Pulsed kT magnetic field generation by ns laser-matter interaction with application to guided relativistic electron beam transport

L. Giuffrida1, M. Bailly-Grandvaux1, D. Batani1, R. Bouillaud1, M. Chevrot4, S. Dorard4, J.-L. Dubois3, P. Forestier-Colleoni1, S. Fujioka2, J. Gazave3, S. Hulin1, K. Ishihara2, E. Loyez4, J.-R. Marques4, Ph. Nicolai1, H. Nishimura2, A. Poyè1, D. Raffestin3, J. Ribolzi3, F. Serres4, V. Tikhonchuk1, Ph. Vacar4, Z. Zhang2 and J.J. Santos1

1 Univ. Bordeaux, CNRS, CELIA, Bordeaux, France
2 Institute of Laser Engineering (ILE), Osaka University, Japan
3 Commissariat à l’Energie Atomique (CEA-CESTA), Le Barp, France
4 LULI, CNRS, CEA, Ecole Polytechnique, Palaiseau, France

The generation of strong magnetic fields (B-field) of a few kT on laser facilities opens new frontiers in several research areas, such as atomic-, nuclear- and astro-physics, and, more specifically, in inertial fusion science.

Building upon previous works [1, 2, 3], we systematically studied the B-fields generated in the interaction of an intense laser beam (1 ns, 500 J, 10^{16}-10^{17} W/cm²) with capacitor-coil targets, by varying the target material (resistivity and magnetic permeability) and geometry (coil radius, single- and double-turn coils). The B-field evolution with time was characterized by the measurements of both an inductor coil (B-dot probe) and laser-accelerated proton-trajectory deflections. The latter technique also allowed characterizing the B-field spatial distribution, corresponding to a magnetic dipole with magnetic energy distributed over a characteristic volume of 1 mm^3. The data analysis for the best set of parameters reveals the maximum B-field amplitude of the order of 1 kT at the coil center, 1.5 ns after the laser pulse and with a characteristic duration of 3.5 ns. The experimental results are successfully compared with a theoretical model describing the mechanism of the charge separation in the target capacitor disks and the B-field generation in the coil connecting the disks.

This B-field generation scheme can be used for efficient and compact devices for controlling the collimation of intense electron and ion beams. Preliminary results of a proof-of-principle experiment on the magnetic-collimation of a relativistic fast electron beam propagating in a solid target will be also presented. This experiment will be carried out in May 2014.

References