Section 3
DEVELOPMENTS IN PICOSECOND ELECTRO-OPTICS

3.A Electro-Optic Prepulse Suppression at LLE

In laser fusion experiments prepulse suppression is of pre-eminent importance, i.e., the main laser pulse must not be preceded by unprogrammed low intensity pulses. Typically, prepulse requirements are less than a few μJ of accumulated prepulse energy over the last ~20 nsec and less than 100 μJ over 100 μsec before the main laser pulse. The former is generally called prepulse energy emanating from the oscillator while the latter is due to amplified spontaneous emission (ASE) from the amplifier chain. Either one of these pulses can puncture, deform, evaporate, or transform the target into a plasma of undesirable characteristics for the actual laser fusion experiments.

While ASE is easily detected and may be controlled by large aperture Pockels cells[12] near the output of the laser, prepulse detection and suppression is more complex. Frequently, the most detrimental prepulses occur within the last nsec before the main pulse. In this region, detection of such prepulses is extremely difficult due to the dynamic range and bandwidth requirements placed upon the detection system. Active suppression is made difficult by the fast rise time and high contrast requirements placed on the Pockels cell system.

The standard prepulse suppression implemented on most high power lasers has involved saturable dye cells in the initial portion of the laser system. The fast response times of these dyes easily fulfill the bandwidth requirements. However, saturable dyes also tend to adversely affect the overall laser beam quality by enhancing structure (modulation) already present in the spatial and temporal intensity distributions. Furthermore, dyes are more effective for short pulse operation ($\leq$150 psec) due to their relatively high bleaching thresholds.

At the Laboratory for Laser Energetics we have developed an alternate, completely opto-electronic prepulse suppression scheme[13]. It utilizes a fast optically triggered Silicon (Si) high voltage (HV) switch[14], based on Auston's low voltage solid state switch[15,16], to provide a very fast rise time HV pulse to a Pockels cell switchout system. The very fast rise time and low jitter of the Si switch allows opening of the Pockels cell switchout system very close to the leading edge of the desired pulse in the mode-locked train. Recent improvements of this switch have allowed practically jitter free operation of psec streak cameras[17] and ultrafast Pockels and Kerr cells.[18,19] This was made possible by the ability to switch quasi DC or DC high voltage with $\lesssim$ 1 psec jitter.

The Si switch providing the HV pulse consists of nearly pure (intrinsic) Si (30 k$\Omega\bullet$cm), 10 mm long, 1 mm wide, 0.5mm thick, replacing part of the central conductor of an HN connector. Electrodes are applied on one side of the crystal with a 2 to 3mm gap in between. Without incident light the switch impedance is 100kΩ. Through a window in the connector a single 1.054μm laser pulse activates the switch. This produces electron-hole pairs in the bulk of the Si wafer and reduces its impedance to levels much below that of the charging and transmission cables.

In practice, about 50 μJ of light energy are sufficient for full (i.e., ~ 90%) HV switching. The switch stays in the ON state during the carrier recombination time of ~20 μsec. Its rise time is determined by the laser pulse duration, impedance mismatch in the switch, electrical dispersion in the cables and Pockels cells, and the optical trigger energy. Under optimum conditions, the rise time is approximately equal to the optical pulse width at half maximum, e.g., ~30 psec rise time for a 30 psec (FWHM) laser pulse. In order to obtain the 4 kV electrical pulse utilized in this application, 8 kV must be applied to the switch.

