Development of Nd:YAG Thomson Scattering System for Time Evolution Measurement of Plasma Profile on Heliotron J

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Introduction

The various improved confinement phenomena, such as the edge transport barrier (H-mode) or the internal transport barrier formation, show a rapid transition of a plasma profile with the confinement enhancement. Recently, an improved confinement with the rapid profile change by a supersonic molecular beam injection has been observed in Heliotron J[1]. Therefore, a time evolution measurement of a plasma profile is essential for an investigation of a transport physics of a magnetic confinement fusion device. In addition, these results also suggest that the control of the plasma profile can enhance the plasma confinement to improve a fusion plasma performance.

We are developing a new Nd:YAG Thomson scattering system for the Heliotron J device[2], because it is preferable for the time evolution profile measurement compared to other 2D thomson scattering methods such as the LIDAR Thomson scattering or TV Thomson scattering[3, 4].

In this paper, we report an overview and a present status of the development and construction of the new thomson scattering system of the Heliotron J.

Overview of the new Nd:YAG Thomson scattering system

Because of the investigation for the improved confinement physics, we determine performance goals of the new Nd:YAG Thomson scattering system on Heliotron J[5] (major radius: $R_{ax} = 1.2m$, averaged minor radius: $\langle a \rangle = 0.17m$, plasma volume: $V = 0.7m^3$) are spatial resolution: $\sim 1cm$, spatial channels: 25, time intervals of measurement: $\sim 10ms$, measurable range of T_e: $10eV - 10keV$, and measurable range of n_e: $> 0.5x10^{19}m^{-3}$. Precise measurements of the electron temperature and density are important to study a subtle changes of the plasma profiles from one laser pulse to the next. Accordingly, required power of the Nd:YAG laser is greater than $500mJ$. It is important to measure at least the temporal evolution of the Heliotron J plasma with a time intervals of $10ms$, because the confinement time of the Heliotron J is several millisecond. Consequently, we choose a combination of the two 50Hz Nd:YAG lasers which are made by the Continuum inc.

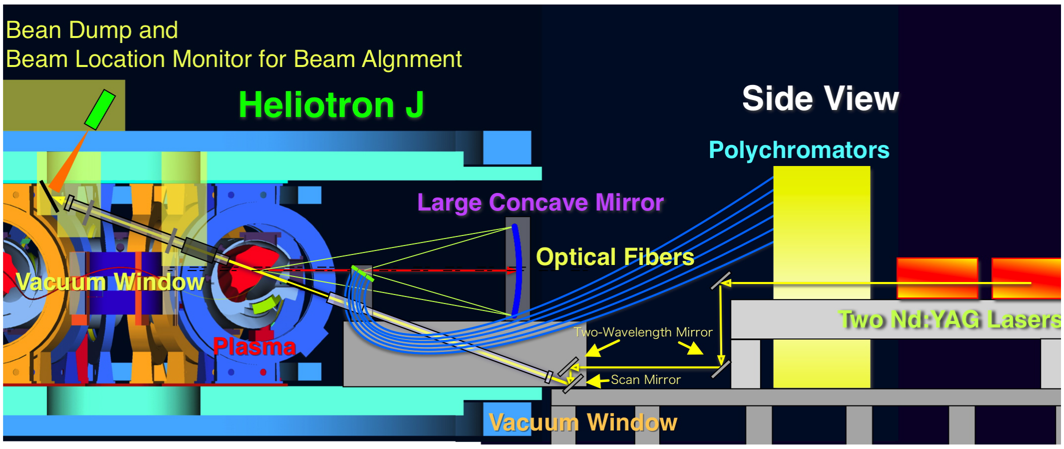

Figure 1: Schematics diagram of the Nd:YAG Thomson scattering system on Heliotron J

As shown in Fig.1, the laser beam is injected from obliquely outer downward to inner upward side of the Heliotron J, and obliquely backscattered light (scattering angle is 160°) is detected to avoid interference with a coil and a support structure[2]. The scattered light is collected with a large concave mirror (D=800mm, f/2.25) with a solid angle of $\sim 80-100 mstr$[2]. This configuration has a merit of a signal to noise ratio improvement due to the small background plasma region in sight of the collection optics. The collected scattered light is transferred to 25 polychromators by the optical fiber bundles which plugs into the polychromators. Because a required numerical aperture of the fiber is less than 0.3, we choose a polymer clad optical fiber bundle made by the Mitsubishi cable industries LTD ($3mm \times 1.5mm$, $NA = 0.39$, number of core wire is 12). Because the magnification of the image is 0.3-0.4, the plasma profile can be measured with $\sim 10mm$ resolution.

