PHASE MEASUREMENTS IN AN AC/DC INTERFEROMETER PROTOTYPE FOR THE IR-TJII DIAGNOSTICS

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1. Introduction

Laser heterodyne interferometers are commonly used in plasma diagnostics experiments for density measurements [1]. In the TJII Stellarator built at CIEMAT (Spain) an IR CO_2 (10.6 μm) heterodyne laser interferometer is been implemented as a density measurement diagnostic (10^{19} – 10^{20} m^{-3}) using a vertical view of the plasma [2]. This IR heterodyne interferometer has a He-Ne (0.633 μm) laser for mechanical vibrations compensation following the same path as the CO_2 IR interferometer. By acousto-optic modulation at 40 MHz (10.6 μm) and 80 MHz (0.633 μm) the two laser beams of the interferometer are phase modulated in a Michelson heterodyne interferometer scheme with a 8 meter path length in each arm. The phase shift induced by plasma density variations will be obtained by phase detection of the 80 MHz and 40 MHz signals with Si (APD) and HgMnTe photoconductor detectors. These two signals are mixed down to a common 1 MHz IF and the phase measurements are obtained using a phase detector built at the Carlos III University Laboratories.

In order to test the phase measurements in the TJII heterodyne interferometer (CO_2, 10.6 μm, and He-Ne, 633 nm), where resolutions in the order of 10^{-2} of a fringe are requiered, an AC/DC interferometer prototype has been built. Mechanical vibrations are applied using a PZT (piezo-electric transducer). This AC/DC interferometer is a Michelson homodyne interferometer (DC interferometer) that shares an arm with a Mach-Zehnder heterodyne scheme (AC interferometer). This system will allow us to validate the phase measurements in the AC (heterodyne) interferometer by comparing to those obtained in the standard Michelson interferometer (homodyne).

This paper is organized as follows. First we present the optical set-up of the AC/DC interferometer and its principle of operation. We follow with a brief description of the electronic system implemented for data acquisition, and we finish with the first measurements that show a very good agreement between the phase shift measurement in both interferometers (heterodyne and homodyne).

2. Description of the system

In Figure 1 we show the interferometric set-up under study. It consists of a standard Michelson scheme and an heterodyne Mach-Zehnder interferometer with a common arm. The light from a 5 mW He-Ne laser goes through a Acousto-optic modulator (frequency of modulation 80 MHz) that acts as a beam-splitter for the heterodyne system. The zeroth order then goes to a beam-splitter and completes the Michelson interferometer (reference arm BS1-M2-BS1 and measurement arm BS1-M4-BS1). Detection is performed at detector 1 (Si photodiode). The heterodyne interferometer also has a reference arm (M2-M3-BS3) and a measurement arm (BS1-M4-BS2-BS3) and after recombination in BS3 the output signal is detected in detector 2 (Si APD). In Figure 1 we also show the use of a piezoelectric transducer (PZT in the Figure 1) to produce a mechanical displacement of the mirror M4 and in this way introduce a common phase shift in both interferometers.
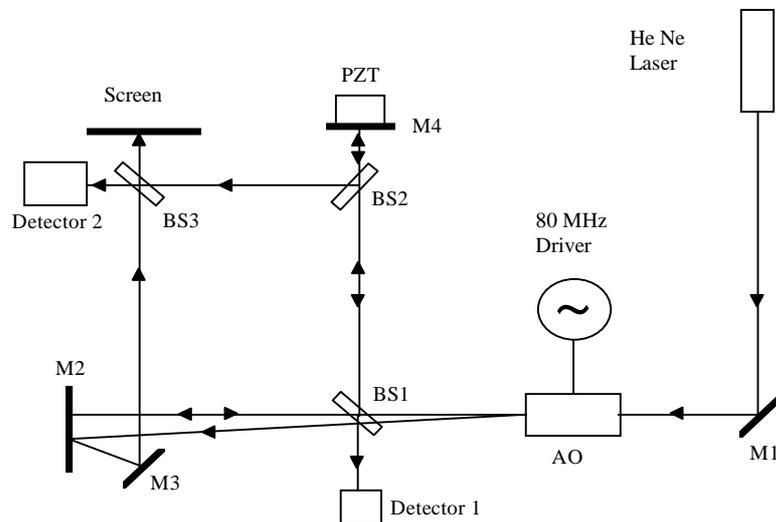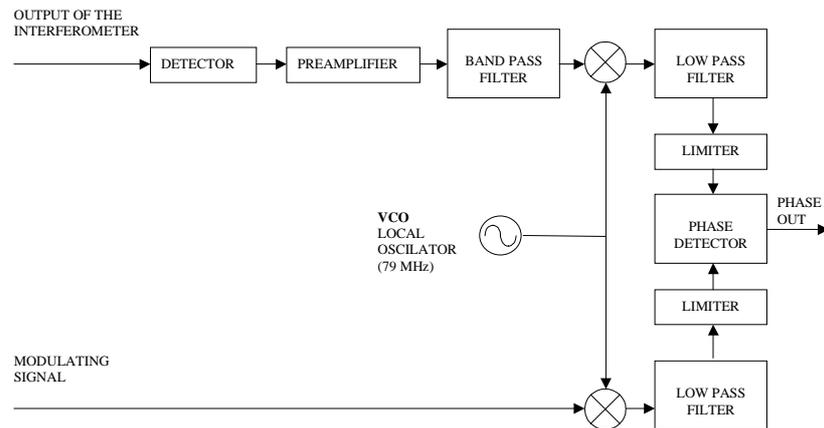

