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TITLE GATED SIT VIDICON STREAK TUBE

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Gated SIT vidicon streak tube

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Abstract

A recently developed prototype streak tube designed to produce high gain and resolution by incorporating the streak and readout functions in one envelope thereby minimizing photon-to-charge transformations and eliminating external coupling losses is presented. The tube is based upon a grid-gated Silicon-Intensified-Target Vidicon (SITV) with integral Focus Projection Scan (FPS) TV readout. Demagnifying electron optics (m=0.63) in the image section map the 40-mm-diameter photocathode image unto a 25-mm-diameter silicon target where gains $\geq 10^3$ are achieved with only 10 KV accelerating voltage. This is compared with much lower gains (~ 50) at much higher voltages (~ 30 KV) reported for streak tubes using phosphor screens. Because SIT technology is well established means for electron imaging in vacuum, such fundamental problems as "backside thinning" required for electron imaging unto CCDs do not exist. The high spatial resolution (~ 30 lp/mm), variable scan formats, and high speed electrostatic deflection (250 mm^2 areas are routinely rastered with 256 scan lines in 1.6 ms) available from FPS readout add versatility not available in CCD devices.

Theoretical gain and spatial resolution for this design (developed jointly by Los Alamos National Laboratory and General Electric Co.) are compared with similar calculations and measured data obtained for RCA 73435 streaks fiber optically coupled to (1) 25-mm-diameter SIT FPS vidicons and (2) 40-mm-diameter MCPTs (proximity-focused microchannel plate image intensifier tubes) fiber optically coupled to 18-mm-diameter Sb_2S_3 FPS vidicons. Sweep sensitivity, shutter ratio, and record lengths for nanosecond duration (20 to 200 ns) streak applications are discussed.

Introduction

For nearly a decade, the Los Alamos National Laboratory has made use of streak cameras as one major part of a multichannel recording instrument. The input to the streak tube (the photocathode) obtains input from a linear array of optical fibers, where each fiber is identified as a light data channel. Output from the streak tube (the phosphor) is then recorded either on photographic film or a single frame television system.

This paper will discuss a present solution to the problem of multichannel recording by combining the streak tube with a silicon-intensified-target (SIT) FPS vidicon, known as a SITV. Another way of stating this is that the image section of a SIT vidicon is modified to include sweep plates. In addition, a theoretical comparison will be made between this approach and other methods in a somewhat historical sequence.

Streak tube - film combination

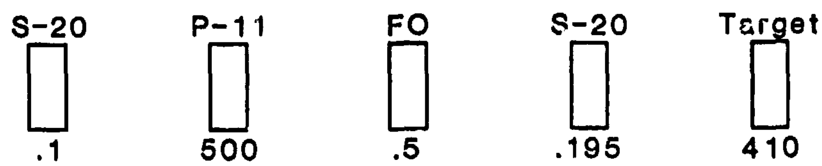
The first approach to reading out the streak camera was using photographic film as the recording media. In general, this was a film type like Royal X-Pan which was a fast, medium grain film with an ASA rating of around 1200 and a resolving power of around 30 lines/mm. It is already obvious that this isn't a very good match for the streak tube with 2% limiting resolution around 25 lines/mm. Calculating the gain characteristics of this recording system gives a streak tube gain of approximately 50, and to get a density of .3 above fog in the film requires about 10^9 photons/cm^2 from a P-11 phosphor.

10^9 photons/cm^2 represents about 2.4×10^6 electrons/cm^2 being emitted from the photocathode. So for a 70-micron fiber, this represents about 92 electrons or a SNR of 9.6 before the system even starts to record data. Neglecting space charge of the streak tube, saturation occurs on the film around 9×10^{10} photons/cm^2 from P-11 phosphor. The photocathode emission becomes 2×10^8 electrons/cm^2. Again for a 70 micron core fiber, this number of electrons emitted from the photocathode becomes 7700 electrons. This is a SNR of 88 to 1 at the film's saturation point. It should be pointed out that the streak camera will start space charge limiting around 7×10^6 electrons/cm^2. Such a system will have a dynamic range of around 31 to 1.

