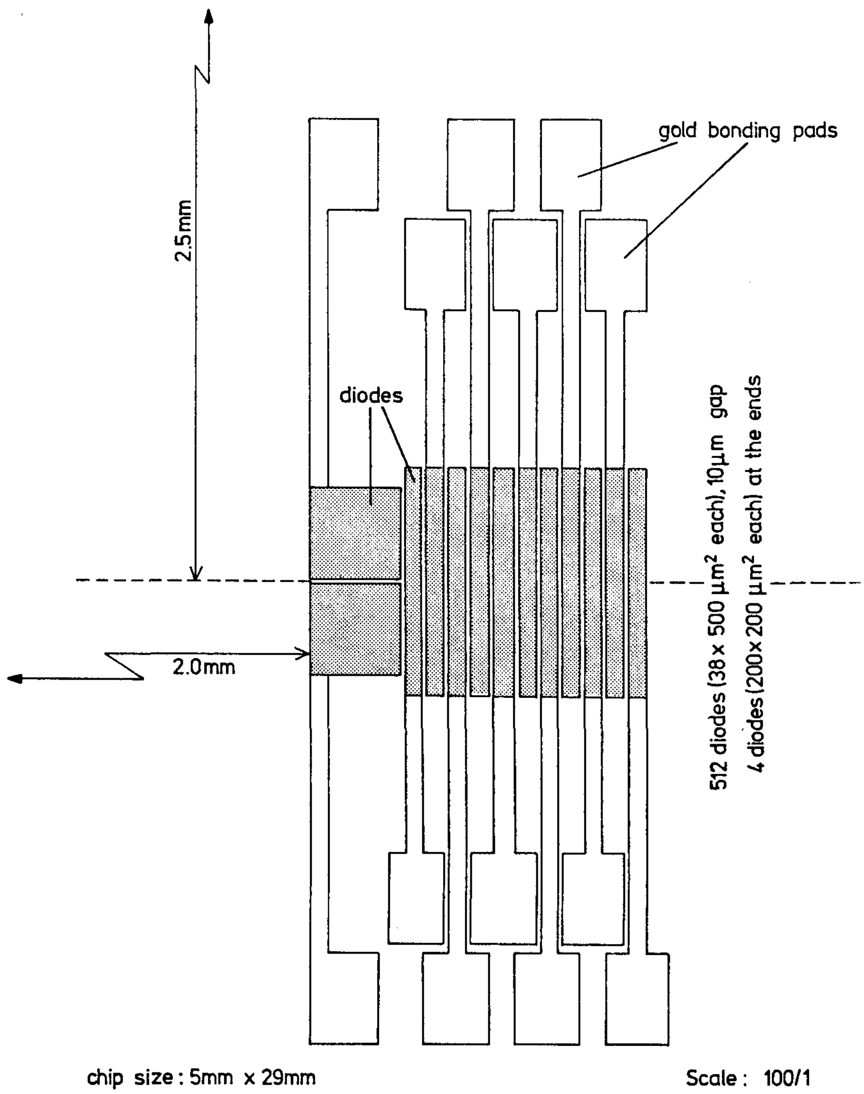

Fig.3 Diode array

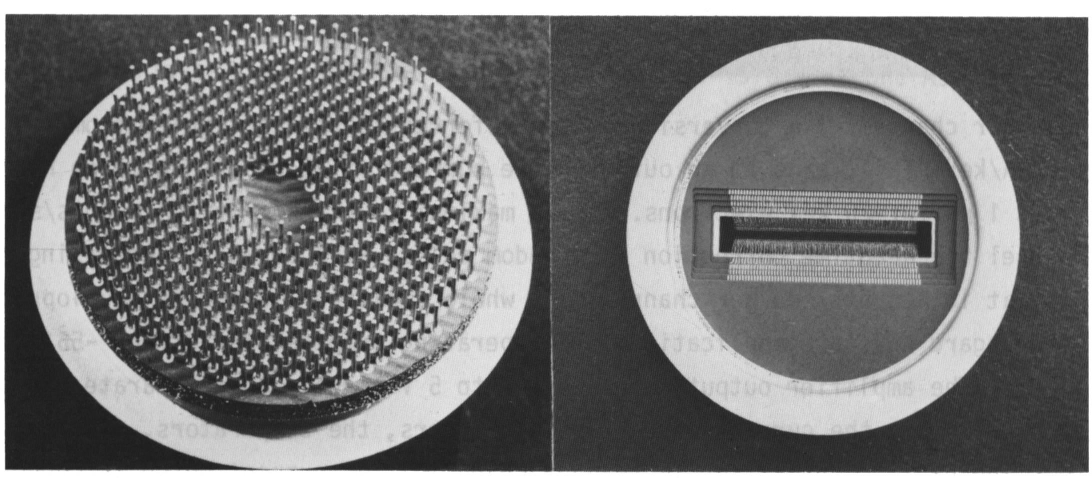

Fig.4 Ceramic header: backside and frontside with mounted array

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in a gold-plated mould by gold-silicon eutectic bonding. The diodes are wire-bonded to gold-plated pads on the ceramic. Fig. 4 shows the backside and the frontside with the mounted diode array of the ceramic header. The complete encapsulted tube is shown in Fig. 1. For our detector version the Spectracon solenoid was shortened to a total length of 33 cm. All other characteristics were kept unchanged.

