

**Implementing Agreement for Cooperation in Development  
of the Stellarator-Heliotron Concept**

**2010 Executive Committee Annual Report  
to the Fusion Power Coordination Committee**

**January 2011**

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## **EXECUTIVE SUMMARY**

The present report overviews the scientific and technical progress achieved in 2010 by the parties to the Stellarator-Heliotron Concept Implementing Agreement, who have greatly benefit from its international collaborative framework. The document reports the collaborations in 2010 and the parties' research plans for 2011, including technical reports on 2010 activities.

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# **1 JOINT ACTIVITY: COORDINATED WORKING GROUP MEETING (CWGM) FOR STELLARATOR-HELIOTRON STUDIES**

The Coordinated Working Group Meeting (CWGM) for Stellarator-Heliotron Studies has been continuously held since its 1<sup>st</sup> meeting in Kyoto in Sep. 2006. The main long-term goals of CWGM activity were specified as to identify critical issues for helical systems, to perform thorough and critical assessment of data, and to define a data base for system/reactor studies. These goals can be achieved through obtaining the comprehensive, complementary and deductive perspectives to provide highly reliable extrapolations. The helical system research by exploiting the diversity of the three-dimensional nature of magnetic configurations provides the best opportunity to achieve this through joint comparative studies. The CWGM has offered the appropriate forum to accomplish this, and has been held typically in between the major international conferences, such as the IAEA fusion energy conference (IAEA-FEC) and the international Stellarator-Heliotron workshop (ISHW), to facilitate collaborative research documented in joint papers.

The 7th CWGM was held from Jun 30 - Jul 2, 2010 at IPP Greifswald being a virtual meeting at the same time. This format opened the door for remote presentations which contributed much to the documentation of data on the other hand, the specific work and ideas for joint activities befitted much from face-to-face discussions. Purpose of the meeting was to align ongoing cooperation and to discuss strategies leading to a more comprehensive inter-machine comparison of Stellarators-Heliotrons.

About 28 local attendees and 20 remote contributors participate. Working sessions to prepare joint papers have been held. The two topics being prepared for the forthcoming IAEA-FEC, H-mode studies in 3-dimension (or Stellarator-Heliotron devices (Hirsch et al.) and magnetic topology (Narushima et al.) have been significantly benefited from the inter-machine comparison. A report on a recent EPS paper (Ramisch et al.) on the quite new edge turbulence database initiated a first systematic data assessment. Interestingly, this activity found significant contributors from the tokamak community (ASDEX Upgrade, MAST) as well. Promising outcome with regard to indications of universal scaling behavior showed the benefit of comparative studies. And new ideas for follow-up papers have been formulated showing a long-term perspective of the studies.

Reports on the progress of MHD data bases, high-beta and energetic particle studies have been given. In a technical session, data base issues have been discussed also covering issues related to the comparison of tokamaks and 3d devices. This activity is intended to link the technical documentation of tokamaks with 3d devices and is considered to be step towards comprehensive, concept independent documentation of fusion devices. The cooperation with ITPA working groups has also been covered in a round table discussion resulting in an agreement to propose reviews on relevant 3d physics to the chairmen of the ITPA topical groups.

Following the working sessions, ideas for joint experiments and analysis proposals were discussed and work-plans have been developed. In addition to activities related to the working session, experiments on LHD have been called/discussed and the status

of ongoing activities (field-line measurements, divertor investigations) has been reported. Moreover, initiated by successful benchmarking activities from the International Cooperation on Neoclassical Transport (being reported in a joint session with the ICNTS collaboration), proposals for the validation of the neoclassical transport models have been agreed. For the database activity and the physics documentation of 3d devices, this inter-machine physics study is a new quality on the way to a comprehensive physics basis of 3d reactor concepts.

The 8th CWGM will be held in Japan at NIFS (Toki, Japan) in March 2011.

