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Detailergebnisse / Details

TEC Main Topic 3 — Impurity Transport and Radiation

1. Impurity survey during the DED start-up phase

During the start-up phase of TEXTOR after the DED installation, a variety of plasma impurities was detected during the discharges. Two different types of impurity events can be clearly distinguished and the elements involved can be identified by means of VUV spectroscopy, which measures the intensity of the characteristic spectral lines of the impurities. The first case: Small metal dust particles, which were remaining in the vessel after the long-term in-vessel work. These particles were released to the plasma mainly due to the action of the magnetic AC fields during DED operation, which lead to a mechanical vibration of vessel components. Since the number of stored particles in the vessel is limited, the number of these impurity events per discharge decreased significantly in the course of the experimental campaigns. The number of the detected particles is in the range of 10^{15} to 10^{18} impurity atoms released to the plasma, where the lower limit is defined by the sensitivity of the spectrometers, while larger impurity events may lead to fast disruptions of the discharge induced by radiation cooling. A typical example is shown in figure 1, where the spectra from three different cases are displayed: a) the typical impurity spectrum from a discharge with oxygen as the dominating impurity species; b) the spectrum during an impurity event releasing Ni and Cr into the plasma, and c) the spectrum from a Cu based impurity event.

The second type of impurity events is caused by the material release due to the direct plasma-wall contact. During normal plasma operation the released material is mainly carbon, from which the plasma-facing components are made. However, in case of technical and physics problems such as loss of plasma position control, electrical problems or overheating of in-vessel components, also other materials apart from carbon may come into contact with the discharge and may reach significant concentrations in the plasma. As an example we show the spectrum from Zr, which is used on TEXTOR in form of ZrO_2 as insulator behind the DED carbon tiles.

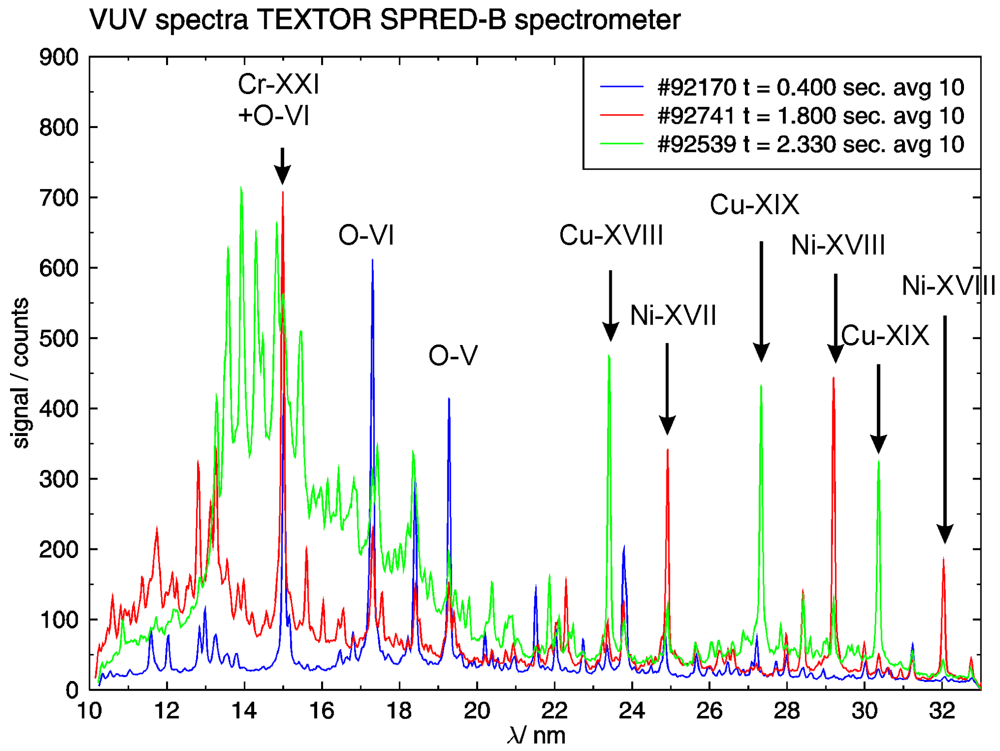

Figure 1: Impurity spectra dominated by spectral lines from oxygen, nickel/chromium and copper

