BURST-MODE HIGH POWER FEMTOSECOND LASER PROPAGATION THROUGH THE ATMOSPHERE

Catergory: Laser Applications and Optical Instrumentation Systems

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Abstract

We describe the first demonstration of self-channeling in the atmosphere by bursts of high power femtosecond laser pulses. We study the long distance energy propagation and ablation of solid targets by the self-channeled beam.

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Summary

It is now well-known that high-intensity ultra-short laser pulses propagate through the atmosphere in a fundamentally different way to high power continuous and conventional laser pulses. Laser beams from the latter diverge according to the classical laws of optics and are affected by atmospheric turbulence and optical scattering sites just as is normal light. The propagation of high intensity femtosecond laser pulses through the atmosphere is dominated by the quasi-equilibrium of two competing processes. Self-focusing in air due to the contribution of the nonlinear index of refraction n_2 produces a positive contribution to the refractive index $n = n_0 + n_2 I$, while weak ionization of the air by the self-focusing beam induces multi-photon ionization liberating free electrons that gives a compensating negative contribution to the total refractive index. A quasi-dynamic equilibrium sets in, and a filament, or stable self-channeling of the laser beam occurs[1,2]. Theoretical models of this mechanisms[3-5] are now being verified by experimental characterization[6]. This phenomena if efficient, has wide implications for many future applications of femtosecond lasers for defense, communications and remote sensing. The latter has already been demonstrated in a number of studies[7]. The process could also have a major impact on the transmission of powerful laser pulses over long distances. The implications for ablating material, or disturbing the integrity or environment of material structures at a distance could be profound.

We are making propagation and ablation measurements of 100 fs, 850nm, laser pulses with energies in the 1-250 mJ range over distances of ~ 30 m and greater. Over these distances we observe greater than 50% transmission of the pulse energy through the channel. We are examining the ablation of different materials by the self-channeled beam. Fig.1(a), shows the ablation spot produced on Silicon by a 12 mJ single 100 fs pulse propagated through a 30 m channel. The estimated beam energy density in the center of the self-channeled beam is in excess of 15 J/cm^2 with intensities of ~ 2 x 10^{14} W/cm^2.

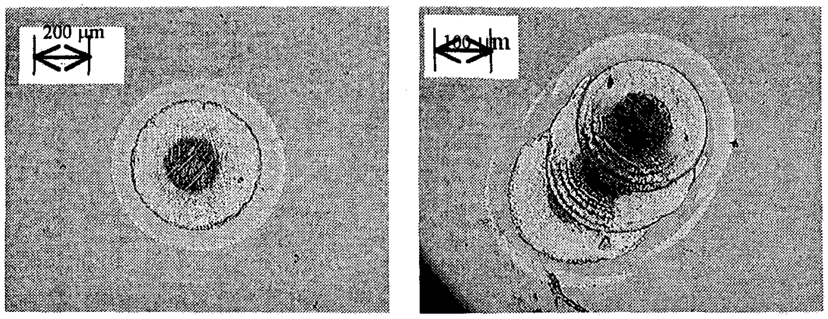

Fig.1. Single pulse ablation of Si produced at 30 m by a self-channeled beam (a) for a single 12.5 mJ 100 fs laser pulse, and (b) by a train of three pulses, separated by 10 ns, total energy 36.5 mJ

We are also examining the propagation and ablation of bursts of 1-10 femtosecond pulses separated by variable times, and with variable intensities. Fig.1.(b), shows the ablation produced on Si by a single burst of three pulses, separated by 10 ns with a total energy of 35 mJ. The separate ablation regions demonstrate that each pulse produces its own channel within the 10 ns inter-pulse time. Effects of subsequent pulses on the superheated region in the center of the beam can be observed in the rippled region of the ablated distribution.

We will describe a comprehensive study of the propagation of burst-mode femtosecond laser pulses through the atmosphere, and some studies, including time-resolved studies, of the ablation of various materials at different distances along the self-created laser channel. The parameters of the burst mode will be varied widely, and its effect on the channeling and ablation described.

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