LINE EMISSION PROFILES OF FAST HELIUM BEAMS FOR FUSION PLASMA DIAGNOSTICS

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Summary

Visible HeI beam emission profiles have been measured at JET using 70 and 130 kV pure and doped He beams in a radially swept high clearance L-mode plasma. The measured spectra are very clean with good spatial coverage. Altogether, the profiles of 7 different lines could be measured in plasmas with $1.5 \leq Z_{eff} \leq 2.1$. These profiles will be used to develop a reversion code extracting density- and temperature profiles from the He beam emission profiles.

1 Introduction

Thermal helium beams have been successfully used for measuring electron temperature and -density in tokamak edge plasmas [1]. Fast lithium beams are widely used for diagnosing the density profile [2] in the plasma edge. It has been proposed to use beam emission spectroscopy from fast helium beams as density- and temperature diagnostics, for covering a wider range than either for thermal helium beam or fast lithium beam diagnostics [3]. To make fast He beams routinely available, the concept of a doped D_2/He beam was developed, which allowed using a heating beam parasitically as a He particle source [4]. Fast He atoms, produced by charge exchange from accelerated He ions, have non-negligible metastable fractions. In the case of the doped beam, this fraction is of the order of 10%. In pure ground state beams singlet to triplet line rations are mainly sensitive to temperature. This feature is lost in a beam with noticeable initial metastable population, due to the different life times of singlet and triplet metastable states. This means that the deduction of temperature- and density profiles from the beam emission profile is more complicated with fast He atoms than with

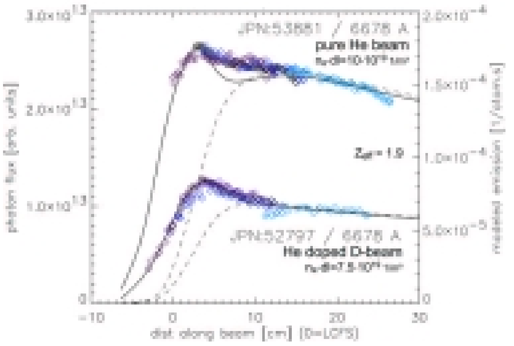

Fig. 1: Comparison of given singlet beam emission profile for a doped D/He and a pure He beam.

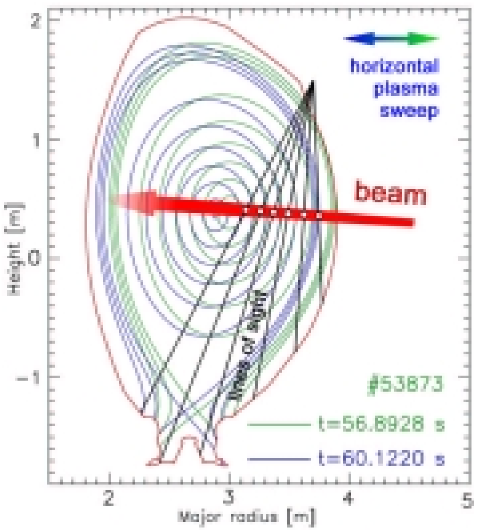

Fig. 2: Flux surfaces (EFIT) for the extreme positions of the horizontal sweep.

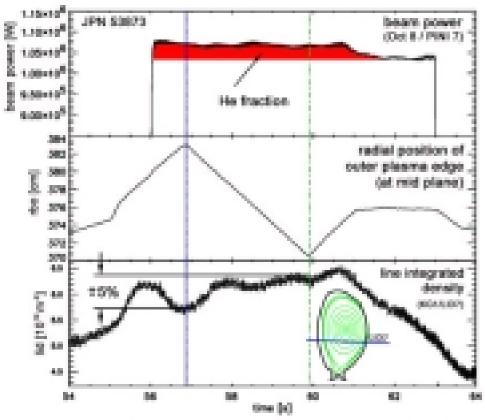

Fig. 3: Time trace of injected beam power, plasma position and line integrated density during a sweep pulse.

thermal ones [5]. For development and testing of a suitable reversion code high quality HeI beam emission profiles are required.

