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Fast bolometry on the CASTOR tokamak

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Introduction

A new fast bolometric diagnostic tool based on arrays of the AXUV diodes has been installed on the small-size CASTOR tokamak with a circular plasma cross-section (R=0.4 m, a=0.85 m, B_T=1.3 T, n_e~0.5-1.5x10^{19} m^{-3}, T_e~100-200 eV, L-mode: 30 ms pulse length, P_{OH}=30 kW). The set with unique temporal resolution of 1 µs and spatial resolution of about 1 cm allows monitoring of total radiated power and consequently to observe fast changes of a radiation losses profile and its relaxation. Additionally, turbulent structures in the edge plasma region, in correspondence with Langmuir probes measurements [1], are identified.

Experimental setup

Two arrays of the fast AXUV-20 ELM based bolometers from International Radiation Detectors Inc. (IRD) were installed on the CASTOR tokamak in mutually perpendicular directions. The first array equipped with 16 channels is placed inside the bottom tokamak port at the distance of 267 mm from a plasma centre; the second one operating with 19 channels is located at the same poloidal cut and placed inside the horizontal port at low field side (LFS) at the distance of 342 mm from a plasma centre. Bolometers look at the plasma column through the aperture slit (“camera obscura”). The slits have rectangular shape with the size 4x0.2 mm and 4x0.19 mm respectively, what was optimized to reach reasonable intensity together with the requested spatial resolution of 11 mm and 9 mm. Each channel detects a plasma radiation along the appropriate chord covering the whole poloidal plasma cross-section of 17 cm in diameter, so that a spatial profile of the radiated power can be reconstructed.

The spectral response of AXUV silicon diodes is roughly flat above several hundreds eV with the value of 0.26 A/W ± 5%. Output currents from the diodes as low as 0.1 µA are amplified and converted to voltage of hundreds milivolts by the preamplifier unit constructed in Kurchatov Institute, Moscow. The unit and the data acquisition PC are located very close to the array itself (less than 2 m) that the temporal resolution is not influenced by the connecting cables and is given only by a sampling rate of collecting PCI card (inside PC). It is usually 20 μs in standard measurements or 1 μs for fast events studies.

Methods of profile description and reconstruction

Bolometric data are integrated over the chords. An obtained dependency of the radiated power on a distance of the chord from the plasma centre is usually peaked during the typical CASTOR discharge. Fitting the data with Gaussian curve, it is possible to estimate the radiation losses centre (roughly corresponding to the plasma column position), radiation FWHM (full width at half of maximum) and the maximum of radiated intensity. In some cases, namely at the beginning of the discharge, the plasma profile is not peaked, but hollow. Then the data don't fit to the Gaussian distribution; consequently more complicated approximations should be used, for example the fit consisting of two Gaussian curves. In this case, introduction of the above mentioned parameters is problematic and is used only for a comparison. Asymmetrical Abel inversion [2] can be used for a reconstruction of the radiation profile from single array data at each time step, i.e. 1 μs, assuming a radial symmetry in one direction. The tomography, what combines data from both arrays, is under consideration.

Measurements and observations

Typical bolometric data from the standard discharge of the CASTOR tokamak and a reconstruction of the radiation profile using asymmetrical Abel inversion are shown in Fig.1 and Fig.2.

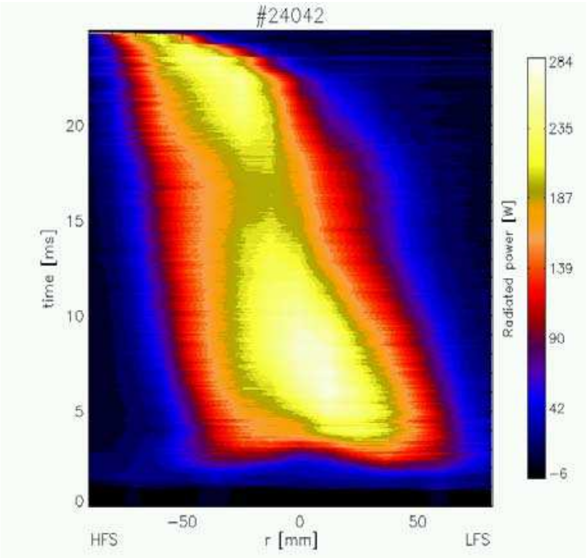

Fig.1 Shift of plasma column towards HFS during discharge measured by bolometers.

