

FIRST RESULTS OF THE PROTOTYPE CO₂ – He Ne INTERFEROMETER FOR ELECTRON DENSITY MEASUREMENTS IN THE TJ-II STELLARATOR

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1. Introduction.

Laser heterodyne interferometry is a proven method for measuring electron density in fusion plasmas. CO₂ (10.6 μm) and He-Ne (633 nm) lasers have typically been used [1], though recently the use of shorter wavelengths have been reported (Nd:YAG, 1.064 μm) [2]. Though mainly used in Tokamaks, the idea of having a low cost, reliable diagnostic for electron density in Stellarators [3] and small machines [4] using these sources has recently been under study.

This work shows the first results of the laboratory prototype of the IR Heterodyne Laser Interferometer for electron density measurements in the TJ-II Stellarator. This diagnostic will be of critical importance during the second phase of operation of the Stellarator (NBI heating). The interferometer uses CO₂ and He-Ne laser beams traveling along the same path (15 meters) for vibration subtraction. Acousto-optic modulation at 80 MHz (He-Ne) and 40 MHz (CO₂) are used. A dedicated phase detector working at 1 MHz intermediate frequency is used for phase detection [5].

This work is organized as follows. In section 2 we describe the laboratory prototype we have used for the study of the mechanical vibration subtraction error, and we estimate the expected electron density measurement resolution. In section 3 we detail the main parameters of the final interferometer currently being installed on TJ-II Stellarator, and we finish in section 4 with the final considerations.

2. Experimental tests of the vibration phase measurements.

In order to study the limits for electron density measurements due to mechanical vibrations we have used a laboratory prototype similar to that discussed in Ref. [2]. The same lasers (CO₂ and He-Ne), optics, and detection system has been used that is planned for installation on TJ-II, but with a 1.5 meter path length. The beams are attenuated with neutral density filters for the CO₂ and polarizers for the He-Ne to match the intensities expected on TJ-II.

In figure 1 we show the output of the interferometer, in units of CO₂ fringes, with the vibrations subtracted according to:

$$\text{Error} = \varphi_{\text{CO}_2} - \varphi_{\text{He-Ne}} * \frac{\lambda_{\text{He-Ne}}}{\lambda_{\text{CO}_2}} \quad (1)$$

The high frequency component in the signal has been identified as electrical interference in the CO₂ channel. The error that this small ripple would introduce in the electron density measurements is of the order of 1/500 of a CO₂ fringe.

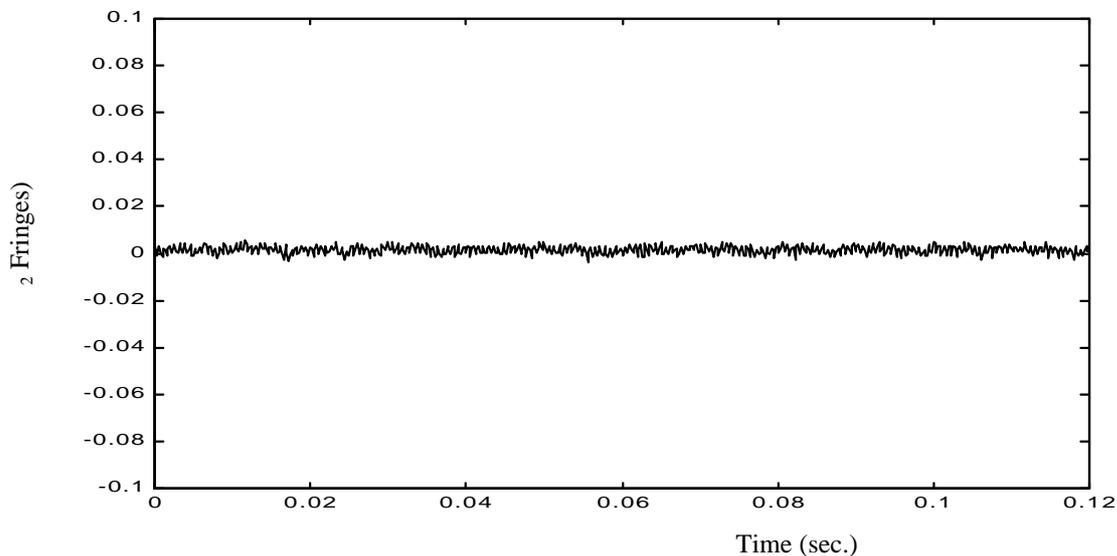


Figure 1
Output of the Interferometer while at rest

In figure 2.a. we show the vibrations produced at each wavelength, again in units of CO₂ fringes, by hammering the optical table. The subtraction error, shown in figure 2b , is less than 0.02 fringes. We are currently investigating the source of this error.

