Wissenschaftlicher Ergebnisbericht / Scientific Report 2003

Schwerpunkt / main research area	Energie / Energy
FE-Vorhaben / RD project	**E05 Kernfusions- und Plasmaforschung**
Institutsbeitrag / institute's contribution	22205
	Institut für Plasmaphysik /
	Institute for Plasma Physics (IPP)
Verantwortlich / in charge	Dr. V. Philipps v.philipps@fz-juelich.de
HGF-Forschungsbereich / Research Field	*Energy*
HGF-Programm / Programme	***Nuclear Fusion***
HGF-Thema / Topic	*Tokamak Physics*
Internet	www.fz-juelich.de/scientific-report

Detailergebnisse / Details

TEC Main Topic 1 — Plasma-Wall Interaction

Plasma Wall Interaction affects the energy release and fuel dilution in the plasma core by impurities released from the walls, the lifetime of wall components by erosion and the long term retention of the fuel gas in the walls. This year, the activities were concentrated on the analysis of both deuterium and tritium recycling, hydrocarbon signal evaluation and radical formation both in the JET divertor (within the Task Force E – exhaust and edge physics) and in front of carbon test limiters in TEXTOR. Additionally, carbon migration was studied in JET using a shot resolved deposition monitor in the inner divertor (QMB). Analysis of the effect of erosion and carbon deposition on mirror properties was started in TEXTOR and during in situ laser desorption/ablation with the aim to develop an in situ diagnostic for material deposition and fuel retention in ITER.

Hydrogen recycling properties

A way of studying the properties of released fuel components is the determination of their velocity distribution and atomic and molecular composition. Isotope exchange experiments are helpful to identify the local and global fuel recycling in more detail. Fulcher-band spectroscopy can support these measurements by measuring the variation of the molecular composition of the hydrogen isotopomeres in front of PFCs. This could be shown in TEXTOR (see report 2002) and has been extended to tritium containing compounds in JET. Fig. 1 shows the identified T_2 molecular lines detected in front of the T_2 gas inlet valve.

Hydrocarbon formation

The release of carbon has been intensively studied both in the JET divertor and in front of carbon test limiters in TEXTOR. At high surface temperatures (around 1500 ^{0}C) carbon will be strongly released in form of C_2, which may both stem from higher order hydrocarbons and direct molecular release. Fig. 2 shows such a molecular release around the strike point region in the JET divertor.

Because of the complicated dissociation chain and the restricted diagnostic methods of passive spectroscopy it is vital to study the emission pattern of the accessible C_2 and $CD^{(+)}$ emission both in

identical discharges and as detailed as possible. Therefore, in TEXTOR gas blow experiments have been performed both through nozzles and extended compact graphite limiters. Fig. 3 displays a spectrum under these conditions obtained with a highly resolving Echelle spectrometer (see report 2002), which reveals all of the spectrally interesting regions simultaneously.

