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Laser Wakefield Structures and Electron Acceleration in Gas Jet and Capillary Discharge Plasmas[1]

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Laser-driven plasma wakefield accelerators have the potential to become the next generation of particle accelerators because of the very high acceleration gradients. The beam quality from such accelerators depends critically on the details plasma wave spatial structures. In experiments at the University of Michigan it was possible in a single shot by frequency domain holography (FDH) to visualize individual plasma waves produced by the 40 TW, 30 fs Hercules laser focused to the intensity of 10^{19} W/cm^2 onto a supersonic He gas jet [1]. These holographic "snapshots" capture the evolution of multiple wake periods, and resolve wavefront curvature seen previously only in simulations. High-energy quasi-monoenergetic electron beams for plasma density in the specific range $1.5\times10^{19} \leq n_e \leq 3.5\times10^{19}$ cm^{-3}were generated [2]. The experiments show that the energy, charge, divergence and pointing stability of the beam can be controlled by changing n_e, and that higher electron energies and more stable beams are produced for lower densities. An optimized quasi-monoenergetic beam of over 300 MeV and 10 mrad angular divergence is demonstrated at a plasma density of $n_e=1.5\times10^{19}$ cm^{-3}. The resulted relativistic electron beams have been used to perform gamma-neutron activation of ^{12}C and ^{63}Cu and photo-fission of ^{238}U with a record high reaction yields of ~5x10^5/Joule [3]. Experiments performed with ablative capillary discharge plasma demonstrate stable guiding for laser power up to 10 TW with the transmission of 50% and guided intensity of ~10^{17} W/cm^2. Study of the staged electron acceleration have been performed which uses ablated plasma in front of the capillary to inject electrons into the wakefield structures.

[1] N. H. Matlis et. al., Nature Physics **2,** 749 (2006).
[2] A. Maksimchuk et. al., Journal de Physique IV **133**, 1123 (2006).
[3] S. A. Reed et. al., Appl. Phys. Lett. **89**, 231107 (2006).

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