1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams

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We used laser-plasma processes to generate extreme discharge currents in coil-shaped targets [1]. We explored two distinct laser interaction regimes – using either high-energy nanosecond or high-intensity short-pulse lasers – leading respectively to strong quasi-static magnetic fields (B-fields) [2, 3] or to fast, transient electro-magnetic pulses (EMPs) propagation along the coil targets [4].

When using high-energy ns pulses, a compact target setup of two plates connected by a single-turn coil can produce discharge currents of few 100 kA. The coil yields reproducible B-fields on the excess of 500 T, as measured by proton-deflectometry and high-frequency bandwidth B-dot probes [1, 2]. Hot electrons ejected from the irradiated cathode provide the source for the quasi-static super-Alvénic current, accounting for the space charge neutralization and the plasma magnetization between the target plates. The major control parameter is the laser irradiance $I\lambda^2$ as the maximum current is proportional to the hot electron temperature [5].

The produced quasi-static B-fields on the excess of 500 T are long enough to magnetize secondary targets through resistive diffusion, paving the ground for many investigations of magnetized high-energy-density matter. The magnetization of dielectric targets has been successfully used in experiments of laser-generated relativistic electron transport into solid matter. The imposed B-field of 600 T yielded an unprecedented enhancement of a factor 5 on the relativistic electrons energy-density flux at 60 μm depth, compared to unmagnetized transport conditions. The transported electron beams were characterized by imaging the coherent transition radiation (CTR) emitted from the targets' rear surface in conjunction to benchmarked 3D PIC-hybrid simulations coupled to a CTR post-processor. For optimized experimental parameters, 70% of the electron beam energy transported to the rear side is kept on-axis within the size of the electron beam source [6].

We also demonstrated that the EMPs streaming along coil-targets – triggered by the target irradiation in the ps-laser relativistic regime – act as micro-lenses, tailoring the transport in vacuum of ion beams accelerated by a second intense laser pulse [4]. We measured efficient focusing of protons with energy up to 10 MeV over ≈ 10 cm distances. The short duration of the discharge, ≈ 30 ps – probed by proton-deflectometry – allows to select the energy of the focused protons by tuning the delay between the lasers. The pulsed discharges can be described as a neutralizing EM mode of ~10 GV/m, streaming close to the speed of light, as inferred from heuristic simulations of the proton-diagnostic coupled to *ab initio* 2D PIC simulations of the laser-target interaction and EMP discharge.

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