§12. Bench Testing of a Nd:YAG Laser Dispersion Interferometer on FFHR-d1

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The line averaged electron density is one of indispensable parameters for operation of FFHR-d1. The fusion output will be controlled with the line averaged electron density [1]. To surpress variations of the fusion output less than 0.1 GW, a high density resolution of 4×10^{17} m^{-3} is necessary. In addition, measurement failure such as fringe jumps of conventional interferometers is not allowed.

A dispersion interferometer is one of candidates of the density monitors on FFHR-d1. Since it is insensitive to mechanical vibrations, a vibration isolation stand, which is sometimes larger than a main device, is not necessary. A density resolution of 2.5×10^{17} m^{-3} without the vibration isolation system is obtained with the CO_2 laser (wavelength of 10.6 μm) dispersion interferometer on LHD [2]. According to the reliability of measurement, there is no fringe jump error in the CO_2 laser dispersion interferometer when data sampling time is enough shorter than time scale of a density rise of 2π (a sampling frequency of 100 kHz seems to be enough for LHD).

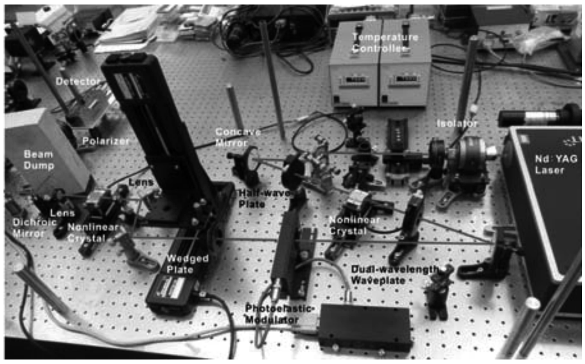
For suppression of the fringe jump errors, the small phase shift (fringe shift) is preferable because miscount of fringe is due to multiple fringe shifts. If the fringe shit is smaller than 1 fringe, the phase shift can be determined uniquely and there is no fringe jump in principle. Even though the fringe shift is larger than 1 fringe, small number is preferable because it can be corrected easily. In the case of a wavelength of 10.6 μm, which is used on LHD, the fringe shift is about 17 fringes. On the other hand, the fringe shifts of the Nd:YAG laser light with a wavelength of 1.064 μm is about 1.7 fringe. Although the fringe shift is slightly larger than 1 fringe, the Nd:YAG laser is a candidate for laser source of the dispersion interferometer on FFHR-d1.

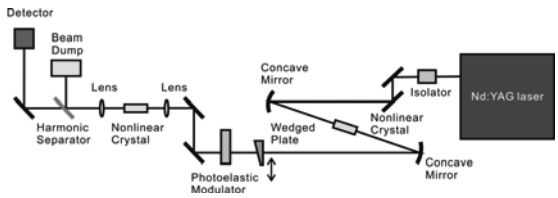
Figure 1 (a) shows a photograph and schematic view of Nd:YAG laser dispersion interferometer. To avoid degradation of the signal to noise ratio caused by reflectivity degradation of in-vessel mirrors, high power Nd:YAG laser is used for the laser source. Its output power is 8 W and an interference signal can be measurable even if the reflectivity decreased 1/100 of initial condition.

Figure 1(b) shows the variations of the zero line measured with the bench testing. The density resolution is determined by this variation: 3.7×10^{17} m^{-3} for short time (100 s) and 1.0×10^{18} m^{-3} for short time (3000 s). Although the requirement 4×10^{17} m^{-3} is satisfied for the short time, further improvement is necessary for steady state operation. One of reasons of variations is temperature drifts. The changes in the temperature causes changes in the refractive index of nonlinear crystals and that may lead to additional phase shift. A temperature control system of the crystals and a cover to the optical system will be introduced.

Figure 2 shows the phase shift measurement with a wedged glass plate, which simulate a plasma. The wedge is scanned perpendicular to the beam path as shown in Fig. 1. The slop is determined by the wedged angle 142±11. The measured results (slop of 140.8) agree with the expectation and reasonable measurement with the Nd:YAG laser dispersion interferometer is proved.

(a)





(b)

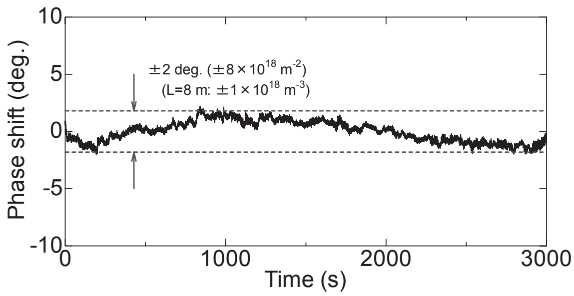


Fig. 1: (a) Photograph and schematic view of bench testing of the Nd:YAG laser dispersion interferometer. (b) Baseline drifts of the dispersion interferometer.

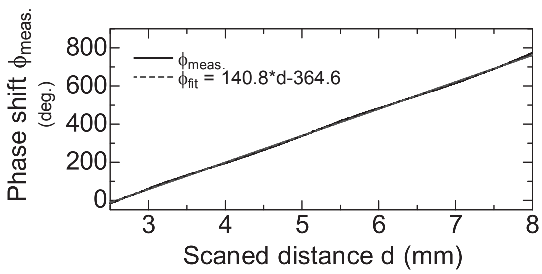


Fig. 2: A measured phase shift of the dispersion interfeomer with a wedged plate.

1) T. Goto *et al*., Fusion Eng. Des. 89, 2451 (2014).
2) T. Akiyama *et. al.*, Rev. Sci. Instrum. 85, 11D301 (2014).