Gianfranco, you have been appointed leader of the new EFDA department for Power Plant Physics and Technology (PPP&T). For those of us who are used to the term 'power plant' in reference to DEMO, could you explain how the department is linked to DEMO?

My understanding is that PPP&T, or 3PT, as we tend to call it, will be looking at post-ITER-class fusion devices, i.e., those that enable fusion to be converted from the domain of experimentation and research into demonstrating fusion power production in possible future commercial exploitation. The emphasis of 3PT should be placed on the definition of a conceptual design for a Demonstration Power Fusion Reactor (DEMO).

Continued on page 2.
What are the objectives of 3PT?

As I said the main aim is to develop a DEMO conceptual design, a task which should be completed in about five years time, assuming adequate resources are made available. This includes the selection of the machine concept, the design parameters and modes of operation, as well as the preliminary design and the integration of its main components. We should also identify and coordinate the R&D activities necessary to validate the assumptions underlying the concept and estimate the costs and time needed to build this device. The significant physics-related questions to be addressed are, for example, the divertor power exhaust, which I consider to be one of the most crucial reactor-related problems to be solved, the definition of a reliable mode of operation, the need to guarantee plasma performance at high density, and the avoidance and mitigation of disruptions and ELMs, which can damage the in-vessel components. The most important technology-related problems to be solved include the qualification of resilient materials for in-vessel components, the development of sound technological solutions for the divertor and of optimised remote maintenance schemes for high machine availability, the achievement of adequate thermal efficiency and tritium breeding, and the reliability and efficiency of heating and current drive systems.

It must be recognised that some of these issues are quite daunting and we need to be innovative but realistic. In this respect, I welcome an element of early involvement of industry with its culture of ‘design for buildability, operability, reliability and maintainability’.

Even though the tokamak is undeniably the most mature concept today, I would say that, at this stage, and in the absence of a ‘clear winner’, we need to work without preconceptions and not discount studies of alternative concepts such as stellarators or spherical tokamaks. While we expect that the operation of ITER will provide all the necessary knowledge needed to control the plasma and its power in a more powerful demonstration reactor, the fact is this remains a hope. This is why I believe that at this stage we should not turn our backs on any opportunity and try to keep, at least at the beginning, more than one door open.

When will the department start operating, how much manpower will it have and where will it be located?

I was appointed at the end of October and I expect to work on this full-time by the beginning of next year, knowing that, for the first two years especially resources will be rather limited. We will have to maximise synergies and collaborations among the different institutions involved. I intend to establish a core team at EFDA CSU Garching, along with distributed design teams in a small number of dedicated Associations. This should somewhat resemble the ITER EDA work methodology, which has proved to be an efficient and successful setup. Once set up, the core group in Garching will lead the overall machine design and physics integration and supervise and manage all design and R&D activities. The ‘co-centres’ will focus on specific component design and R&D, assist design integration work conducted in Garching and provide primary support in areas where specific expertise exists.

In which fields will 3PT coordinate the activities of the Associations?

I believe that there is an urgent need to reorient the non-ITER part of the Fusion Program in Europe and to establish a sustained and reciprocal commitment of the European Commission and EFDA Associates with the shared aim of developing the necessary knowledge for the design, construction and operation of a demonstration fusion power plant. This requires strong competences in various physics and technology fields and EFDA, representing the combined expertise of the European Associations, would provide the ideal framework for this project. The current concept, as proposed by the EFDA Leader, that I fully support, would create an EFDA Implementing Agreement on 3PT, where participating Associations and the Commission are willing to allocate resources at a predefined minimum commitment level from the very beginning.

If set up in the way planned, the 3PT Agreement would embody the original spirit of EFDA well. A spirit oriented
Looking at your experience in fusion engineering – where would you say European fusion research stands with respect to a Demonstration Fusion Power Reactor concept?

Europe still retains a leading position in fusion, but in order to consolidate a credible fusion road map for the realisation of commercial fusion power, our ability to build a technically sound and economically viable demonstration fusion power reactor must be confirmed. Considering the time required to carry out the conceptual studies and subsequent R&D, the road to fusion power will be hindered, if the activities for DEMO do not start now. In ITER, for example, the conceptual design phase lasted for about 5 years, excluding the previous important work done in Europe on NET, and was followed by an engineering design phase in excess of ten years in length. In total about 20 years passed between the start of the conceptual study and the beginning of construction. Moreover, we need these studies to ensure early definition of the constraints on plasma operation and machine configurations e.g., plasma facing materials to leverage plasma scenario developments on present devices and ITER.

The challenge of qualifying materials and components that withstand the harsh conditions expected in a reactor, i.e. high heat and neutron fluxes, also demands urgent investments to be made on the construction of fusion material irradiation facilities, for example IFMIF. Just as urgent is a decision regarding the possible role of a satellite tokamak designed for testing reactor-relevant divertor concepts. The same is to be said for the possible role of a component testing facility to accelerate the development/qualification of reactor-grade blankets and wall structures. Both these issues require proper feasibility studies.

