Impurity Line Emissions in VUV Region of TCABR Tokamak

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Abstract. Spectral emissions in the vacuum ultraviolet region from 50 nm to 320 nm have been measured on TCABR tokamak using an one meter VUV spectrometer and a MCP coupled to a CCD detector. Among the 98 emissions classified, 37 are from first order diffraction, 29 are from second order, 24 are from third order, 7 from fourth order, and one from fifth order diffraction. Main impurity lines are OII to OVII, CII to CIV, NIII to NV, FVII, besides working gas plasma hydrogen Lyman lines.

Keywords: VUV impurity lines, higher order diffraction emissions, tokamak plasma.

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INTRODUCTION

The study of the tokamak plasma light emissions in the VUV region is important because many impurity spectral emissions are in this region. Also, these emissions can be used to determine the ion temperatures and densities from different species at different spatial positions inside the plasma, including core region, according to their temperatures.

The VUV spectrum from 50 nm to 320 nm wavelength was analyzed in the TCABR tokamak [1] plasma including higher order diffraction emissions. Almost 100 spectral lines have been identified, where 37 are from first order diffraction, 29 from second, 24 from third, 7 from fourth, and one from fifth order diffraction.

Main emissions are from impurity atoms, such as oxygen, nitrogen and carbon, with high ionization level. Examples are OVII 162.4 nm, NV 123.8 nm, and CIV 154.8 nm. All the spectra beyond 220 nm are from higher order diffractions and can be used to study the impurity lines with much better resolution power as well as angular dispersion.

DETECTION SYSTEM

The VUV spectrometer is a 225 McPherson with one meter focal length and normal

incidence. It has a 1200 groves/mm concave grating, with Al and MgF2 coating, and blazed at 200 nm, giving a linear dispersion of 0.83 nm /mm and covering 50nm to 350 nm. The spectrometer is pumped below $1x10^{-6}$ torr by a 250 l/s turbo molecular pump and connected to the TCABR tokamak chamber by a 3.6 cm diameter, 4.80 m long stainless steel tube with differential pumping, and is aligned to observe the equatorial plane of the tokamak.

The multichannel detector is an open 40 mm diameter MCP plate (BrightView XUV2010 G, XSI instruments) coupled to a CCD device (Marconi CCD30-11, Andor Technology) with 1024x256 pixels, with each pixel having 26 μm x 26 μm. The MCP plate is coated with CsI to convert VUV photons in electrons, and has a phosphor screen to convert the electrons in photons. A reducing coherent glass fiber array was used to couple the MCP to the CCD [2].

SPECTRAL EMISSION MEASUREMENTS

The measurements in the VUV region of TCABR tokamak plasma covered emissions from 50 nm to 320 nm and is divided in five sections. Each section is the result of three similar tokamak discharges, where only central part of each measurement per discharge has been taken into account avoiding the use of the CCD matrix edge.

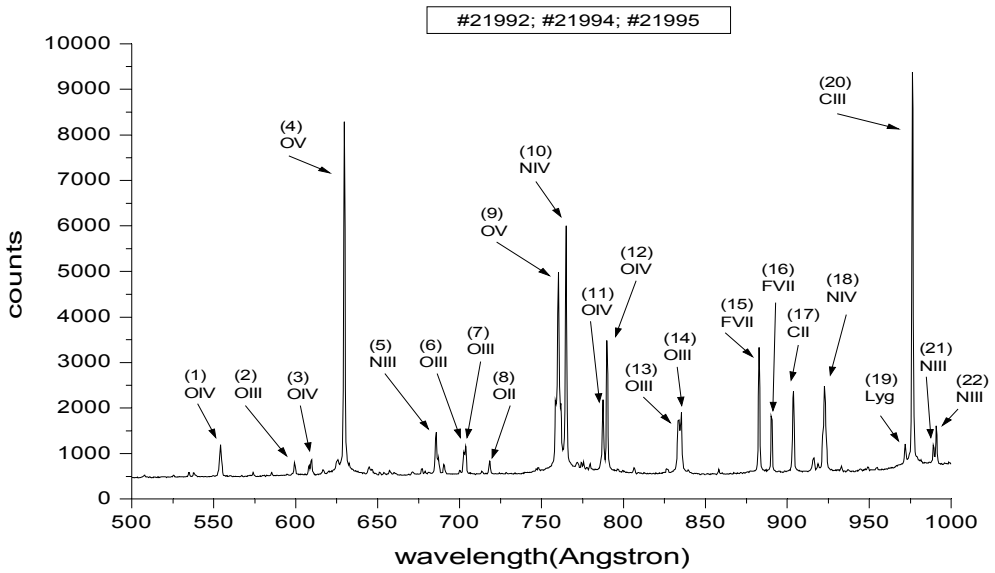

FIGURE 1. TCABR VUV spectra from 50.00 to 100.00 nm with 22 first order emission lines.

In figure 1, spectral lines from 50.00 nm to 100.00 nm are shown. There are 22 first order emission lines, where the important lines are (1), (4), (11), (12), (15), (16), and (20) due to their intensity, profile and spectral localization. Many of these emissions have also been observed in other tokamak as in the references [3], [4], [5], [6], and [7]. The lines (15) and (16) are from fluorine [4] in the Teflon material used in our microwave interferometer window.