Streak tube - SIT tube combination

As a convenience in gathering data and for better dynamic range, a SIT tube was used as the readout device. Because the gain can be varied in the SIT tube, the low end of the transfer curve can be made to equal one electron within the 70 micron resolution element. Assuming a dynamic range of 200 to 1 in the SIT camera, the adjustment can be made so that the video signal is just perceptable. This would represent a signal around 3.5 nA peak to peak coming from the SIT tube target. *Targets on SIT cameras typically saturate around 7 nA, giving the required 200 to 1 dynamic range.

The low end signal of 3.5 nA represents 1969 electrons produced at the target. Therefore, the system's total gain must be around 2000 to give the 1 required electron at the photocathode of the streak tube. The gain of the streak tube is approximately 50, so the remaining gain must come from the SIT tube. Typical gain figures are given below for each of the system's interfaces.



The gain to the target becomes 48.75 electrons/photon. To obtain a gain of 2000, the SIT camera must have a gain of around 410. Gains of this value are well within reason for standard SIT tubes.[1] Therefore, from this simple calculation, we have changed the system's dynamic range from 84 to 1 in the film readout system to 200 to 1 in the SIT camera.

It would seem this completes the readout problem for the streak camera. But when the streak tube-SIT combination is measured in the lab, dynamic ranges in the order of 100:1 are measured. The discrepancy may come from the fact that traps have to be filled in the SIT tube's target before a signal can be obtained. This in essence makes the low end require more electrons, therefore reducing the dynamic range.

Streak tube built into SIT

Interpretation of measurements on the streak tube-SIT camera combination give indications that the loss of dynamic range may come from the phosphor-photocathode combination. Phosphor curves indicate a reduction in the phosphor's efficiency with increased beam current.

In an attempt to eliminate the streak tube-SIT phosphor photocathode interface, an integrated single envelope SIT streak (GE Z7823) was designed and fabricated.

The silicon target was favored, not only for its higher gain, but also because previous studies[1,2] on reciprocity in the 150 ps to 2.5 ns range show no reciprocity failures exist. These same measurements repeated for MCPTs with P-20 phosphors also indicate no failures. However, the agreement between calculated and measured signals from SITVs is better than for intensifiers involving phosphors.

The tube, shown in Fig. 1, is a scaled-up version of the 25-mm-diameter gated SITV.[2] The gate was retained to permit gating-off the photocathode while the tube is not being swept. The TV camera head and deflection printed circuit board are in Fig. 2. Figure 3 shows tube internal structure.

Operating Modes

1. In the streak mode, a slit image of light from a transient optical event is focused on the photocathode. The resulting electron image is scanned across the silicon target by means of an electrical ramp on the image deflecting plates. The image stored on the target is then read off by scanning a beam in the normal vidicon fashion. Thus a display of light intensity vs distance (x) and time (t) is obtained (as opposed to the conventional time dimension display of light as a function of x and y). The gate electrode may be used to cut off the electron image before and after the event of interest.

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*Recent work with large beam apertures show that the 700 nA can be extended to 2 μA with 2-mil apertures.

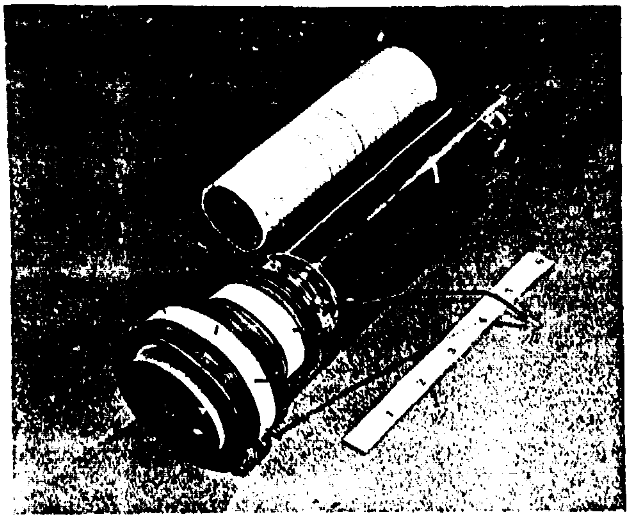

Fig. 1. The GE SIT streak tube.

