

4 JET Experimental Campaigns 2008 (C20 to C25)

As regards our participation in JET experimental program in 2008, 12 people took part in C20-C25 campaigns (in all 104 pw). We participated in diagnostics of X-ray and VUV spectroscopy, neutron activation diagnostics and Integration of transport and MHD codes at JET. Apart from the above-mentioned diagnostics we are considering our participation in modernization the system of Neutron activation diagnostics under JET Notification. We also take part in Task agreement as regards Tritium processes and waste management. Our task is Laser diagnostics of in-vessel components and dust generated during detritation process using optical spectrometry. It is worth emphasizing that involvement in the JET programme provides a very important platform for integration of the Polish fusion community.

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4.1 Analysis comparisons between KS6 and KT4 line intensities

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Abstract

The soft X-ray/EUV radiation is the main source of information about the plasma impurities. One of the main impurities in JET plasmas is carbon. Comparison of the average intensities of the C VI line at 3.34 nm, registered at the same time by KT 4 and KS 6 spectrometer shows that the values available in PPF files varies in the long time (order of years) scale. The values registered by KT 4 reveals gradually, exponential decrease. For KT 4 the “correction function” have been proposed. Values registered by KS 6 appear to be unreliable for pulse number lower than 60000.

Introduction

Carbon is one of the main impurities present in JET plasma. The most prominent, Lyman_α line of hydrogen-like carbon, at 3.4 nm is monitored by paddle instrument of KS 6 spectrometer and simultaneously registered by KT 4. KS 6 is a flat crystal spectrometer, equipped with the proportional counter as a detector. The spectrum is obtained by swinging movement of the paddle with fixed flat crystal. KT 4 is a grazing incidence, grating spectrometer equipped with complex detector containing multichannel plate, phosphor, fiber optics and array of photodiodes. Regardless of the difference in the construction of the spectrometers, as KS 6 as well as KT 4 are registering the radiation integrated along horizontal diameter of plasma, one can expect that the ratio of intensities of the same line registered by this two spectrometers should be constant. Step change of the value of this is expected only after relocation of KT 4 from torus hall to the diagnostic hall.

Results

In order to compare the registered intensities the average value of C VI line intensity in initial, limiter phase of the discharge have been determined. The length of this phase (averaging time) have been estimated based on intensity of C IV line registered by KT 2 spectrometer.

The ratios of C VI line intensity registered by KS 6 to the intensity of the same line registered by KT 4, determined for different pulse numbers are not constant. It turned out that both KS 6 and KT 4 line intensities differs significantly for different pulse numbers (see Fig. 1).

The values obtained by KT 4 reveals gradually, exponential decrease, associated probably with some decrease of the system sensitivity. The result can be corrected using the simple formula (Fig. 2):

$$I_{corrected} = I_{measured} \cdot \exp [7.8 \cdot 10^{-5} \cdot (Pulse\ number - 46000)]$$

The values produced by KS 6 present very unusual and unexplained behaviour for pulse numbers lower than 60000. For higher pulse numbers the average intensity of C VI line is constant.

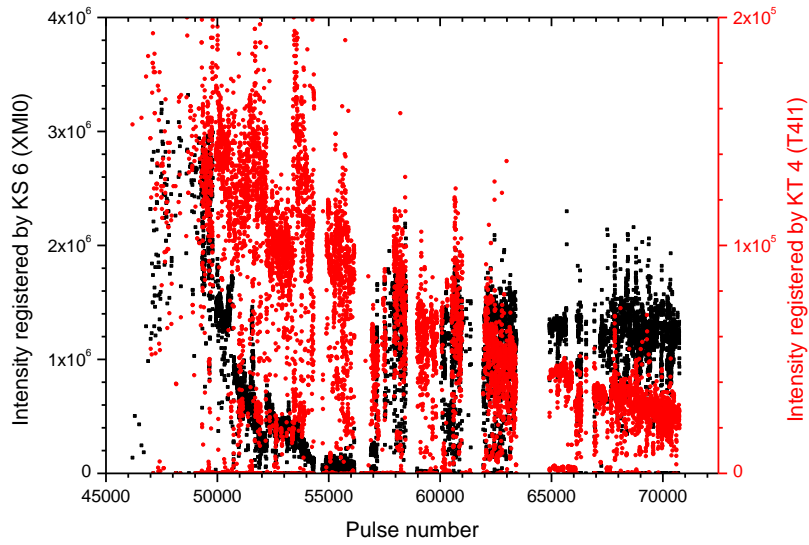


Figure 1. The average values of intensities of C VI line at 3.4 nm, determined in limiter phase plotted versus pulse number.