In figure 2 are shown emissions from 100.00 nm to 160.00 nm. In this interval we

observe 9 first order and 9 second order diffraction spectra. Emissions from OVI (24, 25), Lyman alpha (29), NV (31, 32) and CIV (39, 40) are the strongest first order emissions. The duplet lines of OVI (24, 25) and CIV (39, 40) also are frequently used in tokamak diagnostics. As can be noticed the second order emission lines, due to the first emissions of figure 1, start to appear at 110.00 nm.

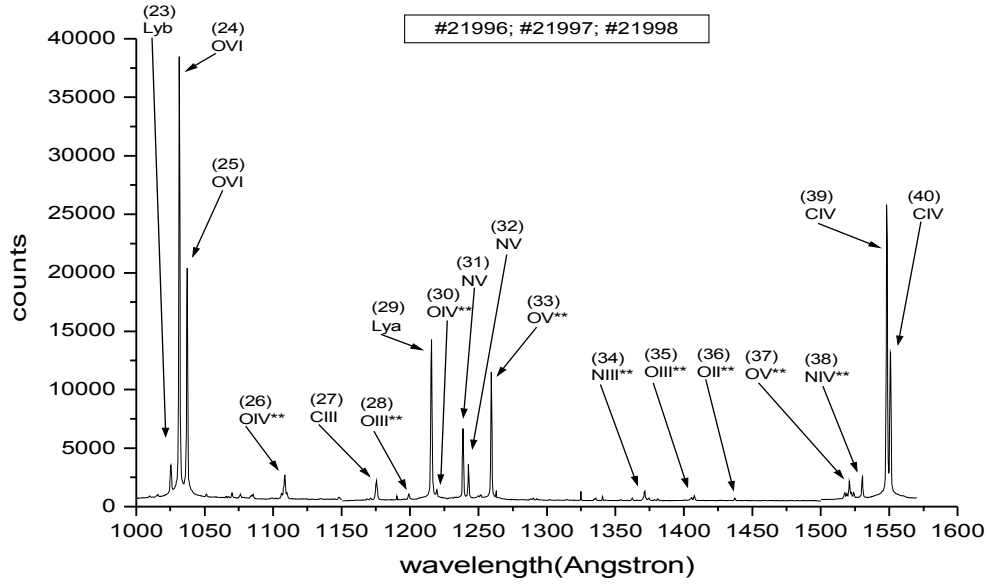

FIGURE 2. VUV spectra from 100.00 to 157.50 nm with 9 first order and 9 second order diffraction spectra.

Figure 3 shows the emissions from 155.00 to 210.00 nm. Where 6 are from first order, 13 from second order and 2 are from third order diffraction. The U1 (56), an unidentified line, is the last first order diffraction spectra of our measurements. The OVII (43) is a very strong and isolated line which could be used for diagnostics. The doublet OVII (44) and (45) also are interesting emissions due to clearness of their emissions.

Following to figure 4, the emissions are from 220.00 to 260.00 nm with 4 second order, 13 third order, and 5 fourth order diffraction emissions. There are no more detectable first order emissions, and all the spectral lines are low intensity counts, but still well defined and useful for analysis. The multiplet OV***(66,67,68,69,70) shows very good separation, and many higher order diffraction emissions as CIII**(72), OIV***(73), OIV***(74), Lyalfa**(75), and OV****(83) are well isolated and interesting for diagnostics. Here, **, ***, ****, stands for second, third and fourth order emissions respectively.

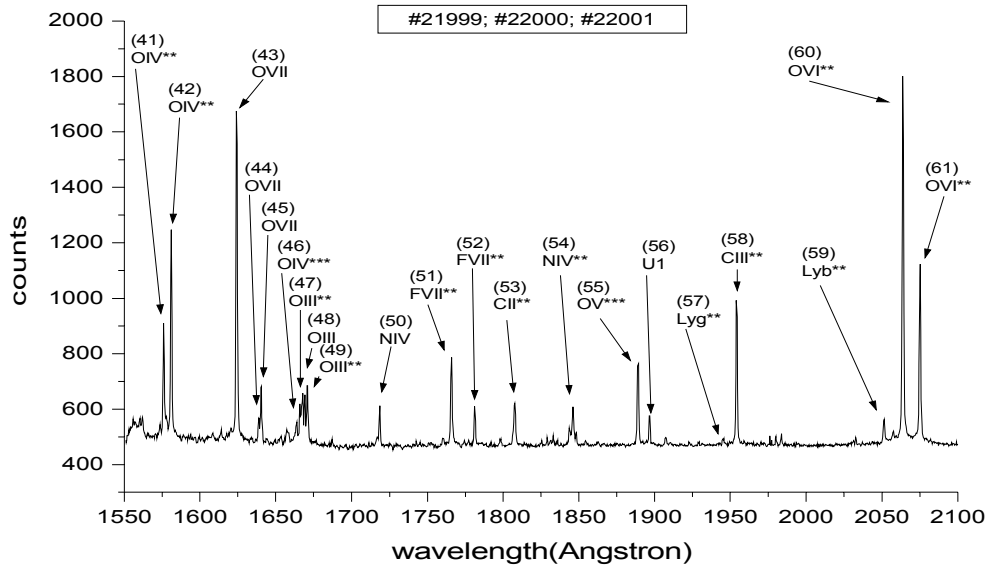

FIGURE 3. VUV spectra from 155.00 to 210.00 nm, where 6 are from first order, 13 are from second order, and 2 are from third order diffraction spectra.

