GENERATION OF HIGH POWER ULTRA-WIDEBAND ELECTRICAL IMPULSE BY OPTOELECTRONIC TECHNIQUE

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ABSTRACT

Progress in the application of ultrafast optics and photoconductive switching for the generation of high power ultra-wideband electrical impulses is reviewed. Several techniques are described. Megawatt pulses with picosecond rise-and falltimes and variable pulse duration have been obtained. Using photoconductive switch both as a closing and opening switch in an inductive energy storage system the electrical pulse power enhancement of a factor of 50 has been demonstrated for the first time.

INTRODUCTION

Ultra-wideband (UWB) radio frequency (RF) technologies have many unique applications. One of them is UWB impulse radar. The UWB features result in high resolution, accurate target-identification, high foliage penetration, and low probability of intercept. However, to realize the UWB impulse radar one has to overcome a number of critical path technologies, among them the generation, shaping and synthesizing of high energy short electrical pulses.

At the University of Maryland we have demonstrated the generation of RF impulse as short as one RF cycle, with peak power in excess of megawatts by using picosecond photoconductive switches made of bulk GaAs.[1−2] The bandwidth of the pulses extends from dc to the reciprocal of the pulse width, e.g., in excess of tens of GHz. Using frozen-wave generator in conjunction with the ps photoconductors RF pulses ranging from two-and-one-half cycles to coded aperiodic waveforms have also been demonstrated.[3]

In this paper we will review these and other new techniques for the generation of UWB impulses using photoconductive switching.

EXPERIMENT

The basic approach taken in generating ultra-wideband electrical pulses is using picosecond optoelectronic switching. In this approach (Fig. 1) a material with high dark resistivity such as GaAs, is used as a photoconductive switch in the center conductor of a transmission line pulse forming network (PFN). Without optical illumination the input bias voltage is isolated from the load. Upon picosecond laser pulse illumination the photoconductor resistance is reduced immediately, and a picosecond risetime electrical pulse appears at the load. Fast falltime can be obtained either by PFN or using a high voltage photoconductor which has picosecond carrier decay time. We have investigated both approaches and they both work. At the University of Maryland we are capable of routinely generating ultra-wideband pulses. The challenge is to generate such impulses with peak power in the kilowatts to megawatts range, and with waveform appropriate for specific application.

To this end we have employed various approaches. For example, a composite miniature stack-line structure is used to generate megawatt electrical pulses (Fig. 2). Two photoconductive switches (one GaAs and the other Si) are used, along with voltage multiplication and pulse forming lines, to generate over 14 kV pulses from a DC bias of only 9 kV.[2] These megawatt pulses have picosecond synchronization and can vary in width from nanoseconds to picoseconds. In the second approach, a single-picosecond GaAs photoconductive switch is used to pulse excite a microwave resonant cavity, thus generating a variety of RF waveforms. Waveforms ranging from one RF cycle to several hundreds of cycles have been demonstrated. In this approach the power spectrum can be shifted according to the design of the impulse generator. The third approach is using a frozen wave generator. A frozen wave generator, a simple and effective device consisting of several segments of transmission lines connected in series by means of picosecond photoconductive switches, is also capable of generating a sequential waveform of arbitrary temporal characteristics. We have demonstrated a coded waveform generation with peak amplitude in the kilovolt range.[3]

The fourth approach is using photoconductive closing and opening switch in an inductive energy storage pulsed power system Generation of an 80 kW, 2 kV pulse has been demonstrated with GaAs photoconductive semiconductor switch (PCSS) in a current charged transmission line (CCTL)[4]. The CCTL configuration (Fig. 3) provided a power gain of 50 and a voltage gain of 7. This is the highest power gain achieved to date with a CCTL and PCSS. Power gain is achieved by discharging a capacitor through the GaAs PCSS into a shorted transmission line, the CCTL.

The PCSS is closed by a specially tailored square laser pulse of duration 540 ns. When the laser pulse is extinguished, the switch opens and the inductive energy stored by the current in the CCTL is delivered to a matched 50Ω load in parallel with the CCTL. The PCSS used in the experiment was a 5 mm cube of p-i-n GaAs with narrow p and n layers near the contact surfaces in order to reduce contact resistance. A ~10 mJ pulse of 1.054 μm Nd:Glass laser light was sufficient to lower the switch resistant below 3Ω, providing enough charging current in the 2.0 m long CCTL to achieve a significant power gain. With the 1.1 μF capacitor initially charged to 300 V an output volt-

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age pulse of 2 kV was observed corresponding to a voltage gain of 7. If the power gain is taken as the ratio of the peak power delivered through the CCTL configuration to the peak power which would be delivered directly into the load from the capacitor, the corresponding power gain is 50.

CONCLUSION

Several approaches for the generation of high power ultra-wideband electrical impulses by optoelectronic techniques have been reviewed. The unique feature common in all approaches is the jitter free nature of picosecond photoconductive switch. This provides a technology base for generating ultra-wideband impulse waveform. Since it is jitter-free switching, the electrical impulses thus generated is in complete time synchronization with the command laser pulse. Using the same laser pulse to actuate several switches either simultaneously or in some kind of phase-coherents (definite time relation) manner, power combining in space or inside the circuit from a multi-elements system is also feasible, thus pushing the peak power into the gigawatt range.

ACKNOWLEDGEMENT

This work was supported by the Air Force Office of Scientific Research and the strategic Defense Institute Organization/Innovative Science and Technology managed by the Office of Naval Research.

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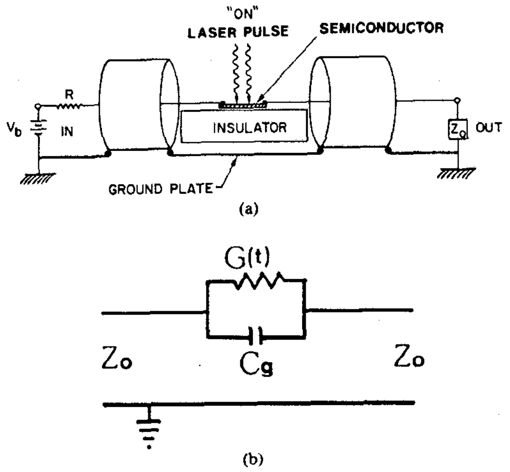

Fig. 1. (a) Schematic of the elemental photoconductive switch arrangement, (b) Equivalent circuit of (a)

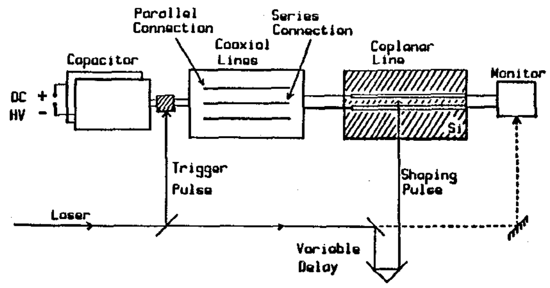

Fig. 2. Schematic of the stack-line structure.

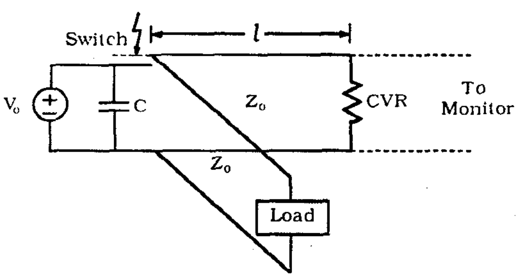

Fig. 3. The current charged transmission line with a semiconductor closing and opening switch.