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newsletter

EUROPEAN FUSION DEVELOPMENT AGREEMENT

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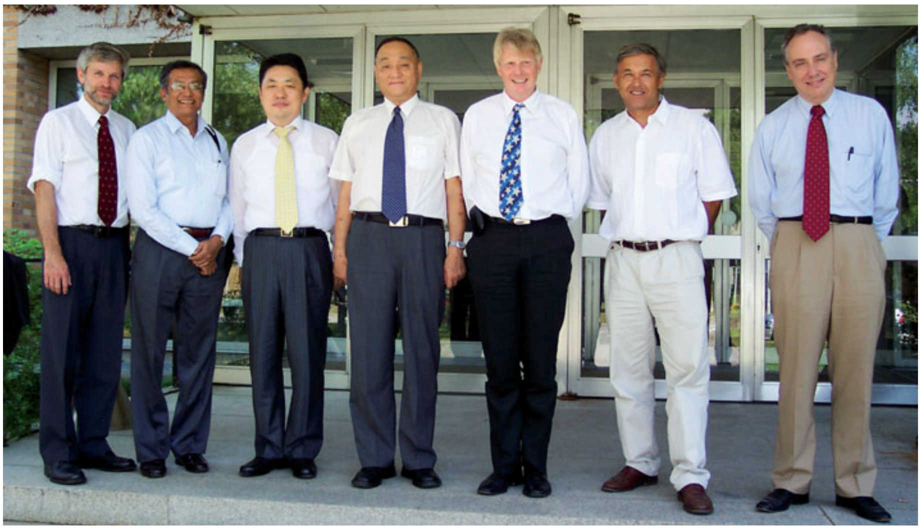
ITER Senior Management Team Completed



The top management structure for the ITER Organisation is decided. The six Deputy Director General nominees are (from left to right): Gary Johnson, Dhiraj Bora, Yong Hwan Kim, Shaoqi Wang, Carlos Alejaldre (far left) and Valery Chuyanov (not in the picture). In July, the nominees presented themselves to the EFDA staff in Garching, together with EFDA Leader Jérôme Pamela and the ITER Principle Deputy Director General nominee, Norbert Holtkamp (see page 6).

JET enhancement projects receive go-ahead

At the EFDA Steering Committee held in Barcelona on the 14th of July, the JET enhancements projects (EP2) received the final approval. The EP2 projects form a coherent set of enhancements that comprises the installation of a wall in JET that uses the same mix of materials (beryllium and tungsten) as that foreseen in ITER, a substantial increase of the neutral beam heating power, a better plasma control system, a new pellet injector and a set of new diagnostics. The modifications will allow the preparation of ITER plasma operation in the most relevant conditions achievable in today's fusion devices. (see article *Tungsten coatings for the JET ITER-like project* on page 4).

Chinese tokamak EAST achieves first plasma

The EAST superconducting tokamak, based at the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China, achieved its first plasma discharge on September 27th. The plasma current reached up to 220 kA, and the maximum pulse length was 2.7 seconds. EAST, which is the most advanced fusion research device in China, is the largest superconducting tokamak equipped with a divertor. It will be used to study steady-state plasma operation issues.

Educating engineers for ITER

In order to reinforce the engineering capabilities needed for ITER construction, EURATOM has implemented a European Fusion Training Scheme (EFTS), especially covering areas that are critical for the construction of ITER components. These areas are material technology, fuel cycle, remote handling, superconducting magnets, electron cyclotron and the ion cyclotron systems.

Also, a training network for engineers specialised on optical diagnostics has been implemented. Optical diagnostics are used on ITER to derive important plasma prop-

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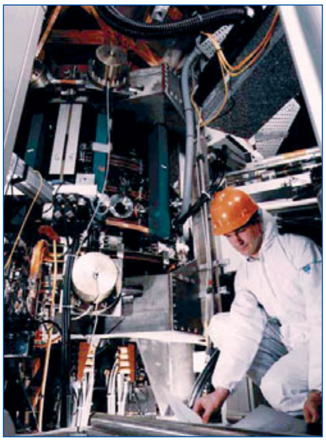
erties based on the measurement of plasma radiation. Therefore a European consortium of seven fusion laboratories has been formed to organize the training of eight young engineers on Engineering of Optical Diagnostics for ITER (EODI).
www.eodi.eu

Norbert Holtkamp

ITER — "We need the best people we can find"

"My task is even more complicated than my title - and this is complicated enough." On April 1st Dr. Norbert Holtkamp was nominated Principle Deputy Director General (PDDG) of the international ITER Project. As Project Construction Leader, the 44 year old German physicist will be responsible for the technical realisation of ITER. On the 26th of July, Norbert Holtkamp introduced himself to the EFDA staff in Garching and Barcelona. He stressed the importance of the employment scheme, which will include the recruitment of approximately 70 professionals plus 50-70 support staff by the end of 2007. By the end of 2009, Holtkamp wants to have reached operational level with approximately 300 professionals and 300 support staff. "The next three years will be critical to get the right people on board. With respect to the scope of this project we will need the best people we can find."



UKAEA engineer working on the Compass-D tokamak.

Compass-D moves to the Czech Republic

On 20 July 2006, the Euratom Consultative Committee on Fusion (CCE-FU) unanimously endorsed the awarding of Priority Status Phase II to the "COMPASS to Prague" project. This gives a strong message of encouragement for Czech fusion scientists, who already obtained the necessary national support for the transfer and installation of the tokamak COMPASS-D (currently at UKAEA Culham Science Centre) to the Institute of Plasma Physics AS CR, Prague by decision of the Czech government on 2nd November 2005.

"Among others, this facility will increase motivation of new students and will improve R&D environment for Czech companies that operate in the sector," said the then Deputy Prime Minister Martin Jahn.