Figure 1.
Interferometric Set-up

3. Electronics Processing

To definitively use this interferometric system to compare the phase shift obtained in the heterodyne system to that obtained in the standard Michelson scheme a data acquisition system that will look to both outputs.

The light from the Michelson interferometer is directly detected with a PIN photodiode and directly recorded but the output of the heterodyne system requires a more complex phase detection scheme. First of all, the phase detection is made at an intermediate frequency (1 MHz) instead of directly at the carrier frequency (80 MHz). In this way we can take advantage of the lower frequency to decrease the speed requirements of the electronic devices used in this system.
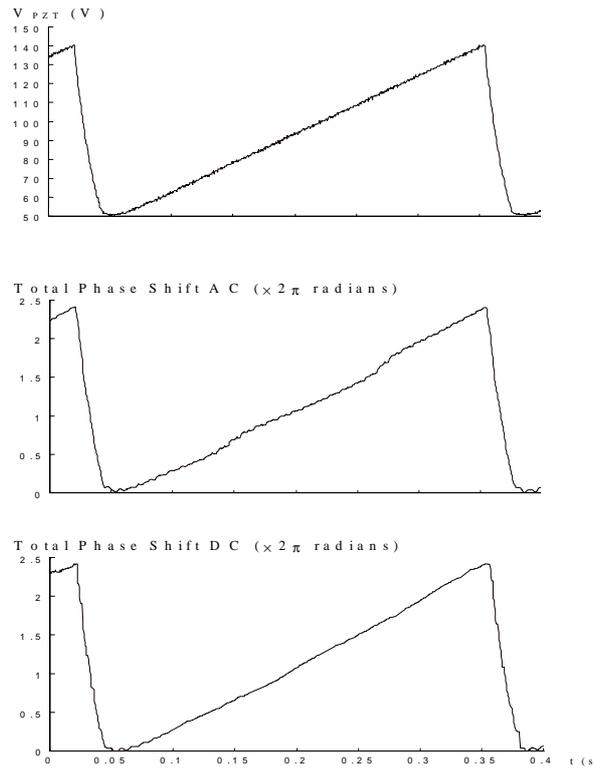

Figure 2.
AC Interferometer Detection Electronic Subsystem

In Figure 2 we show the block diagram of the electronic subsystem developed for phase detection in the heterodyne interferometer. We can see in this scheme that both the interferometric signal and the drive signal for the acousto-optic modulator (which we use as phase reference) are translated in frequency using the same local oscillator. This phase detector is described elsewhere and has a range of 256 fringes with a resolution of 1/300 of a fringe (He-Ne λ= 633 nm) [3].

4. Results

In Figure 3 we show a typical result of the output of the AC/DC interferometer. The total phase shifts measured by the AC system and the DC system are compared to the PZT excitation.

We show the voltage ramp applied to the PZT (between 50 and 140 V, frequency 3 Hz) and the phase shift detected with both interferometers expressed in fringes. The total phase shifts measured is 2.5 fringes (He-Ne, λ=633 nm) giving a total displacement of 0.8 μm (note that the path length increase in this scheme is two times the phase shift measured). We can see very good agreement between these measurements.

Figure 3.
Top trace: PZT excitation, Middle trace: Time evolution of the phase shift meausred by the Heterodyne Interferometer (in Fringes, equivalent to 2π radians). Lower trace: Time evolution of the phase shift measured by the Homodyne interferometer (in Fringes, equivalent to 2π radians)

5. Conclusions

In this paper we have validated the phase detection system developed for the TJII IR heterodyne interferometer for electron density measurements. We have shown very good agreement between the phase shifts measured in an heterodyne interferometric system and a homodyne one that share an arm experiencing a controlled mechanical displacement. With these measurements we will be able to estimate the final resolution of the electronic density measurement in TJII Stellarator.

References

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