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The front cover shows the view through the Titania laser cell into the multiplexing area.

The back cover shows part of the Titania pulsed power area in R2.

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SHORT PULSE PROPAGATION THROUGH PREFORMED PLASMAS

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INTRODUCTION

The study of the interaction of intense laser pulses with long scalelength plasmas is of crucial importance for laser-driven Inertial Confinement Fusion (ICF). In fact, the conditions of laser-plasma coupling in the expanding underdense *corona* surrounding the ICF capsule are critical in order to determine, for example, the level of energy absorption, the uniformity of energy deposition and the possible generation of fast electrons leading to undesirable target preheating.

Thanks to the recent developments in laser technology, the generation of ultrashort (<1 ps), high-intensity (>10^{17} Wcm^{-2}) laser pulses is nowadays possible. In this regime the oscillating electric field can be comparable with the atomic field, and the electron *quiver* velocity can approach relativistic values; the ponderomotive pressure can be on the order of Gbars. On the other hand the laser pulse duration becomes comparable to the time scale of atomic and plasma processes. The study of laser-plasma interactions in this regime is of great physical interest since the dynamics is typically nonlinear and can lead to a number of new light-induced phenomena [1]. Moreover the propagation of an ultrashort pulse is of crucial interest for a number of scientific applications including the new *fast ignitor* scheme for ICF [2], which is presently being investigated in a number of experiments world-wide.

Our experiment was devoted to the study of the propagation of a short laser pulse with an intensity between 10^{16} and 10^{17} W cm^{-2} through a long-scalelength underdense ($n_e<n_c/10$), hot ($T_e>500$ eV) plasma, preformed by irradiation of a thin dot target by opposite pairs of laser beams. The experimental geometry was essentially the same of a previous experiment in which the preformed plasma was accurately characterized and found very suitable as a test bed for the study of coronal interactions [3]. Significant progresses in the chraracterisation of the preformed plasma were achieved in the reported experiment thanks to the use of a ps pulse probe and are described elsewhere in this Report [4].

In the conditions of the experiment, collisional absorption of laser light was virtually suppressed due to the high intensity of the laser pulse. However, the short pulse energy could be absorbed through residual ionization processes in the Al plasma.

In this paper we show and briefly discuss preliminary experimental results concerning the propagation of the short pulse in the plasma.

SET-UP

The experiment was performed in the Target Area East of the Central Laser Facility. The target consisted of a thin (0.4 μm) Al dot with a 0.8 mm diameter, coated on a thin plastic substrate or held by four arms in the shape of a X. Four 600 ps, 1 μm wavelength beams from the VULCAN laser were focused on the target at oblique incidence in opposite pairs to preform the plasma. The heating irradiance on each target side was kept below 10^{14} W cm^{-2}. A detailed description of the production technique and of the diagnostics used for characterising the plasma is presented in [3,4].

The short interaction pulse (1 ps duration and energy up to 10 J) was generated with the CPA technique. A minor portion of the pulse was split, frequency doubled and used as an optical probe for interferometric measurements of the plasma density. The interferometric technique is described in detail elsewhere in this Report [4]. The interaction pulse was focused with either a *f*/15 or a *f*/7.5 optics in a spot smaller than the plasma cross section, in order to avoid refraction effects at the plasma boundary. The short pulse interacted with the preformed plasmas 2-2.5 ns after the peak of the heating beams.