A building extension, new power supply systems, a neutral beam heating system, control and data acquisition system and a large part of the plasma diagnostics will have to be purchased in the framework of the project, with first plasma expected in 2009. Based on the current expertise of the Association EURATOM-IPP.CR — mainly acquired during the operation of the tokamak CASTOR — the proposed scientific programme for Compass-D expands the original UKAEA research into current ITER-related topics, thus directly exploiting the ITER-like plasma configuration and the H-mode capability of the facility. The programme will consist of edge plasma physics (H-mode studies and plasma-wall interaction, including material studies) and wave-plasma interaction studies (parasitic lower hybrid wave absorption and lower hybrid wave coupling in detached plasmas).

The project enjoys a practical support of the UKAEA Fusion staff, while several other Associations have already indicated their strong interest in future co-operation. Fusion scientists and engineers in the Association EURATOM-IPP.CR expect that the new facility will substantially enhance their capability for participating in the overall European fusion research activities. In order to attract "fresh blood" to fusion research the Faculty of Nuclear Sciences and Physical Engineering of Technical University in Prague (member of the Czech Association) launched a new MSc course on "Physics and technology of fusion".

US Domestic Agency team completed

A 12-member-team of scientists and engineers has been chosen to manage the United States' contribution to ITER.

The Team will be headed by Dr. Ned Sauthoff, who has joined ORNL after completing a distinguished career at Princeton Plasma Physics Laboratory, where he served as U.S. ITER's planning officer for 18 months before becoming US ITER Project Manager in February. Dr. Sauthoff headed PPPL's Offsite Research Department, which supports fusion research collaborations around the world. He is a former president of the Institute of Electrical and Electronic Engineers-USA.

As US ITER Project Manager, Sauthoff will direct all non-governmental aspects of U.S. involvement with the international ITER project, which includes: securing technical assistance from within U.S. fusion community labs, universities and industries; procuring and shipping U.S. hardware contributions; arranging for U.S. personnel to work abroad at the ITER site; and representing the U.S. before the international ITER Organization on construction and preparation for ITER operations.

The team members are currently employed by the Oak Ridge National Laboratory, the Princeton Plasma Physics Lab, and the Savannah River National Laboratory. Information on the individual members can be found on the news section of the EFDA website. ■

Australian scientists voice interest in ITER

A group of more than 100 scientists and engineers have formed the Australian ITER Forum, which aims to develop the case for an Australian role in the ITER project, both by participation and by the formation of an International Centre of Research Excellence in Fusion-Related Research. With Federal Government support, the Australian Forum has scheduled an international workshop for October 12-13 this year titled "Towards an Australian involvement in ITER". The Australian ITER Forum will bring together international ITER team-members, Australian industry and government, and representatives from the ITER Parties to explore possibilities how Australia can be involved in constructing, operating and using ITER. "Australia has expertise and resources in areas that ITER will need", it says on the Forum´s homepage.
www.ansto.com.au/ainse/fusion ■

European Commission outlines proposed Joint Undertaking for the European contribution to the ITER fusion energy project

On the 22nd of August the Commission has published proposals for the creation of a Joint Undertaking to provide the European contribution to the ITER international fusion energy project. The *European Joint Undertaking for ITER & the Development of Fusion Energy* will work with European industry and research organisations to build around half of the high-technology components that make up the ITER fusion project. It will also support other projects to accelerate the development of fusion as a clean and sustainable energy source for the 21st century. The Joint Undertaking will be based in Barcelona and should be up and running by the first half of 2007.

Janez Potočnik, EU Commissioner responsible for Science and Research

"Building upon the success of the integrated Euratom fusion research programme, the Joint Undertaking will be a dynamic new organisation that will play a leading role in the construction of ITER and enhance Europe´s role in the technological development of fusion energy" Commissioner Potočnik said today.

The Joint Undertaking´s primary task will be to meet Europe´s wide-ranging obligations towards ITER, by working with European industry and research organisations to supply the components for the construction of ITER and will administer the EU´s financial contribution to the project, which will mostly come from the Community budget.

The Joint Undertaking will also contribute to the implementation of the "Broader Approach", an agreement between the EU and Japan conceived to work on a number of joint projects to accelerate the development of fusion energy. These projects, including finalising the design for a materials testing facility and the upgrade of a fusion experiment, will complement ITER by filling possible knowledge gaps. A proposal on the "Broader Approach" will be made by the Commission later this year.

Looking to the longer term, the Joint Undertaking will progressively implement a programme of activities to prepare for the first demonstration fusion power reactors, building on the experience of ITER. ■

JET

Tungsten Coatings for the JET ITER-like Wall Project

Author: Dr. Hans Maier, IPP

In the beginning of 2005, the ITER-like Wall Project was initiated at JET. The ambitious goal of this project is to investigate for the first time in a real tokamak-environment the plasma-facing materials combination that is intended to be used in ITER. Since JET is currently the largest tokamak experiment in the world, it is best suited for this purpose from a physics point of view, for example when the response of the materials to tokamak-specific pulses of high heat flux, so-called edge-localized modes (ELMs), is of concern.

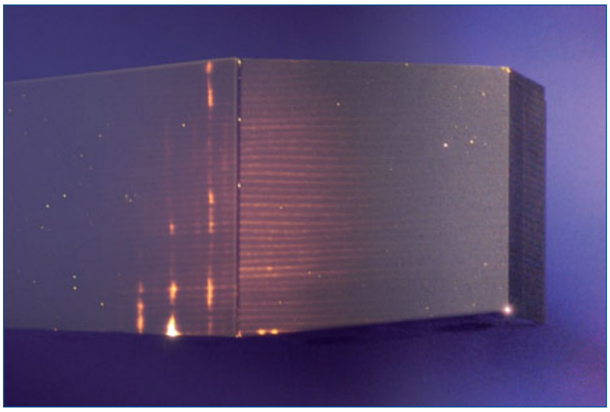


Figure 1: A pair of tungsten coated carbon fibre compound tiles during heat loading with a hydrogen beam in the GLADIS facility at IPP Garching. The bright horizontal lines correspond to the fibre direction. The vertical features on tile on the right are tensile cracks in the coating. As described in the text, they are oriented perpendicular to the fibres.

