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Measurements of line radiation power in the CASTOR tokamak

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Introduction.

The determination of absolute values of radiated power of selected spectral lines is required for comparison of VUV spectroscopic data with bolometric measurements to estimate the full radiated power and also the impurity content in plasma. In the paper the procedure of calibration of VUV spatial imaging spectrometer is described. The comparison of measured radiation power in different spectral regions is presented.

Calibration of VUV spectrometer.

The technique of calibration of spatial imaging VUV spectrometer was developed on the GOL-3 facility in the Budker Institute [2]. The line branching ratio method is used for calibration [3]. The main idea of the method is following: two spectral lines with common upper level, lying in the VUV and visible spectral ranges, are simultaneously observed. The ratio of intensities of selected lines is a constant, depending only on internal atomic structure of radiating ion. In the visible range, the calibration can be carried out by conventional technique using black-body radiation source.

Spatial resolved spectrometer allows simplifying the calibration procedure. In such a case the distance from the radiation source as well the area of collection of radiation does not influence the results of measurements, if the VUV and visible spectra are recorded along a common chord of view.

The wide list of spectral line pairs suitable for calibration is given in [3]. In presented experimental measurements, the pair of hydrogen lines Lβ (102.6 nm) / Hα (656.3 nm) with intensity ratio equal to 12 is used. Photo multiplier tube (PMT)-based detector with interference filter calibrated by black-body source (tungsten filament lamp) is used for light registration in visible branch. The main problem of calibration using these lines is that Lβ line lies near to bright oxygen doublet OVI (103.2, 103.7 nm) and cannot be sufficiently resolved by spectrometer. Thus, first millisecond of discharge, when hydrogen lines dominate in spectrum, is used for calibration, Fig.1.

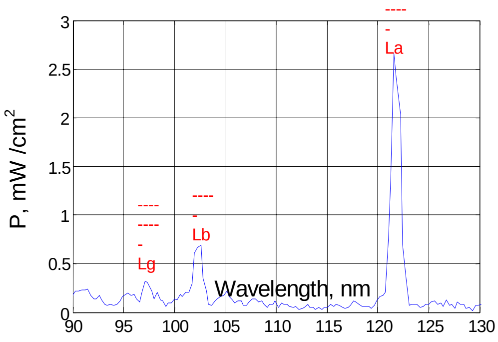

Fig.1 Spectrum of plasma radiation during the first millisecond of discharge

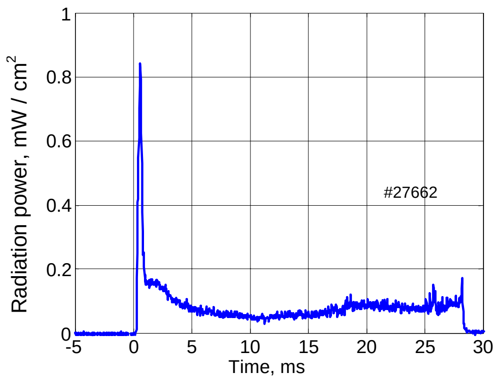

Fig.2 The time history of the Hα (656.3 nm) spectral line. The peak observed in the first millisecond corresponds to bulk ionization of hydrogen.

Hydrogen lines radiation.

During the first millisecond of discharge, the hydrogen lines dominate in the spectrum and are suitable for the calibration procedure. The time history of the Hα spectral line is shown in Fig.2. The peak observed in the first millisecond corresponds to bulk ionization of hydrogen. It is well known that the rate of ionization and excitation of atom fulfill a similar dependence on temperature and density. The ratio of ionization rate to radiation probability of selected line, S/(XB) (ioniSation/(eXcitation·Branching_ratio)) is practically constant for wide range of plasma parameters. For Hα spectral line the S/(XB)=15 in the plasma temperature range from 10 to 1000eV. It means, that fifteen ionization events are accompanied by emission of one Hα photon [4]. Thus, the increase of ionized hydrogen atoms can be derived from detected Hα radiation power during the ionization peak. In the presented shot in Fig.2, the value of estimated ionized hydrogen atoms density of $0.6\cdot10^{19}$ m^{-3} is compared with measured plasma density by interferometer, $0.8\cdot10^{19}$ m^{-3}. The electron temperature measured by electric probes exceeds some eV even in the shadow of the limiter. Recombination of hydrogen is negligible in the plasma edge. So the neutral hydrogen flux can be calculated from Hα power measurement via S/(XB) value. Such estimation gives the value equal to $(3\text{-}5)\cdot10^{19}$ atoms/$m^2\cdot s$ of the neutral hydrogen influx.

Dynamics of impurities ionisation.

