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Radiation losses study on the tokamak T-10 using AXUV-detectors

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AXUV-photodiodes and diagnostic design.

The bolometric diagnostic system on the T-10 tokamak is based on silicon AXUV-photodiode (Absolute eXtreme UltraViolet) detectors. AXUV-photodiode detectors permit absolute radiated power measurements over an extremely wide range in photon energies 1eV < E < 6000 eV with the nearly constant conversion efficiency (0.25 A/W) somewhat reduced in the region E_{ph}<30 eV [1,2]. AXUV-photodiode are also insensitive to neutral particles (E < 500 eV) and to radiation from the electron cyclotron heating system. One of the most attractive AXUV-photodiodes feature is high temporal resolution that makes it possible to follow fast processes.

The tokamak T-10 has a round cross-section, major radius of 1.5 m, minor radius of 0.3 m. The diagnostic system consists of a pinhole camera equipped with a linear array of the 16 AXUV-photodiodes viewing the plasma from below. At the same toroidal position wide view pyroelectric bolometer is installed in the opposite location. The field of view for both types of bolometers is approximately the same (-30 cm ÷30 cm) and provides full plasma cross-section coverage. A spatial resolution of the AXUV-photodiodes is determined by a chord width of 4cm at the vessel midplane, temporal resolution is limited to 16 µs due to present digitizer.

Total radiated power measurements.

The total radiated power on T-10 is measured by pyroelectric bolometer having a global view and also can be obtained from absolute AXUV-photodiods chord measurements. In typical working regimes there is a difference in the results of the total radiated power measurements obtained by the detectors. In contrast to the AXUV- photodiode the pyroelectric bolometer measures energy carried by neutral particles as well as by photons. Besides for plasmas with electron temperature T_e<100 eV (typical for the plasma edge), measurements by the AXUV-photodiodes may lead to underestimation of the radiated power due to emission of low charge states of low Z impurities in the spectral range of 1 eV<E<30 eV where the efficiency the AXUV-photodiods is reduced.

Shown in Fig.1 is good agreement in the results obtained by the detectors of both types in the presence of heavy impurity traces. Also comparison of the total radiated power measurements between the photodiodes array and the pyroelectric bolometer is made possible by injecting trace impurities into the discharge. The additional radiation due to neon gas puffing measured by both detectors was the same when taking into account the reduced conversion efficiency of the AXUV-detectors (equal to 0.18 A/W and corresponding to the main peak of neon radiation around 30 eV).

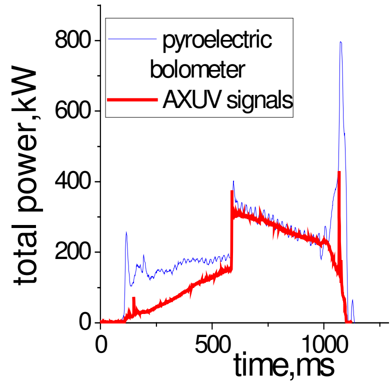

Fig.1. *The total radiated power in the presence of iron traces.*

Emissivity profiles and fast processes.

To obtain local emissivity the data inversion has been performed using algebraic algorithm. Assuming symmetry of the shells with equal emissivity the ith chord-integrated brightness is given by $g_i = \Sigma_j\ \varepsilon_j\ S_{ij}$, where ε_j is the jth shell emissivity, S_{ij} is an area determined from geometrical consideration. The inverted emissivity is given by $\varepsilon_j = \Sigma\ S_{ij}^{-1} g_i$.

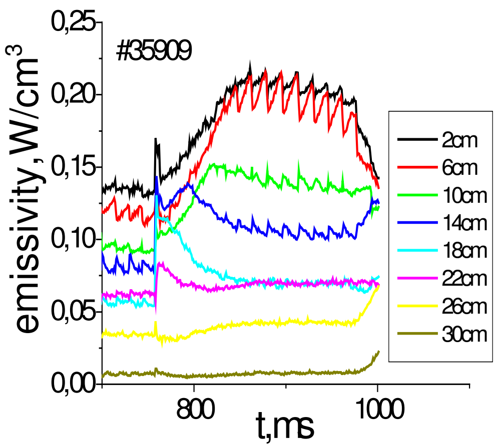

Fig.2 *Temporal evolution of emissivity.*

For the detectors array an average spatial resolution is adequate for imaging MHD structures of similar scale. Fig.2 shows a temporal dependence of inverted emissivity on which the restored localized sawteeth fluctuations are clearly seen.

High temporal resolution of photodiods permits to observe fast plasma processes. In the omic heated plasma discharge #35886 several modifications of emissivity distribution during changes in magnetic field configuration can be followed by AXUV-photodiodes after pellet injection. Shown on the time-space graph of Fig.3 snake-like perturbation occurs when deuterium pellet reaches the q=1 surface and a high radiating magnetic island at that surface appears [3]. The «snake» persists about 100 µs and is followed by plasma density peaking in the plasma center (Fig.3). Simultaneously with electron temperature rising and central electron density degradation during 50 ms following the injection impurities accumulation in the plasma center is clearly seen

(Fig.3, and Fig.3,c). For the observed electron density peaking a neoclassical accumulation mechanism due to an enhanced inward flux of impurities is likely to be considered. In t=700 ms MHD activity starts again resulting in disruption with emissivity spreading to the periphery followed by emissivity peak arising in the plasma center.

