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TITLE: A FOCUSSED MCP IMAGE INTENSIFIER TYPE FOR HIGH SPEED GATING

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A Focussed MCP Image Intensifier Tube for high speed gating

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ABSTRACT

This tube is aimed at shuttering speeds faster than 200 picoseconds, with required electrical gate pulse less than 80 volts. Similar tubes were described in a 1984 paper at this meeting. One new feature is the use of a microchannel plate (MCP) to provide high and adjustable signal gain. This tube, in comparison with proximity-focussed tubes, conserves resolution by using an electrostatic focus lens. Also new is the use of transfer photocathode technique to eliminate stray emission from the gate mesh. Measured performance: Gating speed, Gain, On-Off signal ratio will be presented. Tube construction and the transfer photocathode technique will be discussed. The noise which shows up in high-gain imaging systems will be discussed.

TEXT

The work described here follows that of SPIE paper 497-10, 1984. We are working with a focussed image intensifier diagrammed in Fig. 1. A concave photocathode on the fiber optic input faceplate generates electrons in response to light falling on the faceplate. In the "on" state, the electrons emitted from any point of the image are accelerated through the tube to a focus at the image plane. The present tube has a microchannel plate, at this plane, which amplifies the electron current; the amplified electron image is accelerated to a phosphor screen using proximity focus. The output faceplate is fiber optic for convenience in coupling to following devices.

The gate electrode is a fine mesh curved screen close to the photocathode. The "on" voltage applied to this electrode is equal to that which the equipotential sphere would have had in the absence of the mesh, so that the mesh causes minimal disturbance to the electric field. The gate is "off" for any voltage on the mesh lower than the photocathode potential by more than a few volts. The finite resistivity of the photocathode material limits the speed with which an electrical signal applied to the edge of the photocathode can reach the center. The time required for this is of the order of the RC time constant given by the photocathode surface resistivity and the capacitance between the mesh and the photocathode. In order to have low photocathode resistivity, we use a conducting substrate under the photocathode. For the spacing between the photocathode and mesh, a design compromise is made between the RC time and the pulse voltage required. The present

design has a 50-mil spacing which gives a required pulse voltage of 80 volts and a time constant of well under 100 ps.
The substrate is an evaporated nickel layer. Absorbtion of light in this layer gives about 50% light transmission.

We are in the process of switching over from making image intensifier vidicons with silicon targets, (SIT vidicons) to making this image intensifier tube with a microchannel plate. The exhaust equipment had not yet been modified for the electron scrubbing normally used on microchannel plates during the exhaust cycle. The tube we used for test was made without scrubbing and as a result the microchannel plate outgassed excessively in operation, degrading tube performance. Specifically, decreasing photocathode sensitivity and causing an as yet undetermined electrical loading effect which limited the voltage we could apply to the phosphor, further reducing the over-all sensitivity.

Nevertheless, we were able to obtain some measurements. The turn-on was checked; it was found that the turn-on does occur over a narrow range of gate voltage as expected, as shown in Fig 2. The turn-on is not abrupt because of the distribution of initial energies of electrons starting at the photocathode and because of electric field reaching through the mesh openings. The latter effect is small with our fine mesh, (1000 lines per inch). The much higher gating voltage is used to bring the gate electrode to the neutral voltage, described above, for best resolution. Thus we desire a rectangular electrical pulse, but for high speed pulses "rectangular" is hard to obtain, hence we lose some resolution for such pulses.

Gating time was measured in a system where the light was applied to the tube as a pulse from a quenched laser of about 10 picoseconds, much shorter than the available electrical pulse. The light pulse could be moved through the electrical pulse by adjusting delay times. A sequence of images at various times within the electrical pulse was obtained. These were too poor to display, but it was determined that the effect of RC time was insignificant compared to the 650 picosecond electrical pulse used. The effect of RC time would have been that the image would appear initially at the edge of the circular area, and then progress inward until it fills the whole tube, and likewise at the closing of the gate, the image would disappear first at the edges. This effect has long been observed for tubes without conductive substrate under the photocathode.