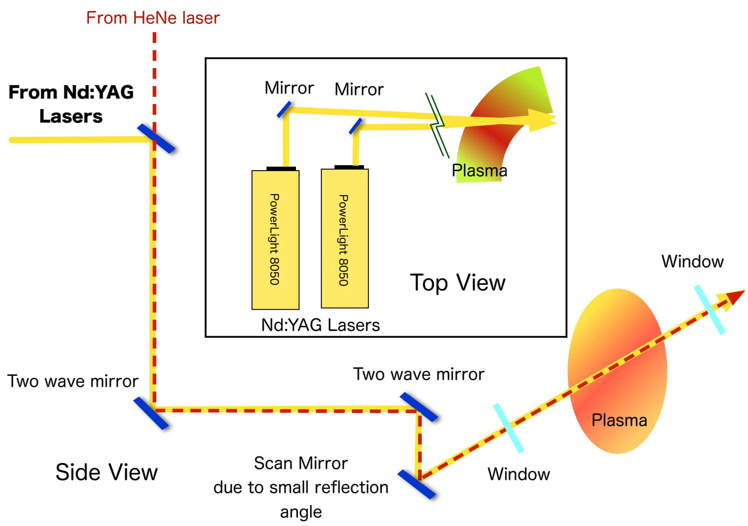

Figure 2: Schematic diagram of the Nd:YAG laser transmission system on Heliotron J. Top view is also shown in the box.

A real-time VME computer system is used for a data acquisition system. The system is constructed on a VME bus operating of which throughput is 30Mbyte/sec. CPUs are Motorola

68060 with 60MHz clock rate. The system is operated under the CINOS(CHS Integrated No Operation System)[6], which was first developed for CHS data acquisition system. The CINOS is not a multi-task operating system, but a system software that make a time invariant data acquisition without OS. The acquired data are transfer to LINUX computer by LAN. The data are analyzed immediately following a plasma discharge by the computer for the data analysis.

Laser transmission optics

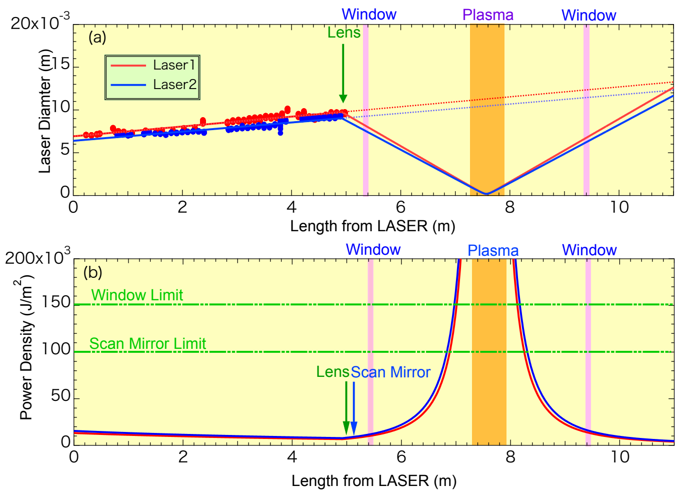

Figure 3: (a)Measurement of the Nd:YAG laser beam diameter with a beam profiler (circles) and estimation of the diameter focused by a lens after the last point of the measurement (lines) (a) and power density (b). Results of two lasers are shown. Location of vacuum window, plasma, scan mirror and lens are denoted.

The Laser beams are transmitted to a laser window by 4 mirrors which consist of a high power laser mirror, two-wavelength mirrors, a scan mirror (Fig. 2). For beam alignment, a HeNe laser is transmitted on a collinear with the Nd:YAG lasers, and they are transferred by the two-wavelength mirror by which two different wavelengths (HeNe and Nd:YAG lasers) beams can be reflected. The scan mirror is chosen as the last mirror of the beam transfer system, because the input angle is 35°. The laser beams are combined closely together along a common beam path by the mirror and overlapped in the plasma center where they are focussed to a common point. Laser input and output windows are located far from the plasma (1-2m) by stainless pipes due to the reduction of a stray light that is produced from the laser window.

The diameter of the laser beam is measured with a laser beam profiler from the exit aperture of the laser to the location of the $L = 4350mm$. As is shown in Fig. 3(a), the diameter is broadened with the length from the aperture. The laser beam is focused by the lens to improve a signal to noise ratio of a scattered light from the plasma. Because the laser beam profile is approximately modeled by the gaussian profile, the beam transmission with the lens is estimated by the gaussian beam model. Form this estimation, we choose the plane-convex lens that has a focussing length of $2290mm$@ wavelength $=1064nm$. As shown in Fig. 3(b), the power density of the laser beam is small enough to avoid damage to the vacuum window and the laser mirror, while the dimeter of the laser beam becomes less than 1mm, when the laser beam go through the plasma of Heliotron J.

Summary

The new Nd:YAG Thomson scattering system is developed on the Heliotron J to study of the improved confinement physics. Two high repetition Nd:YAG lasers ($> 550mJ@50Hz$) realize the measurement of the time evolution of the plasma profile with $\sim 10ms$ time intervals. The laser beam is injected obliquely from outer downward side to inner upward side. The obliquely backscattered light is detected using the large concave mirror (D=800mm) and the optical fiber bundles in the staircase pattern. The laser transmission optics to the plasma is well optimized to achieve the higher signal to noise ration of the scattered light. The system has 25 spatial points with $\sim 10mm$ resolution. The data acquisition is performed by the VME-based system which is operated by the CINOS.

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