2 Recent measurements of HeI beam emission profiles at JET

For these measurements a doped D/He and a pure He beam with 70 kV and 6 s duration from the octant 4 injector, or a doped D/He beam with 130 kV from the octant 8 injector were used. From a comparison of the singlet beam emission intensities between the pure beam and the doped beam (Fig. 1) a beam current of 5A is estimated for the doped beam. The current of the pure beam was 16A.

By sweeping the plasma, high spatial coverage could be obtained with a limited number of lines of sight (Fig. 2). The overlap of neighbouring lines-of-sight allowed to calibrate them in against each other. To obtain a quiescent plasma, a high clearance L-mode discharge was selected. The plasma was slowly swept radially by ± 60 mm with a ramp rate of roughly 50 mm/sec. The main plasma parameters are shown in table I. The timing of the He injection is shown in Fig. 3. The line average plasma density was constant to ±5% during the sweep. To vary Z_{eff} either CD_4 or D_2 was puffed into the plasma during He injection.

Table I: Plasma parameters	
line averaged density	7-10 $10^{19}m^{-3}$
central el. temperature	1.5 - 2 keV
toroidal field	2.4 Tesla
Plasma current	2.5 MA
add. heating	3 MW

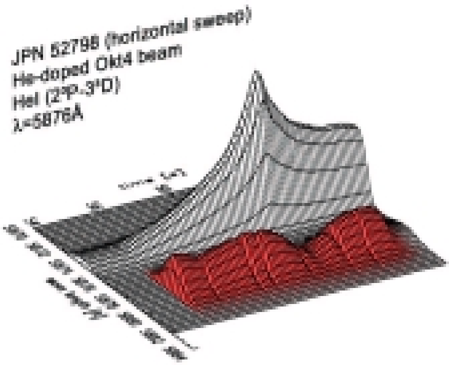

Fig.4: Beam emission profile showing the Doppler-shifted emission (right, red) and the unshifted emission (left) for a 6s doped 74 kV beam.

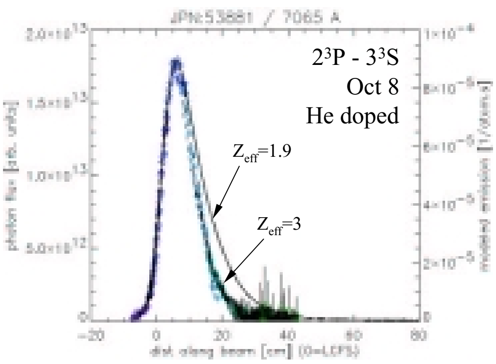

Fig. 5: HeI beam emission profile of the 2^3P-3^3S triplet line (He doped beam 130 keV).

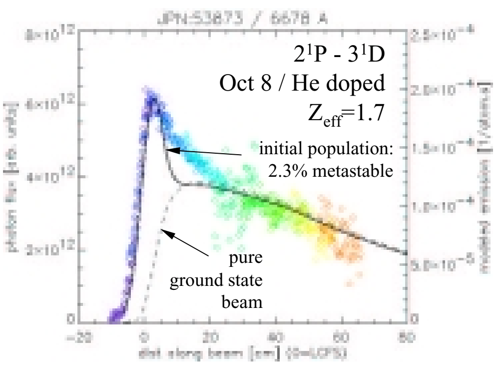

Fig 6 HeI beam emission profile of the 2^1P-3^1D singlet line (He doped beam 130 keV).

3 Experimental Results

Fig. 4 shows the beam emission spectrum of the most intense singlet line (2^1P-3^1D) at 668 nm during a plasma sweep. The Doppler shifted beam emission is well separated from the unshifted edge emission and not obscured by impurity lines. The intensity varies with time due to the plasma sweeping. The short interruptions (40 ms) of the beam current due to breakdowns are also clearly visible.

