ELECTROSTATIC PROBE VACUUM SYSTEM FOR TCABR TOKAMAK

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RESUMO

Este artigo descreve o projeto e a implementação do sistema de diagnóstico instalado no tokamak TCABR, para medir parâmetros da borda do plasma. O sistema é composto por quatro sondas de Langmuir operando por controle remoto.

ABSTRACT

This paper describes the technical design and performance of the diagnostic system installed in the tokamak TCABR to measure parameters of the plasma edge. The system consists of four Langmuir probes under remote control.

1. INTRODUCTION

Particle and energy transport in tokamaks is dominated by turbulence generated by flows and gradients [1]. With the aim to understand and control this transport a considerable quantity of diagnostic instrumentation was developed to study the structure of turbulence processes and to identify the origins of plasma loss. The purpose of the study of turbulence is to identify specific theoretical mechanisms with experimentally measured fluctuations.

Langmuir probe techniques are used to examine edge fluctuation phenomena and narrow the search of appropriate theoretical edge models. These probes are used as a standard tool to measure local averages of electron temperature, density, plasma potential, and their gradients near the plasma edge of tokamaks. They also measure fluctuations of these same quantities. Due to usually high plasma temperatures in tokamaks, these probes can function only in the edge; even so they measure all the quantities important for obtaining radial transport with high spatial accuracy in this region.

Langmuir probes are in principle a very simple diagnostic: a conducting surface is inserted in the plasma in order to intercept some of its charged particles and produce electric signals which, once measured and interpreted give information on plasma properties. Several types of arrangements (concerning the number of employed electrodes, the way they are connected, and the regime they are operated) have been developed in order to adapt the method to several applications and plasma conditions [2]. Our probe system is installed in the equatorial plane of TCABR tokamak. Fig. 1a shows schematically the position of the diagnostic and the coordinate system of the tokamak machine.

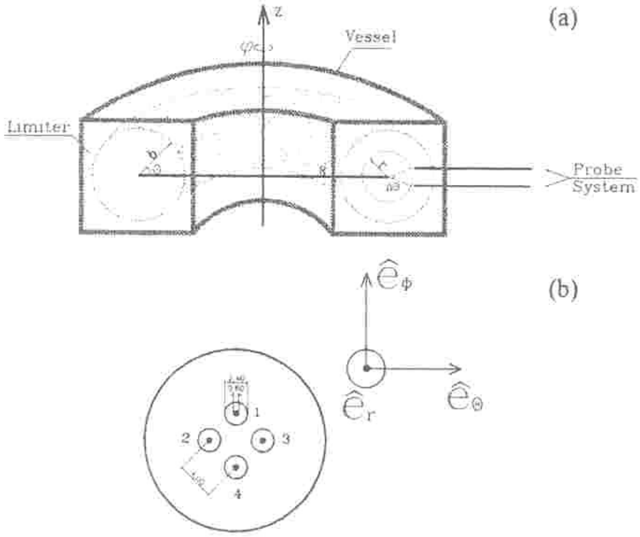

Fig.1 – Scheme of the coordinate system of the tokamak device (a). Scheme of probe system (b); 1 is a single probe for measurement of mean density, potential and electron temperature, 2 and 3 are probes that measure the potential fluctuations, and 4 measures the density fluctuations.

The system consists of four tips of tungsten wire, 0.6×10^{-3} m diameter and 5×10^{-3} m long. The disposition of probes is chosen to avoid the shadowing of one probe electrode to another on the same field line. The probe 1 is a single probe used in the sweep mode, to sweep the probe voltage and record the characteristic curve to obtain mean density, electron temperature, and plasma potential. The sweeping circuit has a voltage that can be varied from −100 to +100 V and the sweeping frequency can be varied from 0.1 Hz to 20000 Hz. To determine potential fluctuations we measure floating potential fluctuations with probes 2 and 3; and to determine density fluctuations we measure ion saturation fluctuations with probe 4. Data are acquired simultaneously at a sampling rate of 1MHz in the probes 2, 3, 4 after high pass filtering at 2 kHz. The fluctuating data are submitted to wavelet spectral and bispectral techniques [3, 4, 5] to obtain the correlation, the dispersion relation, the particle transport, and the diffusion coefficient.

