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Reconstruction activities and first results from the Thomson scattering diagnostic on the TCABR tokamak

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Abstract. An incoherent and infrared Thomson scattering diagnostic (ITS) was transferred from ISTTOK (Lisboa) and reconstructed on TCABR (S. Paulo). In the first phase of this international collaboration, the diagnostic uses a Neodymium:Glass laser with up to 10 Joules per laser pulse and a first generation polychromator with three pairs of interference filters and avalanche photodiodes. It measures 90° scattered radiation in a single volume of observation with a single laser pulse to obtain the instant plasma electron temperature. This paper reports the reconstruction activities already carried out and presents the first experimental results. These activities include: new data model performance, laser refurbishing, new laser delivery system, stray-light reduction in the vacuum vessel, new collection lens and relative diagnostic calibration. A long run of experiments with this diagnostic shows consistency and coherence with the other TCABR diagnostics and gives indications to be able to contribute effectively to the Alfvén heating program of this tokamak.

1. Introduction

In a typical Thomson scattering system the discrete volume of the plasma to be analyzed is occupied by electrons that are illuminated by a laser pulse light.

The incoherent and infrared Thomson scattering diagnostic (ITS) developed for the tokamak ISTTOK in Lisboa was transported and reassembled on the tokamak TCABR in São Paulo, following an agreement where different local teams and hardware merged in the denominated infrared based ITS diagnostic installed on TCABR (ITS-TCABR).

This paper includes a brief overview of the ITS-TCABR hardware in Section 2. The Section 3 covers the commissioning activities carried out which will describe the prerequisites and pitfalls of the infrared based ITS diagnostic. Preliminary scattering results are presented in Section 4 along with discussion and commissioning activities still to be completed that are covered in the Section 5.

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2. ITS-TCABR Hardware

TCABR is a tokamak with 61 cm major radius, 18 cm minor radius, toroidal magnetic field of 1.1 T, and typical electron density and temperature values of $2 \times 10^{19} \text{ m}^{-3}$ and 400 eV respectively. The hardware of the Thomson scattering diagnostic is almost the same diagnostic on ISTTOK [1].

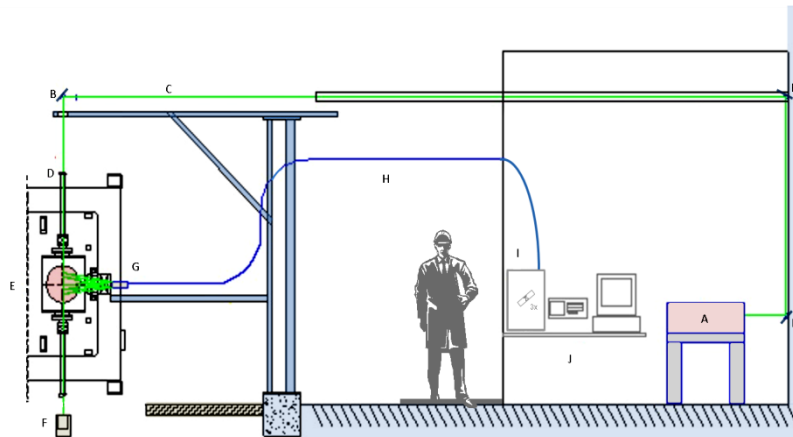


Figure 1. The ITS diagnostic lay-out at the TCABR tokamak with approximate sizes: (A) Nd:Glass laser (Quantel PG38); (B) Dichroic mirrors from CVI; (C) laser delivery system; (D) focusing lens and input window to the vacuum vessel from Thorlabs; (E) poloidal section of the TCABR tokamak; (F) main laser measurement and absorption dump from Scientech; (G) observation window and doublet collecting lenses from Thorlabs; (H) single optical fiber with 1.8 mm diameter; (I) polychromator with 3 pairs of avalanche photodiode and interference filters from former AEA-UK; (J) digital oscilloscope and PC data acquisition. The plasma is represented as a pink disk and the future collection lens is shown.

3. COMMISSIONING ACTIVITIES

3.1. The laser

The Neodymium glass rod in the oscillator was with a small internal optical imperfection and a pair of Neodymium glass rods was purchased from the Chinese enterprise “Shanghai Daheng Optics”. Then a final alignment of the laser was made by the Quantel representative in Brazil. To decrease the risk of damage of the glass rod, and to avoid the use of two defective high energy capacitors, the maximum energy of the laser pulse (30 J) was reduced to 10 Joules.

3.2. Laser beam delivery system and collecting lenses

Inside the 2 m long laser box, we introduced the first high power dichroic mirror. This mirror deflects the laser beam by 90° sending it to the adjacent wall at about 2 m distance. In this wall there are two other dichroic mirrors that bend the laser beam back to the tokamak. This simple setup ensures mechanically stable positions and avoids significant temperature effects. Between the tokamak and the laser, we installed a 3 m high steel pillar. This pillar has two perpendicular branches: one branch upward, with 2 meter long, is for holding the last mirror and the focusing lens with $f=1 \text{ m}$ and the lower branch is for the collecting lens with a $F\# 10.2$ and making a 18 mm spot size on the laser cord. The total laser beam path length is 12 m.

3.3. Polychromator

The ISTTOK polychromator is the first generation of these devices made in the Culham Laboratory (UK). It was adapted on-site to the new environment of the TCABR laboratory.