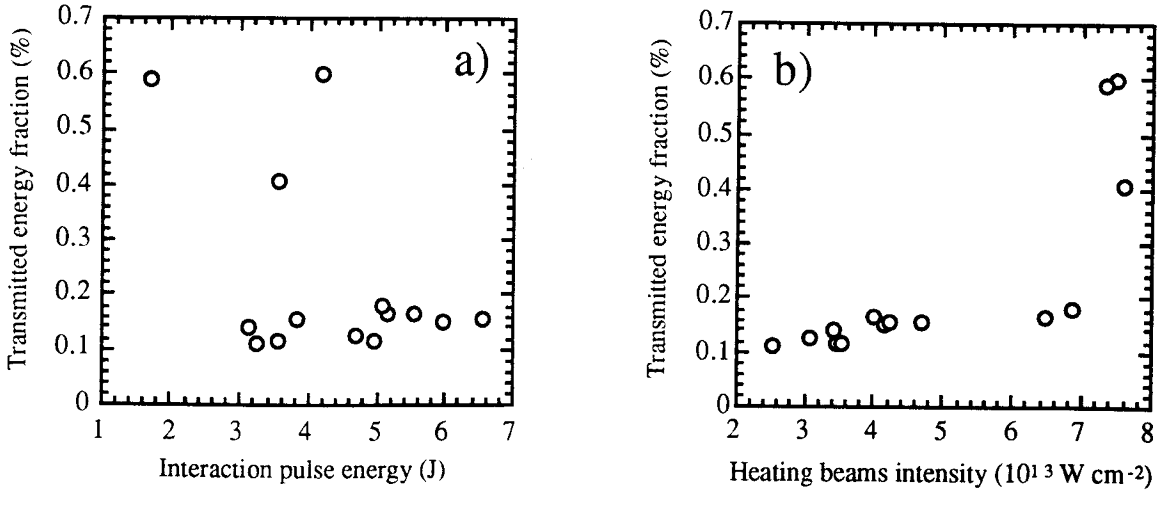

Fig. 1: transmitted energy fraction of the short interaction pulse vs. a) interaction pulse energy and b) heating beams energy.

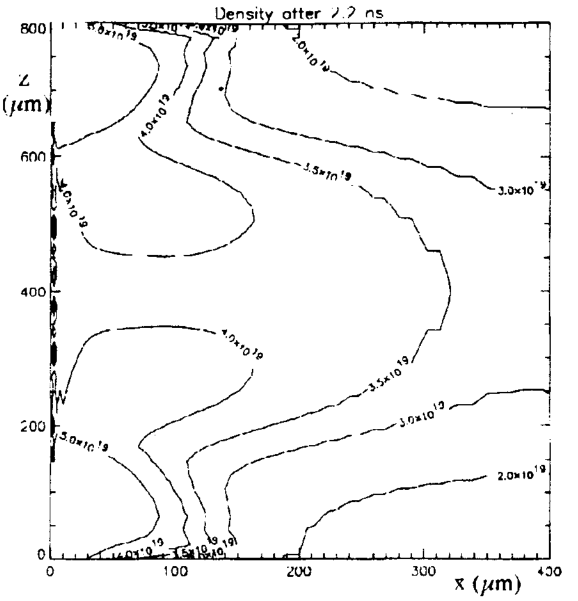

Fig. 2: POLLUX 2-D simulation of the plasma electron density at times corresponding to the short pulse interaction. The original target position is at x=0, y=400. The heating intensity is 8•10^{13} Wcm^{-2}.

investigated via calorimetry and beam cross-section imaging of the fraction of the pulse transmitted through the plasma. Density perturbations induced in the plasma by the short pulse were studied by delaying the interferometric probe pulse in order to obtain density maps of the plasma at various instants after the interaction.

STUDY OF SHORT PULSE TRANSMISSION

The characterization of the preformed plasma is described in detail in refs. [3,4]. Here we only discuss results relative to the short pulse propagation.

The energy of the short interaction pulse transmitted through the preformed plasma was monitored using a calorimeter. The background contribution due to plasma self-emission and scattered heating radiation was measured in shots in which only the heating beams were focused on target.

