Intensity radial profiles of VUV line radiation near the solid target in a hot plasma

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An investigation of hot plasma interaction with solid target is carried out at the CASTOR tokamak (IPP Prague) and the GOL–3 multi–mirror magnetic trap facility (Budker Institute, Novosibirsk) [1], [5]. In both experiments, the Imaging Seya–Namioka Spectrometer based on a spherical dispersion grating has been upgraded to monitor the radial profiles of the chord–integrated low–Z impurity line intensities in VUV spectral range. Such spatial resolved intensity monitoring in radial direction together with application of the radiation code simulation allows obtaining a radial distribution of ions of different ionization stages near the target immersed in edge plasma. The energy release from plasma to the target is order of 100 J/m^2 in the CASTOR tokamak and 30 MJ/m^2 in the GOL–3 magnetic open confinement system.

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1 Introduction

Long years experience clearly demonstrates, that Carbon, Nitrogen and Oxygen are the most frequently intrinsic impurities appearing on existing fusion research machines, including CASTOR and GOL–3. The radiation on high–temperature plasma devices, namely emitted from the plasma periphery, falls in the VUV part of the spectrum. The emission lines occur due to the hot electrons collisions with low–Z atoms or ions. It supplements the total power losses considerably. In both experiments, the Imaging Seya–Namioka Spectrometer has been installed to monitor the radial profiles of the line intensities in the spectral range from 60 to 200 nm [3], [6]. The solid target immersed in plasma edge becomes the source of neutral atoms. The spectroscopy measurements can be used to estimate the particle influx and radial distribution of ions.

2 VUV Imaging Seya–Namioka Spectrometer

The design of the spectrometer was based on vacuum spectrometer BM–3, product of Ioffe Institute, St.Petersburg, and assembled according to the Seya–Namioka scheme [3]. In Fig.1, the optical scheme of the Seya–Namioka spectrometer is shown. The spherical dispersion grating with gold cover, radius of curvature $r = 0.5$ m, 1200 grooves per mm, wavelength resolution 1 nm in the first order, was installed in this instrument. The angle between incident and diffracted ray is $a + b = 70°15'$. The incident radiation coming through the input slit and after the diffraction at the grating is focused on the output slit (window) displaced near to the Rowland circle. Turning the grating body around the central axis does the spectrum scanning shot by shot. The two–dimensional detector system of the spectrometer consists of set of two channel–plates of working area $\phi = 38$ mm. CsI covers the front of the first channel plate. The output electrons are accelerated onto the scintillator of the fiberoptic lightguide, which is consequently used as a vacuum throughput. The image of the intensity radial profile of chosen lines could be taken during the whole period of the plasma discharge in $2 \div 10$ ms exposition time, if the channel plate–system is operated in the pulse regime. The image is recorded by a CCD camera optically coupled to the lightguide output. The CCD element contents 165×192 pixels of rectangular form.

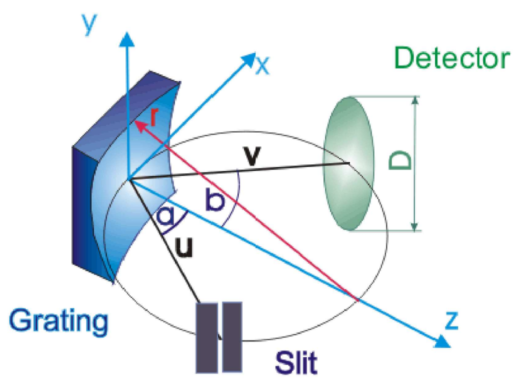

Fig. 1. Scheme of Seya–Namioka spectrometer

3 Intensity radial profiles of VUV line radiation near the solid target in CASTOR

Two different targets are available in tokamak CASTOR. For material transport studies, the tungsten bulk target is used. The other one: carbon–biasing electrode inducing the electric field shear in SOL suppresses the plasma turbulences in edge plasma. We note here the characteristic parameters in CASTOR: $R = 0.4\,\mathrm{m}$, $a = 8.5\,\mathrm{cm}$, $B_T \approx 1.3\,\mathrm{T}$, $n_\mathrm{e} \approx 4 \div 20 \times 10^{18}\,\mathrm{m}^{-3}$, $I_p \approx 10\,\mathrm{kA}$, $T_\mathrm{e} \approx 200\,\mathrm{eV}$, $\tau_p \approx 1\,\mathrm{ms}$.

