§12. Application of Precise Phase Detector for Density Profile and Fluctuation Measurements Using CO$_2$ Imaging Heterodyne Interferometer on LHD

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A two-color CO$_2$/YAG laser imaging heterodyne interferometer (HI) was recently equipped with a precise digital phase detector (PD), which was developed at Budker Institute of Nuclear Physics in Novosibirsk and is described in detail elsewhere [1, 2]. The PD has phase resolution $1\cdot10^{-4}$ fringes and temporal resolution 1 μs. Both are one order of magnitude finer than that of previously employed analog phase detectors. This modification enables detailed measurements of plasma density dynamics during pellet ablation and, in addition, observations of density fluctuations [3]. Better temporal resolution is important in pellet discharges with fast rising density gradients. With new PD, it is possible to combine HI with a phase contrast imaging (PCI), particularly in discharges with relatively large edge fluctuations. Though HI has a lower sensitivity to density fluctuations compared to the phase contrast method, it is free from the inherent shortcoming of PCI - the insensitivity to low-k fluctuations. The additional advantage of HI for measurement of density fluctuations is that absolute calibration is not required.

The temporal resolution of the new PD is illustrated by Fig. 1 where a small fraction of 3-second time trace of the line-integrated density of the discharge with multiple pellet injection is presented. The spatial resolution of the heterodyne interferometer and sensitivity of the PD to density fluctuations is demonstrated in Fig.2. The line-average density fluctuation amplitude profile, <δNeL>, has a maximum at chord position R=4.15 m, which penetrates to a minimum normalized radius of ρ=0.9. The total frequency spectrum for this discharge is shown in Fig. 3. The plasma signal exceeds the noise more than order of magnitude. At low frequencies, the noise level is mostly determined by vibrations. The spatial spectrum is shown in Fig.4

References
1. P.V.Zubarev , A.D. Khil'chenko, Instruments and experimental techniques, 46, 171, (2003)
2. V.F.Gurko, et al, Instruments and experimental techniques, 46, 619, (2003)
3. L.N. Vyacheslavov et al., to be published Rev. Sci, Instrum.

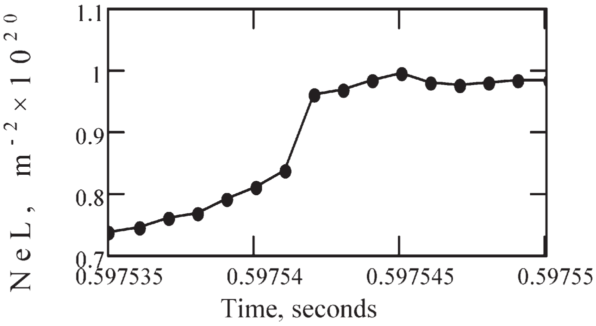

Fig.1. Line-integrated density recorded in a pellet discharge with magnetic configuration having R$_{ax}$=3.75 m

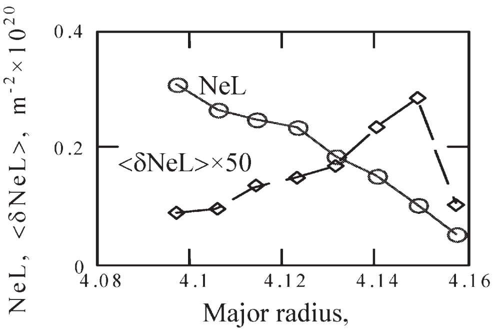

Fig.2 Line-integrated density recorded in a pellet discharge with magnetic configuration having R$_{ax}$=3.75

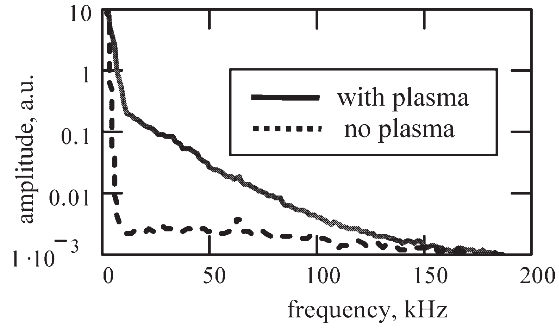

Fig.3. Frequency spectra of density fluctuations. No vibration compensation is applied in these experiments.

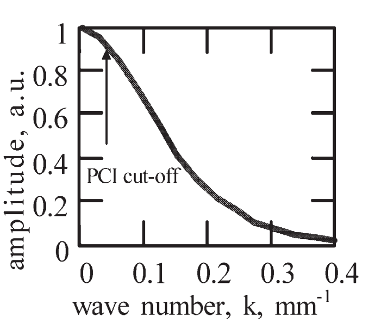

Fig.4. Spatial spectrum of density fluctuations for frequencies greater than 5kHz. The arrow indicates the low k limit that the phase contrast technique would have, for this system.