In shuttering applications, it is desired that no unwanted signal should accumulate during the "off" time. As a measure of performance, we determine the ratio of "on" signal to "off" signal and require that this be at least a million to one There are three reasons for non-zero signal during the "off" time. (1) Light may penetrate through the the tube from input to output. This is insignificant in the present tube because an aluminum coating on the phosphor blocks the light, but in alternate versions of this tube in which a silicon diode array target with vidicon read-out is used in place of the MCP and phosphor, this is significant. (2)The microchannel plate gives stray electron emission under maximum gain conditions. We do not anticipate this will be a problem because maximum gain is not useful as will be explained later.

(3) Photoemission from the gate mesh is not cut off by mesh voltage, and was a significant factor in previous tubes, where the photocathode processing caused slight sensitivity on the mesh. Present tubes are made by the photocathode transfer technique described below. Recent work shows that this technique does eliminate such sensitivity.

Tube exhaust is done in a bakeable vacuum bell, see Fig.3. The procedure in outline is as follows: The tube body including the gate mesh is placed in the bell in the left station, indicated as a the faceplate carrying the thin nickel substrate is placed in the right station, at b, resting on the processing chamber. This chamber is used to contain the alkali metal vapors during photocathode formation. The system is then closed by bolting on top and bottom flanges. The system is pumped and baked. The photocathode is then processed and the faceplate moved over the tube body and sealed. The system is then unbolted and the completed tube recovered.

While light gain is not the primary function of this tube, it is important in the design of the total system. The random noise introduced by the quantum nature of light and electrons is one factor. Let us draw a quantum gain diagram for this tube, see Fig. 4. Location in the tube is plotted horizontally and log of the number of quanta is vertical. We arbitrarily start with one input light quantum. The probability of emission of an electron from a photocathode is about 10 percent, but the nickel substrate may absorb half the light, making net gain of .05. The mesh has a transmission of .5. The channel plate has a fraction of open area greater than .5, but the randomness of gain in the channels adds a little noise, so we consider its open area .5. The gain in the MCP is high and variable with the voltage applied across it. Let us assume a gain of 1000 and assume the phosphor gives a quantum gain of 10.The usefulness of this quantum gain diagram is that the lowest point in the diagram approximately sets the system noise! Suppose we want an individual pixel to have a signal-to-noise ratio of 30. Since the random noise goes as the square root of the number of quanta, we need about 1000 electrons per pixel at this point. We then set the vertical scale, and find the number of input light quanta to be 80000 per pixel.

FIGURE CAPTIONS

Fig. 1. Electrode diagram for focused gatable image intensifier.

Fig. 2. Gate voltage characteristics of image intensifier.

Fig. 3. Transfer photocathode system.

Fig. 4. Quantum gain diagram for image intensifier.