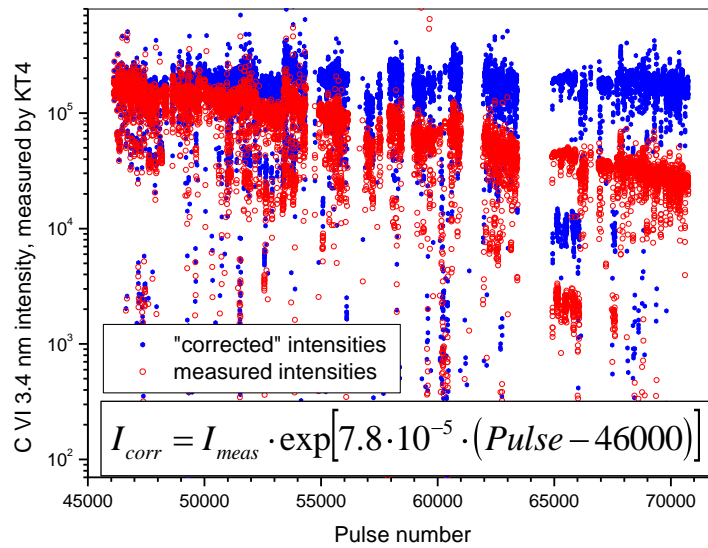


Figure 2. The correction function applied for the intensities produced by KT 4 diagnostics..

Conclusions

The values obtained by KT 4 gradually decrease in long time scale. In order to compare values obtained during different campaigns one have to apply a correction function as presented above. After the relocating of KT 4 from torus hall to diagnostic hall, and acquiring sufficient data samples one ought to check if the changes of diagnostic sensitivity reveal the same dependency.

The values produced by KS 6 diagnostics are dubious for low pulse numbers but for pulses after 60000 seems to be very reliable.

4.2 Development and application of the neutron diagnostics based on activation method for magnetic confinement devices

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Abstract

Neutrons produced in plasma are the evidence of the proceeded thermonuclear reactions. They carry the information about plasma condition and fusion power production, therefore neutron diagnostics are crucial in every magnetic confinement device.

Neutron activation method allows estimating both flux density and energy spectrum in any position close to the neutron source. It finds application also as main neutron fluence monitor or to inter-calibration other neutron diagnostics.

This method is developed at EFDA–JET by the members of IPPLM–EURATOM Association.

Summary

Neutron activation system (KN2) is one of the essential diagnostics for JET. It is used, among other things, to cross-calibrate neutron rate monitors (KN1) which are the basic instruments to determine neutron and fusion power output [1].

Fusion neutrons are originally 2.45 and 14.1 MeV in energy. In magnetic confinement devices these energies are broadened because of applied plasma heating systems and phenomena of energy transfer from these systems to the plasma. During selection there were chosen materials and reactions sensitive for 2.5 and 14 MeV neutrons [2].

The selection was made on the basis of the following demands:

- 1) availability of the desired material;
- 2) suitable longevity of the neutron reaction product (from a few second up to a few days);
- 3) noticeable probability of nuclear reaction (sufficiently high cross section);
- 4) suitable decay γ -quantum energy (from about 100 keV up to 2 MeV).

In 2008 there have been used by us at JET two detectors for γ -ray counting: pre-calibrated High Purity Germanium (HPGe) detector and a scintillation probe equipped with a modern LaBe3(Cs) scintillator (BrilLanCe–380). Both belong to IPPLM-EURATOM Association. The advantage of applying pre-calibrated HPGe detector is ability to calculate its efficiency for any measured material in almost any geometry without necessity of carry out additional experiments.

