THE EFFECTS OF EMISSIVITY PROFILES ON POLARIZATION MEASUREMENTS AT TEXTOR 94

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1. Introduction

A common experimental technique used to measure x-ray polarization involves crystal spectrometers which act as polarizing elements under the right configuration. For Bragg reflection with an angle of 45^o, only the component of the radiation with a polarization perpendicular to the plane of incidence will be reflected with any significant intensity[1]. Linear polarization can be measured by orienting two crystal spectrometers perpendicular to each other. This configuration has been employed to measure the polarization of He-like argon (Figure 1) on the tokamak TEXTOR 94. One Johann spectrometer is oriented parallel to the midplane of TEXTOR 94, and a second Johann spectrometer is oriented perpendicular to the midplane of TEXTOR 94 (Figure 2).

A difficulty in making polarization measurements on TEXTOR 94 arises from the geometry of the spectrographs and the source. For Johann spectrometers, each spectral line is observed from a slightly different location in the plasma. This is a problem, since the emission profiles of the He-like argon lines are narrow for conditions where polarization is expected to be strongest. The spatial variation of the plasma combined with the geometry of the Johann spectrometer results in different intensities measured by the vertical spectrometer for each line.

This paper focuses on the role that geometrical affects play on the measured intensities of the spectral lines of He-like argon on TEXTOR 94. Two ohmic operating conditions were investigated where geometrical effects were strong. The first consisted of a plasma current of 210 kA, with an electron density of 2.0×10^{13} cm^{-3} and an electron temperature of 0.8 keV. The second consisted of a plasma current of 350 kA, with an electron density of $2.5 \times 10\ cm^{-3}$ and an electron temperature of 1.1 keV. The emissivity profiles were measured, to ensure that they were known, and then the plasma was moved to determine how the intensity of each spectral line varied as a function of plasma position. A model was used to simulate the behaviour of the plasma movement. From the understanding of these geometrical affects, reliable results can be obtained for polarization experiments on TEXTOR 94.

2. Emissivity profiles

The emissivity of a plasma depends on the local conditions in the plasma. For the emission of He-like argon, the emissivity is given by

$$I = n_e \; n_{He-like}(T_e, n_e) \left\langle \sigma v \right\rangle (T_e) \,, \qquad (1)$$

where n_e is the electron density, $n_{He\text{-}like}$ is the density of He-like argon, T_e is the electron temperature and $\left\langle \sigma v \right\rangle$ is the excitation rate which is different for each line[2,3]. The emissivity profiles can then be calculated if electron density, ion density, electron temperature, and excitation rates are known. It is assumed that the ion density is proportional to the electron density, and that the ionization distribution corresponds to coronal equilibrium. For TEXTOR 94, the electron density and temperature profiles are given by

$$n_e(r) = n_e(0)\left(1 + q\left(\frac{r}{a}\right)^2\right)^{-2/3} \qquad T_e(r) = T_e(0)\left(1 + q\left(\frac{r}{a}\right)^2\right)^{-4/3} \qquad q = 590\,\frac{B_t(T)}{I_p(kA)}\,, \qquad (2,3,4)$$

where r is the radial position in the plasma, a = 46 cm is the minor radius of the plasma, B_t is the toroidal magnetic field, and I_p is the plasma current[4].

The theoretical profiles were checked for TEXTOR 94 by measuring the emissivity profiles. The profiles were obtained by rotating the crystal of the vertical spectrometer across the plasma from shot to shot, while keeping the horizontal spectrometer fixed. The profiles were found by taking the ratio of each line obtained in the vertical system with the w line obtained in the horizontal system. This was performed to take out the differences in argon concentration that might result on different shots. The w line was used because is one of the strongest lines and suffers the least from statistical errors.

Figure 3. shows the results of the emissivity profile measurements for the w, x, y, and j+z lines compared to theoretical profiles obtained using equation 1. There is good agreement between the experimental and theoretical profiles. This means the calculation of the emissivity profiles for TEXTOR 94 under various operating condition can be performed. The theoretical emissivity profiles were then used to calculate the affects of plasma movement on lines measured by both spectrometers.

3. Plasma position effects

Due to the geometry of the spectrometers and the spatially dependant emission, it is expected that if the emission profile changes or if the position of the profile changes, there will be a difference in the measured intensities of the spectral lines. This effect can be modeled by using ray tracing techniques. The model simply integrates over the volume observed by each spectrometer for every line and determines how this varies as the plasma is moved.

To test the theory, a series of experiments was carried out on TEXTOR 94 where the plasma position was intentionally changed. The results can be fitted by the model for the configuration of the spectrometers on TEXTOR 94(Figure 4). A constant factor was introduced to take into account the difference in response between the two detectors used. In addition, the scaling factor for the vertical position of the plasma, measured by the position diagnostic, was varied. A good fit was found for only one set of these parameters. The response of the vertical relative to the horizontal system was found to be 3.0, and the scaling factor for the vertical position was found to be 2.1. This is slightly higher than the scaling factor of 1.65-1.75 suggested from another method at TEXTOR 94, but the accuracy of the method is not known.

4. Conclusions

We have succeeded in modeling the geometrical effects of the spectrometers and source for TEXTOR 94 under the assumptions of coronal equilibrium for the ionization distribution, an ion density proportional to the electron density, and the appropriate temperature dependence for the excitation rates for the emissivity profiles. By understanding the geometrical effects it becomes possible to begin investigating polarization.

