Annual Report 2011

INSTITUTO DE PLASMAS E FUSÃO NUCLEAR

ipfn INSTITUTO DE PLASMAS E FUSÃO NUCLEAR

ASSOCIATED LABORATORY WITH FCT
ASSOCIATION EURATOM/IST

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INSTITUTO DE PLASMAS E FUSÃO NUCLEAR

Director´s Foreword

2011 was a year of challenges that IPFN professionals have faced with a strong commitment towards making the Portuguese science and technology competitive and well recognised internationally. Following the initiative started last year, a more compact and elegant version of our printed Annual Report - along with an electronic version of the detailed report- is presented to you. This year we decided to focus our report on the research infrastructures, either located in our facilities at IST or abroad, where IPFN staff developed their outstanding work. With this approach we aim to reach a broader audience and transmit not only what we are doing at IPFN, but also to show our contribution to key international experiments. This is also accompanied by a strong effort to prepare the future generation of researchers and engineers by fostering excellence through high quality Education in the areas of Engineering, Science and Technology.

IPFN is a research unit open to the outside where excellence, innovation and internationalization arise from the activities in nuclear fusion, plasma physics and technology and intense lasers. The quality of our research and development activities is well expressed by the scientific output (approximately 2.5 papers per PhD researcher) as well as by the international participation of several members of our staff in management bodies of programmes and projects as well as in the organisation of scientific conferences. Among all 2011 events, some achievements in particular should be underlined for their relevance:

- Signature with FCT of the Strategic Project for funding in 2011-2012 of the Contract of Associated Laboratory;
- Signature of two new contracts concerning ITER CODAC, one with Fusion for Energy and another with ITER International Organisation;
- Leadership a second F4E grant on remote handling;
- 6th largest participation in JET experimental campaigns;
- Demonstration of radial position control of the ASDEX- Upgrade plasma with reflectometry;
- Publication of two papers in Nature Physics;
- Approval by ESA of the design of the ESTHER Shock-Tube facility;
- Production of gamma rays from the resonant betatron dynamics in a laser wakefield accelerator in the Astra Gemini laser; and
- Development of a prototype for long plasma cells for plasma wakefield accelerator experiments with long hadron and lepton beams.

It was also a year of recognition from the community with several prizes awarded to IPFN staff:

- UTL Science Prize in Physics to Luís Oliveira e Silva (senior award) and Jorge Vieira (junior award);
- Seed of Science Award “Exact Sciences” to João M. Dias and Nuno Lemos and Seed of Science Award “Junior” to Frederico Fiúza;
- Oscar Buneman Award for Scientific Visualization awarded to Frederico Fiúza;
- ISCTE-IUL Scientific Achievement Prize–2011 awarded to Ricardo Fonseca;
- Best Contributions Prizes in Conferences to D. Baião, J. L. Martins, F. Ribeiro J.M. Dias, A. Castanheira-Dinis and C. P. João;
- Honorable mention, Prémios Investigadores UTL Science Prize in Physics, J. Páramos;

I hope you find the next pages and the work they describe simultaneously exciting and enjoyable.

Carlos Varandas

About IPFN

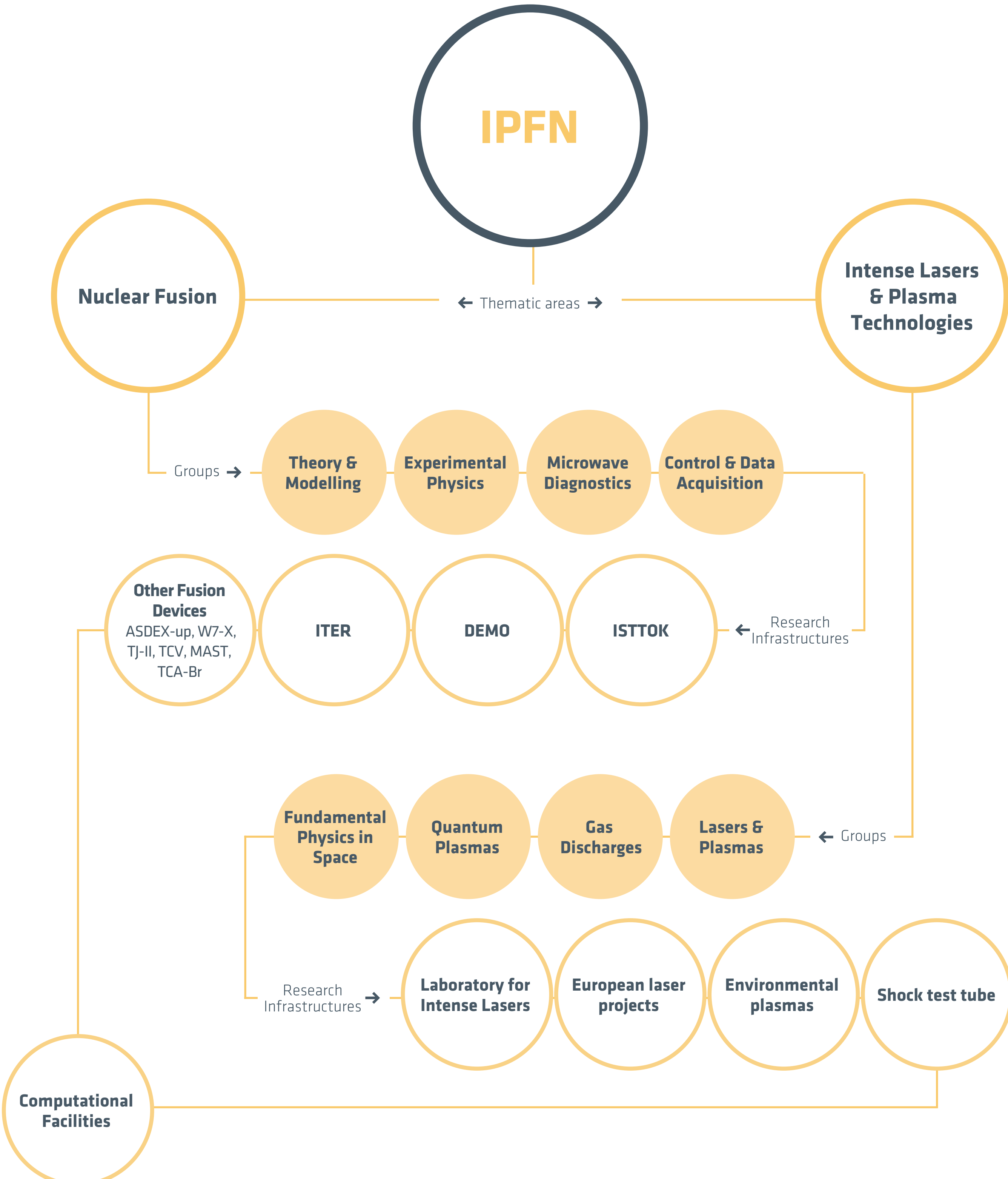
Instituto de Plasmas e Fusão Nuclear (IPFN, Institute for Plasmas and Nuclear Fusion) is a research unit of Instituto Superior Técnico (IST) with the status of Associated Laboratory granted by Fundação para a Ciência e a Tecnologia.

IPFN is also the research unit of the Contract of Association Euratom/IST, which frames the Portuguese participation in the Euratom Fusion Programme.

The main aim of this Programme is the development of a commercial reactor based on nuclear fusion reactions. The roadmap towards a fusion reactor is focused on three devices: JET, its successor ITER and a demonstration reactor called DEMO. While JET represents a pure scientific experiment, the reactor scale experiment ITER is designed to deliver ten times the power it consumes. The next foreseen device, DEMO, is expected to be the first fusion plant to reliably provide electricity to the grid.

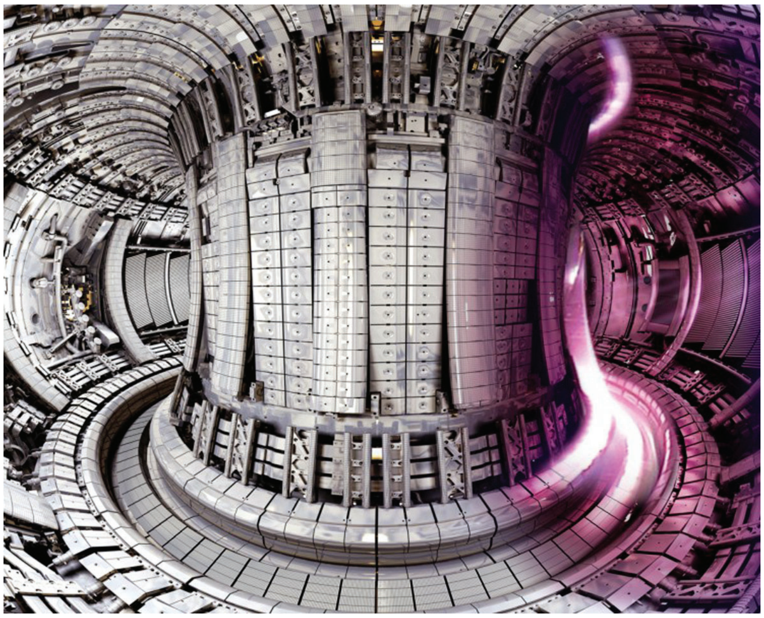
The Research Line on Intense Lasers and Plasma Technologies takes advantage of the critical mass of the groups within it to address frontier questions in gas electronics, sources of particles and radiating species, ultra-short, ultra-intense lasers and their applications, plasma accelerators and advanced radiation sources, ultra cold plasmas, and fundamental science in space.

