## 1. INTRODUCTION

### **1.1. FOREWORD**

This document describes the main activities carried out in 2004 in the frame of the Contract of Association between the European Atomic Energy Community (EURATOM) and "Instituto Superior Técnico" (IST) and presents a summary of the main scientific and technical results.

The Contract of Association EURATOM/IST frames the Portuguese participation in the EURATOM Specific Research and Training Programme in the Field of Nuclear Fusion Energy, hereinafter referred as Community Fusion Programme. This Programme has as its long-term objective the development of a prototype commercial fusion power plant. It is presently implemented through several Agreements, in particular: (i) Contracts of Association signed between EURATOM and Institutions of the Member States of the European Union and Switzerland (Associates); (ii) the European Fusion Development Agreement (EFDA); and (iii) the Mobility Agreement, both signed by EURATOM and its Associates.

The work programme of the Association EURATOM/IST includes activities carried out in Portugal (mainly related with the tokamak ISTTOK) and abroad related with the operation and scientific exploitation of large and medium-sized tokamaks and stellarator (JET, (Figure 1.1) ASDEX-Upgrade, TCV, MAST and TJ-II) as well as with the design of the next generation fusion devices (ITER (Figure 1.2) and W7-X).



Figure 1.1 – Tokamak JET

## 1.2. MAIN PROJECTS IN 2004

The Association EURATOM/IST had in 2004 the following main Projects:

- Tokamak ISTTOK;
- Participation in the collective use of the JET facilities by the EFDA Associates;
- Participation in the ASDEX-UPGRADE Programme;
- Participation in the TJ-II Programme;
- Participation in the MAST Programme;
- Participation in the TCV Programme;
- Participation in the ITER Project;
- Other activities on theory and modeling;
- Other activities on control, data acquisition and signal processing;
- Keep-in-touch activities on inertial fusion energy;
- Participation in the Fusion Technology Programme.



Figure 1.2 – Tokamak ITER

The research and development (R&D) activities carried out in the frame of these projects are summarized in the following section of this chapter and described in detail in chapters 3 to 13, which also present the main scientific and technical results. Chapter 14 describes other fusion related activities while chapter 15 contains the list of publications.

Table 1.1 presents information about the responsible person(s) and the Institutions involved in each project.

Project	Responsible Person(s)	Collaborating Institutions		
		Portuguese	Other	
Tokamak ISTTOK	Carlos Varandas	$CFN^1 UBI^2$ ,	CIEMAT <sup>5</sup> , IPP-Kharkov <sup>6</sup> ,	
		$CEI^3$ , $CFA^4$	UI <sup>7</sup> , IFUR <sup>8</sup> , IFUSP <sup>9</sup>	
Participation in the collective use of the	Fernando Serra	CFN, CEI,	EFDA <sup>10</sup> CSU <sup>11</sup> Culham	
JET Facilities by the EFDA Associates		UBI	UKAEA <sup>12</sup>	
Participation in the ASDEX Upgrade	Maria Emília Manso	CFN	IPP-Garching <sup>13</sup>	
programme	Fernando Serra			
Participation in the TJ-II programme	Carlos Varandas	CFN, CEI	CIEMAT	
	Maria Emília Manso			
Participation in the MAST programme	Carlos Varandas	CFN	UKAEA	
	Maria Emília Manso			
Participation in the TCV programme	Carlos Varandas	CFN	CRPP <sup>14</sup>	
Collaboration with the ITER Project	Carlos Varandas	CFN	EFDA CSU Garching	
	Maria Emília Manso			
Other studies on theory and modelling	Fernando Serra	CFN	IFP <sup>15</sup> , PT <sup>16</sup> , DFRC <sup>17</sup>	
	J. Pedro Bizarro			
Other activities on control and data	Carlos Varandas	CFN, CEI	IFUSP	
acquisition				
Keep-in-touch activities on inertial	J.T. Mendonça	$CFP^{18}$		
fusion energy				
Participation in the Fusion Technology	E. Alves	ITN <sup>19</sup>		
Programme				

Table 1.1 – Responsible person(s) and collaborating Institutions in the 2004 projects of the Association EURATOM/IST.