Unlike ITER, JET will start this programme with a full tungsten divertor. This allows the investigation of a full metal first wall without carbon contamination, a configuration which ITER might be willing to use for its D-T experiment. The divertor could later be changed to the presently foreseen ITER configuration by installing Carbon Fiber-reinforced Carbon (CFC) targets. For the outer horizontal divertor target plate, the so-called load-bearing septum replacement plate, a solution employing bulk tungsten lamellae has been developed at Forschungszentrum Jülich (see EFDA Newsletter Vol 2006/1). This rather complex approach is, however, expensive and could not be applied to the whole divertor. Instead, it was decided to go for the less expensive approach of tungsten coatings.

As a substrate material the currently employed two-directional carbon fibre-reinforced carbon (CFC) was chosen, since the qualification of a new material with respect to all relevant properties and tile design details would not have been possible within the given tight time frame. Due to this boundary condition, thermo-mechanical problems were to be expected, since the anisotropic CFC material and tungsten are not particularly well adapted with respect to thermal expansion. For this reason, a rather large effort was undertaken to investigate a variety of tungsten deposition methods. Three different coating thicknesses were investigated; two thin types of 4 µm and 10 µm and one thicker type of 200 µm. This resulted in a total of fourteen different sample types, each a combination of a tungsten deposition method and an applied coating thickness. This strategy was chosen to maximise the chance for finding a viable solution.

Research and development was performed at five Euratom Associations: CEA Cadarache, ENEA Frascati, IPP Garching, MEdC Bucharest with support from CEA Cadarache, and TEKES Finland. With the exception of the Romanian Association, this was done in cooperation with industry. The position of task coordinator was assigned to IPP Garching, taking into account the fact that, in the frame of the ASDEX Upgrade tungsten program, IPP had already gathered experience in the field of tungsten coatings dating as far back as 1995 (see EFDA Newsletter 2003/5).

After a short R&D period in 2005, the Associations delivered their optimised coatings to IPP Garching. They were deposited on specially designed identical test tiles incorporating some features of actual JET divertor tiles, which had been manufactured at IPP Garching and, after baking at JET, had been distributed to all participants. At IPP Garching all coating types were subjected to a test program, including for example metallographic investigation and the analysis of the coatings impurity content. The latter was also supported by Forschungszentrum Jülich.

Thermal expansion mismatch

The main part of the test program was a high heat flux investigation conducted in two steps in IPP's new high heat flux facility GLADIS (see EFDA Newsletter Vol 2005/5). The first step consisted of a thermal screening procedure, where samples were subjected to a number of successively increasing central power densities and pulse durations to determine the ultimate performance limits of the individual coating sample types. This was done up to a central power density of more than 23 MW/m^2, which led to peak surface temperatures in excess of 2000°C after a pulse duration of 1.5 s. Based on the results of this screening procedure, a number of coating types were selected for the second step, a thermal cycling procedure.

Given the risk of thermo-mechanical problems mentioned above, this step was considered to be of great importance, since the thermal expansion mismatch between CFC and tungsten might lead to fatigue phenomena. A program of 200 cycles of 10.4 MW/m^2 for 5 seconds was adopted. With a typical cooling time between pulses of 2-3 minutes, this took two experimental days per sample pair. The waiting time was determined to allow the tungsten coatings to cool down below the ductile to brittle transition temperature. A third heat load qualification step was performed in the JUDITH facility at Forschungszentrum Jülich, where 1000 ELM-like pulses of 350 MW/m^2 were applied for a duration of 1 ms. In parallel to these tests, the possibility of non-destructive testing of the tungsten coatings was investigated at CEA Cadarache and partly also at UKAEA Culham.

Figure 1 shows a pair of samples during thermal loading with a hydrogen beam in the GLADIS facility during the thermal cycling step. In this step, two tiles are placed next to each other while the power density profile is centred in the middle so that two tiles are loaded simultaneously. On some samples the coatings developed partial delamination and subsequent local melting during the screening program.

A general result, however, was the formation of tensile cracks in the coatings during heat loading, due to the thermal expansion mismatch of tungsten coatings and CFC substrate tiles. The cracks occurred in the fibre reinforced direction of the CFC material, in which the thermal expansion of the substrate is smaller than that of the tungsten coatings. From the orientation of the cracks it must be concluded that the failure occurred after the coatings had become stress-relaxed at high temperature. In the non-reinforced direction of the substrate material, coatings which are stress-relaxed at high temperature experience compression upon cool-down.

The second principal result was that tungsten films in the micrometer range of thickness are not stiff enough. Upon repeated compressive stress this insufficient stiffness leads to instability against delamination and buckling. This is accompanied by fatigue cracks. This buckling and cracking is illustrated in the scanning electron image shown in figure 2.

Except for the samples produced by the Romanian Association MEdC, this buckling instability failure occurred on all samples with coatings in the µm range. Only the thick 200 µm coatings proved to be stable against buckling in the cyclic loading program. Therefore the 200 µm coating thickness was selected for application in the JET tungsten divertor. Since some of the tested 200 µm coatings displayed local failures, it was decided that a test at a moderate heat flux is mandatory for all tiles prior to installation in JET. This will be done in the JUDITH II facility in Forschungszentrum Jülich with support from IPP Garching for real-time data processing.

JET is equipped with a plasma heating system based on neutral beam injection. Energetic neutral hydrogen atoms are produced and injected into the plasma. These particles collide with plasma particles, are then ionized and deposit their energy into the plasma. Some of them can, however, pass through the whole plasma diameter without collisions - these are the "shine-through" particles. They hit the wall at full energy which can correspond to a considerable heat load. Therefore some locations of the main chamber inner wall will also require tungsten coatings.

