OPTICALLY INDUCED SURFACE FLASHOVER SWITCHING FOR THE DIELECTRIC WALL ACCELERATOR*

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Fast, low jitter command triggered switching is key to the successful implementation of the dielectric wall accelerator (DWA). We are studying a UV induced vacuum surface flashover switch for this purpose. We present our initial data using a Nd:YAG (λ=1.06 nm) laser incident onto a high gradient insulator surface at 1ω, 2ω, 3ω, and 4ω. Best 1σ jitter was <1 ns with no degradation of the switch after 500 shots.

I. INTRODUCTION

The dielectric wall accelerator (DWA) is a new accelerator concept particularly suited for short pulse (<10 ns) and high currents (>1 kA) [1]. A pulsed acceleration field is developed by a series of asymmetric Blumleins (i.e., pulse forming lines) incorporated into the insulator structure (Fig. 1). Combined with new high gradient vacuum insulator technology, short-pulse-high-gradients of greater than 20-30 MV/m may be possible [2,3].

The asymmetric Blumlein consists of two stacked pulse forming lines of different transit times (i.e., differing permittivities, ε_r) and ideally, of equal impedances (Fig. 2). When the conductor in common with both lines is charged to potential, V_o, and shorted at the end opposite the accelerator beam tube, two reversed polarity wavefronts in each line move at velocities proportional to $\varepsilon_r^{-0.5}$ toward the beam tube. For a fast pulse line length of time, τ, and a slow pulse line length of time, 3τ, an energy gain of $2V_o$ occurs across a single Blumlein structure into a matched beam load over the interval τ to 3τ.

For short pulse applications, fast, low jitter switching is required to preserve usable pulse width. Further, the switch must be capable of gradients at least comparable to that of the main accelerator structure. Potential technologies which

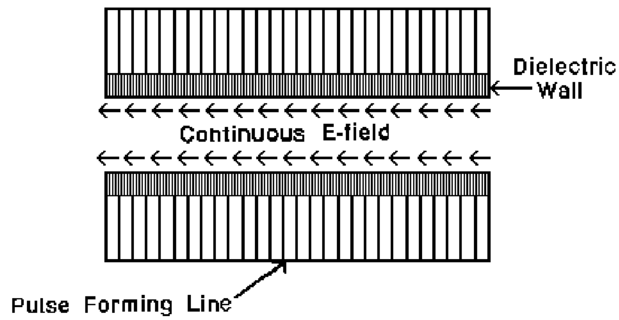

Figure 1. Dielectric Wall Accelerator (DWA).

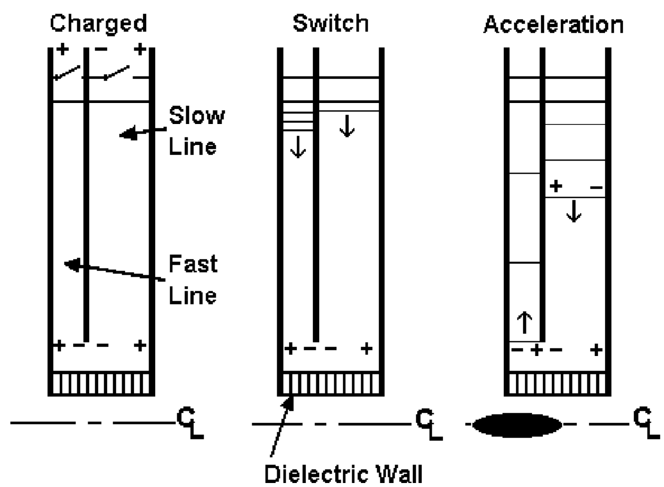

Figure 2. Asymetric Blumlein operation.

meet this requirement include photo-conductive or electron beam induced solid-state switching (particularly those based on diamond films), high pressure gas, and liquid dielectric switches.

For the near term, vacuum surface flashover switching appears the simplest to implement. Such a switching technique relies on the initiation of a fast high current vacuum surface discharge on a moderately stressed insulator. Earlier work by others using field distortion triggering showed low jitter (order 1 ns) [4]. High current rate of rise (dI/dt >10^{13} A/s) appears possible based on data from surface flashover

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discharges [5]. Further, high gradients are possible with new insulator technology [2,3]. We present our initial results here.

II. APPARATUS

A diagram of the switch apparatus and optical layout is shown in Fig. 3. The laser was a Q-switched, Nd:YAG laser (λ=1.06 μm), with a 200 mJ output in an approximately 10 ns pulse. The switch substrate was a high gradient insulator sample 2.5 cm diameter by 0.59 cm thick. A 10 J "mini-Marx" generator which was used to develop a pulsed voltage of approximately 1.3 μs FWHM (3.0 μs base-to-base) and up to 250 kV amplitude across the sample.