During C20 to C25 Experimental Campaigns at JET in 2008 the IPPLM-EURATOM Association members carried out the series of experiments aimed developing of the activation method paying special attention to apply it in magnetic confinement devices like JET and ITER. There were tested chosen materials and reactions. Many of them appear to be very useful whereas some have been rejected. Particularly functional is yttrium which has not been used before as activation detector. As a result of the carried out tests we had to abandon some of selected reactions. It concerns the reactions on selenium, cadmium, hafnium, bromine, zirconium, erbium, lead, molybdenum and some reactions on gold. The reactions induced in indium, yttrium and nickel appear to be very valuable. They were registered with less than 10% uncertainty.

Among reactions singled out only for 14 MeV neutrons as useful turned out all reactions on aluminium, iron, cobalt, titanium and niobium. The induced activities were always low, nevertheless they were usually estimated with uncertainties not larger than 10%–15%.

During planned deuterium-tritium campaigns and even during trace-tritium experiments at JET the number of 14 MeV neutrons increase a few orders of magnitude. Then the uncertainties of measured activities will be much lower.

During C25 Campaign there was used first time at JET by us the activation technique to measure thermal (slowed-down) neutrons. It consists in simultaneously irradiation in given neutron field of two identical gold samples in which occur radiative capture reaction – one sample in cadmium shield, one without shield. The result of this research was in well agreement with MCNP calculations and it shows that in 3U irradiation end there is only a little of thermalized neutrons – the majority are epithermal neutrons.

At present we are using over 10 different activated materials in one JET pulse and up to 20 nuclear reactions are there identified.

To reconstruct neutron energy spectrum registered by means of activation samples there is necessarily to proceed deconvolution procedure. This procedure needs some preliminary spectrum which is then fitted to the experimental results. The initial spectrum can be obtained from neutron transport calculations carried out by means of MCNP code [3]. In 2008 our team initiated calculations of neutron transport in the JET facility paying special attention to 3U (Octant 3, upper position) irradiation end – the only one located inside vacuum vessel [4] – used by us to carry out described irradiations.

Conclusions

Up to 12 different materials were irradiated with neutrons in one JET discharge.

The decay γ -ray radiation emitted from the samples were analysed using a HPGe detector and a BrillLance probe equipped with a LaBr3(Cs) scintillator.

A dozen of nuclear reactions were identified for which value of $\langle\sigma\cdot\phi\rangle$ was estimated.

It was found that the estimated activity of the sample changes linearly (roughly) with the total neutron yield

Collaboration

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4.3 Impurity behaviour during operation of the new ITER-like antenna (ILA) at JET

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Abstract

The influx of metallic impurities is known to be a possible limitation for ICRH experiments. The impurity question is of increasing concern as rf power and pulse length increases and therefore it is specially relevant to the assessment of the ITER-like antenna (ILA), commissioned during 2008 JET campaigns, for which powers up to 7.2 MW are expected. To this end, trends have been presented of main plasma impurities such as Ni, Fe, C, Cr, Cu, Be with the ILA heating power.

Summary

The objective of this work is to study the behavior of impurities with different JET heating systems using spectroscopy measurements.

Spectroscopy is a key diagnostic for the identification and monitoring of impurities in fusion plasmas. Impurities such as Ni, Fe, Cu, Cr, Be with different charge states were monitored by VUV [1] and X-ray [2] spectroscopy (KT2 and KS6 diagnostics at JET, respectively) with lines-of-sight through the geometric midplane of the machine, and divertor VUV spectroscopy (KT7D) with line of sight through the outer divertor or inner divertor. The effective charge state Z_{eff} , derived from bremsstrahlung measurements by filter arrays observing a narrow spectral range free from spectroscopic line emission, has been obtained from KS3 visible spectroscopy with vertical and horizontal lines of sight.