For this application, 10 µm coatings are sufficient and are now being produced by the Association MEdC Bucharest. They are made by a combination of magnetron sputtering and energetic ion beam implantation for simultaneous stress relaxation. They are equipped with an intermediate layer of molybdenum. These samples did not develop the above-mentioned buckling failure in the GLADIS cycling tests and failed only under the extreme conditions of ELM-like loading which are not expected to occur on the “shine-through” protections. A setup for coating large tiles will be constructed and commissioned in Bucharest. After a further qualification step, this setup will be used for large-scale production with accompanying support and testing at IPP Garching. ■

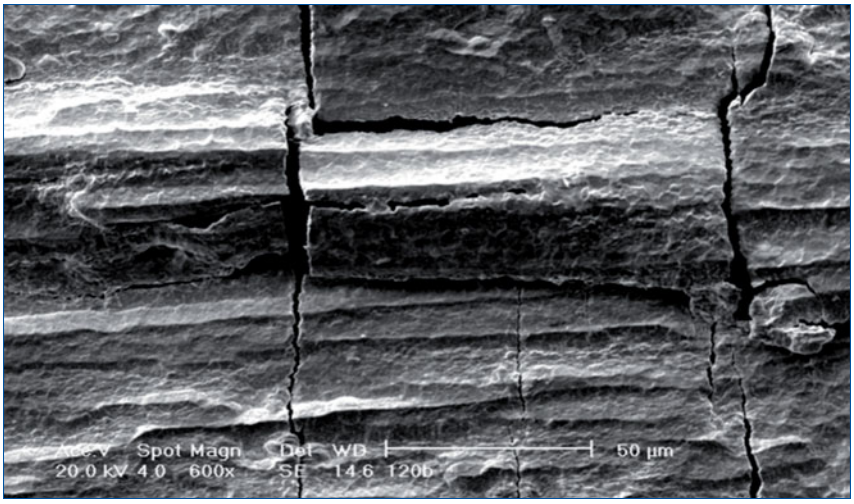


Figure 2: Scanning electron microscopic image of the buckling failure described in the text. This failure occurred on thin coatings during cyclic heat loading. The image is taken such that the coating looks like being illuminated by a light source. In the centre of the image a buckle therefore appears with a bright and a shadowed flank. The cracks running vertically in the image, i.e. perpendicular to the fibres, are the tensile cracks described in the text. The horizontal cracks running parallel to the buckle flanks are a fatigue phenomenon.

Special

ITER Deputy Director Generals appointed

During the 9th ITER Preparatory Committee meeting held in Cadarache(France) on July 13, delegations from the seven ITER Parties approved nominee Director-General Kaname Ikeda´s proposals for the six Deputy Director Generals posts in the top management structure of ITER. The designation marked the start of a new stage in the preparations for the project, that will come into effective operation once the ITER Agreement is signed. The signing is expected in late November this year.

Carlos Alejaldre – Safety and Security

Born in 1952 in Zaragoza, Dr. Carlos Alejaldre received his Doctorate in Electrophysics at the Polytechnical Institute of New York in 1983 and became an Assistant Professor there. He joined the Centro de Investigaciones Energeticas, Medioambientales y Technologicas (CIEMAT). In 1986 he became Head of Theory and Plasma Simulation, in 1993 he became Director of the Spanish National Laboratory for Magnetic Confinement Fusion. From 1999 to 2004 he was head of the CIEMAT-Euratom Association. In 2004 he was appointed Director General for Technology at the Spanish Ministry of Education and Science.

Between October 2001 and 2003 Alejaldre was also Director of ITER Spain, responsible for preparing and presenting Spanish proposals for siting ITER in Vandellós. So there should be no doubt concerning his commitment to the project in which he sees “the global solution for the future“. As Deputy Director General Alejaldre will be responsible for all safety and security issues of ITER, for all the necessary licensing issues, and for the assurance of a nuclear safety culture in ITER. “It´s my professional challenge to make ITER materialize. This is the right project at the right moment.”

Shaoqi Wang – Administration

Born in 1944 in Beijing, Dr. Shaoqi Wang received his Doctorate in Electronic Engineering in 1984 in France, at the Institut National Polytechnique de Grenoble. Before that he had been an electrical engineer at the China Xinhe shipyards for ten years, responsible for electrical engineering design and installation.

In 1984 he became Director of European Affairs at the Department of International Cooperation of the State Science and Technology Commission of China. After four years as Science Counselor in the Chinese Embassy in Paris he returned to China as Director-General, Department of International Cooperation, Ministry of Science and Technology of China. Since 2001, Shaoqi Wang returned to Paris as Minister-Counselor at the Chinese Embassy. His French therefore is close to perfect, which will help him as ITER Deputy Director General for administration. As such he will be responsible for all human resources aspects of the project as well as budgeting, contract procurements and – last but not least - public relation affairs. “As more and more people learn about the project there will be an increasing demand for information”, he says.

Shaoqi Wang will be busy right from the start, in view of getting the first budget approved at the next multi-Party meeting at the end of November. “Then we can start with the procedures for recruiting people and prepare the financial frameworks for the future.” Wang truly believes in the ITER project: “Fusion is the best solution for humankind to resolve the problem of future energy supply.”

Dhiraj Bora – Control, Data Acquisition and Diagnostics

Born in 1951 in Guwahati, India, Dr. Dhiraj Bora received his Masters Degree from the Peoples' Friendship University of Moscow in 1974, and his Doctorate in Physics from the Physical Research Laboratory in Ahmedabad. For almost 25 years since then he has been active in plasma physics research, most recently at the Institute for Plasma Research (IPR) in Gandhinagar.

Dr. Bora´s primary interest has been radio frequency heating and current drive in tokamaks. He has been the project leader of the RF group in his institute since its inception. In the past fifteen years the group has developed heating and current drive systems based on high power commercial tubes at megawatt levels and different frequencies. In his earlier days Dr. Bora was involved in microwave diagnostics and bolometers in tokamak plasmas.

