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OPERATION OF A CO_2-HeNe LASER HETERODYNE INTERFEROMETER IN THE TJ-II STELLARATOR

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I. INTRODUCTION.

Laser two-color heterodyne interferometry is a proven method for measuring electron density in fusion plasmas [1]. Though mainly used in Tokamaks with high electron densities, the idea of using two-color laser interferometers also for Stellarators and small machines taking the place of FIR laser interferometers has recently been under study [2]. The objective is to have a low cost, reliable, easy to operate diagnostic for electron density measurements in these machines [3].

In this sense, a two-color laser interferometric system has been installed in the TJ-II Stellarator (R = 1.5 m, a < 0.22 m, B = 1T) [4]. The interferometer uses CO_2 (λ=10.6 μm) and He-Ne (λ=633nm) laser beams travelling along the same nine meters path for vibration subtraction along with acousto-optic modulation for heterodyne detection. In this paper we show the first electron density measurements in the TJ-II Stellarator with such a system

This work is organized as follows. In section II we describe the two-color interferometer optical layout. In section III we describe the interferometer phase detection system. The first electron density measurements with this CO_2-HeNe laser interferometer are shown in section IV.

II. DESCRIPTION OF THE INTERFEROMETER.

Figure 1 shows the optical layout of the two-color laser interferometer (Michelson configuration) for electron density measurements in the TJ-II Stellarator. The optical components are located on an optical table 420 cm long and 150 cm wide placed directly under the access port to the Stellarator. The projection of the port is also shown in this Figure 1.

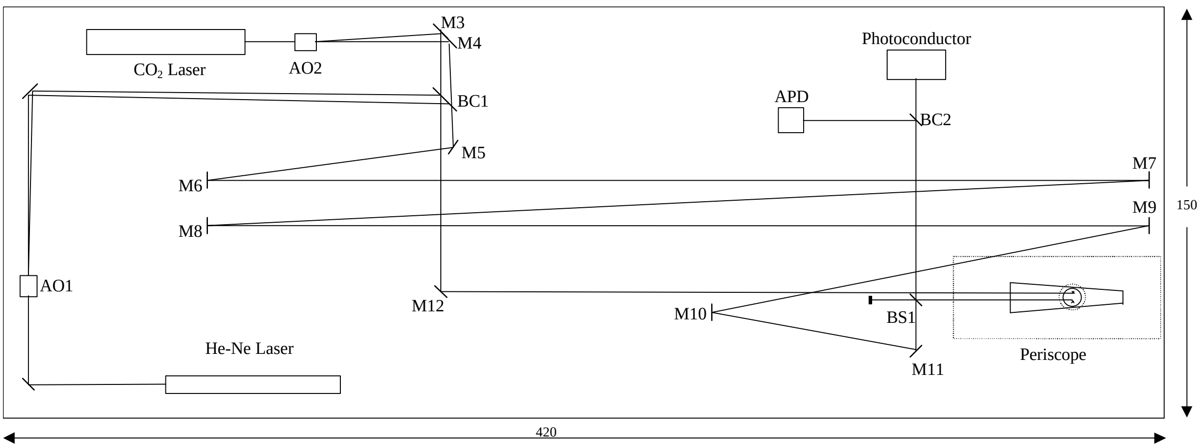

Figure 1. Optical layout of the interferometer.

In this Figure 1 we can see the two lasers (CO_2, λ= 10.6 μm, and He-Ne, λ= 633 nm) with their acousto-optic modulators. Modulation frequencies are 80 MHz for the He-Ne and 40 MHz for the CO_2. The two wavelengths are put together with the help of beam-combiner BC1. At this point both the measurement arm and the reference arm have both wavelengths travelling along the same path. The reference arm is confined in the table and it bounces back and forth the optical table (mirrors M5 to M11) to match the path-length of the measurement arm. The later is sent through the port with the aid of a periscope (see Figure 1), reflected back by a flat top mirror (fixed directly to the Stellarator structure) and redirected by the same periscope mirror to the beam-splitter (BS1) for combining the reference and measurement beams. Detection is performed with a photoconductor for the CO_2 radiation and a Si APD for the He-Ne.

