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6B3-4

Artificially Structured Solid State Plasmas*

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Electronic and optical properties of artificially structured semiconductor systems (e.g., quantum wells, superlattices, quantum wires, quantum dots) have been extensively studied in the last ten years. It is useful, in many instances, to think of these systems as structured, low-dimensional solid state plasmas. Taking this approach, we discuss a number of electronic properties of low dimensional semiconductor microstructures from the plasma physics viewpoint. In particular, the possibility of various types of possible collective plasmon modes which could arise in these structures is pointed out and their dispersion relations are discussed. Particular emphasis is put on comparing and contrasting plasma dispersion relations in one, two, and, three dimensional semiconductor structures. A number of these plasma modes have been experimentally observed via Raman scattering and/or far infrared absorption spectroscopy. We critically compare existing theoretical results with the available experimental data, finding that in most situations the random-phase-approximation (or, equivalently the time-dependent self-consistent) formalism is quantitatively adequate to describe the plasma dispersion relations in these systems. Finally, we discuss the energy loss of fast external electrons to these solid state plasmas as they travel through these structures (as, for example, in hot-electron transistors or other similar high speed electronic devices).

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6B5

OBSERVATION OF SQUARE PULSE GENERATION IN A DUAL OF THE BLUMLEIN LINE WITH AN OPTOELECTRONIC OPENING SWITCH*

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For the first time, square output pulses were obtained with a dual of the Blumlein line (DBL),[1] a new inductive pulsed power system. The DBL is formed wtih a parallel connection of two equal-length transmission lines (RG-213) of characteristic impedance $Z_0 = 50\Omega$. The matched load ($Z_0/2 = 25\Omega$) is located at the junction of these two lines. An optoelectronic opening switch placed at the end of one line is connected to a 1.1 μF capacitor. This capacitor is initially charge to a voltage V_0. The end of the other line is shorted by a current viewing resistor (0.1Ω) which is used to monitor the charging current. The advantage of the DBL is that it produces output pulse power twice that by a current charged transmission line.[2] In the experiment, the optoelectronic opening switch of a 5 mm cube GaAs p-i-n diode[3] with ~5 ns carrier recombination time was used. The Nd:glass laser system used to activate the switch is specially designed to provide nearly square laser pulses at 1.054 μm with a rise-time and a fall-time of ~7 ns. The duration of the laser pulse is 540 ns and the pulse energy is ~10 mJ, which is sufficient to lower the on-resistance of the switch to ~ 2Ω. The length of these two transmission lines is $l = 1.5$ m. The highest output pulse was obtained at a charging voltage of $V_0 = 200$ V. The corresponding charging current in each line was 75 A and the output voltage pulse across the 25Ω matched load was 1.25 kV. For charging voltages higher than 200 V, it is observed that the output voltage pulse decreased and its shape became irregular. This may be attributed to an effect similar to the "lock-on" effect[4] during the opening phase of the switch.

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6B6

80 kW PULSE GENERATION BY A PHOTO-CONDUCTIVE SEMICONDUCTOR-OPENING-SWITCH INDUCTIVE PULSED POWER SYSTEM*

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Generation of an 80 kW, 2 kV pulse has been demonstrated with GaAs photoconductive semiconductor switch (PCSS) in a current charged transmission line (CCTL)[1] inductive energy storage pulsed power system. The CCTL configuration provided a power gain of 45 and a voltage gain of 6.7. 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 voltage pulse of 2 kV was observed corresponding to a voltage gain of 6.7. 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 45.

In addition, an effect similar to "lock-on" was observed during the opening of the PCSS whenever the induced field across the PCSS exceeded the "lock-on" field of ~4 kV/cm. This limited the output voltage to ~2 kV independent of the initial charging voltage. Higher output voltages may be achieved if a longer switch is used in order to reduce the field across the PCSS. This "lock-on" behavior as well as the use of longer switches are currently under investigation.

*Work supported by AFOSR.

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6B7

THEORETICAL AND EXPERIMENTAL CONSIDERATIONS OF A SILICON JUNCTION SEMICONDUCTOR SOLID STATE OPENING SWITCH

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There are two distinct opening mechanisms in semiconductor switches. In the first, the opening process for direct gap materials, such as GaAs (Ref 1) or diamond, depends on the short carrier lifetime; the natural recombination of the electrons and holes depletes the device of carriers. The process of recombination is exponential with time, and so this first mechanism provides a three order change in resistance in around 10 time constants. In applications such as pulse compression, an opening switch needs to conduct for durations longer than the opening time. Consequently, continuous illumination of the switch is required to overcome the recombination process and maintain a suitable carrier concentration.

The second approach, reported here, employs a junction in a material with a long carrier lifetime, such as silicon. The junction is rendered conductive in the reverse direction by electron - hole generation from photon absorption, in the same manner as switches in the paragraph above. Lifetime limitations not withstanding, conduction in a back-biased junction ceases when the carriers are removed through carrier transport and a depletion layer is created. This is the well known "snap - off" process used in **storage diodes.** In contrast to the conventional low power "snap off" regime, here we report on an opening switch power of one megawatt.

This paper will discuss the theory of junction opening switches and two experiments. In the first experiment we obtained opening from a 3 kA current in 4 ns. In the second experiment we show a successive opening and closing process used to charge and discharge a transmission line. Some applications and limitations of these switches will be described in a companion paper (Ref 2).

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6B8

ON THE UTILIZATION OF LIGHT ACTIVATED JUNCTION SEMICONDUCTORS AS SATURABLE CAPACITORS, THEORY AND APPLICATION IN COMPRESSION LINES.

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In a companion paper (Ref 1), we describe theory and experiments with reverse-biased, light activated junction semiconductors and discuss their characteristics and capabilities as opening switches.

In this paper we discuss the circuit properties of these devices and describe their behavior as saturable capacitors whose characteristic amp-second product is tunable. The complementarity of saturable capacitors to saturable inductors (volt-second devices) allows for unique nonlinear compression (electromagnetic shock) lines to be constructed by the judicious combination of both types of devices. The characteristics of this "doubly" nonlinear line are unique, with characteristics not realizable in transmission lines using either type alone. For instance, the "doubly" nonlinear line operates at a constant average impedance, unlike e.g. saturable inductance lines where the impedance reduces with every stage. We shall discuss how the fundamental limits of the devices affect the parasitic inductances and capacitances and how they in turn affect the compression efficiency. Furthermore, we describe an analytic treatment which establishes an optimum scenario for such compression lines where the influence of the switch characteristics and the number of stages influence the compression efficiency and overall efficiency.

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6B9

Plasmon-Pole Approximation of Hot Carrier Relaxation in Semiconductor Microstructures

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For high carrier densities, the standard single-particle approximation for hot carrier energy relaxation in semiconductors is inadequate due to the pre-