Present Status of ETE Diagnostics

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1. Introduction

The spherical tokamak ETE (**E**xperimento **T**okamak **E**sférico) [1] has started its operation at LAP/INPE. The ETE is a small aspect ratio tokamak (R/a = 1.5), with major radius R = 0.3 m and minor radius a = 0.2 m. In the first phase of operation the following macroscopic plasma parameters are expected: toroidal induction field of 0.4 T, ohmic current up to 220 kA, plasma pulse duration of 15 ms, density of about 5×10^{19} m^{-3} and temperature around 300 eV. A set of fundamental diagnostics is now being implemented comprising electromagnetic, Thomson scattering, mass spectrometer, fast visible spectroscopy and CCD camera. Other diagnostics as fast neutral lithium beam probe, CO_2 interferometer and soft X-ray tomographer are being developed.

2. Available diagnostics

Some of the electromagnetic diagnostics are already installed, including three Rogowski coils to measure the currents in the toroidal, vertical and ohmic circuits; one Rogowski coil placed inside the chamber for plasma current measurements and one outside the vessel to measure the induced current; twelve loop voltage coils (six around the vessel, five around the ohmic heating solenoid and one inside the chamber), and four magnetic probes inside the vessel to measure the vertical and radial fields. Figure 1 shows the signals of an initial ETE shot, with 11 kA in the toroidal magnetic coils, 4 kA in the ohmic coils and 2 kA in the equilibrium coils. The ETE vacuum vessel manufactured with Inconel has no electrical break in the toroidal direction. For the shot presented in figure 1, the induced current in the vessel reached 60 kA. For this shot a plasma current of about 8 kA was obtained with loop voltage of 15 V.

A high speed CCD camera with 1/500 to 1/20,000 frame speed and 30 to 500 FPS (upgradeable to 10,000 FPS) is being used. Since in the present condition the duration of the discharge is limited to 1.5 ms, just one frame per shot can be obtained. Figure 2 shows the upper part of the plasma cross-section taken with the CCD camera. The expected D-shaped cross section is clearly observed. A monochromator (1200 lines/mm, 12 Å/mm) coupled with a photomultiplier tube has been installed for ion temperature measurements by Doppler broadening. The $H_á$ behavior is being measured by a fixed slit (22 Å) monochromator with a photomultiplier tube. A photodiode is being used to measure the continuous emission (300 nm to 1100 nm). A mass spectrometer connected to the port of the vacuum system is used for measurements during vacuum chamber conditioning.

3. Diagnostics being installed

A 10J ruby laser Thomson scattering system (TS) [2] is being assembled (figure 3) to measure the plasma density and temperature profiles. A special collection lens allows to measure up to 22 spatial plasma points (with 15 mm spatial resolution) along the laser line and a five channel polychromator (that detects temperatures from 20 eV to 2 keV and densities greater than 10^{19} m^{-3}) will be used to measure the scattered light. A 1.3 m flight tube and a dump with special black anodized inserts were designed to prevent stray light effects.

A 10 keV Fast Neutral Lithium Beam probe (FNLB) [3] with current density up to 1 mA/cm^2 and life time of 400 min is being assembled for measurements of the boundary plasma density and its fluctuations. This plasma diagnostic method is adequate for use in fusion devices because it does not perturb the plasma and it provides data with high space and time resolution for the entire discharge lifetime. Figure 4 shows the schematic of the FNLB for the ETE tokamak. The ion beam is extracted from a heated (~ 1153^{o}C) glassy â-eucryptite [4] source and a set of three electrostatic lenses is used to extract, accelerate and collimate the beam that is neutralized by sodium vapor before entering the tokamak chamber. A flight tube with differential pumping prevents the plasma contamination. The lithium line profile will be measured at 90^o using a multichannel detection system composed of a spectrometer and photomultipliers, allowing simultaneous multipoint measurements.