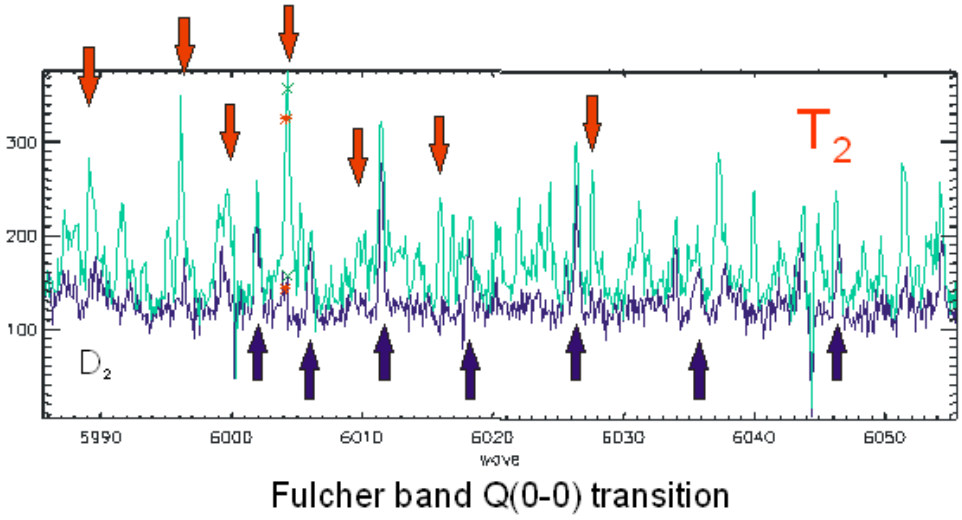

Fig 1: *Molecular plasma mixture during T_2 gas blow experiments in JET.*

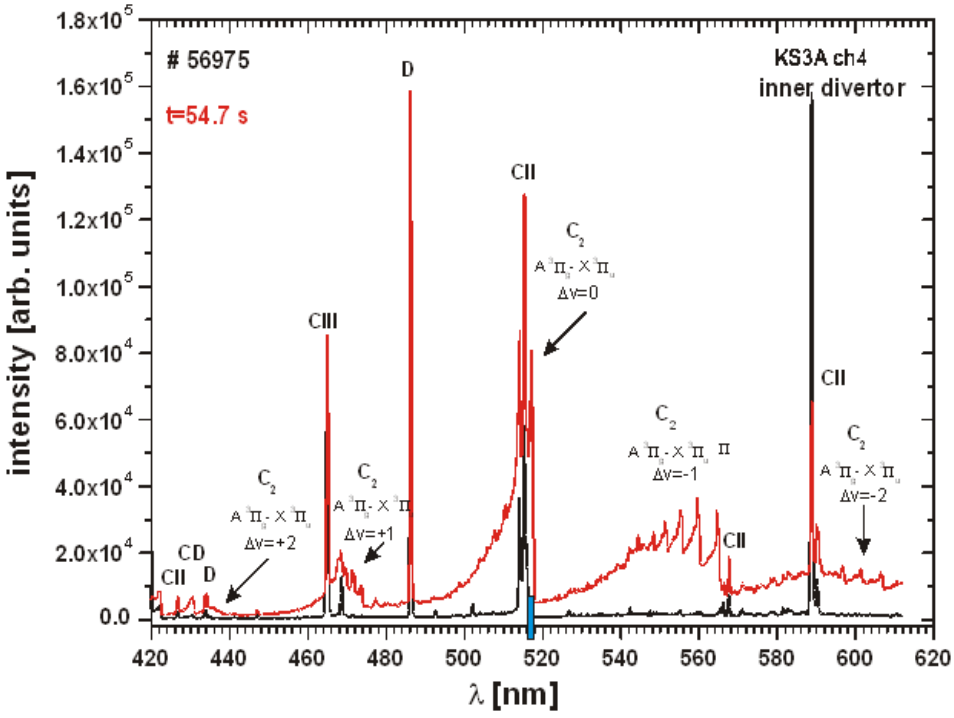

Fig 2: *Molecular C_2 ablation at the inner JET divertor.*

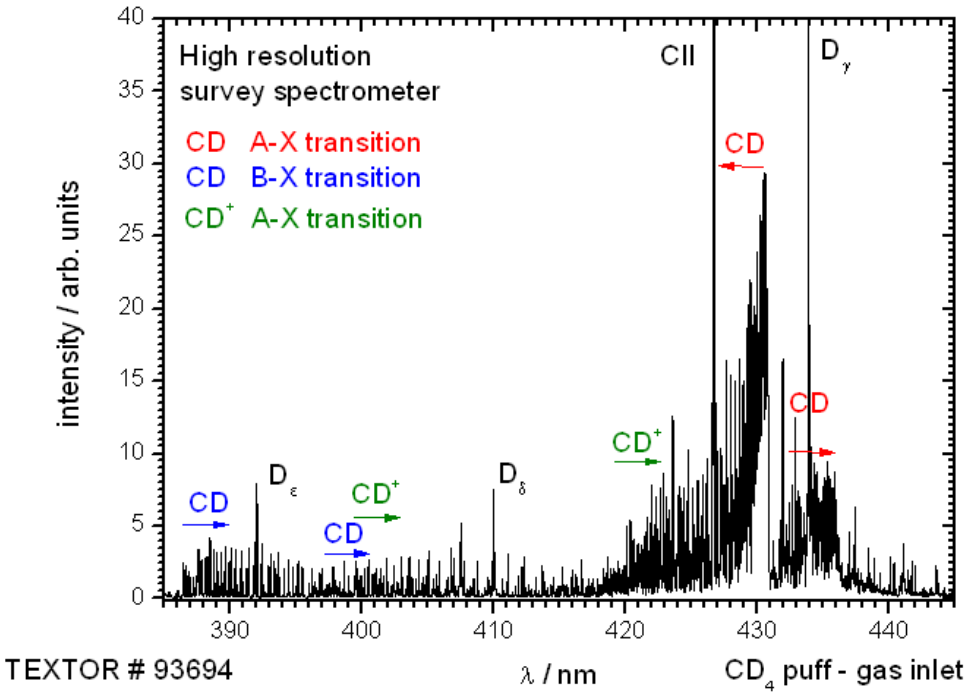

Fig 3: *Molecular spectra during a CD_4 puff through a nozzle into a TEXTOR boundary plasma.*