3.1 Tungsten bulk target installed in the view field of spectrometer

Tungsten bulk target is installed in the view field of spectrometer and can be moved in radial direction up to 32 mm from axis, what is deeply inside the last closed flux surface (LCFS). In Fig. 2, the maximum of Lyα HI (121.6 nm) line chord–integrated intensity is located near to the target positioned at radial distance of 60 mm. As well as, the chord integrated intensities of chosen lines of lower ionization stages of the light impurities grow in the target location, as we see in Fig. 3 and Fig. 4. The radial profile maximum of the both CIII lines (97.7 nm and 117.5 nm) appears close to the target surface, where the temperature of plasma cloud is in the range of $5 \div 10$ eV. In consequence of temperature growth in the plasma core, the higher ionization stages appear at larger distance (> 10 mm) from target. The radial intensity profiles of NV (123.8 nm), Fig. 5, and OVI (103.2 nm), Fig. 6, remain more or less axially symmetric. In the CASTOR tokamak, the total energy load on the wall is relatively small, in order of 100 J/m^2, while in multi–mirror magnetic trap facility GOL–3 the energy load on the wall can reach 30 MJ/m^2. As reported in [5], the behaviour of the radial profiles of line radiation of lower and higher ionization stages of the same light impurities are similar in the vicinity of the solid target in both experiments. Thought, the target surface becomes a source of the hydrogen and light–Z atoms, due to the recombination of the plasma ions impacting the surface.

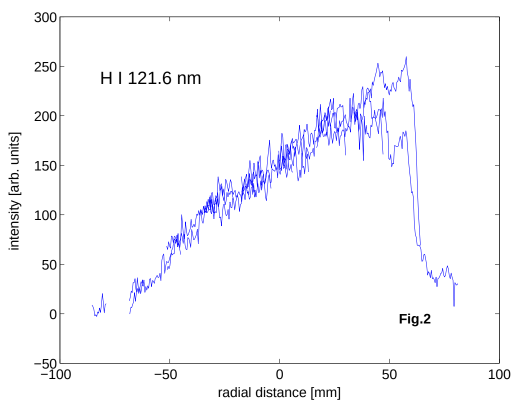

Fig. 2. Dependence of chord–integrated intensity of Lyα HI (121.6 nm) line on chord radial distance. The target is located at radial distance of 60 mm.

3.2 Carbon–biasing target electrode installed in CASTOR

Carbon–biasing target electrode installed in CASTOR can be moved in radial direction and is positioned at the toroidally opposite side to tungsten bulk target; biasing electrode is not in the field view of spectrometer. The biasing pulse duration is 5 ms and can be delayed from 0 to 40 ms during the full discharge duration. Depending

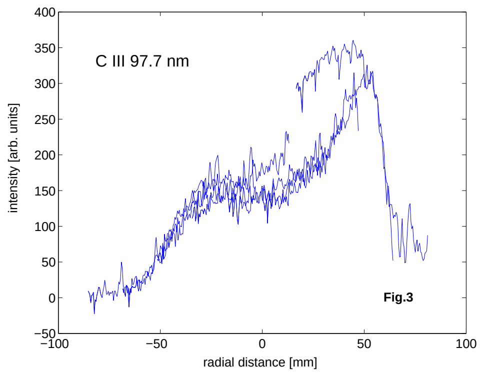

Fig. 3. Dependence of chord–integrated intensity of C III (97.7 nm) line on chord radial distance. Typical profile of lower ionization impurity stages.

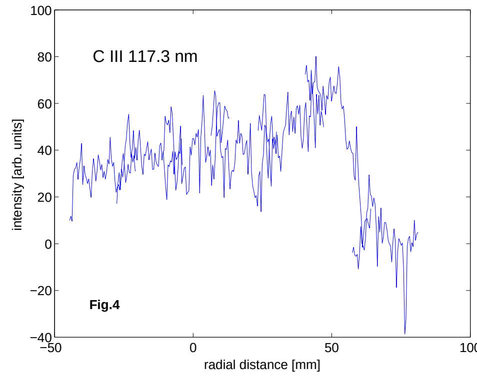

Fig. 4. Dependence of chord–integrated intensity of C III (117.3 nm) line on chord radial distance.

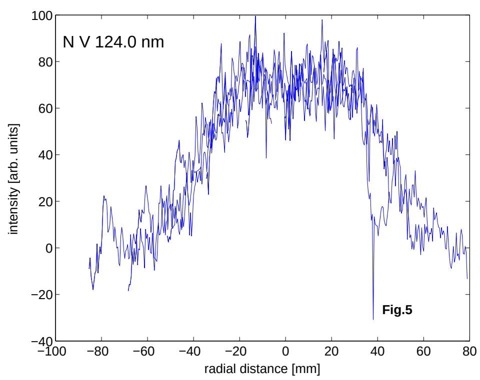

Fig. 5. Dependence of chord–integrated intensity of N V (124.0 nm) line on chord radial distance.

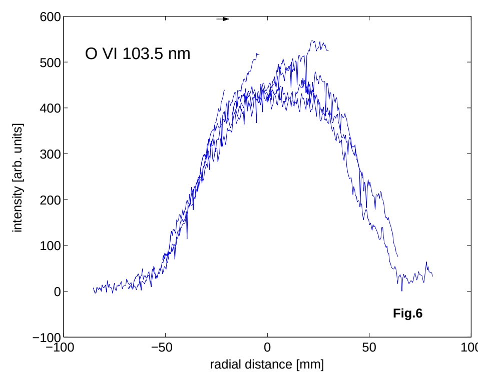

Fig. 6. Dependence of chord–integrated intensity of O VI (103.5 nm) line on chord radial distance. Typical profile of higher ionization impurity stages.

on electrode radial position and applied biasing potential the different influence on plasma parameters like line–averaged electron density and Hα (656.2 nm) line radiation, both measured at central chord, has been found [4]. As a result three different biasing regimes – so called “radiating regime”, “non–radiating regime” and “reduced Hα regime” have been identified.