About IPFN


IPFN
Thematic areas
Nuclear Fusion
Intense Lasers & Plasma Technologies
Groups
Theory & Modelling
Experimental Physics
Microwave Diagnostics
Control & Data Acquisition
Research Infrastructures
Other Fusion Devices ASDEX-up, W7-X, TJ-II, TCV, MAST, TCA-Br
ITER
DEMO
ISTTOK
Groups
Fundamental Physics in Space
Quantum Plasmas
Gas Discharges
Lasers & Plasmas
Research Infrastructures
Laboratory for Intense Lasers
European laser projects
Environmental plasmas
Shock test tube
Computational Facilities

About Nuclear Fusion

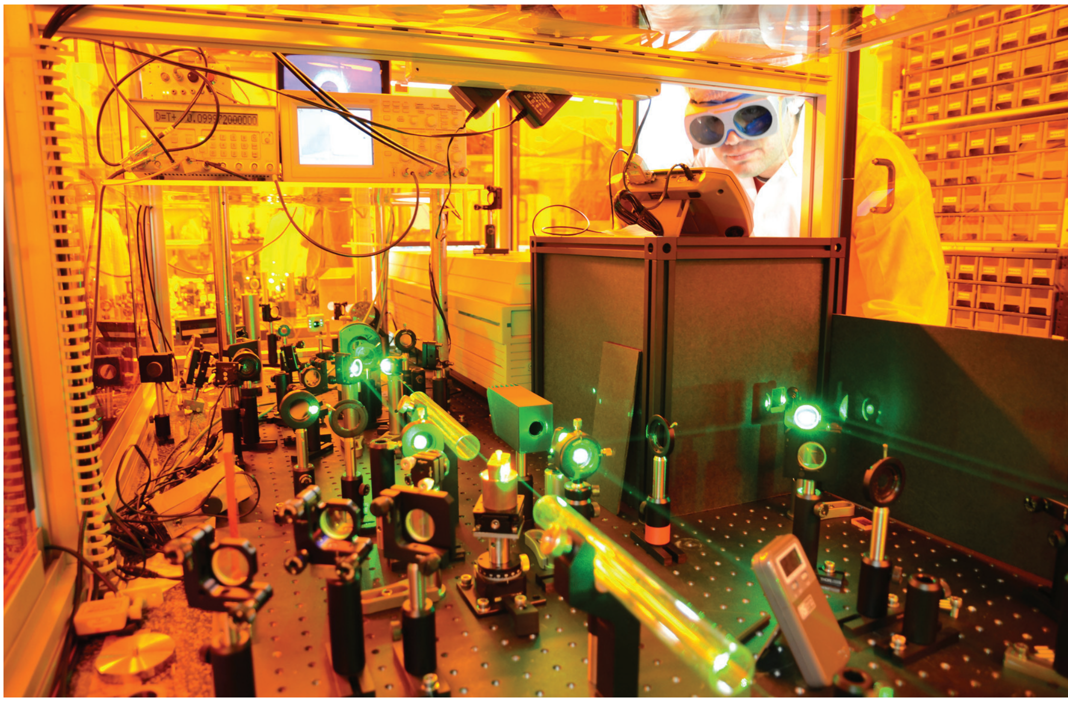
- Fusion is the process at the core of stars, such as our Sun, that produces amazing quantities of energy.
- It occurs when light atoms such as hydrogen become so hot that they fuse into new elements, releasing large amounts of energy.
- The most efficient fusion reaction reproducible in the laboratory is that between two hydrogen (H) isotopes, deuterium (D) and tritium (T), which produces the highest energy gain at the 'lowest' temperatures.
- Fusion ingredients are abundant on earth, and no greenhouse gases or long-lived nuclear waste are created by fusion.
- One way to achieve a controlled fusion reaction is inside a device called a tokamak, where magnetic fields are used to contain and control the hot plasma.
- Once harnessed, fusion power will be a nearly unlimited, safe and climate friendly energy source.
- The Fusion Programme of the European Atomic Energy Community (EURATOM) aims at the development of models, design, operation and scientific exploitation of experimental facilities which may allow the construction of fusion power plants capable of producing electric energy.



Plasma at JET tokamak.
JET is the only device in the world with capability to operate deuterium-tritium (DT) plasmas.

About Plasma Technologies and Lasers

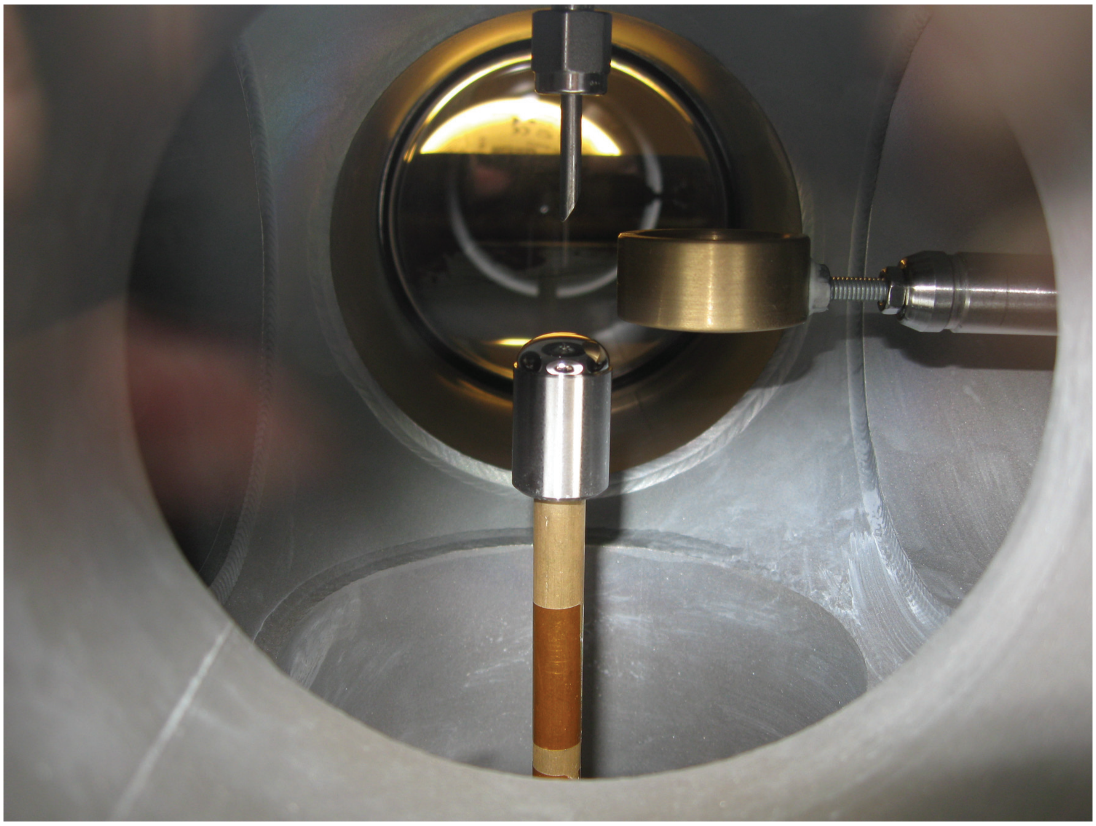
- The plasma state is commonly called "the fourth state of matter". It is generated when energy is provided to a solid, liquid or gas such that a fraction of its atoms are ionised.
- The plasma state is the most abundant state of visible matter in the universe, comprising the stars and the interstellar space. On Earth, we are used to natural plasmas, in the form of lightning and flames; and artificial plasmas such as plasma TV displays and fluorescent lamps.
- Plasmas come in an amazing variety of parameters, making plasma science a fascinating subject, both at the fundamental and application levels.
- Plasma-based technologies are used today in a variety of fields spanning from microelectronics and materials processing to waste treatment and environmental control, biotechnology and health care.
- Laser-produced plasmas are test beds for extreme regimes of nature, where electrons can oscillate at relativistic velocities – and, for instance, become accelerated to GeV energies in a few millimeters, thanks to the overwhelming electric fields associated to electron plasma waves.
- Research at IPFN in plasma technologies and intense lasers is dedicated to investigating a multitude of topics in these areas, encompassing theory, simulation and experimental research, in a strongly international environment, and in the frame of several important collaborations with world-leading institutions.



Laboratory for Intense Lasers:
Regenerative amplifier.

ISTTOK
Portuguese Tokamak

ISTTOK is a small tokamak with a circular cross-section, a poloidal graphite limiter and an iron core transformer. Most of the components of the tokamak, as well as its diagnostics and control and data acquisition system, were designed and constructed by physicists, engineers and technicians of the Association EURATOM/IST. ISTTOK effectively provides an experiment on magnetic confinement in fusion at Instituto Superior Técnico. Its main goals are focused on the education and training of physicists, engineers and technicians in physics, engineering and technology related to nuclear fusion, the development of new diagnostic techniques, control and data acquisition concepts as well as undertaking plasma physics studies.



Galium sample, for hydrogen retention studies, shown inside the preparation chamber.

ISTTOK provides an experiment on magnetic confinement in fusion at IST.

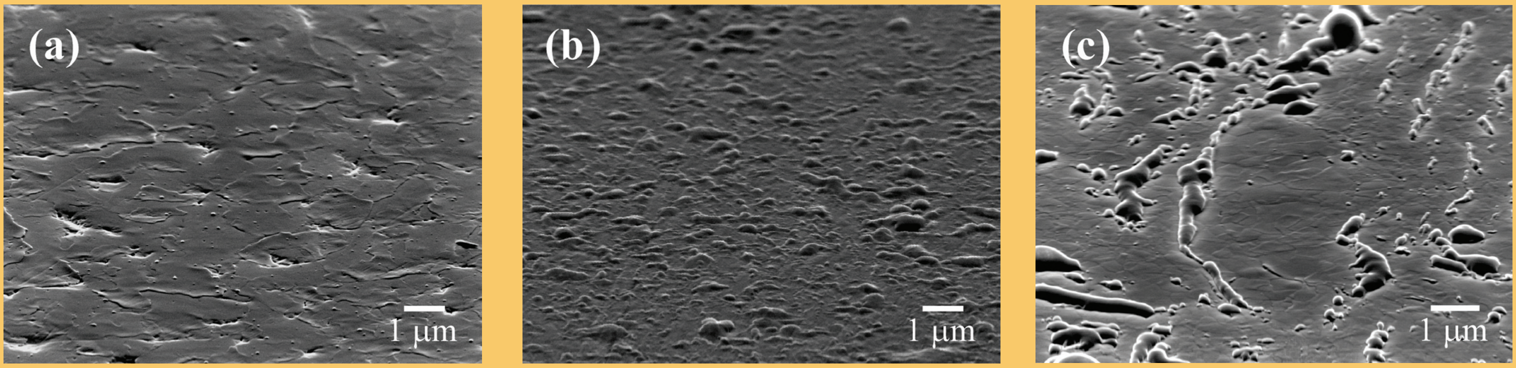
Highlights

- Evidence for saturation of hydrogen retention in gallium samples exposed to ISTTOK plasmas.
- Development of a novel control system to improve the discharge stability and increase the number of AC discharge cycles.
- Simultaneous measurement of the parallel and perpendicular ion temperature in the edge plasma with a pinhole probe.
- Further development of diagnostics based on solid-state detectors for measurements of super-thermal and runaway electrons.
- Investigation of the interplay between mean and fluctuating ExB shear flows in the edge plasma.
- Observation of a dynamic interplay between particle turbulent flux and density radial gradient in the edge plasma.