4. Planned Diagnostics

One chord CO_2 (10.6μm) Michelson heterodyne interferometer modulated at 40 MHz has been designed to measure the line density. A HeNe laser (633 nm or 3.39 ìm) will be used to eliminate the effect of mechanical vibrations. The viability of a multipass interferometer to increase the wavelength shift is under consideration. Figure 5 shows this possibility, where two spherical mirrors can be set outside the vacuum vessel to reflect the CO_2 beam several times (22 passes in this case) before it leaves the plasma.

The application of a 64-channel photomultiplier for multipoint Thomson scattering is now under development [5]. Each channel of the detector has a 2.54mm $\times$ 2.54mm sensitive area, 5.0 ns response time, 10 stage dynodes with gain of 1x10^6 at 1150 V, 270nm to 800nm spectral response, and 14% cross talk (measured) between channels. The detector is mounted on a SPEX spectrometer (11 Å/mm, f = 1 m) that allows temperature measurements up to 500 eV. Rayleigh and spectral calibration was performed in the plasma laboratory at UNICAMP. Figure 6 shows the multichannel detector intensity calibration.

5. Conclusion

Since ETE started operation in November 2000 the main efforts are concentrated on conditioning the vacuum vessel to achieve better plasma discharges and to install the basic diagnostics. The TS system should be operational in a two months period and nitrogen Rayleigh scattering will be used for density calibration. The FNLB should start probing the plasma by the middle of 2002. The design of the interferometer system (INPE/UNICAMP) is ready and it should be operational in two years from now. Multichannel detectors for the TS upgrade are being developed jointly with the UNICAMP plasma group.

6. References

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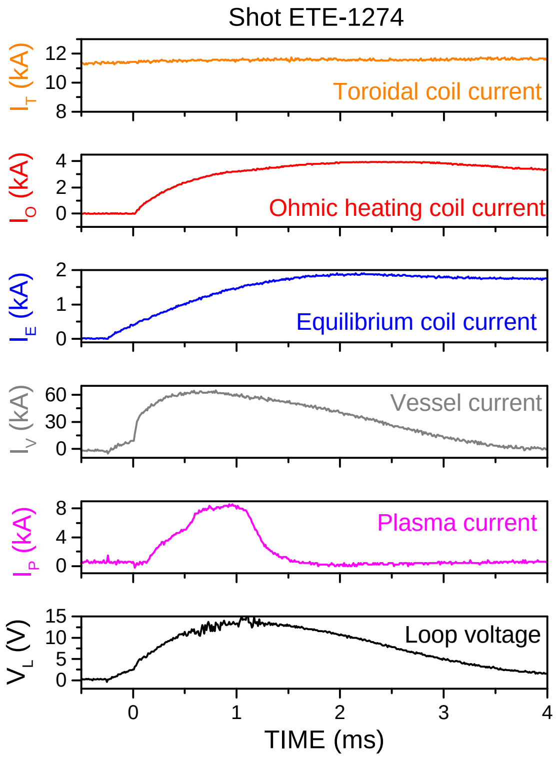

