§43. Enhancement of Coupling Efficiency in Fast-ignition Laser Fusion by Controlling Self-generated and External Magnetic Field

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Efficient energy coupling between heating laser and a fusion fuel is required for the fast-ignition laser fusion. Heating laser is converted to energetic electrons by laser-plasma interactions, heating laser energy is carried by the electrons, and the electrons deposit their energy in the fusion fuel. In usual, divergence angle of the laser produced electron beam is too large to keep sufficient energy flux at the fusion fuel position. In this study, strong magnetic field is applied to reduce the divergence angle of the energetic electron beam and to guide the beams to the fuel core. Strength of magnetic field to guide an energetic electron beam (hot electron temperature is less than 2 MeV) was estimated to be 10 kT with two-dimensional particle-in-cell (2D-PIC) code.

Such a strong magnetic field can be generated by compression of magnetic field seed with an imploding plasma. Figure 1 shows a schematic of the magnetic field compression. Dense plasma (diamagnetic substance) was used as a magnetic piston, and laser-driven imploding plasma compressed magnetic field seed. The compression up to 6 kT has been achieved on OMEGA laser facility [1].

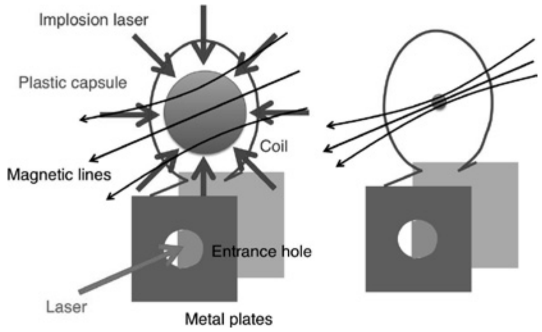

Fig. 1: Schematic of the magnetic field compression

Magnetic field seed was produced by laser-driven micro-coil target shown in Fig. 2 [2]. In this scheme, two planar plates connected by a wire loop is used. The second plate is irradiated by intense laser through the hole of the first plate. At $I\lambda^2$ above 10^{16} W/cm^2 μm^2, a fraction of the laser energy is resonantly absorbed, heating approximately 10% of the electrons to temperatures exceeding 10 keV. The hot electrons stream down the electron density gradient ahead of the expanding plasma plume and impact the front plate. The front plate acquires electrical charge, and a large electrical potential develops between the plate. The potential difference drives a reverse current through the wire loop. Courtois studied recently this scheme in detail [?]. They found some scaling laws to estimate strength of magnetic field produced by this scheme. The scaling laws show that we can obtain several handreds T of the seed field with GEKKO laser.

380 T of the maximum value was measured by B-dot probe in the last year experiment. The magnetic field achieve its maximum at the timing when the expanding plasma arrives at the front target. This is about forty times stronger than that used in the OMEGA experiment, in which conventional capacitors were used. We can achieve 10 kT by compressing the seed field by factor 26. We will measure compressed magnetic field by using Zeeman splitting and Landau quantization in FY2012.

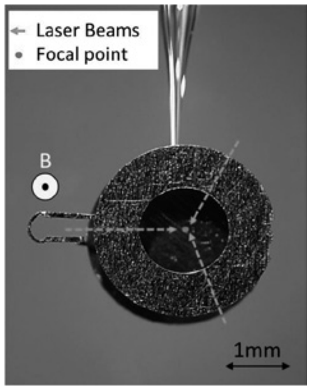

Fig. 2: Photograph of the micro-coil target

1) J. P. Knauer, O. V. Gotchev, P. Y. Chang, D. D. Meyerhofer, O. Polomarov, R. Betti, J. A. Frenje, C. K. Li, M. J. E. Manuel, R. D. Petrasso, J. R. Rygg, and F. H. Séguin. Compressing magnetic fields with high energy lasers. *Phys. Plasmas*, Vol. 17, p. 056318, 2010.

2) H. Daido, F. Miki, K. Mima, M. Fujita, K. Sawai, H. Fujita, Y. Kitagawa, S. Nakai, and C. Yamanaka. Generation of a strong magnetic field by an intense co2 laser pulse. *Phys. Rev. Lett.*, Vol. 56, p. 846, 1986.