Soon Dr. Bora will move to Cadarache to take over as DDG. Being responsible for diagnostics, CODAC, heating and current drive systems, he will have to make sure “that the plas-

Special

ma within the ITER device behaves the way we want it to", he said. But besides finding solutions to the outstanding questions on heating and current drive issues in prospect of the upcoming design review, Dr. Bora will have to rely on his diplomatic skills. "Fusion technique attracts people from all over the world. So we are dealing not only with a wide variety of nationalities, but also with very different working cultures. To join the nations together will not be an easy task. Therefore I think communication will play an important role for the smooth functioning of the project."

Gary Johnson - Tokamak

Born in 1955, Gary Johnson received his Master of Science in Mechanical Engineering at the University of Tennessee in 1983. Until 1993 he worked on the Atomic Vapor Laser Isotope Separation (AVLIS) program in Oak Ridge and later at Livermore National Laboratory, where he was Mechanical Group Leader for seven years.

Between 1993 and 1999, he was ITER Vacuum Vessel Group Leader at the Garching Joint Work Site. Since 1999 he has been working on the Spallation Neutron Source (SNS) Project at ORNL. Early responsibilities included defining requirements for buildings and oversight of the Architect Engineer and Construction Manager, as well as coordination of the mechanical design of the warm linear accelerator, and planning and overseeing all assembly, installation and testing of that system at ORNL. In 2004 he became Experimental Facilities Division Installation Manager.

As DDG for the Tokamak, Gary Johnson will be responsible for "the core of the system". He will have to coordinate the various contributions by the ITER Parties and ensure a high quality in the construction of the device. "There is little room for mistakes."

Yon-Hwan Kim – Central Engineering

Born in 1958, Dr. Yon-Hwan Kim received a Doctorate in Mechanical Engineering at Warwick University, England in 1989. Later he was Science Counsellor at the Korean Embassy and the Permanent Mission to the IAEA in Austria for three and a half years, and then served as Director-General of the Atomic Energy Bureau in the Ministry of Science and Technology (MOST). He has over 20 years of management experience in the administration of science and technology. Most recently he was Secretary-General of the Presidential Advisory Council on Science and Technology. As Deputy Director General for Central Engineering, Dr. Kim will be responsible for all engineering issues outside the tokamak.

Valery Chuyanov – Science and Technology

Born in 1941 in Volgograd, Dr. Valery Chuyanov received his doctorate in Physics at Moscow State University in 1976, working on feedback control of plasma instabilities. He worked for short periods during this time also at Culham and Livermore laboratories. At the Kurchatov Institute he was involved in the design, construction and experimental programmes of 3 major mirror machines and 2 tokamaks, in different capacities ranging from junior scientific officer up to scientific leader of the project.

Valery Chuyanov actively participated in the ITER Conceptual Design Activities as head of Fusion Engineering Division at Kurchatov, Leader of the ITER USSR Home Team, and member of the ITER Science and Technology Advisory Committee. He was appointed Deputy Director and Head of the San Diego Joint Work Site at the outset of the Engineering Design Activities. In 1999 he became Head of the Garching Joint Work Site.

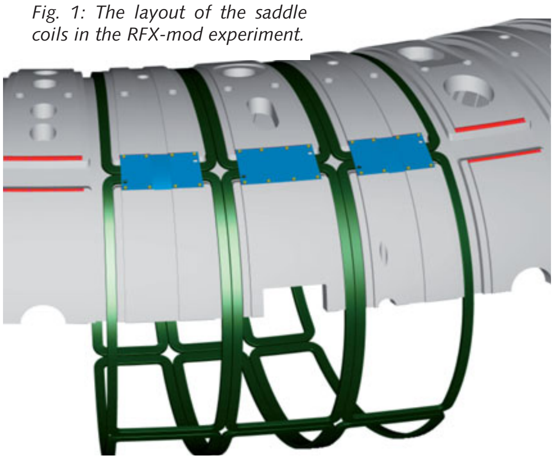
So for the last twenty years Chuyanov has played a vital role in the fusion world and in building up the ITER project. "ITER is my life", he frankly admits. As nominated Deputy Director General he will be responsible for the scientific and technological program. However, his main task he sees "in creating an organisation which will be capable to attract physics talents from all over the world, and that, in time, will grow to become a research organisation which can successfully exploit ITER".

Associations

Italian RFX-mod experiment demonstrates active MHD control

In Tokamak advanced scenarios for ITER and for future fusion reactors new magneto-hydrodynamic (MHD) instabilities are predicted to grow, whose active stabilization will be mandatory to achieve the expected performance. This class of instabilities are called Resistive Wall Modes, since their growth rate depends on the electrical resistance of the conducting wall that surrounds the plasma column. A perfectly conducting wall would fully stabilize these modes, but that is unfeasible in practice. As a consequence, active stabilization by means of suitable coils and feedback-controlled amplifiers will be needed in future fusion devices.

Fig. 1: The layout of the saddle coils in the RFX-mod experiment.



In the modified RFX experiment (RFX-mod), operating at Consorzio RFX in Padova, such active stabilization coils were installed as part of a programme to obtain a more stable plasma in RFX, and to conduct Resistive Wall Mode stabilization experiments. The experiment implements active feedback control of the magnetic field to effectively produce and maintain an almost ideally conducting wall at the plasma boundary. Similar experiments have been performed at low current on the EXTRAP-T2R device and on the DIII-D tokamak with a partial set of feedback coils.

To accomplish this, RFX-mod includes a new active MHD control system consisting of 48 toroidal x 4 poloidal saddle coils (see fig. 1), which are independently powered. They have been installed and tested during 2003-2004. The system has then been used under various control scenarios including experiments on local radial field cancellation over the entire torussurface to mimic an ideal wall, which is also called a "Virtual Shell".