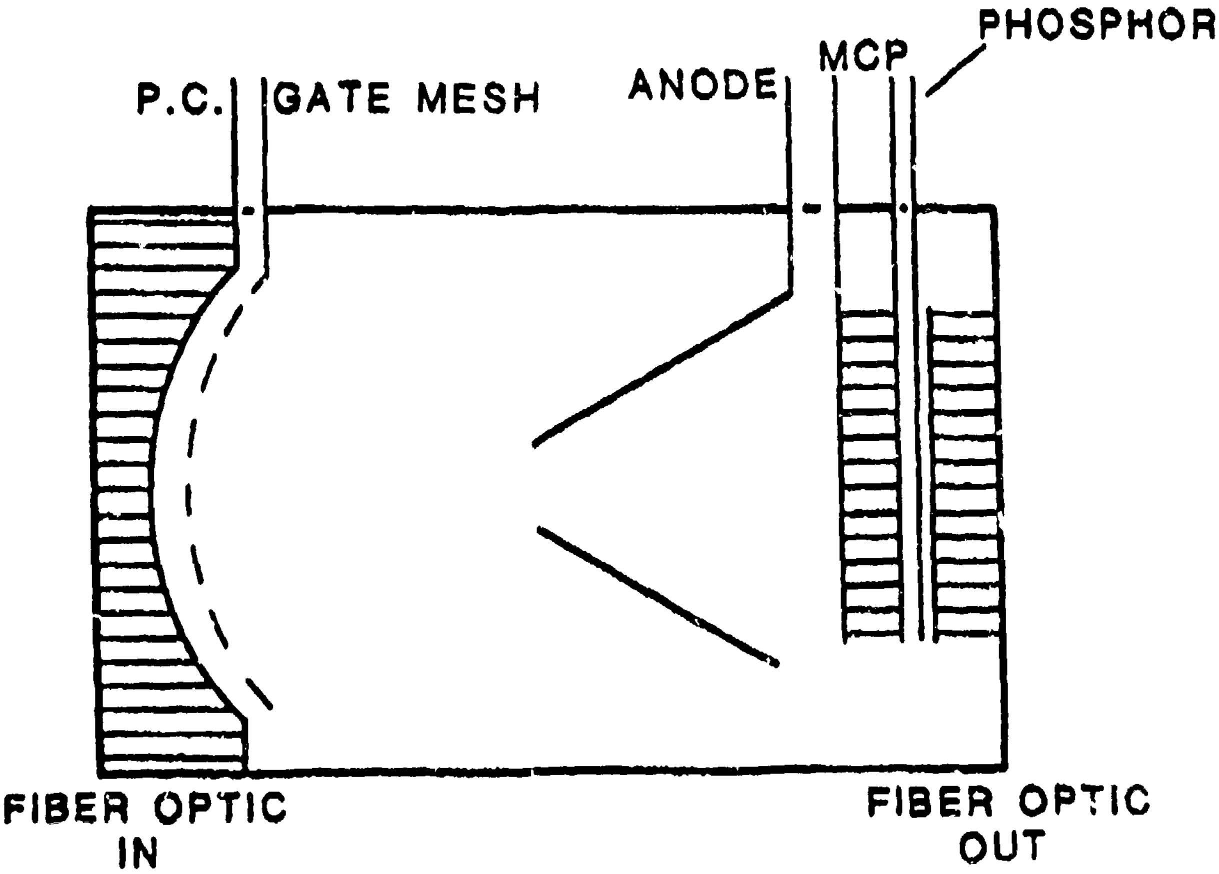
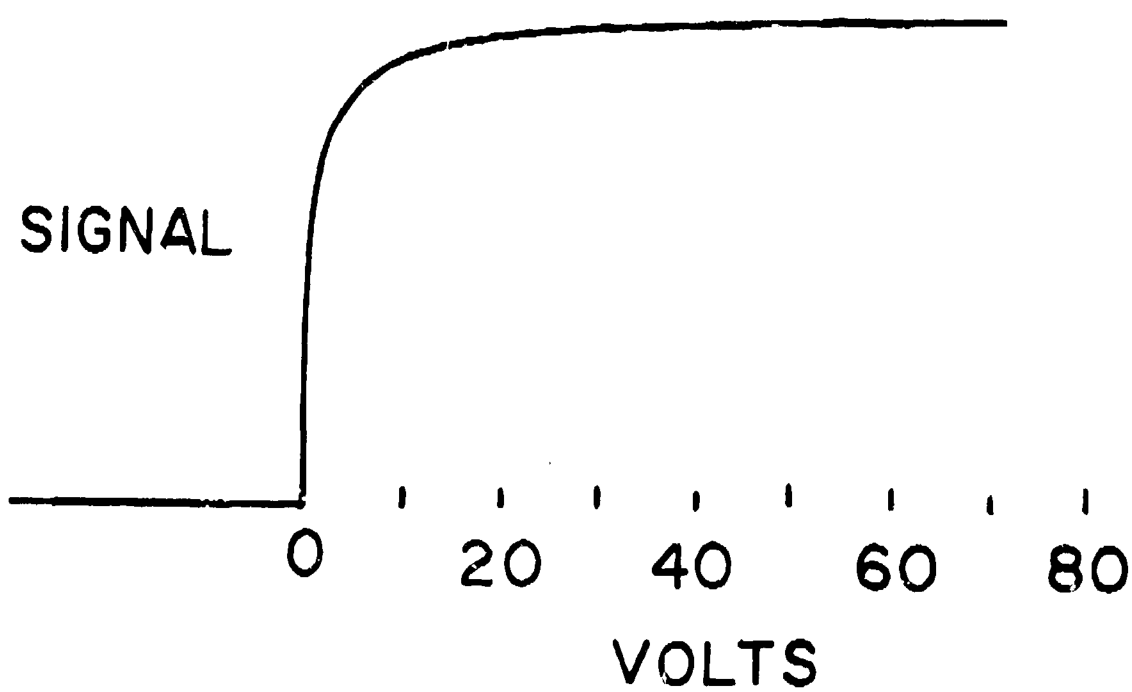