## **1.3. EXECUTIVE SUMMARY**

## 1.3.1. Tokamak ISTTOK

This project had this year four main research lines: testing of the liquid metal limiter concept, diagnostics, control and data acquisition and plasma physics studies.

#### • Testing of the liquid metal limiter concept

IST/CFN has proceeded with the collaboration with the Association EURATOM/University of Latvia on the testing of the liquid metal limiter concept. The liquid metal loop experimental rig has been commissioned in the ISTTOK Laboratory. Tests of this experimental apparatus have begun. A controlled heating system intended to ensure a 60

°C stable temperature in the main liquid metal loop has been designed, implemented and tested. A device to introduce oxide-free Gallium in the main loop for compatibility with Ga and UHV operation has been implemented and tested. The Gallium cleaning system has been tested. A heating backup system designed to keep Ga in the lower part of the loop always above the melting point has been implemented. A free expansion tank where Gallium could be stored for long periods has been designed, implemented and tested. One Portuguese Researcher has participated in Riga in an experimental campaign aiming at testing a new fast frame camera and studying the jet stability with several diameter nozzles (1.5, 1.8, 2.1 and 2.4 mm).

<sup>4</sup> CFA means "Centro de Física Atómica da Universidade de Lisboa"

<sup>&</sup>lt;sup>1</sup> CFN means "Centro de Fusão Nuclear"

<sup>&</sup>lt;sup>2</sup> UBI means "Universidade da Beira Interior"

<sup>&</sup>lt;sup>3</sup> CEI means "Centro de Electrónica e Instrumentação da Faculdade de Ciências e Tecnologia da Universidade de Coimbra"

<sup>&</sup>lt;sup>5</sup> CIEMAT means "Centro de Investigaciones Energeticas Medioambientales y Tecnologicas"

<sup>&</sup>lt;sup>6</sup> IPP- Kharkov means "Institute of Plasma Physics of the National Science Center" "Kharkov Institute of Physics & Technology".

<sup>&</sup>lt;sup>7</sup> UI means "University of Innsbruck".

<sup>&</sup>lt;sup>8</sup> IFUR means "Institute of Physics of the University of Riga"

<sup>&</sup>lt;sup>9</sup> IFUSP means "Instituto de Física da Universidade de São Paulo"

<sup>&</sup>lt;sup>10</sup> EFDA means "European Fusion Development Agreement"

<sup>&</sup>lt;sup>11</sup> CSU means "Close Support Unit"

<sup>&</sup>lt;sup>12</sup> UKAEA means "United Kingdon Atomic Energy Authority"

<sup>&</sup>lt;sup>13</sup> IPP-Garching means "Max-Planck-Institut für PlasmaPhysik"

<sup>&</sup>lt;sup>14</sup> CRPP means "entre de Recherches en Physique des Plasmas de École Polytechnique Fédérale de Lausanne"

<sup>&</sup>lt;sup>15</sup> IFP means "Istituto di Física del Plasma"

<sup>&</sup>lt;sup>16</sup> PT means "Politécnico di Turino"

<sup>&</sup>lt;sup>17</sup>DFRC means "Department de Recherches sur la Fusion Controlée".

<sup>&</sup>lt;sup>18</sup> CFP means "Centro de Física dos Plasmas"

<sup>&</sup>lt;sup>19</sup> ITN means "Instituto Tecnológico e Nuclear"

### o Diagnostics

A new diagnostic for magnetohydrodynamic (MHD) studies has been implemented using signals from a set of 12 equally spaced Mirnov coils. A new Gundestrup probe for flow measurements has been developed, giving particular attention to the materials used in its construction. The time-of-flight technique for plasma potential measurements by the heavy ion beam diagnostic with a multiple cell array detector has been optimized. The possibility of using this diagnostic for zonal flows studies has been theoretically evaluated. The design of a soft X-ray tomography diagnostic based on commercial CCD cameras has started. The emissive electrode used in the biasing experiments has been optimized aiming at easy replacement of the emitter material and operation for longer periods.