Figure 2. D-shaped plasma picture taken with the CCD camera

Figure 1. Rogowski and loop voltage signals

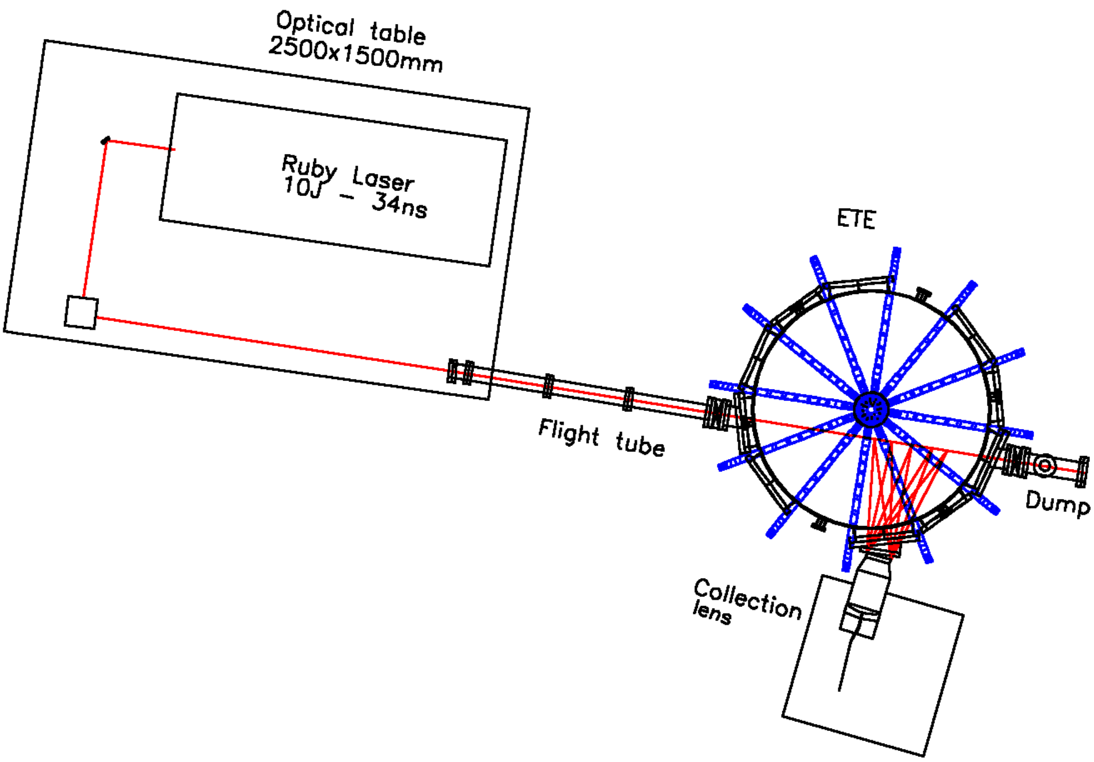

Figure 3. Thomson scattering system for the ETE tokamak

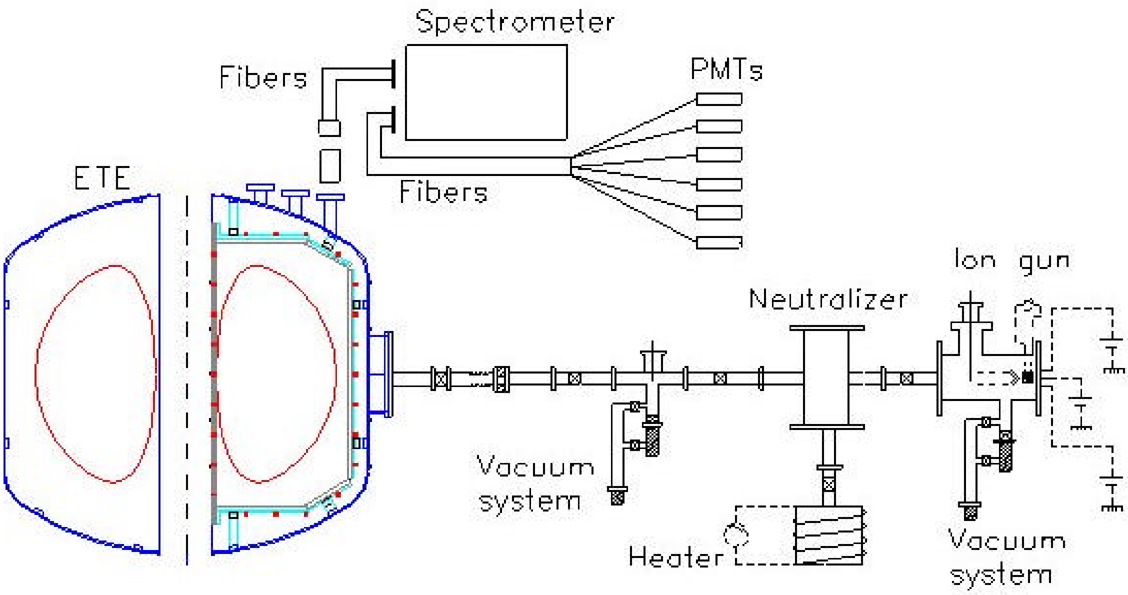

