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Spatial Filtering of Intense 30 Femtosecond Laser Pulses by Thin Foil Plasmas

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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 [1] at an intensity of 3×10^{18} W/cm^2, in absence of precursor plasma. Cross-section images of the trasmitted light show that the thin foil target act as a "spatial filter" for the short pulse.

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.

The diffusing screen also gave information on the intensity distribution in the near field beyond the focus. A typical example of such data is shown in Fig (a) and (b), where the cross section of the transmitted pulse (b) at the intensity on target of 3×10^{18} W/cm^2 is compared with that taken without the target (a) at the same intensity. The three perpendicular lines visible on the images are spatial calibration markers placed on the diffusing screen. A preliminary survey of these results shows that the pulse transmitted through the foil does not suffer major changes. The angular spread appears slightly reduced after interaction with respect to the free propagation while the transmitted intensity pattern is elongated in the horizontal direction .

Very interesting is the comparative spatial Fourier analysis of these patterns with and without the target. The square root of the intensity distribution of the images taken by the diffusing screen, i.e. a quantity proportional to the electric field in the near field, was Fourier transformed using a 2-dimensional FFT algorithm. The square of the modulus of the Fourier transform distribution is then calculated: within the paraxial approximation, and with appropriate assumptions on the phase, we obtain the intensity distribution of the laser light in the far field, i.e. on target. The calculation has been performed for both patterns (a) and (b) and the logarithm of the results are shown in Fig. (c) and (d). The intensity distributions in the near field of the transmitted pulses without and with the target were normalized to the corresponding average transmitted intensities, i.e., 1 and 0.76, in order to allow a direct quantitative comparison of the results.

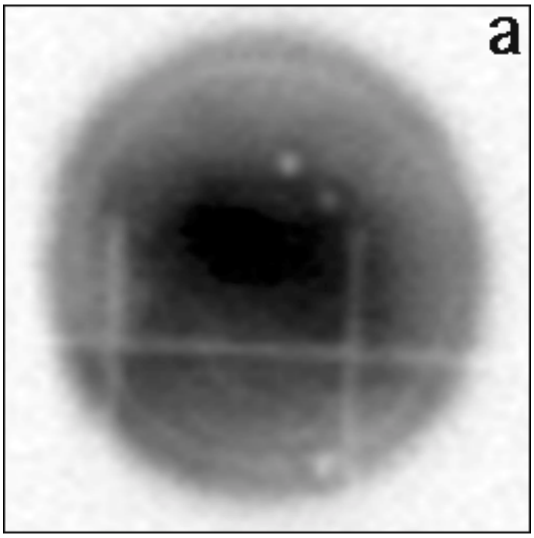

Fig.(a): near-field image of the transmitted pulse without the target, at the intensity of 3×10^{18} W/cm^2 at focus

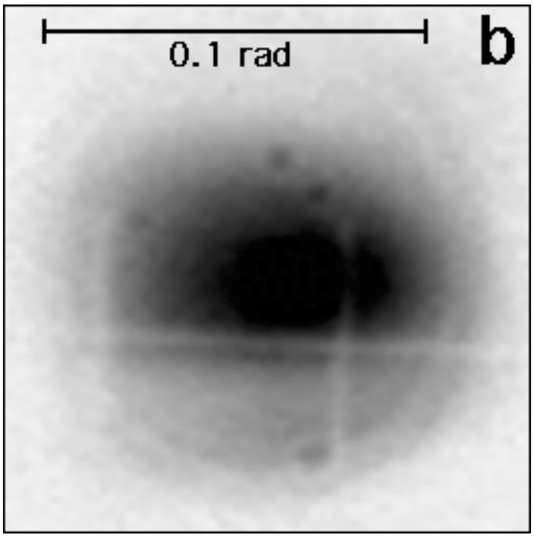

Fig.(b): near-field image of the pulse transmitted through the target, at the same intensity of fig.(a)

