Group: Physics

SILASI

European TMR-Network on
Superintense Laser Pulse-Solid Interaction

No. ERBFMRX-CT96-0043

http://www.physik.tu-darmstadt.de/tqe/silasi/

First Annual Report
June 1st, 1996 – May 31st, 1997

including

the Annual Progress Report,
a printed version of the updated Database Report,
the Annual Statistical Summary,
and a Collection of Scientific Letters

Observation of Solid Density Laminar Plasma Transparency to Intense 30 Femtosecond Laser Pulses

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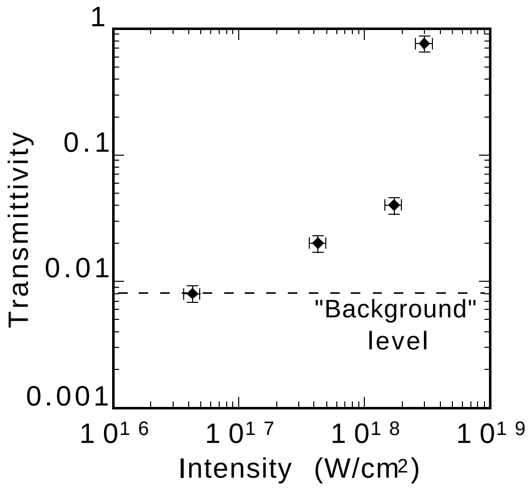
Near total transmission of 30 fs laser pulses through 0.1μm plastic foil targets has been observed for the first time at an intensity of 3×10^{18} W/cm^2, in absence of precursor plasma. This level of transmittivity is by far above the level predicted by current theoretical models or numerical simulations. The transmittivity was found to drop by 40 times at an intensity of 4×10^{17} W/cm^2 and was within the experimental background level at 5×10^{16} W/cm^2.

In the experiment the LOA 815 nm, 30 fs laser pulse was focused f/7.5 onto a 0.1μm thick plastic foil target, using an off-axis parabolic mirror, with an angle of incidence on target of 20 degrees. The laser pulse was linearly polarized with the electric field in the plane of incidence (*P*- polarized). The focal spot was 10μm in diameter; the intensity was varied between 5×10^{16} W/cm^2 and 3×10^{18} W/cm^2, by varying the energy in the pulse. The transmitted pulse was studied by using a diffusing screen placed beyond the target, on the laser propagation direction, at a distance 1.8 times the focal length of the focusing optics. A demagnified image of the screen was formed onto a CCD array and on the entrance slit of a spectrometer. A second CCD array was placed on the output focal plane of the spectrometer. The laser system was characterized by an ASE *pedestal* lasting approximately 10 ns. The measured contrast ratio was better than 10^7. A severe test on the effect of the ASE on target was performed by firing the laser system, but without injecting the fs pulse in the amplifier chain. In this condition, we observed no damage on target over the whole range of ASE intensities. This test is a proof "a fortiori" that in real shots the target does not explode before the arrival of the femtosecond pulse, for two distinct reasons. Firstly, since no energy is spent in the amplification of the fs pulse, the level of ASE is greater than in the case of operation with fs pulse injection. Secondly, only the leading part of the ASE pulse prior to the arrival of the main fs pulse is relevant in determining the interaction conditions of the main pulse.

Within the explored range of intensity of the main 30 fs pulse, an ultrafast ionisation [1] of the target material (FORMVAR: $C_5H_{11}O_2$) is expected to occur. In this sense, even though direct electron density measurements have not been carried out, we are led to the conclusion that the results presented here refer to interaction with a solid-density $\approx5\times10^{23}$ cm^{-3} laminar plasma. The dependence of transmittivity on the incident laser intensity is presented in the plot. Transmittivity was obtained by the ratio between the laser energy transmitted when interaction occurs and the laser energy propagated



Plot of transmittivity vs. intensity of the 30 fs laser pulse incident on 0.1 μm thick plastic target. The background level indicates the level at which the energy in the pedestal (ASE) is comparable with the transmitted energy.

freely without target. According to the plot, the transmitted fraction at incident intensities below 10^{17} W/cm^2 is within the experimental background level. the transmitted fraction increases dramatically with intensity and the target becomes basically transparent at 3×10^{18} W/cm^2.

In conclusion we observed the propagation of intense 30 fs laser pulses through 0.1μm plastic targets. The measured transmittivity for laser intensity greater than 10^{17} W/cm^2 is orders of magnitude higher than the transmittivity predicted by current models. In particular, when the intensity was 3×10^{18} W/cm^2, i.e. only weakly relativistic ($a_o \approx 1.2$), we observed almost complete transparency. This observation opens a completely new area of investigation, very promising for applications like the fast ignitor scheme, and challenging for theoretical plasma physics.

This work has been supported by the European Commission through the TMR Network SILASI (SuperIntense LAser-Solid Interaction) No.ERBFMRX-CT96- 0043.

[1] A. Giulietti *et al. Spectroscopic Evidence of Ultrafast Ionisation of Solids by .intense 30 fs laser pulses*
This Report.

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