Are you already in a position to set out your ideas for a workplan?

In line with the recommendations of the ad-hoc group on DEMO activities, the most urgent tasks to be conducted initially will be oriented towards assessing key issues in an actual design context and directing the associated necessary design and R&D activities. I am preparing, in collaboration with the EFDA Leader, a work programme that addresses a limited number of urgent priorities for the near future, keeping in mind that, at the time of this interview, I still do not know how many resources and what kind of implementing tools I will have available to me next year.

To be more specific, I plan to concentrate the initial efforts on a few critical areas. Firstly, the development of a system code for integrated design and development together with consolidation and revisiting of the physics knowledge basis achieved so far and required for the design of DEMO; secondly, the analysis of the power exhaust problem in a reactor and the development of consistent physics scenarios and sound technological solutions for the divertor and the first wall; and thirdly, starting the assessment of well known fusion reactor integration problems and associated R&D needs. Also, the compatibility between pulsed and steady-state designs should be investigated relatively soon.

EURATOM/IST Association celebrates 20th anniversary

On 6th October, the Contract of Association Euratom/IST celebrated its 20th anniversary in Lisbon, Portugal. This occasion, twenty years ago, marked the birth of formal nuclear fusion research in Portugal. The anniversary was attended by more than 200 people and consisted of a plenary session held at the Congress Centre of Instituto Superior Técnico. Manuel Heitor (Secretary of State for Science, Technology and Higher Education), António Cruz Serra (President of IST), Octavi Quintana Trias (Euratom Director) and Carlos Varandas (President of IPPN and Head of the Research Unit of the Association Euratom/IST) all delivered speeches regarding the history of the Association and its impact on the Portuguese and European research landscape. Prof. Varandas also marked the occasion by recalling the important role played by several personalities over the course of the last twenty years, and offered, as a symbolic gift, a book made specially to commemorate this event. Among the distinguished were Professors Tito Mendonça, first director of the Association, José Artur da Costa Cabral and Fernando Serra, former Heads of the Research Unit, Günther Hasinger, Director of IPP, Germany, and António Cruz Serra and Manuel Heitor.

Among the many guests were the Professors Sucena Paiva and Pedro Sampaio Nunes (former Secretaries of State of Science and Technology), Hardo Bruhns (former Head of the Associations Unit of the Euratom Directorate), Pablo Fernandez Ruez and Umberto Finzi (former Directors of the Euratom Fusion Programme), Francesco Romanelli (EFDA Leader), Roberto Andreani (former EFDA Associate Leader for Technology), Frank Briscoe (Director of Fusion for Energy) and Günther Hasinger (Chairman of the EFDA Steering Committee). The event was followed by an animated evening dinner bringing together all guests and many current and former collaborators of the Association.

Gonçalo Figueira and Carlos Varandas, IST
EFDA appoints new Task Force Leaders & Topical Group Chairs

During the meeting which took place in October in Lisbon, the EFDA Steering Committee appointed new Leaders and Chairs for most of the Task Forces and Topical Groups.

Here we introduce the new Chairs of the Diagnostics and Plasma Stability and Control Topical Groups. The next issue will discuss the Chairs and Leaders of the Transport Topical Group and the Plasma Wall and Integrated Tokamak Modelling Task Forces.

Plasma Stability and Control (MHD) Topical Group

Chair

Piero Martin is professor at the Physics Department of the Padova University, Italy, and head of the science program of the European Reversed Field Pinch (RFP) experiment RFX. He presently serves as Chair of the EFDA Topical Group on “Plasma Stability and Control”, and of the Executive Committee of the IEA Implementing Agreement on RFP research. He is a member of the EU delegation in the ITPA Agreement on RFP research. He is a member of the EU delegation in the ITPA Agreement on RFP research.

Piero Martin is member of the “International Liaison Committee” of the “Center for Magnetic Self-Organization”, a frontier physics center founded by the US National Science Foundation. He serves in the coordinating committees of the EURATOM Bilateral Cooperation Agreement between FZJ FOM, The Netherlands, and ERM/KMS, Belgium, on the scientific exploitation of the TEXTOR tokamak in Jülich. Since the start of JET under EFDA he has frequently participated in the work of the MHD Task Force at JET. In 2005, he became Deputy Leader of this Task Force and has been its Leader since 2008. Furthermore, he is the present leader of the IV (MHD) Task Force on ASDEX Upgrade and co-ordinates the tokamak physics activities on TEXTOR.

Simon Pinches graduated with a degree in Mathematical Physics before undertaking a PhD at CCFE (formerly UKAEA) Culham studying the non-linear interaction of fast particles with Alfvén waves. He subsequently took over a position at the Max-Planck-Institut für Plasma Physik in Garching. During this time he was able to collaborate with the stellarator community and then returned to JET as the MHD Task Force Leader. In 2006, he accepted a position with CCFE and he is now the Leader of the Equilibrium & Stability Group, the Stability Programme Area Leader on MAST and a member of the ITPA Topical Group on Energetic Particles. His research interests span a broad spectrum of stability issues but he continues to have a special interest in the influence of energetic particles upon plasma stability.