III. PHASE DETECTION SYSTEM.

In figure 2 the block diagram of the phase demodulation electronic system is shown for the He-Ne channel (modulation frequency 80 MHz). The signal at the output of the APD is first amplified to fix the signal to noise ratio and then filtered before being mixed with a local oscillator (LO in figure 2) in order to generate an intermediate frequency (1 MHz) where the phase information is recovered. This is done by comparing the phase of this signal with a down-converted sample of the acousto-optic driving signal. There are two reasons for using an intermediate frequency (IF) for phase detection. Firstly, we can take advantage of the lower frequency to decrease the speed requirements of the electronic devices used in the phase detection system, and secondly, we can use the same phase detector for the CO_2 channel (modulation frequency 40 MHz) only by properly changing the local oscillator frequency.

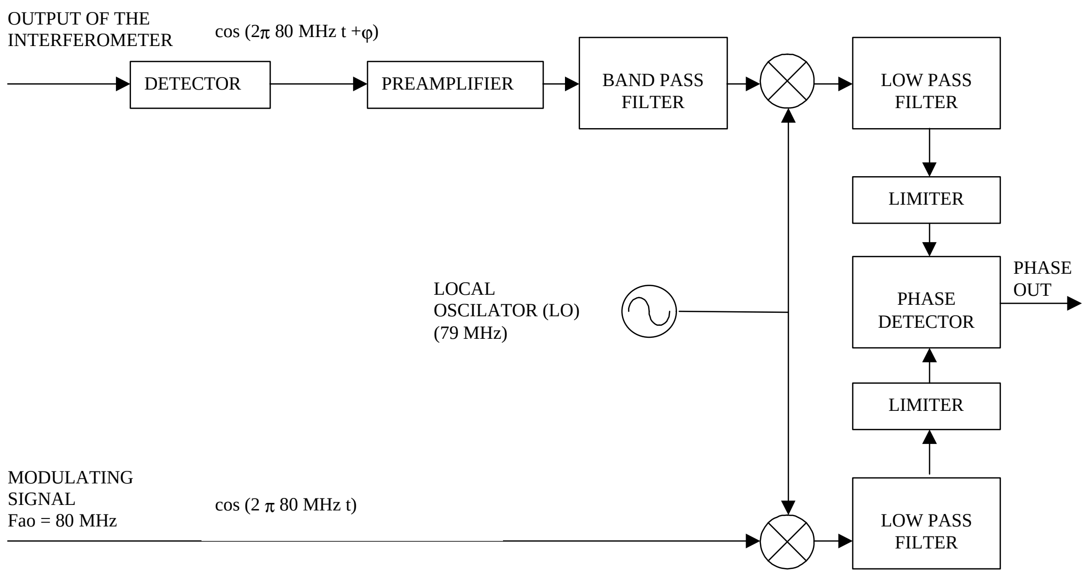

Figure 2. Schematic diagram of the phase demodulation electronics with intermediate frequency (IF) at 1 MHz.

The intermediate frequency (IF) stage at 1 MHz is common for both channels (the measurement channel from the APD, and the reference channel from the modulating signal) and consists of a low past filter to reject the unwanted harmonics at the output of the mixer and an amplifier to achieve the voltage levels needed at the input of the phase detector (Figure 2).

In Figure 3 we show the block diagram of the phase detector (figure 2). The idea is to obtain the total phase shift in two steps. First we have two fast counters counting the zero crossing of both 1 MHz reference and interferometric signals. One counter increments positively while the other counts down. The sum of the two counts represents the number of full fringes in the phase shift between the two signals. The divide by two counter outputs are used as inputs for an XOR circuit (Figure 3) which is then integrated to create an analog voltage signal proportional to the partial phase difference between the two signals. This voltage output is then converted in 10 bits signal with an A/D converter. This way the outputs of the phase detector are 10 bits reminder output and 8 bits from the counter.

