7.1 - Project name

Other fusion-related activities

7.2 - Project team

Name	Degree	% participation
H. Fernandes	Doctorate researcher	5%
Jorge Sousa	Doctorate researcher	5%
Nuno Cruz	Master researcher	100%
Carlos Silva	Dr	5%
Humberto Figueiredo	Master	5%
Patricia Carvalho	Dr	20%
José Brito Correia	Dr	10%
Vanessa Livramento	Master	20%
Daniela Nunes	Master	80%
Rodrigos Mateus	Dr	10%
Eduardo Alves	Dr	10%
João Figueiredo	Master	100%
Pedro Carvalho	Dr	10%
Álvaro Manuel Combo	Master's Degree	30%
Luis Alves	Dr	10%
N.P Barradas	Dr	10%
Bernardo Carvalho	Doctorate researcher	5%
Miguel Correia	Master's degree	10%

7.3 - Summary and highlights of research achievementes

Provide a concise description of the main research achievements during the year.

Figures, tables, graphics etc must have captions.

Graphic files must be submitted separately from the text (i.e. not embedded), and have a resolution of at least 150 dpi.

7.3.1 Introduction

7.3.2 Collaboration with Brazilian Institutions

7.3.2.1 Collaboration with TCA/Br

- *Study of the edge plasma rotation and characterization of the large scale fluctuations*

  The edge plasma rotation has been measured in the TCA/Br edge plasma using a gundestrup probe. Modest values of perpendicular rotation were found (M ~ 0.1), being larger in the SOL. Long-range (~1 m away) correlations have been found but only during the electrode biasing phase. This correlation may not be due to Zonal Flow like structures are plasma parameters slowly evolve during biasing.

7.3.3 Collaboration with IPP Greifswald

7.3.3.1 Assessment of the use of ATCA controller for long pulse operation

- *Proof of concept in the use of ATCA with IPP timing units*

The FPGA code of the 32-channels, 2 MSPS ATCA digitizer was modified to be compliant with the IPP timing units; tests confirmed the correct and synchronous operation of the timing setup; development of additional FPGA code to allow data time stamping are in progress.A complete ATCA test system was assembled and tested.

- *Design and implementation of a low drift integrator.*

The architecture of the low drift integrator was developed; the engineering design comprising the schematics and PCB layout are in progress and expected to be finished in the 1st quarter or 2011, as well as a prototype.

7.3.3.2 Study of the feasibility of Support Vector Machines to perform a tomography inversion

A novel tomography algorithm was researched, based on Support Vector Machines (SVMs). SVMs are objects originally developed for classification problems, but were quickly extended to regression problems. The application to tomography would require the adaptation of regression SVMs to an inverse problem. This adaptation was introduced in a paper by Vapnik but it was found that this solution did not depend on the inputs from the training data, but rather on the coordinates of the pixels in the reconstruction. It was a way to represent the result of a previously solved inverse problem as a collection of support vectors, thus reducing the amount of data of the result.

The concept of using regression SVMs to perform tomography was still pursued using the libSVM library, however, none of the pre-existing basis functions yielded satisfactory results. Some further research on SVMs is required in order to apply these algorithms to perform tomography inversions.

7.3.4 Participation in the TCV programme

7.3.4.1 Development of the TCV Advanced Plasma Control System (APCS)

- *Simulation and test of vertical plasma control algorithms; design of new algorithms to drive the coil amplifiers more efficiently; new nonlinear controller.*

An upgrade of the vertical control observer and control algorithm of the digital control system installed at TCV was performed, targeting the implementation of new non-linear vertical plasma control algorithms.

When migrating from the analogue control system into the digital control system some precautions had to be taken to ensure the digital system would cope with the demands and specifications of the currently running system.

The noise on the measurement of the vertical position of the plasma affects the overall stability of the closed loop control of the plasma. The initial analogue vertical position control loop for the internal fast coils was composed of an I_pZ observer (from integrated magnetic probe signals) and a D (derivative) controller. When migrating to the digital control system the D algorithm run on the digitized observer

signal proved to be too noisy. Further analysis followed this conclusion showing the transfer function of the D controller could not be used over the digital data.

Fig. 1.The magnetic field measured by the probes and the standard plasma vertical observer coefficients.

Fig. 2. The derivative of magnetic field as seen by the magnetic probes and the coefficients of the new observer

This fact justified the need for a new type of observer that permits the use of a P controller. In TCV the unintegrated raw signals from 20 magnetic probes are also available for real time measurement by the control system. Using these 20 non-integrated magnetic probe signals, a new observer was built for use with a P controller. Figure 1 depicts the time derivative of the magnetic field as measured by the magnetic probes and the coefficients of the new observer while figure 2 shows the magnetic field (integrated probe signals) and the standard plasma vertical observer coefficients.

