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Spectroscopic Evidence of Ultrafast Ionisation of Solids by 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. The experimental conditions are reported in another paper [1] of this Report. The spectral data reproduced sidewards show that the interaction process results in a blue shift at moderate and intermediate intensities, while producing no shift at high intensity. In this latter case the bandwidth is also left unchanged by the interaction. The spectral properties of the transmitted pulse were found to be stable from shot to shot, except at intermediate intensity (4×10^{17} W/cm^2) were shot to shot variations in shifs and width were observed.

At the lower and intermediate intensity the blue shift in the spectrum of the transmitted pulse is a clear signature of ultrafast ionisation. This is well supported also by the amount of the blue shift, which is about 13 nm at 5×10^{16} W/cm^2, and about 20 nm at 4×10^{17} W/cm^2. Let us attribute the shift to self-phase modulation of the laser pulse, namely to the ultrafast decrease of the refraction index due to the laser induced ionisation. Considering a change $\Delta\mu\approx-1$ in the refraction index, due to the transition from zero electron density to the critical density, we can evaluate the time scale Δt of such a transition from

$$\delta\omega \approx -(L/c)(\Delta\mu/\Delta t)\omega_0$$

Taking the interaction path equal to the foil thickness L=0.1 μm, we find $\Delta t\approx20$ fs and $\Delta t\approx13$ fs for the low and intermadiate intensity, respectively. The definite consistency of these values, confirms that an ultrafast ionisation actually occurs. The absence of shift in condition close to the full transparency, namely at 3×10^{18} W/cm^2, suggests that in this case the ionisation involves a negligible portion of the pulse, while the spectral variability observed at intermediate intensity may be due to the proximity of a sort of threshold for the effect leading to the transparency.

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[1] D. Giulietti *et al*. *Observation of solid density laminar plasma transparency to intense 30 fs laser pulses* This Report.

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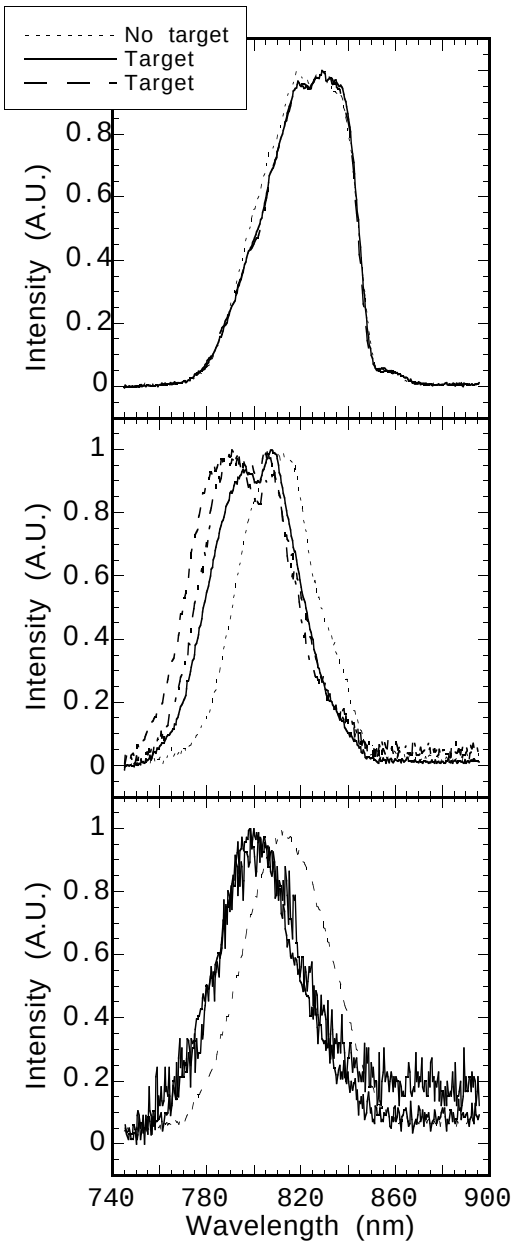

Space resolved spectra of the transmitted pulse at three different intensities on target, 3×10^{18} W/cm^2 (upper), 4×10^{17}W/cm^2 (middle) and 5×10^{16} W/cm^2 (lower). The unperturbed laser spectrum (dotted line) obtained without the target at each laser intensity is also plotted for comparison.