#### o Control and data acquisition

Software for shared remote data consulting and analysis has started to be developed, aiming at replacing the existing applications based on DOS and allowing data viewing and analysis by any authorized user, from any personal computer, anywhere in the world. The upgrade of the ISTTOK data acquisition system from the former "dbf" files-based system to an Open Source RDBMS PostgreSQL database has begun, by creating a PostgreSQL data mirror in a Linux server, replicating the original data structure and copying the pulse data on a daily basis to the new relational database, using script codes written in "Python". A modular USB controller for low speed (8 kbytes/s) data acquisition has been developed. The system consists of a small printed circuit board that incorporates 8 I/O lines, 8 open collector lines for power control (500mA each), I2C bus, as well as 4 analog lines (12 bit of maximum resolution). A library of functions in C language has been also developed to be used with this interface, which allows a quick a simple implementation of this system in slow control and a data acquisition systems. A cooperative, multi-user program has started to be developed in Java to control and launch ISTTOK discharges, replacing the present DOS shot launcher program.

#### • Plasma physics studies

Studies related with edge transport during emissive electrode biasing experiments<sup>20</sup> and edge fluctuations measured with emissive probes<sup>21</sup> were carried out in 2004.

## **1.3.2.** Participation in the collective use of the JET facilities by the EFDA Associates

IST/CFN has proceeded with its participation in the collective use of the JET Facilities by the EFDA<sup>22</sup> Associates, with activities in the areas of operation, scientific exploitation, enhanced performance project and management.

#### o Operation

Three members of the IST/CFN staff have been involved in the JET operation: Drs. Sebastien Hacquin and Isabel Nunes have participated in the JET Operation Team, through Secondment Agreements with the Association EURATOM/UKAEA, working respectively in the "Electron Kinetics Group" and "Operation Group". Mr. Luis Meneses has provided technical support to the operation and maintenance of the KG8 correlation reflectometer.

#### • Scientific exploitation

The participation in the JET 2004 Work Programme had contributions from fifteen scientists to the experimental campaigns C13 and C14 at the JET site. The work has been focused on code developments, leading to the following studies and/or tasks in plasma physics and/or engineering mainly related with Task Forces M, D and E: (i) study of the sawtooth stability in plasmas with counter-NBI; (ii) expansion of the JET sawtooth database; (iii) validation of q-profiles in JET optimised shear discharges; (iv) documentation of JET diagnostics for analysis of fluctuations; (v) stability domains for the internal kink mode; (vi) limiter H-mode studies in JET; (vii) evidence of fast ion redistribution during fishbones from TAE in JET deuterium plasmas; (viii) transport studies in tritium plasmas; (ix) time-frequency analysis of non-stationary fusion plasma signals by comparison between the Choi -Williams distribution and wavelets; (x) disruptions and runaway electrons in JET; (xi) effects of large magnetic islands on particle confinement trace-Tritium studies (TRANSP modelling); (xii) cross-correlation between parallel and radial fluctuating velocities; (xiii) design of a new reciprocating probe head; (xiv) studies of MHD and turbulence based on microwave reflectometry results.

#### o Enhanced Performance Project

IST/CFN was responsible in 2004 for four tasks of the JET Enhanced Performance Project: (i) Mw Access-Project Management and Implementation; (ii) MPR-Project Design and Procurement Activities<sup>23</sup>; (iii) TOF-Project Design and Procurement Activities; and (iv) RTP-Development Real-time Test Facility.

Concerning the Mw Access – Project Management and Implementation, Dr. Luis Cupido has assured the coordination of the Project, including the supervision of the commercial contracts. Test and measurement activities of the antenna cluster have been also carried out.