“I see the general aim of the EFDA MHD Topical Group to find solutions to those stability issues which inhibit progress towards the delivery of fusion power as an energy source.”

Hans Rudolf Koslowski has worked in fusion research for more than 20 years. He received his PhD at the University of Bochum working in atomic physics. He then joined Forschungszentrum Jülich (FZJ) and started to work in plasma diagnostics, measuring the electron density and current distributions, and studying a wide variety of MHD instabilities, from sawteeth and NTMs in the plasma centre to ELMs at the plasma edge.

“Europe has an impressive fusion landscape offering an extremely wide range of expertise and fusion devices in different configurations and of various sizes. We should share our knowledge, learn from each other, work together, and activate synergies in order to solve urgent problems on our way to develop a new energy source. EFDA provides a framework where all this can be achieved for the benefit of our common goal: controlled fusion.”

Diagnostics Topical Group

Chair

Andrea Murari has installed various diagnostic systems in several European experiments. Between 1998 and 2002, he was responsible for supporting all the diagnostics of the RFX experiment in Padua. Dr Murari has been the Diagnos-
his PhD at FOM-Instituut voor Plasmafysica in Rijnhuizen, The Netherlands, and first arrived at JET in 1999. He has a wide range of experiences in both diagnostic and tokamak plasma physics. His key research areas of interest are pedestal and ELM physics with strong collaborations in international teams within the scope of the Pedestal and ELM Physics ITPA. He was closely involved in the development of the new JET High Resolution Thomson scattering system and is now also involved in the design of the ITER LIDAR system. He is author and co-author of over a hundred scientific publications.

"The EFDA Topical Groups have as the most important task to be an intermediate between the scientists in various EU laboratories. In times of tight budgets it is even more important to use our European resources efficiently and I hope that we as Topical Group Chairs can contribute to this."

Marc Beurskens leads the JET Thomson scattering group and is Deputy Leader of the JET Task Force E1. He received his PhD at FOM-Instituut voor Plasmafysica in Rijnhuizen, The Netherlands, and first arrived at JET in 1999. He has a wide range of experiences in both diagnostic science and tokamak plasma physics. His key research areas of interest are pedestal and ELM physics with strong collaborations in international teams within the scope of the Pedestal and ELM Physics ITPA. He was closely involved in the development of the new JET High Resolution Thomson scattering system and is now also involved in the Diagnostics Topical Group as a wonderful opportunity to promote, develop and reinforce the use of real-time control techniques in the fusion domain.”

Marc Beurskens

Didier Mazon has been Deputy Leader of the “Task Force Diagnostics” at JET since 2007 and Leader of the EFDA “Feed-back Control Group” since 2008. His main duties are to coordinate the control activity in Europe in preparation for ITER and DEMO, but he also follows up on and leads the diagnostics activities at JET and encourages the implementation of new diagnostics and new techniques. Dr. Mazon spent many years at JET as a research scientist, working on real-time plasma equilibrium reconstruction, real-time measurement systems, data mining and feedback control of plasma parameters. He also performed many fields of profile control experiments at JET with the aim of reaching steady state scenarios. In 1999, he joined CEA, where he is responsible for Bremstrahlung emission and Soft X-rays diagnostics. He currently works on the development of real-time diagnostics and feedback algorithms for the simultaneous control of the current density and pressure profiles with direct applications in JET and Tore Supra. His research interests include plasma physics, in particular, the understanding and control of internal transport barriers, control systems, plasma equilibrium and transport studies. He has great experience in teaching physics and still supervises students during internships or PhD thesis. He has published more than 200 articles in renowned international journals and conferences as author or co-author.

"The Diagnostics Topical Group must be innovative, in particular, to contribute to the active preparation of DEMO and ITER. I see my recent nomination as co-chair of the Diagnostics Topical Group as a wonderful opportunity to promote, develop and reinforce the use of real-time control techniques in the fusion domain.”

Didier Mazon

Jesús Vega began his research activity in nuclear fusion with soft X-ray diagnostics (pulse height analysis and tomography). He has been very involved in the fields of data acquisition, control, remote participation and data analysis. His current research topics involve data mining techniques and machine learning methods, with a main focus on the analysis of massive databases in Tokamaks (primarily JET) and stellators (essentially TJ-II). Dr. Vega is currently Head of the Data Acquisition Unit of EURATOM/CIEMAT as well as Vice Chair of the EFDA Topical Group on Diagnostics. In addition, he was appointed leader of the EFDA Working Group on “Data Analysis and Calibration Techniques”.

"In my opinion, the most important tasks of the EFDA Diagnostics Topical Group for the coming two year period lie, on one hand, in increasing the level of coordination in the areas of diagnostics, data analysis, data acquisition, data validation and control and, on the other hand, in improving the dialogue with other Topical Groups and Task Forces.”