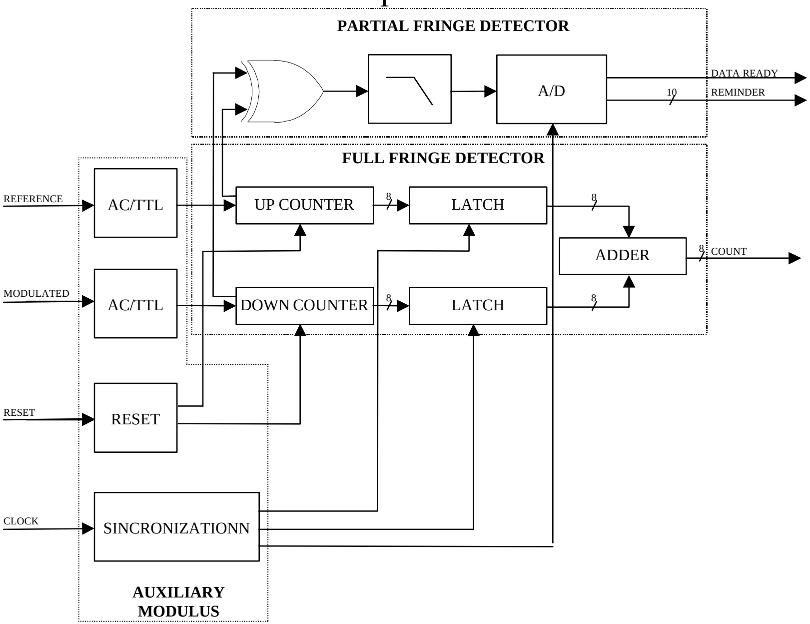

Figure 3. Phase detector block diagram.

IV. FIRST ELECTRON DENSITY MEASUREMENTS WITH THE TWO-COLOR LASER HETERODYNE INTERFEROMETER.

In Figure 4 we show the first line integrated electron density measurements obtained with the two-color laser interferometer along with the trace of the microwave (2 mm) interferometer for the TJ-II shot number 2550. We can see that the new two-color laser interferometer reproduces the results from the microwave interferometer quite well. Differences in the total line integrated density measurement is due to differences in the path traveled along the plasma by each interferometer. While the microwave line of sight crosses the plasma through the axis, the two-color laser interferometer chord is displaced from the center of the plasma.

In this Figure 4 we can also see that the two-color laser interferometer signal is much noisy showing a ripple due to uncompleted subtraction of the mechanical vibration of a maximum amplitude of 2.5 10^{-17} m^{-2} ($3x10^{-3}$ of a fringe) in the 100 Hz range. This will give an error in the density measurement of 3 10^{17} m^{-3}. Nevertheless, this interferometer is intended to be used for density measurements in the NBI heating phase of operation of the TJ-II Stellarator [4], when much more dense plasmas are expected ($n_e \cong 10^{20}$ m^{-3}), and this resolution in the electron density measurement is equivalent to 3 10^{-3}.