Both in Tokamaks and Reversed Field Pinches, the MHD instabilities can be seen as helical deformations ("modes"), which are easily detected by radial magnetic field measurements. If a suitable number of coils is available, the feedback action can effectively reduce the amplitude of the modes across the whole spectrum.

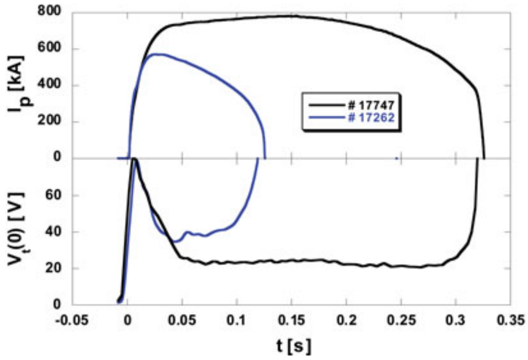


Fig.2 (left): Plasma current and toroidal loop voltage waveforms. Comparison between a typical shot without active control (blue) and one of the recent shots with the virtual shell active control scenario (black). The benefit of active control is evident both from the longer duration of the current pulse and from the lower loop voltage, which means less power losses.

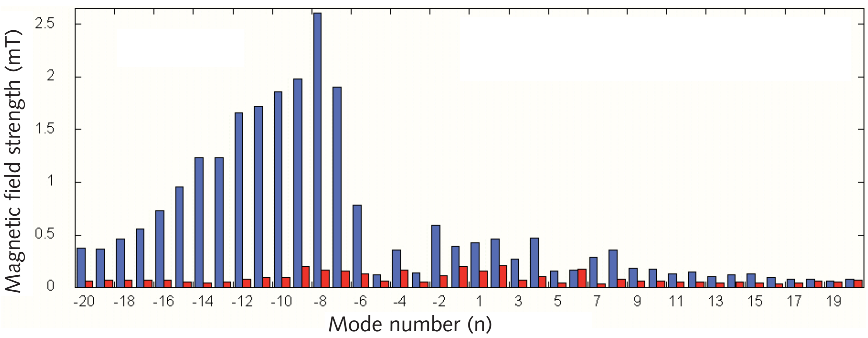
During the experiments, successful Virtual Shell operation has been achieved leading to:

- A threefold increase in pulse length, from 100 to 300 ms, and well-controlled pulses up to nearly 800 kA of plasma current (see fig.2)
- A one order of magnitude reduction of the radial field at the plasma edge (see fig.3)
- A twofold increase in global energy confinement time.

When operating without active control, resistive wall modes are observed to grow in agreement with linear MHD theory predictions, i.e. on the timescale for the diffusion of the radial field through the shell. Recent experiments have clearly demonstrated feedback stabilization of resistive wall modes; both single and multiple helical modes have been successfully stabilized.

Overall, the results obtained in the first year of operation are very encouraging, and form a solid base for an intense experimental program which will focus on the study and control of the MHD dynamics, and on improving the confinement by increasing the plasma current to the mega-ampere range. ■

Fig.3: Comparison between the toroidal mode spectrum without (blue) and with (red) active control (virtual shell scenario). The amplitudes of the radial field components measured at the sensors located on the vacuum vessel are reduced to values of around 0.1 mT. The strong reduction of the mode amplitudes has a clear benefit in reducing energy transport, with a significant impact on plasma performance (see fig.2)



Events

Report on the 24th SOFT conference

During the 11-15th of September, the Symposium on Fusion Technology (SOFT) was held in the Palace of Culture and Science in Warsaw, Poland. SOFT, the largest fusion conference in Europe, is held every second year. This year's conference has broken all records with over 660 participants. An R&D and industrial exhibition with 26 participant organisations and companies was part of the conference.

During the opening ceremony, the director of the Energy Directorate of DG Research in the European Commission, Pablo Fernández Ruiz, reminded the SOFT participants they were there "*to develop the knowledge base for the creation of prototype reactors for power stations which are safe, sustainable, environmentally responsible, and economically viable, and to realise ITER as the major step towards this objective*", as it is formulated in the seventh Framework Programme of the EU. Mr. Ruiz stressed that the present leading EU position stems from key contributions of the Fusion Associates within the integrated European Fusion Programme, and that, to maintain this leading role, the essential competences of the Associates need to be mobilised by further European integration. Furthermore, he stressed that through the new Joint Undertaking that will soon be set-up in Barcelona as the European Domestic Agency for ITER, the Fusion Associates and European industry will have a key role to play in participating to ITER construction. As a consequence of the start of this new entity, the year 2007 will also see a significant evolution of EFDA and the Contracts of Association with Euratom.

Norbert Holtkamp, ITER Principal Deputy Director General, in charge of leading the project construction, gave an overview of ITER. He underlined that for its size and cost, and the involvement of countries representing over half of today's world population, ITER will become a new reference term for big science projects. "ITER, within the collaboration, has access to 70% of the world population. We need to find the best and the brightest within this pool". Mr. Holtkamp emphasized his commitment to implement the construction of ITER on schedule and on budget. "The SOFT conference was my first exposure to the international Fusion Community and associated industries. It certainly was an opportunity to learn about the status of Fusion in general and also about open issues with ITER. At the moment, we are clearly in a phase of transition from a research project to a construction project."

Jérôme Pamela, EFDA leader, spoke about the JET programme in support of ITER. Plans for an ITER-like wall and for fully integrated ITER-relevant plasma scenario's, in addition to the ability to work with the real deuterium-tritium fusion fuel, will make sure that JET plays a major role in supporting ITER by preparing adequate plasma operation.