<sup>&</sup>lt;sup>20</sup> Work in collaboration with the "Laboratório de Plasmas, do Instituto de Física, da Universidade de S. Paulo", Brasil.

<sup>&</sup>lt;sup>21</sup> Work in collaboration with the University of Innsbruck of the Association EURATOM/OAW.

<sup>&</sup>lt;sup>22</sup> EFDA means "European Fusion Development Agreement".

<sup>&</sup>lt;sup>23</sup>Work in collaboration with the Association EURATOM/SKN.

Regarding the Development Real-time Test Facility, transition from the initial design based on a System-On-Chip approach to a PC based system has been made. The schematic and layout design of the waveform generator (WG) PCI module prototype have been performed. One WG prototype board has been assembled and tested. Four final WG modules have been commissioned and tested. Firmware codes have been written for the development for the programmable logic devices, including the design, simulation and test of a CIC interpolator filter and sharpening FIR filter, both programmable in real-time. The low-level Digital Signal Processor (DSP) software has been implemented. A code for interfacing with the ATM realtime network has been developed. A complete PC based system with four waveform generator modules has been assembled. The system Linux based control software, the application programming interface and the MDSPlus interface software have been developed.

Concerning the MPR-Project Design and Procurement Activities and the TOF-Project Design and Procurement Activities, the two prototypes of the time digitizer (TD) module have been assembled and tested. A Matlab<sup>®</sup> data analysis program for automatic detection of functional and performance errors on TR has been developed. Six plus two spare TR boards as well as three TD boards have been assembled and tested at IST and sent to the Swedish EURATOM Association for integration on the MPRu and TOFOR diagnostics. The modules control and test software both for the Windows and Linux OS have been completed. Software and hardware manuals have been finished. IST/CFN staff has collaborate with the Swedish Association on the integration of the modules in the diagnostics.

#### o Management

The Association EURATOM/IST has collaborated on the management of the use of the JET facilities by the EFDA Associates in the following manner: (i) Dr. Bruno Gonçalves as a member of the staff of the Close Support Unit to the EFDA Associate Leader for JET; (ii) Dr. Duarte Borba as deputy Task Force Leader for TFM; (iii) Prof. Horácio Fernandes and Dr. Paulo Varela as members of the Remote Participation Users Group.

## **1.3.3.** Participation in the ASDEX-UPGRADE programme

The Portuguese participation in the ASDEX-Upgrade<sup>24</sup> (AUG) Programme has been mainly focussed on the areas of microwave reflectometry (microwave systems and electronics, control and data acquisition, data processing, modeling and plasma physics studies), MHD and turbulence studies and management.

#### • Microwave reflectometry

Concerning the microwave systems and electronics, a new active frequency multiplier for the Q-band X-mode channel

has been installed, replacing an old passive multiplier with strong signs of efficiency degradation and increasing the available power by 8 dB. A permanent marker switch has been implemented to permit the obtention of dynamic calibration curves for all frequency sweeps in all shots. All heterodyne channels have been tested and new IF filters with larger bandwidth have been installed allowing proper operation with fast sweeps. A new mixer in the Vband X mode channel has been implemented. The V-band X-mode antenna has been modified. A new and more detailed dynamic frequency calibration circuit using a millimetre wave delay line has been developed, to provide together with the frequency markers a more accurate frequency calibration. A new in-vessel directional coupler at the Ka band HFS channel has been installed, replacing the one damaged by the ECHR operation. A new thermal and plasma protection for the waveguides at the LFS access port has been implemented, that should avoid Halo currents in the waveguides. A vacuum window misalignment for the expected polarity in the W band LFS has been detected and repaired by rotating the tapers and twisting the fundamental waveguides to rotate polarity.

