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TITLE: OVERVIEW OF PULSERS FOR NANOSECOND GATING OF IMAGE-SHUTTER TUBES

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Overview of pulsers for nanosecond gating of image shutter tubes

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Abstract

The capability of generating a useful optical shutter of a few nanoseconds or less utilizing gated proximity-focussed microchannel-plate (MCP) wafer tubes or silicon intensified target (SIT) vidicon tubes depends strongly on the driving electrical pulse.

A proximity-focussed MCP wafer tube can be optically shuttered by applying a short electrical pulse between the photocathode and MCP interface.¹ This interface is electrically reverse-biased by approximately 30V to prevent photocathode electrons from reaching the MCP. The gating pulse, typically 80V, is of opposite polarity to generate an effective forward bias to "shutter" the system. Light intensity ratios for gated on to off conditions (shutter ratios) of greater than 10^5 are obtained. The more recently developed gated SIT vidicon tubes² are gated by applying an effective forward bias between the photocathode and a 50% transmission grid in close proximity to the photocathode. Equivalent shutter ratios have not been achieved as yet, with 10^5 shuttering efficiency measured for typical SITs.

Assuming the optical gate width is determined by the electrical gate width one requires pulses with rise and fall times of less than a nanosecond and amplitudes in excess of 80 volts into a 50 ohm impedance. Such pulses have permitted shutter times of ± 1.5 ns and ± 800 ps for the MCP and SIT tube systems respectively while preserving their resolution capabilities.

The problem of matching an electrical pulser's driving impedance to that of the optical shutter is one still under study. The intrinsic impedance of a proximity-focussed MCP optical shutter is that of a distributed capacitance and resistance.^{1,3} A measurement of the resistance and capacitance vs a frequency network of 10 MHz with an HP4191A impedance analyser indicated a relatively constant equivalent series capacitance of 31 pf and a photocathode equivalent series resistance in the range from $\pm 10\Omega$ to 30Ω for individual intensifiers. The capacitance values are roughly independent of frequency up to ± 120 MHz. For frequencies > 120 MHz, and therefore gate rise times less than ± 3 ns, the equivalent series inductance becomes effective causing varying impedance values which complicates the problems of electrically driving these systems.

This paper will provide a summary of some of the electrical gate pulsers utilized in studying both proximity-focussed MCP imaging intensifiers and gated SIT FPS vidicon tubes. All of these pulsers are designed to drive 50 Ω impedances although work is currently being directed to lower impedances. The circuit diagram for a 1.6 ns FWHM, 80V pulser based on avalanche transistors is given in Fig. 1. An overview of the MCP image intensifier and its associated divider string is also shown. The output pulse with the system terminated in 50 Ω without the MCP intensifier attached is given in Fig. 2a. This pulser is capable of driving a MCP intensifier from ± 1.2 ns to 5 ns total optical shutter on times. The optical resolution is reduced to below 4lp/mm for shuttering intervals ± 2 ns for total on/off times. The variable optical shutter times are obtained by varying the reverse bias applied between the photocathode and MCP. There is a limit as to how low a reverse bias one can use. This is determined by the "ringing" caused by improper impedance matching of the pulser to the optical shutter. This mismatch can be seen in Fig. 2b, obtained by observing a 1% sample signal at the input to the optical shutter. The second pulse will turn on the optical shutter thereby extending the shutter duration.

Two alternative methods of driving proximity-focussed MCP image intensifiers involving the above pulser are to form a bipolar pulse (shown in Fig. 3) through feedback summation and to attempt improved impedance matching by coupling through a toroid (pulse transformer) and a constant impedance network. The toroid system is schematically shown in Fig. 4. Both methods reduce the total available amplitude by 50%, resulting in insufficient

Fig. 1. Proximity Focused MCP image intensifier electronic schematic

Fig. 2a. Avalanche pulser output terminated in 50 ohms.

Fig. 2b. Sampled avalanche pulser output terminated with MCP.

Fig. 3. Summation network for bipolar pulse generation.

Fig. 4. Pulse transformer impedance matching network for pulser to MCP coupling.

amplitude for gating. As a result, higher amplitude pulsers are being investigated. A pulser system based on a MCP photomultiplier tube is schematically shown in Fig. 5. A fast laser diode is driven with a low amplitude fast electrical pulse. The gain associated with a MCP photomultiplier (10^3) can be utilized to achieve electrical pulses in excess of 100V and widths of ~ 750 ps FWHM (see Fig. 6). The limitations of this driving technique are the nanocoloumbs per pulse available from the MCP and the sensitivity of the S-20 extended red photocathode to the laser diode light. The short lifetime of these phototubes in an extended current application is an additional drawback of this method.

Fig. 5. Schematic of MCP photomultiplier - laser diode pulser and sampling system.

Fig. 6. Output pulse generated with system in Fig. 5. 20V/DIV and 500 ps/DIV.

The fastest useful pulsing system for our optical shuttering studies is derived from a ~ 50 ps electron burst stopped in a fast Faraday Cup at the EG&G Santa Barbara linac facility. The pulse as delivered to the optical shutter location and terminated into 50 Ω is shown in Fig. 7 from a Tektronix sampling system. Pulses in excess of 180V and ~ 200 ps FWHM are obtainable. The linac RF and the laser light pulse utilized to characterize the optical shutters are synchronized. This system is shown in Fig. 8. A variable delay with ± 30 ps jitter permits one to vary the relative time between light pulse arrival at the optical shutter photocathode and the application of the electrical shutter pulse. The device under study can therefore be "frozen" into a particular phase of its shuttering sequence since the light pulse duration is ~ 10 ps long.

Fig. 7. Sampling scope data from fast Faraday Cup generated by electron linac. 40V/DIV and 200 ps/DIV.

Fig. 8. Schematic of Argon laser - electron linac coupling used for evaluation of optical shuttering devices.

In conclusion, we have presented three different methods of generating fast electrical pulses and two variations in utilizing these pulses to permit characterization of electrically driven optical shutters. The proximity-focussed MCP image intensifiers are presently resolution limited in going to optical shutter times < 2 ns for full on/off intervals. The pulsed, when terminated in 50Ω are not the limiting factor. When the $< 50\Omega$ loads form the termination, impedance mismatches produce excessive reflections and ringing. Also, the capacitive loading represented by the image shutters adds shunt capacity which causes the pulse width to increase over the properly terminated case. Better impedance matching coupled with improved pulse injection and transmission methods are currently being designed. Impedance matching is the dominant problem. The gated SIT FPS vidicon tube is also limited by our ability to get an electrical gate pulse across the photocathode-grid interface. In this case however resolution is not seriously degraded for optical shutter times shorter than a nanosecond. The linac pulser system described above is again not the limiting factor in optical shutter times.

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