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Fast rise time, long pulse width, kilohertz repetition rate *Q*-switch driver

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We describe a versatile Pockels cell *Q*-switch driver that can generate high voltage electrical pulses having both fast rise times and long duration, with a repetition rate in excess of 1 kHz. The circuit is simple and easily adaptable to most types of *Q*-switched lasers and regenerative amplifiers. *© 2007 American Institute of Physics.* [DOI: 10.1063/1.2757474]

Fast rise time (<10 ns), high voltage pulses are required to drive Pockels Cell *Q*-switches in high gain lasers,[1] where the optical buildup times and output pulses are typically less than 100 ns, and in regenerative amplifiers,[2] so as to trap the injected pulse in the amplifier. For lower gain *Q*-switched lasers,[3] which have buildup times of several microseconds, a longer duration pulse (>1 μs) is required and the rise time is less important. Thus, high voltage *Q*-switch drivers with either a fast rise time[4] or a long pulse duration[5,6] have been reported.

Injection-mode-locked *Q*-switched lasers for sodium guide star applications, however, require drivers that have both a fast rise time and a long pulse duration,[7] and a 1 kHz repetition frequency. To our knowledge, circuits for such drivers have not been published. In this article, therefore, we describe a fast, high voltage, long pulse duration *Q*-switch driver that is reliable and inexpensive, and can easily be adapted for use in most types of *Q*-switched lasers and regenerative amplifiers.

The circuit for the *Q*-switch driver is shown in Fig. 1. It uses metal-oxide semiconductor field-effect transistors (MOSFETs) as the switching element, thereby providing reliability and a long lifetime. Single MOSFETs that can switch voltages of up to 1.5 kV and currents of up to a few amperes are readily available. Higher voltages can be switched by connecting MOSFETs in a series provided that each MOSFET never receives more than its maximum rated voltage during any part of the switching. Voltage sharing in our driver is achieved by connecting metal-oxide varistors (300 V ac) across each MOSFET,[6] as they can quickly change their resistance to share the total voltage evenly. The varistors are operated near the middle of their normal operating region to impart maximum protection.While switching of only 3.5 kV was required for the present application, the circuit shown in Fig. 1 could easily be adapted to higher voltages by increasing the number of MOSFETs in the chain.

To improve the rise time of the *Q*-switch, the high capacitance gates of the MOSFETs need to be charged quickly. While high current MOSFET gate drivers are available, faster switching was achieved by driving the gates via an intermediate MOSFET (7N60C) with a voltage pulse that is much higher than the threshold voltage and by clamping the gate voltage with a Zener diode (SA12) to prevent damage. A 100 Ω resistor is used to limit the current passing through the Zener after the gate capacitance is charged and to reduce power dissipation, thereby enabling higher repetition rates. The parallel 1.2 nF capacitor enables the fast rise time of the gate drive pulse to pass unimpeded.

The gates of the MOSFET chain are driven through transformers to isolate the gate drive circuit from the high voltages on the gates. We use two transformers that are trifilar wound on Neosid 28-794C36S ferrite cores, as this provides high coupling with only two turns, which enables a fast rise-time gate pulse. To increase the duration of the pulse, the gate is charged through a diode (11DQ06), thereby preventing gate discharge through the transformer. The 5 kΩ gate discharge resistor was selected to provide the required pulse duration; increasing this resistance would increase the pulse duration.

The 100 kΩ load resistor in Fig. 1 serves two purposes. It discharges the Pockels cell at the end of the pulse and provides a low voltage monitor point. This resistor must have a high voltage and power rating, high Ohmic value, and low inductance to prevent "ringing." This could be achieved using either a single thick film resistor (22 kΩ RCH50) or a parallel-series combination of four rows of six 68 kΩ, 1 W metal glaze chip resistors, which was the type finally used.