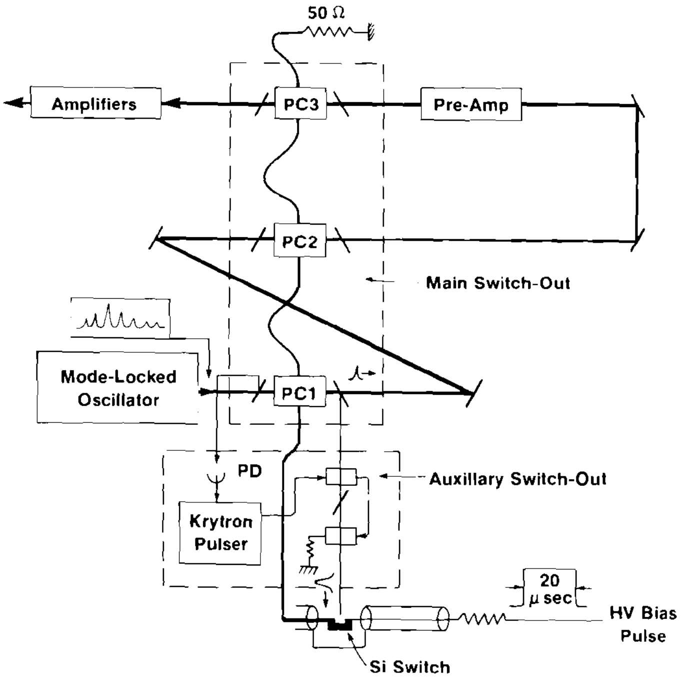

Figure 16 *High precision single pulse switch-out system on ZETA. Pockels cell PC1, PC2, and PC3 are timed for optimum synchronization of the single optical pulse and the HV electrical pulse. The auxiliary switch-out uses a conventional HV pulser to select a single pulse from the mode-locked train which then drives the HV high precision Si switch.*

Due to the thermal characteristics of Si and its finite initial gap impedance the HV on the charge line can only be applied for a finite time before thermal carrier excitation activates the switch. We therefore apply to the charge line a flat-top HV pulse of 50 to 100 nsec rise time and of 20 μsec duration. The pulse duration easily accomodates the 3 μsec jitter encountered in the emission time of most mode-locked oscillators.

The main features of the single pulse switch-out and prepulse suppression system are shown in Figure 16. This switch-out system is placed between the mode-locked oscillator and the amplifier chains of the University of Rochester's 3TW, ZETA laser system. The effect of this switching system on a typical laser pulse is demonstrated in Figure 17. The pulse shape of a 40 psec (FWHM) pulse was measured over 10 orders of magnitude and over 1 nsec range by means of third harmonic correlation crystal techniques[20]. When the overall transmission of the high speed switching system is folded in with the oscillator produced pulse shape, the calculated output pulse shape shown in Figure 17 is produced. Note that the processed pulse exhibits a power contrast (peak pulse power/prepulse power) of 10^{11} at 400 psec before the peak of the pulse, whereas the initial pulse has a power contrast at that point in time of only 10^6.

The high contrast attained by this technique has greatly improved the reproducibility of the data obtained on the ZETA and GDL laser systems.

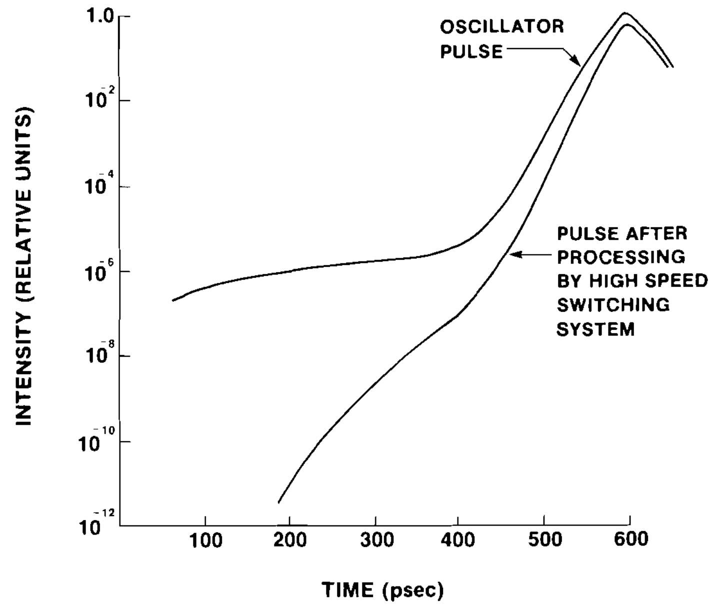

Figure 17 *The measured oscillator pulse shape for the 40 psec pulse (FWHM) compared with the calculated shape after processing by high speed switching system.*