Atomic and molecular data

For the interpretation of the measured spectral line intensities in terms of fluxes and densities the conversion factor S/XB (ionisations per photon) has to be known. Various tools exist for the determination of these values – codes like GKU, R-matrix, databases (ADAS) etc. TEXTOR offers also the possibility of comparing these theoretical data with experimentally found results. S/XB values for B I & B II (Fig. 4) have been obtained by $B(CH_3)_3$ puffing and are compared with code calculations.

Important tools (codes **ATI**mpact**P**arameter**M**ethod and **ATC**lose**C**oupling) for the calculation of atomic data were developed. They extend the package "ATOM" developed earlier. They were tested on the example of the *3s-3p-3d* system in He I. Further development of these codes are the inclusion of other elementary processes and the extension of the region of application. The corresponding D/XB values for the methane family have also been tested in TEXTOR and JET and show the complexity of a transfer of the values derived from different fusion edge plasma configurations.

Erosion, deposition and fuel inventory

Material deposition has been studied in the inner divertor of JET using the quartz microbalance technique. The most prominent parameter determined the material deposition on the measuring position is the plasma geometry in the divertor. With the strike point on the vertical target and the QMB in the private flux region the deposition is small (typically 0.1-1 nm/shot) but increases with moving the strike point in the direction to the QMB. Much more deposition is measured with the strike point on the horizontal target and the QMB in the SOL. A history effect has been observed showing large deposition during the first discharge with the plasma strike point touching a fresh area. The rate strongly decreases in successive shots keeping the strike point fixed. . Therefore the

carbon deposition pattern found after long term plasma operation is the integral result of a many different plasma configurations.

N	Transition	Wave length	IPP (pl.cond.1)	IPP (pl.cond.2)
1	$3d\ ^3D - 4f\ ^3F$	4123.0 Å	1.1e+2	2.3e+2
2	$3p\ ^1P - 4s\ ^1S$	4196.0 Å	8.1e+1	8.4e+1
3	$3s\ ^3S - 3p\ ^3P$	7032.8 Å	1.2e+1	3.7e+1
4	$3d\ ^1D - 4f\ ^1F$	4941.7 Å	5.3e+1	5.9e+1
5	$3d\ ^3D - 4p\ ^3P$	4785.4 Å	1.2e+2	4.8e+2
6	$3p\ ^3P - 4s\ ^3S$	4473.9 Å	2.0e+2	4.6e+2
7	$3p\ ^3P - 4d\ ^3D$	3324.4 Å	1.3e+2	2.7e+2
8	$3d\ ^1D - 5f\ ^1F$	3303.4 Å	1.4e+2	1.4e+2
9	$3p\ ^1P - 4d\ ^1D$	3180.3 Å	1.3e+2	1.3e+2
10	$2s^2 - 2p\ ^1P$	1362.4 Å	1.6e-1	1.7e-1

Fig. 4: *Theoretical S/XB values for B II obtained by the code GKU from the P.N. Lebedev Institute, Moscow; experimental IPP ≡ D/XB values for transition 1 are a factor of 2 to 3 smaller!*

Performance of mirrors after plasma exposure

The performance of optical mirrors from polished polycrystalline molybdenum has been analysed after exposure in the SOL of TEXTOR in erosion and C-deposition dominated regions. The optical reflectivity has been measured before exposure in a wide wave length range and polarisation angle followed by post mortem analysis. A strong degradation on the deposition areas is observed due to carbon deposition, while the degradation is smaller on the erosion areas. In particular areas the Mo surface was molten leading to strong grain grow and an enhanced optical reflectivity. Another set of mirrors has been mounted for long term exposure in a periscope system with controlled temperature and exposed to the SOL plasma for about 500 plasma seconds. A first analysis indicates that in this special geometry the carbon deposition is reduced in plasma shadowed regions of the periscope.

