Switching Notes
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LOW POWER LASER-TRIGGERED SWITCHING AT VOLTAGES > 500 KV

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Abstract

The laser-triggered switching of a 575 KV, Van de Graaff charged, high-pressure, gas-filled spark gap is described. Subnanosecond switch jitter could be maintained with laser power of only 10 MW. The application of this technique to repetitive switching of high-voltage, pulsed-power systems with nanosecond delay and subnanosecond jitter is considered.

The repetitive triggering of a high-voltage spark gap by a low-power, Q-spoiled Nd(3+) doped YAG (Yttrium Aluminum Garnet) laser was first reported by Guenther and McKnight (1). They initiated conduction of a 38 kV gas-filled spark gap at rates up to 50 pps with ∿ 20 nsec delay and ∿ 1 nsec jitter. This technique was later refined by Bettis and Guenther (2) who achieved 50 pps repetition rates with jitter as low as 0.1 nsec. This report describes the extension of that work to the low-power laser-triggering of a 575 kV high pressure, gas filled spark gap, and comments on the suitability of using this technique to repetitively initiate switches at very high voltages with high reliability.

A Nd doped YAG laser was chosen for these studies for several reasons. Firstly, experimental evidence indicates that laser-initiated gas breakdown thresholds are less at 1.06μ, the predominant operating wavelength of Nd doped active materials, than at the wavelength of other possible laser candidates (e.g. Cr^{+3} in $A\ell_2 O_3$ @ 0.69μ). Burcher, et al, (3) have reported that laser-induced breakdown thresholds in Argon and Xenon were about an order of magnitude less at 1.06μ than at 0.69μ. Secondly, Nd^{+3} doped YAG is about the most durable laser material from a damage resistance standpoint. Furthermore, it can be operated Q-spoiled (or high peak power mode) at repetition rates into the several kilohertz region for very long periods with excellent reproducibility.

Several commercial YAG laser systems have operated for several million firings at 50 pps without need for component replacement. The laser system employed in this work emitted approximately 80 millijoules (mj) per pulse with a pulse width (FWMH) of 6-7 nsec. Beam divergence was approximately 1.5 milliradian (4).

The experimental arrangement used was similar to that previously described (5). The output from an ITT bi-planar photodiode with an S-1 photocathode was used to monitor the laser pulse on a Tektronix Model 519 oscilloscope. A 76 mm focal length, fixed-position lens located coaxially in the ground electrode was used to focus the laser beam on the opposing positive charged electrode. Gap breakdown was indicated by the signal from a di/dt pickup loop. The spark gap configuration consisted of hemispherical stainless steel electrodes 11 cm in radius at a separation of 2.0 cm. The gas dielectric was a 350 psia mixture of 50% Argon, 40% Nitrogen, and 10% SF_6, by partial pressures. This gas composition was chosen because of its reported high dielectric strength and low switching jitter (6). Measurements were taken at voltages from 75% to 97% of the self-breakdown voltage of 575 kV on a single shot basis.

In order to optimize the focal point location of the laser, an adjustable inverse Gallilean telescope was inserted between the laser and the 76 mm fixed lense. The focal point was adjusted by varying the telescope spacing until lowest delay and jitter were obtained.

As noted in previous studies (2, 7, 8, and 9) the optimum focus was obtained when the laser was focused slightly into the electrode. Using the method of Kogelnik (10) the spot size at the target electrode was calculated to be 0.06 cm in diameter. Assuming a reflective optical loss, from various lenses and the diagnostic beam aplitter, of 15%, the power density at the electrode was approximately 4×10^9 W/cm^2.

Figure 1 exhibits the variation of breakdown delay with charging voltage. Each point represents an average of five events, and the error bars (jitter) indicate the average deviation from the mean value of delay at each voltage. The general behavior depicted in Fig. 1 is consistent with previous work on laser-triggered switching where jitter is always a minimum when the delay is no longer than the effective pulse width of the laser emission (2).

The data reported here was not obtained on a repetitive basis because of power supply limitations. The Van de Graaff generator charging source allowed a firing rate no greater than about once every two minutes. However, it is believed the data can reasonably be extrapolated to repetition rates up to at least 50 pps. The YAG laser is capable of firing at that rate and assuming the use of an adequate power supply the only serious limitation on repetition rate is the recovery time of the gas dielectric for short discharge events. and reasonable electrode loading (i.e. the charge passed by the switch). It was shown

