*36th EPS Conference on Plasma Phys. Sofia, June 29 - July 3, 2009 ECA Vol.**33E**, P-4.187 (2009)*

Works toward the evaluation of the ultimate spatial resolution of the new two-color heterodyne interferometer for electron density measurements in the TJ-II Stellarator

P. Pedreira[1], L.Esteban[2], A.R. Criado[1], P. Acedo[1], M. Sánchez[2] and J. Sánchez[2]

[1]*Grupo de Optoelectrónica y Tecnología Láser, Universidad Carlos III de Madrid, Leganés (Madrid), Spain*

[2]*Laboratorio Nacional de Fusión por Confinamiento Magnético-CIEMAT, Madrid, Spain*

I. INTRODUCTION.

Multichannel laser two-color heterodyne interferometry is a proven method for measuring electron density profiles in fusion plasmas [1]. Currently we are finishing the works previous to the installation of a multichannel, expanded beam, high spatial resolution, two-color (CO_2, λ=10.6 μm, Nd:YAG, λ=1.06 μm) heterodyne interferometer for density profile measurements in the TJ-II Stellarator (R=1.5 m, a<0.2, B= 1T), planned for summer 2009. The system is based on the already operational single channel two color heterodyne interferometer [2], and both (single channel and expanded beam) will coexist during the first operational runs. The ultimate design objectives for such a system for the TJ-II Stellarator are 32 channels with a 4-5 mm chord lateral separation and line integral error measurements $<10^{17}$ m^{-2}. In this paper we describe the final tests carried out before installation of the system that extend the previous studies on the expected limits on electron density measurement spatial resolution [3]. We also have evaluated the influence on the measurement of wavefront degradation due to plasma effects, optics and window degradation; and made the final test of the different optical and electronic components to be installed.

II. TWO-COLOR HETERODYNE LASER INTERFOMETER PROTOTYPE.

As a continuation of our previous works on the characterization and reconstruction of interferometric heterodyne wavefronts [3], where we studied different methods for interferometric heterodyne spatial profile reconstruction, we have designed a CO_2/He-Ne expanded beam heterodyne interferometer that has been installed at the laboratories of Carlos III University with the following goals: to validate the use of the different tools that we will use to design the two-color expanded-beam heterodyne laser interferometer for the TJ-II Stellarator, to validate and characterize the different optical and electronic components for the final system to be installed at the TJ-II (specially the CO_2 photovoltaic detector array and associated electronics), and, finally to study the heterodyne interferometric wavefronts for both wavelengths.

The two-color expanded beam heterodyne interferometric set-up is shown in Figure 1. Two telescopic systems that consist of two spherical mirrors have been used in order to obtain the expanded-beam reference and measurement arm. As mentioned before, one of the main objectives of this prototype is to validate the optical design tools to be used in the final design for the TJ-II interferometer. In this sense we have used the optical system design software Zemax. This software allows us to obtain information of the Gaussian beams (spot size, waist, divergence angle…) at any localization of the interferometer. In the prototype described in Figure 1 we have experimentally measured the spot sizes for different positions in the optical system as well as the detector outputs, and the results obtained are similar to those obtained through Zemax. These results validate the use of this software for the optical design of two-color expanded-beam heterodyne interferometer for the TJ-II as well as for the evaluation of the spatial resolution in the electron density profile measurement.

The second objective for this set-up was the characterization and validation of the CO_2 array. This 32 elements, 1 mm sensor separation, and high responsivity photovoltaic sensor have been designed with the collaboration of Vigo Systems. The sensor is packaged using a butterfly package to obtain high bandwidth and low crosstalk between channels. For this array we have designed the amplification and processing electronics that allow us to obtain the signal levels required at the phase detector input. This electronic system consists of several amplification stages as well as band-pass and low-pass filtering. Details of the two sensors (CO_2 and He-Ne) are shown in Figure 2.

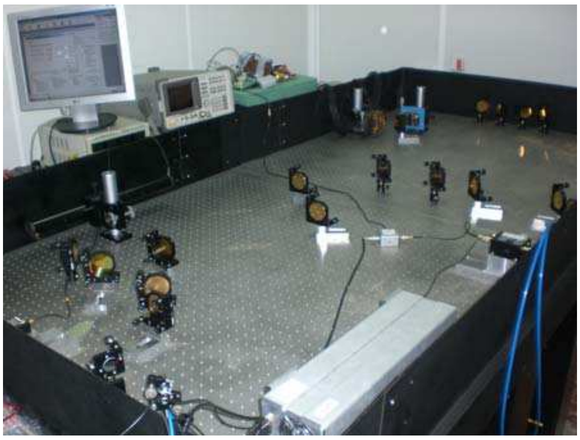

Figure 1

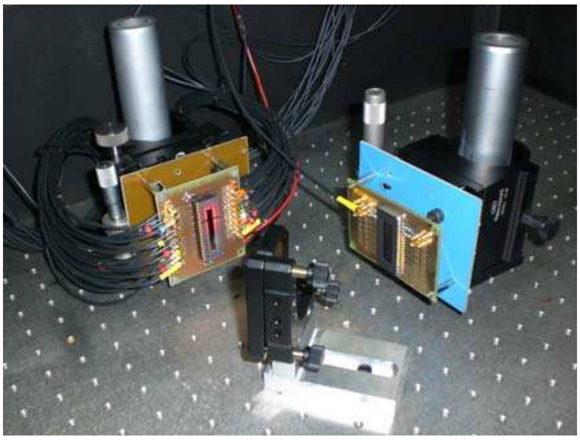

Figure 2

Finally, in figure 3 we show the first results obtained with this prototype. The first objective was to validate proper mechanical vibration subtraction. This is shown in this figure where we can see how both wavelengths (CO_2: blue line, He-Ne: red line) are able to track the induced vibrations when we knock on the optical table, allowing us their cancellation in the final system.