A Round Table on *ITER industrial participation and procurement* was held, chaired by the former French research minister François d'Aubert and attended by Maurizio Gasparotto (EFDA Associate Leader for Technology), Angelo Airaghi (chairman of Ansaldo Energia, Finmeccanica), Marcel Gaube (EFET), Jean-Philippe Girard (ITER), Norbert Holtkamp (ITER), and Herkko Plit (TVO, Olkiluoto). The main topic of discussion was the management of risks in ITER, which are very specific with the in-kind procurements by seven Parties. Mr. d'Aubert stressed that "one of the first tools to develop is communication. The interfaces between the partners need to be very clearly defined". Holtkamp underscored that the physical distances need to be managed, and that great care needs to be taken to make sure everyone understands each other: "The Earth is round, which is an issue when you want seven parties around the table."

Captivated audience during the SOFT conference in Warsaw, Poland

On the topic of division of responsibility, it was agreed that the ITER Organisation has the responsibility for the overall technical design, installation and operation of ITER and will approve the technical specifications. Holtkamp stressed that in cases where procurement sharing has led to possible difficulties in the integration of designs, it may be useful to form inter-Party consortia to solve the resulting complicated interfaces.

In the course of the five-day conference, a total of fifty oral presentations covered a broad range of subjects, from experimental fusion devices, plasma control and diagnostics, to plasma facing components, socio-economics of fusion, materials technology and future fusion power plants conceptual studies. As was to be expected, the ITER project was a focus of many of the presentations. During the poster sessions a total of 440 posters were displayed, which drew a large crowd.

The organisation of this years' SOFT conference by the Polish Euratom Association IPPLM was greeted by all participants as a great success. The next conference will be held in Germany, near Greifswald. ■

Education

Explaining nuclear fusion to students is quite a challenge. Around Europe, Associations attract the next generation of fusion scientists, with innovative methods and in a very personal way.

Fire-fighter or fusion scientist?

How do you attract the kids´ interest in science and fusion: invite them to the cinema and take them on a world-tour to the frontiers of science. In July, more than 80 students, pupils and teachers from schools in and around Munich took the chance and attended the live video conference that linked to four leading European research institutes, CERN in Geneva, ESO in Chile, JET in Culham and the joint laboratories of EMBL, ILL and ESRF in Grenoble. The videolink was part of this year's European Open Science Forum (ESOF) in the Deutsches Museum, Munich, and was organized by EFDA as an EIROforum activity. Its intention was to give schoolchildren and students the possibility to communicate with representatives of the scientific community and by doing so hopefully raise their interest in research and perhaps a scientific career.

After a visit to a huge underground cavern in CERN, home of the new Large Hadron Collider, and to the cold Atacama desert in Chili, where ESO builds it's telescopes, the audience in Munich connected to the control room at the Joint European Torus (JET) at Culham, where the two physicists Marco de Baar and Sandra Grünhagen explained the principles and the aims of fusion research. “When will fusion be ready for commercial use”, the audience wanted to know. “What is work like at an international place like JET? And, is there a chance for engineers to participate?”

After a final stop in Grenoble, where Christoph Müller explained live from his lab about the structure of biological molecules, the trip to the frontiers of science returned to the cinema theatre in Munich. Connecting a young audience live to researchers across the globe proved to be a very effective way of communicating the excitement of doing research, and giving a taste of what it means to be a scientist.

Rolf Landua from CERN, moderating the video conference. Photo: Hans-Hermann Heyer

Audience attending the live video conference, organized by EFDA. Photo: Hans-Hermann Heyer

A lesson from the “kidsbits” program, organized by IPP.

Bringing fusion to the classroom

Since 2004, selected scientists and special skilled staff of the Max-Planck-Institute for Plasma Physics in Garching tour around schools and kindergartens in the Munich region, teaching pupils the basics of fusion. But, first of all Dr. Elisabeth Wolfrum and her colleague Dr. Axel Kampke bring the kids down to earth. “How much energy would you say does the oven in your kitchen at home need? And how much energy would you guess do we all together use per year?”. The 13 to 14 year old boys and girls

Education

of a school in Garching, were primed by their teachers before the visit, and are quick to provide the right answer. A special chair game follows, giving the children a feeling for the extreme variation of energy consumption in different parts of the world.

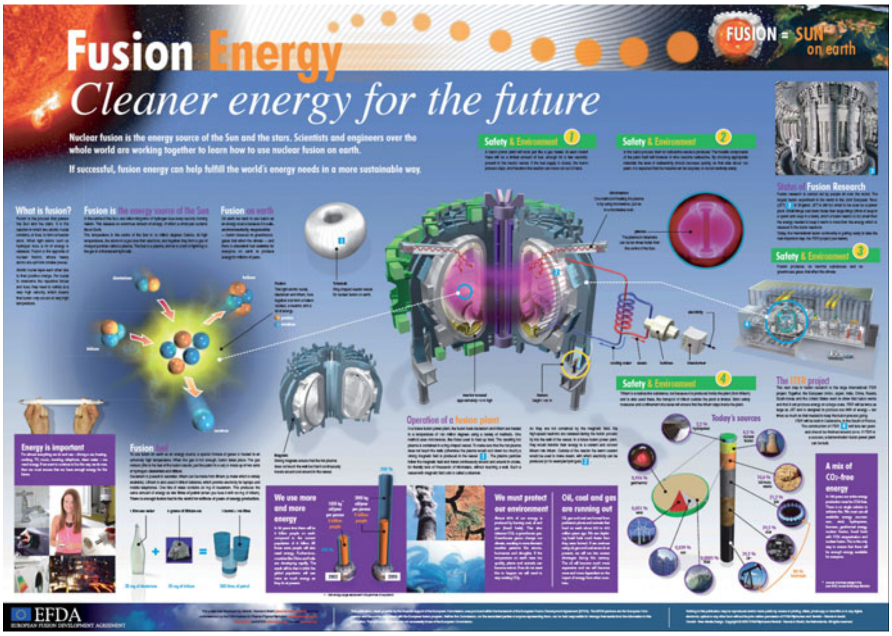
After the game, it is time for serious matters: “Attention, now it is time for some physics! What do you know about atoms!”.

