

Transient Electromagnetic Fields for High Energy-Density Beam Tailoring Driven by ps-Laser Pulses

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We present experimental studies of an open-geometry platform for energy selective tailoring of laser-accelerated particle beams, with reference to different target geometries and optimization prospects. The presented results are supported by theoretical analysis based on PIC simulations and modelling. In the all-optical principle, a high intensity ps-laser pulse drives electromagnetic (EM) target-discharge and subsequent propagation of strong transient EM-fields guided by the target geometry. A sub-mm coil-shaped part of the target rod creates lensing effects that arise due to magnetic- and electric-contributions, in particular we imaged energy-selective proton beam focusing over cm-scale distances by proton-deflectometry and we showed the clear evidence of a some Tesla strong magnetic field component based on its polarity.

The experiment was carried out at the PHELIX/GSI laser facility, using 500 fs, 50 J laser pulses focused at $5 \cdot 10^{18}$ W/cm² into a flat-disc target conductively connected to a 50 μ m-thick wire shaped as a coil of 500 μ m diameter. The discharge time and spatial scales were captured by proton-deflectometry (Figure 1), revealing the propagation of transient EM-fields emanating from the laser-plasma interaction. The measured phase speed through the target rod is $(0.95 \pm 0.05) c$. The discharges stream around the coil over ≈ 25 ps, producing efficient focusing of the protons passing inside the coil: 12 MeV-protons are collimated over distances of several cm. In Fig. 1, the emittance of 6 MeV protons shrinks to 30% of the initial value. Energy-selection for the focused particles is possible by tuning the delay between the laser pulse driving the coil and the one accelerating the proton beam.

Analysis with transport- and field-simulations using the PAFIN code [DOI: 10.13140 / RG.2.1.3855.7847] assuming a dynamic EM-discharge pulse streaming along the target capture the discharge dynamics with amplitudes of tens of GV/m and tens of T. Detailed PIC simulations of the laser-target interaction and the successive propagation of the EM-waves streaming along the target and propagating in the free space around the target agree in field strength and point us to different electromagnetic effects difficult to separate: the propagation of fast electrons, EMP and neutralization wave.

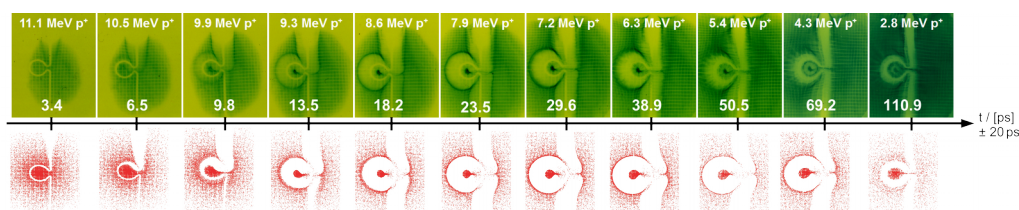


Figure 1: Experimental data in the top row, PAFIN simulation results in the bottom row.