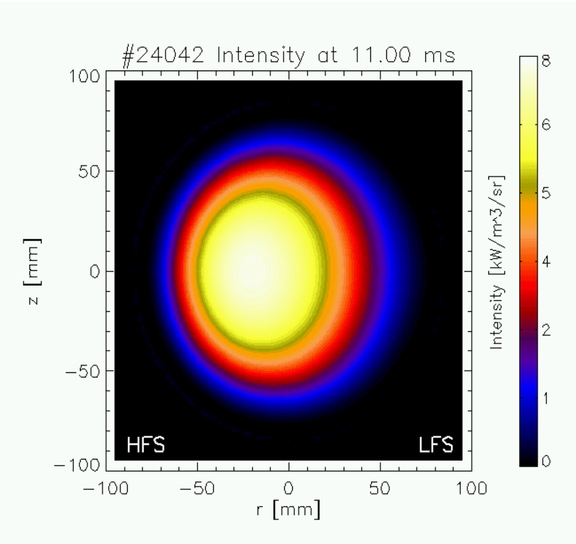

Fig.2 Reconstructed peaked profile at 11^{th} ms of the discharge.

Usage of fast bolometers is very suitable for analyses of the edge plasma biasing experiments [3]. The biasing causes a gradual increase of the total radiated power, a quick rise of FWHM and a shift of maximum radiation towards HFS, see Fig. 3. Very fast changes of plasma radiation can be studied thanks to the high temporal resolution of AXUV based bolometers. In the biasing experiments with the electrode inserted deeply in a hot plasma region the relaxation events, Fig. 4, and fast oscillation were induced. In this case, plasma rapidly changes its radiation profile from centric to hollow during 30 µs. This is followed by the increase of total radiated power and the radiation profile becomes broader. Then plasma slowly relaxes back to its original state with the characteristic time 500 µs, sometimes with a few smaller relaxations. Very fast oscillations (10-50 kHz) were observed in the biasing experiments with segmented probe [4]. In Fig. 5, the clearly seen event was observed by the bottom bolometric array. Meanwhile the Langmuir probes and bolometers detect 10 kHz oscillations at the plasma edge, 40-50 kHz vibrations were seen namely by central bolometric chords. Their typical duration was 0.2 ms; in exceptional case up to 1 ms. These oscillations affect the radiation width and the intensity in the opposite way so that the total radiated power remains constant.

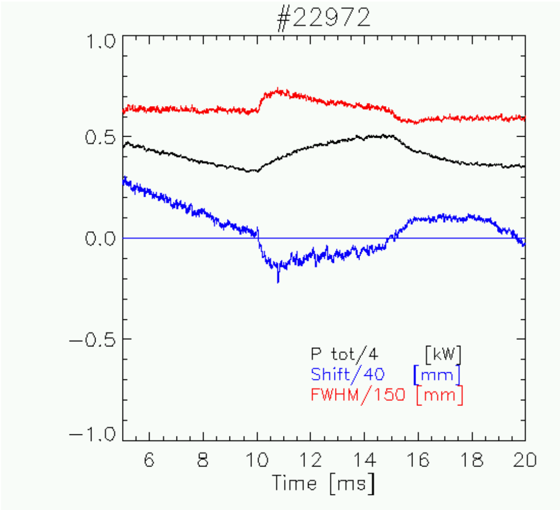

Fig.3 Effect of biasing (U_B=150V, r_B=50 mm) on FWHM, total radiated power and plasma column shift.

