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6A1

Pulse compression in a GaAs photoconductive semiconductor opening switch controlled pulsed power system

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ABSTRACT

It has recently been shown that the GaAs photoconductive semiconductor switch (PCSS) exhibits many ideal opening switch characteristics including fast opening time (a few nanoseconds), high voltage and current handling capability, and absence from jitter. These characteristics may be utilized in a pulse compression technique to deliver high voltage pulses to a load with power gain.

The current charged transmission line (CCTL) scheme is used for pulse compression. In this scheme a shorted transmission line is connected in parallel with a matched load and charged with current through a PCSS. The PCSS is then closed by a square optical pulse from a laser. While the PCSS remains closed, the current in the CCTL is doubled after each successive travelling wave reflection. When the laser pulse ends, the PCSS opens and the CCTL becomes matched to the load. Consequently, the stored current is delivered to the load, producing an output voltage opposite in sign and many times greater than the charging voltage. The power gain, in this ideal case, is given by $(t_{ch}/\tau_{rt})^2$, where t_{ch} is the charging time (switch closed) and τ_{rt} is the round trip transit time for a travelling wave in the CCTL.

Our experimental work exploits the <10 ns opening time of the PCSS by using short CCTL's with round trip times, τ_{rt} , on the order of 20 ns. Pulses of up to 80 kW have been delivered to a 50 Ω load with 45 \times power gain. This required a charging time of 540 ns and a switch on-resistance of $\sim 1 \Omega$.

Typically the load resistance must be much greater than the switch on-resistance. However, it would be beneficial to operate the PCSS at on-resistances which are well above 1 Ω . This allows less laser energy to be used, with the idea of eventually using a semiconductor laser rather than an Nd:Glass laser. It may also allow the switch to be operated below the optical threshold for "lock-on," alleviating some of the problems with scaling to higher voltages. Therefore, we have developed a circuit structure which reduces the effect of the PCSS on-resistance.

The series CCTL (SCCTL) scheme consists of several CCTL's each connected to a matched load which are charged in series through the PCSS. The SCCTL circuit structure allows a higher switch on-resistance than the CCTL by increasing the switch to total load resistance ratio. Experimental results with two series CCTLs and $\sim 4 \Omega$ switch on-resistance reveal a factor of three times improvement in voltage gain over the single CCTL. This concept can easily be extended from 2 series CCTL's to n series CCTL's for operation at even higher switch on resistances.

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Diode Voltage Measurement with a Bremsstrahlung Spectrometer in Plasma Opening Switch Systems

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Load voltage measurements are crucial for characterizing the performance of pulsed power systems. Vacuum voltage measurements on terawatt class pulsers are difficult, however, because of the extremely high electric field environment. For this reason, voltage measurements are usually made in water or oil upstream of the tube insulator. The load voltage is then calculated using the measured rate of change of current and the known inductance between the monitor and the load. In inductive energy storage systems, however, the monitor and load are coupled through a plasma opening switch (POS) whose electrical characteristics are not well understood. In particular, experiments have shown that the plasma moves downstream toward the load, thereby altering the switch current path during the conduction and opening phases. This plasma motion not only changes the inductance for the Ldl/dt correction, but also generates a motional voltage Idl/dt .

Bremsstrahlung provides a convenient probe of the voltage in a relativistic electron beam diode, because these X-rays readily escape the vacuum vessel and are easily detected. The shape of the high energy X-ray spectrum is determined primarily by the electron energy, i.e., the diode voltage through which the electrons are accelerated. Because the X-ray attenuation length increases with photon energy it is possible to unfold the bremsstrahlung spectrum from a number of X-ray measurements performed with differentially filtered detectors. Our differential absorption spectrometer consists of seven filter-detector pairs contained in a thick Pb housing. The seven Pb filters have thicknesses of 2, 3, 4, 5, 7, 10, and 15 mm respectively, and are optimized for diode voltage measurements from 0.5 to 2.0 MV. The detectors are 0.125 mm thick p-i-n diodes with 1.6 mm Al, 0.1 mm Cu, and 1.0 mm Sn filters to absorb fluorescent X-rays. The p-i-n diode is reverse-biased at 1000 V to give a minimum FWHM of 3 ns.

The diode voltage is unfolded with theoretical calibration curves calculated for monoenergetic electrons using the CYLTRANM coupled electron/photon transport code. The theoretical detector dose versus filter thickness data are well fit by the function $y = \exp(a+bx+c/x)$, giving a characteristic attenuation length which increases with electron energy but is insensitive to the electron incidence angle or converter thickness. To unfold the experimental spectrometer data at each point in time, we perform a least squares fit of the seven detector signals versus filter thickness. We then calculate a characteristic experimental attenuation length and interpolate on the theoretical electron energy versus attenuation length curve to obtain the diode voltage. This unfold technique has been benchmarked on a flash X-ray source driven by a conventional pulse forming line, where the inductively corrected diode voltage is believed to be accurate.

We will present a comparison of voltage measurements on bremsstrahlung diodes driven by inductive-store, opening-switch generators. In addition to the spectral and corrected voltages described above, we can also deduce the voltage waveform shape from the ratio of X-ray doserate to diode current, which is a monotonic function of diode voltage. In general, the peaks of the spectral and corrected diode voltages are in good agreement, but the spectral voltage rises later than the corrected voltage; the shape of the spectral voltage waveform also provides better agreement with the shape of the doserate/current waveform. Errors in the corrected diode voltage are caused by plasma motion downstream from the POS and by transit time effects in the long MITL separating the diode from the capacitive voltage monitor.