Active Spectroscopy on the Neutral Beams in ASDEX Upgrade

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On the ASDEX Upgrade tokamak, eight beams of fast deuterium atoms with kinetic energies of up to 93keV and a power of 2.5MW per beam are used to heat the plasma. The beam diameters are about 30cm. Several optical heads comprising some 200 lines-of-sight are used to observe three beams. The observed intersection volumes of beams and the lines-of-sight have diameters of a few mm up to 3cm depending on the required spatial resolution. Silica fibres guide the light from the optical heads out of the tokamak vessel and the experimental hall to a suite of 12 spectrometers, which record the spectra with a temporal resolution ranging from of a few ms down to 50μs.

This large experimental effort is motivated by the main advantage of active spectroscopy, i.e. the possibility to obtain local measurements with good spatial resolution. Furthermore, charge exchange reactions between D and fully ionised impurities lead to visible radiation from the recombining ion, which allows for the determination of impurity densities that are otherwise not accessible by spectroscopic observation. Most of the spectrometers are used for this measurement technique called Charge EXchange Recombination Spectroscopy (CXRS), by which the light elements between He and Ne are usually studied. The radiance, width and shift of the emission lines deliver impurity ion density, temperature and rotation velocity. Combined measurements of poloidal and toroidal fluid velocities yield the radial electric field via the force balance equation. For CXRS with He^{2+}, the recombined ion can be excited by electron collisions before re-ionisation takes place and thus emit another photon. This leads to a delocalised contribution to the active signal, whose influence on line shape and line strength has lately been resolved using an elaborate Monte-Carlo model. The non-thermal fast ion population of D^{+} is studied by measuring the Dα radiation from the recombined ion at a correspondingly large Doppler shift. Also here, a Monte Carlo code is used for a quantitative analysis of the signal.

The Dα emissions from excited atoms within the neutral beams contain important information and are recorded with 3 spectrometers. Due to the large atom velocities and the strong magnetic field in the tokamak, there is a large electric field in the rest frame of the atoms and the Dα □□□□□□□□□□□ up in a spectrum with 9 strong lines and 6 very weak lines. The line splitting and the polarisation dependence of the emission from individual lines can be used to determine the magnetic field direction. The total line strength gives information on the neutral beam density, which is attenuated along the beam path in the plasma. It replaces the beam density from attenuation calculations whose uncertainty is increasing with increasing path length. Thus, the uncertainty of the impurity density evaluation is reduced by these measurements. The beam attenuation is caused by ionisation and charge exchange collisions. The charge exchange between plasma D ions and beam neutrals leads to a cloud of thermal D neutrals around the beam, known as the beam halo. The Dα emission from the beam halo is usually the prominent feature of the measured spectra and it turns out that charge exchange between halo atoms and impurities can lead to a rather large contribution of the active CXRS signal (up to 40%) and needs to be included in the evaluation.

The talk will give an overview of the spectroscopic techniques employed at ASDEX Upgrade with emphasis on the methods described above.