# §39. 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 relativistic electrons by laser-plasma interactions, heating laser energy is carried by the electrons, and the electrons deposit their energy in the fusion fuel. It was found in previous experiments that the electron beam diverges during transport with an angle of 100 deg. Active controll is requried to reduce the divergence angle of the relativistic beams. One candidate scheme is to apply an external magnetic field parallel to the beam propagation direction in the fuel. When the magnetic flux density exceeds 2 kT, relativisitc electrons are trapped by the magnetic field lines and lateral transport of the electrons is strongly suppressed.

We use a laser-driven capacitor-coil target to generate the magnetic field instead of the conventional magnetic field generation scheme. Figure 1 shows a schematic of the magnetic flux density measurement with Faraday effect. The horizontally polarized second harmonics of a Q-switched Nd : YAG laser (wavelength $\lambda = 0.532$ $\mu$m) were used as the probe. Fused silica was used as a Faraday medium in this experiment, whose Verdet constant is 298 12 deg./T m for 0.532 $\mu$m probe light. Probe light transmitted through the fused silica cylinder was divided into horizontally and vertically polarized components by a Wollaston prism and the divided probe light was imaged on a visible streak camera. The rotation angle can be determined from the intensity ratio ($I_H/(I_H + I_V)$) between the horizontal ($I_H$) and vertical ($I_V$) components.

We measured the magnetic flux densities by varying the intensity and wavelength of the drive laser and the thickness of the fused silica cylinder to obtain a scaling law of the flux density against laser intensity and wavelength. Figure 2 summarize the maximum magnetic field obtained.

The flux density generated with a laser-driven capacitor-coil target is high enough that it can be applied to the collimation of the relativistic electrons. Furthermore, the initially diverged magnetic field line may reduce the electron reflectivity at the magnetic waist generated around the fuel core. This magnetic field will be implemented in an integrated fast-ignition experiment.

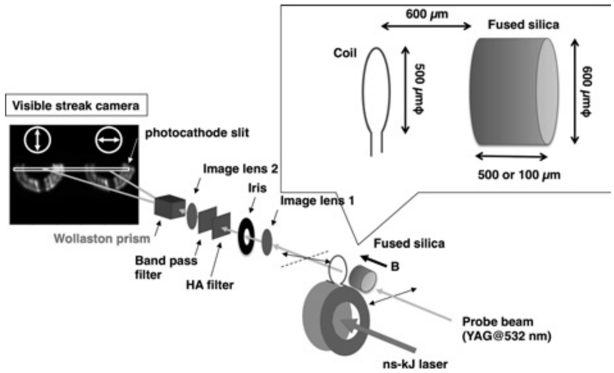


Fig. 1: Magnetic flux density measurement using the Faraday effect. A cylinder made of fused silica, whose diameter and length are respectively 600 $\mu$m and 500 or 100 $\mu$m, is located away from the coil. Horizontally polarized second-harmonic light from a Nd:YAG laser is used as the probe. The transmitted probe light is imaged by lens 1 onto the iris. The central part of the image, having a diameter of 100 $\mu$m on the Faraday medium, is selected by the iris. The image is transferred to the visible streak camera by lens 2. Heat absorption and bandpass filters between the iris and lens 2 exclude the laser harmonics and the thermal emission from the plasma. The Wollaston prism divides the rotated light into horizontal and vertical components.

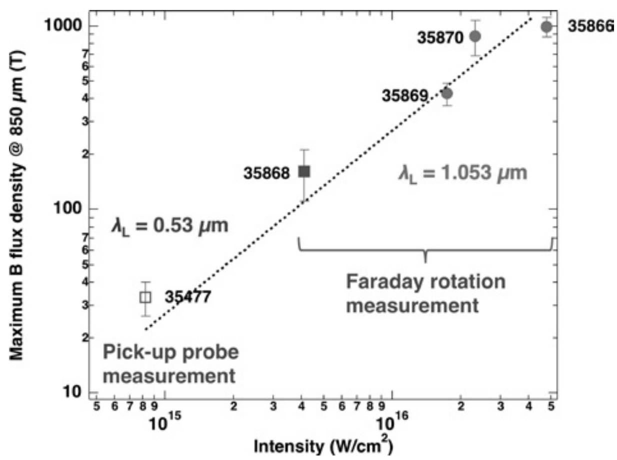


Fig. 2: Variation of the magnetic flux density at 850 $\mu$m from the coil as a function of the laser intensity. The red circles and green squares represent the flux density generated by a 1.064-$\mu$m laser and a 0.526-$\mu$m laser, respectively. The closed or closed marks represent results obtained with the Faraday rotation or the pick-up coil measurements. The dotted line shows a liner line as $B(I_L) = 2.7 \times 10^{-14}\ I_L$.