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VUV Imaging Spectroscopy on CASTOR Tokamak

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I. Introduction

The radiation of plasma, namely emitted from the plasma periphery, at tokamak temperature falls in the VUV part of the spectrum. The VUV spectrum and the magnitude of the radiate flux from a plasma are directly related to the plasma density and plasma impurities content.

Spatially resolved observations of the VUV emission in combination with plasma emission modelling provide a possible method of the plasma impurities behaviour investigation and can result in an evaluation of diffusion coefficient, effective charge, ..etc. The application of the spherical dispersion elements, like as diffraction grids [1] and or multilayer mirrors [2], makes it possible to create an image of the radial profile of the chosen spectral line intensity. It is well known the transport effects lead to some deviations of the radial distribution in the line emission density from those calculated using pure coronal equilibrium. They can be deduced from the chordal measurements of the radial profiles of the spectral lines intensity and or intensity ratios of spectral lines of different ionisation states both measured by chord-integrating spectrometer.

II. VUV imaging Seya-Namioka spectrometer

The spectral instruments equipped with curved diffraction gratings have been used elsewhere for getting of common information on spectrum in VUV emission range, where the use of the optical elements like lenses, prisms is undesirable due to the high absorption of VUV radiation in such elements.

Spectrometer beam line arrangement

The design of the spectrometer was based on vacuum spectrometer BM-3, product of Ioffe Institute, and assembled according to the Seya-Namioka scheme. In **Fig.1** the optical scheme of the Seya-Namioka spectrometer is shown. The spherical dispersion grating with gold cover, radius of curvature ρ=0.5 m, 1200 grooves per mm, was installed in this instrument.

The angle between incident and diffraction ray is 70°15’. The incident angle is smaller than the diffraction angle and the spectrum is obtained in negative orders. The incident radiation is coming through the input slit and after the diffraction at the grating is focused on the output window displaced near to the Rowland circle. The spectrum scanning is done by turning the grating body around the central axis.

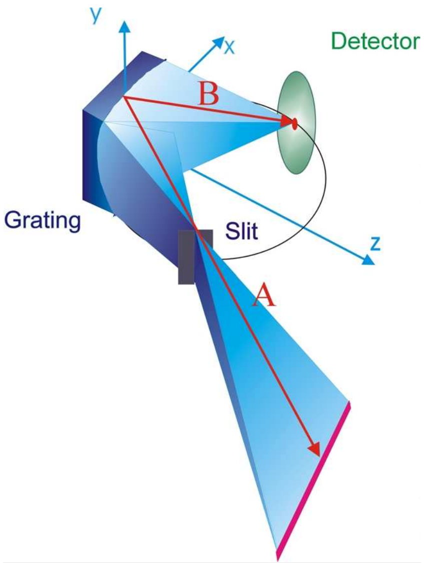

Fig.1. Formation of the image in spectrograph. The linear source located in vertical focus of the device, is represented as a point in a plane of registration.

Detector - converter system

The two dimensional detector system of the spectrometer, we have operated on CASTOR tokamak, consists of set of two channelplates of working area diameter, 38 mm. The front of the first channelplate is covered by CsI. The output electrons are accelerated onto the scintillator of the fiberoptic lightguide, which is consequently used as a vacuum throughput. The DC or impulse voltage, up to -1200V, is applied on channel plates set, while the electrons leaving the channelplate converter are accelerated up to 3100V before impact the scintillator. The spectra could be taken during the whole plasma discharge in 1÷10 ms exposition time, if the spectrometer detection system is operated in the pulse regime.

III. Spectrum and line intensity measurements

The theoretical limit of spectral resolution of the instrument is roughly equal to the number of illuminated grooves of grating. In our case, the spectral resolution could be expressed as the product of the tokamak input slit size, 20 mm, and grooves density, 1200/mm, so it has been found: $m\lambda/\delta\lambda=24000$.

The real instrument spectral resolution is basically determined by the width of the input slit and defocusation effect of the plane detector at the curved focal surface. The deviation of the flat detector from the focal surface grows with wavelength λ. For λ=200nm this deviation represents 1.5 mm at the frame edge. If we suppose the diffraction grating is illuminated at 20 mm length in so far that the line width ranges from 0.09 nm to 0.15 nm.

Spectrum observation

The spectrum of the line emission of the low-Z impurities was measured in 50 - 200 nm wavelength range on CASTOR tokamak, see **Fig.2.** The first order of line emission is indicated up to the wavelength 110 nm, then the lines of second and third order are seen in the range up to 200 nm. Above the 200 nm, the sensitivity of the channelplates falls and the detected spectrum contains the lines of higher orders. According to the spectrum analyse, it follows, the presence of the from Carbon-like to Lithium-like ionised states of plasma impurities was confirmed.

