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Collimated particle acceleration driven by intense vortex laser

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With the development of advance laser technologies, an LG laser has the potential to be extended to the relativistic regime. Now the highest intensity of the LG laser can reach up to 6.3×10^{19}W/cm^2 [1] by using the reflected phase plate on the petawatt laser facility in experiments. The relativistic LG laser is expected to open new doors for particle manipulation in relativistic interacting regime, because the hollow intensity distribution of the LG laser may generate a transverse potential well on the beam axis and provide a confining force to collimate matters. It is believed that particles can be accelerated in a concentrated manner in a new regime, to overcome some of the drawbacks of Gaussian-laser driven particle acceleration to a certain extent.

In experiments, the a high-reflectivity phase mirror is applied in the femtosecond petawatt laser system to generate a relativistic hollow laser at the highest intensity of 10^{20}W/cm^2 now [2] (Figure 1 left). A simple optical model has been used to verify that the vortex laser may be generated in this new scheme; using such a relativistic vortex laser, the hollow plasma drill and acceleration for the ultrathin foil are achieved experimentally and proven by particle-in-cell simulations.

In PIC simulations, we report on a self-collimated acceleration scheme for a plasma beam using an ultra-intense Laguerre–Gaussian (LG) laser irradiating a thicker solid target [3] (Figure 1 right). Three-dimensional (3D) particlein-cell simulations show that a plasma beam with a high current density is stably formed by the radiation pressure of the hollow LG laser. The initial interaction of LG laser with solid target can be approximately researched by a deformable mirror model. Under the effect of the ponderomotive force of the LG laser, the plasma converges in the center axis to form a narrow beam. An elongated strong-magnetic tunnel (B ~ 2 kT) is self-generated around the plasma beam, capable of trapping some electrons in a region with a radius of less than 500 nm (r < 500 nm). Compared with the case driven by the conventional Gaussian laser, the beam radius size is dramatically reduced from themicroscale to hundreds on the nanoscale. The beam density is increased by at least ten times.

References

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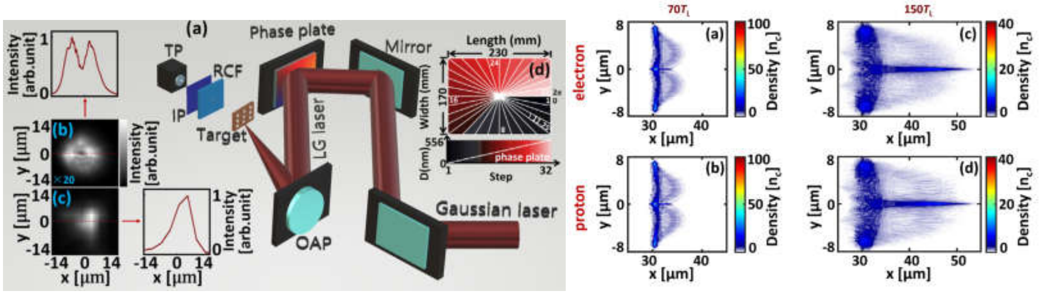

Figure 1. Experimental setup for LG laser generation (left). Density distributions for electrons and protons in PIC simulations (right). The electron bema is first concentrated in the beam center then drags protons inward at t = 70 T_L. Finally, a long jet is formed at t = 150 T_L, which is collimated by a strong-magnetic tunnel around the plasma beam.