J Indian Inst. Sci., Mar.–Apr. 1996, 76, 273–278.

A variable nano-second pulse duration laser pulse slicer based on high-voltage avalanche transistor switch

J. A. CHAKERA, P. A. NAIK, S. R. KUMBHARE AND P. D. GUPTA
Centre for Advanced Technology, Indore 452 013, India.

Received on October 10, 1994.

Abstract

A laser pulse slicer has been set up using avalanche transistor Marx-bank high-voltage nanosecond step pulse generators. This can provide single short-duration laser pulses variable from 4 ns to a few tens of nanoseconds by simply changing a cable delay. Optical configuration and electrical circuits involved and the performance characteristics of the pulse slicer are described. A sliced laser pulse of 4 ns (FWHM) is obtained with an energy transmission of ≈ 14% from an input laser pulse of 28 ns (FWHM). An intensity contrast ratio of ≈ 1200 is achieved between the peak and any prepulse

Keywords: Laser pulse slicer, avalanche transistors, Marx-bank circuit, nanosecond, Pockel cell.

1. Introduction

High-power pulsed lasers of nanosecond duration are widely used for a variety of research investigations and applications, *e.g.*, intense XUV-soft X-ray generation in laser-produced plasmas[1], laser–tissue interaction[2], laser material processing[3], etc. In many of these studies, not only the laser energy density but also the interaction time (governed by the laser pulse duration) plays a significant role. In such cases, it is desirable to vary the laser pulse duration to study its effect on various physical processes involved. A Q-switched laser normally gives a pulse of a few tens of nanoseconds duration. It is then necessary to temporally slice the laser pulse to a desired pulse duration.

A laser pulse slicer is essentially based on temporally controlling the transmission of a laser beam passing through a Pockel cell, *i.e.*, a KD*P crystal kept between two crossed polarizers. When a half wave voltage [$V(\lambda/2)$] is applied to the crystal, polarization of the laser beam rotates by 90°. Thus, transmission of the laser beam through the crossed polarizer would occur only when this high-voltage gate pulse is present on the Pockel cell. Further, instead of a $V(\lambda/2)$ gate pulse, a quarter wave voltage [$V(\lambda/4) = 3.3$kV] gate pulse can be used if the laser beam makes a double pass through the KD*P crystal.

Stacks of avalanche transistors have been used for fast switching (1–2 ns) of high voltages[4-7]. A combination of two such stacks with appropriate cable delay introduced in their output pulses can be used to generate the desired $V(\lambda/4)$ gate pulse. Instead of this, a high-pressure spark gap or a dielectric switch can also be employed for fast switching of high voltages[8]. These techniques have been widely used for a single pulse selection from a train of mode-locked laser pulses[9]. However, the use of these switches has not been reported for pulse slicing of nanosecond-duration laser pulses. This is primarily because the trigger pulse for switching of the avalanche transistor stacks has to be derived from the initial part of the laser pulse unlike the case of a mode-locked laser where a train of laser pulses is available. Further, the high-voltage gate pulse should be well synchronized to the peak of the laser pulse for maximum laser energy transmission. In this paper we describe a laser pulse slicer using avalanche transistors stack as a high-voltage fast switch providing single short-duration laser pulses variable from 4 to a few tens of nanoseconds duration with an intensity contrast ratio of ≈ 1200.

2. Experimental set-up and results

Optical configuration of the laser pulse slicer is shown in Fig. 1. A plate polarizer (polarization contrast ratio ≈ 2500) reflects the incident s-polarized beam which then passes through the KD*P crystal (Pockel Cell Model 850–10 of Electro-Optic Development, UK). This beam is back-reflected at a small angle through the KD*P crystal (EOLM) by using a 100% reflecting mirror M_1. During the period the gate pulse is applied to the EOLM, the laser beam is transmitted by the polarizer. A second mirror

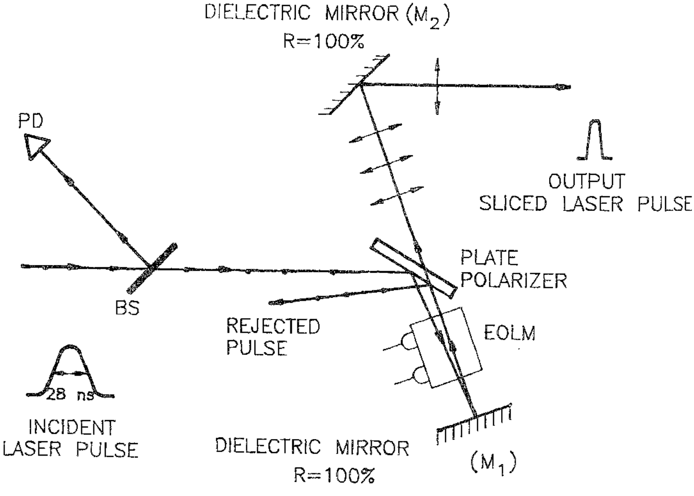

FIG. 1. Optical configuration of the laser pulse slicer.

