§4. A Suppression of Beam Positioning Fluctuation by Use of Kepralian Image Relay Optics in LHD Thomson Scattering System

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A beam positioning stability is an important issue for Thomson scattering (TS) system. A fluctuation of beam positioning induces a misalignment of the collective optics for scattering light and probe beam line in the plasma. As the result the accuracy of absolute light intensity is reduced due to changing a collective efficiency of scattering light. One of the solutions for maintains stable beam positioning is active controlling of beam direction by use of piezo actuator and position sensor [1)]. It has been demonstrated in LHD TS system and suppressed the low frequency vibration of beam positioning. For high frequency fluctuation, it is need to develop a new method. In this paper we report the passively suppression of a beam fluctuation by use of image relay optics. It can maintain beam position automatically at all frequency range.

The Keplerian image relay telescope configuration is a basic optical system. It uses only 1 pair of convex lenses as figure 1. This telescope can transport the first image of IP1 to the IP2 under the condition of d1 + d2 = f1 +f2 where d1 and d2 are distance between lens and image point and f1 and f2 are focal length. It can calculate by the ABCD matrix ray tracing that is useful method for the understanding the laser light propagation. With an image relaying case it can express as follows:

$$\begin{pmatrix} r_2 \\ s_2 \end{pmatrix} = \begin{pmatrix} 1 & f \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 2\cdot f \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & f \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} r_1 \\ s_1 \end{pmatrix} = \begin{pmatrix} -r_1 \\ -s_1 \end{pmatrix}. \tag{1}$$

And without an image relaying case, the ABCD matrix is given by

$$\begin{pmatrix} r_2 \\ s_2 \end{pmatrix} = \begin{pmatrix} 1 & 4\cdot f \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} r_1 \\ s_1 \end{pmatrix} = \begin{pmatrix} r_1 + 4\cdot f \cdot s_1 \\ s_1 \end{pmatrix} \tag{2}$$

where f is a focal length of convex lens. r_1 and r_2 is a position of image point 1 and 2. s_1 and s_2 is a divergence of a ray at the same image point.

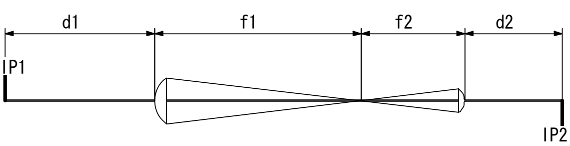

Fig. 1. A schematic diagram of the Keplerian image relay telescope. Focal lengths of convex lenses are f1 and f2. IP1 and IP2 are image point of this optical system. d1 and d2 are the distance between lens and image.

From equation 1 and 2, TS beam position error at LHD core plasma was calculated under the condition of with or without image relay case as a function of initial beam direction which means laser pointing fluctuation, machine vibration at optical bench and so on. As the result, figure 2 shows the perfectly compensation of beam position under the condition of image relaying.

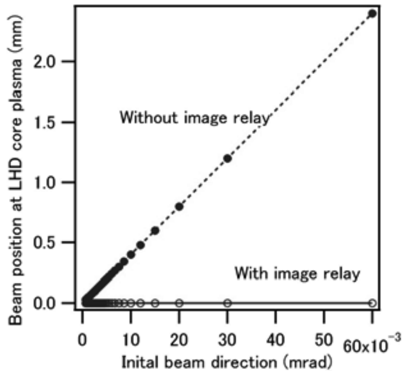

Fig. 2. A beam position error at LHD core plasma was calculated under the condition of with or without image relay case (f = 10m, r_2 = 5 x10^{-3}m) as a function of initial beam direction.

A suppression of beam positioning fluctuation was demonstrated in the actual optical system. The image relay system was constructed in the beam line of TS probe laser. The transportation length of first image to second image point was 40 m. He-Ne laser was used for test probe laser and detected by PSD sensor at 40 m point. Figure 3 shows the result of demonstration. The beam fluctuation is reduced to one sixth by using image relay system.

We have demonstrated the image relay system for a suppression of beam fluctuation. This scheme makes it possible to acquire more precise TS data.

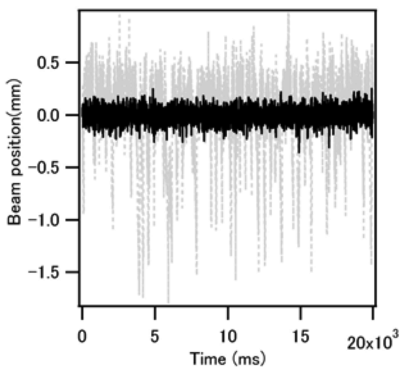

Fig. 3. A beam position of TS beam line at the 40 m from the laser output. Gray line is without image relay. Black line is with image relay.

1) I. Yamada et al., NIFS Ann. Rep. 2008-2009, 130 (2009).