To validate the observers and the method used to find the correct coefficients, the plasma position was evaluated and compared using the different methods. Figure 3 shows the observer signals and the PID control output voltages for both control loops during a TCV shot where the plasma was subjected to a small preprogrammed vertical oscillation. Both observers are compared to the plasma position given by LIUQE equilibrium plasma reconstruction code.

The implementation of a new nonlinear controller to test the quality of the “bang bang” algorithm for vertical position control in the presence of power supply voltage saturation, which was not achievable with the previous linear analogue control system, is in progress.

Fig. 3.Verification of the observer signals and the PID control output voltage for the two control loops during a TCV shot where the plasma had a small “yo-yo” movement (vertical oscillation)

7.3.5 Participation in the MAST programme

- Studies of pellet phenomena using Thomson Scatering diagnostic

The enhanced Thomson Scatering Diagnostic was exploited during the MAST scientific campaigns and data analysis of pellet experimental sessions performed. MAST pellet discharges have been studied and characterized using MC3 (MAST Chain Control Centre), an interactive data preparation tool designed to generate a self consistent set of MAST data for high level modelling such as TRANSP. The transport simulation code TRANSP was subsequently used for simulations on a relevant set of data. Output parameters of TRANSP such as the major radius of the magnetic axis and neutrons count were compared to the experimental data for a given discharge to prove the method reliability. Fast ion diffusion coefficient values were scanned in order to get a simulation properly mimicking the experimental conditions. This validaded data will be used on turbulence studies with the GS2 code (based on a continuum single flux tube principle).

7.3.6 Other activities on data acquisition and real time control

7.3.6.1 Development of new instrumentation standards

- *Participation on the xTCA Development Group of PICMG on the extensions to ATCA for Physics: ARTM and timing proposals.*

The collaboration for the xTCA ARTM and timing specifications is in progress.

7.3.7 Fusion materials studies

- *Production and characterization of consolidated Cu-nanoDiamond and W-nanodiamond alloys*

The concept of property tailoring involved in the design of metal matrix composites has led to several attempts to use nanodiamond (nDiamond) as reinforcement. Powder mixtures of copper and nDiamond with 20 at.%C were mechanically alloyed and consolidated via hot extrusion or spark plasma sintering. TEM analysis of the consolidated samples showed bonding between the copper grains and nDiamond particles. Density measurements indicate that the results depend on the consolidation route with superior results for hot extrusion. It was demonstrated that the pristine crystal structure of diamond is conserved during processing.

Following our previous demonstration of the feasibility of mechanical alloying of nanodiamond and tungsten and its consolidation with spark plasma sintering (SPS), the use of microdiamond in such composites was investigated. Different batches of W-μD were produced by MA, using mixtures of powders W – 40%at μD. The milled powders were consolidated with SPS at several temperatures (1073 K, 1123 K, 1273 K and 1423 K). Microdiamond is more favorable than nanodiamond in view of phonon transport performance leading to better thermal conductivity.

- *Screening of an alternative production route/capacity for Be pebbles*

Be pebbles and different Be grades produced at KIT were analysed and the composition and oxide layer measure. The thickness of oxide layers on the beryllium pebbles was measured by means of ion beam analysis using Rutherford backscattering spectrometry (RBS) and particle-induced x-Ray emission (PIXE). He+ 1.6 MeV and H+ 2.0 MeV focused beams were used for simultaneous RBS and PIXE analysis. The growth of the BeO layer on the pebbles under oxidation in air was measured at 600, 800 and 850 oC, (see figure below). The results reveal an continuous increase fo the oxide in agreement with the results found in the literature. Moreover PIXE data shows also the heavily contamination with Ti, Cr, Fe, Ni and Cu of the pebbles.

The major conclusions are:
At 850 oC the oxidized surface layer extent reaches 600 nm and no significant redistribution of the major imputrities was observed during the annealing. The presence of C was detected within the first 100 nm of the surface layer.

Figure: 1.6 MeV He+ RBS spectra of as-received and oxidised beryllium pebbles. The increase of the oxygen peak allows the measurement of the thickness of beryllium oxide layer on the pebble surface.

- *Study of irradiated Be compounds at HIDOBE*

Several 0.5 mm, 1 mm Be pebbles and Ti beryllides irradiated in HIDOBE-01 campaign (up to 3000 appm He production) were analysed with ion beam techniques. The impurity mapping and depth distribution of the impurities and major trace elements was determined. The study of titanium beryllides with different compositions was also performed. The medium long term activated isotopes present in the samples were also assessed. With respect to the minority

impurities distribution the results are comparable to no irradiated samples. A strong activity due to the presence of 60Co was measured in all the samples.