(Left) Smooth surface blistering along the grain boundaries in a pure W plate after ion implantation of 30 keV He^+ ions with a fluence of 5×10^{17} He^+/cm^2.

(Middle) Surface blistering in a pure Ta plate after ion implantation of 30 keV He^+ ions with a fluence of 5×10^{17} He^+/cm^2, revealing the higher ductility of Ta comparatively W.

(Right) Surface of a W-Ta composite obtained from W and Ta powders after ion implantation of 20 keV He^+ ions with a fluence of 5×10^{17} He^+/cm^2, presenting the characteristic blistering behaviour of the individual W (lighter) and Ta (darker) components.



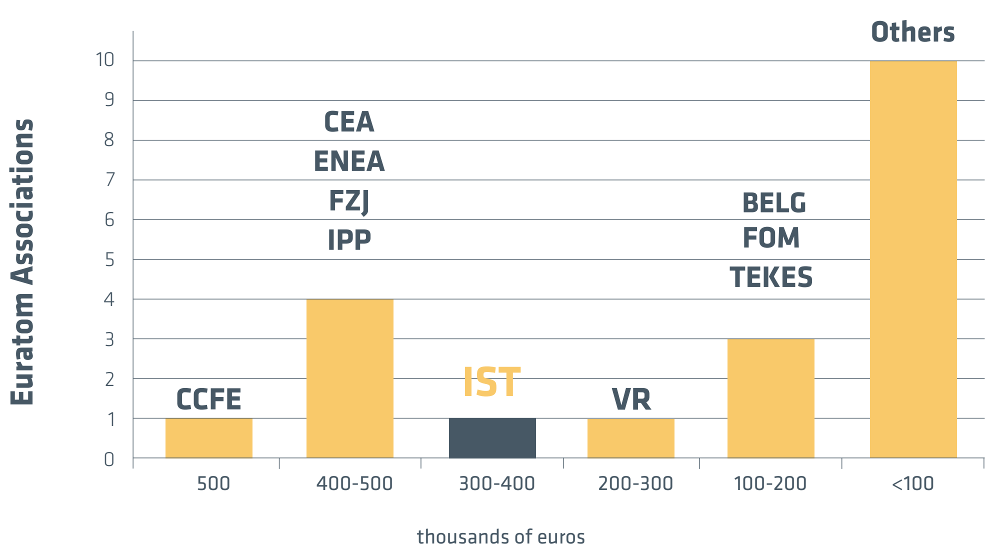
JET
Joint European Torus

Researchers at the Joint European Torus (JET) investigate the potential of fusion power as a safe, clean, and virtually limitless energy source for future generations. The largest tokamak in the world, it is the only operational fusion experiment capable of producing fusion energy. As a joint venture, JET is collectively used by more than 40 laboratories of EURATOM Associations.

Equipped with unique facilities needed to operate a fusion power plant, JET paves the way to meet ITER's ambitious goal. JET operation encompasses all the activities leading to a better understanding of the plasma operation issues, scenario development and comprehension of the physics basis, as well as to the development of algorithms and models for data analysis and modelling activities.

IPFN aims at continuing a strong participation in the collective use of the JET facilities by the EFDA Associates. With activities spanning from the immediate to the long term, IPFN will continue providing staff for the operation (JET Operation Contract), experimental campaigns (S/T Orders) and management (Close Support Unit) and will continue developing new hardware on microwave reflectometry and control and data acquisition.

The physics studies are focused on plasma rotation, edge plasma turbulence, MHD and transport.

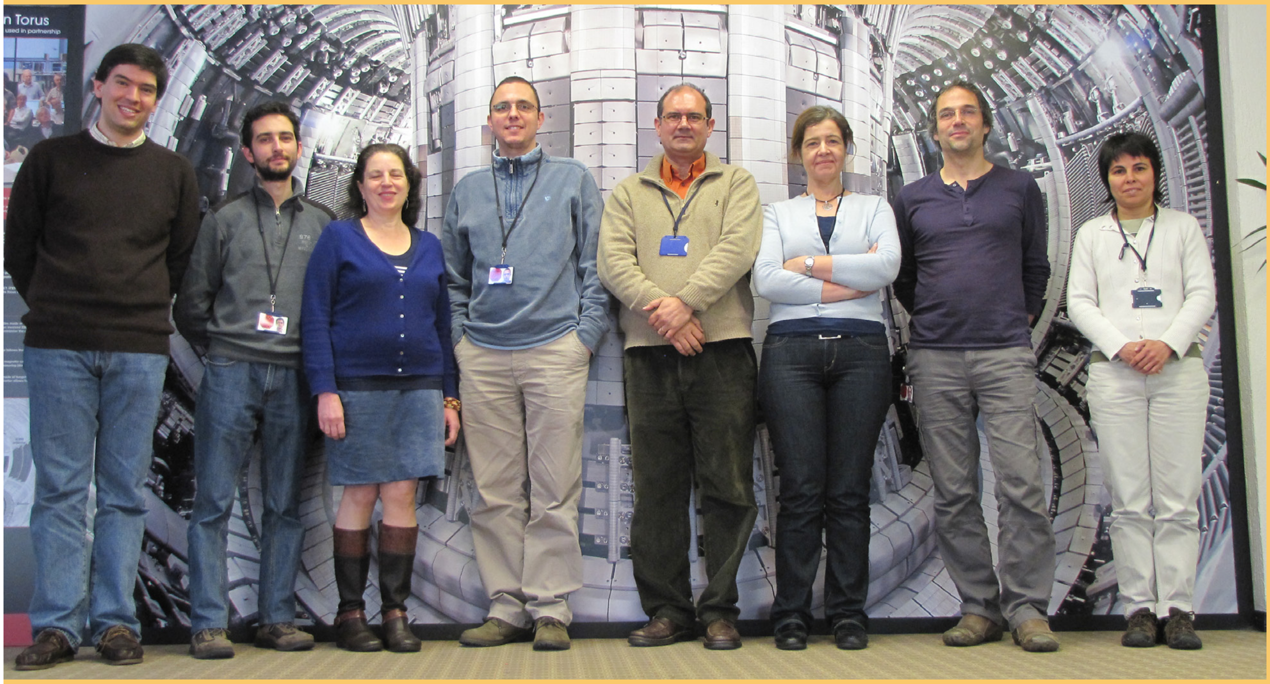


IST, through IPFN, has the 6th highest participation in JET 2011-2012 campaigns.

As a joint venture, JET is collectively used by more than 40 laboratories of EURATOM Associations.

Highlights

- 6th highest participation in JET 2011-2012 campaigns.
- Strong participation in JET operation. IPFN provided three Session Leaders, one Diagnostic Coordinator, four trainee Session Leaders, three researchers at JET operations group (under JOC) and one Person at CSU Operation department.
- Leadership in several JET enhancement projects: Microwave correlation reflectometry, Real-time measurement & control Diagnostics and Infrastructure and Data acquisition for Neutron Camera diagnostic & Gamma Ray Spectroscopy.



Portuguese team in JET.

ITER
International Thermonuclear Experimental Reactor

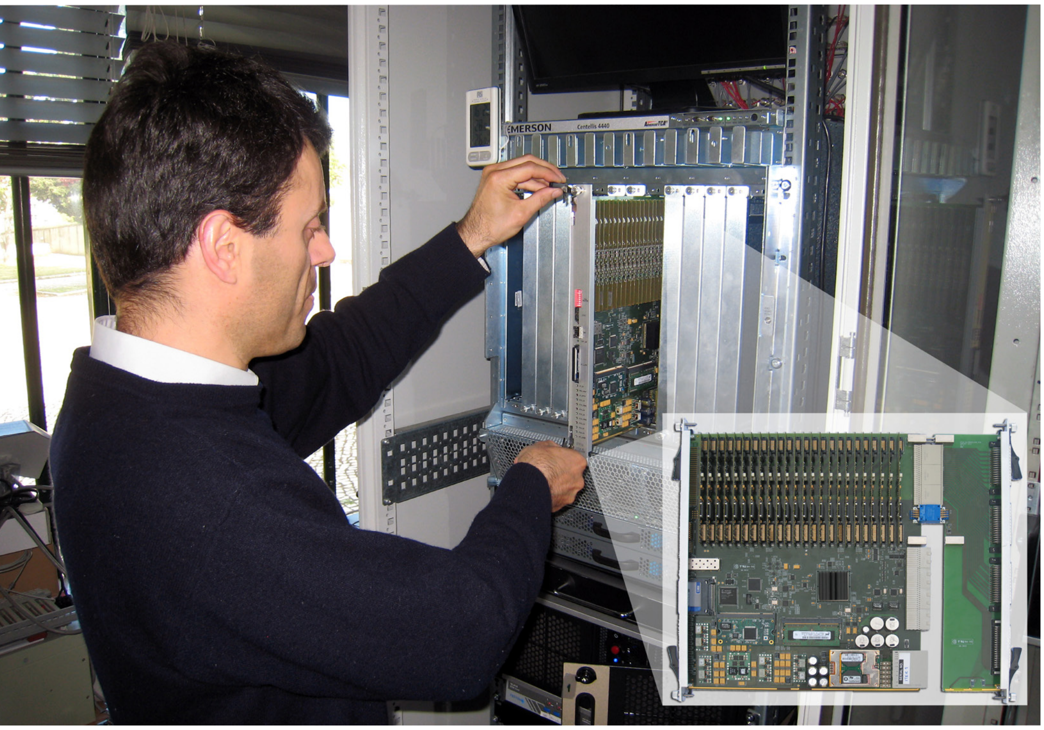
ITER is a large-scale international scientific experiment that aims to demonstrate the scientific and technical viability of producing commercial energy from fusion.

IPFN contributes to activities related to the construction of ITER and preparatory R&D activities leading to it. This programme also includes all the engineering activities towards diagnostic development and integration into different fusion machines.

The programme for the Portuguese participation in the ITER construction is focused on:

- Plasma Position Control based on microwave reflectometry,
- Remote Handling,
- Control and Data Acquisition for long-time operation of fusion experiments and R&D on high-availability and high-reliability.

