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PERFORMANCE OF MICROCHANNEL-PLATE IMAGE INTENSIFIERS
UNDER NANOSECOND GATING

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PERFORMANCE OF MICROCHANNEL-PLATE IMAGE INTENSIFIERS UNDER NANOSECOND GATING

ABSTRACT

The application of microchannel-plate image intensifiers (MCP's) in high-speed photographic systems has created a need to analyze their performance under nanosecond gating conditions. This report gives performance test results for two commercially available units. A 5-nsec effective gate width was measured for both units, and the pulsed resolution was better than 6.8 line pairs per mm. Energy gains of 10^5 were measured for a range of output energies from about 10^{-4} to 10 ergs/cm². Pulsed light sources as short as 5 psec were used as MCP illumination during the gated tests.

EXPERIMENTAL SETUP

The two MCP's evaluated are units available from Galileo and ITT.* The method of evaluation is similar to the procedure used by Lieber at LASL.¹ Figure 1a shows the variable bias supply used to establish the operating voltages and to measure dc parameters. Figure 1b shows the fixed bias supply used to measure resolution and gain in the pulsed gated mode. The fixed, grounded phosphor supply allows the phosphor to be placed in direct contact with the photographic film. The variable supply is used in pulsed gated mode and dc mode, while the fixed supply is used in pulsed gated mode only.

Both MCP's tested have a P20 output phosphor (see Fig. 2 for P20 response curves). The light source for the nanosecond region is a ruby laser, operating in the pulse transmission mode, which provides a 2.5-nsec-FWHM pulse at 6943 Å. Figure 3 shows the setup for this test. The output of the laser is directed to a beam splitter where a portion of the pulse, about 5%, is picked off and directed to a photodiode. The output of the photodiode, through one arm of a 50-Ω matching tee, provides a trigger for a Tektronix 7904 oscilloscope and a laser monitor signal to a Tektronix 519 oscilloscope. The other arm of the 50-Ω matching tee sends the output of the photodiode through a Lumatron passive delay providing up to 60 nsec of signal delay,

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U. S. Atomic Energy Commission to the exclusion of others that may be suitable.

1. Albert J. Lieber, "Nanosecond Gating of Proximity Focused Channel Plate Intensifiers," Rev. Sci. Instrum. **43**, 104 (1972).

Fig. 1. Bias supplies used for the tests. (a) Variable supply used to establish operating voltages and measure dc parameters. (b) Fixed supply used to measure resolution and gain in pulsed gated mode.

Fig. 2. Response curves of P20 phosphor.

Fig. 3. Setup for nanosecond gating tests.

variable in 1-nsec increments. The output of the Lumatron delay chassis is applied to the MCP gate generator. The gate generator is an avalanche-transistor-switched Blumlein pulser, which provides a -300-V, 2.5-nsec FWHM pulse into $100\ \Omega$. This pulse is capacitively coupled to the MCP photocathode.

The delay through the Blumlein pulser is ~ 10 nsec with a time jitter of ± 200 psec. The remaining 95% of the optical pulse is delayed through a long optical path and directed to a white surface which reflects $\sim 20\%$ of the pulse as a Lambertian radiator. A portion of this reflected pulse, $\sim 5 \times 10^{-3}$ erg/cm², is attenuated by neutral density filters and applied to the MCP photocathode. The neutral density filters are selected to provide input illumination to the MCP photocathode of $\sim 4 \times 10^{-9}$ to 4×10^{-6} erg/cm².

The light source for the picosecond region is a mode-locked dye laser operating at $6140\ \text{\AA}$. The output of the dye laser is a train of pulses. Each pulse is ~ 5 psec in width, pulse separation is ~ 3 nsec, and pulse train length is $\sim 1\ \mu\text{sec}$. The setup for this test is shown in Fig. 4. The output of the dye laser is sent through a beam splitter to a white surface in a manner similar to that described for the ruby laser. In this case, the delayed trigger for the Blumlein pulser is selected to occur in the approximate center of the dye laser's pulse train.

The MCP was mounted in a lighttight housing with provisions for installing either a photomultiplier tube or a camera at the output phosphor. Wiring inductance was held to a minimum especially for the photocathode gate circuits. A shutter and neutral density filter holder were provided on the input of the MCP mount. When used for resolution tests, a resolution chart was coupled with optical grease to the photocathode surface.

The photomultiplier and photodiodes used were calibrated at $\sim 5000\ \text{\AA}$ and $6943\ \text{\AA}$, respectively. The photomultiplier gave 7×10^5 A/W and the photodiode 8×10^{-3} A/W. The rise time of the photomultiplier is ~ 2 nsec and that of the photodiode ~ 1 nsec. Where film was used for an energy measurement, a calibrated density-step wedge was placed on the film by the Technical Photography Group. The density of the MCP image was determined with a densitometer and used to calculate the exposure energy.

