§23. Advanced Laser Diagnostics for Electron Density Measurements

Kawahata, K., Akiyama, R., Pavlichenko, T., Tanaka, K., Okajima, S., Nakayama, K. (Chubu Univ.)

Measurements of the refractive index of the plasma by using electromagnetic waves are a well-established technique for measuring electron density profiles in high temperature plasmas. In the LHD, a 13-channel far infrared laser interferometer [1] has been constructed and routinely operated for the precise measurements of the electron density profile almost every shot except in the case of a high-density plasma produced by an ice pellet injection. In the latest experimental campaign of the LHD, a super dense core plasma as high as 5 x 10^{20} m^{-3} has been achieved by an internal diffusion barrier created by the use of the local island divertor and multiple pellets injection. In these high density plasmas, steep density gradient is formed leading to the fringe jumps on the density traces measured by fringe counters. In order to overcome this difficulty there are several approaches, which are classified into two categories, the interferometry and the polarimetry.

In the first category, interferometry, we need to develop short wavelength laser diagnostics to avoid the beam bending effect caused by the density gradient. However, it is also necessary to equip a second wavelength interferometer to compensate for a fringe shift due to mechanical vibrations of the optical components since the fringe shift caused by the vibrations is inversely proportional to the wavelength. In the LHD, a CO_2 laser imaging interferometer [2] has been developed for detailed profiled measurements of density and density fluctuation. For the sake of vibration compensation a 1.06-μm YAG laser interferometer is employed. In this way, the conventional two color laser interferometer systems use two independent laser interferometer. In this type of the two color system, the fringe shift caused by the mechanical vibrations cannot be canceled out completely since the optical path difference between two independent interferometers remains and effects due to optically dispersive components are significant when the wavelength of two laser sources is different largely.

In order to overcome these difficulties, a new type of two color laser interferometer system of the Michelson type has been developed (Fig.1). The optical arrangement is similar to a single heterodyne interferometer system. The laser source is a twin optically-pumped CH_3OD laser, which simultaneously oscillates at 57.2 and 47.6 μm in wavelength, which are pumped the 9R(8) CO_2 laser line. By tuning the cavity lengths, the beat frequency of each heterodyne interferometer can be set at an optimum value, around 500 kHz for 57.2 μm and 1.2 MHz for 47.6 μm, which is determined considering detector IF frequency band width, laser tunability and frequency characteristics of band-pass filters to separate beat signals of each laser interferometer.

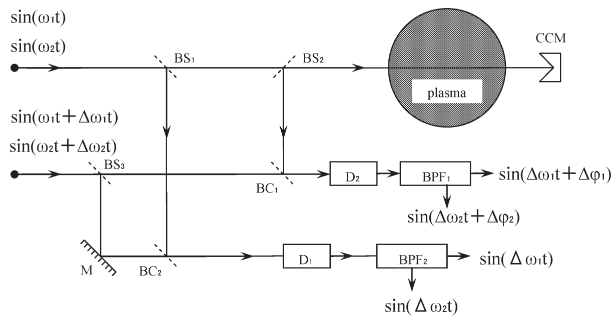

Fig.1. Schematic drawing of a new type of the two color laser interferometer of the Michelson type. The optical components are the same as a conventional heterodyne interferometer with a single laser oscillation line.

An example of vibration subtraction test is shown in Fig.2. In this case the reflecting mirror is placed on a piezo-electric transducer to confirm the idea of the two color laser interferometer and to find out what kind of problems need to be solved. The position of the mirror is modulated in a triangular waveform (Fig.2(a)) at 10 Hz with the amplitude of ~118 μm to change the optical path length. The displacements of the mirror measured by 57 and 48 μm laser interferometers are shown in Fig. 2(b). The difference of these displacements measured is also plotted in Fig. 2(b), which shows the effectiveness of the vibration compensation using two color laser oscillations.

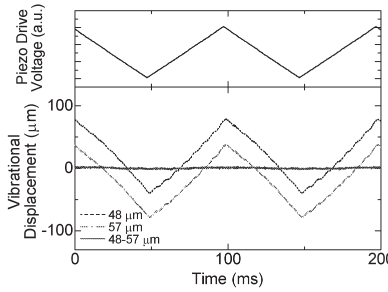

Fig.2. (a) Waveform of the applied voltage on the piezo-electric transducer. (b) The measured displacements of the vibration mirror by a 57 μm and 48 μm CH_3OD laser interferometers, and their difference.

References

[1] K. Kawahata, *et al.,* Rev. Sci. Instrum.**70**, 707 (1999).

[2] K. Tanaka, *et al*., Rev. Sci. Instrum. **75**, 3429 (2004).