

DESIGN NOTE

A low-inductance, long-life, triggered spark gap switch for Blumlein-driven lasers

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Abstract. A low inductance, triggered spark gap switch suitable for a high-current fast discharge system has been developed. The details of the design and fabrication of this pressurized spark gap, which uses only commonly available materials, are described. A transverse discharge Blumlein-driven N_2 laser incorporating this device gives a peak output power of 700 kW with a FWHM of 3 ns and an efficiency of 0.51%, which is remarkably high for a pulsed nitrogen laser system.

1. Introduction

There is an increasing interest in the development and fabrication of fast switches for high voltage applications, such as in pulsed lasers, electron beam generators, flash tubes, Kerr cells and Pockels cells. The two types of switches usually employed are thyratrons and spark gaps. Thyratrons are triggered easily and have low jitter and long life (Santa *et al* 1984). However, due to their slow switching speed, thyatron-based switches have only limited applications. Many workers (Mechtersheimer *et al* 1986, Subash and Sathianandan 1984) have shown that switching speeds of a few nanoseconds together with a longer life can be achieved by using simple spark gaps as the switching element. Apart from their simplicity and cost-effectiveness, spark gaps are the best means of switching high levels of stored energy with low loss and low inductance. In this note, a novel design of a simple, low inductance and long-life spark gap switch suitable for a pulsed nitrogen laser is described. It comprises aluminium electrodes in a high pressure cavity and is driven by a trigger circuit.

In order to have fast switching, the total inductance in the discharge path must be very small (Schwab and Hollinger 1976). The inductance generally increases with the number of mechanical contacts and decreases when operated under a gas pressure in the range of a few atmospheres. The intense sparking within the spark gap produces heat, thereby raising the temperature of the

electrodes and the gas. The materials used should therefore be able to withstand the high current and high voltage as well as the high temperature. This imposes some constraints on the materials that can be used for the fabrication of switching elements.

2. Design of a triggered spark gap switch

Based on the above considerations, a pressurized spark gap has been designed, as shown in figure 1. Hylam sheet is used as the insulator in order to withstand higher temperatures. The electrodes are aluminium rods of 10 mm diameter. One of the electrodes that can move easily through the insulator is sealed off by two O-rings, so that its movement is strictly coaxial. The trigger electrode is introduced through a hole coaxial to the cathode machined in the aluminium block. It is insulated from the electrode by a ceramic tube. Heat is removed by the fairly large surface area of the metal part in contact with the gas. Cooling fins are provided to enhance the efficiency of heat dissipation. Since no appreciable increase in temperature occurs during the operation, the pressure seals can withstand up to 12 atmospheres (1.2 MPa), and material deterioration is very low. By sliding the electrode through the O-ring seal, the electrode gap can be adjusted between 0 and 10 mm. Also the electrodes can be easily removed and cleaned because the internal assembly is removable.

The spark gap was used to drive a transverse double-Blumlein type N_2 laser system. The design of the trigger

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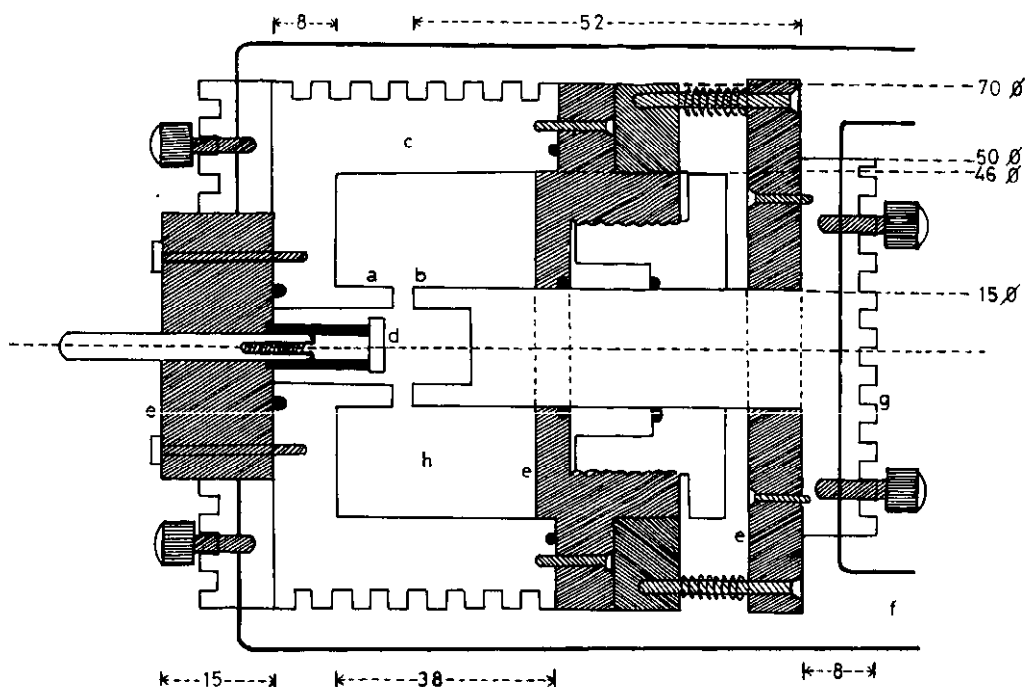


Figure 1. Sectional view of the triggered spark gap switch assembly (all dimensions in mm). a, cathode; b, anode; c, aluminium body; d, trigger electrode; e, hylam; f, copper sheet as leads; g, cooling fin; h, pressurized N₂ gas.

circuit is shown in figure 2. This circuit consists of two ICs (NE 555) which generate pulses of 5 μ s duration with a rise time of less than 1 μ s. The voltage pulse is fed to the gate of an SCR wired to the primary of a pulse transformer (an automobile ignition coil will suffice). The capacitor C is charged to about 450 V. The SCR is fired through the timing circuit and the capacitor is discharged through the primary of the pulse transformer. The output of the secondary is a transient voltage of about 4 kV. This high voltage pulse is fed to the trigger pin of the spark gap. The pulse repetition frequency can be set between 0.1 Hz and 1 kHz. Provision for manual triggering is also included in the circuit. The circuit has

safety provisions against current reversals and surge voltages.