These activities are carried out through the European Joint Undertaking for ITER and the Development of Fusion Energy (F4E) calls for participation or through International calls issued by the ITER International Organisation.



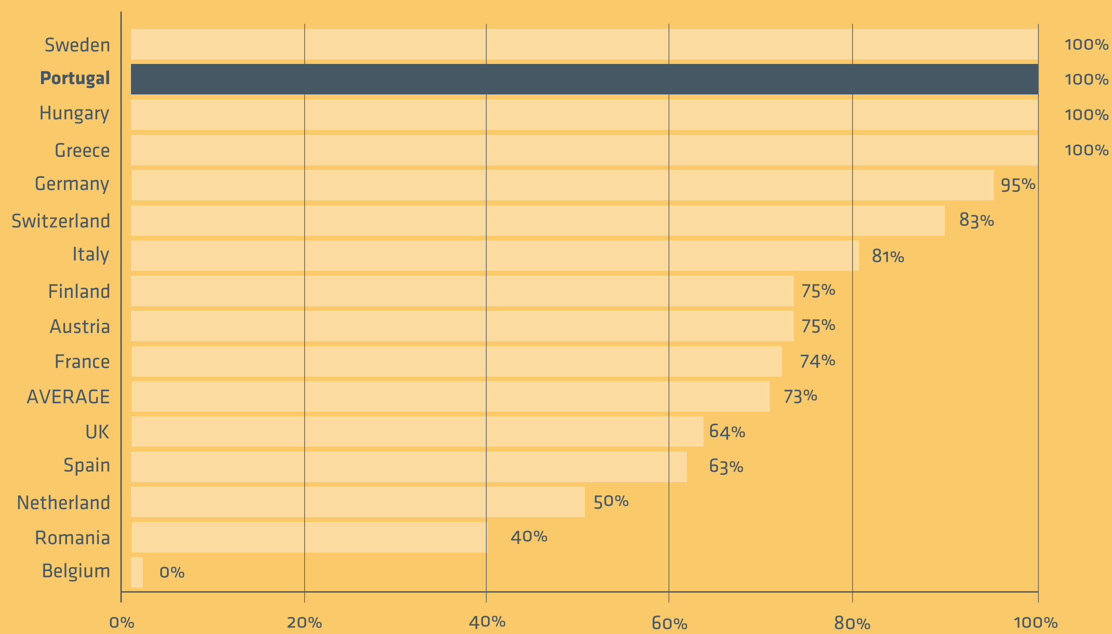
The ITER Fast Plant System Controller fostered development of state-of-art control and data acquisition cards based on ATCA..

IPFN contributes to activities related to the construction of ITER and preparatory R&D activities leading to it.

Highlights

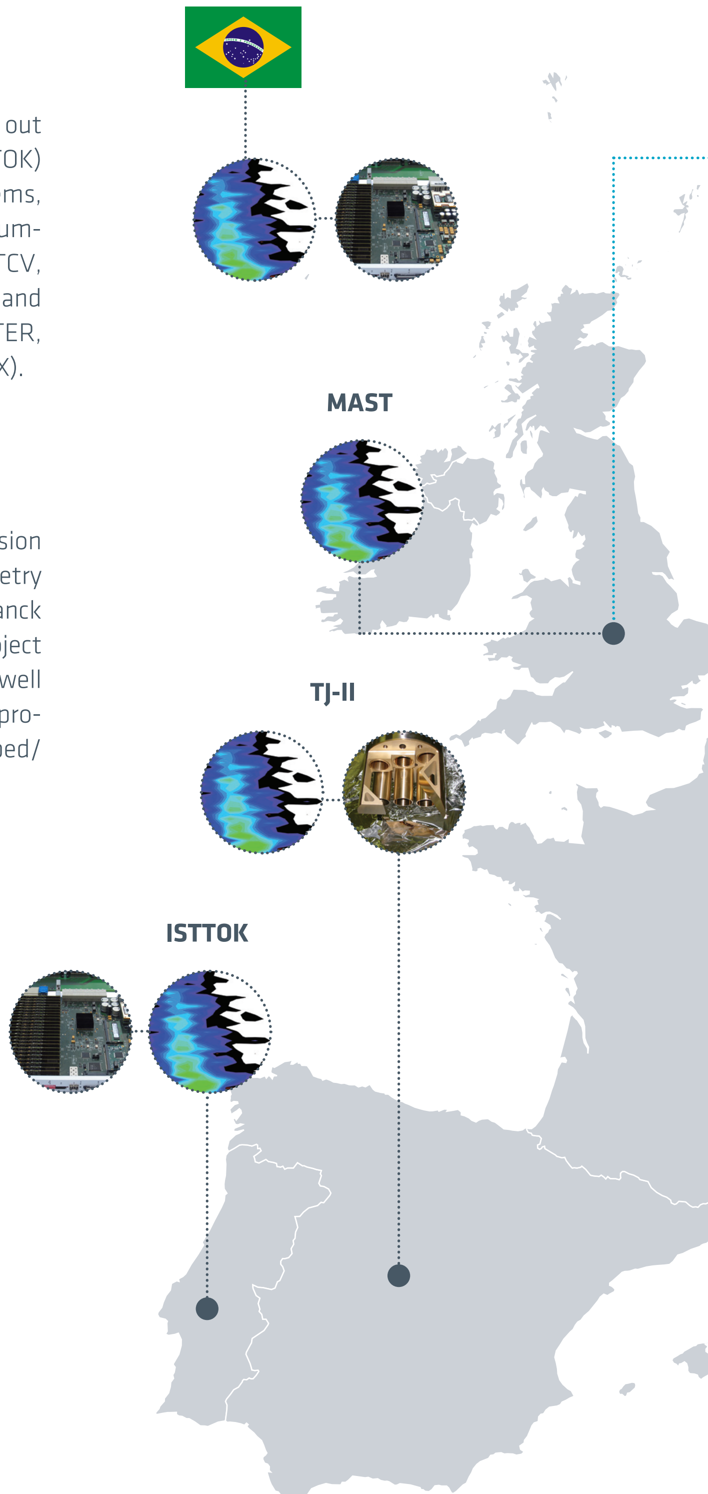
- Signature of a new contract with ITER International Organisation for continuing the development of a fast plant system controller based on Advanced Telecommunications Computing Architecture (ATCA) using data acquisition and control cards developed at IPFN,
- Member of the winning consortium, led by INDRA, for supplying engineering services to F4E in the area of systems, instrumentation, control and data acquisition.

SUCCESS RATE IN GRANTS
No.of awards/ No.of answers



IPFN has had a 100% success rate in F4E grant applications.

Other
Fusion Facilities

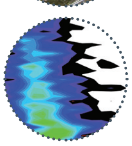


The IPFN work programme includes activities carried out in Portugal (mainly related with the tokamak ISTTOK) and abroad, associated with the development of systems, operation, scientific exploitation of large and medium-sized tokamaks and stellarator (JET, ASDEX-Upgrade, TCV, COMPASS, MAST and TJ-II) as well as with the design and construction of the next generation fusion devices (ITER, ASDEX-Upgrade, TCV, COMPASS, MAST, TJ-II, and W7-X).

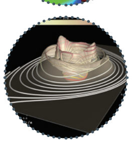
Highlights

- First time demonstration that position control of a fusion plasma can be performed using microwave reflectometry signals at ASDEX Upgrade (AUG) tokamak (Max Planck Institut für Plasma Physik-IPP, Germany), on a project lead by IPFN. The reflectometry diagnostic at AUG as well as its dedicated real time data acquisition and data processing (both hardware and software) were developed/operated by IPFN.