To study the properties of switch closure at different wavelengths, three additional harmonics were generated at 2ω, 3ω, and 4ω (λ=532 nm, 355 nm, and 266 nm, respectively). Type I doubling in CD*A was used to obtain 2ω. A BBO two crystal, Type I, walk off compensated scheme was used to produce 4ω from the second harmonic. 3ω was generated by summing the first and second harmonic in a KD*P Type II tripler. Maximum available output energies at 2ω, 3ω, and 4ω were 100 mJ, 40 mJ and 40 mJ respectively with pulse widths of approximately 6-8 ns.

Optical energy from the laser was delivered through a UV grade fused silica window. Energy delivered to the target was measured on each shot by sampling from an uncoated fused silica wedge with a cross calibrated joule meter. Temporal optical pulse shape was also measured with a fast rise-time (500 ps) pyroelectric detector. Fluence delivered to the target was determined from the measured energy and approximate beam area at the sample. The effects of a semicircular beam image and partial illumination were also investigated.

The high gradient insulator was prepared by interleaving individual layers of 0.064 mm stainless steel and 0.127 mm polycarbonate film. The structure was slightly compressed between polished bare aluminum electrodes. The entire assembly was placed in a turbo-molecular pumped, stainless-steel chamber. Experiments were generally performed at 10^{-6} T.

II. EXPERIMENTAL RESULTS AND DISCUSSION

Our preliminary delay data for 3ω and 4ω (Figs. 4 and 5, respectively) shows a decreasing trend in the delay time and jitter with increased fluence. We define delay as the time from the 50% point in peak fluence to the 50% point in peak switch current. Statistics are based on a minimum of 8-10 pulses from the laser.

Delay varies only slightly from 30 ns at a fluence of 30 mJ/cm^2 to 19 ns at 230 mJ/cm^2 for 3ω and from 25 ns at a peak of 15 mJ/cm^2 to 6-11 ns at 100 mJ/cm^2 for 4ω. The 1σ jitter (error bars) decreased significantly from approximately 10 ns at a fluence of 30 mJ/cm^2 to 0.97 ns at 230 mJ/cm^2 for 3ω. And likewise, the 1σ jitter decreased significantly from approximately 10 ns at a fluence of 15 mJ/cm^2 to 0.80 ns at 100 mJ/cm^2 for 4ω. Representative data showing timing distribution at two fluences is shown in Fig. 6.

Delay time dependence on voltage, spot size, and spot shape was not evident within the statistics of the data nor was shot-to-shot degradation evident over the approximately 500 shots necessary to acquire the data.

Probability of closure is shown in Figure 7 as a function of fluence and incident wavelength. For a 20% closure prob-

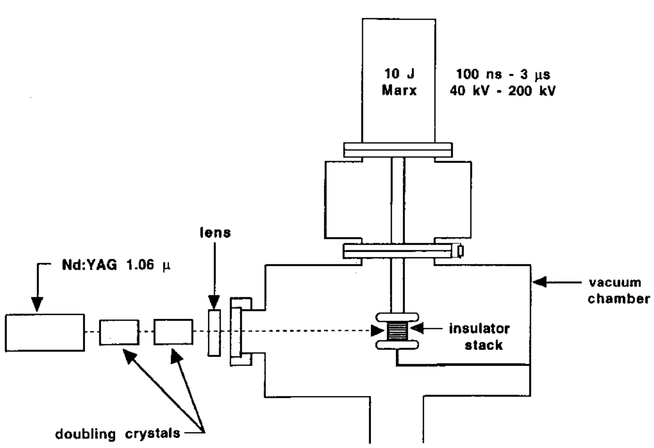

Figure 3. Experimental Apparatus (shown for 4ω).

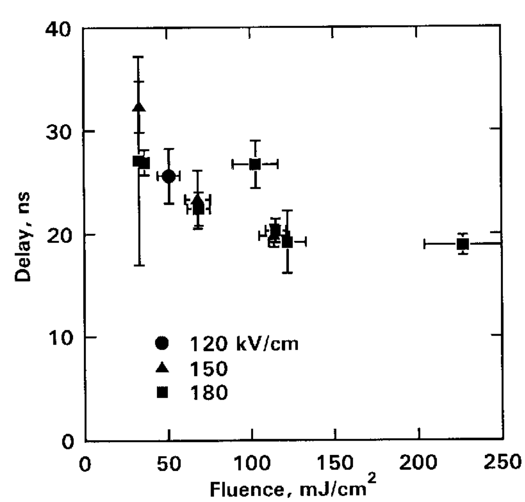

Figure 4. 3ω switch closure delay results.