2. PROBE ASSEMBLY

Essentially three parts compose our system: the mechanical section, the vacuum system, and the remote control system. The system was mechanically designed for high vacuum conditions. Simplicity, easy maintenance, and absence of virtual leaks were taken into account. To make the vacuum seal viton O-rings and conflat-seal were used. To avoid impurity contamination, special care with the problem plasma-probe interaction was taken.

The mechanical section is composed by a stepper-motor of high torque (7 N/m) and high velocity (1 step in 10×10^{-3} s). Transmission is made by a gear coupled to the engine axis and one toothed rack coupled to the probe system Fig.2.

When the probe is fully retracted, it can be isolated from the main vessel by a gate valve. A separate vacuum system is available so the probe can be removed to be repaired or modified and then reinstalled without affecting the main vacuum of the tokamak. The pumping vacuum system used turbomolecular pump. Details of the pre-vacuum system and four bellows operated shaft are seen in Fig. 3. The pressure measurement is made through a sensor type Bayard-Alpert. The system rapidly attains pressures under 10^{-4} Pa.

The probe system is mounted on a four bellow-operated shaft Fig. 2. The total excursion of the probe is 30×10^{-2} m.

The remote control section is an interface for a parallel PC port. This interface has basically four functions: to lock the system, verify its position, display its direction (in or out), and optical coupling to the reference signal. The lock system is a bipolar key at the bottom of the gate valve. In the case of gate valve-shot the interface gives the information and the system is locked avoiding a collision of probe tips with the valve top. When the valve is open, the system releases the probe for motion. We determine the exact probe position, in relation to the center of the vessel, with an LPOT coupled to the shaft engine that measures the potential difference between the cursor and ground. We use an analogic digital convertor (ADC0804LCJA) of 8 bits and a LATCH (74HC573), and with the PC parallel port we read the value of this signal. The engine is operated by a clock generated by the PC. We developed a software to control the number of pulses and frequency and consequently the velocity of motion.

We can move the probe during a single shot in four different positions, consequently profiles of the plasma parameters of these positions can be obtained in a single shot avoiding errors associated to shot to shot reproducibility. Also the same parameters can be obtained for the whole discharge in the radial interval of 15×10^{-2} m $< r <$ 23×10^{-2} m (distance referred at the center of the plasma column, plasma radius equal 18×10^{-2} m).

Fig.4 shows the measured signals of the four probes of Fig.1, for a position of $r = 15\times10^{-2}$ m in the plasma edge. These signals permit to obtain important parameters of the plasma, such as electron temperature, density, potential and their fluctuations. The signals of Fig 4c,d,e allow the study of turbulence in the plasma edge. Understanding turbulence in this region may lead to the development of appropriate control methods to improve plasma confinement in tokamaks.