Microwave Diagnostics



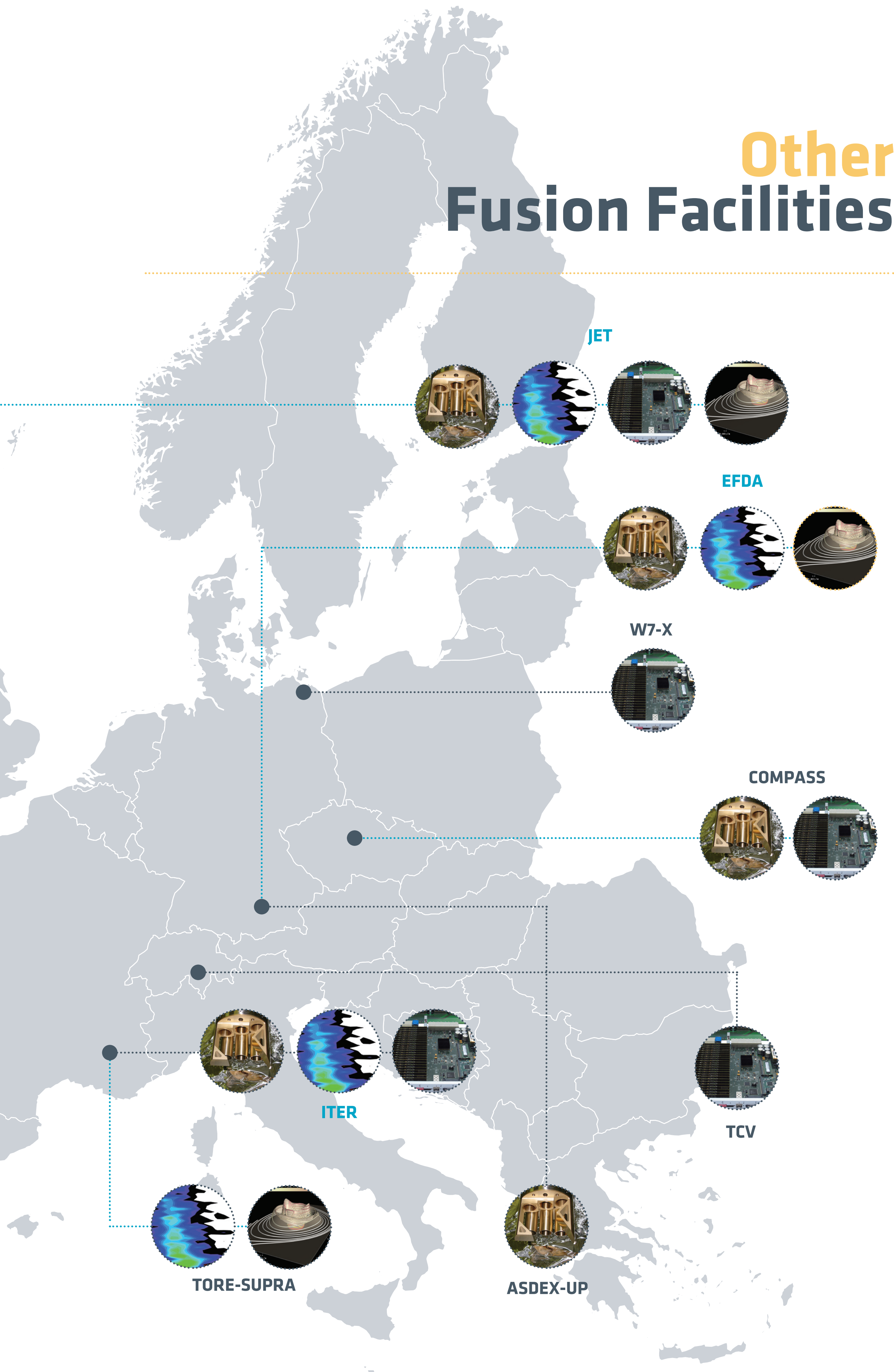
Experimental Physics



Theory & Modelling

Control & Data Acquisition

Other Fusion Facilities

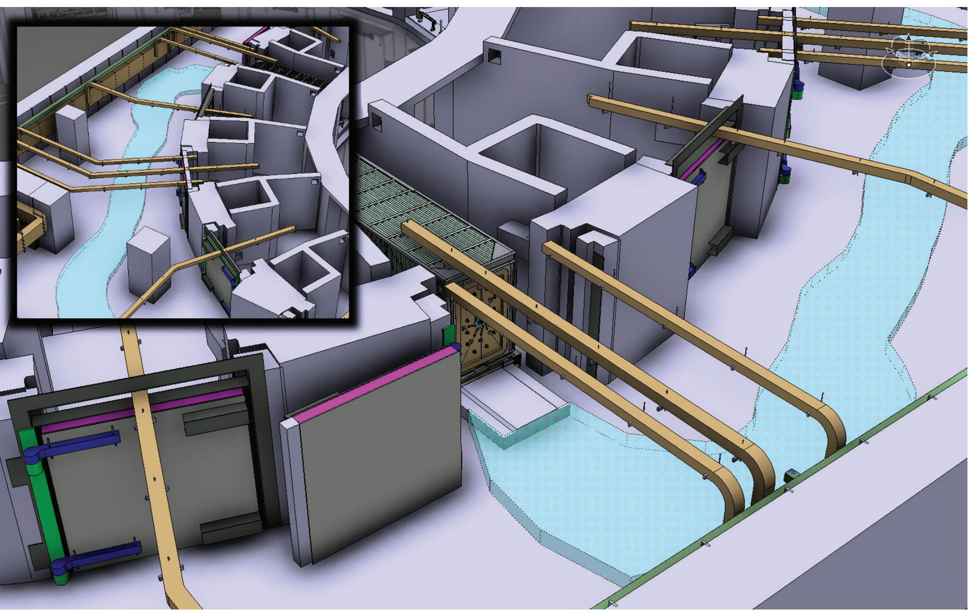


DEMO

The demonstration of fusion-driven electricity production by 2050 is the ambitious goal set for the European Fusion Programme. By building on the successful construction and operation of ITER it is required to consolidate and integrate further advances in physics and technology into the design of a fusion power Demonstration Reactor (DEMO) that must be ready for construction around the beginning of 2030.

Highlights

- Participation on the Implementing Agreement for Power Plant Physics and Technology.
- Leadership of the Socio-Economic Research on Fusion (SERF) activity with an emphasis on preparing the wider energy community to include fusion energy in its long term planning and to understand the social and economic implications.



Remote Handling operations of Cask Transfer System (CTS) disassembling in ITER. The remote handling experience gathered in ITER is essential for the success of DEMO operation.

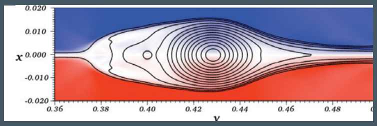
Computational Facilities

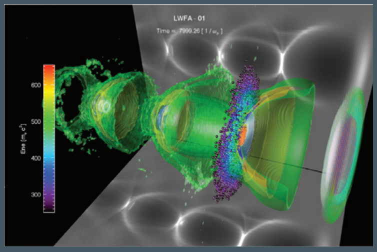
IPFN research makes extensive use of large-scale computing facilities for running massively parallel numerical simulations. In 2011 the Controlled Nuclear Fusion Group was awarded 20 million core hours on Jügene (the largest supercomputer in Europe) under a PRACE award, 20 million core hours in Shaheen (KAUST, Saudi Arabia), the largest and most powerful computer in the Middle East (ranked #53 in the world late 2011) and also 300 thousand core hours on HPC-FF (Jülich). IPFN has also started the work to secure its participation in the scientific exploitation of the HELIOS HPC system (composed of 4410 nodes with a peak performance of 1.52 petaflop and available memory of 256 TB) at the IFERC Research Centre, with proposals on MHD and plasma turbulence.

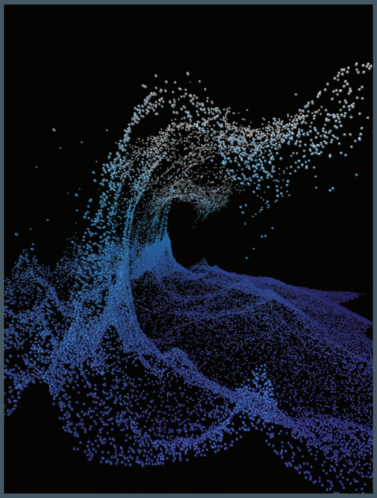
The Group for Lasers and Plasmas was awarded more than 30 million core hours to run on Jügene under a PRACE award and 10 million core hours to run on the #1 supercomputer in the US, Jaguar, under the AOSCR Joule metric initiative in a collaboration with UCLA (USA).

Highlights

- Beyond Sweet-Parker reconnection: characterisation of the magnetic reconnection in plasmoid-dominated current sheet configurations.
- Pushing the limits of particle-in-cell simulations to the petascale realm with the demonstration of Osiris performance in production runs of 0.74 petaflop.
- Exploring the properties of electrostatic and electromagnetic shocks and identifying the conditions that can give rise to monoenergetic beams from electrostatic shocks, and the associated instabilities (Kelvin-Helmholtz and Weibel).





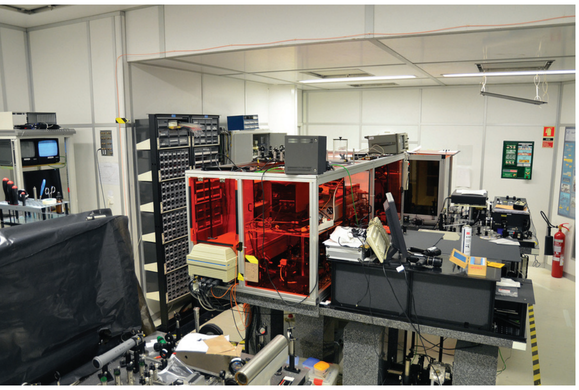


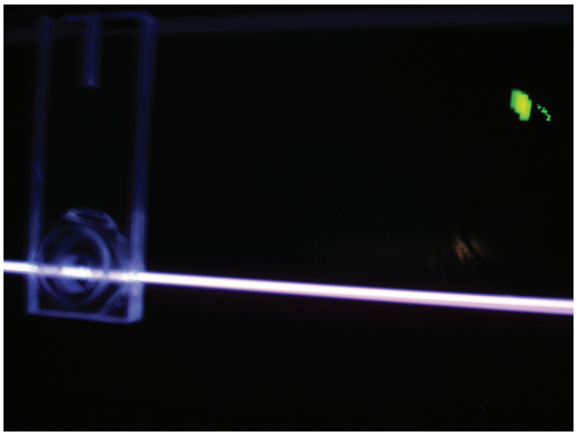
(Top) Coalescing predator-prey plasmoids at high Lundquist numbers. Lines of constant magnetic flux are also shown.

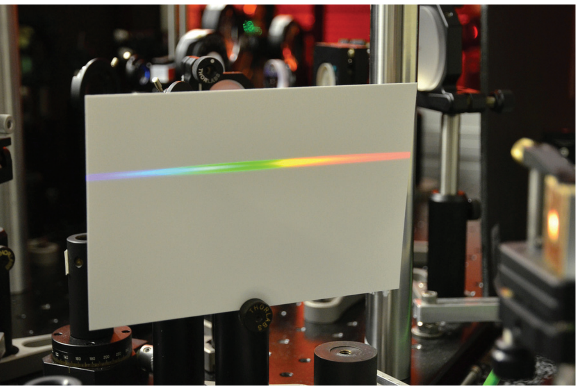
(Middle) Electron density (isosurfaces) and energy of a sample of electrons (spheres) in a laser wakefield accelerator, showing the structure of multiple buckets. On the right hand side, the laser electric field isosurfaces are also represented (blue and red).

(Bottom) Phase space of the ions in an electrostatic collisionless shock (the color and the vertical position of the spheres denotes the energy of the ions).

L2I
Laboratory for Intense Lasers







The Laboratory for Intense Lasers (L2I) is a research facility located at the main IST campus and operated by IPFN researchers. It hosts a 15 TW CPA-type laser system based on Ti:sapphire / Nd:glass, operating at 1053 nm. The target area is equipped with optical, IR, VUV, X-ray, and particle diagnostics. The main research areas are plasma sources, plasma channels, high harmonic generation, diode-pumped lasers and optical parametric amplification. L2I also plays an important role in the advanced training of young researchers and technological development.

Highlights

- Progress in the design of advanced plasma channels, through the development of the technology for a new high-power pulse generator for production of plasma channels and the design of a long plasma source for plasma-wakefield accelerators.
- Demonstration of the suitability of using white light continuum generation in bulk media using 250 fs, 1 mJ, 1053 nm pulses for seeding ultra-broadband parametric amplifiers by characterising the broadened spectrum using a cross-correlation frequency resolved optical gating (XFROG) diagnostic.
- Development and demonstration of a high dynamic range contrast measurement diagnostic based on optical parametric amplification correlation.
- Development of new designs for structured gas cells that have been successfully used in high harmonic generation experiments.