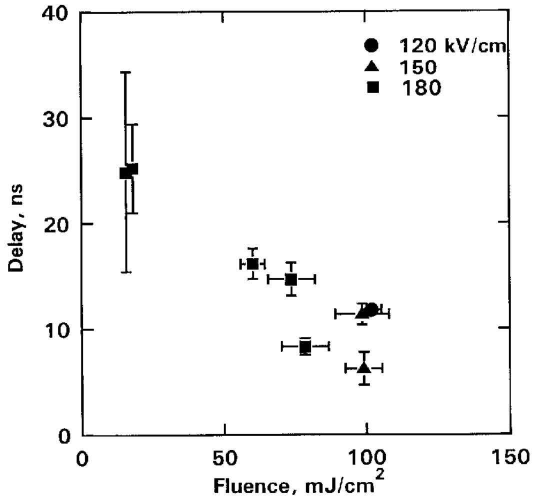

Figure 5. 4ω switch closure delay results.

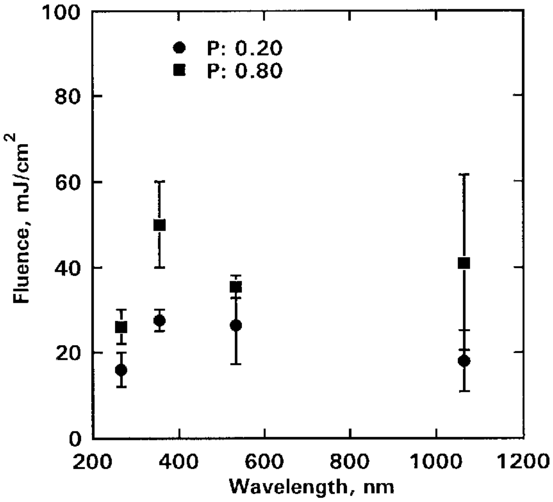

Figure 7. Closure probability.

ability, fluence requirements varied from 15-27 mJ/cm^2. An increased fluence of 26-50 mJ/cm^2 resulted in an increased closure probability of 80%. Similar results taken at approximately 4ω were observed by others [6].

There was a decreasing fluence threshold trend above 3ω that cannot be explained based on the statistics of the data. As the sample was transparent in the visible, we speculate that a certain amount of focusing and internal reflection could have occured. An increase in the fluence could have therefore resulted. Lastly, as can be seen from the data, a reasonable closure probability was possible for 1ω and 2ω. Delay times were from 75 ns to 225 ns for 1ω and 25 ns to 35 ns for 2ω. Significant scatter in the data was present, however.

IV. SUMMARY

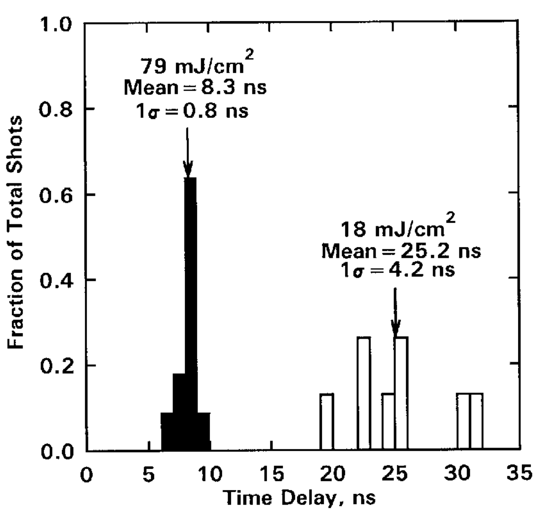

Figure 6. Typical distribution (λ=266 nm, E=180 kV/cm).

We have performed initial testing of a laser initiated vacuum surface flashover switch. Experiments were performed with a Nd-YAG laser optical source (λ=1.06 μm) and a high gradient insulator. We observed that closure is possible at 1ω, 2ω, 3ω, and 4ω; statistically meaningful data were only obtainable for 3ω and 4ω in our experiments. At elevated fluences, delay times were measured to be 6-19 ns, jitter was below 0.9 ns. Closure thresholds were measured and for 80% probability of closure, was found to be 26-50 mJ/cm^2.

V. REFERENCES

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