# §32. Feasibility Study of a Interferometer with Self-correction of Mechanical Vibrations on Heliotron J

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The electron density is one of indispensable parameters not only for physical analysis but also for fueling control. A heterodyne interferometry is a main density measurement method at present fusion devices. However, there are two disadvantages. One is measurement errors due to mechanical vibrations and the other is fringe jump errors in a high density range. These days, the electron density in Heliotron J is increasing by SMBI and configuration with low toloidicity. Hence, the density measurement method which can be used with high resolutions and high reliability even in the high density range is required.

A dispersion interferometer can compensate the mechanical vibration by itself [1] and the vibration isolation system are not necessary. The principle of the dispersion interferometer is shown in Fig. 1. The probe beam is a mixture of the fundamental and the second harmonic beams, which is generated with a nonlinerar crystal. After passing through a plasma, the other second harmonic beam is generated from the fundamental beam with the other nonlinear crystal and the interference between the two second harmonic beams is detected. Then, the phase shifts due to the mechanical vibrations are canceled because the beam paths of the two second harmonic beam are the same and then the vibrations are also the same. Therefore, only the phase shift due to a plasma remains in the interference signal. This is the reason why the dispersion interferometer can compensate the vibrations by itself. The small phase shift due to a plasma less than one fringe is acceptable, because the phase shift due to mechanical vibrations, which cause measurement error, is almost canceled. This means that the density can be determined from the phase shift without 2π uncertainty: no fringe jump error in principle.

Figure 2 shows the variations of the baseline of the $CO_2$ laser dispersion interferometer installed on LHD. The variation determines the resolution of the line-integrated density resolutions and is within +/- $2\times10^{17}$ $m^{-2}$ with a response time of 30 μs. On Heliotron J, it is expected that the laser source of the dispersion interferometer is the $CO_2$ laser on Heliotron J, too. The laser light is supposed to be injected from the outboard to inboard sides and to be reflected by a retroreflector installed inside the vacuum vessel. Then, the path length in a plasma is 0.6 m in double path. In the case that the above resolution is obtained on Heliotron J, the expected phase shift and the signal to noise ration (S/N) are shown in the Table 1. Here, S/N is defined as the ratio of the line averaged density times the path length (0.6 m) to the density variations ($2\times10^{17}$ $m^{-2}$). The S/N larger than 100 is realized when the line-averaged electron density is larger than $3.3\times10^{19}$ $m^{-3}$. The electron density when the phase shift exceeds one fringe is $2.3\times10^{20}$ $m^{-3}$, which is much higher than the expected density in Heliotron J. Hence, the phase shift of the $CO_2$ laser dispersion interferometer is can be always supposed to be less than one fringe and the line-averaged density can be determined without 2π uncertainty

In conclusion, the CO2 laser dispersion interferometer on Heliotron J can be operated without fringe jump errors even in the case of high density discharge.

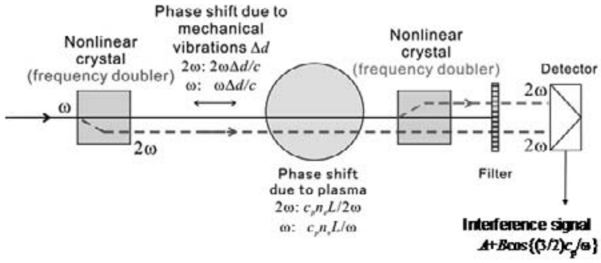


Fig. 1: Principle of the dispersion interferometer

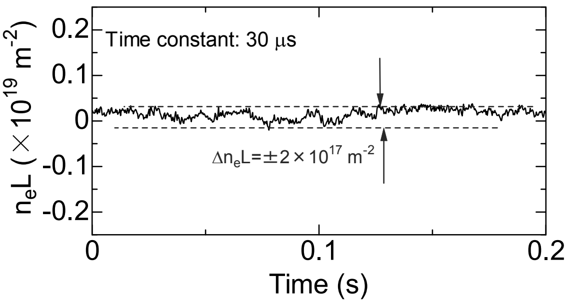


Fig. 2: Baseline variations of the dispersion interferometer on LHD. The density resolution is determined by this width of the variations.

Table 1: Expected signal to noise ratio S/N and the phase shift on Heliotron J in the cases of several density

| $n_e$ ($m^{-3}$) | $n_e L$ ($m^{-3}$) | S/N | Phase shift (deg.) |
|---|---|---|---|
| $1.0\times10^{19}$ | $6.0\times10^{18}$ | 30 | 15 |
| $3.3\times10^{19}$ | $2.0\times10^{19}$ | 100 | 50 |
| $1.0\times10^{20}$ | $6.0\times10^{19}$ | 300 | 150 |
| $2.3\times10^{20}$ | $1.4\times10^{20}$ | 700 | 360 |

1) P. A. Bagryansky *et. al.*, Rev. Sci. Instrum. **77**, 053501 (2006).