The impurity question is of increasing concern as rf power and pulse length increases and therefore it is specially relevant to the assessment of the new ITER-like antenna (ILA) [3] in JET (commissioned during 2008 JET campaigns), for which powers up to 7.2 MW are expected. The ILA is using a close-packed array of straps mounted as four Resonant Double Loops (RDL's), each consisting of two poloidally adjacent straps, arranged in a 2 toroidal by 2 poloidal array. During this time the 4 Resonant RDLs of the ILA have been tested at frequency 42 MHz up to 42 kV for 5 seconds in 10 minute intervals. The time behaviour of the impurity emission has been followed throughout plasma discharges #73000-74010. The correlation between normalized signals of different spectral lines and the ILA heating power has been calculated. Absolutely calibrated line intensities were normalized by using the line integrated electron density observing the core (LID3) or the edge (LID4) plasma, depending on impurity charge. For each pulse averages of normalized line intensities were calculated in time ranges corresponding to steady-state JET plasmas. The correlation between the intensity of impurity lines and the ILA heating power (2.55 MW coupled from lower half) in L-mode with ROG of 4-6 cm is presented in Figure 1.

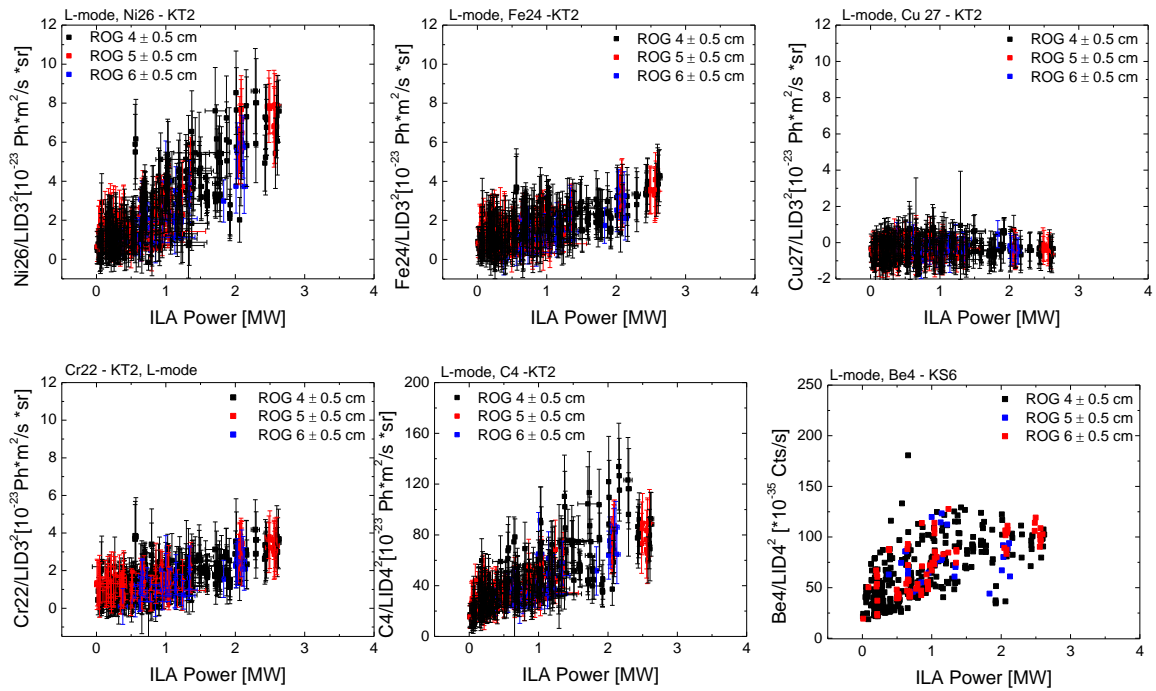


Figure 1. Correlation between the absolutely calibrated intensity of line (for different impurities) normalized by line integrated electron density, and the ILA heating power

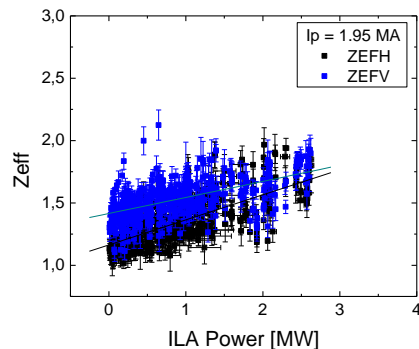


Figure 2. Correlation between Z_{eff} and ILA heating power.