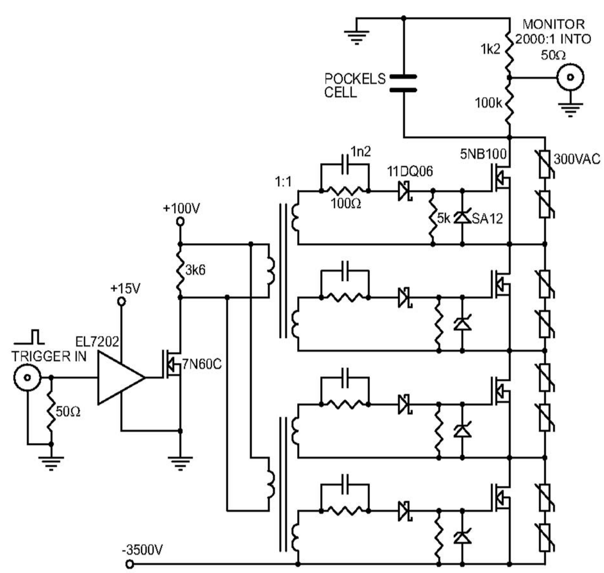

FIG. 1. Circuit diagram of the Pockels cell *Q*-switch driver.

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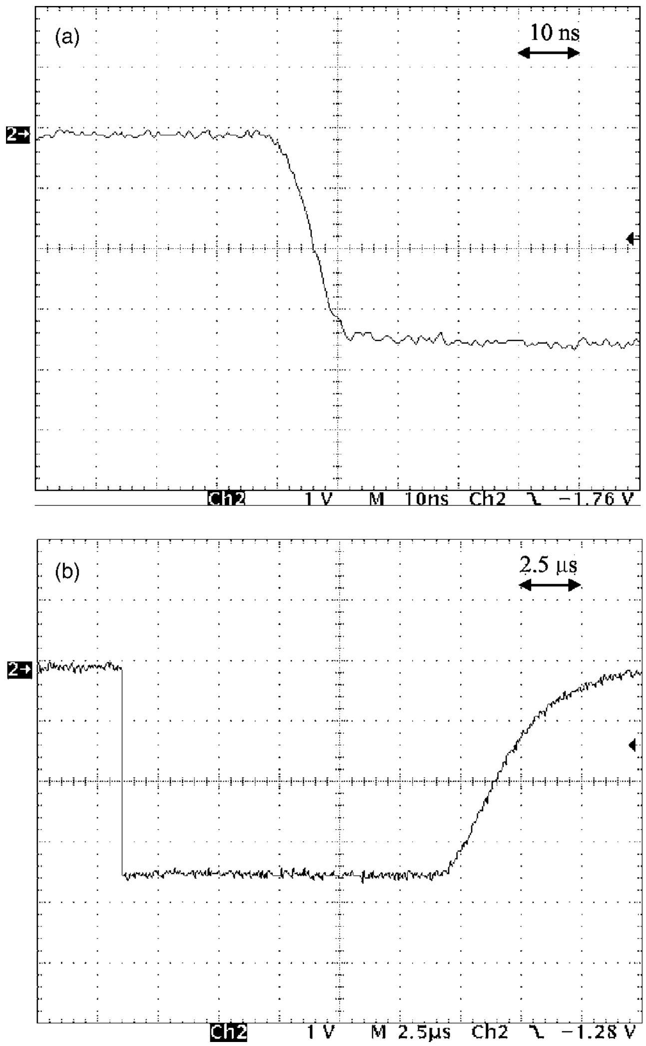

FIG. 2. Measured output pulse of the Q-switch driver with a 14 pF Pockels cell, showing (a) the 9 ns rise time and (b) a pulse width of 12 μs. The vertical scale is 1 kV/division.

The circuit shown in Fig. 1 was used to drive a Pockels cell that had a capacitance of 14 pF. Pulses with a rise time of 9 ns and a pulse width of 12 μs are shown in Fig. 2. A repetition rate in excess of 1 kHz could be maintained for long periods.

The components for the Q-switch driver (excluding the high voltage power supply) cost around US$100, and the complete switch was able to comfortably fit in a box of dimensions $13 \times 8 \times 4$ cm^3. Special care was taken with the circuit layout to minimize inductance and, hence, ringing on the pulse edge. The device was mounted directly on top of the Q-switch to eliminate the need for a coaxial cable to deliver the pulse. The use of a coaxial cable should be avoided as a terminated coaxial cable greatly increases the current drawn by the switch, while an unterminated coaxial cable adds capacitance and problems with reflections. The Q-switch driver was used over a period of six months without any reliability issues or component failures.

The rise time for this circuit may currently be limited by several effects: the total charge required to turn on the 5NB100 MOSFET switches, the response time of the varistors or the rise time, and the output impedance of the gate drive circuitry. A systematic study of these effects would be required to determine the dominant effect and to further reduce the rise time.

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