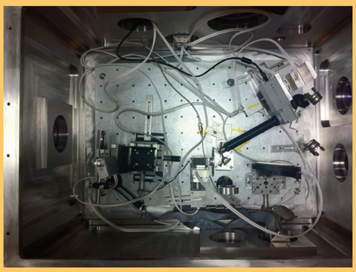
(Top) Laboratory for Intense Lasers: View of laser system.
(Middle) Partial view of 3 meter long argon plasma.
(Bottom) White light continuum in the visible generated by focusing 250 femtosecond pulses in sapphire.

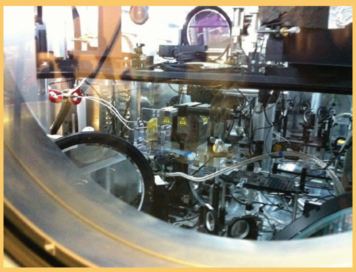
European Large-Scale Laser Facilities

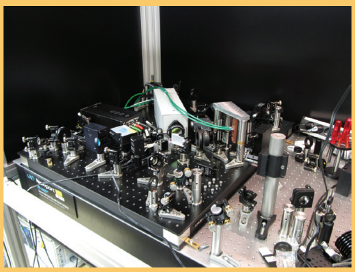
IPFN researchers from the Group of Lasers and Plasmas perform a number of experiments every year at European laser facilities, such as the Astra Gemini laser at the Rutherford Appleton Laboratory (RAL, UK) or the short pulse lasers at the Laboratoire d'Optique Appliquée (LOA, France). Their participation is typically integrated in international laser teams, either as PI's or collaborators. On a number of occasions, these experiments are carried out under the Access Program of the Laserlab-Europe programme.

Highlights

- Electron acceleration experiment at the Astra-Gemini laser facility, RAL. The experiment was proposed by IPFN in collaboration with Imperial College (UK) and RAL. Plasma channels up to 4 cm long and produced by high-voltage discharges in structured gas cells (developed at IST) were used with 10 J laser beams to produce electron bunches beyond 1 GeV.
- Demonstration of a gamma-ray source based on bremsstrahlung radiation from laser-plasma accelerated electrons at the Astra Gemini laser (collaboration with the University of Strathclyde, UK).
- Participation in the development of a 10 mJ, 1 ps diode-pumped Yb:KGW amplifier for the new OPA-based, high contrast front-end of the PHELIX petawatt laser at GSI Darmstadt (collaboration with IOQ-FSU Jena and GSI Darmstadt).
- Participation in an experiment using the LCLS (Linac Coherent Light Source) at SLAC (USA) to produce high-density plasma states, probed using an infrared laser synchronised with the x-ray laser pump. IPFN researchers were among the first users of this facility – the world' first X-ray laser, providing up to 3 mJ of sub-10 Å laser light in under 100 fs. These studies were completed at LOA by irradiating thin foil targets with comparable intensities in the infrared, and probing them with coherent XUV radiation.







(Left) View of inside of LOA target chamber, thin foil irradiation experiments.
(Center) View of inside of target chamber at Astra Gemini electron acceleration experiment.
(Right) Diode pumped 10 mJ Yb:KGW laser amplifier for the PHELIX laser front-end.

PEL
Plasma Engineering Laboratory

The facilities at PEL include various microwave plasma sources and diagnostic equipment for:

- Visible emission and absorption spectroscopy (atomic and molecular)
- Ultraviolet and extreme ultraviolet spectroscopy
- Fourier-Transform infrared spectroscopy
- Laser diagnostics (TALIF, photodetachment)
- Mass spectrometry
- Electrical diagnostics

Present research focuses on:

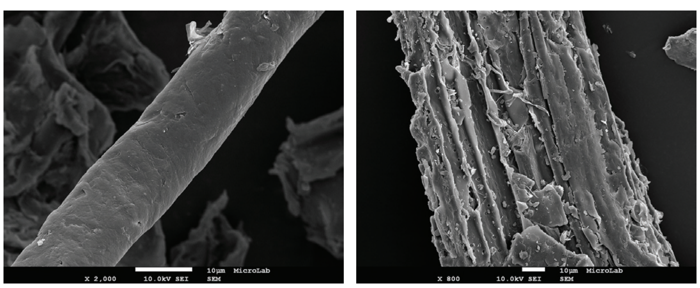
- Plasma production of nanoscale materials (e.g., graphene, carbon nanotubes), as key enablers of the nanotechnology revolution
- Plasma technologies for renewable energy sources (e.g., production of hydrogen from alcohols) and environmental improvements (e.g., NOx, CFCs, VOCs and fly ash decomposition, bacteria inactivation)
- Plasma sources for biomedical applications (e.g., wound healing, blood coagulation, treatment of living tissues, killing of bacteria and cancer cells, sterilisation, etc.)

The experimental work is paralleled by modelling of plasma kinetics, wave electrodynamics, wave-plasma coupling and surface kinetics, for interpretation of the measurements.

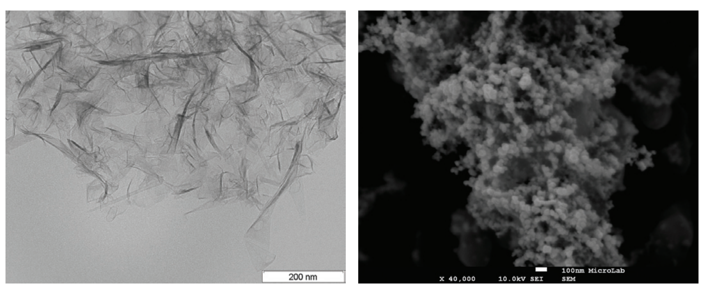
Highlights

- A surface wave (2.45 GHz) atmospheric air-water plasma source was proven to be an effective source of O(3P) and NO species and NO (γ) radiation (UV), for applications in plasma therapy and sterilisation processes.
- Efficient microwave plasma reforming of alcohols for the production of H_2.
- Use of atmospheric microwave plasma torches at 2.45 GHz in Ar-steam and Ar-air for sugarcane pretreatment to produce cellulosic bioethanol.
- A microwave atmospheric plasma torch in Ar was used to create carbon nanomaterials (graphene, nanoparticles) with ethanol and methanol as liquid precursors.
- Investigation of EUV emissions from He and H_2 microwave plasmas at 0.1 – 2 mbar vs. pressure and power. The 30.4 nm line of He II, the Lyman α and β lines of H and the H_2 Werner and Lyman bands were measured and their spectra compared with simulated ones.
- Development of a portable surface wave Ar plasma source at 2.45 GHz, which creates dense plasmas in continuous and pulsed regimes, for environmental and industrial applications.

SEM images of untreated and plasma pre-treated sugar cane biomass.



Nanoscale graphene sheets and carbon particles.



ESTHER
European Shock Tube for High Enthalpy Research

The ESTHER two-stage Shock-Tube, a facility specifically designed for supporting European planetary exploration and Earth return missions, is developed by an international consortium, under funding from the European Space Agency.

The facility is capable of reproducing the conditions of a spacecraft entry in a planetary atmosphere, allowing validation of the vehicle design, and namely of its thermal protections.

The ESTHER Shock-Tube is a world-class high-performance facility, capable of reaching shock speeds in excess of 10 km/s. The facility deploys a large array of state-of-the-art optical diagnostics, including optical emission and absorption spectroscopy, laser spectroscopy, and microwave interferometry. These diagnostics encompass a large spectral range, from the vacuum-ultraviolet to the Infrared regions, and will allow achieving a better understanding on the elementary energy exchange processes taking place in such high-temperature, nonequilibrium plasmas.

ESTHER is managed by IPFN, and is located on the campus of Loures, in the outskirts of Lisbon, Portugal.

Facility Specifications

- Length: 16 m
- Test-section diameter: 80 mm
- Shock Velocities: 4-12+ km/s
- Pre-shock pressures: 0.1-100+ mbar
- Planetary compositions: Air (Earth), CO_2-N_2 (Venus, Mars), N_2-CH_4 (Titan)

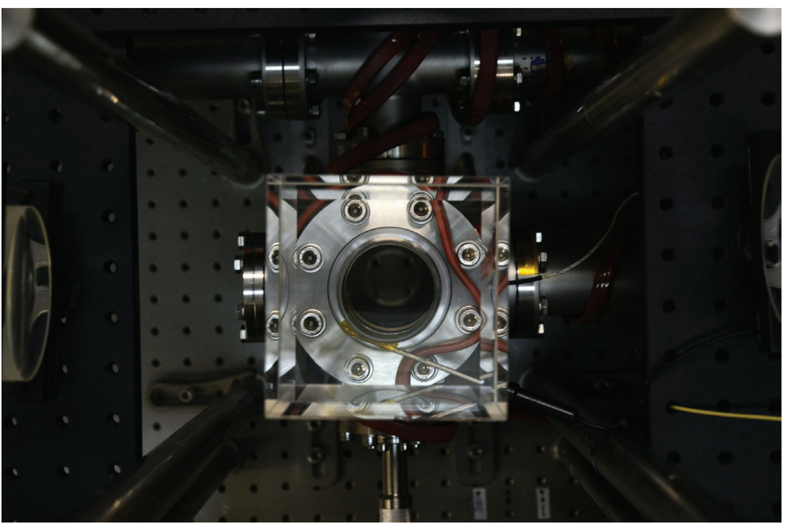
For more information please check:

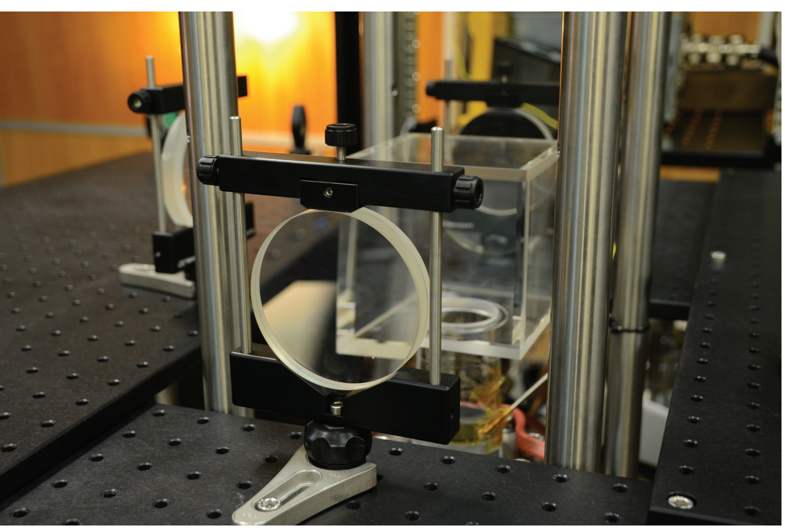
http://esther.ist.utl.pt

ESTHER Facility located on the campus of Loures.