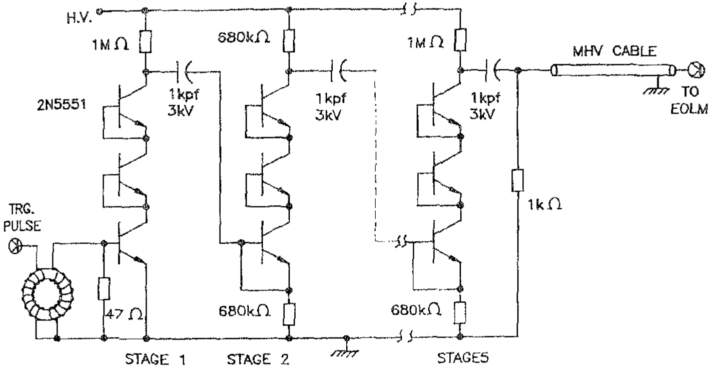

FIG. 2. High-voltage fast switching curcuit based on avalanche transistors.

M_2, kept at an angle of 33°, provides the output beam in a direction parallel to the incident laser beam. A part of the incident laser beam is reflected by a beam splitter (BS) on to a biplanar photodiode (PD) to generate a trigger pulse for the high-voltage switch.

The V (λ /4) gate pulse on the EOLM is generated from two identical 5-stage Marx-bank circuits using Motorola 2N5551 avalanche transistors[4–7]. Figure 2 shows the details of the Marx-bank circuit. Each stage of the Marx bank consists of three avalanche transistors connected in series. All the transistors used are selected with similar breakdown characteristics to obtain fast switching time. In the present case, the breakdown voltage was 325V. A DC voltage power supply of ~900V was used to charge the low-inductance ceramic capacitors (470pF/3kV) in the Marx bank. Voltage drop across each arm of the three transistors was ~800V. Each of the two Marx-bank circuits was housed in separate metallic enclosures and was powered by separate high-voltage power supplies to minimize any false triggering due to external electromagnetic noise or that generated due to switching of one of the circuits.

Trigger pulse for the switching circuits can be obtained from the biplanar photodiode detecting a part of the incident laser pulse. However, it was observed that the long duration (28 ns) of this trigger signal resulted in a frequent random triggering of the transistor stacks and also shortened their lifetime. Furthermore, any change in the intensity and duration of the incident laser beam would also affect the trigger signal and consequently alter the performance of the high-voltage switch. These problems were sorted out by using a nanosecond duration trigger pulse generator circuit.

The above pulse generator is also based on avalanche transistor (2N5551) (Fig.3). When a trigger pulse is applied to the base, it produces an output pulse of about 7 ns (FWHM) with an amplitude of ~35 volts. The time delay between the output pulse and

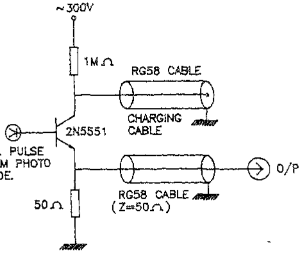

FIG 3. Nanosecond pulse generator circuit.

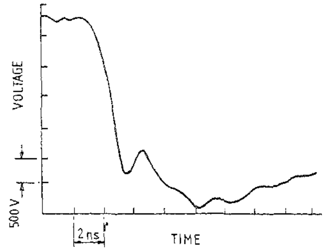

FIG. 4. H.V. step pulse generator waveform.

the trigger pulse is about 2 ns. For the purpose of laser pulse slicing, this pulse generator is triggered by the output signal of ~2 V obtained from the biplanar photodiode.