The non–radiating regime, $U_{\mathrm{BIAS}} = +100$ V, and in biasing electrode position

$r_{\mathrm{BIAS}} = 50 \div 75$ mm, was selected to carry out the experiments on monitoring of plasma impurities by VUV imaging spectrometer. In Fig. 7, an example of smoothed radial profile of N III (99.0 nm) and N V (123.8 nm) measured in OH regime without the edge plasma biasing (solid line) – the electrode is outside, and with biasing – the electrode is inside the plasma at radius 75 mm (dotted line) and 50 mm (dashed line) is presented. The displacement of the biasing electrode deeper into a plasma column was accompanied by a signal decrease.

The radial intensity profile of N III (99.0 nm) line remains almost unchanged; but the line intensity in a whole profile strongly depends on the electrode radial position. The radial intensity profile of NV slightly changes with electrode radial position, especially an increase of intensity in central part can be seen for a deep biasing electrode insertion.

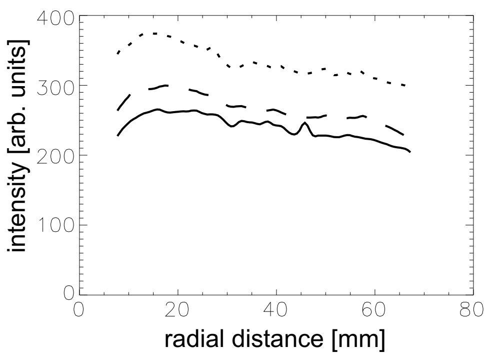

Fig. 7. The smoothed spatial profiles of N III line 99.0 nm (left) and N V line 123.8 nm (right) in OH regime without the edge plasma biasing (solid line) – the electrode is outside, and with biased electrode at radius 75 mm (dotted line) and 50 mm (dashed line)

4 Conclusions

The experiments on interaction of hot plasma with solid target are carried out in tokamak CASTOR and multimirror magnetic trap GOL–3. The edge plasma parameters in both facilities are similar to that expected in the divertor of next generation of fusion devices with exception of fast high–power wall loads. In both experiments, the Imaging Seya–Namioka Spectrometer has been installed for monitoring of the radial profiles of the low–Z impurity line intensities in the spectral range from 60 to 200 nm. The solid target surface becomes a source of the hydrogen and low–Z atoms, due to the recombination of the plasma ions. The radial profiles of chord–integrated intensity of Lyα H I and chosen lines of C III, N V and O VI were determined. Such spatially resolved intensity measurements together with application of the radiation code simulation also allow to obtain a particle influx and a radial density distribution of ions of different ionization stages and also to estimate the plasma parameters such a local electron temperature and density near the target [2], [5]. The simulations were started on CASTOR in cooperation with GOL–3 in the last year and will be continued. The numerical code is currently extended to determine the values of impurity flows and transport coefficients in a plasma. Moreover, the radiation of small–determined portion of the injected low–Z atoms by the target is considered to use for an in–situ calibration of impurity monitoring spectroscopic system.

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References

[1] V. Piffl, Vl. Weinzettl, A. V. Burdakov, S. V. Polosatkin: *Line Intensity Radial Profiles Evolution in VUV and XUV Spectral Range*, 30^{th} EPS Conference on Controlled Fusion and Plasma Physics, St. Petersburg, ECA Vol. 27A, P–1.061(2003).

[2] V. Piffl, Vl. Weinzettl, A. V. Burdakov, S. Polosatkin: *Diagnostic potential of the VUV and XUV imaging spectroscopy*, Transactions of Fusion Science and Technology **43**/No.1T (2003) 231–236.

[3] V. Piffl, Vl. Weinzettl, A. Burdakov, S. Polosatkin: *VUV Imaging Seya–Namioka Spectrometer*, Czechoslovak Journal of Physics **52**/Suppl.(2002) 70–76.

[4] V. Weinzettl, I. Duran, J. Zajac, V. Piffl: *Edge plasma biasing experiments on the CASTOR tokamak: spectroscopic investigation and microwave measurements*, Czechoslovak Journal of Physics 53 (2003) 925–935.

[5] I. A. Ivanov et al.: *Spectroscopic investigation of plasma–wall interaction on CASTOR and GOL–3 facilities*, 31st Zvenigorod Conference on Plasma Physics, 2004, Zvenigorod, Russia.

[6] A. V. Burdakov, Vl. Weinzettl, V. Piffl, S. Polosatkin: *VUV Imaging Spectroscopy on GOL–3 device*, 10th Russian Conference on High–Temperature Plasma Diagnostics, 2003, Troick, Russia, contrib. N5, p. 77–78.