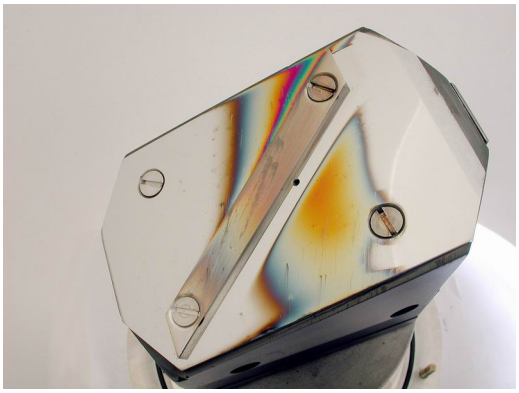

Fig. 5: *Appearance of a Mo optical mirror after exposure to the SOL plasma of TEXTOR.*

Laser induced desorption

The hydrogen content on a test limiter surface during plasma pulses of TEXTOR has been determined in situ by the laser desorption technique. A single pulse ruby laser operated in a free generation mode with a maximum energy of 15 J and a pulse duration of about 0.3 ms was used with a spot size on the limiter surface of about 8 mm. The temperature of the limiter surface in the centre of the laser spot was measured by a fast optical pyrometer(15 µs) and the light emitted by thermally desorbed particles in the plasma was detected by means of a five channel polychromator with a temporal response of about 5 µs. For a graphite limiter the surface temperature in the laser spot during laser pulse increases up to about 800 °C. The increase of Balmer line emission during surface heating exceeds the background level caused by recycling by one order of magnitude. The total number of desorbed hydrogen and deuterium atoms was deduced from the number of the H_α and H_β photons emitted during the laser pulse using the S/XB coefficients (photon per ionisation) from the ADAS database. Values corresponding to hydrogen surface concentrations in the range of 10^{15} – 10^{16} (H+D)/cm^2 are found for different experimental conditions.

Similar experiments have been performed with the edge Lidar laser system on JET using a long laser pulse of about 0.3 ms. Desorbed hydrogen and carbon has been detected using the fast KS3 spectrometer during the limiter phase of the plasma before formation of the X point. Hydrogen and C II signals are clearly correlated with plasma loading of the desorbed surface but the amount of desorbed particles saturates quickly. This indicates that under the low laser power conditions in JET (18 kW/cm^2) only a shallow surface layer is depleted by the laser pulse.

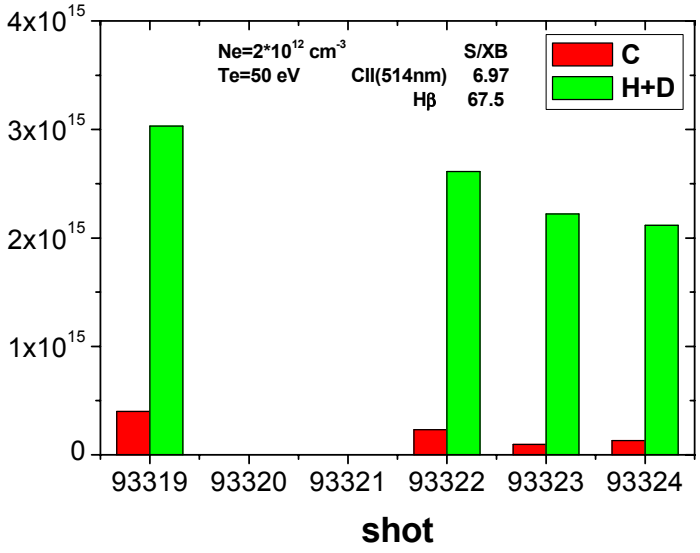

***Fig. 6**: Amount of hydrogen and carbon evaluated from C II and H_β light released by means of laser desorption from a graphite test limiter.*

Modelling

Modelling of the transport of $^{13}CH_4$ molecules injected from a declined test limiter has been continued using newest available data for rate coefficients of the CH_4 reaction chain and an enhanced chemical erosion (Y_e) of re-deposited carbon layers compared to the erosion of substrate graphite. An enhanced chemical erosion yield for re-deposits of about Y_e = 8% by the background hydrogen the hydrogen returning with the hydrocarbons is needed. The modelling therefore supports a picture

of long-range carbon transport where carbon can be re-eroded much more effectively after re-deposition on plasma-wetted areas which can explain the carbon transport to shadowed areas in JET and TEXTOR. Modelling of carbon erosion and re-deposition at the TEXTOR ALT shows a qualitative agreement with erosion-deposition patterns after several months of plasma operation. First calculations of the beryllium and carbon transport in the linear plasma simulator PISCES-B have been done with a main emphasis on the observed Be emission profile. Predictive calculations of tritium retention and target lifetime in ITER have been performed taking into account a revised formula for chemical erosion (including surface temperature, energy and flux dependencies) and atomic hydrogen flux as additional eroding species.