First Heterodyne CO2 Laser Based Dispersion Interferometer Measurements Made on DIII-D

Recently, as part of a Japan / US collaborative agreement, T. Akiyama from the National Institute of Fusion Science (NIFS), working with DIII-D researchers, developed the first large bandwidth CO2 laser based heterodyne dispersion interferometer (DI)[i].

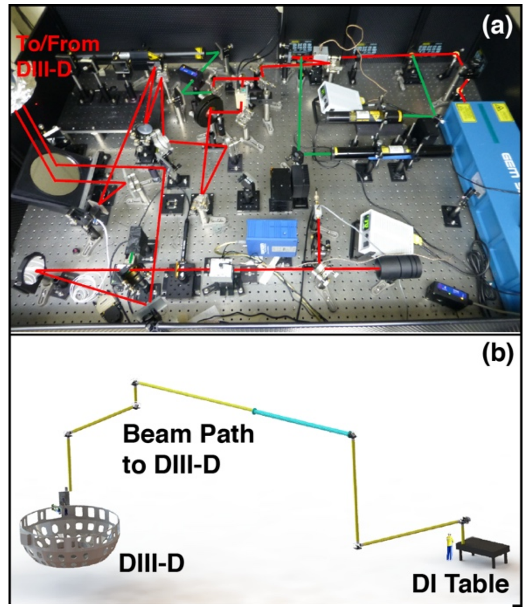

Figure 1. (a) Heterodyne CO2 laser dispersion interferometer optical table. (b) Beam path from DI Table to DIII-D.

Low-noise, large-bandwidth interferometer measurements are a requirement for reliable density control in magnetic fusion devices. Typically, this is accomplished with a two color interferometer where one color is a mid-infrared laser and the other color is a shorter wavelength, often visible, laser. The two wavelengths are used to separate the phase shifts induced by the plasma and vibration of the optical components. The dispersion interferometer is a special type of two color interferometer. However, in the DI approach, the shorter wavelength is generated by a frequency doubling crystal and interference only takes place at the shorter wavelength after the combined beams pass through a 2nd doubling crystal. Advantages of this approach include inherent cancellation of vibration, no need for a reference leg, orders of magnitude fewer fringes, reduced susceptibility to interference “fringe skips” as well as improved line-averaged density resolution.   The DI system developed as part of this collaboration (See Figure 1) is the first large bandwidth heterodyne DI implementation as well as the first DI in operation on a large tokamak.

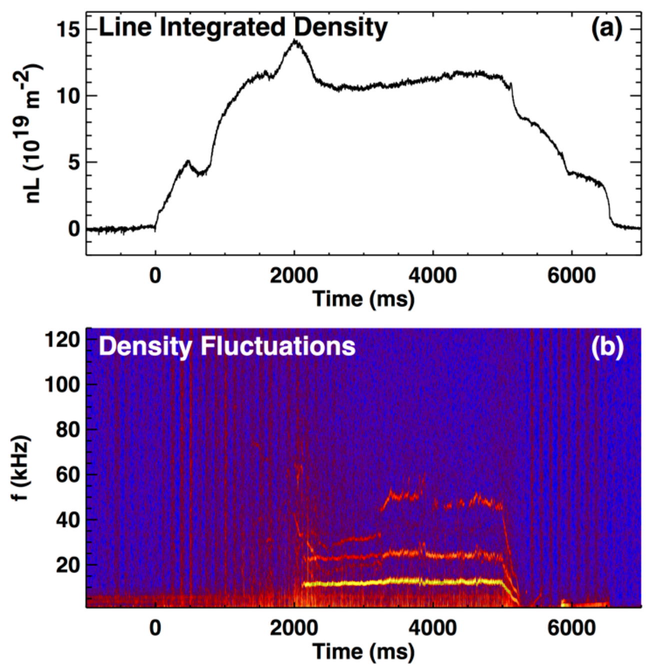

Figure 2. DI measurements of DIII-D discharge 167520. (a) Line-integrated density. (b) Spectrogram showing DI measured density fluctuations.

The new DI system on DIII-D shows extremely good density resolution (See Figure 2a) and the system’s large bandwidth capability allows it to clearly resolve plasma disruptions, rapid bursts of plasma associated with edge localized modes and high frequency density fluctuations in the plasma core (See Figure 2b). While similar to lower bandwidth systems in operation on the Large Helical Device (LHD) at NIFS and previously the TEXTOR tokamak in Germany, the dispersion interferometer here makes use of high conversion efficiency frequency doubling crystals developed with DOE SBIR funds (DE-FG02-08ER85208) as well as a 40 MHz acousto-optic modulator to improve the system bandwidth and phase resolution. In principle, the heterodyne DI bandwidth is limited only by the 40 MHz acousto-optic cell drive frequency. The DI implementation on DIII-D temporarily used the ~100 m beam path for the ITER prototype interferometer that will be installed in this fall. Additionally, key to the success of this measurement was the use of a feedback alignment technique, developed for the ITER interferometer system (DE-AC02-09CH11466), which is able to keep the return beam aligned on a ~500 micron active area of a frequency doubling crystal in the presence of large motion.

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[i] T. Akiyama, M.A. Van Zeeland, R.L. Boivin, T.N. Carlstrom, et.al, "Bench Testing of a Heterodyne CO2 Laser Dispersion Interferometer for High Temporal Resolution Plasma Density Measurements", Rev. Sci. Instrum., In Submission (2016)