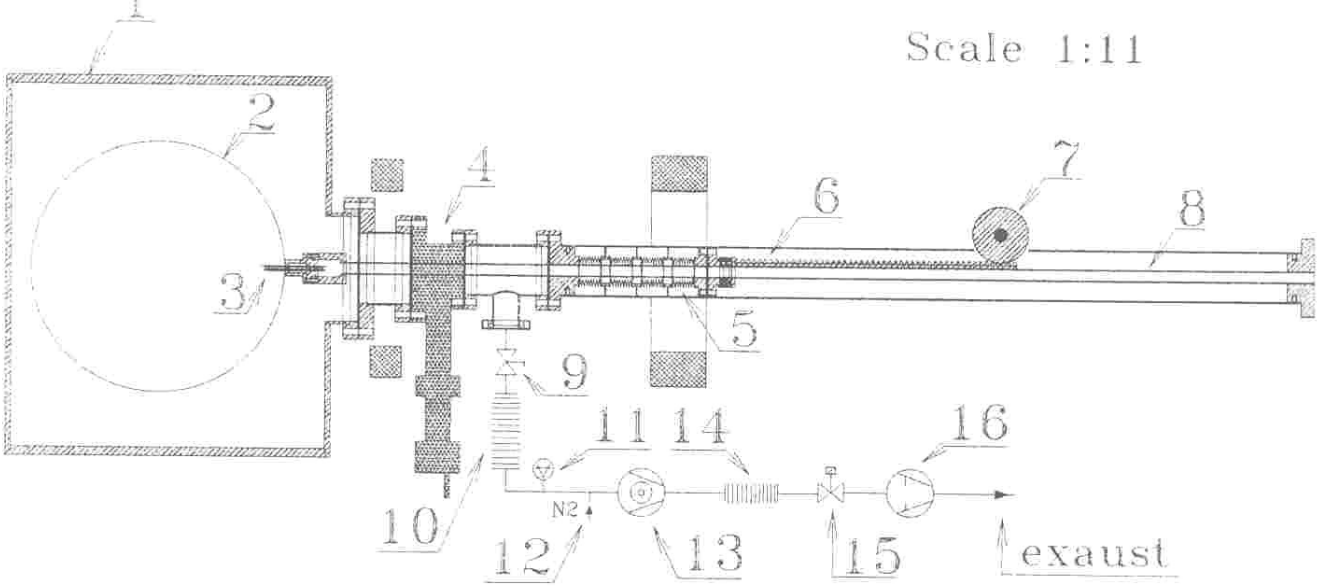

Fig. 2- Schematic view of mechanical system coupled to the probe diagnostic. Where: 1-Vacuum vessel; 2- Plasma column; 3- Probe system; 4- Gate valve; 5- Bellows; 6-Toothed rack; 7- Gear; 8- Tube for the probe system support; 9- Manual valve; 10- Bellows; 11- Bayard-Alpert sensor; 12- Vent valve; 13- Turbomolecular pump; 14- Bellows; 15- Pneumatic valve; 16-Mechanical Pump.

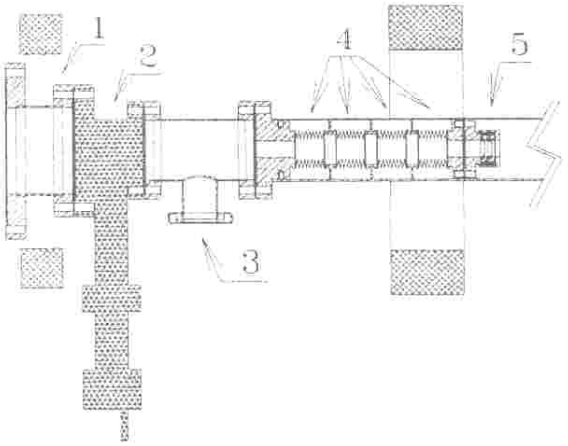

Fig 3- Schematic detail of the camera constructed to permit the installation of the gate valve and the four bellows operated shaft. Where: 1 – CF160-CF100 adapter; 2 – Gate valve; 3 – Pre-vacuum chamber; 4 – Bellows; 5 – Double fence with viton O'ring.