Jesús Vega
EFDA welcomes new Head of Public Information

On 1st December, Dr. Petra Nieckchen took on her new role as Head of EFDA Public Information replacing Örs Benedekfi, who returns to the Hungarian Association HAS.

Petra Nieckchen is a Public Relation professional and holds a PhD in chemistry. She started her professional career at Max Planck Institut für Plasmaphysik in Garching in 1999, where she was responsible for internal communications and exhibitions. In this position, she edited the quarterly in-house magazine “Impulse”, and designed and managed exhibitions, guided tours and educational workshops for youngsters. In June 2008, she was seconded to EFDA-JET as Responsible Officer for Public Information and Web, where she oversaw all of the communication activities. She edits the quarterly Newsletter “JETinsight” and recently redesigned the EFDA-JET web page.

Outstanding scientists honoured

At their annual conference, held between June 21st – 25th 2010 in Dublin, Ireland, the European Physics Society Plasma Physics Division (EPS PPD) rewarded researchers for outstanding scientific or technological results. The awards are a central instrument to re-inforce excellence in science.

Allen Boozer, Professor at Columbia University, US, and Jürgen Nührenberg, Professor at Max-Planck Institut für Plasmaphysik and Greifswald University, Germany, received the 2010 divisional Hannes Alfven Prize “for the formulation and practical application of criteria allowing stellarators to have good fast-particle and neoclassical energy confinement”.

The two scientists revolutionised fusion research by developing stellarator magnetic fields that yield confinement properties compatible with those of tokamaks. Their ideas have already partially been confirmed at the Wendelstein 7-AS (IPP, Germany) and HSX (University of Wisconsin, USA) stellarators and provide the basis for the world’s largest stellarator under construction, Wendelstein 7-X.

The 2010 Plasma Physics Innovation Prize is awarded to Uwe Czarnecki, Professor at Ruhr-Universität Bochum, Germany, “for his outstanding contributions in the discovery of the Electrical Asymmetry Effect, its scientific characterisation and for its development up to
EFDA Fusion News

the level of successful industrial application”.

Czarnetzki discovered a novel method of individually controlling ion energy and density in technical plasmas. These are the two essential parameters necessary for plasma materials processing and have, until now, not been possible to control accurately. The research has resulted in a patent, which is being used e.g. by leading manufacturers of large area solar cells. The EPS award recognises Czarnetzki’s entire outstanding contributions to low temperature plasmas.

November the exhibition was housed in the Atrium of the Palace of the Academies, right next to the Royal Palace. Belgian’s first Astronaut Viscount Dirk Frimout was given the honour of cutting the opening ribbon along with one of the students. Located conveniently near the train station, the exhibition drew not only a large number of school classes, but also hundreds of individual visitors. Many took the challenge to try how much energy they could produce by pedalling on the “bike power station”. Even the most curious of bikers were unable to produce more than about one quarter of the 1,000 Watts of electricity that an average Belgian consumes every year! Fusion Expo was also boosted by a new 3D interactive movie from the European Commission which appealed to younger visitors in particular. Wearing polarised glasses, they immersed themselves into the world of the little girl Fusia. Steering with a joystick, they joined Fusia in her flying saucer on a journey to the sun where she explained what fusion is about.

Another 3D movie, Starmakers, immersed the audience into a computer animated ITER, its control room and its buildings, giving them a taste of the size and complexity of a real fusion machine.

An academic event took place on 24th September and provided extra exposure for the Expo, welcoming His Royal Highness Prince Philippe of Belgium, along with distinguished speakers representing the European Commission and the ITER project. Among them, the EC’s Research Director General Robert-Jan Smits placed ITER in the context of the current and future Framework Programmes and underlined the willingness to support this endeavour.

The newly appointed director general of ITER, Professor Osamu Motojima presented ITER as an opportunity and a reality, saying that “the project has now gone beyond the stage of being a mere dream”. Dr Jérôme Paméla, director of ITER-France, outlined the timeline of ITER and emphasised the important role that Europe has to play in the realisation and success of this machine.

Both, Fusion Expo and the Academic Event were organised by the Association “EURATOM-Belgian State” together with ITER-Belgium, in collaboration with the DG Research of the European Commission.

Fusion Expo in the heart of Brussels

Where will our energy come from in future? Young people, in particular, are very much aware of the serious economical and environmental issues behind this question. Despite the high level of awareness with regard to energy issues, however, relatively few are more than superficially familiar with fusion power and even fewer realise the great potential it holds. The current Belgian EU presidency appeared to be the ideal pretext to provide an insight into the status of fusion research and to offer an opportunity to discuss the topic with experts by bringing Fusion Expo, an exhibition of EFDA and the European Commission, right into the heart of Brussels. Between 25th October and 15th

The PPD 2010 PhD Research Award was given to five young scientists for their exceptional quality of work: Xavier Davoine, CEA, France, for improving the numerical procedure for modelling electron dynamics; Guilhem Diff-Pradalier, CEA, (now at University of California, San Diego, US), for a fundamental discussion of the formalism needed to describe turbulence and transport in magnetised plasmas; Emeric Falize and Berenice Loupias, CEA France, for their investigation of similarities between laser induced plasmas and astrophysical plasmas; Peter Manz, Stuttgart University, Germany, for his comprehensive analysis of turbulence in magnetised plasmas.