3. Results and discussion

A nitrogen laser of the double-Blumlein type, using this triggered spark gap, gives an output power of 700 kW with an electrical to optical efficiency of 0.51%. This value is remarkably high for an N₂ laser compared with reports from earlier workers (Stankov *et al* 1987, Baltog *et al* 1986, Bergmann 1976). The high power and conver-

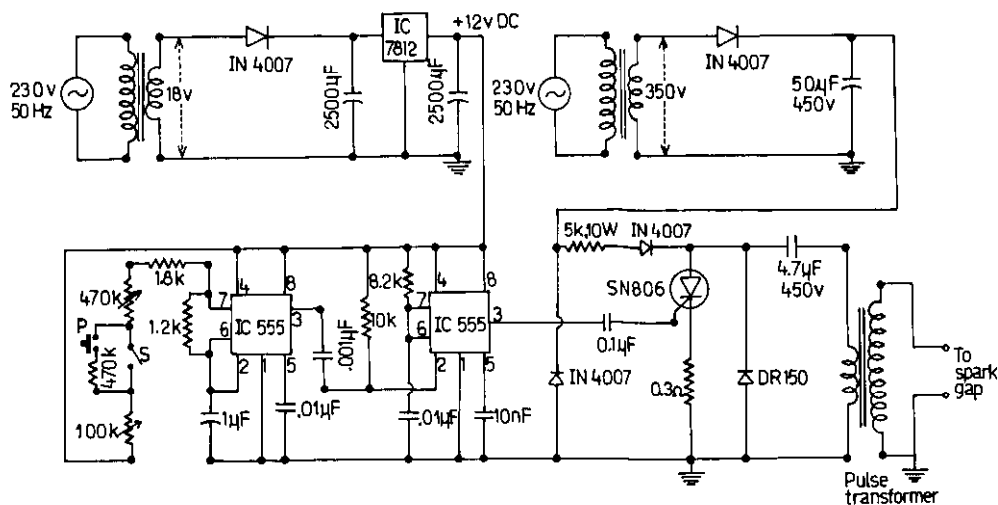


Figure 2. Trigger circuit.

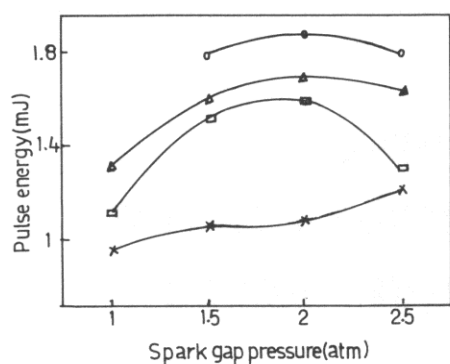


Figure 3. Variation of pulse energy with spark gap pressure for different voltages (in kV): x, 8; □, 10; △, 12; ○, 14. The plasma tube pressure is 80 Torr (10.6 kPa).

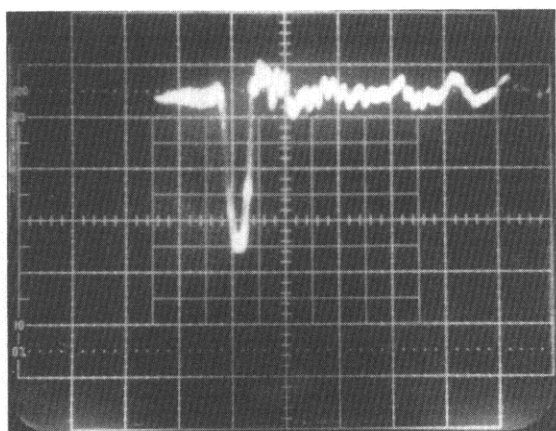


Figure 4. Nitrogen laser pulse shape. Sweep speed: 5 ns/div; gain: 0.5 V/div.

sion efficiency are attributed to the low inductance of the system.

The pressure in the spark gap affects the inductance of the discharge circuit. It is observed that the higher the pressure in the spark gap, the lower will be the inductance. The optimum output power obtained is at around 2 atmospheres of pressure. The variation of pulse

energy with the spark gap pressure at a plasma tube pressure of 80 Torr (10.6 kPa) for different voltages is shown in figure 3.

The output pulse shape recorded on a 466 DM44 Tektronix storage oscilloscope using a hp-2-4207 Hewlett Packard photodiode is shown in figure 4. The pulse width measured is 3 ns (FWHM). The system operates well even at a supply voltage of 15 kV. The unit described above has been in successful operation for several months. Erosion of the electrodes is very low in practice. Cleaning the electrodes once every 2000 hours is required to remove the aluminium oxide powder deposited due to the traces of oxygen impurity in the commercial grade nitrogen gas used to pressurize the spark gap.

Acknowledgments

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