Laser guiding at > 10^{18} W/cm^2 in plasma channels formed by the ignitor heater method

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Abstract: Experiments explore guiding of intense laser pulses, optimization using channel formation beams and gas jet targets, and the interplay of channel guiding and relativistic self guiding. Impact on laser wakefield particle acceleration is being assessed.

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Laser wakefield accelerators in the self guided regime and in pre-formed channels are studied at LBNL's L'OASIS facility (10TW, 2E19W/cm^2, 800nm) with the goal of a compact 0.1-1GeV accelerator module. In laser wakefield acceleration, the pondermotive pressure of an intense laser pulse ejects electrons, and a strong plasma wave 'wake' follows the laser pulse [1]. Recent experiments have shown acceleration of electrons by laser wake fields in plasmas to 30 or more MeV over mm scale distances, corresponding to gradients of 30GeV/m [2].

Simulations indicate guiding the laser pulse with a plasma channel can substantially increase particle energy and reduce energy spread by increasing length over which the laser remains intense [3]. We have used channels formed by hydrodynamic shock to guide acceleration relevant intensities of 10^{18}W/cm^2 in initial experiments.

To guide the intensities required for wakefield acceleration, 10^{18}-10^{19}W/cm^2, we use fully ionized low Z plasmas produced in a gas jet to avoid further ionization by the guided pulse which would destroy the guide. The plasma is ionized by a high intensity (>5E14 W/cm^2) 'ignitor' beam coaxial with the guided beam, then heated by inverse bremsstrahlung using a 300mJ cylindrically focused beam at 10^{13}W/cm^2 incident from the side (Fig. 1a) [4]. The resulting plasma expands, forming a shock wave that produces a density minimum on axis which can guide the pulse. The channel structure is analyzed by an interferometer (Fig. 1b). The guided beam mode, energy, and spectra are measured by a CCD and spectrometer. The electron beam produced is characterized by a charge transformer (ICT), radiation detectors, magnetic spectrometer, and phosphor screen.

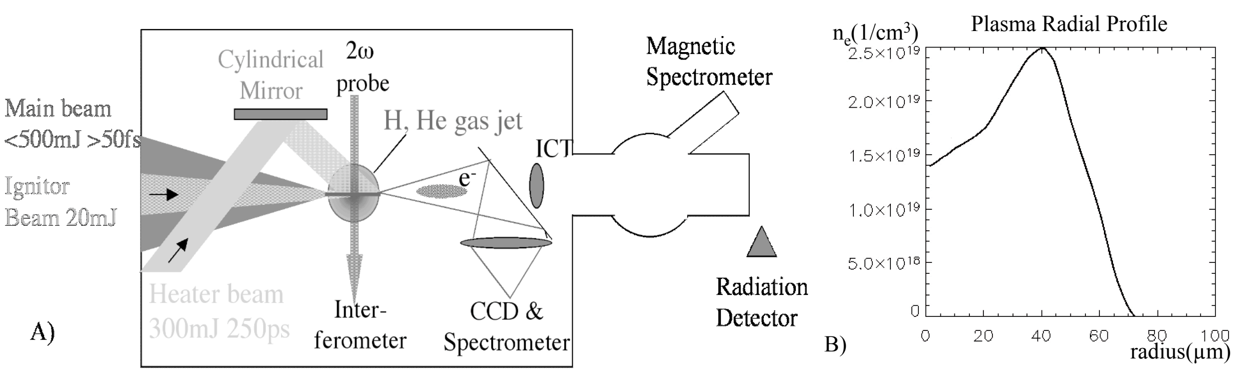

Fig. 1. a) Schematic of the experiment, indicating beams and diagnostics. b) structure of the channel from the interferometer showing guiding profile.

Fig. 2 shows the input mode and the mode at the end of the plasma for a case where the input beam is 5TW, 50fs, and 5E19W/cm2. With the gas jet on and the channel off, the beam is diffracted more quickly than in vacuum by ionization induced refraction due to a plasma density peaked on axis. This is true even though P>Pc~1TW for self guiding in this case, indicating that self guiding does not transport the pulse efficiently over this length. By contrast, when the guide is on, more than one third of the energy is transported in a well confined spot with a size near the original spot size. Intensities as high as 10^{18}W/cm^2 have been transported, and further optimization of the guide using the timing and modes of the production beams as well as the profile of the gas jet profile is under way to further increase guided intensity. Current experiments are characterizing the effect of guiding on the electron beam produced.

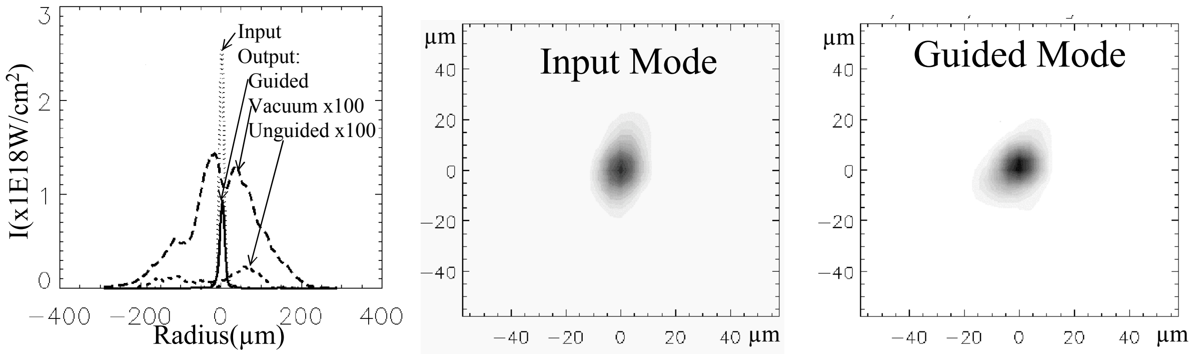

Fig. 2. The output mode of the guided beam, showing enhanced transmission with the guide on (unguided modes multiplied by 100 to appear on the same scale). The guided and input modes (right, normalized scale) are similar.

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