Regarding control and data acquisition, the control software of the broadband channels has been optimized. The control software has been modified after the installation of a new RS232 control boards aiming at improving the control hardware. New functionalities have been added to the broadband system: (i) new channels been implemented. allowing have testing and measurement of calibration signals; (ii) a logfile has been introduced to control any hardware problems that may occur; (iii) software has been developed to permit switching on and off remotely each microwave source. The control software for a new "hopping" frequency system has started to be developed

Concerning data processing, the burst mode data analysis technique used for automatic density profile evaluation under the presence of turbulence with a 2D FDTD numerical code has been validated. Software tools for automatic evaluation of the very edge density profile with X-mode probing waves have been developed.

In the area of diagnostic developments, a software tool to simulate O/X mode reflectometry has been developed. The reliability and accuracy of plasma position measurements using a dedicated workbench of numerical tools has been assessed.

Regarding modeling, unidirectional transparent signal injection in finite-difference time-domain electromagnetic codes has been modelled.

Finally, Studies on the impact of type I and type III ELMs on the plasma edge density profile, MHD and turbulence were carried out in 2004.

#### • MHD and turbulence

The effect of electron cyclotron current drive on Alfvén Eigenmodes on Asdex-Upgrade has been studied. A code

<sup>&</sup>lt;sup>24</sup> ASDEX-Upgrade is a tokamak of the Association EURATOM/IPP, in operation in Garching.

for the analysis of turbulence and transport in the SOL of AUG has been developed.

### • Management

Two members of the IST/CFN staff have participated in the management of the AUG project: Prof. Maria Emilia Manso is a member of the AUG Programme Committee and Dr. Duarte Borba is the Task Force Leader for TF V (MHD).

### 1.3.4. Participation in the TJ-II programme

The CFN participation in the TJ-II<sup>25</sup> Programme has been mainly focussed on the areas of microwave reflectometry, heavy ion beam diagnostic and edge plasma physics.

## • *Microwave reflectometry*

The work in this research line has been mainly focussed on the development of a "Fast Frequency Hopping Reflectometer" (operating on Q-band, 33-50 GHz). The hardware developed and constructed by CFN has been delivered to Madrid and test at CIEMAT. The operation of this diagnostic began after the installation of the vacuum windows by the TJ-II technical staff. Manual configuration of the diagnostic has been performed during the initial tests. The diagnostic started to be routinely used after the development at CIEMAT of some control and acquisition software. Plasma physics studies based on the analysis of the experimental results have been initiated.

## • *Heavy ion beam diagnostic*

The work in this research line has been mainly focussed on the improvement of the dedicated data acquisition system. Calls for tenders for a new VME computer and a new trigger module have been made. The operating system has been converted from OS-9 to LINUX. The new VME computer has been tested. The operating software has been implemented and the VME drives have been compiled. Thirty-six transimpedance amplifiers have been commissioned and tested.

## • Edge plasma physics studies

The turbulent transport studies have been proceeded using data from the TJ-II Langmuir reciprocating probe with particular emphasis on the momentum redistribution between mean flows and turbulence and on the dynamical relation between parallel flows and instabilities. The study of the transport and fluctuations during electrode biasing experiments has been carried out.

## 1.3.5. Participation in the MAST programme

The main objective of this project is the development and scientific exploitation of a microwave reflectometer for MAST<sup>26</sup>. During 2004, the VCO oscillator (Ka-band) has

been replaced, resulting in a significant decrease of higher order harmonic levels. New static and dynamic calibration curves have been extracted to include in the data processing. The video amplifiers have been replaced aiming at improving the noise level. Some problems have been detected due to some modifications in the tuning section of the oscillators. The tuning circuit has been upgrade to fulfil the requirements of full band operation. The dedicated fast data acquisition system based on a VME board developed by CFN with capability to preprogram the samples has been brought to full operation. Several software tools for data analysis have been adapted. The scientific exploitation of the diagnostic has started.