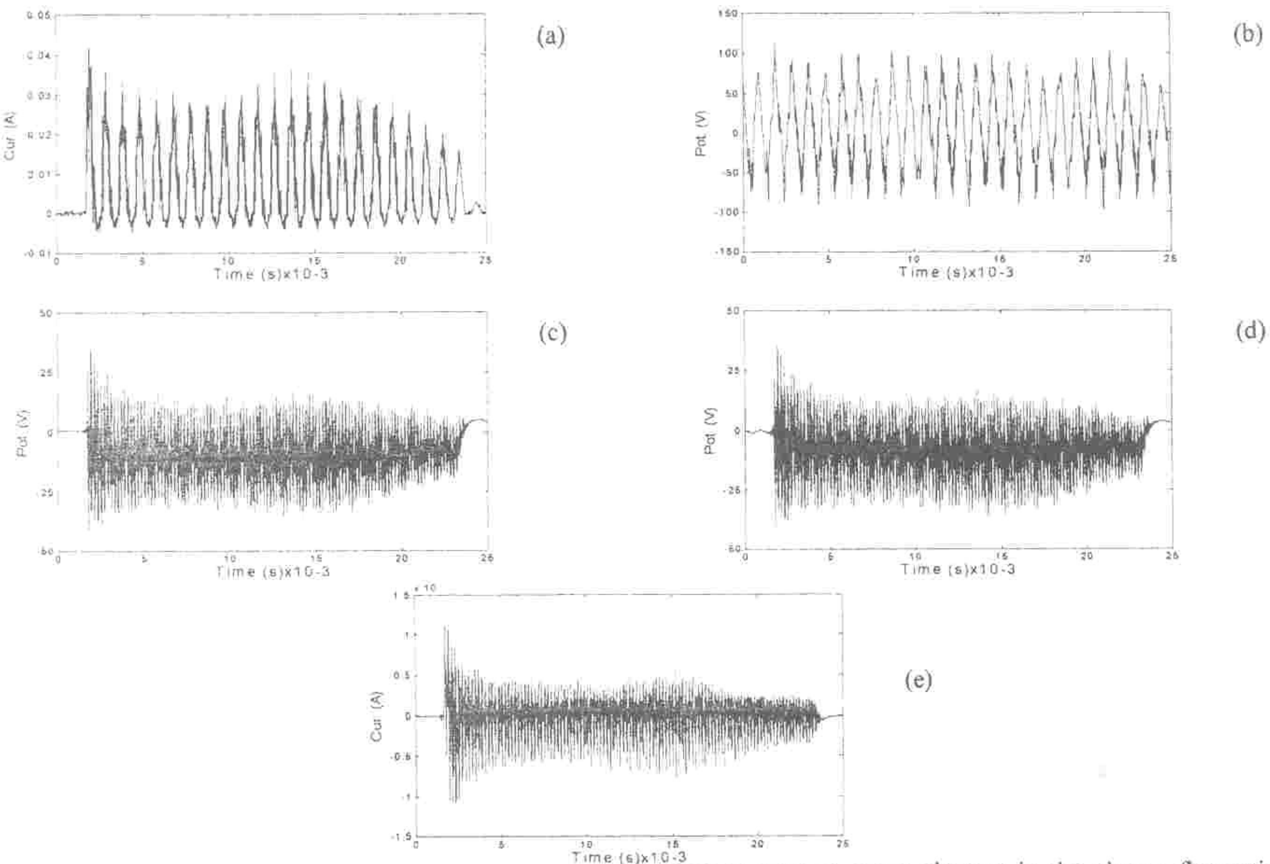

Fig. 4- Signals obtained with the diagnostic. Signal (a) and (b) from probe 1, signal (c) and (d) from probes 2 and 3, and signal (e) from probe 4.

The diagnostic system reported in this work is flexible and can be easily adapted for different probe configurations. The system is especially useful to study turbulence in the plasma edge as well to detect changes in the plasma fluctuations submitted to Alfvén wave heating installed in the tokamak TCABR [6].

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REFERENCES

[1] N. Bretz, Rev. Sci. Instrum. **68**, 2927 (1997).

[2] R. M. Castro, M. V. A. P. Heller, R. P. da Silva, I. L. Caldas, F. T. Degasperi, and I. C. Nascimento, Rev. Sci. Instrum. **68**, 4418 (1997).

[3] B. Ph. van Milligen, E. Sánchez, T. Estrada, C. Hidalgo, B. Brañas, B. Carreras, L. Garcia, Phys. Plasmas **2**, 3017 (1995).

[4] R. Jha and Y. C. Saxena, Phys. Plasmas **3**, 2979 (1996).

[5] M. V. A. P. Heller, Z. A. Brasilio, I. L. Caldas, J. Stockel, J. Petrzilka, Phys. Plasmas **6**, 1 (1999).

[6] A. G. Elfimov, R. M. O. Galvão, I. C. Nascimento, and G. Amarante Segundo, Plasma Phys. Control. Fusion **39**, 1551 (1997)