Overview of results from the IAEA-CRP 3rd International Joint Experiment on the tokamak ISTTOK

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1. Introduction

The 3rd Joint Experiment (2007) in the framework of the IAEA Coordinated Research Project (CRP) on "Joint Research Using Small Tokamaks" [1,2] was carried out on the tokamak ISTTOK in Lisbon with 29 participants from 13 countries (Austria, Belgium, Brazil, Canada, Czech Republic, Egypt, Isl. Rep. of Iran, Kazakhstan, Mexico, Poland, Portugal, Russia and UK). The experimental research topics covered were: i) control and data acquisition, ii) AC/DC tokamak operation, iii) edge plasma studies, iv) plasma facing materials (Ga liquid limiter), and v) the utilization of some new diagnostic techniques. The paper summarizes some of the main results obtained.

ISTTOK is a large aspect ratio circular cross-section tokamak (R = 46 cm, a = 8.5 cm, B_T = 0.5 T, $\bar{n}_e(0) = 5\text{x}10^{18}$ m^{-3}, $T_e(0)$ = 150 eV, $I_p \approx$ 4-6 kA) with a poloidal graphite limiter. Around the limiter radius the electron temperature is about T_e=20 eV and the electron density is 0.5-1×10^{18} m^{-3}.

2. Structure of edge plasma fluctuations

ISTTOK is equipped with two probe systems that allow the investigation of fluctuations in the plasma boundary: (i) a 8-pin radially movable poloidal array of Langmuir probes with a resolution of 2 mm, installed in an equatorial port; and (ii) a 8-pin radial array of Langmuir probes with a spatial resolution of 3 mm, toroidally located at about 120º from the poloidal array and installed near the top of the poloidal cross-section. Such an experimental arrangement allows the investigation of the three-dimensional characteristics of edge fluctuations. Both Langmuir probe systems can be operated in floating potential (V_f) or ion saturation current (I_{sat}) mode. The poloidal array can also be operated in mixed mode (one pin measuring I_{sat} and the remaining V_f) so that the cross-field fluctuations induced particle flux, Γ_{ExB}, can be evaluated. Data were simultaneously sampled at 2 MHz and the analyses performed during the discharge flat top (~20 ms).

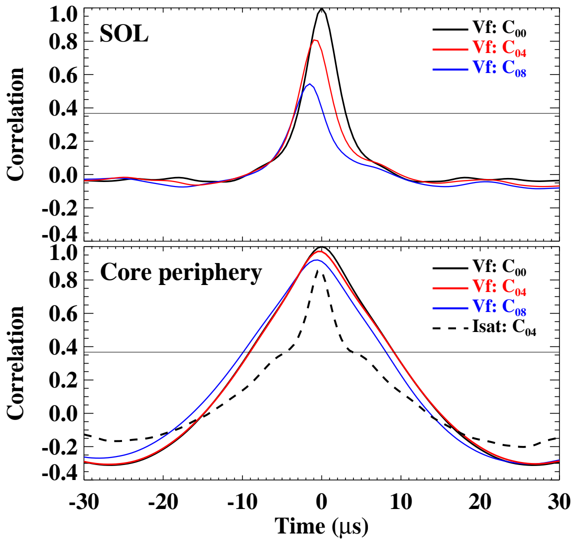

Figure 1: Floating potential cross-correlation for pins poloidally separated by 4 (C_{04}) and 8 mm (C_{08}) measured in the SOL and in the core periphery. The V_f auto-correlation is also shown (C_{00}) as well as the I_{sat} cross-correlation in the core periphery.

The fluctuations exhibit distinct characteristics for r>a (scrape-off layer, SOL) and r<~ a (core periphery, just inside the last closed flux surface, LCFS). As seen in Fig. 1, SOL fluctuations are characterized by short correlations both in space (poloidal) and time (λ_c~5-10 mm and τ_c ~5-8 μs, respectively), poloidal wave numbers in the range of k_θ<3 cm^{-1}, and a broad frequency spectrum. In the core periphery the correlation is significantly larger (λ_c>>10 mm, τ_c~30 μs), the wave numbers are shorter (k_θ<0.5 cm^{-1}) and the spectrum is dominated by low frequency components (10-25 kHz). A significant correlation (up to 0.7) has been found in the core periphery between toroidally separated probes measuring the floating potential. This correlation increases when probes are approximately at the same radial location; it is only significant for frequencies around 10-25 kHz and its cross-phase is close to zero.

