Line Intensity Radial Profiles Evolution
in VUV & XUV Spectral Range

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I. Introduction

Light impurities transport in tokamak plasma near the edge region

One of the important topics in a fusion research is the study of the character of the impurities transport in tokamak plasma periphery. In plasma near the edge region, identification of impurity sources and the impurity transport play an important role in getting high temperature plasmas and designing the future thermonuclear reactor. In global, analysis of particle transport is required for the explanation and predication of reactor plasma confinement.

The radiation of the hot plasma, namely emitted from the plasma periphery, falls in the VUV and XUV part of the emission spectrum. The advanced imaging spectroscopy diagnostic methods of the plasma vacuum ultraviolet (VUV)- and ultra-soft X-ray (XUV) emission can provide the way of light impurity transport investigation [1,2]. It is well known, the radial distribution of the line emission density is influenced by the transport phenomena and differs from those calculated using pure coronal equilibrium. In some tokamak plasma regimes, the ion recombination time is comparable to the characteristic time of the particle transport. This fact leads to a distribution of ionised states, which is not in equilibrium with the electron temperature, as it would be expected according to the coronal model. The broadening of the radial profile for each ionised species is the typical effect of transport phenomena and can be determined by radial profile measurements of the chord-integrated intensity of the chosen line.

II. C4⁺ (308 eV/4.03 nm) radial intensity profile measurement

The radial profile of the chord - integrated intensity of C4⁺ (308 eV/4.03 nm) spectral line is measured by tilting of the Imaging XUV Monochromator over the full plasma radial cross-section of 170 mm in diameter. The emission from the plasma volume of 60 mm in radial dimension is imagined at the two stage microchannel plate assembly of 20 mm effective diameter, which is screened by 0.24 µm thick Ag filter. The detector consists of the eight anode-collectors each of 2 mm width and has 0.5 mm spacing. The signal of each collector
represents the emission power detected at different view angle and can be processed for line profile reconstruction. The use of the multi-anode collector brings another useful remarkable profit: an observation of the time evolution of radial profile of the spectral line emission [3].

III. Effect of biasing on C4⁺(308 eV/4.03 nm) radial intensity profile

A biasing electrode installed in CASTOR can be moved in radial direction. Usually the biasing potential is applied in quasistationary plasma conditions, approximately ten milliseconds after the discharge start. The biasing pulse duration is 5 ms only. Depending on biasing electrode radial position and applied biasing potential the different influence of biasing on plasma parameters behaviour is observed. If the biasing electrode is positioned inside the last closed magnetic surface, at radius of 50 mm, and applied potential is 150-200V, the intensity of Hα falls during the biasing and consequently the chord-integrated intensity of C4⁺ line emission grows up, while the intensity of C2⁺(464.7 nm) line, which is proportional to Carbon inflow, stay unchanged. During the biasing pulse the profile does broader and the maximum slightly shifts outward of the biasing electrode, Fig.1.

IV. VUV imaging Seya-Namioka spectrometer

The Imaging VUV Spectrometer was assembled according to the Seya-Namioka scheme [4]. The spherical dispersion grating with gold cover, radius of curvature ρ=0.5 m, 1200 grooves per mm, was installed in this instrument. The incident radiation after the diffraction is focused on the output window displaced near to the Rowland circle. Turning the grating body around the central axis does the spectrum scanning.

The two-dimensional detector system consists of set of two channel-plates of the working area diameter, 38 mm. The DC or impulse voltage, up to -1200V, is applied on channel plates set, while the electrons leaving the channel-plate converter are accelerated up to 3100V before impact the scintillator.

Fig.1 Time and space evolution of C4⁺(4.03 nm) line intensity contours. Biasing at 10 ms, Δt=5 ms
V. Effect of biasing on radial shape of the chord-integrated VUV lines intensity

The radial profiles of the chord-integrated intensity of the lithium- and beryllium-like oxygen ions O5+(103.2 nm and 103.7 nm), Fig.2, and O4+(63.0 nm), Fig.3, were measured by tilting of the Imaging VUV Spectrometer [4]. The spatial resolution is found to be better than 5 mm. Optical enlargement of the system is 2.93, so the viewed part of the plasma is 70 mm in height.

The shapes of the radial profiles were investigated basically in two different discharge regimes: ohmic heating regime and plasma polarized regime (biasing).

In ohmic heating discharge regime without polarisation, the radial profile is axially symmetric, Fig.2a. The maximum profile value achieves around 25 mm apart from the centre, where the local minimum of intensity is usually located.

In Fig.2b, the radial profile of the chord-integrated intensity of oxygen ion line O5+ is shown, if the biasing electrode is positioned inside the last closed magnetic surface at radius of 50 mm, and applied potential is +150V. The emission radial profile does displace from the polarisation electrode, consequently the intensity falls almost to zero near to the polarisation electrode.

**Fig.2** O5+ radial profile
- a) OH regime (above)
- b) OH + biasing regime (down)

**Fig.3** O4+ radial profile
- OH regime (red)
- OH + biasing regime (black)
VI. Conclusion

The Imaging VUV Spectrometer and the Imaging XUV Monochromator are operating on the CASTOR tokamak and provide the radial profile of the chord-integrated intensity measurements in the VUV (50-200 nm) and XUV (4.03 nm, C4+ line) spectral ranges. The effect of transport can be deduced from the chordal measurements of the line intensity radial profiles.

The radial profile shape of the O5+(103.2 nm) and O4+(63.0 nm) lines were also modelled by emission/transport code STRAHL. The result of such modelling is shown in Fig. 4. The calculated radial profile shape seems to be broader as measured one, like as the real diffusion coefficient of the oxygen impurity be lower than fitted, D⊥ ~ 2 m²/s and constant at radius.

The observed radial profile of the chord-integrated intensity of the C4+ (4.03 nm) line emission is central peaked, for the excitation potential of this line is much higher than central electron temperature. Such character of the radial profile is consistent with model calculations, using again the emission/transport code STRAHL, if the central electron temperature is taken near to 200 eV, the profiles of Te and ne are fitted in parabolic form and average diffusion coefficient D is higher than 2 m²/s.

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References:
[1] V. Piffl, Vl. Weinzettl, A. Burdakov, S. Polosatkin
Diagnostic potential of the VUV&XUV imaging spectroscopy,
Transactions of Fusion Science and Technology, Jan. 2003, Vol. 43, No.1T, pp. 231 – 236
[2] V. Piffl, H. Weisen:
Ultra-soft X-ray spectroscopy using multilayer mirror,
[3] V. Piffl, J. Badalec, Vl. Weinzettl, A. Burdakov:
Intensity radial profile study of CV(308 eV) line at tokamak CASTOR,
28th EPS Conference, Madeira, June 18-22 June 2001, P 3.085
VUV Imaging Seya-Namioka Spectrometer,