HIGH POWER RF GENERATION WITH OPTICALLY ACTIVATED BULK GaAs DEVICES

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ABSTRACT

Utilizing sections of charged transmission line cables and optically activated semiconductor switches, the direct generation of high power RF was demonstrated. A Nd:YAG laser was used to switch an array of GaAs semiconductors, biased at 2 KV DC, resulting in a peak RF output of 7.0 KW at VHF.

INTRODUCTION

At ETDL a great deal of effort has been devoted to the investigation of photo-conductive semiconductor devices [1-2]. The unique features of the optically activated switch (OAS) are its fast risetime, low jitter and high power capabilities. Such properties may be used to good advantage to directly produce high intensity microwaves, using arrays of OAS devices. Relying on this concept, C. Chang et. al. [3] reported RF generation by laser illumination in a three stage "frozen wave" configuration. In this paper, significant modifications in the frozen wave generator are reported, allowing for enhanced RF output and efficiencies. The improved characteristics are achieved by the introduction of new GaAs switches and fiber optic bundles to activate each of the three switches.

EXPERIMENTAL PROCEDURES

RF Circuit

The RF generator consisted of charged coaxial transmission lines (PFL) and gridded GaAs OAS devices. As shown in Figure 1a, the circuit has three segments of PFL's charged by positive and negative voltage Vo. Adjacent PFL's are connected with a bulk GaAs OAS. Since semi-insulating GaAs has a high resistivity ($>10^7$ ohm-cm), the leakage current is negligible. When all switches are fired simultaneously, the standing waves, which have amplitude Vo/2, start to move in the forward and backward directions. The forward wave travels toward the output load and appears on the load resistor. The backward wave moves toward the open termination end, is totally reflected from the open termination end, and then moves back toward the output load. The half period of the RF generated is the transit time for the standing wave to travel across the PFL of length L. The repetition frequency of the burst of RF is determined by the repetition rate of laser system. The predicted generation of the RF burst is given in Figure 1b.

New OAS Devices

In most high power bulk OAS devices the light is introduced perpendicular to the applied field direction. Although these devices showed very high power capability, multiple OAS operation requires highly efficient devices as well. Recently, optically activated gridded silicon PIN diodes demonstrated high efficiency [4]. Utilizing this concept, optically activated gridded bulk GaAs devices were designed and fabricated at ETDL. The typical bulk GaAs OAS is shown in Figure 2. In these switches the light is introduced parallel to the applied field direction. The test results of these devices shows significant improvement of efficiency. With light from a 20 ns Q-switched Nd:YAG laser, emanating a fiber optic bundle, the switch turn-on was sustained for 150 ns without distortion. The Figure 3 shows the laser light pulse waveform leaving the fiber optic bundle and the resulting switch current waveform with a 200 ns PFL, biased at 2 KV. The OAS was turned on with laser energy as small as 0.8 mJ. The current latch-on and low threshold laser energy is assumed due to field-induced avalanche effect. On-state voltage was very small. The parametric relationship of applied voltage, optical energy, and output pulse width will be discussed elsewhere [5].

Laser Light Delivery with Fiber Optic Bundles

It is necessary to supply each of the switches with sufficient laser energy. This was implemented with fiber optic bundles. The advantage of this technique is that each bundle may contain