More information about all of the award-winners can be found here:

http://plasma.ciemat.es/awards.shtml

Carlos Hidalgo, Chairman of the EPS Plasma Physics Division

Where is Fusion Expo?

Bratislava, Slovakia:
5th January – 18th February, 2011
Vienna, Austria:
28th February – 13th March, 2011
Edinburgh International Science Festival, UK: April 2011

http://plasma.ciemat.es/awards.shtml

Carlos Hidalgo, Chairman of the EPS Plasma Physics Division

Thanks to Dirk van Eester, ERM/KMS, for his input
Nitrogen as a potential remedy for power loads
Notes from the 9th EFDA PWI Task Force meeting
Between the 3rd and 5th November, the European Task Force Plasma Wall Interaction (EU PWI-TF) met at Vienna Technical University. Hosted by the Austrian Association EURATOM-OEAW, the event drew almost 50 participants (representatives from individual EURATOM Associations, EFDA and other European and international organisations). The agenda covered the most urgent PWI-related issues for ITER and the progress made during the last year.

The discussions concentrated on fuel retention and removal, dust in fusion devices, the effect of material mixing arising from the parallel use of beryllium, carbon and tungsten and the impact of transient and steady state power deposition on erosion and integrity of plasma facing components. One of the hot topics, and one which touches on most of the fields mentioned above, is the effect of the injection of nitrogen into the plasma edge for the reduction of power loads. Although details are still under discussion, promising results have been obtained for plasma behaviour which are combined with a negligible influence on the plasma facing material. The programme for the next two years was developed in conjunction with colleagues from the ITER Organization and from non-European institutes. The meeting clearly profited from perfect organisation by the Austrian hosts and the inspiring architecture of the university’s festival hall.

Rudolf Neu, PWI Task Force Leader

Fusion technology updates – the 26th SOFT conference
Fusion researchers and engineers took a good look at the current state of fusion machines, engineering solutions and materials research at the 26th Symposium on Fusion Technology (SOFT) held in Porto, Portugal between 27th September and 1st October. The conference drew over 1,000 participants, including more than 200 industrial representatives and an excitingly large number of young researchers. Here we provide a brief review based on a broader conference summary carried out on behalf of the International Organising Committee.

The new ITER Director General, Dr. Osamu Motojima, took the opportunity to introduce his plans for the ITER project to the fusion community. He touched, among other things, on the proposed new departmental and management structures as well as on cost and risk minimisation strategies. Along with Frank Briscoe, Director of Fusion for Energy, Motojima gave a status update and, with the ITER baseline accepted in July 2010, was able to report that arrangements for more than 60 percent of the total procurement value have already been signed. Motojima’s account of the SOFT conference can be found on ITER newsletter: http://www.iter.org/newsline/148/433

Going into more detail during the ITER physics session, Motojima also called for an aggressive R&D programme with respect to the effectiveness of the in-vessel coils planned for ITER. One of several highlights of the ITER sessions was the good progress made in the ITER divertor cassette remote handling system which is under development at the Divertor Test Platform DTP2 in Tampere, Finland.

Status updates of other machines under construction showed that the projects were proceeding well. At Wendelstein 7-X (IPP, Germany), 40 percent of the device assembly is completed and all large components and sub-components are on site. Most of the in-vessel components have been manufactured and the project schedule has been stable for more than three years now. JT60-SA (Naka, Japan) EU Home Team Leader Pietro Barabaschi presented the new project baseline. He expects to complete testing of all magnetic coils by 2016. KSTAR has installed all in-vessel components to enable 20 second shots and aims to achieve 9 megawatts heating and current drive in 2012. At EAST, the integration of plasma facing components is already underway. With actively cooled carbon and tungsten, lithium wall conditioning and a flexible divertor, the programme aims to implement steady state operation in five years.

Only a brief selection of the discussed technological concepts and reported results from various fusion experiments shall be given here: JET researchers gave an update of the ITER-Like-Project, the ITER-Like-Antenna, the plasma vertical stabilisation system upgrade (see also this issue). Tore Supra’s upgraded lower hybrid launcher as well as newly developed diagnostics tools and their potential for long pulse operation were also presented. ASDEX Upgrade team showed a video based realtime system designed to protect wall components. On the material sciences side, the development of the Intense Neutron source for IFMIF-EVEDA was reported to be well on track. Characterisations of low activation steels (CLAM) show that the material resembles the creep and fracture properties of RAFM steels. Oxide dispersion strengthened ferritic steels produced by mechanical alloying and pressing were reported to exhibit high strength and promising fracture behaviour.