Conclusions

The work done during the 2008 JET campaigns has been focused on the observation of impurity behaviour with ILA heating power. It has been observed that impurity concentration and influx are dependent on ILA heating power. All the main plasma impurities were observed to increase with ILA power. Beryllium seems to level above 1 MW, which needs to be confirmed for higher ILA power. Small differences in behaviour of impurities for different ROG (4-6 cm) have been observed. Z_{eff} (Figure 2) increased with ILA heating power. In summary, the ILA with higher power density performs well, with a low release of impurities into the core plasma.

Collaboration

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4.4 Attempt of calibration of KT4 JET VUV spectrometer in the short wave range

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Abstract

An attempt of calibration of the short wave length part of the KT4 spectrometer (indicated KT4/1) basing on the calibration data for the long wave part of KT4 (indicated KT4/2) and using the branching ratio method was made. A candidate pair of lines for the branching method was proposed but after the detailed analysis it turned out that the long wave length line is blended by two other strong lines which cannot be separated.

Summary

The KT4 spectrometer [1] installed on JET is a time-resolving VUV multichannel instrument that permits the simultaneous measurement of emission in two different spectral ranges 17-42 Å (KT4/1 detection system) and 160-319 Å (KT4/2 detection system). The instrument is equipped with two multichannel detectors, which are microchannel plates placed on the Rowland circle. They scan the radiation reflected from the grating. The microchannel plates are associated with a phosphor screen image intensifiers that are coupled to semiconductor photodiode arrays, which deliver the output signals. The KT4/1 operating in the short wavelength region is losing sensitivity and actually there is a need for re-calibration. A special calibration procedure was proposed to carry out the re-calibration that is based on the branching ratio method. It exploits the fact that the KT4/2 part of the spectrometer is well calibrated and may be considered as a reference. The branching ratio method was applied for calibration of the short wave range of the KT4/1 UV spectrometer basing on the calibration data of the KT4/2. To make a comparison of sensitivity of both ranges, a pair of lines coming from the same atomic level (of a given ratio of intensities), namely CVI L β (1s – 3p) line at 28.466 Å, seen by the KT4/1, and the CVI H α (2s – 3p) line at 182.097 Å, seen by KT4/2, were exploited for the method. Unfortunately, the 182.097 Å line is blended with another CVI line (2p-3d, 182.230Å) of high intensity, which is separated by only 0.13 Å. A special code written by K. D. Lawson was used for separation of the overlapping lines. Some tests were being made to evaluate the precision of the separation, but meanwhile, unexpectedly, another close high-intensity blending line (182.088 Å) was found. The overlooked blending line was not mentioned in some serious spectrometry catalogues previously studied. As we could not find another useful pair of lines for the method applied, we are trying to check if it is possible to solve the problem by finding the proportion of the three mixed lines using some available spectroscopy codes, which simulate the plasma that we deal with. Further attempts of absolute calibration of the KT4 spectrometers with the use of a standard light source [3], which will be carried out for the long wave range, are planned during shutdown period that starts at the end of the year 2009.

Conclusions

A branching method was applied for absolute calibration of the short-wave range of the KT4 VUV spectrometer, measured by the KT4/1 detection system. A pair of lines for the method was proposed but after detailed analysis it turned out that the long-wave-length line located in the well calibrated range of the KT4 is blended by two other strong lines which cannot be separated. As we could not find another useful pair of lines for the method applied, we are trying to check if it is possible to solve the problem by finding the proportion of the three mixed lines basing on computer codes simulating XUV emission. During the planned shutdown of JET at the end of 2009, a standard lamp of known parameters for checking the absolute calibration of KT4 in the long wave range is going to be used.

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References

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4.5 Modelling of JET discharges

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Abstract

Two problems for selected JET discharges has analyzed by modeling the discharges with help of COCONUTS package. For high recycling regime the radial density profiles in the divertor and the scrape of layer and the possibility of the flow reversal appearance has been studied. For the discharges with the different position of X point the changes of the power threshold for L to H mode transition has been observed. The attempt to find the explanation for this phenomena has been undertaken.

