

Self-guiding of 100 TW Femtosecond Laser Pulses in Centimeter-scale Underdense Plasma

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In regime of “relativistic engineering”, propagation of ultra-high intensity ($> 10^{18}$ W/cm²) laser beams in plasmas has recently received much attention with regard to potential applications such as laser-based accelerators, x-ray lasers and “fast-ignition” of compressed Inertial Confinement Fusion. For all of these applications, it is necessary that a high intensity beam can be propagated controllably over long distances. For example, laser driven plasma wakefield accelerators have demonstrated high accelerating gradients of up to several hundred GV/m, making them attractive as next generation sources of particles and radiation. The generation of relativistic electrons in this femtosecond (10^{-15} second) pulse regime was found to be dependent on the nature of laser propagation: the ponderomotive pressure of an intense laser pulse is used to drive a density oscillation waked in a plasma, the longitudinal field of which accelerates particles. Recent experiments have produced beams of narrow energy spread by extending the distance of propagation using a guiding channel. Therefore, it is crucial to find a way to guiding laser channel for long distance.

First experiment based on 100 TW femtosecond (Ti:Sapphire) laser was performed in collaborate with Laser Fusion Research Center, China Academy of Engineering Physics on SILEX-I laser facility. Experiments for laser self-focusing have been carried out with 30 fs laser pulse into a long slit (1.2×10 mm²) gas plasma. Extremely long self-guided plasma channel with length ~ 10 mm is formed, that is longer than 20 times the laser diffraction length in vacuum. This is the **longest** self-guided plasma channel stimulated by a single laser pulse incident into gas plasmas until now. Undoubtedly the majority of the laser energy has been self-focused and transmitted to long distance. Channel anisotropic characteristics such as laser hopping (focusing and defocusing periodically), plasma hosing, bending and cavity formation are demonstrated experimentally. Plasma density and laser power are key factors for this long channel formation under irradiation by femtosecond laser pulses.

In case of long self-guiding, formation of plasma “bubble” is demonstrated experimentally for the first time which trapping electrons inside, compressing their energy distribution and accelerating them to monoenergetic bunch. Accelerated electron bunch is tightly collimated with low emittance $< 0.8 \pi$ mm mrad and with electron charge current up to ~ 10 nC/shot.