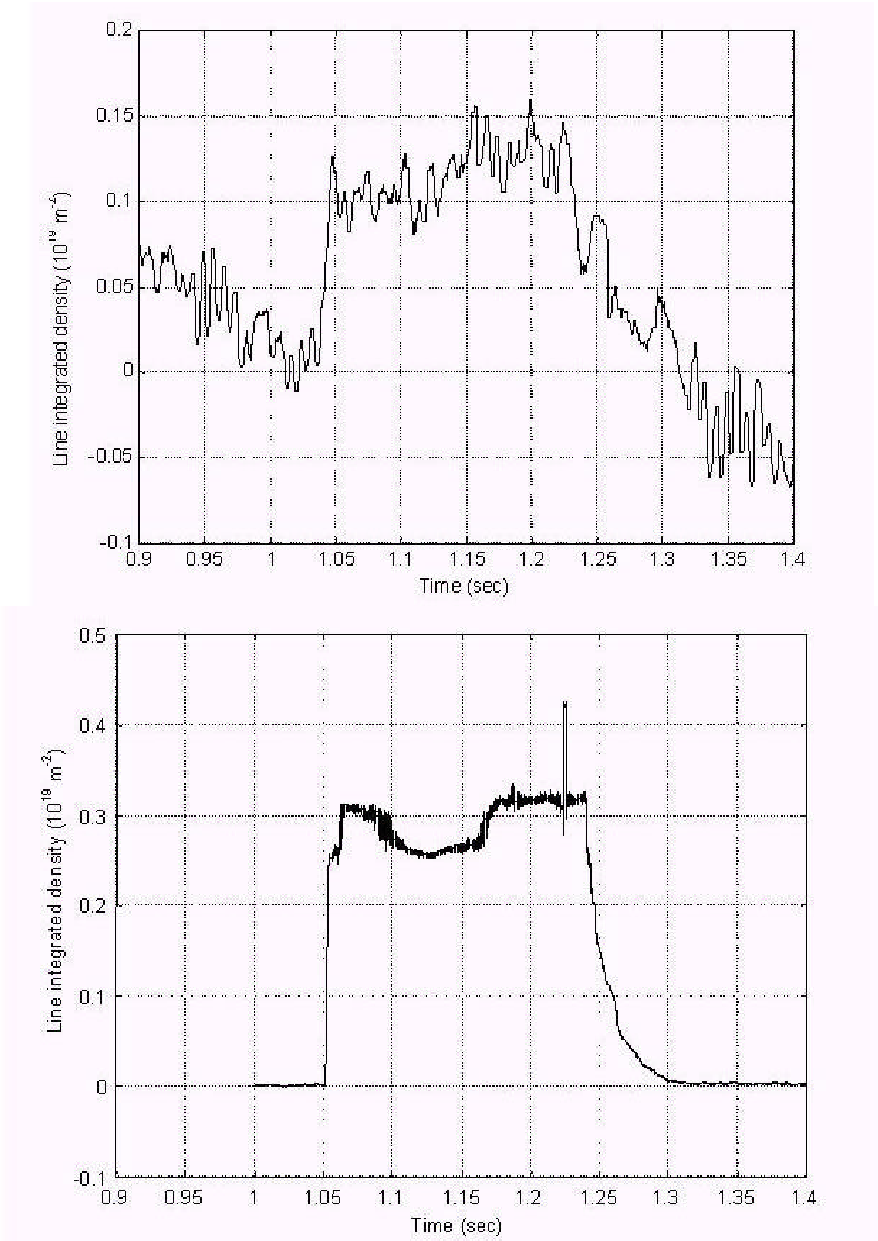

Figure 4. Line integrated density measured by the two-color laser interferometer (top) and the microwave (2mm) interferometer (bottom). Shot 2550.

V. REFERENCES.

[1] D.R. Baker and Shu-Tso Lee Dual Laser Interferometer for Plasma Density Measurements on Large Tokamaks Rev. Sci. Instrum., Vol. 49, N” 7, pp. 919-922, July 1978.

[2] H. Lamela, P. Acedo and J. Irby Phase measurements in an AC/DC interferometer prototype for IR-diagnostics Proceedings 1998 ICPP&25 th EPS, Praha 29 June- 3 July, Vol 22C, pp. 1639-1642, 1998.

[3] P. Acedo, H. Lamela and J. Irby First Results of the Prototype CO_2 He-Ne Interferometer of Electron Density Measurements in the TJ-II Stellarator Proceedings 1999 ICPP&26th EPS, Maastricht 14-18 June, Vol. 23 J, pp. 397-400, 1999.

[4] J. SÆnchez et al. Diagnostic Systems for the TJ-II FlexibleHeliac Plasma Fusion Res. SERIES, Vol. 1, pp. 338-341, 1998.