In two years time, 24th – 28th September 2012, the SOFT will be held in Liège, Belgium.

Thanks to Thomas Klinger, IPP Greifswald, and Bruno Soares Gonçalves, IST, for their input.

www.soft2012.eu
Where does fusion research stand?

Notes from the Fusion Energy Conference

The International Atomic Energy Agency (IAEA) held its 23rd biennial Fusion Energy Conference (FEC), often called “the Olympics of fusion” in Daejeon, in the Republic of Korea, between 11th and 16th October. The Korean Prime Minister Hwang-sik Kim and IAEA Deputy Director General Werner Burkart, Head of the Department of Nuclear Sciences and Applications, opened the event which drew more than 1500 participants from 39 countries, who in turn contributed 100 oral and 800 poster presentations. The high quality of the scientific programme reflected the vitality of the fusion programme around the world. Socio-economic studies presented at the meeting highlighted, once again, the potential competitiveness of fusion energy with low proliferation risks and the potential to contribute to a significant proportion of the electricity market by 2100. In the closing ceremony speech, the International Fusion Research Council Chairman Gyung-Su Lee reiterated the commitment made by Korea in participating in the development of fusion energy.

The vast majority of papers addressed key physics and technologies issues in preparation for ITER exploitation. Newly appointed ITER Director Osamu Motojima presented one of the overview papers on the ITER status and progress. This was complemented by a number of papers related to ITER construction in the ITER session.

A number of other highlights and novel ideas in the field of magnetic confinement covered key areas of research such as: new divertor concepts, energy and particle confinement, plasma flows and electric fields, good plasma confinement (H-mode) access and related instabilities (ELMs), fast particles and tokamak disruptions. Some of these discussions are summarised below.

Divertor designs that reduce the heat loads to the plasma facing components are key for future fusion power plants. Concepts with elongated connection length, such as the “snow flake” divertor at TCV tokamak in Lausanne, show promising results in this respect. These ideas will be further investigated at the spherical tokamak MAST at CCFE with the so called super-x divertor concept.

Reaching high confinement H-mode regimes closest to ITER parameters is another important aspect. Capitalising on its unique capability of operating at high current, JET experiments achieved good confinement H-modes at a plasma current of 4 megaamperes. They established that the auxiliary power needs to exceed 1.7 times the H-mode threshold, in order to maintain the good confinement properties in a steady state. Studies of the H-mode access dependence on the plasma composition have indicated little difference between helium and deuterium plasmas. This is another important result since ITER will need to access the H-mode during the initial non-activated phase in helium in order to qualify a number of systems and techniques ahead of nuclear operation.

Good plasma confinement must be maintained in conditions compatible with a tokamak with all-metal plasma-facing components. Here, several experiments (i.e. at C-MOD and ASDEX Upgrade) indicate that plasma edge seeding with neon and nitrogen mitigates the heat loads at the metal divertor components. Seeding the plasma edge with nitrogen yields also improved plasma confinement, as the ASDEX Upgrade results show. Other experiments indicate that lithium coated walls might increase the operating space and improve confinement.

A fundamental understanding of the mechanisms involved in the improved confinement of the H-mode regimes has always been a challenge. Improved diagnostics techniques and better theoretical understanding has resulted into new ideas and insights into these complex processes. The TJ-II stellarator showed correlations between the mean and fluctuating plasma flows and the transitions to H-mode. Fine scans of the twisting of the magnetic field lines also highlighted the role of resonant magnetic surfaces in the quality of the H-mode. ASDEX Upgrade showed an intermediate phase prior to the transition to H-mode, indicating interplay between long wave length fluctuations and the decorrelation of the turbulence structures at the edge. A new mode of operation with similar characteristics was reported by C-MOD, the so called I-mode. It shows L-mode like particle confinement with an energy confinement that is similar to that of H-mode.

Duarte Borba, EFDA
The Karlsruhe Institute of Technology (KIT) is in charge of the development, construction and testing of two prototypes and 14 series current leads for the stellarator Wendelstein 7-X (W 7-X) which is under construction at the Max-Planck-Institut für Plasmaphysik (IPP) Greifswald, Germany. Tests of the prototypes show excellent results for current carrying capability, losses and stability and thus fully confirm the design and technical construction.

The W 7-X current leads connect the power supply, which is at room temperature, to the 4.5 Kelvin cold superconducting magnet coils. They carry a nominal current of 14 kiloamperes (kA) and a maximum current of 18.2 kA. Having successfully realised the 68 kA ITER HTS current lead demonstrator in collaboration with CRPP (Switzerland) in 2003, KIT designed the 2.5 metres long current leads for W 7-X in a similar way (see image). A clamp contact forms the connection to the superconducting bus bar. Since the high currents would produce too much heat if standard current leads were used, the lower temperature part of the lead is made of a High Temperature Superconductor (HTS) which covers temperatures between 4.5 and 60 Kelvin and which is cooled by heat conduction from the 4.5 Kelvin end. At the 60 Kelvin end, the HTS module is connected to a copper heat exchanger that is cooled with 50 Kelvin helium. This copper heat exchanger was optimised to cover the temperature gradient from 60 Kelvin to room temperature and to allow optimum cooling in the unusual upside down operating condition of W7-X. In this configuration, the warm end of the current lead is at the bottom, which causes the helium at the cold end to sink and the warmer helium to rise, thus counteracting the cooling efforts. The heat exchanger is designed in a way that it prevents this free convection.

