5 JET Collaborations

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Polish contribution to the JET experimental programme concerns the realization of the following tasks:

- Participation to the JET experimental campaigns C29(8)-C30
- Numerical analyses of plasma discharges in JET ILW configuration with the help of the code COREDIV
- The activation measurements in support of the JET neutron calibration
- Measurements and calculations of neutron streaming through JET Torus hall ducts
- Gas Electron Multiplier detector for X-ray Crystal Spectrometry (GXS)

Introduction

In 2011/12, JET started operation with its new ITER-Like Wall (ILW) made of a tungsten (W) divertor and a beryllium (Be) main chamber wall. The achievements of the Association IPPLM in the JET activities during the experimental campaigns C29(8)-C30 were related to the installation of two GEM (Gas Electron Multiplier) detectors into the ending port window of the KX1 x-ray diagnostic and first measurements of radiation emitted by Ni^{26+} and W^{46+} ions. In addition, using the VUV spectrometer, measurements of Ni impurity content during ICRH (Ion Cyclotron Resonance Heating) and NBI (Neutral Beam Injection) heating were investigated. Moreover, the numerical analyses of impurity seeded plasma discharges in JET with the help of the COREDIV code were done. In the frame of Fusion Technology task JW11-FT-4.21, the neutron activation measurements were performed as a benchmark against numerical calculations for neutron diagnostics calibration at JET. Also, a study performed at JET within JW12-FT-5.45 task, aiming the measurements and calculations of neutron streaming through JET Torus hall ducts were accomplished. For this purpose, thermoluminescence detectors (TLD) were used for dose measurements at JET. It would enable validation of the safety assessment calculations made for ITER biological shield.

Results

Preliminary measurements of the x-ray spectra registered by KX1 diagnostic

The KX1 x-ray diagnostic has been upgraded at JET. Two diagnostic channels were prepared for W and Ni impurity monitoring. By means of cylindrically curved (1011) quartz (2d=6.68 Å) and (220) Ge (2d=4.00 Å) crystals used in order to diffract the 7.8 keV and 3.8 keV photons, the diagnostic monitors the x-ray radiation emitted by Ni^{26+} and W^{46+}, respectively. The KX1 spectrometer operates in so-called Johann geometry. The Rowland circle radius of the spectrometer has been measured to be 2R=24.98+/-0.15 m. The horizontal and vertical alignments of both crystals have been verified and synchronized with mechanical parameters of the spectrometer. Two new GEM x-ray detectors have been installed into the ending port window of KX1 diagnostic. Additionally, at the W diagnostic channel a He buffer has been installed in order to optimise the x-ray transmission in 2.4 keV. After its successful installation, test measurements were performed at the Ni diagnostic channel. It was demonstrated that the KX1 diagnostic is able to provide data with a high spectral and time resolution (Δt~10 ms). It has also been shown that KX1 should resolve x-ray radiation originating from different reflection orders.

Ni behaviour in ICRH and NBI heated discharges

The Ni impurity release during ICRH and NBI operation with the ILW was investigated. Spectroscopic measurements were obtained using the VUV spectrometer. The L-, H-mode discharges and divertor/limiter configurations were examined. The influence of the plasma shape, the ICRH antenna phasing, and the minority cyclotron resonance position on the Ni content was investigated. The behaviour of the Ni content in different scenarios was correlated with the bulk radiated power ($P_{rad,bulk}$). The contribution of Ni to $P_{rad,bulk}$ was evaluated. The application of ICRH power results in higher Ni content in the plasma core compared with NBI heating, in both L- and low power H-mode discharges, in divertor and limiter configurations. Differences in plasma wall–interaction for the different plasma shape, antenna phasing, plasma-antenna distance, and the minority cyclotron resonance position constitute another factor influencing impurity release. For the same ICRH power level, -90^{o} phasing gives a significant higher Ni concentration than in the case of dipole phasing. No obvious dependence is seen during ROG variation. The Ni content is less pronounced during the operation of antenna C and D than during A+B operation although the same total power level was coupled. This can be due to differences in antenna spectrum (for A and B only 2 over 4 straps are powered) that could result in higher antenna near fields and higher surface of interaction. The Ni content decreased with increasing line averaged edge plasma density, measured by interferometry. Also increased with plasma triangularity. It was observed that although with the new ILW the main radiation came from W, Ni was also contributing significantly to $P_{rad,bulk}$ up to a 20 % level during ICRH, depending on the plasma conditions. For the same power level, central ICRH resulted in higher Ni concentration in the plasma core in comparison to off-axis ICRH. This effect can be due to the higher central T_e and diamagnetic energy observed with on-axis heating, difference in transport or higher Ni influx.