Discharge #35841 (Fig.4) gives an example of an enhanced core periphery radiation (like H-mode regime on T-10). The L-H transition at t= 690 ms is accompanied by strong emissivity increasing at r=26 cm and r=22 cm with simultaneous decreasing in the central region. At the same time an electron density increases at all radii. An electron temperature remains practically unchanged in the region of enhancing radiation indicating impurity redistribution due to outward flow.

Summary.

The use of the AXUV-photodiods enable fast absolute measurements of radiated power losses due to constant conversion efficiency in the main plasma where electron temperature T_e >100eV. At the plasma edge measurements by the AXUV-photodiodes may lead to underestimation of radiated power due to emission of low-charge impurities (CIII, D_a) in the spectral range 5-15 eV where the AXUV-photodiodes efficiency is reduced. Temporal evolution of emissivity profiles permits to create extreme ultraviolet (XUV) and soft x-ray plasma imaging and to follow the behavior of impurities in different confinement regimes. The location of intergal magnetic surfaces can also be revealed when they are seen on emissivity. The high temporal resolution of the AXUV-photodiodes permits to observe plasma events including L-H transition, «snakes», the saw-teeth oscillations, low m,n modes, disruptions.

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References.

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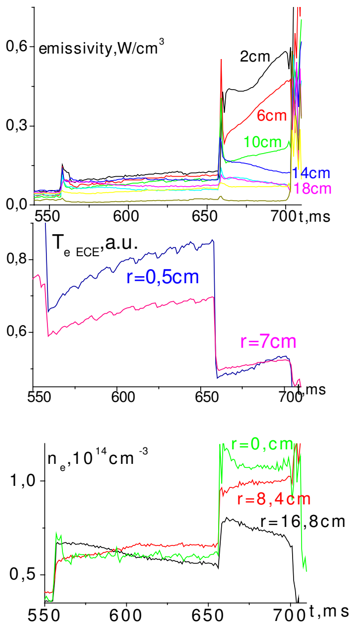
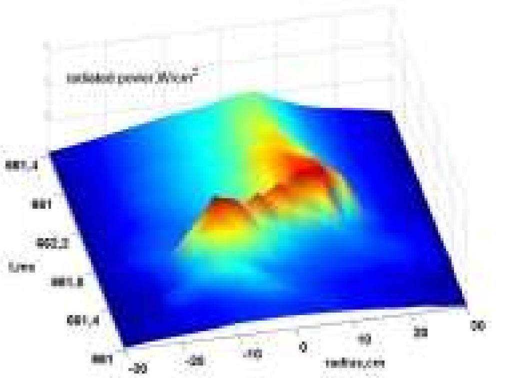
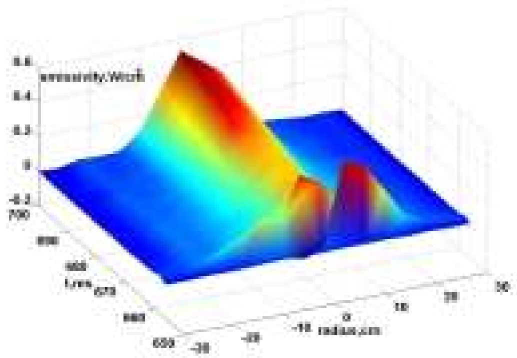


(a)

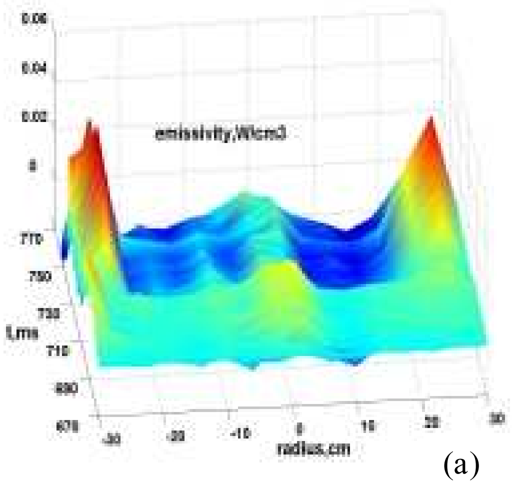


(b)

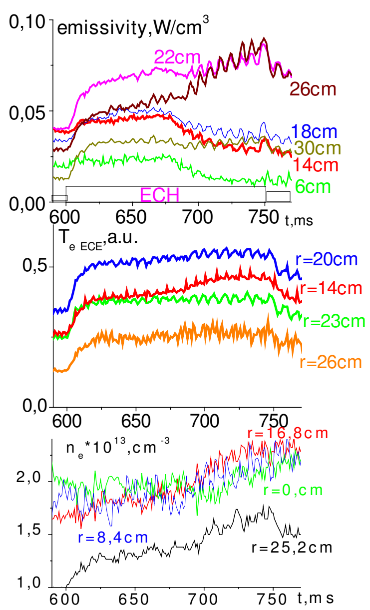


(C)

Fig.3 *#35886. D_2 pellet-injection in OH regime. (a)- emissivity, electron temperature and electron density traces. (b), (c)-time-space emissivity*



(a)



(b)

Fig.4. *#35841(H-like mode). (a)-temporal evolution of emissivity profiles; (b)-emissivity, electron temperature and density traces.*