FIRST MEASUREMENTS OF THE FARADAY ROTATION ON PLASMAS IN TCV

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1. Introduction

Polarimetry is a well known technique used to determine the magnetic field structure in tokamaks since it was first proposed by DeMarco and Segre[1,2]. Recently a far-infrared (FIR) interferometer/polarimeter technique which allows the Faraday rotation induced by the plasma to be deduced from a phase measurement was developed[3] (Method 1). The 14 channel polarimeter upgrade of the FIR interferometer on TCV is based on a modification of this method[4,5] (Method 2). It has been shown that the accuracy of the TCV equilibrium reconstruction will be substantially improved by including polarimeter data[6]. To prove a useful tool the TCV polarimeter was seen to require a precision of $\pm 0.2^0$ Faraday rotation. Due to a serious vacuum problem the TCV opening lasted much longer than predicted and we are unable to present results from actual TCV plasmas.

2. The Polarimeter/Interferometer on TCV

The Tokamak à Configuration Variable (TCV) is a compact medium sized (R=.88m, a=.24m) highly elongated tokamak capable of producing limited and diverted plasmas with currents up to 1 MA. The machine has been designed to produce many diverse plasma shapes without requiring hardware modifications.

An overview of the TCV polarimeter/interferometer system is shown in Fig. 1. The instrument is of Mach-Zehnder type where the probe and local oscillator (LO) beams are transferred from the laser room to the tokamak by means of oversized dielectric waveguides. The probe beam is then expanded into a slab-like beam and traverses TCV from bottom to top via large windows. The absorption of the operating wavelength of $214\ \mu$m in air is quite significant so all the optical elements have been placed in boxes, which, along with the waveguides, have been flushed with dry N_2. The LO is similarly expanded and combined with the probing beam on a large beam-splitter. A system of waveguides focuses the horizontal beams from the main beam combining device onto the detectors. The detection system consists of an array of 15 liquid Helium cooled InSb hot electron bolometers supplied by QMC Instr. Ltd.. A half-wave plate, mounted in a precision rotator, was placed in the path of the probe beam in order to calibrate the polarimeter measurement. A reference signal unaffected by the plasma is also provided.

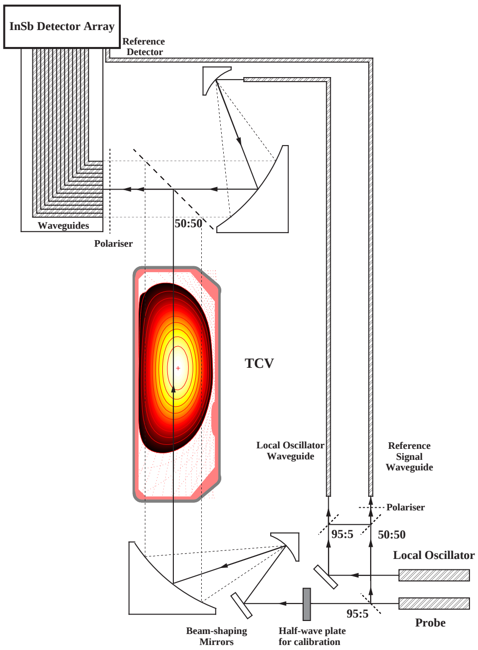

Figure 1. Overview of the TCV polarimeter/interferometer

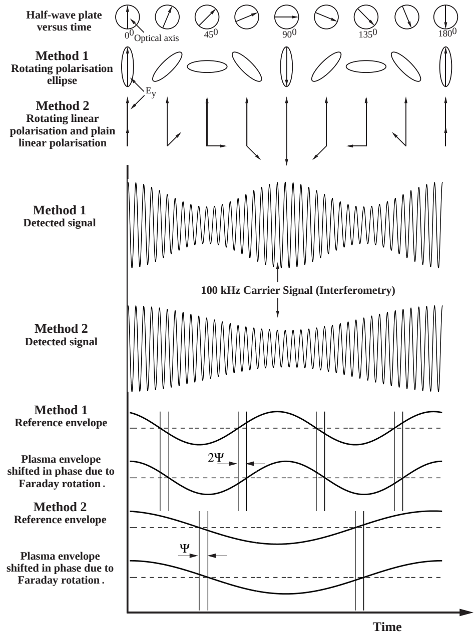

Figure 2. Schematic of the two interferometer/polarimeter methods.