Numerical analyses of impurity seeded plasma discharges in JET with the help of the code COREDIV

The code COREDIV has been used in simulation of JET discharges. The attempts have been made to adjust the parameters external to the code (e.g. T_e, n_e, P_{rad}, Z_{eff}, D and Be fluxes) in order to obtain agreement between calculated and experimental data. The self-consistent simulations of the core and the SOL plasma using the COREDIV code for JET H-mode plasma with nitrogen seeding have been performed in order to understand the discrepancy in core radiation power and W content. It was shown that the changes in electron density at the separatrix (n_{es}) lead to change in the core and SOL density profile, but have very weak influence on Z_{eff}. With increase the n_{es}, decrease of the total and core radiation was observed. Moreover, increase of the radial transport in SOL leads to decrease of the W concentration and in consequence decrease of the plasma radiation. The L-mode JET high power discharge without impurity seeding has been also analysed in order to clarify discrepancies in the W concentrations coming from the experimental measurements and simulations. The calculated concentration of W was $4e^{-5}$ in considered H-mode plasmas and appeared to be about 10 times larger than experimental estimations. Calculations have been done for different levels of the beryllium (Be) fluxes in order to fit into measured Z_{eff} values. It appears that the low Z impurity Be determines the measured Z_{eff}, whereas the W impurity is responsible for the radiation losses in the core. More detailed analysis showed asymmetry in W radiation, strongly shifted to the outer midplane region. This position is not seen by the KT7 diagnostic which was used to calculate W concentrations and therefore reported values of W concentration were much smaller than in simulations. The dependence of the results of the modelling of JET discharges on the assumed transport coefficients profiles has been studied numerically as well. The transport coefficients profiles were taken from the standard Bohm-gyro Bohm model and from the COREDIV model. The numerical results have demonstrated that the global parameters of plasma remain close to each other for the two different transport models.

The neutron measurements as a benchmark against numerical calculations for neutron diagnostics at JET

The well-defined calibration source allows verifying correctness of the MCNP model. As neutron detectors implemented in such model shall be the samples of materials with well-known neutron reaction cross-section. The activation measurements during neutron calibration should be, therefore, a benchmark against the MCNP calculations. The IPPLM Association team prepared above-mentioned measurements. To perform the activation measurements at JET the KN2 system shall be used. The irradiation end located in upper position in Octant 3 (so called 3U) is useful especially due to location inside the vacuum vessel. Taking into account the neutron energy spectrum in 3U obtained by means of MCNP calculations, the following reactions have been chosen to record the neutrons emitted by Cf-252 source: In-115 (n,g) In-116, U-238 (n,g) U-239, Au-197 (n,g) Au-198, Mn-55 (n,g) Mn-56, W-186 (n,g) W-187, In-115 (n,n') In-115m, In-113 (n,n') In-113m, Al-27 (n,p) Mg-27, Fe-56 (n,p) Mn-56, Ta-181 (n,g) Ta-182, Sc-45 (n,g) Sc-46, Ni-58 (n,p) Co-58, Al-27 (n,a) Na-24. The appropriate samples have been prepared. The samples activity after 3-hours irradiation by $4x10^9$-yield Cf-source, located 30 cm below 3U irradiation end has been predicted. The evaluation of the activity was done for 18 mm in diameter and 1 mm thick samples. The JET KN2 pneumatic system was improved. Some modifications of electronics, mechanics and power supply parts have been performed. Pressure valves, pipes and other supported systems were checked. All of the systems – pneumatic, electronic and mechanical seem to work correctly. The activation samples have been prepared, the HPGe spectrometer has been brought to JET. Irradiation of the samples by means of the KN2 system could not be performed due to the cryoplant system fault in April 2012 which was followed by plasma discharges with too low neutron-yield.

Measurements and calculations of neutron streaming through JET Torus hall ducts

Thermoluminescence detectors (TLD) were used for dose measurements at JET within JET FT-12-5.45. Several hundreds of LiF detectors of various types, standard LiF:Mg,Ti and highly sensitive LiF:Mg,Cu,P were produced at the IFJ in Krakow. LiF detectors consisting of natural lithium are sensitive to slow neutrons, their response to neutrons being enhanced by ^{6}Li-enriched lithium or suppressed by using lithium consisting entirely of ^{7}Li. Pairs ^{6}LiF/^{7}LiF detectors allow distinguishing between neutron/non-neutron components of radiation field. For detection of neutrons of higher energy, there is a need of moderators. Cylindrical moderators (25 cm diameter and 25 cm height) have been produced from polyethylene (PE-300) rods. All TLDs, located in the centre of cylindrical moderators, were installed at eleven positions in the JET hall and the hall labyrinth in July 2012, and exposure took place during the last two week of experimental campaign. Measurements of the gamma dose and of the neutron fluence were obtained for all positions over a range of about five orders of magnitude variation. The experimental results were compared with calculations using MCNP code.

Conclusions

Magnetically confined plasmas, such as those produced in the tokamak JET, contain measurable amounts of impurity ions produced during plasma-wall interactions. The impurities including high- and mid-Z elements, such as W and Ni, need to be controlled within tolerable limits, to ensure they do not significantly affect the performance of the plasma. The X-ray and VUV spectroscopy are a key diagnostics for the identification and monitoring of impurities in the confined plasma region. Also, the first physics applications of the COREDIV code at JET tokamak discharges with ILW has been presented. The overall comparison simulation-experiment is rather satisfactorily, both in the core and in the SOL, leading to the accomplishment of the first step towards the integrated numerical modelling of JET plasmas with the new wall. The neutron diagnostics calibration at JET is a good opportunity to test the Monte Carlo (MCNP) neutron transport calculations. It was also confirmed that the TLD technology can be usefully applied in measurements of neutron streaming through JET Torus Hall ducts. Therefore, new detector positions, further in the labyrinth and ducts, will be investigated in the next measurement campaign.

Collaboration

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