“The project is a big success”, Ute Schneider-Maxon, initiator of the “kidsbits”-program, says. More than 24 lessons have been taught so far, the 2006 tour is sold out and vacancies for next year are already rare.

Towards the end of the lesson, it is time for the kids to interrogate the scientists. "So, how exactly does the plasma get inside that thing called tokamak, that has a very similar shape to the new Munich football arena", the kids asked, and "how much energy will ITER produce? And by the way - how much does a physicist earn?"
www.ipp-kidsbits.info

Using a professional actor

Prof. A. Tom and his team of professional actors were the star of the latest Fusion EXPO, which was shown as part of a two-day seminar on ITER at the EFDA Barcelona site. Guided by the weird professor, the youngsters were introduced to the basics of the world energy problem and the potential of fusion energy. ■



New Educational Poster

A new educational poster on „Fusion Energy – Cleaner Energy for the future“ is available now. Teachers can order A0 copies of this poster by contacting Aline Dürmaier. A PDF version of the poster, in an expanding number of languages, can be downloaded from the multimedia section of the EFDA website.
aline.duermaier@efda.org

Prof. A. Tom and his team, performing in Barcelona.

Portrait

The lost story of the Russian scientist Oleg Lavrentiev

This is the story of a young Red Army soldier who writes a letter to Stalin suggesting the use of thermonuclear synthesis for industrial purposes, who is then invited to Moscow and who prompts the later Nobel Prize Winners Andrei Sakharov and Igor Tamm to the idea of the "magnetic thermonuclear reactor". After being kept in the Kremlin´s archives for the last 50 years, Oleg Lavrentiev´s notes have recently reappeared.

Oleg Lavrentiev was born on July 7, 1926, in Pskov, into a family of peasant origin. In school he got so exited about the possibility of initiating a nuclear chain reaction using Uranium isotopes that the 15 year old decided to devote his life to study nuclear physics. But the war disrupted his plans. In 1945 sergeant Oleg Lavrentiev was transferred to Sakhalin Island where he had the opportunity to borrow scientific literature from the library of his regiment and attend evening classes. In May 1949 he graduated from school, having covered three grades in one year.

When the president of the United States, Harry Truman, called on the American scientists to speed up the work on the hydrogen bomb the following year, the ambitious soldier took a courageous next step. He wrote a letter to Stalin, declaring that he knew how to build the hydrogen bomb. No reply arrived, which Lavrientiev attributed to the fact that most likely it had got lost in the flood of congratulations to Stalin´s 70th anniversary.

Lavrentiev didn´t give up. Several months later he wrote another letter, this time to the Central Committee of the Communist Party of the Soviet Union. And this time the reply was prompt: Moscow ordered that the soldier be assigned a guarded room where he was to write his ideas down on paper. On July 29, 1950, the single-copy manuscript was delivered by secret mail to Moscow. Inside the "classified" envelope were his notes for the construction of the hydrogen bomb and a second proposal towards the use of the nuclear fusion reaction by means of electrostatic confinement of deuterium nuclei.

One month later, in August 1950, Lavrentiev requested to be demobilized from the military service and enrolled at the Moscow State University. Shortly after, he was asked once more by the Central Committee to write down his ideas on thermonuclear synthesis. Lavrantiev did as he was told and in January the following year he was asked to come to the Kremlin.

"On the minister´s desk laid a paper, beautifully printed and bound", as Lavrentiev remembered later. Besides the desk there stood Andrei Sacharov.

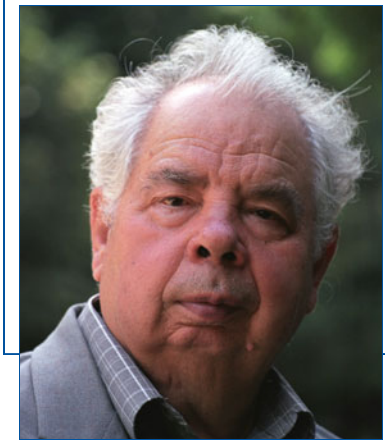
Sacharov was to review Lavrentievs´ work. Sacharov was not happy with the long ranges of particles, which would inevitably lead to undesirable interactions of high-energy particles with the construction materials. "But", he admitted, "the author formulates a very important and not necessarily hopeless problem."

In his memoirs, Sacharov later stated: "I was greatly impressed by the originality and boldness of those ideas that were produced independently, long before any publications on the issue started to appear. [...] The first vague ideas on magnetic thermal insulation started to form, while reading his letter and writing the referee report. [...] Lavrentiev´s work was an impetus to enhance the research on magnetic thermal insulation of high-temperature plasma conducted by myself and Tamm."

By October 1950, Sacharov and Tamm completed their first evaluations of a magnetic thermonuclear reactor, supported by Igor Kurchatov. The rest is well known history. For Lavrentiev, things didn´t turn out bad either. He was granted privileges such as a larger scholarship, a furnished room, delivery of any scientific literature he needed and paid tutors. However, Lavrentiev, who in May this year was awarded the title "Honorary Worker of Science and Technology of Ukraine", never made it to the spotlight of science. Until now, his story is only known to a small circle. It only became public when the once highly classified documents were found in the Kremlin´s archives in 2000. The Russian scientist Boris Bondarenko was one of the few to comment on Lavrentiev´s fate: "The founders of Controlled Nuclear Fusion with the magnetic confinement of hot plasma in thermonuclear reactors are believed to be Andrei Sakharov and Igor Tamm. This is true, of course, but the fact that the name of Oleg Lavrentiev is practically never mentioned in this context is certainly unfair."

Oleg Lavrentiev and his family today live in Kharkov where he still passionately works on his ideas. Lately he has defended his dissertation on electrostatic traps. This July he celebrated his 80th birthday.

This article is based on articles by Boris Bondarenko and Vitali Shafranov, both published in Physics Uspekhi, 44(8), 2001



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