MotLab
Laboratory for Ultra-Cold Atoms and Quantum Plasmas

The Laboratory for Ultra-Cold Atoms and Quantum Plasmas (MotLab) is a research facility located at the main IST campus, and operated by IPFN researchers. It hosts a large magneto-optical trap, capable of confining rubidium atoms at room temperature in a cubic quartz cell, and cooling them down to a temperature of 100 micro-Kelvin through a system of three counter-propagating pairs of laser beams operating in CW mode at 780 nm. The system is equipped with confining magnetic coils and optical diagnostics. The main research areas are ultra-cold atoms, collective atom-atom interactions, and Rydberg ultra-cold plasmas. MotLab intends to play an important role in the advanced training of young researchers and technological development at IST.





Highlights

- Installation and testing of the main parts of the experimental setup, including the optical delivery system, the pumping system and the control and data acquisition system.
- Plan of an experiment on “photon bubbles”, which is predicted to occur for the experimental conditions of the MotLab. The proposed experimental setup was originally conceived by MotLab researchers, in collaboration with the University of Nice (France), and will be carried out in a near future. This is very important in the context of ultra-cold atom systems and is particularly relevant to astrophysics.

(Top) Top view of the glass vacuum chamber in whose center the cluster of ultra-cold rubidium atoms is created.
(Bottom) Lateral view of the glass vacuum chamber and the set of lenses used for focusing the six lasers beams.

Space **Facilities**

Research in fundamental physics in space is devoted to the study of new ideas to understand and interpret the Universe. These include the study of new extensions of quantum mechanics and their impact on laboratory experiments and extreme situations such as black holes. Other topics include extensions to General Relativity, the modelling of the anomalous acceleration of the Pioneer spacecraft and flyby anomalies, and the design of new space missions to better understand the law of gravity.

In 2011, the Group for Fundamental Physics in Space has achieved some relevant results highlighting its broad spectrum of activity:

Highlights

Determination of scientific objectives and design of space missions:

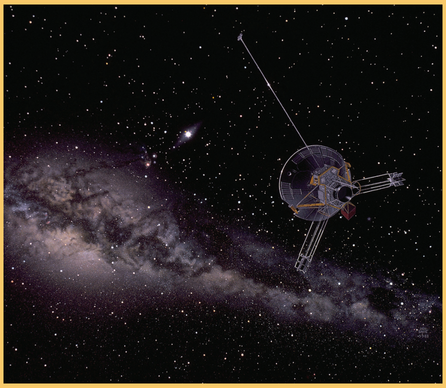
- Contribution to OSS (Outer Solar System) and GAME (Gravitation Astrometric Measurement Experiment), focusing on tests of General Relativity.
- Probing General Relativity and extensions using the Galileo navigation satellite system.
- Proposal to ESA of a small mission with a multi-GNSS receiver to test the flyby anomaly (ongoing).

Thermal analysis of spacecraft

- Joint work with the Secção de Mecânica Aeroespacial of IST.
- Refinement of fully analytical methodology to scrutinise thermal effects.
- Inclusion of reflections via Phong shading.
- Application to the Pioneer anomaly: accounting for reflections, thermal effects explain the bulk of this anomalous acceleration.

Extensions of General Relativity

- Non-minimally coupled f(R) models: and applications. e.g. viable descriptions of dark matter and inflationary reheating.
- Phase Space Non-commutative Geometry: black hole physics and implications at astrophysical scales, relation with Entropic Gravity.
- Alternative models for interacting Dark Energy and Dark Matter.



(Left)
A barred spiral galaxy.
(Right)
Artist's view of Pioneer spacecraft.

Outreach

IPFN is strongly committed to taking an active role in the communication of science and the dissemination of its scientific and technological achievements to the society. Our outreach activities are targeted at a broad range of audiences: from undergraduate students to secondary school students and teachers, from industry representatives to the media.

Both through the Image and Public Communication team and through individual efforts from IPFN researchers, the scope of initiatives is very lively and diversified. In developing these activities, IPFN collaborates with its international Association partners through the EFDA Public Information Group, and at a national level with the Council of Associated Laboratories and the "Ciência Viva" agency.

Highlights

- Hosting more than 80 visits of high-school students to the ISTTOK laboratory and the Laboratory for Intense Lasers.
- Organisation of a 5-day workshop in nuclear fusion for secondary school teachers, including a visit to JET in Culham.
- Talks in high schools about "Nuclear energy: present and future" and to visiting schools during the "Physics Week" at IST.
- Participation in the "UTL in the Summer" training activity, in the field of renewable energies (solar tracking devices).
- More than 10 press-releases about IPFN research results and events, leading to a large number of interviews in national newspapers, magazines and national radio and television and a number of reports in international media.
- Tito's Fest: celebrating the 65th birthday of Prof. Tito Mendonça – Prof. Mendonça, who played a key role in the establishment of the Euratom/IST Contract of Association, is a plasma physicist who has had a remarkably productive 40-year career in science. We organised a special one-day meeting for a general audience with talks by his most prominent collaborators over the years followed by a lively dinner.

(Left) High school students visiting the Laboratory for Intense Lasers.
(Right) Workshop on Nuclear Fusion: high school teachers visit JET in Culham.

Scientific Output

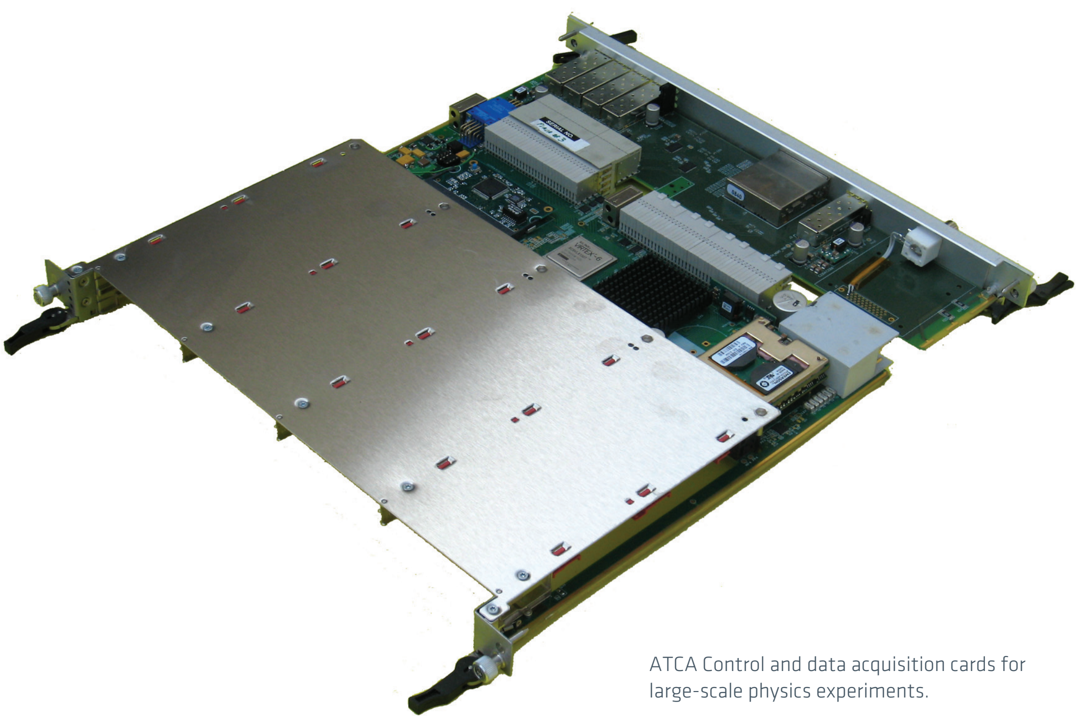
	B	PIJ	PCP	Oral Cont.	Posters	Patents	IR	TR	Lab.P	CNC	MSc Thesis	PhD Thesis	Prizes
Controlled Nuclear Fusion													
Experimental Physics	1	32	19	11	12	2	0	4	5	1	3	0	1
Microwave Diagnostics	0	18	10	10	4	0	8	0	0	0	0	0	0
Theory and Modelling	0	33	19	2	6	0	1	2	0	1	0	0	0
Control and Data Aquisition	0	22	14	10	7	0	2	2	3	12	0	2	0
Sub-Total	**1**	**105**	**62**	**33**	**29**	**2**	**11**	**8**	**8**	**14**	**3**	**2**	**1**
Intense Lasers and Plasma Technologies													
Lasers and Plasmas	0	19	55	37	40	0	0	0	3	7	4	2	9
Gas Discharges and Gaseous Electronics	0	13	32	8	18	0	0	1	7	13	3	0	0
Quantum Plasmas	0	14	4	1	0	0	0	2	0	0	0	1	0
Fundamental Physics in Space	0	12	2	3	0	0	0	0	0	0	0	0	1
Sub-Total	**0**	**58**	**93**	**46**	**58**	**0**	**0**	**3**	**10**	**20**	**7**	**3**	**10**
TOTAL	**1**	**163**	**155**	**82**	**87**	**2**	**11**	**11**	**18**	**34**	**10**	**5**	**11**

B – Books
PIJ – Papers in International Journals
PCP – Papers in Conference Proceedings
IR – International Reports
TR – Technical Reports
Lab. P – Laboratorial Prototypes
CNC – Computational and Numerical Codes

Transfer of Technology

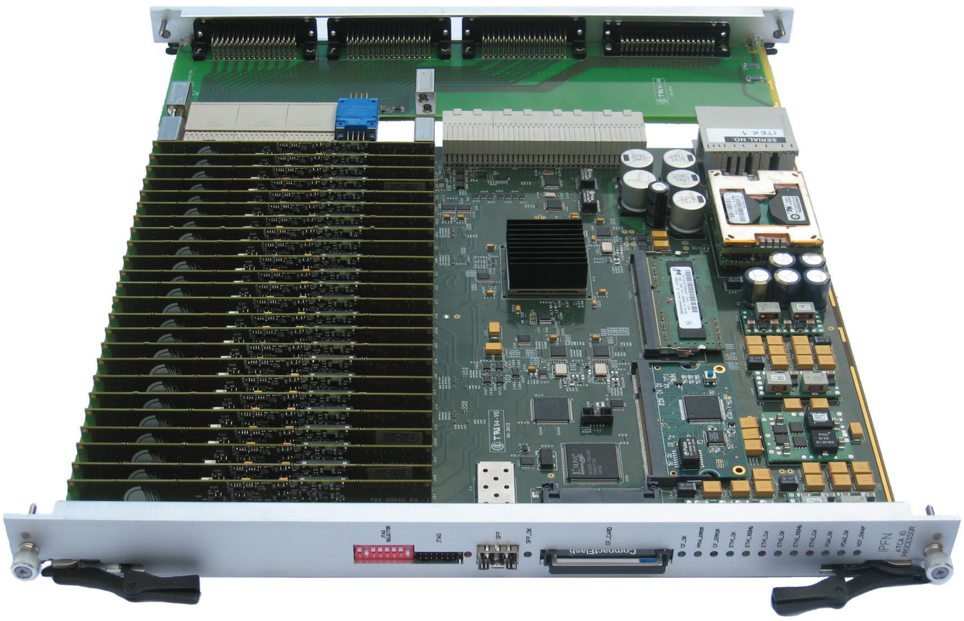
IPFN has been actively working to enhance the contribution of R&D activities to society. The main thrust of these activities is focused on improving the links to industry and, in particular, creating industrial partnerships for the participation in ITER construction. Recognising the importance of the involvement of industry in this challenging R&D project, IPFN has been approaching companies in order to promote the participation of the Portuguese industry and to participate in joint contracts for the construction of the device.

