# §16. Development of a Heterodyne Dispersion Interferometer for High Time Resolution Measurement

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Reliable electron density measurement with a $CO_2$ laser (10.6 μm) dispersion interferometer (DI) had demonstrated on LHD [1]. Since it is free from the mechanical vibrations, a vibration isolation system is not necessary. Even though the optical table is placed on the diagnostic platform without a vibration isolation system, a good density resolution of $4\times10^{17}$ $m^{-3}$ has been obtained. A disadvantage of the phase-modulated dispersion interferometer is a time resolution. The upper limit of the time resolution is determined by the modulation frequency of the phase modulator. On LHD, a photoelastic modulator (PEM) is used and the modulation frequency is 50 kHz. Although this is sufficient for fueling control, it is difficult to measure density fluctuations.

There are two ways to improve the time resolution. One is replacement of the PEM to an electro-optic modulator (EOM). However, the EOM at 10.6 μm is not matured and thermal instability was reported. The other is to introduce a heterodyne technique. It uses a acousto-optics modulator (AOM) with a frequency of 40 MHz. Figure 1 and 2 show the optical arrangement of the proof of principle experiment at General Atomics and its photograph, respectively. One of challenges of the heterodyne DI is beam alignment of the second harmonic (SH) component. Onece the SH is separated from the fundamental component to add the frequency shift with the AOM. Generally speaking, the power of the SH from the conteneous-wave laser light is so small that it is difficult to align the SH. These days, OP-GaAs, whose efficiency of the second harmonic generation is about 100 times higher than that used for the DI on LHD, is developed and became commarcialy available. A power of several mW of SH, whose beam spot can be visualized with a liquid crystal sheet, is obrained from the 10 W injection.

Figure 3 demonstrates the vibration cancellation. Since the beam paths of the fundamental and the second harmonic are common except optics for the frequency shift by the AOM, the phase shift of the vibrations is cancelled. When a mirror just after the AOM is tapped by a small tool, the measured phase shift by the vibration is ±400 deg. On the other hand, the corner cube mirror, where the paths are common, the phase shifts by the vibrations are well cancelled. The standard deviation of the phase is 1 deg. with a time resolution of 30 ns for short time data (1 s). The phase resolution is determined by the offset drift and is approximately 20 deg. over a 100 s interval, which corresponds to a line density of $8\times10^{18}$ $m^{-2}$ [2].

This work was supported by Japan / U. S. Cooperation in Fusion Research and Development.

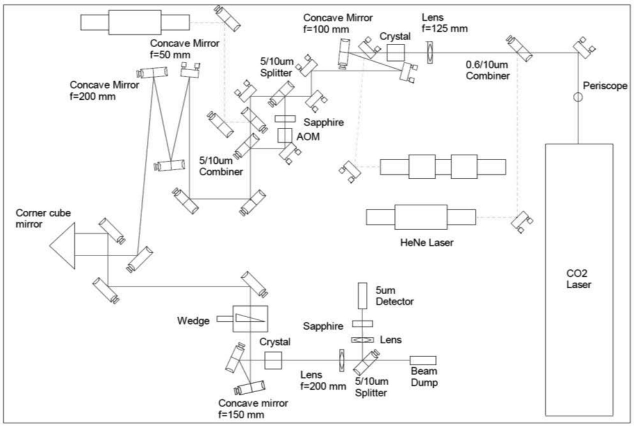


Fig. 1: Optical arrangement of the proof of principle experiment of the $CO_2$ heterodyne laser dispersion interferometer (HDI).

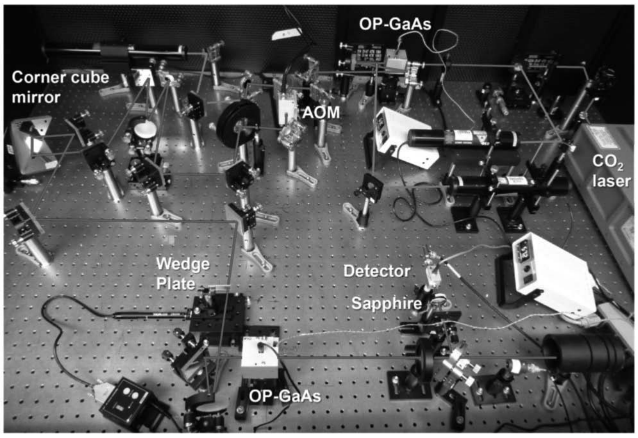


Fig. 2: Photograph of the HDI

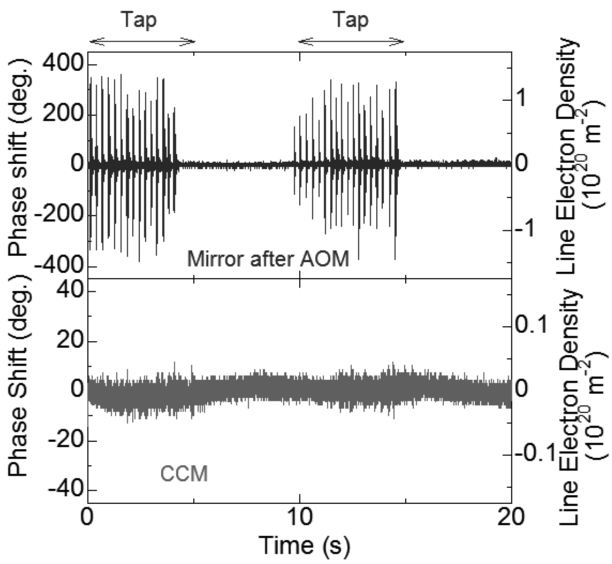


Fig. 3: Vibration cancellation by the HDI

1) T. Akiyama *et. al.*, Rev Sci Instrum. 85, 11D301 (2014).
2) T. Akiyama *et. al.*, submitted to Rev Sci Instrum.