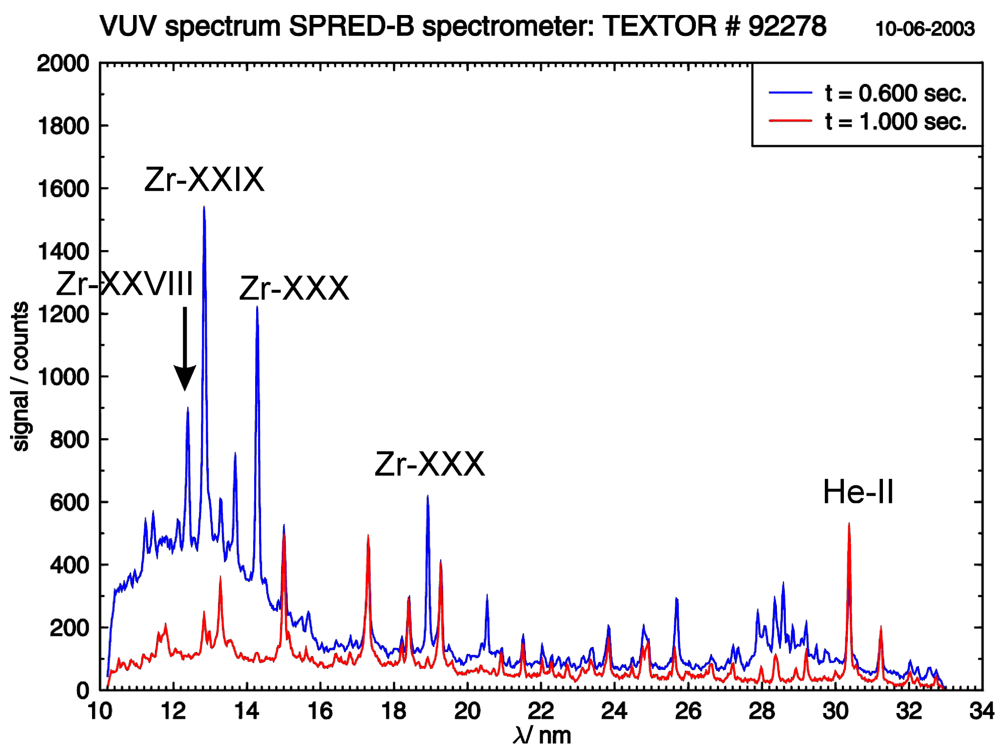

Figure 2: Zirconium spectrum from a TEXTOR discharge

2. X-ray spectroscopy on TEXTOR

The spectra of He-like argon have been revisited to improve the fit of the theoretical models to the experimental spectra. During the analysis it has been found, that the cascades within the system of doubly excited Li-like ions can play a significant role in the level population. Especially levels with small auto ionization rates and hence small population due to dielectronic recombination, can be strongly affected by cascades from higher lying levels within the Li-like system.

The intensity of the q and r satellites can increase up to a factor 2 relative to the direct dielectronic recombination. As these lines have strong contributions due to inner shell excitation by electron collisions, they are applied to the determination of the density of Li-like ions. As the contribution by dielectronic recombination increases if the cascades are taken into account, the measured density of the Li-like ions decreases. In Fig. 3 we show the density of Li-like ions in ohmically heated plasmas relative to the coronal predictions. The density of the Li-like ions is increased due to transport effects and due to charge exchange recombination. The ion transport limits the duration of stay in the hot plasma and prevents the ions to arrive at their final equilibrium stage, and charge exchange with atomic hydrogen reduces the charge state as well. Both effects increase for low plasma density, for high densities, the charge state distribution approaches the coronal equilibrium.

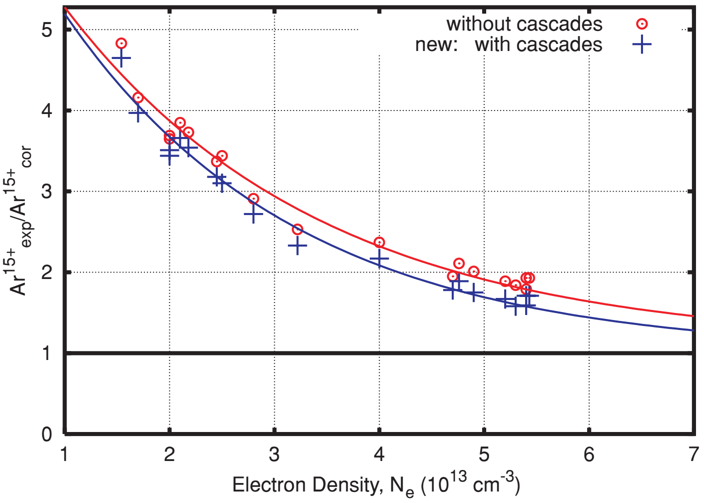

Figure 3: Density of Li-like ions relative to corona predictions.

For the strong lines with high population by dielectronic recombination, the cascades are unimportant. The electron temperature, which is obtained from the intensity of the large dielectronic satellites relative to the resonance lines, does not change if the cascades are taken into account, therefore the previous data are still valid. Density ratio Li-like to He-like relative to the coronal predictions for traces of argon in a deuterium plasma with ohmic heating as a function of the plasma density in the centre. Circles: cascades not included, crosses: cascades included. At high plasma densities, the coronal equilibrium is approached.