Figure 4. Lithium beam probe set up

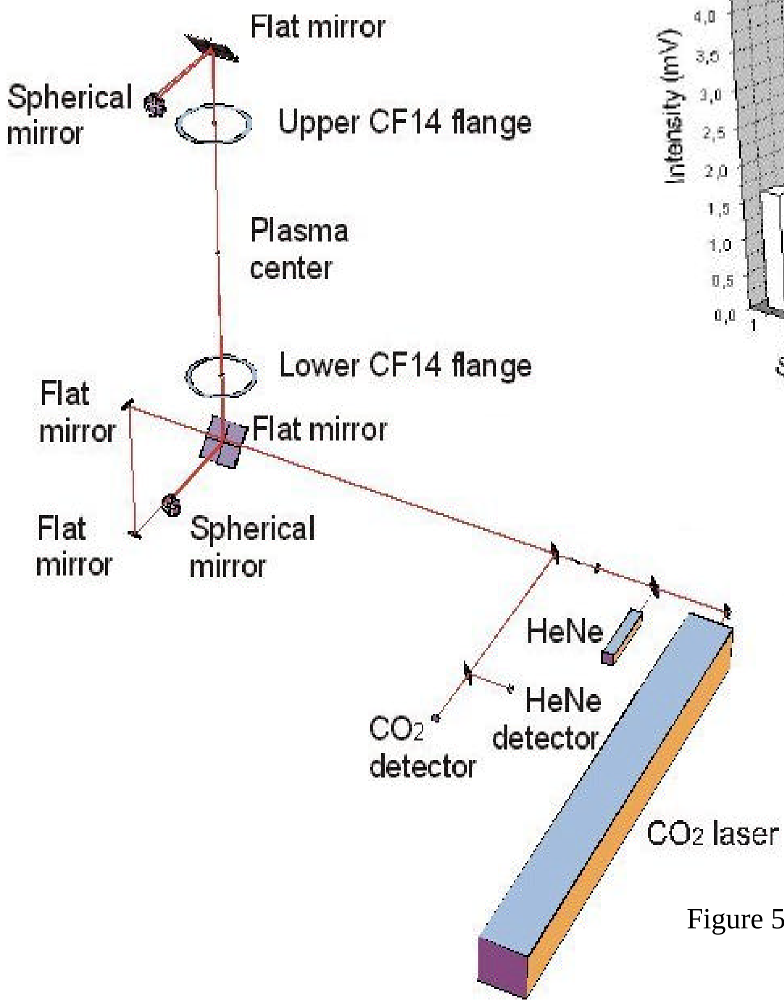

Figure 5. CO_2 multipass interferometer

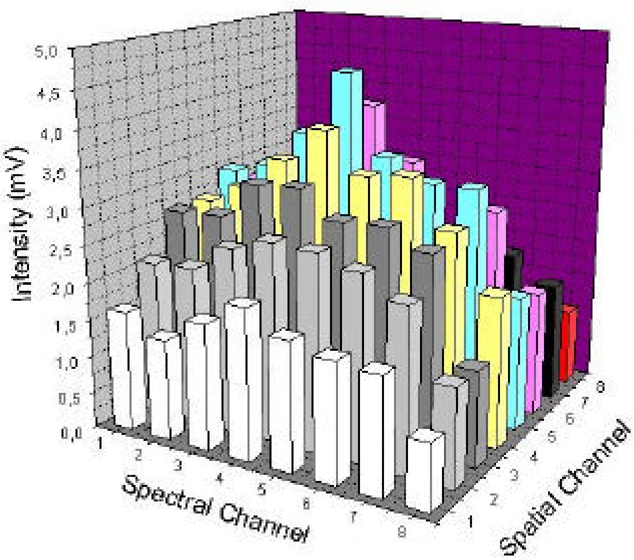

Figure 6. Multichannel detector intensity calibration