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TITLE: THE PICOTRON 100 STREAK TUBES AS A 150-CHANNEL PHOTOMETER

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The picotron 100 streak tubes as a 150 channel photometer

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Abstract

The characterization of a streak camera based upon Picotron 100 tube types[1,2] is given. Both a large (30 cm l x 10 cm dia.) and a small (18 cm l x 5 cm dia.) version of this design has been tested. Over 150 channels of information are simultaneously time resolved with system S.N.R. of 3 at 100 picosecond time resolution without post intensification. Absolute photometric evaluation is given in the dynamic mode, i.e. while operating in the picosecond time domain. Such quantitative data has been lacking in the past, particularly for multiple channel applications.

Introduction

Experimental results on the performance of the Picotron 100 Streak Tube, reported in the 1978 High Speed Photography Congress,[3] showed that high dynamic range in a streak tube can be achieved by reducing the electron optical magnification of the streak tube. The tube design has since been altered to improve its dynamic spatial resolution. Low electron optical magnification and high extraction field near the photocathode region are the two features of this new design which have improved its dynamic spatial resolution to better than 50 microns over a photocathode diameter of 9 millimetres. Unlike many other commercially available streak tubes, there is no retarding field region in this tube, and this resulted in better time resolution at relatively higher current densities on the photocathode. Such a high spatial resolution of high current densities has made the Picotron 100 streak tube uniquely suitable for a multiple channel picosecond photometer. The input and output characteristics of the tube, calibrated in terms of number of photons/sec/cm^2 incident on the photocathode allows the use of the device for quantitative photometry.

Tube description and resolution

The Picotron 100 design uses a 4 electrode focussing arrangement;[4] these are arranged in such a way that the overall tube electron optical magnification remains below 1.5:1. The extraction voltage near the photocathode is 20 kV per cm at an overall tube voltage of 16 kV. The electron optical magnification can be varied between 0.8 and 1.5. Two tubes are described here, of different external dimensions but with comparable tube performance. Table I gives a summary of the physical and electron-optical characteristics of the two tubes, which are shown in Figures 1 and 2.

It is possible to use the tubes at an overall voltage of 30 kV, when the extraction field on the photocathode will be approximately 40 kV/cm.

Figure 3 shows the M.T.F. of the Picotron 100B, which is the smaller of the two tubes, at the axis of the tube, over a photocathode diameter of 4 mm. The limiting eye resolution of 50μ on the screen represents a resolution of 40μ FWHM at the photocathode. This is equivalent to a spatial resolution of 25 lp/mm with an MTF of 4%. Figure 4 shows a streak record using the same tube at a streak speed of 2 ns/mm. The recording was made with a GE SIT Vidicon, operating at a gain of 100, and was coupled to the output of the streak tube with an f/1.2 lens, operating at a magnification of 5:1 between the streak tube output and SIT Vidicon input. The overall gain after the streak tube phosphor is estimated at 0.8. A spatial resolution of 50μ at FWHM was recorded dynamically. Figure 5 shows time resolved 64 ps and 240 psec. R6G dye and Krypton laser pulses respectively, using the SIT camera as described above. This is the first published recording of a 64 picoseconds long optical pulse, using a streak tube with no post streak tube intensification. Previously, we reported photographic recording of 80 picosecond long laser pulses emitted from a Nd YAG laser, without using any post-streak intensification.

When a photocathode diameter of 10 mm is used, the FWHM of the best resolvable spot deteriorates to 30 microns FWHM at the edge of photocathode. By adjustment of focus voltages, static and dynamic resolution across a photocathode diameter of 10 mm can be kept uniform at 75μ at FWHM. This tube therefore shows the potentiality of recording more than 100 channels simultaneously, with a dynamic range of greater than 5000 at 60 picoseconds (if used with a suitable intensifier and film for recording).

Figure 6 shows the static MTF of the Picotron 100 (large tube) which is kept constant over an image diameter of 9 mm, showing a limiting resolution of 25 lp/mm at the photocathode, at 4% MTF, taken when the tube is operated at a magnification of 1.3:1. The dynamic resolution of this tube, measured with a channel plate intensifier and Kodak 2475 film, described before is now compared with the dynamic range at 30 picoseconds, using direct lens coupling to a PAR OMA-1 having an overall system gain (including the collection efficiency and magnification) of 50. The results are shown in Fig. 7. It can be seen that a dynamic range of > 1000 at 30 ps is well within the limit of this tube. At 30 picoseconds with the results obtained with an OMA-1, the slit width was 100 μ on the photocathode and it was 150μ at the screen. The dynamic and static measurements of the FWHM of the streak image at the screen showed a change of resolution, see Fig. 8. The dynamic resolution of this tube would allow it to be used as a 180 channel streak tube.

Dynamic range and SNR

The dynamic range is defined as the range of intensity over which the streak tube functions linearly. This is a function of the time resolution of the tube.[5,6] The upper end is defined as the level of intensity where the instrument shows an apparent broadening of a pulse of known duration by 20%. The lower end can be defined as a signal level at which the pulse width of an input signal can be detected at a signal to noise ratio (SNR) of 1, over the threshold detector noise.

Recording on film from the streak tube directly: Threshold signal per pixel on the photocathode is defined by an equivalent density of 0.2 on film. This is defined (for Kodak 2475 film) as the point where SNR is 1. The light level involved is much higher than that required by photoelectron statistic, limited signal at the first photocathode. The light level at the film plane is equivalent to 5×10^{-11} J/cm^2 at this exposure. At a streak velocity of 30 ps per mm on a phosphor screen, the threshold current density in the picotron 100 (large format) tube with an S-1 photocathode was 50 ma/cm^2 (10 μA/W photocathode sensitivity), for 30 ps laser pulses of 1:06 micron wavelength. The pulse showed broadening at an input photocurrent density of 400 ma/cm^2.

For a pixel size of 50μ radius, this is equivalent to an electron density of 730 per pixel, at the streak tube photocathode, at threshold recording, without any intensification. The electron density at the level of input intensity where a pulse broadening of 20% is observed, was calculated to be 5840 electrons per pixel.

A simple calculation shows that if the intensification in a streak tube was adequate to enable single photoelection detection, a dynamic range in excess of 5000 should be within the linear range of operation of a streak tube of the Picotron 100 or Picotron 100B type.

The linearity of most type of intensifiers are poorer than a range of 100 to 1. It is therefore important to point out that a streak tube based picosecond photometer must have a full calibration of the streak tube, the intensifier and the recording medium.

Conclusions

The capability of the Picotron 100 and the Picotron 100B to operate as 180 and 100 channel (respectively) photometer for picosecond time resolution is demonstrated.

The streak tubes are characterised for picosecond photometry in terms of number of photoelectrons per pixel at the streak tube photocathode. These results were obtained without using any post-streak intensification as such post streak intensification appear to confuse the quantitative evaluation at present. It is expected that with comparable characterization of the intensifier, we shall be able to demonstrate a picosecond photometer with single photoelectron detection capability.

The dynamic range of the Picotron type streak tubes, at 30 picosecond, and without intensifiers is shown to be 8, which indicates our claim that this type of tube will resolve 30 picoseconds with a dynamic range in excess of 1000 when used with suitable intensifiers. The dynamic range at 4 picoseconds has previously[7] been demonstrated to be 120.