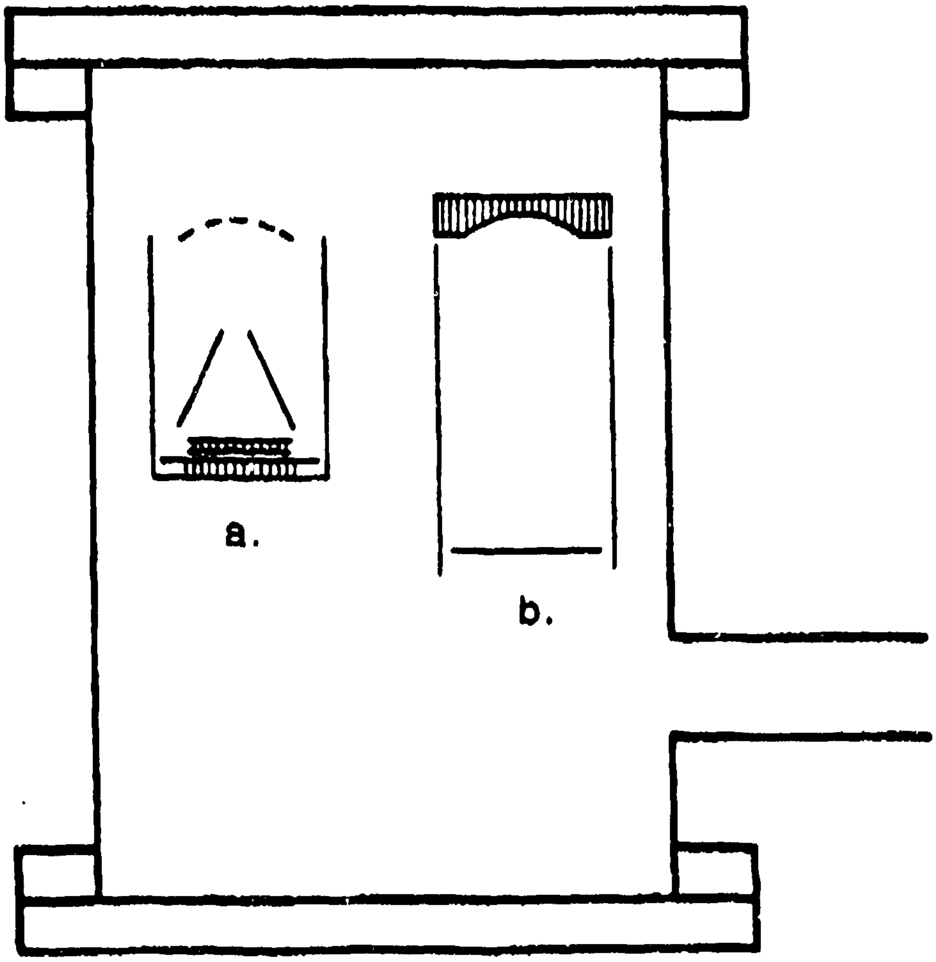