3.1 Triplet beam emission profiles

Fig. 5 shows a measured beam emission profile of the 2^3P-3^3S HeI triplet line at 707 nm together with the modelled profile using the collisional-radiative model of Brix [6]. The profile is only measurable over 300 mm along the beam trajectory, which corresponds to **xxx** mm radially, and has very little noise. To match the modelled profile with the measured one, a Z_{eff} of 3 has to be assumed, in contrast to the measured Z_{eff} of 1.9. For the modelling, carbon is taken as the only impurity with the same profile as the plasma electrons. The modelled beam emission lines are averaged over the radial resolution (40 mm) of the measurement, and a 30 mm shift of the calculated profiles was introduced to improve the fit of the data. This shift is within the accuracy of the mapping.

3.2 Singlet beam emission profiles

Fig 6 shows the measured beam emission profile of the 2^1P-3^1D HeI singlet line at 668 nm together with the modelled profile. The contribution of the initial metastable 2^1S state is noticeable outside of and for the first 150 mm inside the last closed flux surface. A 2.3% initial population of the 2^1S state gives the best fit between measurement and modelling. However, there is a characteristic difference in the range of

	wave length [Å]	relativ intensity	OCT 4		OCT 8
beam			pure He	doped	doped
singlet lines	6678	1	x	x	x
	4922	0.5	x		
	5015	0.2	x	x	
triplet lines	5876	1	x		x
	7065	0.09	x	x	x
	3889	0.08		x	
	4471	0.03	x		

Table II: List of measured HeI lines

50mm ≤ z ≤ 150mm. A similar difference has been observed in the H_α beam emission between the modelled and the measured beam attenuation [7], which also occurs near the plasma edge. One likely reason, as already indicated in [7], for this discrepancy could be a difference in the profile shape between impurity- and plasma electrons. Also noteworthy is the higher peakedness of the beam emission profile in the case of 130 kV particles compared to 70 kV, which requires to assume a higher metastable 2^1S fraction at 130 kV for the modelling. In the present experimental campaign we could measure the beam emission profiles of three singlet and four triplet lines. The relative intensities of these lines are shown in table II.

4 Outlook

Availability of high quality HeI beam emission profiles is a prerequisite for the development and testing of a reversion code extracting density- and hopefully temperature profiles from the He beam emission profiles. Further work along these lines is in progress.

References

[1] B. Schweer, M. Brix, and M. Lehnen, Measurement of edge parameters in TEXTOR-94 at the low and high field side with atomic beams, J. Nucl. Mater. 266-269, pp 673-8 (1999).

[2] E. Wolfrum, F. Aumayr, E. Hintz, D. Rusbüldt, R. P. Schorn, D. Wutte, and HP. Winter, Fast lithium – beam spectroscopy of tokamak edge plasmas, Rev. Sci. Instrum. 64, pp 2285-92 (1993)

[3] S. Menhart et al, Explorative studies for the development of fast He beam plasma diagnostics, Journal of Nuclear Materials 290-293, 673-677 (2001)

[4] H. D. Falter et al, Helium doped hydrogen or deuterium beam as cost effective and simple tool for plasma spectroscopy, Rev. Sci. Instr. 71, pp 3723-27 (2000).

[5] M Proschek, Development of fast helium beam emission spectroscopy for plasma density- and temperature diagnostics, Proceedings of the 18th IAEA Fusion Energy conference, 4-10 October, Sorrento, Italy (2000)

[6] M. Brix, PhD thesis (in German), internal report Forschungszentrum Jülich Jül-3638 (1999)

[7] W. Mandl, Development of active Balmer-alpha spectroscopy at JET, JET-IR(92)05 (1992)

Acknowledgement

This work was carried out within Association EURATOM-ÖAW and supported by Friedrich Schiedel Stiftung für Energieforschung.