Results indicate that the characteristics of the potential fluctuations in the SOL are consistent with the typical broadband turbulent fluctuations, while in the core periphery they are dominated by low frequency oscillations consistent with a symmetric structure in the poloidal direction, characteristic of the geodesic acoustic mode (GAM), which for the

ISTTOK edge plasma is expected to have a frequency of ~20 kHz (T_i=T_e=20 eV). Furthermore, the amplitude of the density fluctuations in the 15-25 kHz range is significantly smaller than that of the potential fluctuations as expected from the GAM theoretical predictions. This and toroidal correlation measurements suggest the existence of GAMs in a narrow region just inside the LCFS .

3. Interaction between liquid gallium jet and plasma

ISTTOK tokamak is equipped with one fully poloidal graphite limiter placed at r = 85 mm radius which acts as the main limiting surface during the operation with the gallium jet. A detailed description of the liquid metal loop installed on ISTTOK to inject gallium at the plasma edge is given in [3]. Figure 2 shows details of the set-up in the vicinity of the plasma-jet interaction region. The jets are generated by hydrostatic pressure, have a 2.3 mm diameter and a 2.5 m/s flow velocity. The liquid metal injector has been built from a ¼" stainless steel pipe reduced to a suitable shaping nozzle and allows the positioning of the jet inside the tokamak chamber, within a 13 mm range (59<r<72 mm). The pressure required to generate a stable, vertical jet is generated by a 1.3 m height liquid metal column. The parameters have been chosen to ensure a 13 cm break-up-length (continuous part of the jet, before its spontaneous decomposition into droplets due to Rayleigh instability).

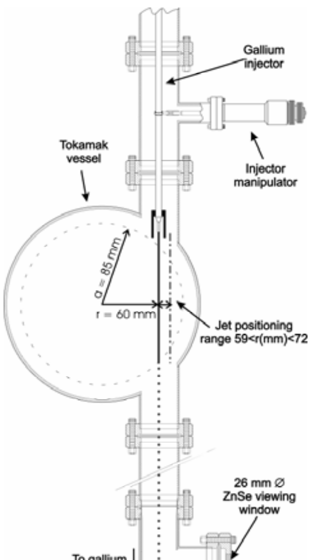

Figure 2: Schematic of the set-up in the vicinity of the plasma-jet interaction region

The interaction of the liquid gallium jet with ISTTOK plasmas has no significant effect on the discharge behavior and no severe effects on the main plasma parameters. The time evolution of visible radiation from gallium characteristic spectral lines close to the jet shows that plasma-liquid metal interaction has only a local effect. This work proved the technical feasibility of gallium jets interacting with plasmas. The jet power extraction capability is extrapolated from the heat flux profiles measured in ISTTOK plasmas. The surface temperature of the Ga droplets was monitored by an IR sensor. Although the expected temperature increase of the jet surface has been estimated, the experimental measurements still require an ongoing calibration procedure of the detector to provide absolute values for this parameter. The jet undergoes a small (<10 mm) radial displacement under the influence of the plasma.

4. AC discharges

Earlier operation of ISTTOK in a multi-cycle alternating plasma current regime has shown that long discharges could be produced merely with inductive operation [4]. The development of a new plasma position controller and digital controlled current amplifiers has enabled to achieve regular 250 ms AC discharges, extending the plasma duration for almost one order of magnitude.

5.Conclusion

This 3rd Joint (Host Laboratory) Experiment on “Joint Research Using Small Tokamaks” has clearly demonstrated that small tokamaks are suitable and important for broad international cooperation, providing the necessary environment and manpower to conduct dedicated joint research programmes. The contribution of small tokamaks to the mainstream fusion research such as edge turbulence, improved confinement, and diagnostics development in the present case can be enhanced through coordinated planning. The activities under this IAEA Coordinated Research Project are already paying visible dividends and resulted in a substantial number of joint presentations and publications.

Acknowledgement

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References

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