3. System Description

3.1. Methods

Method 1, shown schematically in Fig. 2, uses a rotating elliptically polarised probing beam and a frequency shifted local oscillator (LO). The beat signal between the beams is a modulated waveform where the Faraday rotation Ψ, can, after some filtering, be extracted from the phase shift of the modulation envelope and the interferometer information from that of the carrier signal. Therefore, both the interferometer and polarimeter data can be measured using only one detector per channel. It was shown that this method is limited by an additional time-varying phase term which is superimposed on the required interferometer data[7]. This extra term can be effectively removed by low-pass filtering the interferometer data with the subsequent loss of time resolution.

Method 2, also shown schematically in Fig. 2, uses the combination of a rotating linearly polarised beam and a plain linearly polarised beam as the probing beam. This method produces signals similar to those obtained using Method 1 with the following differences; (a) the modulation is a purely cosine without higher harmonics; (b) the modulation frequency is lower by a factor of two; (c) the measured polarimeter phase shift is Ψ as opposed to 2Ψ and (d) the interferometer phase measurement is not corrupted by additional terms provided the difference in path lengths between the two probing beams is a multiple of π. Accordingly, the time resolution can be preserved.

3.2. The Optical Set-Up

The system, shown in Fig. 3, used to produce the probing and LO beams, was designed to incorporate both methods. The incident beam is split into the probing and LO beams and the

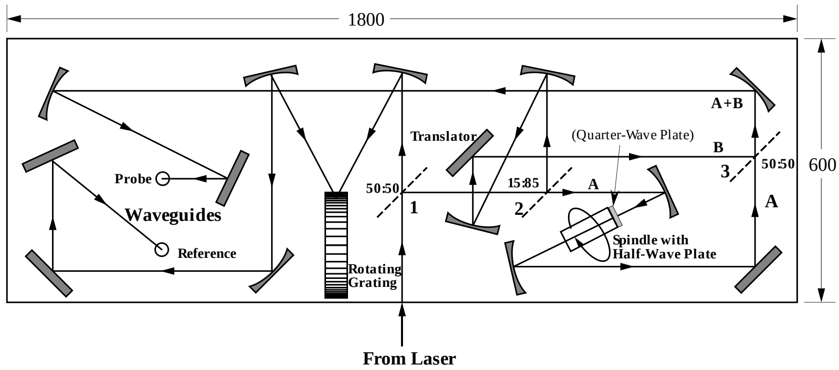

Figure 3. The optical set-up for the production of the probe and LO beams.

latter is reflected off a rotating grating to produce the frequency shift. A small fraction of the probe beam is directed through a $\lambda/2$ plate in a rapidly rotating spindle which rotates its polarisation. It is then recombined with the remainder of the beam on beam-splitter 3. The system can be changed over to Method 1 by simply removing beam-splitter 2 and turning the $\lambda/4$ plate at the entrance of the spindle to introduce some ellipticity into the polarisation of the probing beam.

4. Present State

4.1. Polarimeter

The polarimeter output for Method 1 and 2 showing steps of 0.4^o Faraday rotation on two of the central channels are shown in Fig. 4 and Fig. 5 respectively. The time resolution in both cases is 4 ms. The precision of Method 1 is seen to be the required 0.2^o Faraday rotation while that of Method 2 is $0.2^o \rightarrow 0.3^o$.