3. TEC participation in ITER diagnostics: Active Beam Spectroscopy

A comprehensive package of active beam based spectroscopy tools for ITER has been developed and evaluated. The feasibility study encompasses CXRS (*Charge Exchange Recombination Spectroscopy*) for the measurement of the main impurity ion densities (including helium ash), ion temperatures and toroidal as well as poloidal plasma rotation. *Beam Emission Spectroscopy* is proposed as indispensable cross-calibration tool for absolute local impurity density measurements[1] and also for the continuous monitoring of the neutral beam power deposition profile. Finally, a full exploitation of the '*Motional Stark Effect*' pattern is proposed to deduce local pitch angles, total magnetic fields and possibly radial electric fields.

[1] M. von Hellermann et al.: Proc. Adv. Diag. for Magn. & Inert. Fus., Varenna 2001, 205-208, Plenum Publ. N.Y.

More recently[2], a further promising application has been proposed, that is a study of slowing-down alpha particles in the energy range of 0.1 to 0.6 MeV and 1.6 to 2.4 MeV, respectively, making use of the *2.2 MW 100 keV/amu DNB (Diagnostic Neutral Beam)* and the *17 MW 500 keV/amu HNB (Heating Neutral Beam)*. An important asset of the proposed slowing-down scheme is the potential investigation of anisotropic features in the alpha velocity distribution function making use of top and equatorial observation periscopes.

Performance studies and estimates of expected spectral signal-to-noise ratios are based on atomic modelling[3] of neutral beam stopping and emissivities for CXRS, BES and background continuum radiation as well as extrapolations from present CXRS diagnostic systems. Single high-étendue and high-resolution spectrometers[4] for each radial channel are proposed for thermal CXRS and BES/MSE and high-étendue broad-band spectrometers for CXRS on slowing-down features.

The concept of integrated data evaluation procedures plays a pivotal role for a feasible and successful application of active beam diagnostics on ITER. The issue of measuring the helium ash content is strongly interwoven with the ability of assessing at the same time all complementary ion densities (including bulk ions) and ion temperatures. The consistency of diamagnetic energy data with spectroscopic reconstructions from electron and ion pressure profiles, or the consistency of measured thermo-nuclear neutron rates with modelled predictions from measured ion temperature and deuteron/triton density profiles belong to standard prediction packages (TRANSP, CHEAP) in present day experiments (e.g. JET, TEXTOR). A key issue for the viability of the proposed active beam spectroscopy package is the survival probability of the first mirror in its periscopes. Studies of metallic mirrors deposition[5] and today's experiments on sputtering processes addressing reflection values and polarisation characteristics have given first results[6].

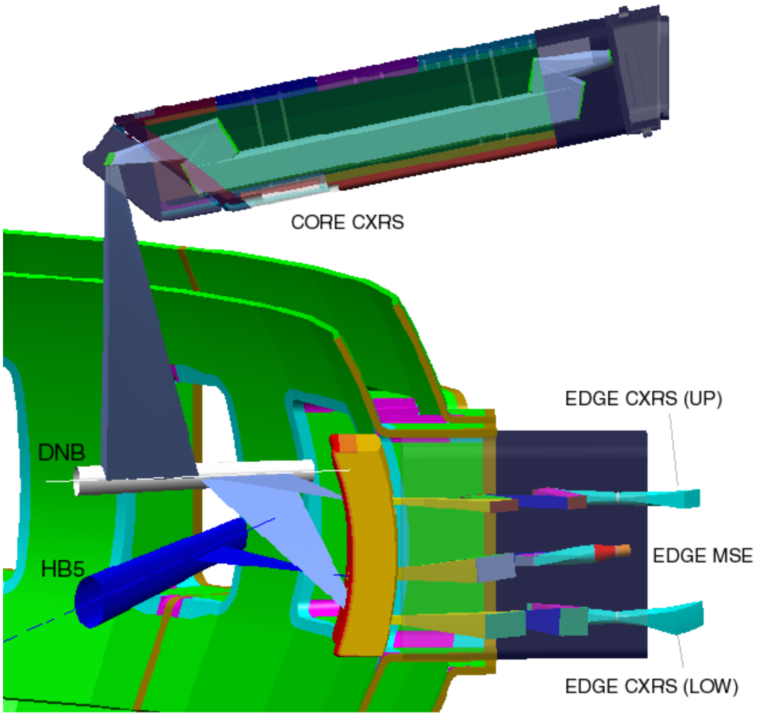

Figure 4: Proposed periscope system on ITER for CXRS and BES (MSE)

[2] M. von Hellermann et al.: Proc. 4th ITPA Topic Group Meeting on Diagnostics, Padova, 17-21 February, 2003
[3] c.f. H.P. Summers et al.: Physica Scripta **T92**, 80 (2001) and *http://adas.phys.strath.ac.uk/*
[4] S. Tugarinov et al.: Rev. Sci. Instr., 74, 2075, 2003
[5] A. Malaquias et al.: Proc. 5th ITPA Topic Group Meeting on Diagnostics, St. Petersburg, 12-18 July, 2003
[6] K. Vukolov et al.: Proc. 4th ITPA Topic Group Meeting on Diagnostics, Padova, 17-21 February, 2003