Internal optical alignment as well as its electronics has been tested using a fast infrared photodiode with a rise time of 10 nsec. The interference filters were replaced and tested for optical transmission. The polychromator was then recalibrated for electron temperature measurement.

3.4. Stray-light reduction

Stray-light reduction is an important step in any ITS diagnostic. Then, from the start of this diagnostic activity we simulate the ITS-TCABR using optical ray tracing with the program Zemax. We made a comprehensive preliminary study of spurious light trying to identify the most critical parts of the system in an early phase.

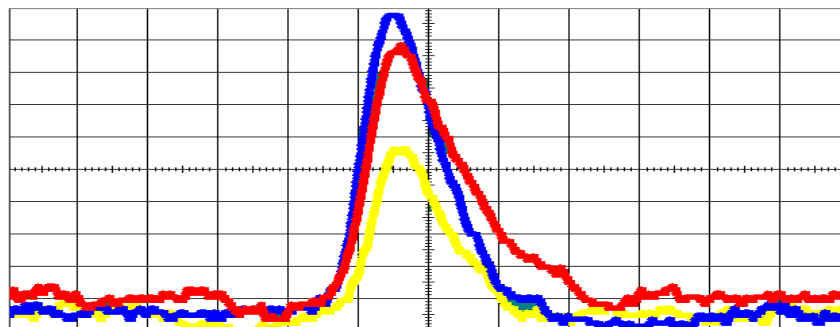


Figure 2. Experimental ITS-TCABR data. The graph shows the 3 pulses from the 3 pair of photodiodes and interference filter. Horizontal axis is time at 20 nsec/div. Vertical axis is voltage at 10 mV div.

4. Preliminary scattering results

A successful intensive experimental campaign of two weeks (in May 2009) was dedicated to ensure that the ITS-TCABR diagnostic was able to work in regular mode without the need of changing any diagnostic parameters or making any change in the optical alignments.

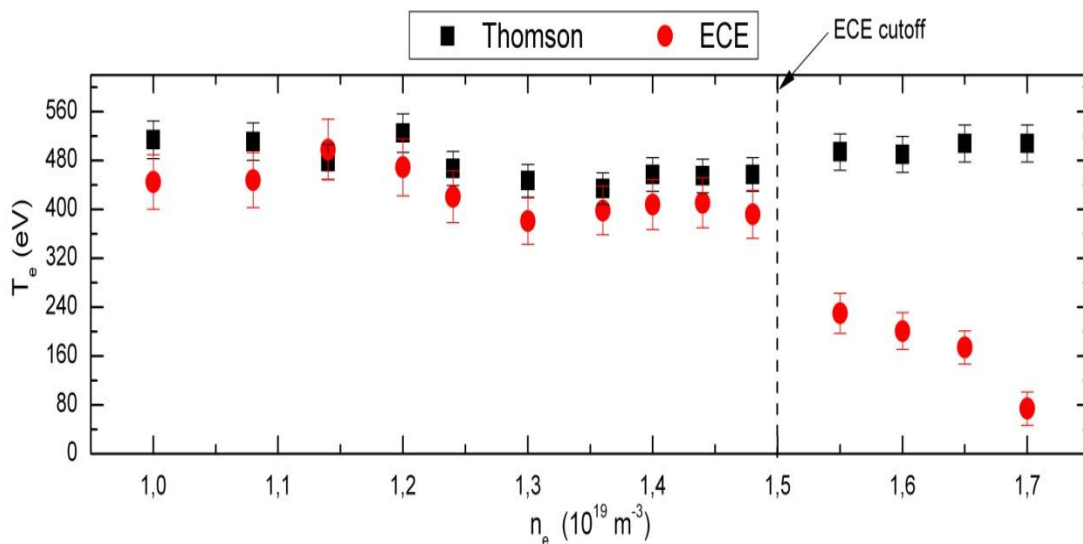


Figure 3. Electron temperature obtained by the ITS-TCABR compared with the values from the ECE diagnostic in the same shots. The right side shows the electron temperature results obtained from the TCABR plasma center with Alfvén heating and with a consequent added increase in the plasma density.

In this experimental campaign electron temperatures from 50 eV up to 600 eV have been measured which are in good agreement with those provided by ECE, especially in ohmic discharge. In discharges with additional Alfvén heating the disagreement observed is most probably due to errors in the ECE measurements and these are related with the value of the electron density cutoff.

5. Conclusions

The ITS-TCABR observation volume has 18 cm length and 2 mm diameter. The data analysis model was completed. The Nd:glass Laser was installed in place, was tested and refurbished. The general stray-light deduced by optical ray-tracing gave satisfactory and practical results. The laser pulse delivery system was concluded and is stable. The polychromator was tested, calibrated and commissioned in site. The ITS-TCABR diagnostic is working satisfactorily and in a routine mode. All the digitalized raw data are stored in a local hard disk of a personal computer.

This paper describes briefly the commissioning activities highlighting the prerequisites and pitfalls of the ITS-TCABR diagnostic. This system fires a single laser pulse with 5 Joules (40 ns) per plasma shot, measuring the electron temperature in the center of the plasma using interference filters and photo-diodes. It was commissioned in May 2009. It was a success history because we fulfill the decided scientific parameters on time. During the commission experimental campaign, more than 200 T_e measurements were carried out, during two weeks, with having no need for change any diagnostic parameter. The determined electron temperatures from 83 eV (shot# 23913) up to 584 eV (shot# 24031) are in agreement with those provided by the ECE diagnostic.

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