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STUDIES OF PLASMAS PRODUCED BY 12 PS KrF LASER PULSES

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INTRODUCTION

The considerable interest in the interaction of short high power laser pulses with matter and its application is now well established throughout the laser-plasma community. High density, high temperature plasmas are produced which are highly transient without significantly being affected by hydrodynamic motion. Consequently processes such as dense plasma effects, ionization dynamics, thermal electron transport, laser plasma interaction, radiative cooling, can be investigated in a novel regime.

We have recently studied (1-4) some of these processes by irradiating solid and thin layered target with the 12 ps KrF laser system of the CLF.

EXPERIMENTAL ARRANGEMENT

The 12 ps - 268 nm SPRITE laser pulse was focussed onto layered and solid targets using an off-axis diffraction limited paraboloid. Energy losses due to two photon absorption in the transmitting focussing optics were then limited. With the low laser beam divergence and the use of CaF_2 windows, incident laser intensities of up to $3*10^{17}$ Wcm^{-2} obtained in a focal spot 10 μm in diameter. A range of almost three orders of magnitude in intensity could be explored by varying both focal spot size and laser energy.

The characterization of plasma conditions was carried out by means of time resolved X-ray and X-UV spectroscopy with very high temporal resolution. Also, preliminary measurements including visible spectroscopy and calorimetry were performed on the backscattered laser light in order to study the process in the novel short pulse regime.

RESULTS AND DISCUSSION

The electron density and temperature and their temporal evolution was inferred from Stark profiles and line ratios of different ionization stages observed by X-Ray and X-UV time resolved spectra. Electron densities above 10^{23} cm^{-3} were inferred by the Stark broadening of H-like Aluminium lines when solid Al target were irradiated at 10^{17} Wcm^{-2} (see Fig.1). Initial electron temperatures of 1.2 keV were obtained by comparison of experimental line ratios with those predicted by a time dependent Average Atom model coupled to the hydro-code MEDUSA. Indeed, substantially different results were produced when a similar analysis was performed using a steady

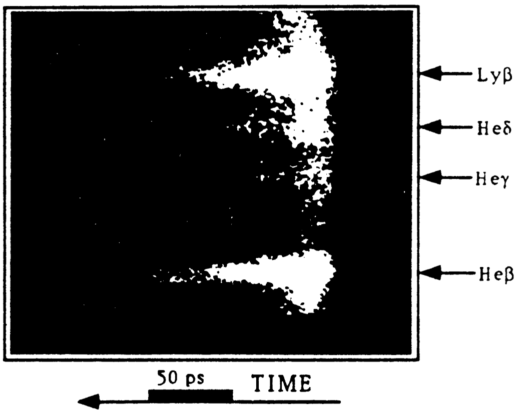

Fig.1 Time resolved X-ray spectrum from irradiation of a solid Al target. The incident laser intensity was 3.0E16 Wcm-2.

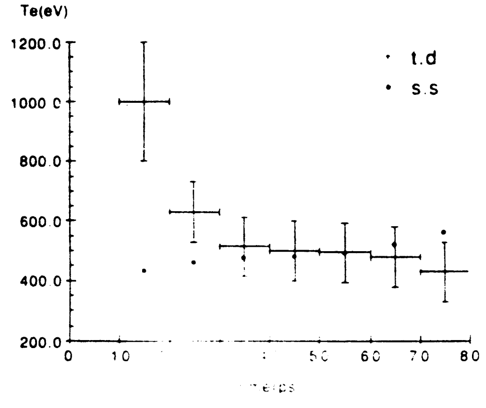

Fig.2 Temporal evolution of electron temperature obtained by a time dependent (t.d.) and a steady state (s. s.) analysis.

state model (RATION) to predict line ratios from plasma conditions (see Fig.2).

The Random Phase Plate technique was employed for the production of high aspect ratio cylindrical aluminium plasmas. The simple introduction of RPP with rectangular elements before the main focussing optics resulted in a fairly uniform line focus (see Fig.3). Time resolved XUV spectroscopy showed that conditions suitable for the study of the H-like recombination X-ray laser were produced.

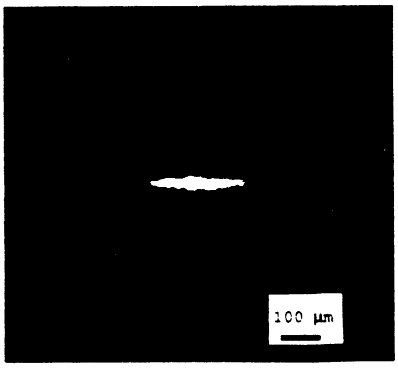

Fig.3 X-ray pin-hole camera image of plasma produced by irradiation of solid Al target with line focus generated by the Random Phase Plate Array. The average laser intensity was 2.0E14 Wcm-2.

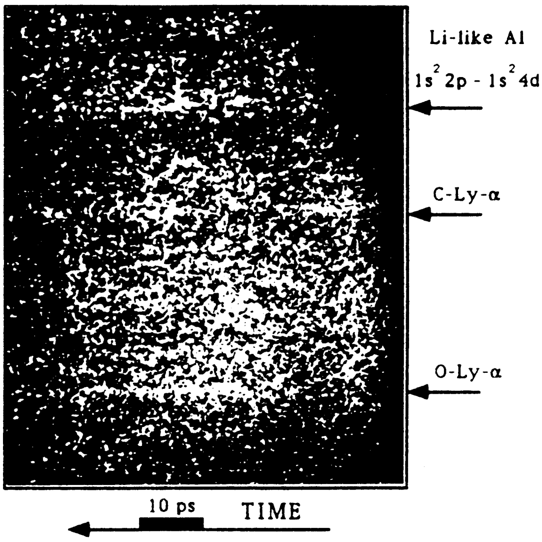

Fig.4 Time resolved X-UV spectrum from irradiation of a layered target (0.1µm CH-0.2µm Al-Mylar). The laser intensity incident on the CH layer was 3.0E16 Wcm-2

A better understanding of basic plasma parameters can be achieved if X-ray and X-UV emission can be resolved during the laser pulse. The use of a new ultra-fast X-ray camera with a 1 ps temporal resolution coupled to an X-UV flat-field spectrometer resulted in the first time resolved X-UV spectra within the laser pulselength. Fig.4 shows a typical spectrum of the X-UV radiation produced when a multi-layer target (CH-Al-Mylar) was irradiated at an incident laser irradiance of 10^{16} Wcm^{-2}. The propagation of the heat front can be monitored as line emission from the different layers of the target and their relative delays are detected. A comparison with the predictions of numerical simulation (MEDUSA) can give information on the parameters involved in the modelling including, for example, the flux limiter. Although a detailed absorption measurement is not yet available, valuable information concerning the coupling of laser radiation with plasma can be gained by the analysis of the backscattered laser light from solid targets. Reflectivities between 5 and 30% of the incident laser light were measured when the irradiance ranged from $2*10^{14}$ to $8*10^{16}$ Wcm^{-2} giving an indication of a poor laser-plasma coupling in the high intensity regime.

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