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EXPERIMENTAL TEST OF RESONANT ABSORPTION THEORY

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Abstract

We report some exciting new results on the angular and energy spectrum of resonantly accelerated electrons from a shock front as measured by a miniature β -ray spectrometer. We have devised a multi-channel electron collector based on printed circuit board technology. It has been multiplexed into a fast oscilloscope to provide a complete absolute spectrum on a single laser shot.

Progress Report

The past three months have been very productive for the laser-shock front interaction experiment. The goal of this work has been to measure the absolute energy and angular spectrum of the electrons emitted by resonant acceleration from a shock front. The basic outline of the experiment is shown in Figure 1. A shock front is generated in an electro-thermal shock tube in deuterium gas. The passage of the shock front is synchronized to the arrival of the 500 psec CO_2 laser pulse by means of a HeNe laser schlieren system. The effect of synchronization is demonstrated in Figure 2. A variation of delay is equivalent to a change of focal spot position from in front of to behind the shock front. At exact synchronization the shock front is located at the CO_2 laser focus. Figure 2 shows that this maximizes the fast electron signal monitored on a silicon surface barrier detector. This spatial overlap must be within ± 100 microns to give the optimum enhanced signal.

The experimental chamber was converted into a miniature β -ray spectrometer by placing it within the pole-faces of a small permanent magnet. The result is a magnetic focusing β -ray spectrometer as illustrated in

Figure 1

Figure 2

Figure 3. The stream of electrons from the laser-shock front interaction region is imaged onto X-ray film or a charge collector array to give a spectrum. Since the electron current is rather substantial, ≥ 1 ampere, it was quite convenient to observe the electron signal in real time on a fast oscilloscope. To this end, the charge collector array was fabricated using printed circuit board technology, as shown in Figure 4. The electrodes were etched into the copper surface, and were positioned and shaped to cover different energy bands at the output of the β -ray spectrometer. Each collector had a separate electrical lead which carried the fast electron current. Since the current pulse lasts less than one nanosecond, it is very easy to time multiplex the different channels by employing varying lengths of 50 Ω cable. By feeding the different cables into the same oscilloscope input, the entire electron energy spectrum for a single shot could be recorded in real time on one oscilloscope photograph. This is shown in the lower right-hand corner of Figure 4, where each spike represents the current pulse from one of the energy channels in the collector array. The sensitivity of the different channels was adjusted by varying the areas of the charge collectors in Figure 4.

The result of one such electron energy spectrum is shown in Figure 5. A rather typical two-temperature spectrum is observed, with T_{hot} corresponding to 36 keV. The energy bands of the different collectors are indicated by the heavy black stripes at the bottom of the graph. The high energy channels are intentionally wider to improve the dynamic range. It is puzzling at this time to notice that less than 1% of the laser energy is converted to fast electrons under our present experimental conditions. This will be a subject of continuing study as we proceed with a parametric

Figure 3

Figure 4

Figure 5

study of the spectrum's dependence on density scale height, laser intensity, $\langle Z \rangle$ of the target gas, etc. In addition, we will shortly be extending our capabilities to much shorter CO_2 pulses of only 30 psec duration, employing the high pressure CO_2 amplifier which was recently funded by the National Science Foundation. The results we observe with these ultrashort pulses will be particularly interesting since the plasma motion will tend to be frozen on that time scale.