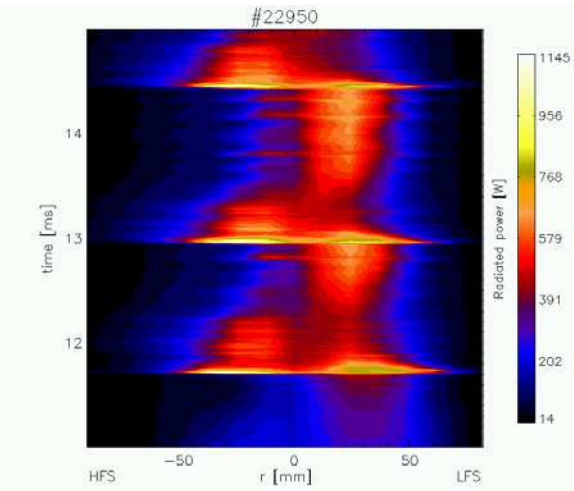

Fig.4 Relaxations at U_B= -300V, r_B=45 mm.

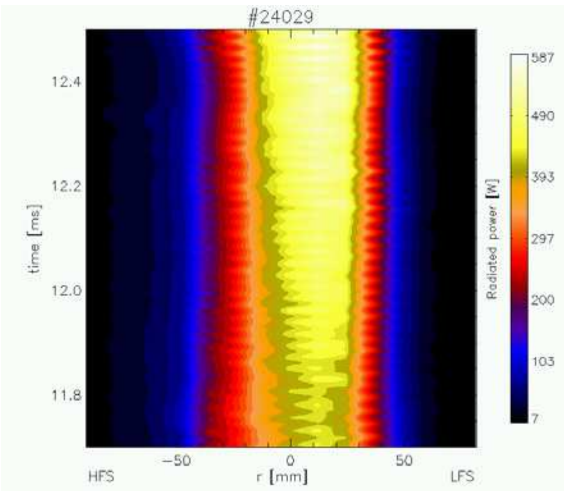

Fig.5 Oscillations at U_B=+250V, r_B=40 mm.

Statistical analysis of signal fluctuations

Radiation from the edge plasma region is influenced by turbulent events. Their typical size is about 1 cm and the lifetime about 10-40 μs [3]. Subtracting the mean value from a bolometric signal, changes of radiation caused by turbulences can be visualized. As example, a movement of the turbulent structures from the top to the bottom is shown in Fig.6. The correlation analysis gives their velocity of order of 2 km/s.

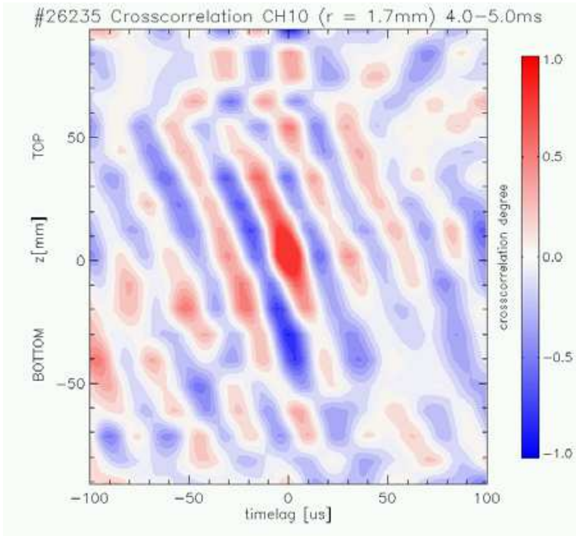

Fig.6 Cross-correlation analysis of data from one bolometric array.

Conclusion

The presence of a gap in UV spectral region together with a low electron temperature on CASTOR do not allow to use AXUV diodes as true bolometers. The total radiation losses measured by AXUV diodes are only 10 % of input power typically. However, their use for measurements of fast events across the whole plasma cross-section is very valuable for the understanding of the nature of particle and energy transport.

Acknowledgement

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