IPFN has also been improving its competitiveness by enhancing its intellectual property return through patents, transfer of technology and licensing to industry.



ATCA Control and data acquisition cards for large-scale physics experiments.

Transfer of Technology



ATCA Control and data acquisition cards for large-scale physics experiments suitable for Multiple-Input-Multiple-Output applications .

Highlights

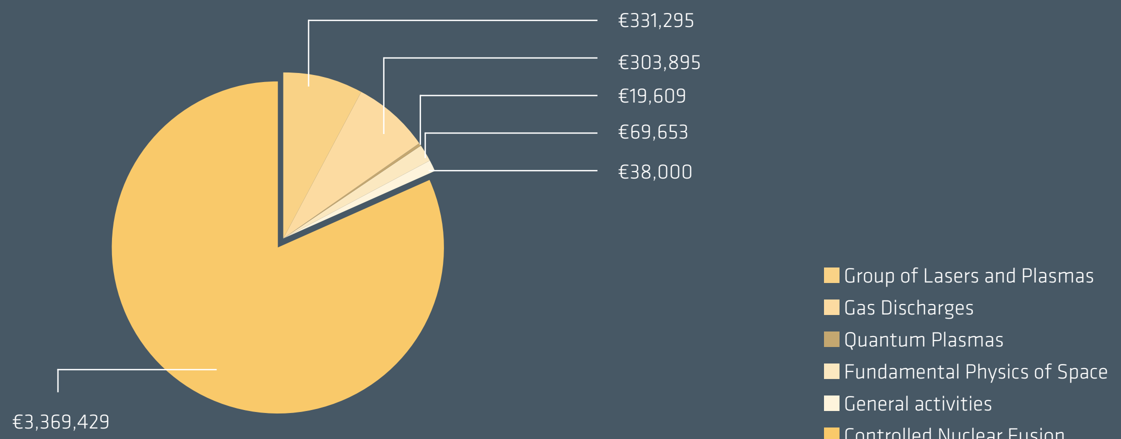
- One Portuguese company (INOV) partnered with IPFN on the contract for the development of ITER Fast Plant System Controller.
- Throughout the year several meetings were held with representatives of Portuguese companies to explain the ITER project, business opportunities and partnership for joint participation in ITER contracts.
- Several discussions were held with industry towards the co-development and commercialis ation of ATCA control and data acquisition systems developed at IPFN.
- Patent of a low profile solar tracker system and a nenatometer with laser range for infant length measure.

IPFN in Numbers

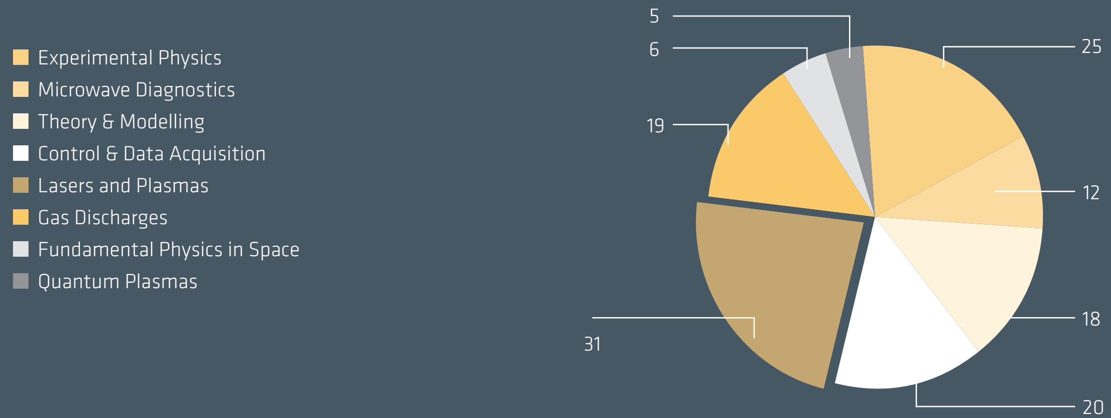
Staff

- IPFN had a total of 170 people on December 31st 2011.
- More than half of these members have a PhD degree .

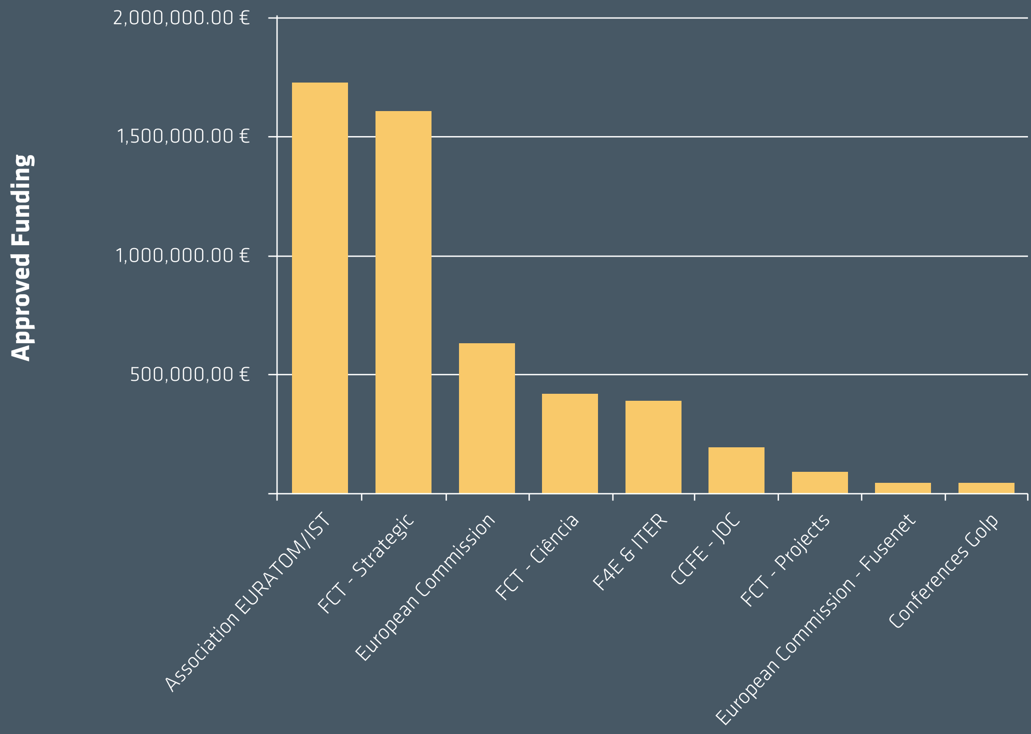
Distribution of budget per groups

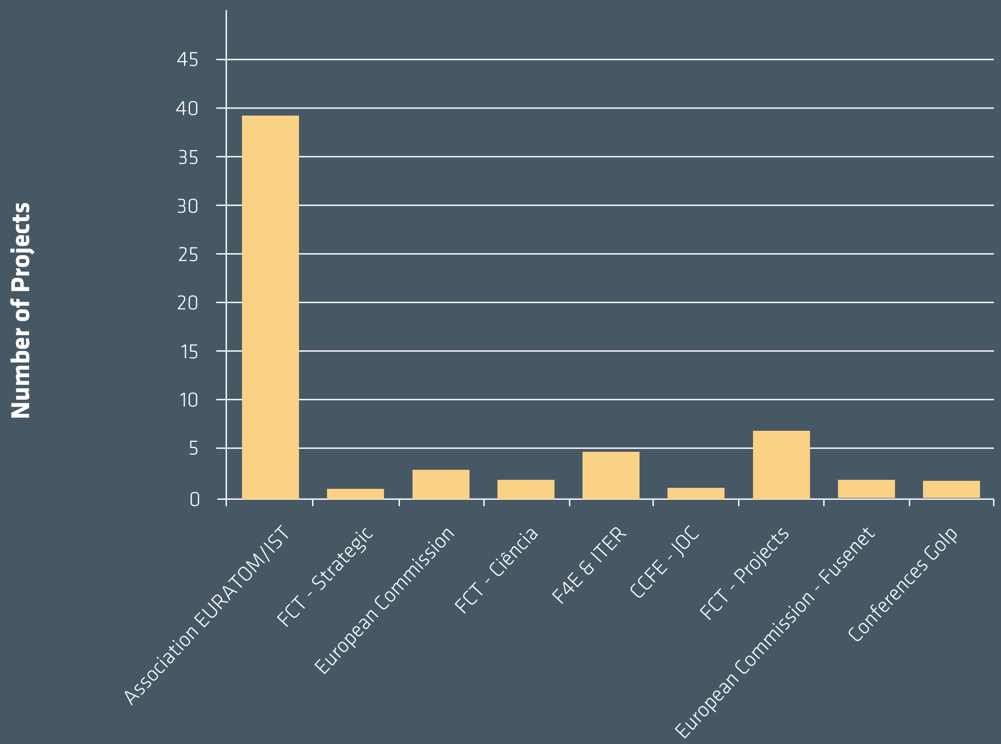


Distribution of researchers by group



IPFN in Numbers





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IPFN Annual Report 2011

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