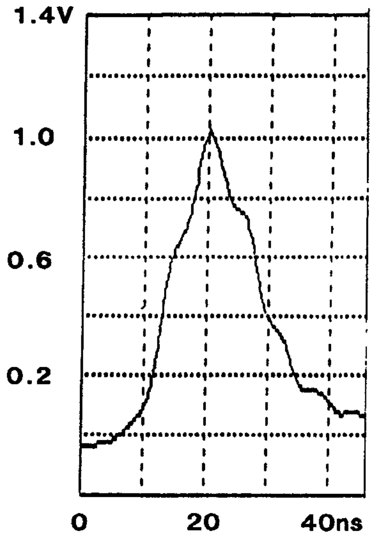

FIGURE 3(a). LASER LIGHT PULSE LEAVING FIBER OPTIC BUNDLE

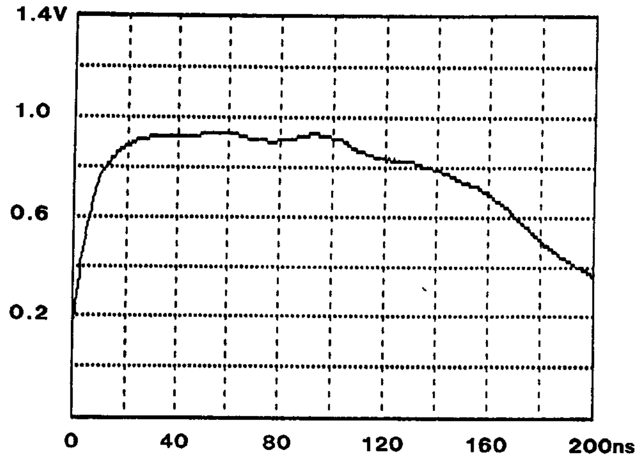

FIGURE 3(b). SWITCH CURRENT WAVEFORM

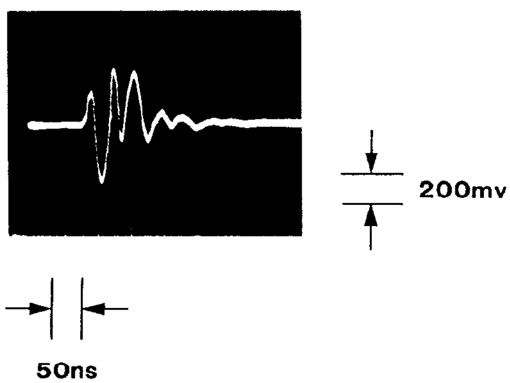

FIGURE 4. OBTAINED RF WAVEFORM WITH THREE STAGE FIBER COUPLED OAS

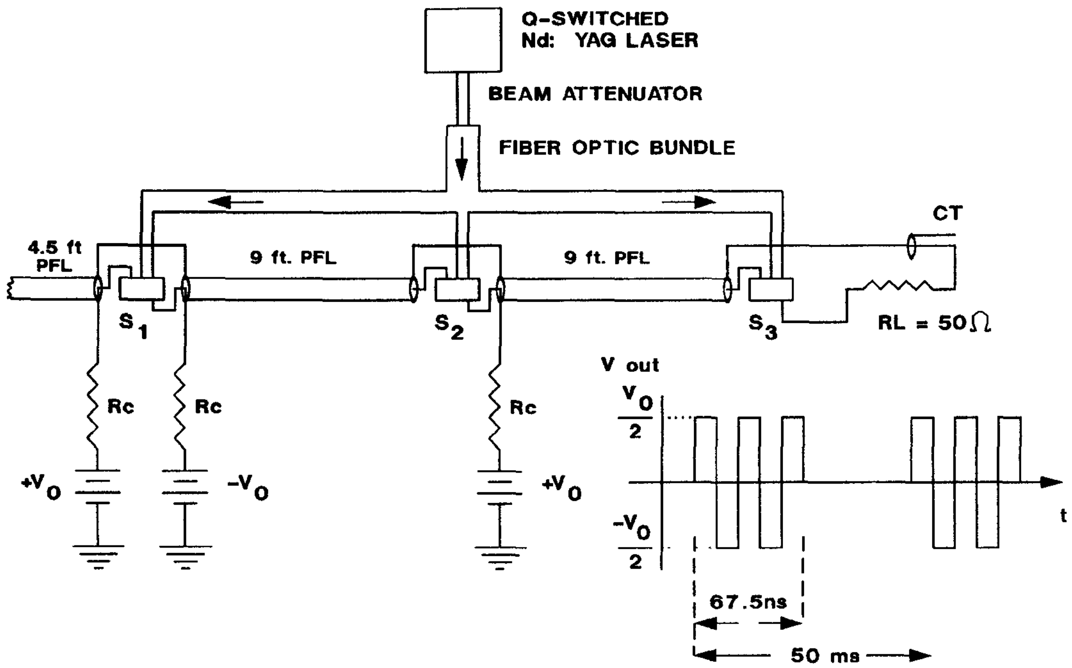

FIGURE 1(a). SCHEMATIC DIAGRAM OF 3-SWITCHES RF GENERATOR

FIGURE 1(b). WAVEFORM FROM THE RF GENERATOR

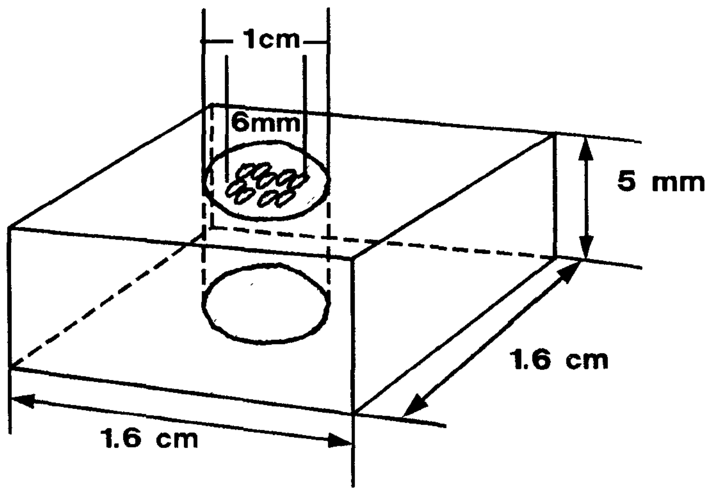

FIGURE 2. GRIDDED OAS DEVICE

varying fiber lengths, thus effectively increasing the width of the light pulse and insuring the switch stays on, until all forward and backward waves pass through.

This is particularly critical for switch number 3, which must stay on the longest time. In this experiment, however, it was unnecessary to use varying fiber lengths, since the OAS gridded device stayed on fairly long, up to 150 ns. In order to achieve wider burst pulse widths, however, the use of incremental fiber lengths may be expected to play a role.

EXPERIMENTAL RESULTS AND DISCUSSION

Each switch was tested individually at 2 KV DC bias with 0.8 mJ light energy from a Q-switched Nd:YAG laser (20 ns pulsewidth). The coaxial cable lengths of the 3-stage generator were 9 feet, 9 feet, and 4.5 feet respectively, with an anticipated total pulsewidth of 67.5 ns. Since this width is less than the recovery time (150 ns) of the OAS, simultaneous triggering of the switches was employed, and thus equal lengths of fibers were used to convey the light to the switches. A typical waveform, is shown in Figure 4, obtained by a current transformer, the Tektronix CT-1.

The maximum current achieved was approximately 12 amps, with a pulsewidth of about 100 ns, instead of the anticipated values of 20 amps and 67.5 ns. The longer pulsewidth, as well as the lower current amplitude, are caused primarily by inductance in the connections between OAS devices. This inductance will be eliminated by incorporating the switch into the transmission line. Narrower light pulses also will be used to minimize the effect of the risetime of the light signal. Unequal distribution of the light among the various switches must also be addressed.

CONCLUSIONS

Using charged transmission cables, gridded bulk OAS devices, a Q-switched Nd:YAG laser, and fiber optic bundles, the concept of high speed and direct high power RF generation was demonstrated. For the demonstration purposes, a simple circuit was fabricated and tested at 7.0 KW peak output power with 30 MHZ frequency. Since the OAS devices have low threshold light energy, long turn-on property, and high voltage capability, it should be possible to apply the same principle toward megawatt or even multi-megawatt RF generators at frequencies up to one gigahertz.

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