References

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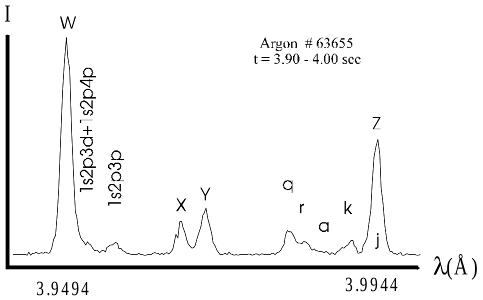

Key	Transition	Wavelength (Å)
w	$1s^2\,{}^1S_0 - 1s2p\,{}^1P_1$	3.9494
x	$1s^2\,{}^1S_0 - 1s2p\,{}^3P_2$	3.9661
y	$1s^2\,{}^1S_0 - 1s2p\,{}^3P_1$	3.9695
z	$1s^2\,{}^1S_0 - 1s2s\,{}^3S_1$	3.9944

Figure 1. He, Be, Li-like argon spectrum.

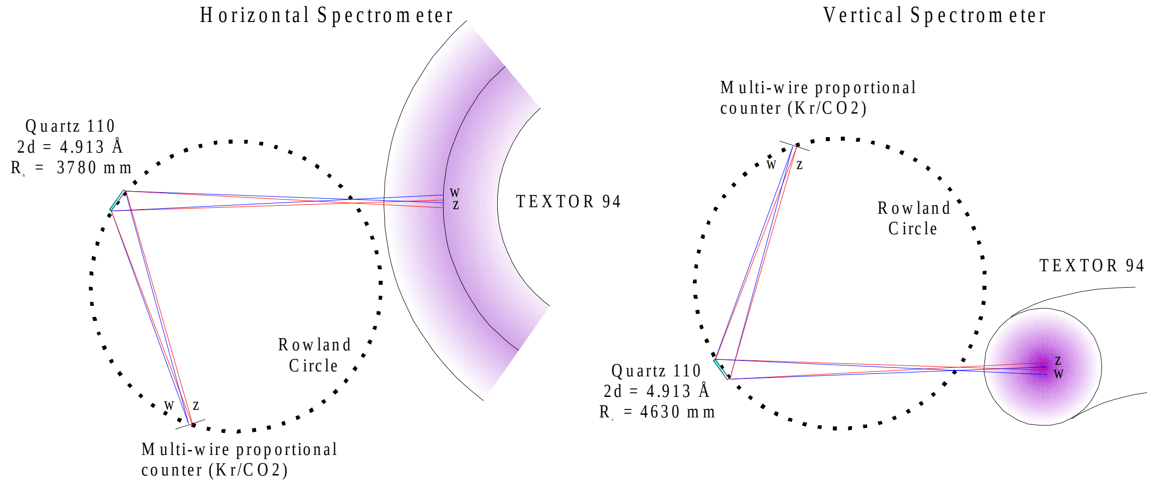

Figure 2. Polarization on TEXTOR 94 is measured with two Johann spectrometers with perpendicular planes of dispersion.

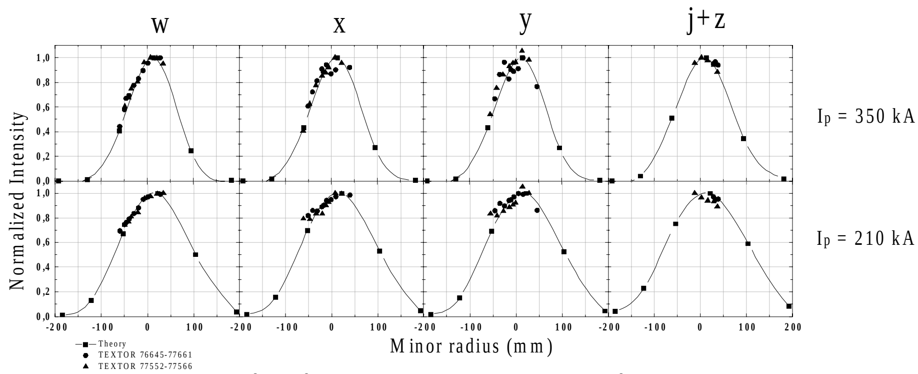

Figure 3. Experimental emissivity profiles for the w, x, y, and j+z lines of He-like argon compared with theory for ohmic plasmas with I_p = 210 kA and I_p=350kA.

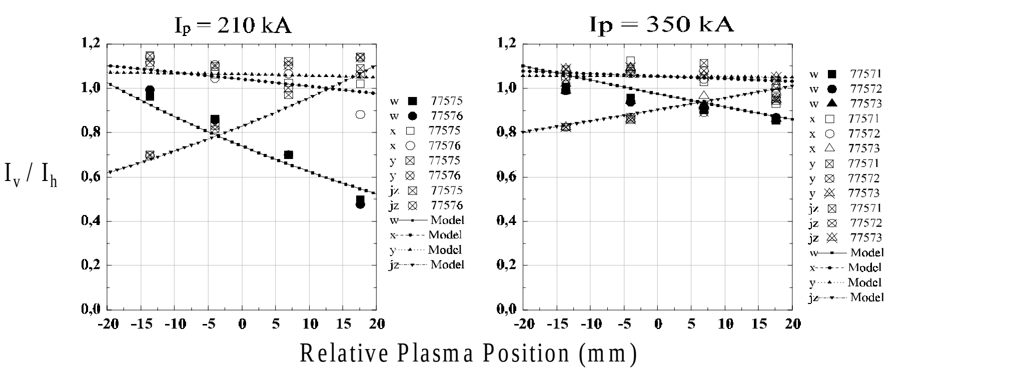

Figure 4. Ratio of the w, x, y, and j+z intensity in the vertical spectrometer to the corresponding intensity in the horizontal spectrometer. The ratios were measured for ohmic discharges with plasma currents of I_p = 210 kA and I_p = 350 kA, and compared with model calculations.