The time history of line radiation power of different oxygen ionisation stages detected during the CASTOR plasma discharge is seen in Fig.3. The plasma temperature linearly

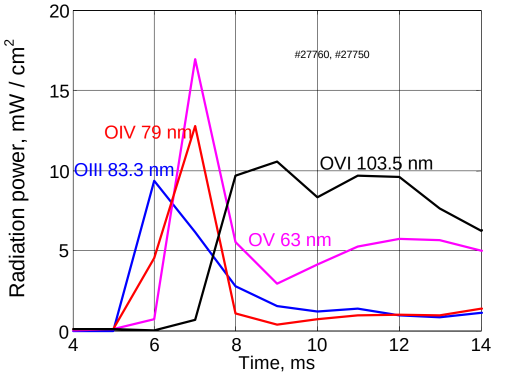

Fig.3. The time history of line radiation power of different oxygen ionisation stages detected during the CASTOR plasma discharge.

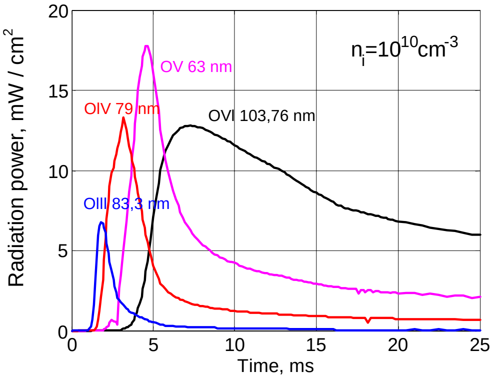

Fig.4. The modeling results of line radiation power dynamic of different oxygen ionisation stages carried out by STRAHL code.
(calculation done in $n_{imp}=10^{16}$ m^{-3}).

growths during the first 5 ms, as can be found from plasma conductivity. The different Oxygen ionisation stages gradually appears The intensity of OVI spectral lines achieves the maximum at 4 ms after the discharge beginning.

The experimental measured time evolution of spectral line intensities are compared with calculation of impurity radiation dynamic carried out by STRAHL code [5]. In the modeling the n_{imp} is constant, electron density is taken from interferometric measurements, electron temperature was calculated from plasma conductivity supposing Z_{eff}~1. The modeling results are shown in fig.4. Comparison of measured and calculated provides the oxygen ion density of 10^{16} m^{-3}. According to the like same modeling, the carbon ions density is of $(0.2\text{-}0.3)\cdot 10^{16}$ m^{-3} in the same plasma discharge.

Comparison of radiation power in different spectral ranges

The time behaviour of plasma radiation power in different spectral ranges is shown in Fig.5. Radiation in visible range was measured by PMT without filters in the wavelength range from 400 to 700 nm. The VUV radiation power is measured by VUV spectrometer in zero order (without spectral selection) in 50-200 nm range, which is limited by grating reflectivity in short and by detector sensitivity in long wavelength ranges. The full plasma radiation power is detected by AXUV bolometers characterized by constant sensitivity from UV up to soft x-ray region.

As it seen in Fig.5, the radiation power in visible and VUV ranges is low in comparison with full radiated power. We have found, that the bolometric signal is determined by short

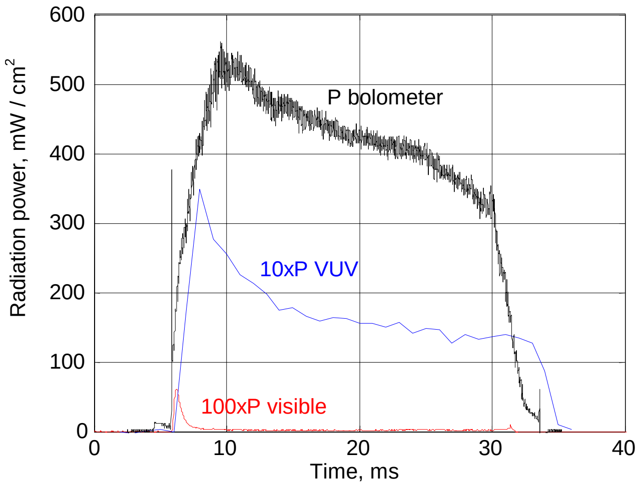

Fig.5. Plasma radiation power in different spectral regions. The radiation power in visible and VUV ranges is low in comparison with full radiated power.

wavelength radiation (XUV and SX) from high temperature plasma core. So the installed imaging system based on AXUV detectors can be applied for hot core plasma shape determination and a control of plasma position time evolution.

Conclusion

The variation of branching ratio method of absolute calibration of spatially resolved VUV spectrometer was successfully applied on the CASTOR tokamak. Neutral hydrogen flux and concentration of light impurities in plasma were estimated by measurement of spectral lines radiation power. It was shown, that main radiation loses are due to the short wavelength radiation emitted by plasma core.

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