For the test, the two prototypes were connected via a short circuit busbar built by IPP. In the TOSKA facility of KIT, this ensemble was installed in a test cryostat with the room temperature end sticking out at the bottom. After cool down, the test campaign started on June 10th with measurements at different current levels. The current lead was operated in a very stable manner in steady state conditions up to 20 kA. Both the measured 4.5 Kelvin heat load and 50 Kelvin helium mass flow rate for cooling the heat exchanger were as expected. The measurements show that no greater cooling is required due to the upside-down orientation of the current leads. The quench temperature, the temperature at which the HTS material loses its superconductivity, was measured to be 85-90 Kelvin, i.e., more than 25 Kelvin above the operating temperature. A simulated loss of helium cooling flow relaxed by accident into the heat exchanger shows that a maximum current of 18.2 kA could be sustained for more than 18 minutes. This demonstrates the excellent safety performance of the HTS current lead. The test campaign ended on June 30th, followed by the warm up of the test cryostat. In subsequent high voltage tests, the electrical insulation of the current leads withstood 13 kV DC, even under pressures as would be reached during a cryostat leakage (so-called Paschen condition).

After this successful test, KIT will set up production for the 14 series current leads for W 7-X.

Reinhard Heller, KIT

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**Forschungszentrum Jülich combines energy and climate research**

The matter of fusion research at Forschungszentrum Jülich (FZJ) is embedded in a new organisational structure: On October 1st 2010 FZJ’s Plasma Physics department became part of the newly founded “Institute of Energy and Climate Research” (IEK). Here, scientists from the former Institute of Energy Research and the Institute of Chemistry and Dynamics of the Geosphere, more than 600 people in total, will set to work on the common goal of realising a sustainable supply of energy for the future. With this step FZJ shows that they consider energy and climate research to be closely linked and that we need to use an integrated approach. In addition to fusion, IEK research topics comprise fuel cells, photovoltaic technology, fission reactor safety, material studies and climate-relevant processes in the geosphere.

Ralph P. Schorn, FZJ
RFX-mod reaches maximum plasma current

Two million megaampere. The 2010 experimental campaign of the RFX-mod reversed field pinch (RFP) experiment will also be remembered as a result of this number. It represents the maximum plasma current designed for the device, which has now been achieved for the first time.

RFX-mod is the largest RFP experiment in the world. It is based at Consorzio RFX in Padova and belongs to the EURATOM fusion program. For RFPs, the electrical current that flows in the plasma is a key operational and physics parameter. It heats the RFP plasma, which does not use auxiliary heating systems. Moreover, several fundamental physics properties of the configuration depend on the level of current. In particular, increasing the current improves the confinement and brings out new and appealing features, for example, improved helical states (See FN October 2009).

The machine is designed to produce a maximum plasma current of two megamaampere (MA). Over the last couple of years extensive operation has allowed plasma regimes to be optimised at around 1.5–1.7 MA. A number of new results have been obtained, opening up promising perspectives for further improvement of confinement.

One of the key missions of RFX-mod is the detailed exploration of RFP performance in the megampere range, which requires extensive experimental activity at the maximum possible plasma current. For this reason, and thanks to the high intrinsic flexibility of the device, a number of operational tools have been successfully designed and commissioned during 2010, for example, the reconfiguration of the power supply. Moreover, thorough work has been carried out on the process of setting up plasma, i.e. on all those processes involved in bringing the plasma up to its final state, and on the optimisation of the magnetohydrodynamic stability active control.

These efforts led, toward the end of the 2010 campaign, to the first successful plasma shot at 2 MA, demonstrating that the machine can be operated at such high currents in a safe manner and without major problems. Given the robust design of RFX-mod this was to be expected, but seeing it in practice is very encouraging. Now the machine is ready for exploration work at 2 MA. A task which is very challenging, since a number of points, for example density control, need to be tackled in order to achieve best performance. But the results obtained so far, in particular on the helical state and the reliability of the device, show that our ambitious goals for 2011 and beyond are realistic.

As in recent years, the 2011 RFX-mod campaign will be launched with a public call of proposals. In addition RFP exploration at high current, the main pillars of the RFX-mod science program will contribute to the development of two main topics in the field of magnetic confinement fusion: Magnetohydrodynamic stability active control and three-dimensional physics. The research will be conducted in strong partnership with tokamak and stellarator programmes and fully integrated into the EU fusion programme. More information on the call for proposal will appear on the Consorzio RFX website (www.igi.cnr.it).