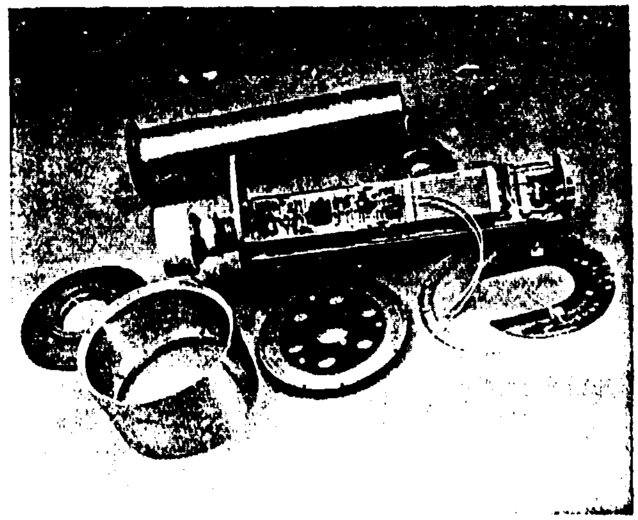

Fig. 2. Camera system for SIT streak tube.

2. The Z7823 may also be used as a shutter or gating tube. (The image deflection plates are not used, but are tied to the anode). The gate electrode is pulsed to place an electron image on the target, and this is subsequently scanned off to give the electrical signal.
3. If a staircase scan is applied to the image deflection plates, then multiple small frames may be placed on the target and later read out with the beam.
4. The streak tube could be used as a conventional silicon intensifier tube, but this is not recommended because the gate electrode causes some loss of resolution, and vignetting (see Figs. 4 and 5a) caused by the sweep plates reduces useful area for imaging.

Electrical Specifications

The general specifications and maximum ratings are shown in Table I.

Test Results

Preliminary data shows the tube has static limiting spatial resolution in excess of 800 TV lines/ph (picture height) as shown in Figs. 4 and 5. The tube was accidentally destroyed in preparation for streak tests, therefore no dynamic measurement data are available. Expected date for fabrication of new prototype is January 1986, and test results will be reported later. We expect that the sensitivity should be similar to that indicated for the SIT-streak combination as shown in Fig. 6.

Shutter ratios of $\sim 10^3$ should be realized from this design.[2] Assuming that full deflection can be achieved in 20 ns, that a 20mm vertical raster is swept out, and that the static horizontal resolution of greater than 30 lp/mm is obtainable (and applies in the vertical direction) in the streak mode, than the record length should be $\gtrsim$ 1200 pixels or increments of time (2 pixels/lp with $\gtrsim$ 17 ps time resolution. For longer streaks, record length remains fixed and time resolution decreases linearly with sweep duration.

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References

1. Yates, G. J., Nanosecond Image Shuttering Studies at Los Alamos National Laboratory, IEEE Transactions on Nuclear Science, Vol. NS-31, No. 1, pp. 484-489, February 1984.
2. Yates, G. J., et al., A High Resolution SIT TV Tube for Subnanosecond Image Shuttering, Los Alamos National Laboratory Report, LA-9771-MS, September 1984.

