1. INTRODUCTION

Reducing the activation of the vessel and its components during the early phase of ITER operation is important. One scheme of minimising the activation is to use helium as the heating neutral beam species. This gives rise to a concern about how effective diagnostic spectroscopy will be with such beams. The diagnostic use of deuterium heating beams is well established yielding, for example, ion temperature profiles, plasma rotation, magnetic fields, impurity concentration, $Z_{\text{eff}}$ and beam penetration measurements. The experience with helium beams is more limited and there are greater uncertainties in the fundamental atomic data. A helium neutral beam has certain potential advantages: a reduced beam halo, no fractional energy components, greater penetration than deuterium beams and possibly more efficient charge exchange donation in certain energy regions.

At JET a series of experiments have been undertaken with helium beams to address these issues. A number of these plasmas have very high concentrations of He, up to 100%, which is also of relevance for future ITER operations. Beam emission and charge exchange spectra were detectable and useful. It is shown that the diagnostic capability is high matching that of deuterium but with some marked differences.

2. JET EXPERIMENTS AND IMPLICATIONS FOR ITER

The JET experiments have used both a He-doped deuterium beam and a full helium beam. The doped $D_2$/He system was developed\(^1\) to make fast He beams routinely available by using the heating beam as a parasitic He source. The beam emission is viewed by a twelve chord spectrometer whose lines of sight are almost parallel to the beam at their intersections, located between the boundary and the plasma centre. By sweeping the plasma, a much higher spatial resolution is achieved together with an in situ relative calibration between lines of sight. A

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high clearance L-mode plasma was selected for all experiments to give ELM free plasmas. The plasma was swept by ±6cm with a ramp rate of ~ 5cm/s. The volume varied by ~ 2% and the line averaged density was constant to within 5%.

2.1. Phenomenology

The two electron nature of helium produces a rich spectral phenomenology from both HeI and HeII emission, from both beam and plasma. This has no equivalent in a deuterium beam but initial studies show it to have special diagnostic potential. Note that at the JET beam energies there is a negligible motional (linear) Stark effect on the n = 3 He levels. Although this simplifies the spectral analysis, there is no direct MSE diagnostic. The immediate analysis focuses on beam emission (BME) and impurity charge exchange (CXS) which are the equivalents of these for deuterium beams and on the role of metastables.

2.2. Beam Emission

Monoenergetic, essentially Stark unperturbed beam emission from helium is much simpler than that from of deuterium. The Doppler beam emission spectra is well separated from the ‘cold’ edge HeI emission at most radii, and is not contaminated by impurities. Figure 1 shows the principal characteristics of the singlet and triplet emission. Weak collisional coupling between the two metastables of helium, 1s^2 1S and 1s2s^3 S, means that there are effectively two beams in the plasma attenuating with different decay lengths. The true excited populations have formation and relaxation lengths of ≲ 3cm and can be treated as quasi-static relative to the unrelaxed beam. The singlet beam is observed to penetrate to the centre of the plasma while the triplet side stops at ~ 30cm along the beam. Initial modelling of the triplet indicates a larger Z_{eff} than measured by bremsstrahlung (without allowance for ‘hollow’ profiles).

The edge triplet BME reflects the decay of an initial metastable entry fraction in the beam rather than a collisionally regenerated population in the plasma. This fraction can be estimated directly from the edge singlet BME as seen in figure 2. Full collisional-radiative BME coeffi-