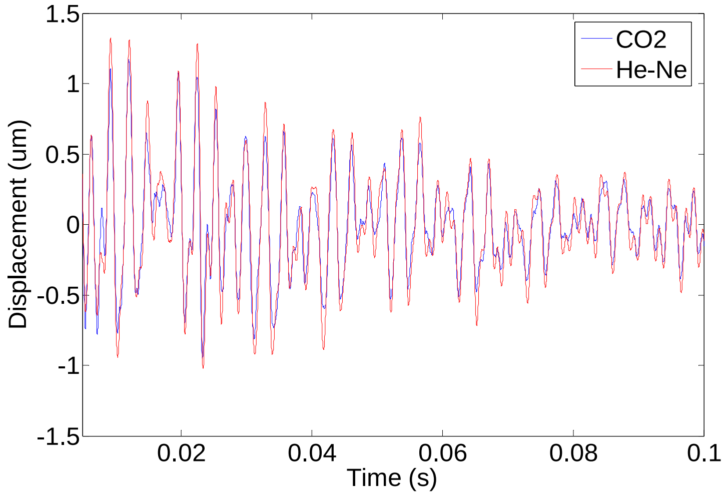

Figure 3

III. INSTALLATION OF A HIGH SPATIAL RESOLUTION TWO-COLOR EXPANDED-BEAM MULTICHANNEL HETERODYNE INTERFEROMETER FOR TJ-II STELLARATOR.

Based on the results shown, we have just finished the final design for the high spatial resolution two-color (CO_2/Nd:YAG) expanded-beam multichannel heterodyne interferometer for electronic density profile measurements for TJ-II Stellarator (see Figure 4). In this set-up a third laser source (He-Ne: 0.633 µm) is used in order to help in the alignment of the system and also to separately study some phenomena of relevance in the interferometric diagnostic that are also objective of this system: the influence of the speckle in the spatial resolution, diffraction due to apertures, and the refraction index variation associated to the ZnSe plasma access windows heating.

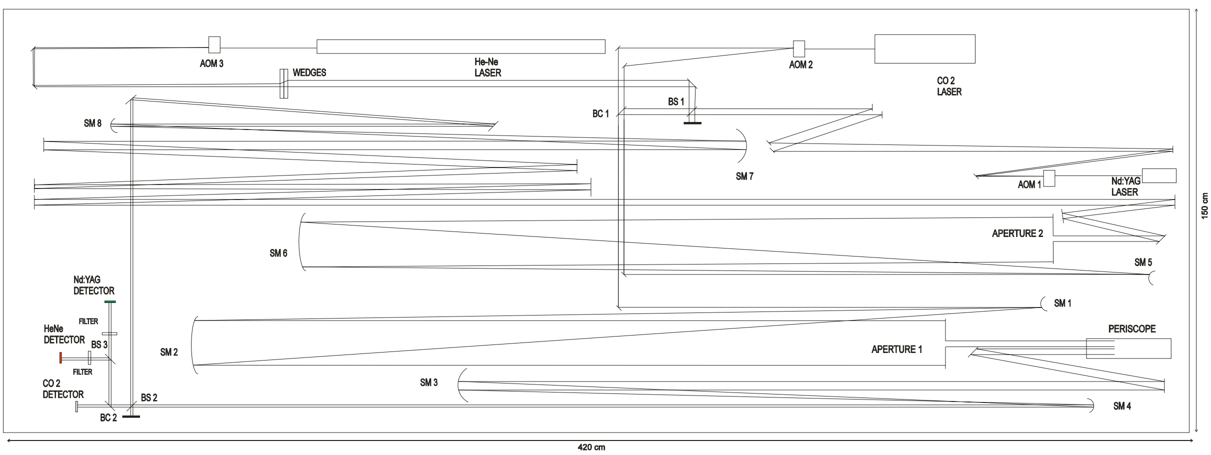

Figure 4

Due to the size of the plasma access window and the coexistence of this inteferometer with the single-interferometric system, the expanded-beams are designed to be of elliptical shape (100 x 10 mm) with the use of two spherical mirrors (SM1-SM2) and a rectangular aperture. Once the measurement arm returns from the plasma in this Michelson configuration, the demagnification is done also with two spherical mirrors (SM3-SM4) and steered to a beamsplitter for recombination with the reference arm. The spot sizes for each wavelength at the detectors are shown in the Table 1.

	Wavelength	Vertical Size (mm)
Measured Arm	CO_2	35.83
	Nd:YAG	34.12
	He-Ne	36.86
Reference Arm	CO_2	36.62
	Nd:YAG	34.53
	He-Ne	36.97

Table 1

The final installation of the interferometer shown in Figure 4 is scheduled to start July 10th 2009 during the TJ-II summer maintenance period. Final evaluation of the spatial resolution in the measurement will be performed on the final system and compared to those obtained in the scaled prototype described in section II. The final objective is to have the high spatial resolution two-color heterodyne interferometer for electron density profile measurements in the TJ-II ready and operational for the 2009/10 campaign.

IV. REFERENCES.

[1] J.H. Irby, E.S. Marmar, E. Sevillano and S.M. Wolfe. Rev. Sci. Instrum., Vol 59, Nº8, pp. 1568-1570, 1988.

[2] P. Acedo, H. Lamela, M. Sánchez, T. Estrada and J. Sánchez. Rev. Sci. Instrum., Vol 75, Nº 11, pp. 4671-4677, 2004.

[3] P. Acedo. P. Pedreira. A.R. Criado, H. Lamela, M. Sánchez and J. Sánchez. Rev. Sci. Instrum., Vol. 79, 10E713 (2008).