EXPERIMENTS

The effective gate width for the Galilco and ITT units was measured using the setup shown in Fig. 3. The Lumatron delay was varied in 1-nsec increments, and the output of the photomultiplier tube was recorded on the Tektronix 7904 oscilloscope. A light intensity of 4×10^{-9} erg/cm² was seen by the MCP photocathode on each laser pulse. The laser was fired at approximately 2-min intervals. Its output was monitored on each shot to maintain MCP input calibration. The output of the photomultiplier was plotted against the Lumatron delay, and a curve ~ 5 nsec FWHM resulted (see Fig. 5). Except for minor variations, the curves for the Galileo

Fig. 4. Setup for picosecond gating tests.

Fig. 5. Curve obtained in determining effective gate width of the MCP units.

and ITT units were the same. The measured 5-nsec effective gate width is consistent with the convolution of a 2.5-nsec illumination pulse and a 5-nsec gate response.

Spatial resolution of the Galileo and ITT units was tested using the 2.5-nsec ruby laser setup shown in Fig. 3. A standard resolution chart was coupled to the MCP photocathode with optical grease. The output was recorded on Polaroid type 107 and Kodak linagraphic film. Polaroid was used for the lower MCP output energies and Kodak for higher energies. The film was positioned in contact with the MCP output phosphor. The resolution was determined to be at least 6.8 LP/mm (line pairs per mm), which was the limit of the resolution chart used. This resolution held through an output energy range of $\sim 10^{-3}$ to 10 ergs/cm². The maximum linear output of the units is ~ 30 ergs/cm².

The spatial resolution of the Galileo unit was also measured with a ~ 5 -psec light source using the setup shown in Fig. 4. The resolution was better than 6.8 LP/mm. The output energy in this case was $\sim 10^{-3}$ erg/cm². The effective gate width was 5 nsec FWHM and the mode-locked pulse spacing 3 nsec, so at least one pulse and no more than two illuminated the photocathode during the gate period. The resolution was the same with one or two pulses. Since the peak-to-valley ratio of the pulse train was specified by the laser manufacturer to be $10^4:1$ and the shutter ratio of the MCP was $10^6:1$, no more than 10% of the energy at the MCP photocathode can be attributed to energy outside of the 5-psec pulses. The ITT unit has not been checked with picosecond light sources as yet, but it is expected to perform at least as well as the Galileo unit since in other pulsed gated tests the two were similar in performance.

The gated energy gain of the MCP was measured as a function of energy required to reach a known exposure on photographic film. A camera back was mounted on the output of the MCP, and the 2.5-nsec laser was used for input illumination. See Fig. 3. The Lumatron delay was adjusted to place the photocathode gate and the laser output in coincidence at the MCP photocathode. Input levels ranging over approximately three orders of magnitude were covered in this manner by using Polaroid type 107 film and Kodak linagraphic shellburst film. The input energy was measured with a calibrated photodiode; also, input energy exposure on photographic film was used as a secondary check. The MCP energy gain measured in this test was $\sim 10^5$ through three orders of magnitude of input energy.

DISCUSSION

The energy gain in the gated mode was consistent with that noted in Lieber's report.¹ Energy gains were measured on film, because the long phosphor fluorescence made pulsed peak gains difficult to interpret.

Tests were done while measuring effective gate width to determine gating efficiency. The output of the MCP was monitored while a 2.5-nsec light source was applied to the MCP photocathode. The MCP was in one case biased on, in the other case biased off and gated on with a 5-nsec gate in coincidence with the 2.5-nsec light

pulse at the photocathode. The MCP output was the same for both cases, indicating 100% gating efficiency.

The effective gate width of 5 nsec is a function of gate source resistance and circuit LC values. Care must be taken when reducing gate source resistance that circuit L is also reduced or severe ringing will result. In the system used for this test, the circuit L was fixed by the MCP mount, and a 100- Ω Blumlein pulser terminated in 130 Ω provided optimum source impedance and damping. Effective gate widths much less than 5 nsec would be very difficult to obtain. The application in the high-speed radiation camera requires a 5-nsec gate width and unity gain for the MCP, and the present system will meet that requirement.²

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2. G. W. Coutts, L. B. Olk, H. A. Gates, and G. St. Leger-Barter, A Six-Frame Picosecond Radiation Camera Based on Hydrated-Electron Photo-Absorption Phenomena, Lawrence Livermore Laboratory Rept. UCRL-76191 Preprint (1974).

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