Group: Physics

# SILASI

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# Experimental and theoretical studies on ultrafast ionisation and related effects

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The recent advances in high-power lasers capable of delivering up to a few joules in tens of femtoseconds have made possible the ionisation of a small portion of matter (≈$10^{-6}$cm$^3$) in a fraction of a laser cycle. In these conditions the laser pulse faces a discontinuity in time in addition to the discontinuity in space. While a space discontinuity (for example when a laser pulse is focused from the vacuum on a plasma boundary) keeps the frequency fixed, but allows for a change in wavevector

$$k = k_0\sqrt{1-\frac{\omega_p^2}{\omega^2}} \quad ,$$

a temporal discontinuity, on the contrary, produces an upshift of the laser frequency

$$\omega_f = \sqrt{k_0^2 c^2 + \omega_p^2}$$

at constant wave vector. It is also predicted that a fraction of the original wave energy remains in the plasma as a steady-state magnetic field (S.C. Wilks et al. Phys.Rev.Lett., **61**, 3134, 1988). The consequences of this physical phenomenon are relevant to the propagation of super-intense laser pulses in overdense plasmas. The IFAM-Pisa group of SILASI has been developing an experimental programme on this topic, with the technique of femtosecond laser irradiation of very thin dielectric foils. This experimental technique has already given important results (SILASI Report 1997; D. Giulietti et al. Phys.Rev.Lett., **79**, 3134, 1997; A. Giulietti et al, this Report, 1998).

Our theoretical studies are mostly devoted to address the problem of propagation of a powerful femtosecond laser pulse through an overdense plasma slab. We study different well known scenarios, including normal and anomalous skin effect, self induced transparency, and hole-boring which can induce an enhancement of the transmittivity in an overdense plasma slab. All these models, however, do not take into account the ultrafast volume ionisation of the target during typically one optical cycle, which can induce a transverse stationary magnetic field. To this respect, we analyse the relativistic motion of a single electron in a vacuum. In this case the electron interacts with a linearly polarised femtosecond laser pulse in the presence of static magnetic field parallel to the oscillating magnetic field of the e.m. wave. Then we solve numerically the relativistic motion of the electron in a magnetised plasma when the laser light propagates as an extraordinary mode. The preliminary results of these studies suggest new physical mechanisms that can induce transparency of highly overdense plasmas.