## **1.3.6.** Participation in the TCV programme

The main objectives of this project are the development and scientific exploitation of three X-ray diagnostics (a horizontal Pulse Height Analysis (PHA) diagnostic, a vertical PHA diagnostic and a rotating crystal spectrometer) and the development of an advanced plasma control system for TCV<sup>27</sup>.

## • Horizontal PHA diagnostic

CFN staff has ensured the operation and scientific exploitation of this diagnostic, which is in operation since 1997. Software tools for data analysis have been improved. Plasma physics studies related with the influence of auxiliary heating on the plasma electron distribution function have been carried out.

## • Vertical PHA diagnostic

This research lines has been put forward to meet the need for high throughput, fast data acquisition and real-time data analysis capabilities. The diagnostic has been dismounted from TCV for inspection and repair of some malfunctions, alignment of the detector, replacement of viton rings, calibration of the filters and aperture positions and repair of one motor. The variable aperture has been redesigned in order to have the correct curvature and gradient. The interface master/slave that actuates the motors has been redesigned aiming at avoiding saturation. A commercial CAMAC data acquisition board has been tested, proving not to be stable for X-ray sources of variable flux. A commercial multi-channel analyser VME board has been installed. Two input channels of this module have been activated to survey the signal coming from the detector pre-amplifier and detection and suppression of the noise sources. The diagnostic has been re-implemented on TCV. The hardware and software for the calculation of the electron temperature using the CFN real-time multi-DSP-based VME module have been developed, tested and improved.

<sup>&</sup>lt;sup>25</sup> TJ-II is a stellarator of the Association EURATOM/CIEMAT, in operation in Madrid.

<sup>&</sup>lt;sup>26</sup>MAST is a Mega Ampere Spherical Tokamak of the Association EURATOM/UKAEA, in operation in Culham.

<sup>&</sup>lt;sup>27</sup>TCV is a "Tokamak de Configuration Variable" of the Association EURATOM/Confederation Suisse, in operation in Lausanne.

## • Rotating crystal X-ray diagnostic

This diagnostic, based on a twenty years old apparatus loaned by the Plasma Physics Princeton Laboratory, has been envisaged to record the soft-X-ray line radiation from highly charged ions of low to medium Z elements from the hot core of the TCV plasma, along a horizontal line of observation. During the last trimester of 2004, the calls for tenders for the micro-channel plates and crystals have been made. The electronic devices of the diagnostic have been revised and improved. The signals that will be provided by TCV system to the diagnostic and from the diagnostic to the TCV data acquisition system have been identified and characterized.

### • Advanced plasma control system (APCS)

This research line aims the development of a new real time digital plasma control system, based on the CFN real-time parallel processing multi-DSP-based VME (RTPROV) board. The commissioning and testing of twelve RTPROV modules have been finalized. The tests of the simultaneous operation of these modules in a VME crate have been initiated. The development and testing of t he data mover bus (DMBUS) have been finalized. The DMBUS and XIO VME modules have been commissioned ad tested. Software for MACH programming and DMBUS management has been developed and tested. The APCS operation system has been developed and tested. Software for the APCS integration in the TCV control and data acquisition system is under development.

#### **1.3.7.** Participation in the ITER project

The Portuguese participation in the ITER project included in 2004 activities related with microwave reflectometry and negotiations.

#### • *Microwave reflectometry*

This research line included in 2004 activities related with the design analysis of the position reflectometer, development of an advanced FM-CW reflectometer and demonstration experimental studies on ASDEX-Upgrade of plasma position/shape measurements in ITER relevant scenarios.

Concerning the design analysis of the position reflectometer, the Association EURATOM/IST has led a Physics Integration Task of the Fusion Technology Programme (TW3-TPDSUP). CATIA models have been developed for the draft design of the waveguide routing of gaps 3, 4 and 5. First simulation studies of the performance of the waveguide routing using HFSS have been performed. The assessment of the possibility to locate the electronics in the port cells has started.