Piero Martin,
Consorzio RFX

EFDA during FP7 – Reinforced coordination of physics and technology in EU laboratories Part 7

Training and career programme

Fusion research is a long-term endeavour. When ITER starts operating in 2018, it will need a large number of very experienced scientists to fully exploit its capabilities. EFDA lays the foundation for future fusion research by promoting the next generation of scientists. With the start of the 7th Framework Programme, EFDA adopted the task of training fusion researchers from the European Commission. Within the framework of Goal Oriented Training Programmes and Fusion Researcher Fellowships, EFDA supports 50 fusion engineers and scientists each year.

For a period of five years, EFDA conducts Goal Oriented Training Programmes which provide funding for around 40 researchers and engineers every year. The programmes must address one of the high priority areas as defined by the EFDA Leader along with partner organisations, such as Fusion for Energy. Furthermore, eligible projects must be a collaboration involving at least three Associations. Each year, EFDA calls for proposals for certain high priority areas. Associations that have applied successfully may recruit their trainees – engineers or scientists who hold at least one relevant diploma – specifically for the training programmes. The training is based on a project of up to three years duration with clearly defined goals. Together with their personal supervisor, the researchers establish a Personal Career Development Plan as a guideline for the training process. The current Goal Oriented Training Programmes can be found here:

http://www.efda.org/about_efda/activities-got.htm

Fusion Researcher Fellowships support up to 10 post-doctoral researchers each year. The grants are awarded within the Associations under the coordination of EFDA and run for up to two years. Every year, EFDA calls for proposals which must be supported and forwarded by the heads of the Associations. The research project must be carried out on a scientific or technical topic that is relevant to the objectives of the European Fusion Programme. The applying researchers must already hold an initial post-doctoral contract in a European fusion laboratory.
JET vertical stabilisation successfully upgraded

A team of researchers within the JET Plasma Control Upgrade Project (PCU) has successfully upgraded the JET Vertical Stabilisation System. The new system enables more sensitive control of the plasma geometry and can withstand larger perturbations, e.g., larger Edge Localised Modes (ELMs). It will also enable scientists to push the plasma performance to its limits without losing control. The project was closed out in summer 2010 and results were presented at the 26th Symposium of Fusion Technology.

The system upgrade became necessary as JET prepares for more powerful experiments with its new ITER-Like-Wall. Not only might there be larger ELMs, but, more importantly, the plasma must not touch the vessel wall at any time since this could result in the beryllium surface being melted at certain points. This requires the upgraded system to react extremely quickly to any vertical plasma movements.

The system’s response time was improved by increasing the amplifier’s maximum voltage. The hardware was replaced to reduce the signal to noise ratio. Processing capabilities have been increased to two gigaflops, allowing more complex control algorithms to determine the corrective magnetic field. Moreover, the system was upgraded giving the option of easily implementing different control algorithms which can be applied to the different phases of the plasma discharge. This allows for a more sensitive and instantaneous reaction to plasma movements. Enabling the system to work with different plasma models according to the actual plasma geometry has further enhanced its reaction time and precision. This feature will be exploited during the next experimental campaign. The software architecture also makes the system more flexible, because new features can be easily introduced by programming plug-ins.

The upgraded system was commissioned within an exceptionally short period of four experimental weeks in summer 2009. Up until the end of October 2009, it demonstrated its capabilities in large ELMs and ELMy H-mode operations at plasma currents up to 4.5 megaamperes. Additional testing with alternative adaptive controls showed that the current swing during the system’s recovery from large ELMs could be reduced without compromising the vertical stabilisation capability.

Some features of the new software have been designed based on plasma models rather than on experimental tests. The successful commissioning proves that the design and implementation of major systems in tokamaks can be realised with a model-based approach.

The upgraded system contributes largely to the design of ITER which will reach different operating scenarios during its long pulses. Its Vertical Stabilisation System will thus need similar flexibility with regard to controllers or measurement algorithms.

Thanks to Gianmaria De Tommasi, Consorzio CREATE, Euratom-ENEA Association, for his input.

3D illustration of the JET vessel, showing the vertical stabilization coils in orange. (Picture: JET)

Vertical stabilisation

In order to increase the energy confinement time, a vital criterion for realising sustained fusion, modern tokamaks use D-shaped rather than circular plasmas. The downside of these elongated plasmas is their instability which, for instance, causes them to move vertically. The movement needs to be stopped by an active feedback system. Based on magnetic field measurements, the Vertical Stabilisation System estimates the vertical plasma velocity. Using plasma models, the magnetic field necessary to counteract this movement is calculated. A power amplifier feeds the electrical current into special radial coils. ELMs are a typical cause of these events and the vertical plasma velocity is correlated to their strength. Bigger ELMs require stronger counteracting magnetic fields and thus larger currents. At JET, the measurements are done every 50 microseconds (μs) and the system reacts within about 200 μs to vertical plasma movements.