§34. Development of the Polarization Controlled Multi-pass Thomson Scattering System in Heliotron J

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The multi-pass Thomson scattering (TS) scheme can provide the several function into the TS measurement. A Multi-pass configuration enable the laser pulse to be injected several times onto the scattering volume, thus increasing the scattering photon number by detecting multiple scattering signals or decreasing a measurement time interval by detecting the each scattering light signal individually [1,2]. Also, this configuration can extend the measurable parameters in Heliotron J and LHD. Originally, LHD TS system has the backward scattering angle of 167°. By using the second pass signal, the forward scattering angle of 13° can be obtained. An observed spectrum from forward pass scattering light is narrower than backward one. Then, forward pass measurement can expand the measurable range of the electron temperature with same setup of the polychromator filters [3]. Furthermore, this backward and forward scattering measurement have a possibility to estimate the electron temperature parallel to magnetic field and perpendicular to magnetic field separately [4].

In this study, we propose a newly scheme of multi-pass TS system by the use of a polarization optics. This scheme can be modified from the basic single pass TS system by adding the high reflection mirror for cavity mirror, lenses used for image relaying the laser beam and polarization control devices of a Faraday rotator and a Pokels cell. It has a collinear beam line in the multi-pass cavity. The system design is carried out by polarization analysis by Jones matrix and optical ray trace. From the result of our design, TS signal at the double passing is 2 times larger than the signal of single pass configuration and at the sixteenth passing signal is 6 times larger than the single pass signal.

To design the optical system of the multi-pass system, we have carried out an ABCD matrix analysis, Jones matrix analysis and the multiplication of the scattering light by the calculation.

$$\begin{pmatrix} 1 & f-a \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 2\cdot f \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & f-a \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} r_1 \\ s_1 \end{pmatrix} = \begin{pmatrix} -r_1 \\ -s_1 \end{pmatrix} \quad (1)$$

where f is the focal length, a is an adjustment length of the telescope, r_1 is the transverse offset, and s_1 is the offset angle. From (1), we can maintain the magnitude of r_1 and s_1. The beam propagation from IP2 to IP1 is expressed by ABCD matrix as follows

$$\begin{pmatrix} 1 & f-a \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 2\cdot f \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & f-a \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} r_2 \\ s_2 \end{pmatrix} = \begin{pmatrix} -r_2 \\ -s_2 \end{pmatrix} \quad (2)$$

The transverse offsets r_1 and r_2 and the offset angles s_1 and s_2 have the same magnitude at IP1 and IP2. This image relay telescope makes it possible to maintain the beam quality during beam propagation. And also, we confirmed polarization system by using the Jones matrix analysis.

As a result of the optical system design, we can estimate the effect of the multi-pass TS system. Figure 1 shows the multiplication of the scattering light as a function of the pass number. This indicates that scattering light signals are increased by a factor of 1.5 for the double-pass configuration. For the fifteenth pass, the light scattering was about 2.8 times larger than the single-pass configuration.

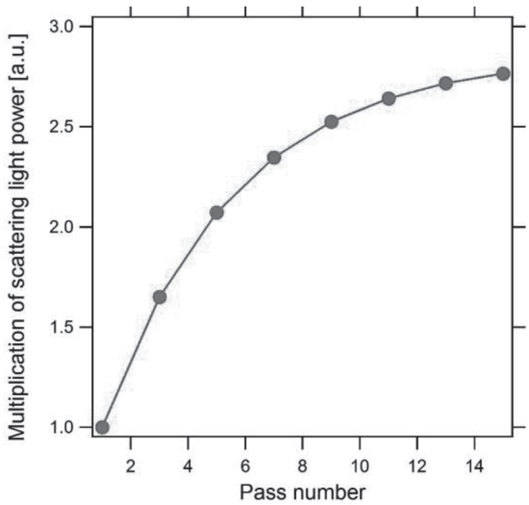

Fig.1. Scattering light power as a function of pass number.

A novel multi-pass TS system configuration was proposed to improve the time resolution and accuracy of electron temperature measurements by the use of a polarization control technique. The configuration can realize perfect coaxial multi-passing at each pass. The number of round trips is not limited by the optical configuration but only by optical loss. By the design, scattering light signals are increased by a factor of 1.5 for the double-pass configuration. For the fifteenth pass, the light scattering was about 2.8 times larger than the single-pass configuration.
These results demonstrates the improvement that can be gained in the data quality of the Heliotron J system and the feasibility of the proposed polarization-based multi-pass system.

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