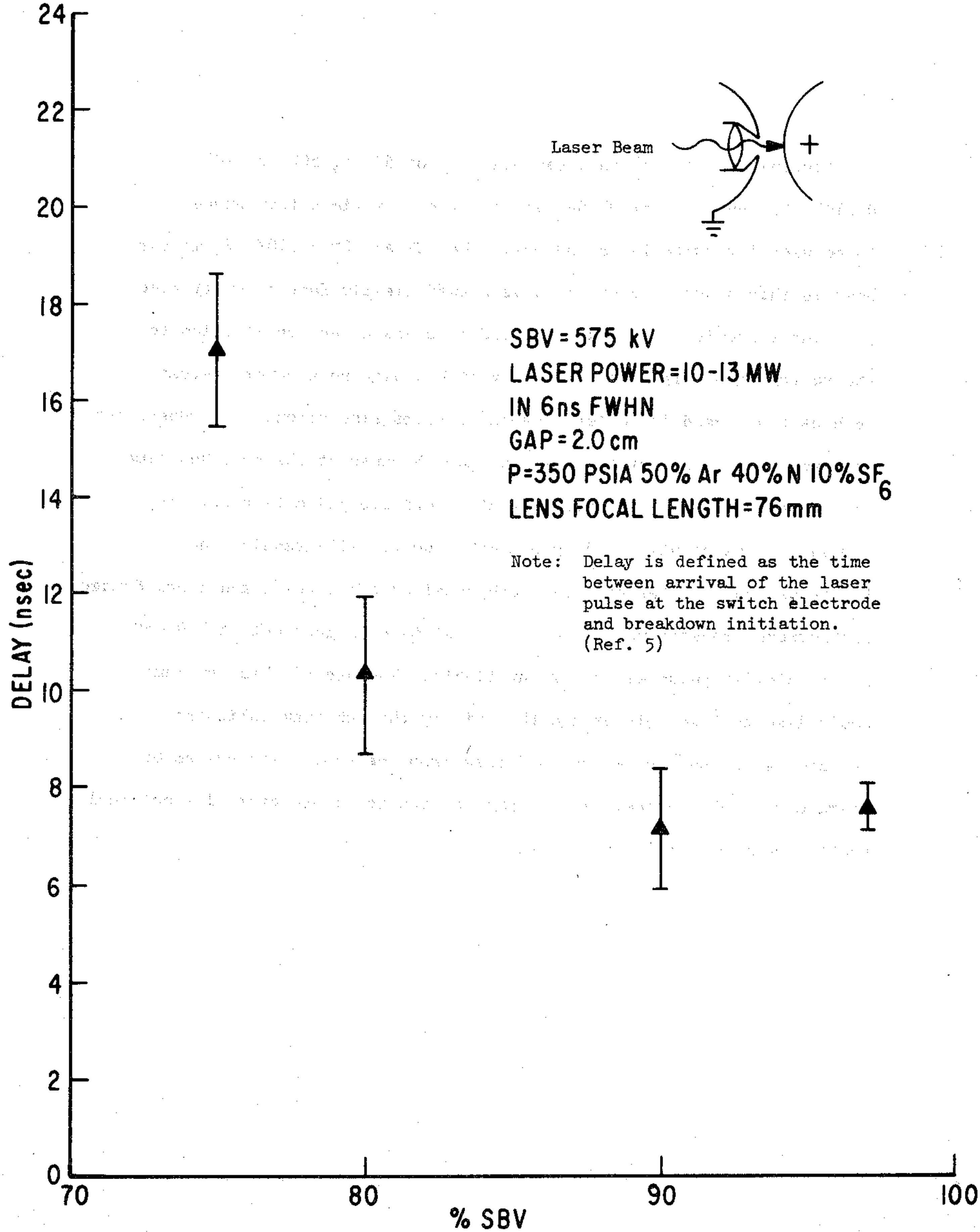

Figure 1. Delay vs % Self-Breakdown Voltage (%SBV)

in previous work (1, 2) that gas mixtures of 50% N_2/50% Ar, 90% N_2/10% SF_6. and 90% Ar/10% SF_6 all had recovery times fast enough to be used for switching at 50 pps. The 50% Ar/40% N_2/10% SF_6 mixture used in this study also should have a sufficiently fast recovery time.

The switching technique reported here has direct application to the switching of high energy, high voltage, high peak power systems such as those used in nuclear weapons effects simulation. The repetition pulsing of some such systems is desirable because of the cost and time savings effected by the efficiency of repetitive pulse testing. In practice, the actual building of such a switch will require the investigation of other problems such as electrode erosion and shock damage. Furthermore, repetitive Nd YAG laser systems of higher output (400-500 m j in similar pulse width) are available. The use of these systems would lead to lower jitter and the ability through beam splitting techniques to operate several switches from the same laser system or operate multiple channels in a single switch to reduce overall electrical system inductance (11).

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