PHOSPHOR
MCP
P.C.
GATE MESH
ANODE
FIBER OPTIC IN
FIBER OPTIC OUT

Fig 1



GATE CHARACTERISTIC

Fig 2



P.C. TRANSFER SYSTEM

Fig 3

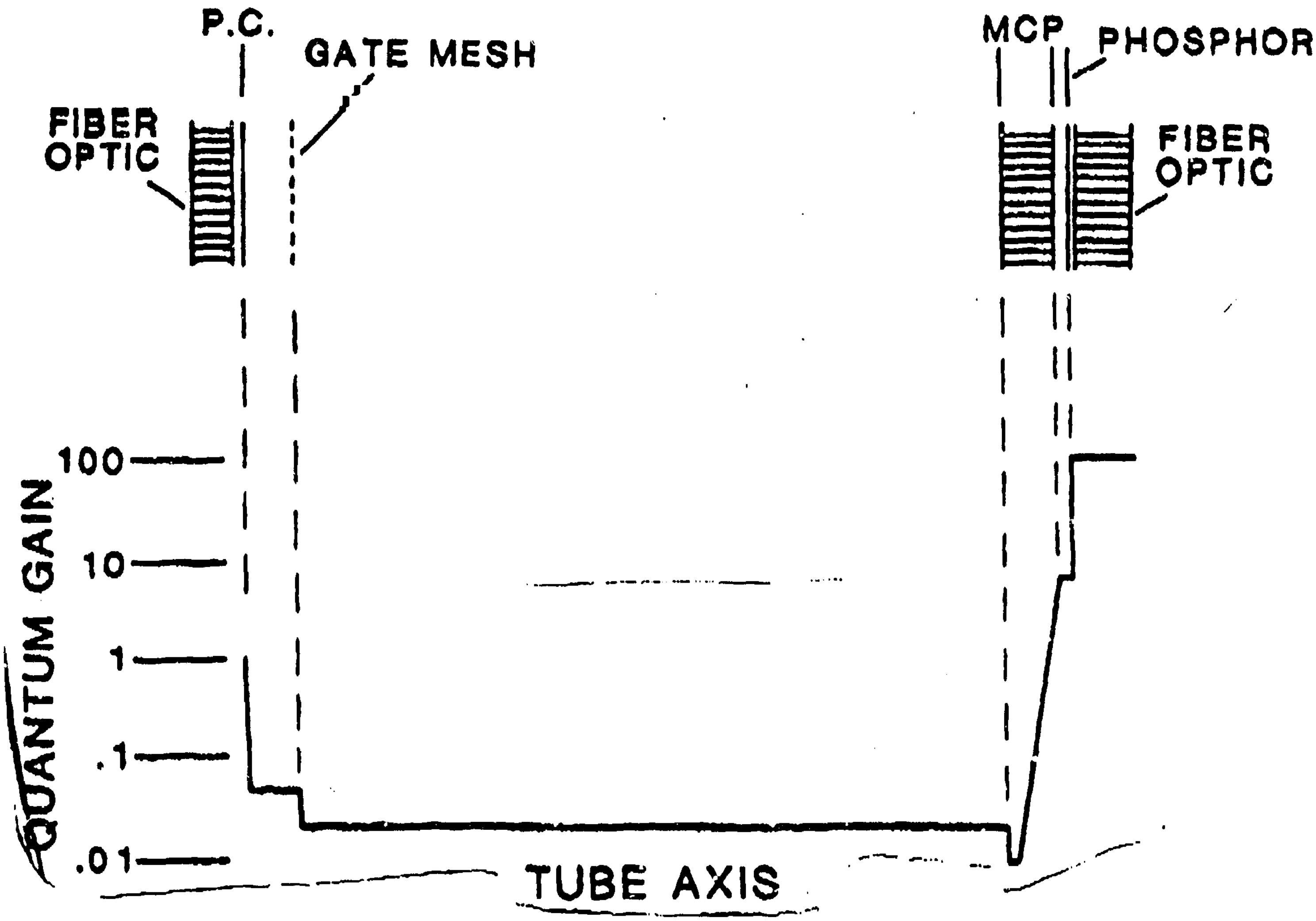

P.C.
GATE MESH
FIBER OPTIC
MCP
PHOSPHOR
FIBER OPTIC
QUANTUM GAIN
100
10
1
.1
.01
TUBE AXIS

Fig 4