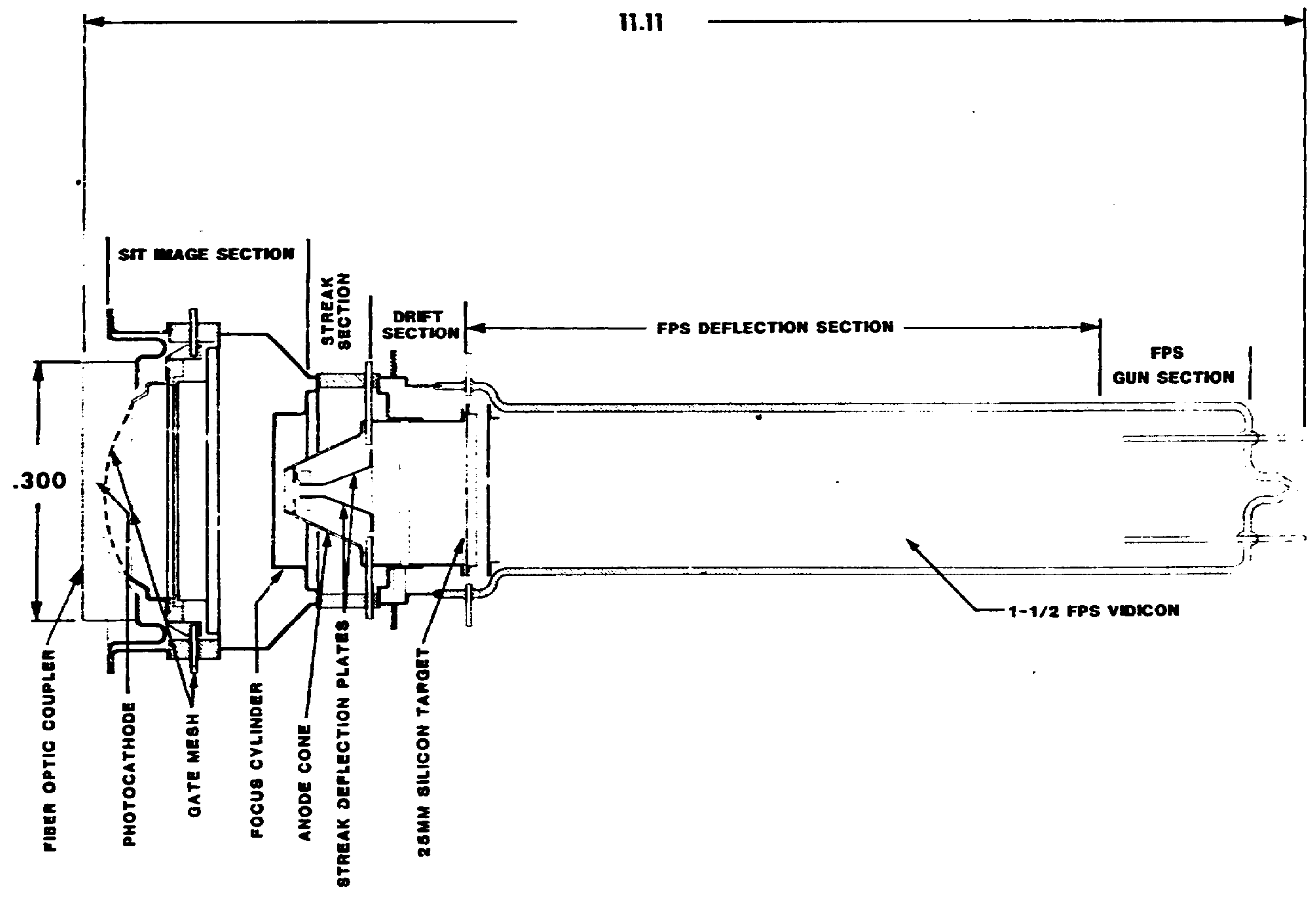

Fig. 3. Cross section (scaled) drawing of SIT streak tube.

569 31

General Specifications

Heater	90mA @ 6.3 ±5% Volts
Scan Beam Focus	Magnetic
Scan Beam Deflection	Electrostatic
Image Section Focus	Electrostatic
Image Section Deflection	Electrostatic
Capacitance Target to all other elements (electrodes tied together)	14pf
Capacitance One Beam Deflection Plate-to all	80pf
Capacitance One Image Scan Plate-to all	4pf
Capacitance Gate Electrode-to all	35pf
Gate System Characteristic time	175pSec.
Storage target	Si-diode array
Target storage capacitance (approx)	2500pf

Maximum and Typical Ratings

	Maximum Rating	Typical Rating
Photocathode area	40mm dia.	24 x 36mm raster
Target area	25mm dia.	15 x 20mm raster
Temperature (storage)	71°C	
Temperature (Operating)		25° - 35° C
Target voltage	+14 Volts	10 Volts
Dark Current		25nA
Target Current	600nA	300nA
Grid No. 3 Voltage (Mesh)	1200 Volts	900 Volts
Grid No. 2 Voltage	750 Volts	330 Volts
Deflection element voltage	750 Volts	440 Volts Average DC
Grid No. 1 Voltage	300 Volts	-35 to -80 Volts
Negative bias value	0	
Positive bias value		
For beam cutoff		-45 to -100 Volts
Heater to cathode voltage		
Heater negative with respect to cathode	125 Volts	
Heater positive with respect to cathode	10 Volts	
Blanking Voltage		
When applied to Grid No. 1		-75 Volts
When applied to cathode		+25 to +35 Volts
Deflection Voltages		
Horizontal for 0.8 mch Scan *		210 Volts P.P. per plate
Vertical for 0.6 inch Scan *		160 Volts P.P. per plate
Focus Coil Operation		14 Volts @150± 20mA

*Sweep voltages applied to +X, -X, and +Y, -Y, deflection plates should have a 180° phase relationship.