Each Marx-bank circuit provided a negative step pulse of ~3.6 kV when triggered by the above pulse generator. The fall time (90 to 10%) under no-load conditions was 1.5 ns. When the Marx bank output was connected to the capacitive load of EOLM (13 pF), the fall time (90 to 10%) increased to 4 ns. A typical high-voltage switch pulse for the latter case is shown in Fig. 4. This pulse is monitored by a high-voltage low-inductance attenuator probe (100 ×) (Fig. 5). A relative passive (cable) delay was introduced between the output pulses of the two Marx-bank circuits to obtain a desired duration of the high-voltage gate pulse of the EOLM. The duration of this gate pulse can be made variable by changing the length of the BNC cable to the two electrodes of the EOLM. Further, it may be noted that there is an overall minimum delay of 12 ns between the photodiode trigger signal and the switching of high-voltage on the EOLM electrodes. The energy transmission of the pulse slicer will be maximum when the high-voltage gate pulse is synchronized to the peak of the incident laser pulse. This condition

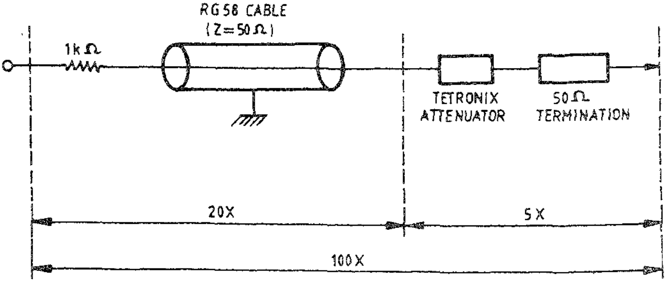

FIG. 5. High-voltage 100 × attenuator probe.

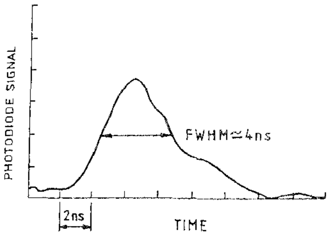

FIG. 6. A typical output laser pulse from the pulse slicer.

was accomplished by taking the photodiode trigger signal from the initial part of the incident laser pulse.

The laser pulse slicer was tested using an input laser pulse from a Q-switched Nd : glass laser (T ≈ 28 ns FWHM). The output pulse duration and the energy transmission of the pulse slicer were measured for different values of the gate pulse duration. A minimum pulse duration of 4 ns (FWHM) of the sliced laser pulse was achieved (Fig. 6) as detected on a Tektronix 7834 storage oscilloscope. For this case, an energy transmission of the pulse slicer was observed to be ~14% which agrees well with that expected from the ratio of output and input pulse durations. Intensity contrast ratio between the peak of the transmitted laser pulse to any prepulse present in the output beam was also measured. A contrast ratio of ~1200 was achieved under optimum alignment condition of the EOLM axis (within ±18 arc-min) with reference to laser beam axis. This is important for many studies such as intense X-ray generation and shock-wave propagation in laser-produced plasmas where an extremely small prepulse intensity is desirable.

This laser pulse slicer is being used to provide variable-duration laser pulses to the laser amplifier stages of a 2-GW Nd : phosphate glass laser chain. Further, it can be operated online in either slicing or unslicing mode without changing the optical configuration. The unsliced operation is achieved by applying a constant V(λ /4) voltage on one of the electrodes while keeping the other at the ground potential.

References

1. NEILL, F. O.	Laser-plasma XUV sources, *Proc. 35th Scottish Universities Summer School in Physics*, St. Andrews, August 1988, pp. 317–350.
2. GITOMER, S. J.	Laser produced plasmas in medicine, *IEEE Trans.*, 1991, **PS-19**, 1209–1219.
3. DAVANLOO, F. *et al.*	Amorphic diamond films produced by a laser plasma source, *J. Appl. Phys.*, 1990, **67**, 2081–2087.
4. BAKER, R. J.	High-voltage pulse generation using current mode second breakdown in a bipolar junction transistor, *Rev. Sci. Instrum.*, 1991, **62**, 1031–1036.

5. Christiansen, J., Frank, K. and Hartmann, W. Fast solid state high-voltage pulse generator, *Nucl. Instrum. Meth Phys Res A*, 1987, **256**, 529–531.

6. Oak, S. M., Bindra, K. S., Narayan, B. S. and Khardekar, R. K. A fast cavity dumper for a picosecond glass laser, *Rev. Sci Instrum.*, 1991, **62**, 308–312.

7. Rai, V N., Shukla, M. and Khardekar, R. K. A transistorized Marx-bank circuit providing sub-nanosecond high-voltage pulses, *Measmt Sci. Technol* , 1994, **5**, 447–449.

8. Kanabe, T , Yoshida, K., Kato, Y. and Nakatsuka, M. Development of a reliable fast response laser-triggered dielectric switch, *Rev Sci. Instrum* , 1986, **57**, 173–176.

9. Matsushima, I., Kasai, T. and Yano, M. Single pulse switch out system for a passively mode-locked Q-switched Nd : YAG laser, *Rev Sci Instrum* , 1981, **52**, 1860–1864.