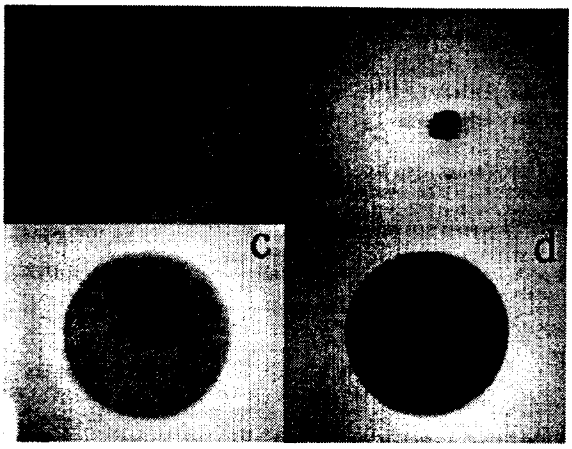

Fig. 3: cross-section images of the short pulse interaction beam a) before interaction: b) after propagation in absence of the plasma; c,d) after propagation in the plasma for two different values of the heating beams intensity (see text).

The transmitted energy fraction of the short interaction pulse was studied as a function of both interaction and heating intensity. The results are shown in fig. 1. It can be noticed that in the investigated intensity range the short pulse transmission through the plasma is substantially not related to the energy of the short pulse itself, while it depends from the heating intensity through a sort of threshold mechanism. In other words, the hydrodynamic evolution of the preformed plasma appears to play an essential role in determining the conditions of the propagation process.

For heating intensities above 7•10^{13} Wcm^{-2} the density and temperature distribution of the plasma 2 ns after the plasma production seems to be favourable for efficient propagation of the interaction pulse. 2-D hydrodynamic simulations performed using the POLLUX code [5] predicted, for an heating intensity of 8•10^{13} Wcm^{-2}, the onset of a density depression along the symmetry axis approximately 2 ns after the plasma production (see fig. 2). This suggests that the short pulse propagates with low losses provided a (even weak) density minimum is set along the propagation axis. The influence of the preformed plasma conditions on the short pulse propagation can also be inferred from the cross-section images of the transmitted interaction beam. Fig. 3a shows the beam cross-section before the interaction chamber. The rectangular shape is due to the cut-off from the CPA gratings.

Fig. 4: interferogram of the plasma 300 ps after the interaction with the short pulse. The horizontal arrow shows the short pulse interaction axis. The vertical arrows show the original target position.

Fig. 3b shows the beam intensity profile after propagation in the chamber in absence of the target. Finally, Fig. 3c and 3d show the beam cross section images after propagation through the preformed plasmas at heating irradiances of 5•10^{13} Wcm^{-2} and 8•10^{13} Wcm^{-2} respectively.

The background light is due to plasma self-emission and scattered light from the heating beams. From the comparison of the two latter images we see that, when the heating irradiance was higher, the short pulse was sensibly less refracted by the plasma.

DENSITY MAPPING AFTER SHORT PULSE PROPAGATION

As mentioned above, 2-D density maps of the preformed plasma before the interaction with the short pulse were reconstructed from the fringe intensity pattern of the interferograms. Due to the high interferometer sensitivity [3] even weak, small-scale density perturbations, as those induced by the short pulse propagation through the plasma, could be detected from the fringe displacement.

Fig. 4 shows an interferogram taken 300 ps after the interaction of the CPA pulse with the plasma. From this interferogram a density perturbation of about 1/10 of the local electron density was evidenced along the short pulse propagation axis. This density perturbation was likely due to ionization induced by the short pulse.

Since the light collected by the detector was spectrally filtered around 0.527 μm, the picture in fig. 4 is also an image in 2nd harmonic light (time-integrated) of the plasma. The dark features are due to 2nd harmonic produced both by the heating and the interaction pulses, and their analysis is also expected to give interesting information on the physics of the interaction.

CONCLUSION

We studied the propagation of a 700 fs laser pulse in a plasma preformed by irradiation of thin foil targets. The propagation of the pulse appeared to be strongly affected by the preformed plasma conditions, while in the investigated range seemed to be independent from the energy of the pulse itself. The short pulse energy fraction transmitted through the plasma was sensibly higher for heating energies above the threshold value 8 1013 W/cm2. Cross section imaging also showed that above this threshold refraction effects became less severe.

Density perturbations induced by the short pulse propagation were detected via interferometry.

The analysis of the experimental data is however still in progress.

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