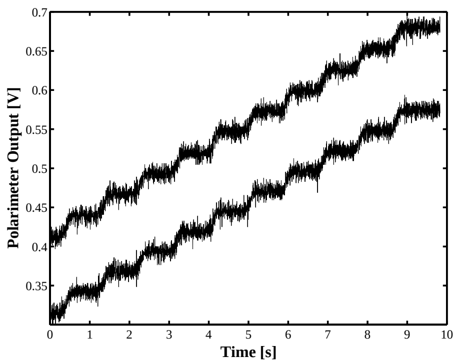

Figure 4. Polarimeter output for Method 1 with steps of 0.4^o Faraday rotation.

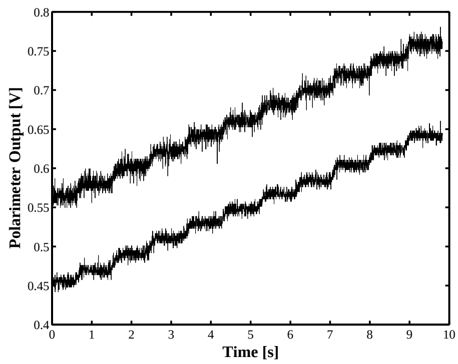

Figure 5. Polarimeter output for Method 2 with steps of 0.4^o Faraday rotation.

4.2. Interferometer

The interferometer outputs for both Methods 1 and 2 with a Faraday rotation of 40^o and modulation indices of 0.48 and 0.4 are shown in Fig. 6 and Fig. 7, respectively. Both signals are seen to have a additional time-varying phase terms which are dependent on both Faraday rotation and modulation depth. The additional term in Method 1 is much larger than that of

Method 2 and as it is inherent to that method cannot be removed. The term in Method 2 is probably due to a non-zero phase difference between the path lengths of the two probing beams and can possibly be reduced by a finer adjustment of the translator installed for that purpose (see Fig. 3). During bench tests it was shown that this term could be set to zero[5].

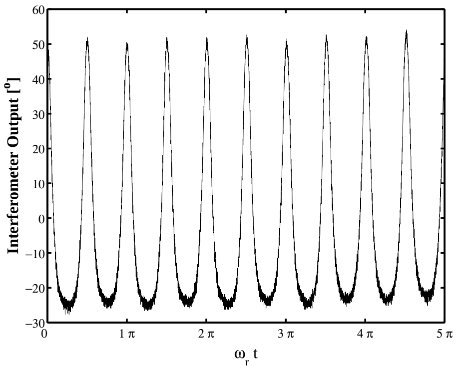

Figure 6. Interferometer output for Method 1 with $\Psi = 40^o$ and $m = 0.48$ where ω_r is the rotation frequency of the $\lambda/2$ plate.

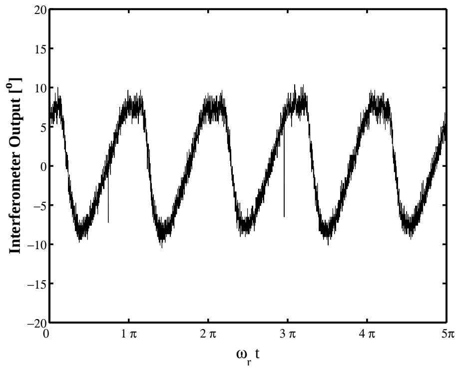

Figure 7. Interferometer output for Method 2 with $\Psi = 40^o$ and $m = 0.4$ where ω_r is the rotation frequency of the $\lambda/2$ plate.

5. Conclusions

The method and system description of the new TCV multichannel FIR polarimeter/ interferometer has been presented. It is based on a system installed on MTX and retains its major advantages with the additional advantage that the extra interferometer phase term is much smaller and can possibly be reduced or even removed completely. The precision of both polarimeters is at or very close to the 0.2^o required to enhance the precision of the TCV equilibrium reconstruction.

Due to a serious vacuum problem the TCV opening has lasted much longer than predicted and we are, therefore, unable to present results from actual TCV plasmas.

Acknowledgments

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References

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