Summary

Using EDGE2D code simulations of boundary plasma profiles were performed. The main goal of those calculations was to analyze radial density profiles and conditions for flow reversal to appear in the high recycling regime. Obtained results were confronted with analytical formulas describing density profiles of plasma in the boundary as well as with results of the other codes.

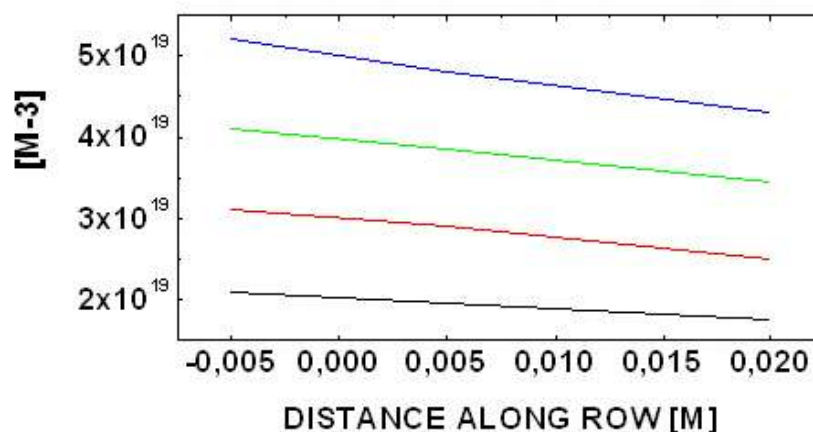


Figure 1. Radial density profiles obtained using EDGE2D for different recycling factor in Outer Mid Plane.

Also different models of radial transport – different formulas of diffusion coefficient – were analyzed. The impact of flow reversal on radial density profile was scrutinized: the appearance of flow reversal at high recycling regime seems to cause radial density profile to be no more exponential like. It can be seen that according to EGDE2D calculations flow reversal takes place in divertor chamber just before neutral ionization region near the separatrix. As shows calculations performed using the other codes (i.e. COREDIV) region of flow reversal can be stretch to the stagnation point in contrast to EDGE2D calculations. The difference can be due to real tokamak geometry applied in EDGE2D code; however there are the experimental evidences that the area of flow reversal is not constrained to divertor chamber as show EDGE2D simulations. It would be worth to study the details of flow reversal phenomena in more detailed way.

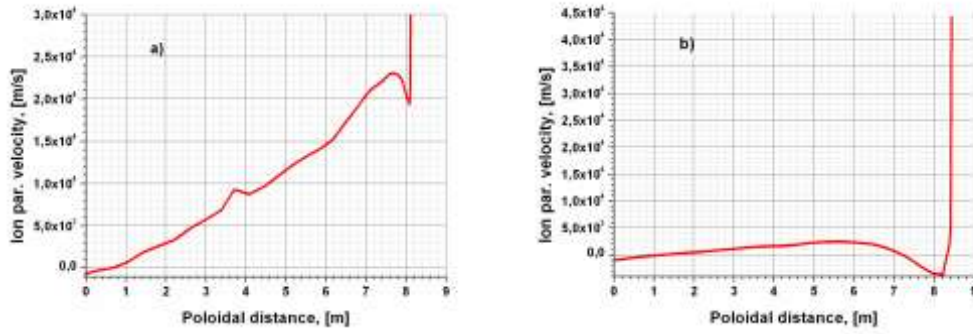


Figure 2. shows plasma velocity along magnetic line near the wall (a) and close to the separatrix (b) at high recycling regime.

The JET discharges with the transition from L to H mode has been simulated. The discharges with different position of X point has been chosen. The experimental data shown the for discharges with the X point shifted down the energy threshold for transition is lower. The simulation shows that different position of X point lead to different distribution of neutrals in scrape of layer and can influence of refuelling. This can explain the difference in L to H mode transition.

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4.6 Modernization of KN-2 neutron diagnostic

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Abstract

Modernization of KN-2 neutron diagnostic relied on upgrading automatic control of capsules transfer system has been undertaken. As a result of this modification synchronization of the capsule transfer system with the CODAS signals and possibility of transfer during JET pulse has been achieved.