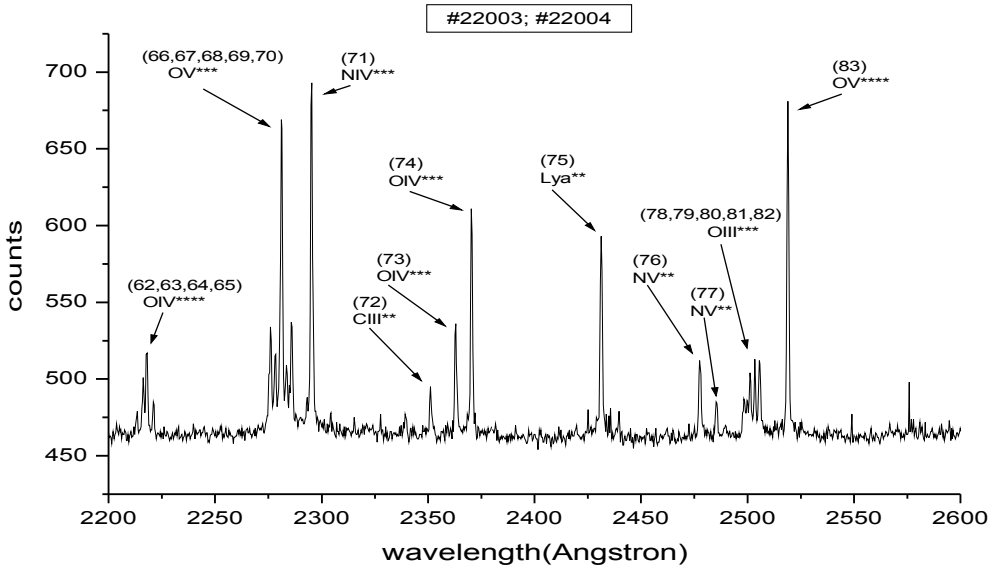

FIGURE 4. VUV spectra from 220.00 to 260.00 nm where 4 are from second order, 13 are from third order, and 5 are from fourth order diffraction emissions.

In the last section of measurements, figure 5 covers the emissions from 260.00 to 320.00 nm. There are 2 second order, 9 third order, 2 fourth order, and one fifth order diffraction emissions. Emissions are mainly from higher order diffraction, and lines as FVII***(84, 85), CII***(86), CIII***(88), Lybeta***(92), OVI***(96), are well isolated. Complete overlapping of OIV***(93) and CIV**(94) giving a giant pulse is also very interesting.

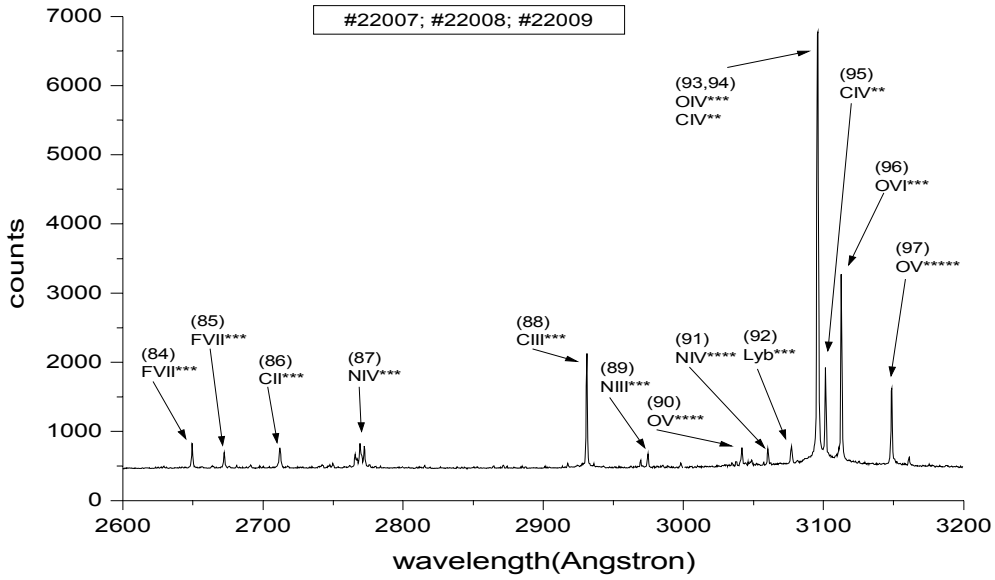

FIGURE 5. VUV spectra from 260.00 to 320.00 nm. Where 2 emissions are from second order, 9 are from third order, 2 are from fourth order, and 1 is fifth order diffraction emission.

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