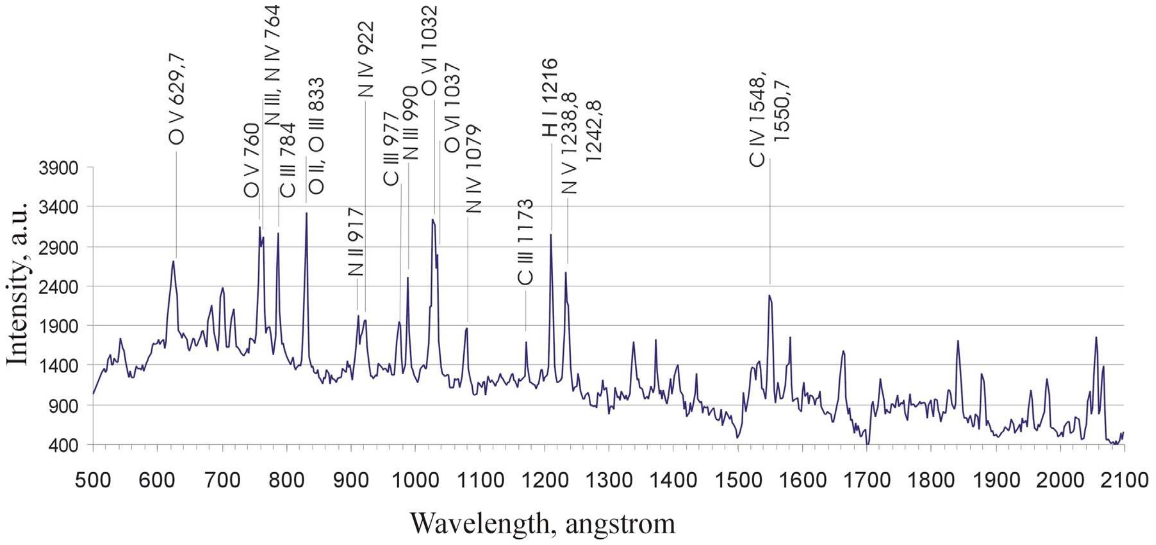

Fig.2. VUV spectrum radiation of the CASTOR tokamak

Consequently, the higher diffraction orders in spectrum have been analysed. In **Fig.3** the part of the plasma emission spectrum with lines in second and third orders are shown. The lines of Lithium-like Oxygen 103.2 nm and 103.7 are perfectly resolved.

Spatially resolved line intensity observation

In **Fig.4** we show some raw data illustrative of that obtained from CASTOR discharges. The shapes of the radial profile of the chord-integrated intensity of the OVI(103.2 nm) and NV(123.8 nm) were measured by tilting of the VUV Imaging Spectrometer, shot by shot, over the full plasma cross-section of 170 mm in diameter. The spatial resolution is found to be about 5 mm. Optical enlargement of the system is 2.93, so the viewed part of the plasma is 70 mm in height.

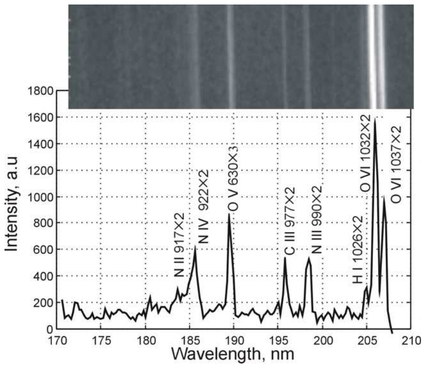

Fig.3. Part of plasma spectrum with lines in second and third orders of diffraction.

As discussed above, in consequence of incomplete illumination of the diffraction grating the sensitivity of the imaging systems falls at the frame edge. Therefore only the central part of frame, characterised by constant sensitivity, has been used in construction of the line radial shape. The blue lines in **Fig.4** correspond to the individual measurements by tilting, the red curve is the result of the data average. The observed displacement of the plasma centre relative to the chamber axis is the characteristic feature of the plasma column indicated by density profile measurement too.

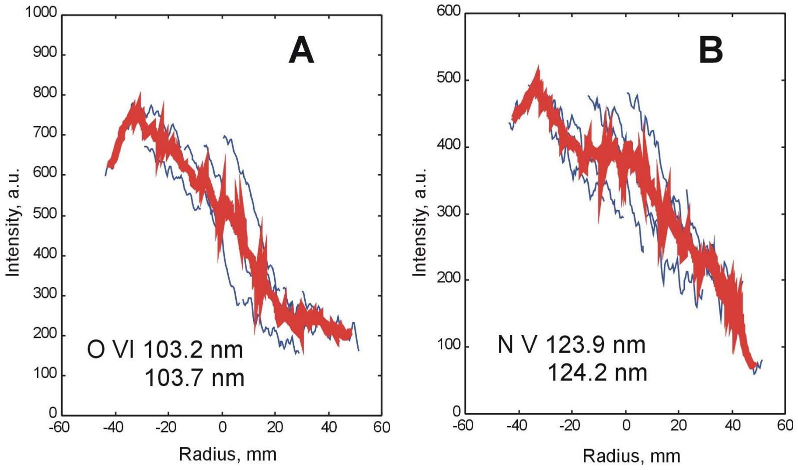

Fig.4. Radial distribution of
spectral line intensity:
a - O VI 103.2 nm, 103.7 nm
b - N V 123.9 nm, 124.2 nm.

IV. Conclusion

The imaging VUV spectrometer is operating on the CASTOR tokamak and provides the line intensity measurements in the 50-200 nm spectral range. There are presented the lines of the Carbon-like up to Lithium-like impurity ion states which could be used for the impurity transport investigation. It is well known that the transport effects lead to some deviations of the radial distribution of the line power density from those calculated using pure coronal equilibrium. They can be deduced from the chordal measurements of the line intensity radial profiles and or line intensity ratios of different ionisation stages both measured by chord integrating spectrometer. Nowadays, the experimentally created radial profiles will be compared to the numerical transport code calculations for transport parameters estimation at plasma periphery.

Acknowledgement: This work was supported by Grant: GA AV A1043002

[1] Burdakov A.V., et GOL-3 team, "Experiments directed to creation of hot plasma with beta~1 at the GOL-3 facility", Transaction of Fusion Technology, Vol.39,No.1T,January 2001, pp.135-138

[2] Piffl,V.,Weisen, H., "Ultra-soft X-ray spectroscopy using multilayer mirror", Transaction of Fusion Technology, Vol.39,No.1T,January 2001, pp.155-158