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INTERACTION OF A TEA-\textit{CO}_2 LASER PULSE WITH A DENSE HYDROGEN PLASMA

C. Richard Neufeld.

\textit{Direction Sciences de base, Institut de Recherches de l'Hydro-Québec, Varennes, Québec, Canada JOL 2PO.}

The physical mechanisms influencing the coupling of energy from intense laser pulses to dense plasmas are of considerable interest for the problem of laser-initiated controlled thermonuclear fusion. Studies of these phenomena in full-scale experiments involve high-speed diagnostic techniques applied to rapidly changing plasma conditions. Interest has consequently been shown in experiments of a modest scale with somewhat relaxed physical constraints in order to simulate certain aspects of the energy coupling problem. Here we describe such a simulation study, in which a dense plasma target, created by a fast Z-pinch discharge, is irradiated by a pulsed \textit{CO}_2 laser.

1. The Plasma Target

The pinch discharge is produced between copper electrodes spaced 25 cm apart in a Pyrex vacuum vessel of 22.2 cm internal diameter. The current is supplied by a low-inductance energy storage bank charged to 23 kV, the oscillating discharge current reaching a maximum amplitude of approximately 500 kA. No preionization was used. The pinch was operated in hydrogen at an initial pressure of 3 Torr, maintained by continuously flushing gas from a pressurized cylinder through the discharge vessel with the aid of a mechanical vacuum pump. High-speed photographs indicate a reproducible first plasma compression (column diameter approximately 25 mm) lasting about 0.5 \mu s. Time-resolved spectroscopic measurements of the discharge were made, as shown on Fig. 1.

![Discharge spectrum](image)

**Fig. 1** Plasma emission spectrum. The dotted line indicates the assumed continuum intensity. The \textit{H}_\beta radiation is crudely approximated by the triangular region superposed on the continuum.

The spectrum is dominated by \textit{H}_\beta radiation (indicated crudely by the triangular region on the figure), the line being strongly Stark-broadened. The width of this line indicates an electron density of \((1 \times 10^{19} \pm 20\%) \text{ cm}^{-3}\), suitable for \textit{CO}_2 laser-solid target simulation experiments.

The observed spectrum is not classical, and its analysis presents some difficulties. However, a self-consistent interpretation of the measurements, including the strong absorption of the \textit{H}_\alpha line (\(\lambda_\alpha = 6563 \text{ Å}\)) and the absence of recognizable \textit{H}_\gamma and \textit{H}_\delta radiation, can be made by recognizing that substantial departures from local thermodynamic equilibrium (LTE) can exist in a plasma undergoing a rapidly-rising degree of ionization. This lack of LTE is not crucial to the electron density deter-
mination, but clearly precludes spectroscopic temperature measurements of the pinch plasma. On the basis of previous work by other authors\textsuperscript{8,9} a kinetic temperature of approximately 10 eV was assumed, a value consistent with elementary pressure balance considerations.

2. The Laser-Plasma Interaction

The plasma target was irradiated transversely by a TERA-CO\textsubscript{2} laser pulse, focussed to give a laser power density (measured in vacuum) of approximately $2 \times 10^{11}$ W cm\textsuperscript{-2}. Visible perturbations of the plasma emission can be observed using high-speed streak photography\textsuperscript{10}. In addition, quantitative measurements were made of the laser radiation backscattered from the plasma column.

A spectrum of the backscattered radiation is shown on Fig. 2. Both a broadening and a shift to longer wavelengths are evident, with essentially no signal present at the incident laser wavelength ($\Delta \lambda = 0$). In addition, the temporal behaviour of the backscattered radiation can be very complex, and often bears no apparent relation to the incident laser pulse. The results indicate that stimulated Brillouin scattering dominates the backscatter process. This interpretation leads to a plasma kinetic temperature in excess of 200 eV during the laser-plasma interaction. At these relatively modest laser power densities only a few per cent of the incident radiation is backscattered. For the higher laser power densities proposed for laser fusion, however, the backscattered fraction may be considerably greater, especially if relatively long (> 1 ms) laser pulses are used\textsuperscript{11}. The plasma target described here can provide a means for checking such a hypothesis experimentally.

References

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