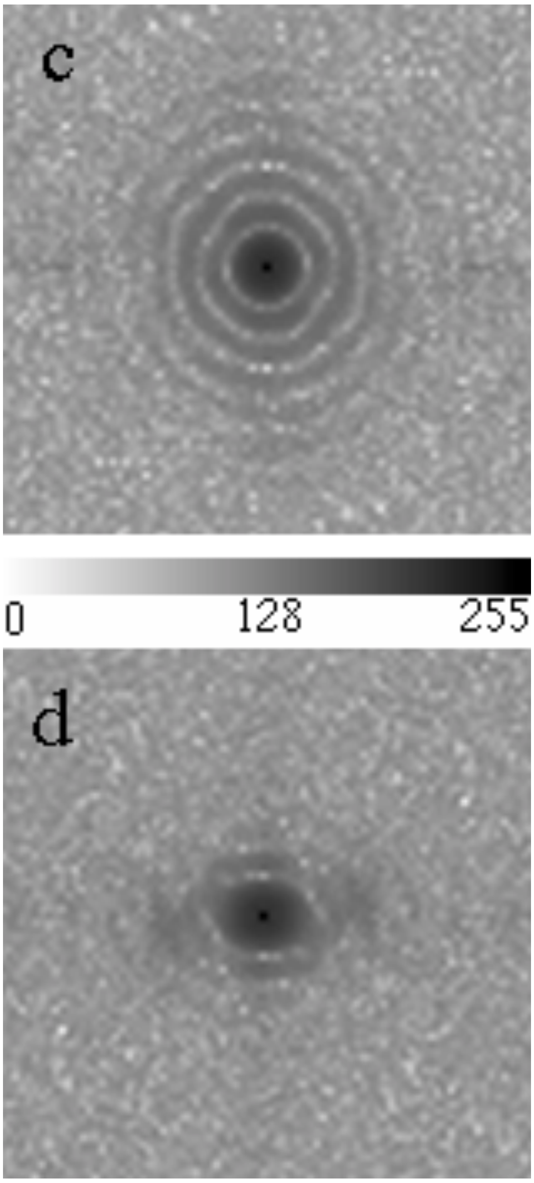

Fig. (c) and (d): far-field intensity distributions obtained via spatial Fourier analysis of the patterns in fig.(a) and (b), respectively.

Some high frequency spatial modes are present in the far field image (c) obtained from the near field image (a) of the free propagating pulse. The modulations (rings) are likely to be due to a sharp radial cut in the amplification and compression chain of the laser system.The far field image of (d), obtained from the near field image (b) taken when interaction with the target occurred, shows that those high spatial frequency modes are basically suppressed by the interaction with the target. In other words, the interaction acts as a spatial filter for the high intensity ultra-short laser pulse.

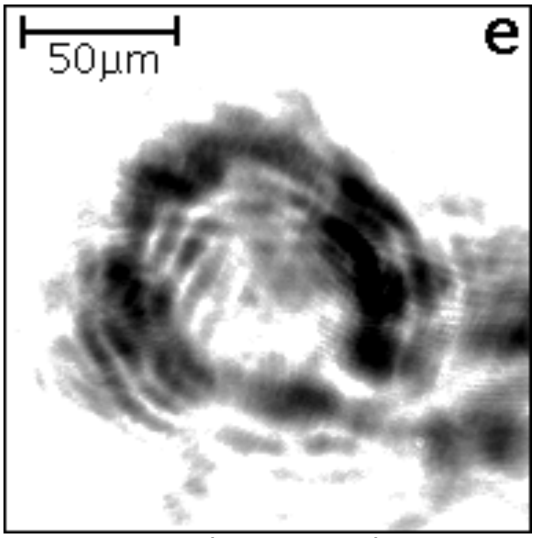

Fig. (e) Image of the target in reflected light.

Further evidence of this observation is given by the images taken on the reflection channel. The image of Fig. (e) shows a CCD image of the reflecting region of the target, that is also the far field of the pulse. It shows that reflection occurs mainly from a region of the target well outside the main spot (≈10µm diameter) and the reflected pattern has a ring-like shape. By comparing each other he Fourier trasform patterns (c) and (d), we can reasonably conclude that the pattern of Fig. (e) is generated by the outer rings in the far field pattern of the incident pulse (filtered out from the transmitted pulse) that is specularly reflected by the target surface.

In conclusion, he effect of spatial filtering by the solid density laminar plasmas we have observed in condition of almost full transparency may have also very useful application to the ultrashort high power laser pulse technology.

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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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