Regarding the development of a prototype of a coherent reflectometer, the basic concept has been developed. The design of the sources and subsequent determination of the operation frequency bands have been finalized. The design of the sweep and digital control has been initiated as well as the study of an integrated FPGA based approach for linear control and frequency synthesis.

Concerning plasma position/shape measurements, automatic density have been obtained in ASDEX Upgrade in ITER relevant scenarios, namely in ELMy H modes, demonstrating clearly the possibility to use reflectometry for plasma position/shape measurements in ITER.

### • ITER Negotiations

Prof. Carlos Varandas has attended two meetings in 2004 of the ITER negotiations, as member of the delegation of the European Union.

### **1.3.8.** Other activities on theory and modelling

This project included in 2004 three research lines: (i) Analysis of the role of magnetic reconnection processes in the dynamics and confinement of thermonuclear plasmas; (ii) Studies on lower-hybrid current drive; and (iii) Modelling of the Grad-Shafranov equilibrium in tokamak plasmas.

• Analysis of the role of magnetic reconnection (ideal and resistive) processes in the dynamics and confinement of thermonuclear plasmas<sup>28</sup>

Studies of the poloidal  $\vec{E} \times \vec{B}$  velocity, mode coupling effects on plasma braking and NTM triggering and parity and topology of tearing mode perturbations have been carried out.

#### • Studies on non-inductive current drive

A method to measure the scattering matrices of lowerhybrid multi-junctions has been developed. Progress has been made on the study of the spectral-gap problem for lower-hybrid current drive. IST/CFN staff has participated in the design of the ITER-like PAM launcher for lower hybrid current drive<sup>29</sup>.

# • Modelling of the Grad-Shafranov in tokamak plasmas

A perturbative GS equilibrium solver, able to deal with realistic pressure and current-density profiles, was adapted to handle the existence of a poloidal-field reversal layer, for which the tangential magnetic field and the enclosed toroidal current do vanish.

# **1.3.9.** Other activities on control, data acquisition and signal processing

This project has included two main research lines:

• Development of a low-cost, fully integrated, eventdriven real-time control and data acquisition system for fusion experiments;

<sup>&</sup>lt;sup>28</sup> Work carried out in collaboration of CNR-Milano, of the Association EURATOM/ENEA.

<sup>&</sup>lt;sup>29</sup> Work performed in collaboration with the Association EURATOM/CEA.

#### • Development of clusters of computers.

In 2004, adequate embedded development tools for the PowerPC processor have been assessed. A preliminary hardware control core of the system, implemented as a System on Chip (SoC), has been designed. Adequate software tools for programming a reconfigurable real-time processing system have been assessed and tested. A reconfigurable hardware PCI module has been developed.

A water-cooled 16 computer cluster has been developed, tested and used for heavy parallel calculus.

# **1.3.10.** Keep-in-touch activities on inertial fusion energy $^{30}$

This project included in 2004 experimental developments (hardware improvements and experiments) as well as theoretical and simulation activities.

Concerning the hardware improvements in the Laser system and target area of the Laboratory for Intense Lasers, a home-built SPIDER (spectral phase interferometry for direct electric-field reconstruction) diagnostic has been implemented and used to optimize the compressed pulse duration and pulse shape. A specially-built vacuum chamber has been installed for housing the current grating compressor, compatible with pulse amplification to the 10 Joule level and subsequent compression to the hundreds of fs level, without air-induced pulse distortion. Afterwards, the laser system has been fully characterized. A new type of tilted pulse front auto-correlator has been successfully tested. A parametrical optimization of the spectral evolution along the laser chain has been also performed, in order to minimize the final pulse duration.

A new experiment on production of plasma channels for electron accelerators was started. Portuguese staff has also participated in an experiment to test a UCLA-developed plasma source<sup>31</sup>. The development of a new generation of plasma sources aiming the production of energetic electron beams by laser-plasma interaction has started. The development of X-ray lasers and XUV diagnostics has been proceeded.