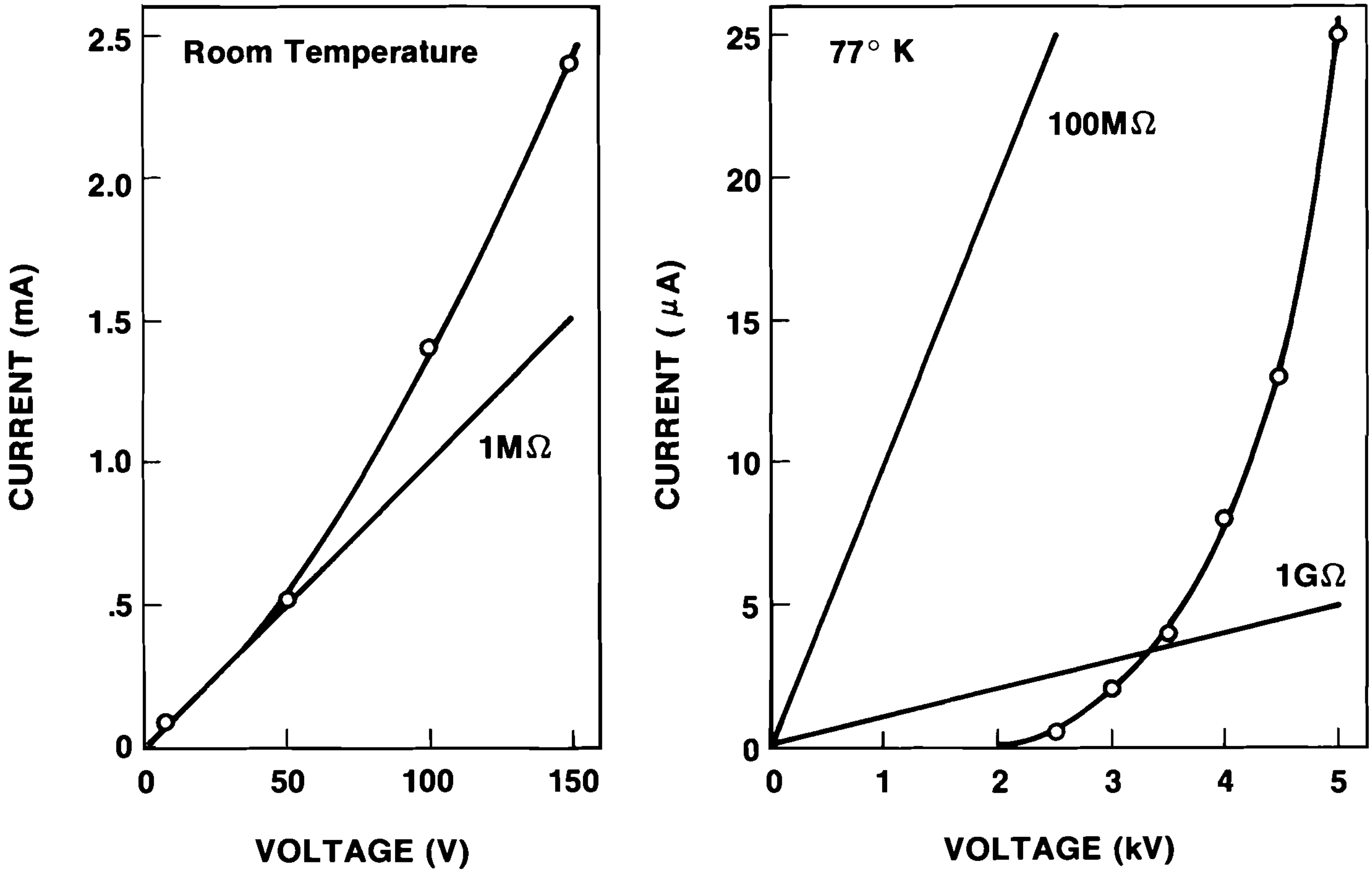

Figure 18 *Current-voltage characteristics for a Au-doped Si switching element at room and liquid nitrogen temperatures demonstrate the improvement in DC holdoff as the temperature is lowered for a 2mm gap. Joule heating and the resultant thermal generation of carriers gives these curves their shape.*