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JT-60SAにおける2波長CO_2レーザー干渉計の開発

Development of two-color CO_2 laser interferometer in JT-60SA

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For the purpose of measurement and control of the electron density, two-color CO_2 laser interferometer has been developed in JT-60SA. The system of the interferometer is a heterodyne configuration and an intermediate frequency is 40 MHz, which is modulated by an acousto-optic modulator. The two wavelengths of the CO_2 lasers are 9.25 and 10.59 μm and they are combined by using the grating to subtract the change of the optical length due to the vibration of the optical elements, etc., which are hardly influenced by the difference of their refractive indices [1]. Because the coherence length of the CO_2 laser is approximately 5 m, the probe beam and the reference beam should propagate in approximately the same length. Besides, the lasers should be placed outside of the radiation-controlled area to take operability and maintainability into account. Thus, the probe beam propagates approximately 220 m, which is longer than the 120 m beam path of the ITER toroidal interferometer and polarimeter [2]. Therefore, in order to suppress the measurement error, the probe and the reference beams are propagated approximately the same position (orange line in Fig. 1.) except for the area where the probe beam is injected into the plasma (red line in Fig. 1.)

Figure 2 shows the temporal variation of the corrected phase which is $\Phi_{10.59}$ - (9.25 / 10.59) $\Phi_{9.25}$. Here, $\Phi_{10.59}$ and $\Phi_{9.25}$ are the phases obtained with 9.25 μm and 10.59 μm CO_2 laser interferometer, respectively. The black line is the case that the probe and the reference beams propagate in the same path length but the different space (case 1). On the other hand, the red line is the case that the probe and the reference beams propagate in the same path length and space (case 2). In the case 1, the large error (standard deviation in 100 s, σ = 0.09 rad.) and the large drift are detected. On the other hand, in the case 2, σ drops to 0.02 rad. and the drift is not detected, even though the path length is longer than that of the case 1. This result indicates that the difference in the air flows between the JT-60SA room and the laser operation room (LOR) affects the phase variation. Figure 2 also shows the temporal development of the phase obtained with the interferometer as the optical design is shown in Fig. 1. (case 3). In this case, σ is 0.06 rad., which is larger than that of case 2. This is because the probe and the reference beams propagate in the different space in approximately 60 m and their path length are a little different. The value of 2σ corresponds to the line integral density 1.78×10^{19} m^{-2} (line average density $\bar{n}_e \sim 1.2 \times 10^{18}$ m^{-3}). Its density resolution is still larger than the requirement (less than 1.0×10^{19} m^{-2}). Thus, it is necessary to suppress the noise, e.g. the difference of the path length between the probe and the reference beams is reduced.

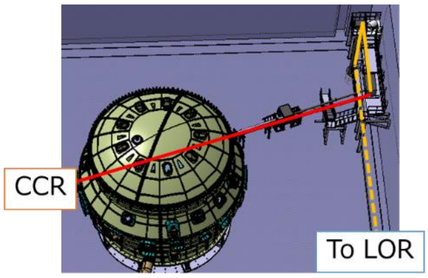

Fig.1. Schematic view of the probe and the reference beams propagation.

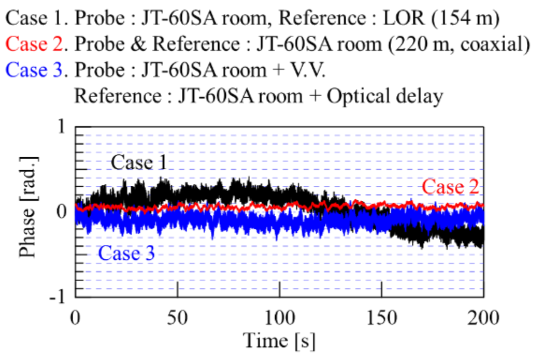

Fig. 2. Error suppression due to the probe and the reference beam propagation in approximately the same position.

[1] Y. Kawano et al., J. Plasma Fusion Res. 73, 870 (1997)
[2] M. A. Van Zeeland et al., Rev. Sci. Instrum. 89, 10B102 (2018)