Preliminary theoretical studies of fast ignition using laser generated electron beams were carried out in 2004 aiming at identifying key physics issues related to the process of fast ignition such as energy deposition by a beam with a broad energy spectrum and current limitation by the self-generated magnetic field of the beam. Plasma simulations on high energy density science or extreme plasma physics have been performed related with the beamplasma instability, fast electron transport in realistic ICF targets, photon accelerator, Osiris 2.0 development, dHybrid, collisionless shocks for fast ignition and proton acceleration, explosion of clusters and neutron vield increase from controlled shock shells. Blow out, wave breaking and self-injection, B-field generation and the inverse Faraday effect and stimulated scattering instabilities driven by broadband radiation sources.

## **1.3.11.** Participation in the Fusion Technology Programme<sup>32</sup>

The participation of the Association EURATOM/IST in the 2004 Fusion Technology Programme was concentrated on the following projects: (i) TW3-TTMA-001 - Structural materials: SiC/SiC ceramic composites. Deliverable D1: Morphological characterization and impurity studies of SiC/SiC composites; (ii) TW4- TPP-ERCAR - Characterisation of carbon erosion and properties of plasma exposed carbon PFCs under ITER relevant Deliverable: conditions. Report on characterisation of the surface morphology of ASDEX-Upgrade tokamak tiles exposed to large plasma fluences (> 10<sup>26</sup> m<sup>-2</sup>); (iii) TW4: TTBB-005 - Helium cooled pebble bed: Breeder and neutron multiplier materials. Deliverable 5: Characterization of Be<sub>12</sub>Ti: 2 types of Be<sub>12</sub>Ti should be analysed to assess the chemical composition, surface and internal composition, oxide layer and secondary phases; and (iv) Study of beryllides stability, carried out in the frame of underlying technology.

### **1.3.12.** Other fusion activities

The Association EURATOM/IST has proceeded with the collaboration with two Brazilian Institutions ("Laboratório de Plasmas do Instituto de Física da Universidade de S. Paulo" and "Laboratório Associado de Plasmas do Instituto Nacional de Pesquisas Espaciais") in the areas of microwave reflectometry, data acquisition, edge physics and transport.

The collaboration with the Portuguese universities on graduation and pos-graduation programmes has been also proceeded. One Ph.D and one master programme have been finalized in 2004, while eighteen Ph.D and six master students have been working in the Association EURATOM/IST.

Some members of our staff have been involved in the management and implementation of the EURATOM Fusion Programme as well as in the organization of scientific meetings. Special reference should be made to the "20<sup>th</sup> Fusion Energy Conference" (FEC-2004), held in Vilamoura, from 1 to 6 November 2004, organized by the International Atomic Energy Agency (IAEA), with the collaboration of IST/CFN. This conference was attended by 604 participants from 32 countries and three international organizations. IST has also organized 28 satellite meetings to FEC-2004 in Vilamoura and Lisboa.

Finally, the Association EURATOM/IST has proceeded with activities on public information. Besides the publication of booklets, IST/CFN has organized, in collaboration with EFDA and the "Consorcio RFX", the exhibition EXPO Fusion, in Vilamoura, from 1 to 6 November 2004.

<sup>&</sup>lt;sup>30</sup> This project has been carried out by "Grupo de Lasers e Plasmas" of "Centro de Física dos Plasmas".

<sup>&</sup>lt;sup>31</sup> Work in collaboration with the Laser-Plasma Group of University of California.

<sup>&</sup>lt;sup>32</sup> This project has been carried out by "Instituto Tecnológico e Nuclear".

## 1.3.13. Publications

Table 1.2 provides information about the publications

Area	Thesis		Papers	
	Master	Ph.D	Journals	Conferences
Magnetic Confinement	1	1	106	74
Inertial Confinement	0	0	17	38
Technology	0	0	3	2

Table 1.2 – Publications in 2004