Table I. Operating specifications for SIT streak.

569 31

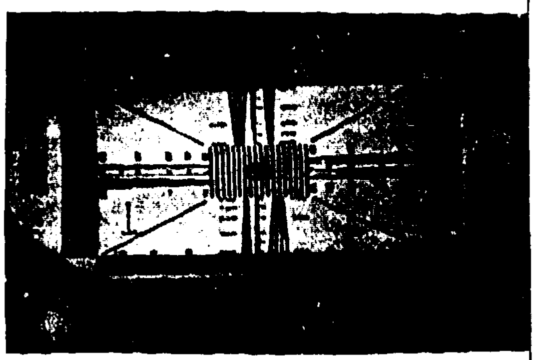

Fig. 4. Standard retma test pattern.

Fig. 5a. PRC-10 test pattern. The five lowest frequencies are 4.58, 9.16, 13.72, 18.18 and 22.90 line pairs per mm respectively. The 22.90 lp/mm ≈ 515 TV lines/picture height.

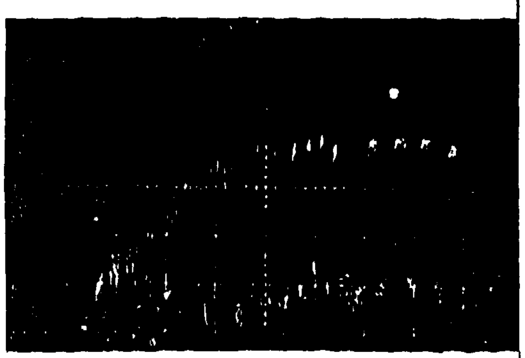

Fig. 5b. PRC-10 test pattern video. Scan is across highest frequencies first. The CTF at 22.90 lp/mm is ≈ 66% of DC response.

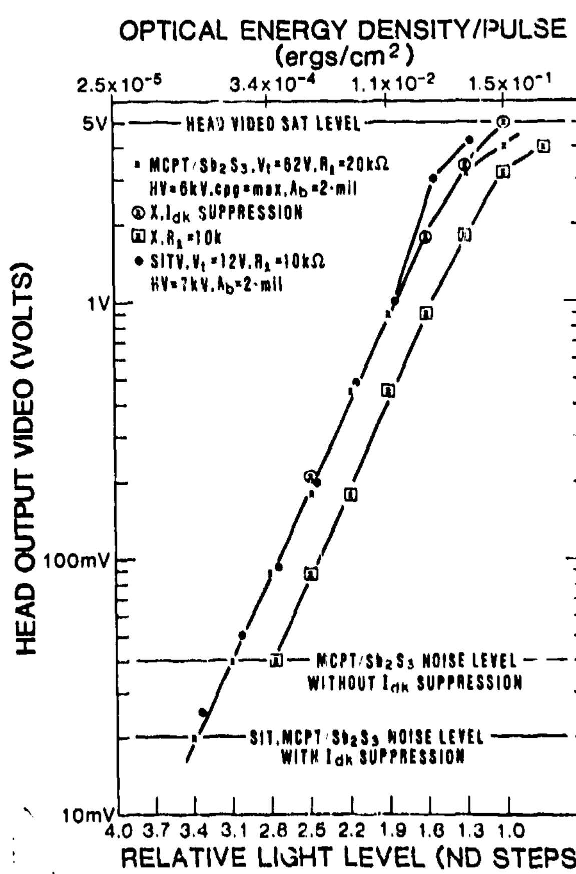

Fig. 6. The responsivity for two different intensified vidicons currently used as readout devices for the RCA 73435 streak tube are shown to the right. These measurements were made with a pulsed strobe 8 μs FWHM and a narrow band interference filter centered at 400 nm. The strobe was pulsed once per second synchronized with the TV camera's vertical sync interval and the vidicon signal amplitude from the subsequent field was recorded. This SITV was approximately 2x as sensitive as the MCPT/Sb_2S_3 combination (other data show samples of each type outperforming the other). For this reason, the preamp load resistor (r_ℓ) was increased for the MCPT/Sb_2S_3 to provide 2x greater voltage from the same vidicon current, thereby making the sensitivity approximately equal to that of the SITV. Insertion into the preamp of a dark current "cancellation" pulse train effectively cancels this useless portion of the video, extending the signal dynamic range as shown.