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DYNAMIC RANGE STUDIES OF THE RCA STREAK TUBE
IN THE LLL STREAK CAMERA

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Fig.4 Typical microdensitometer scan of 220-ps pulses.

A typical densitometer reading of film of streaked 800-ps-etalon outputs with a single 220-ps pulse input is shown in Fig. 4. The full width at half-maximum (FWHM) was measured for each reflection, and this was used to determine dynamic range. As seen, the amplitude ratios of the pulse peaks are inconsistent with those expected from the 70% coated surfaces of the etalon. A slight "walk" or spatial displacement of one pulse of the etalon output from the next, as the pulses fall on the camera slit, can account for this. This walk will occur if etalon alignment and surface parallelism are not perfect, and the effect is compounded by a nonuniform beam profile. For this reason, a plot of peak amplitude ratios from an etalon output cannot easily be used with confidence to determine dynamic range. Except when noted, all our determinations used an input laser pulse that was nominally 40 ps long at 1.06 μm wavelength from an Nd^{+++} YAG oscillator.

Results

Figure 5 shows two typical dynamic-range plots; these are for two different cameras (two different RCA image-converter tubes) but using the same ITT proximity-focused, microchannel, image intensifier tube (PFCIT). The same symbol has been used to plot all the data from the same laser pulse, i.e., from a single streak record.

Table 1 shows a summary of the dynamic range test results on several cameras. All tests used the above-described ITT intensifier type, except where noted. The camera serial number is given in the first column. The low-signal noise intensity is for a part of the film either significantly preceding a high-intensity signal or near a low-intensity signal area. The high-signal noise intensity gives the noise in the vicinity of a high-level (near-saturation) signal. Column 4 gives the intensity for the upper limit of the dynamic range, where the upper limit is the point of 10% broadening of the FWHM as compared with lower-amplitude pulses of the same etalon pulse train. The low and high dynamic ranges are the ratio of column 4 to either 2 or 3. Column 7 gives either a calculated or a best-guess ($\sim$) net RXP film gain. Reference 4 gives details on the significance of these gains.

The intensifier used on camera 5 had become gassy and as a result had to be operated considerably below 50% of rated gain, causing the low dynamic range. Cameras 8 and 11 were tested using the same intensifier (see Fig. 5) and show a 25% difference in dynamic range between the two image-converter tubes and, more significantly, a larger noise level on one. We have discovered that some micro-channel intensifiers can be operated at three to ten times rated gain for short (100- μs) periods without seriously damaging the tube. Cameras 12 and 16 have been run in this mode for use with a silicon, self-scanned, Reticon array read-out system. This readout device is much less sensitive than film, and additional gain is required. These cameras were

Fig.5 Dynamic range of two cameras with the same intensifier; I_n is the noise intensity and I_b is the intensity at 10% broadening.

Table 1. Results from dynamic range tests.

1	2	3	4	5	6	7	8
Camera	Noise intensity		10% broadening intensity	Dynamic range			Comment (II = image intensifier)
	Low signal	High signal		Low signal	High signal	10^3 net film gain	
5	2.85	—	1450	509	—	~0.3	II gasey and noisy (not ITT II)
8	2.39	5.15	6000	2510	1165	1.23	Used same II
11	1.42	4.98	4800	3380	963	1.23	
12	1.42	5.72	12000	8451	2098	~10	II at 5.5 X rated gain
16	0.02V	—	>4V	>200	—	~6	Reticon readout; II at 5 X rated gain
13	1.42	3.05	3910	2754	1282	1.85	ITT II
	3.27	5.34	1300	398	243	0.2	Varo 8606 II
	4.48	8.1	4200	938	519	0.33	EMI 9912 II
14	1.2	4.98	1300	1083	263	~2	II at 1/2 rated gain
15	1.42	5.72	1600	1127	278	~1.5	Sub-spec II
17	3.05	40	7400	2426	185	3	Used ITT image-converter tube
12	—	—	—	5500	—	6.5	Galileo II (see Ref. 3)

operated at approximately five times the rated gain (10^5 white-light gain), allowing the full dynamic range of the Reticon array to be used. Camera 13 was tested with three different intensifiers. The data are discussed in Ref. 4.

A developmental electrostatically focused image converter (streak) tube with an S-20 cathode was made for us by ITT. It was used in camera 17, and the resulting test data are shown for this camera in Table 1. This tube uses a fine mesh for the extraction grid, similar to those used by English Electric Valve, Instrument Technology, Ltd., and Hamamatsu T.V. Co., Ltd., in their streak tubes. The RCA tube uses a coarse (about 5-mm separation) wire grid. We see that the noise level for the ITT tube is very high for a low-amplitude signal and higher than any of the other measurements for a high-amplitude signal.

Camera 12 was tested twice, once using an ITT intensifier run at 5.5 times rated gain, and again using a Galileo intensifier, which had an S-20 cathode and a P11 phosphor. The latter version is the system reported on in Ref. 3.

Dynamic Range vs Slit Width

We have demonstrated that, with low-intensity input laser pulses and with the camera sweep not operating, the image width on the RCA image-converter phosphor remains at about 150 μ m for 10- to 200- μ m

variations in input-slit width.⁵⁾ The slit in this case was in direct contact with the external surface of the cathode window (diffraction effects are probably significant) as opposed to being imaged on the cathode by a lens, as was done for all other tests in this report. Subsequently, similar results have been achieved also with imaged slits of from 2 to over 200 μ m. Further, the image of the slit was visible on the output phosphor during translation of the slit several hundred micrometres both above and below (in the sweep direction) the position for the above tests, which assured that the electron beam was not being perturbed by the streak tube electronics. The implication of the above is that the aberrations in the electron lens of the tube mask any changes in the slit width. The coarse grid wires, biased at +2600 V from the cathode, create a negative lens effect, which causes local tube magnification in the sweep direction to be about 0.2 in the vicinity of the slit image on the usable cathode area, although the transverse magnification is 1.5. From this, even a 200- μ m slit should appear to be about 40 μ m wide on the phosphor screen. However, the aberrations in the focusing-electron optics limit the minimum image width to 150 μ m.

Next, dynamic range was measured for slit widths of 25, 50, 100, 200, and 300 μ m. The input intensity was decreased, decreasing the current density

Fig.6 Dynamic range vs input pulse width.

at the cathode, in direct proportion to the increase in slit width. We discovered this was necessary to keep the output intensity approximately the same for each slit tested. The dynamic range plots were much the same as those in Fig. 5 and are not included. The noise level on the film was constant, and the densities of the saturation intensity levels were, respectively, 1700, 2800, 1700, 2000, and 2100, all close enough that, within experimental accuracy, they can be considered the same. Hence, dynamic range is independent of slit width from 25 to 300 μm . This raises the question of whether or not current density (or space charge) at the cathode surface is the limiting factor for dynamic range in the RCA tube. We are currently investigating this subject.

Dynamic Range vs Input Pulse Width

Our results for this dependence are shown in Fig. 6. Here, data from Friedman⁶⁾ are plotted along with a theoretical curve from Majumdar.⁷⁾

Also included are data from our camera 13, where the 220- and 40-ps-pulse dynamic ranges were measured with an S-1 streak tube at 1.06 μm wavelength and the sub-10-ps (below the camera temporal resolution limit) data were obtained using an S-20 streak tube at 605 nm. The same intensifier was used for all the camera 13 measurements.

References

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