§11. Development of THz Laser Diagnostics

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A two color laser interferometer using THz laser sources is under development for high performance operation on the Large Helical Device. Through investigation of THz laser sources, we have achieved high power simultaneous oscillations[1] at 57.2-μm and 47.6 μm of a CH_3OD laser pumped by a cw 9R(8) CO_2 laser line. The laser wavelength around 50 μm is the optimum value for future fusion devices from the consideration of the beam refraction effect and S/N for an expected phase shift due to plasma. In these short wavelength laser diagnostics it is a critical issue how to compensate the effects of the mechanical vibrations on the interferometer. In order to solve this problem we have been developing a two color laser interferometer[2] in the THz range, using simultaneous oscillations at 57.2 μm and 47.6 μm of a CH_3OD laser.

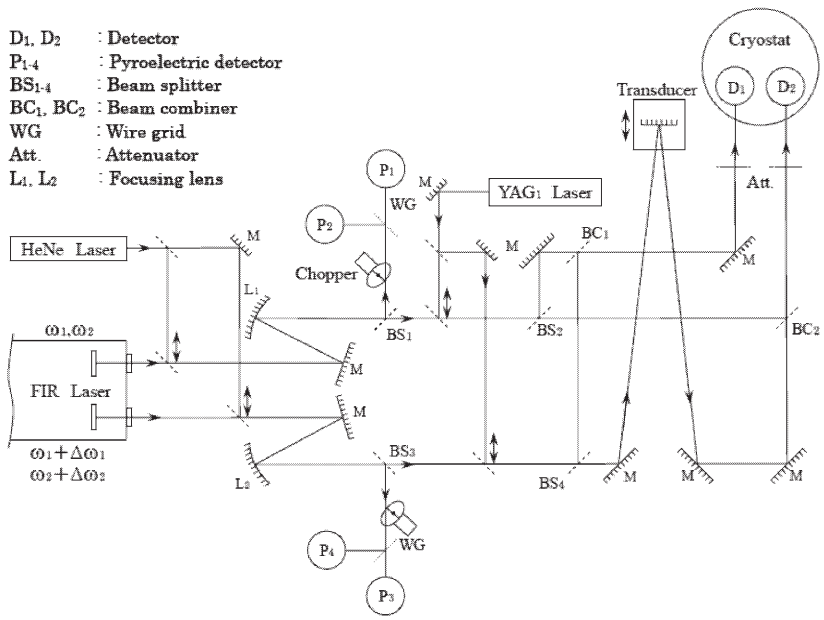
Figure 1 shows a schematic drawing of the two color laser interferometer system, which is presently being tested. The system consists of a twin THz laser having a 3 m cavity length, beam splitters, beam combiners, a laser power monitoring system and gallium-doped germanium photoconductors operating at the liquid He temperature. For the optical axis alignment, both a visible He-Ne and a 1.06-μm YAG lasers are used since the beam splitters ($BS_{1\text{-}4}$) and combiners (BC_1, BC_2) are made of non-doped silicon which is a low absorption material[3] in THz wavelength, but opaque to visible light. The optical axis of the THz laser is measured by using a liquid crystal sheet, and then the axis of a helium-neon laser is set on that of THz laser. After the beam splitters (BS_1, BS_3) optical components are aligned with a 1.06-μm YAG laser with infrared sensor cards. The detectors are specially designed unstressed Ge:Ga detectors by QMC Instrument Ltd. for the improvement of the spectral responsivity around 50 μm. The output power of each laser oscillation (ω_1, ω_2, $\omega_1+\Delta\omega_1$, $\omega_2+\Delta\omega_2$) is monitored by using pyroelectric detectors ($P_{1\text{-}4}$) with mechanical choppers.

The beat frequencies can be changed with the cavity length and pressure of the FIR laser cavity. It is important to know how high a beat frequency is available since the larger frequency modulation enables us to measure the electron density with a higher time resolution. The frequency shift is obtained by changing the length of one laser cavity of the twin laser system via stepping motor with a minimum step size of 0.02 μm, while that of another laser cavity is fixed. The minimum step value of the frequency shift Δf can be calculated by simply using the tuning equation as follows;

$$\Delta f = -f\frac{\Delta L}{L} \qquad (1)$$

where f is the lasing frequency, L is the cavity length, and ΔL is the fractional change of L. The beat frequency can be controlled with the accuracy of ~35 kHz for 57 μm. The noise level of the detection system including detector noise and laser noise is found to be about – 60 dBm, Each beat frequency can be changed from 0.1 MHz to 2 MHz.

In order to simulate mechanical vibration, a reflecting mirror was modulated by means of a piezoelectric transducer, and the mirror holder was shocked mechanically to give high frequency mechanical vibrations. In the present situation, a residual error after vibration compensation is found to be less than 0.3 μm.



[1]S. Okajima, et al., Rev. Sci. Instrum. 72, 1 (2001) 1094.
[2]K. Kawahata, et al., Rev. Sci. Instrum. 79, 10 (2008) 10E707.
[3]K. Nakayama, et al., Electr. Eng. Jpn. 153, (2005) 1.

Fig.1 Schematic drawing of a two color laser interferometer under development.