Summary

Electronics records of KN2 neutron diagnostic were carefully examined. Next step was inspection of mechanical unit of KN2 (carousel). Because PRE Start Trigger signal is in charge of CODAS division consultations with CODAS-Electronics (Mr. Simon Dorling) and CODAS-Control & Diagnostic (Mr. Simon Dalley) were done.

It was agreed that two independent signals, each one of independently controlled delay, will be supplied by CODAS. It will be open-collector, active low pulse, and pulses 500 microsecond long. The terminal blocks were chosen as sockets and the Cubicle YN-2 was chosen as a signal source. CODAS Form 20 (CODAS Hardware Change Request) was filled.

Test device was designed and built. It was connected to the KN2 and proved to be operational. Creation of the fast track from 8U-irradiation end was found possible but complex. Significant changes in mechanical and electronic sections of the device are necessary.

Connections between CODAS terminal blocks (delayed signals PRE1 and PRE2 outputs) and our test device were prepared. Synchronous operation of KN2 diagnostic was tested. After successful test final design and construction was started.

Eight Harwell 50871 modules (serial numbers:01,02,03,04,06,11,12,14) were modified first by adding interface circuits with CNY17 optocouplers and MCX sockets. One 50871 module (serial number 20) was modified earlier but with LEMO instead of MCX sockets. One Harwell 50926 module was also modified. Final control device (sequencer) with 21 input/output lines was built. The principle of operation of this device was chosen to support most frequently used sequence :

- delayed puls PRE1 from CODAS causes dispatch of capsules to their irradiation ends,
- delayed puls PRE2 from CODAS causes dispatch of capsules back to carousel,
- carousel is turned on position "12",
- capsules are sent to their detectors,
- optionally carousel is turned again on position "17" and one capsule is sent to dump.

Finally, control device operation with KN2 diagnostic was tested. Now automatic capsules transfer during JET pulse is possible. Creation of the fast track from 8U-irradiation end was abandoned.

This work was done under supervision and with assistance of Mr. Sergei Popovichev (the person responsible for KN2 diagnostic).

Conclusions

- New automatic control and synchronization unit for capsules transfer system has been designed and produced.
- Synchronization of the capsule transfer system with the CODAS signals is possible now.

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4.7 Influence of refraction on accuracy of JET polarimetry and interferometry diagnostics

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Abstract

Refraction of infrared radiation is analyzed as a potential reason for noticeable inaccuracy in JET polarimetric and interferometric measurements. A computer code has been created for ray tracing calculations, based on experimental plasma density profile. It is shown that, in case of central vertical lines of sight in JET tokamak, refraction has only minimum impact on the ray trajectory and the optical path length is almost unchanged. In the same time deviation of the probing beam in case of the outermost vertical line of sight might be rather significant, so that refraction may decrease the intensity of detected signal due to ray shift over the exit window.

Summary

The work, done in 2008 at JET, was focused on the influence of refraction on accuracy of polarimetric and interferometric measurements in JET tokamak plasma (the curved beam trajectory is shown schematically at Fig. 1). The computer code has been created and numerical simulations for a number of shots have been done.

Results clearly showed that the refraction of vertical laser beams in FIR frequency band, used at JET polarimetry/interferometry system, doesn't change the optical path length significantly and therefore practically doesn't effect on accuracy of measurements that way. However, refraction in high density plasma may be responsible for large angle deviation of the beam and even for observed signal disappearing, especially for outer channel number 4.

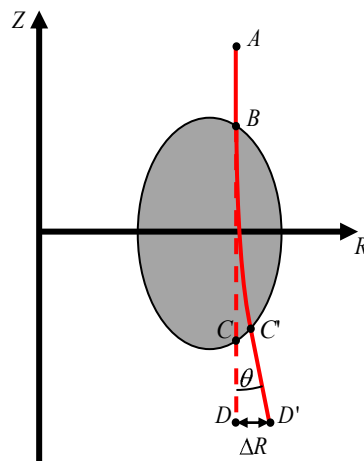


Figure 1. Simplified scheme of the beam trajectory in the inhomogeneous plasma layer

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