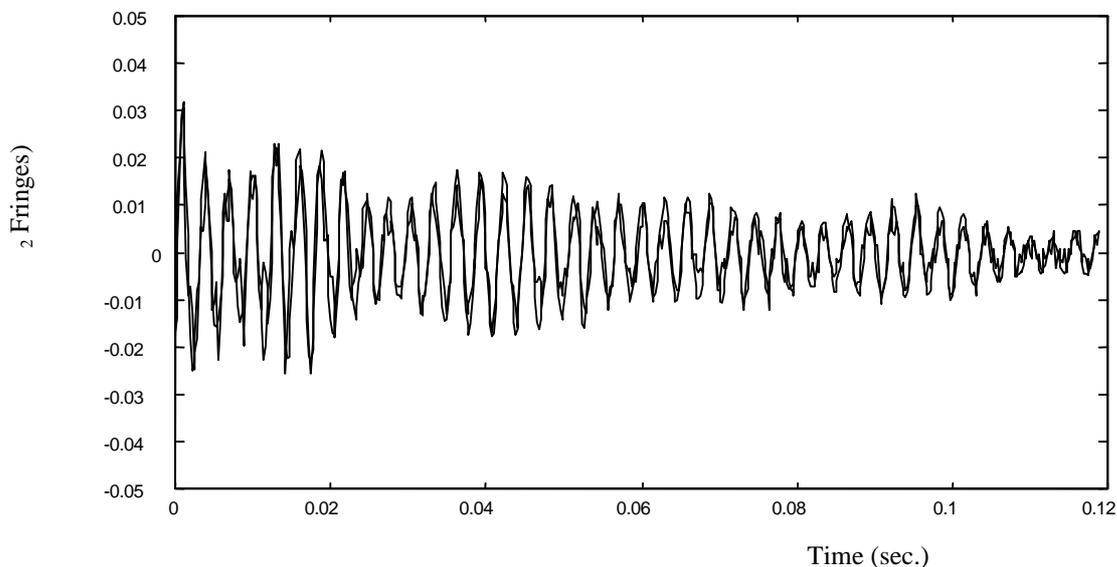


Figure 2.a
CO₂ and He-Ne outputs for the test

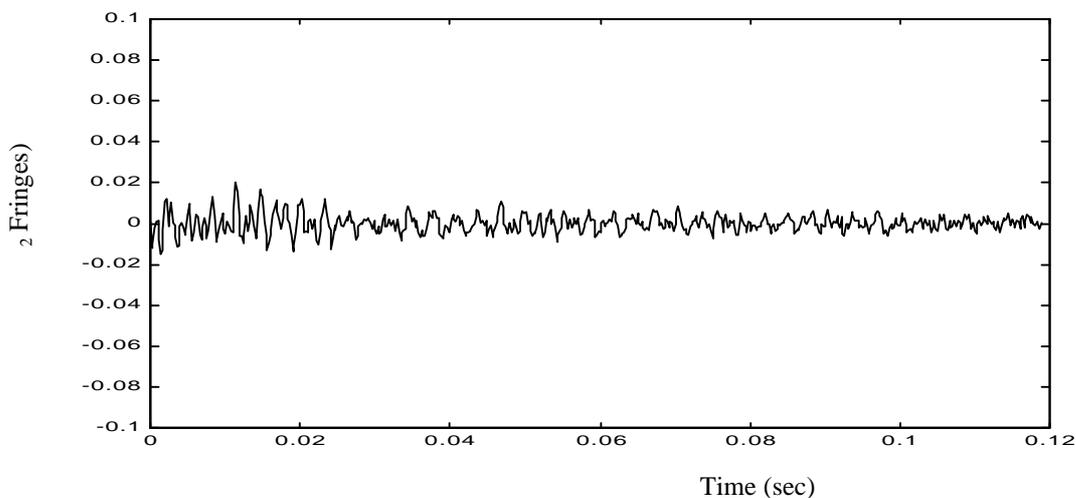


Figure 2.b
Error due to vibrations from Figure 2.a

3. Description of the TJ-II Laser Heterodyne Interferometer.

The final version of the prototype is now being installed on the TJ-II Stellarator. The first electron density measurements are expected in the summer of 1999. This paragraph is devoted to the description of the main parameters of this electron density diagnostic.

The interferometer uses a two pass, 15 m pathlength, Mach-Zehnder scheme to increase its sensitivity. The main optical components are on an optical table which dimensions are 4.2 x 1.5 meters installed directly under the diagnostic window. The measurement beam is directed through the vacuum vessel with a 10 cm diameter mirror mounted at 45° relative to the plane of the table. Another 10 cm diameter mirror located in the top of the machine, but fixed to the machine structure, reflects the beams back to the optical table with a slight angle relative to the incident beam. This angle allows the measurement and reference beams to be easily combined at the last beamsplitter without interference from the outgoing measurement beam.

The detection is performed separately for both wavelengths with the aid of a beam combiner that redirects each wavelength to its detector. For He-Ne we use an APD optimized for a wavelength of 620 nm and for CO₂ a HgCdTe photoconductor is used. The two detector signals at 40 and 80 MHz are both mixed down to a 1 MHz IF frequency so that identical phase detectors can be used for each wavelength. A PC based data acquisition system is used to record the phase information. A circuit to provide a real-time feedback signal of electron density is also being developed for the second phase of TJ—II operation (NBI heating phase).

4. Conclusions.

In this paper we have reported on the final tests of vibration subtraction performance of a laboratory prototype to estimate the ultimate resolution of the laser heterodyne interferometer currently being installed on TJ-II Stellarator (CIEMAT Madrid).

The idea of having a low cost, reliable diagnostic using sources in the near IR for a small machines like the TJ-II Stellarator is very attractive when compared to those using sources in the far Infrared part of the spectrum [7]. Nevertheless, we have to assure great resolution in the phase measurement taking into account the relative small phase shifts due to the electron densities involved and proper mechanical vibration subtraction. In this work we have shown that for our system we can expect resolutions better than 1/200 rms of a fringe even when large mechanical vibrations are induced in the interferometric system.

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5. References

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