Read-out Electronics

Each photoelectron event generates a charge of about 10^{-15} As. This small signal requires a low coupling capacitance and therefore short connectors from the header to the preamplifiers. As the rear end of the tube is very close to the mu-metal backplate of the magnet the preamplifier box can be fixed outside the solenoid with a wiring length of a few cm. Each channel has its own preamplifier, consisting of a charge sensitive input stage, a voltage amplifier with lowpass and a voltage to current converter with highpass. These parts are integrated for 8 channels on a thickfilm hybrid circuit (Fig. 5). The power consumption is only

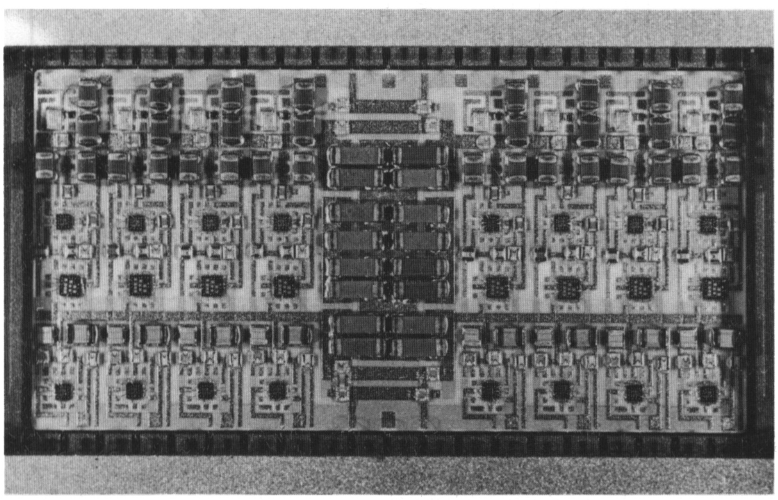

Fig.5 Hybrid amplifier
Substrat size 1"x2"

4 mW per channel. The conversion factor referred to silicon varies from 1.7 to 2.0 μA/keV. This leads to an output pulse current of 40 μA with a pulse FWHM of about 1 μs for 20 keV electrons. At the maximum count rate of 10^5 events/sec per channel the deadtime correction for random pulses will be 10 %, decreasing to 1 %, at 10^4 counts/sec per channel. The whole amplifier layout is developped with regard to space applications. The operating temperature is from -55° to 110° C. The amplifier output is converted to 5 V signals on a separate circuit board carrying the current-to-voltage converters, the comparators, discriminators and 4-bit counters for 16 readout channels. The current pulse is converted to a 160 mV-pulse; the noise is about 20 mV at the comparator input. The reason to use only 4-bit counters combined with a high readout frequency is, that in

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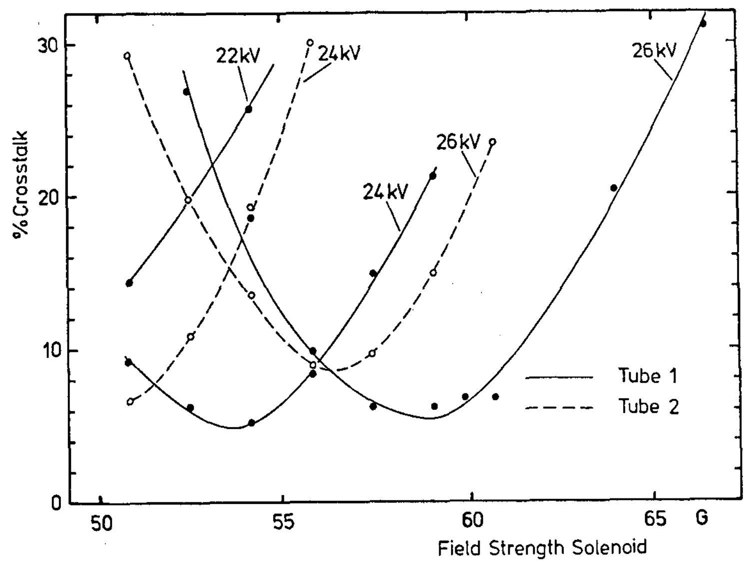

Fig.6 Crosstalk in tube

this way sudden unforeseen noise or bursts (for example from cosmic ray events) cannot influence the counting rate significantly. The crosstalk to adjacent channels as a function of high voltage and magnetic field strength is given in Fig. 6. The distortion is less than ± 15 μm along the total array length. As only an electron which is generated from the photocathode and imaged onto a diode is counted, the background noise mainly depends on the diode size. The average background count rate was 0.012 counts/sec · diode for the first tube unit and 0.004 counts/sec · diode for the second one.

A detailed description is available on request.

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