**A list of joint papers (2010), originated from CWGM activity.**

[17<sup>th</sup> International Stellarator/Heliotron Workshop (2009)]

- M.Hirsch et al., “Overview of LH-transition experiments in helical devices”, Contributions to Plasma Physics, 50 (2010) 487-492.
- T.Akiyama et al., “Status of a stellarator/heliotron H-mode database”, Contributions to Plasma Physics, 50 (2010) 590-593.
- H.Funaba et al., “Data Servers for the International Stellarator/Heliotron Profile Database (ISHPDB)”
- S.Sakakibara et al., “Remarks on Finite Beta Effects in International Stellarator/Heliotron Scaling”
- Y.Narushima et al., “Experimental study of the effect of poloidal flow on stability of magnetic island in LHD”, Contributions to Plasma Physics, 50 (2010) 529-533.
- D.Pretty et al., “Results from an international MHD data mining collaboration”
- B.Nold et al., “Inter-machine edge turbulence data base”

[23<sup>rd</sup> IAEA-FEC (2010)]

- M.Hirsch et al., “H-mode in Helical Devices” (Oral)
- Y.Narushima et al., “Experimental Study of Poloidal Flow Effect on Magnetic Island Dynamics in LHD and TJ-II” (Poster)

**Record of 1<sup>st</sup> to 7<sup>th</sup> CWGM.**

	Place	Date	# attendants (on record) <sup>1</sup>	Remarks: topics discussed etc. (alphabetic order unless marked)
1 <sup>st</sup>	Kyoto Univ.,	19-22, Sep. 2006	41	ISS04(CDB)→PDB, possible topics on collaborations, Joint meeting with Kinetic Theory in Stellarators
2 <sup>nd</sup>	IPP-Greifswald	4-6, Jun. 2007	26	edge/3D divertor, high-beta, impurity, iota/shear, momentum transport, neoclassical (NC) transport
3 <sup>rd</sup>	NIFS	23-24, Oct. 2007	34	current drive (CD), edge/3D divertor, flow/momentum transport, high-beta, high performance, impurity, iota/shear, NC, technical issues of DB, transport codes
4 <sup>th</sup>	CIEMAT	20-22, Oct. 2008	29	<u>reactor</u> , <u>collaboration on technology</u> , <u>3D effects</u> ,



				CD, data access, edge/3D divertor, high-beta, impurity, iota/shear, transport codes,  <u>turbulent transport codes (→ passed to discussions in expert group)</u>
5 <sup>th</sup>	Stuttgart Univ.	6-8, Jul. 2009	29	H mode & ELM, <u>turbulence studies (experiment)</u> , <u>usage of PDB</u> , data access, high-beta, iota/shear, 3D effects
6 <sup>th</sup>	PPPL	16, Oct. 2009	27	database, US experiments, turbulence studies, H mode & ELM, high-beta, iota/shear/ <u>island</u>
7 <sup>th</sup>	IPP-Greifswald	30 Jun-2 Jul, 2010	28 (20 on video)	database issues, edge turbulence database, H mode, magnetic topology, MHD & high-beta, transport code validation, 3D equilibrium, <u>joint experiments</u>

1: On-site/video participants may not be counted

## 2 AUSTRALIA

The H-1 heliac at the Australian National University is a three-period helical axis stellarator with a flexible magnetic topology that allows fundamental studies in plasma confinement and stability, turbulence and flows, and confinement transitions at moderate heating power. Because of its coil-in-tank construction, the device is an ideal test bed for the development of advanced active and passive imaging diagnostic technologies from microwave through to optical frequencies.

In 2010, work began on the ~US\$7M upgrade of the H-1 facility, now known as the Australian Plasma Fusion Research Facility. The funding, under the Australian Government's Super Science Scheme is earmarked for infrastructure upgrades over the period 2010-2013.

Enhancements to the Facility will enable future growth of Australian capability in fusion science and engineering, and as a focus for collaboration within the Australian community, will support the development of world-class diagnostic systems for application to international facilities in preparation for ITER. The upgrade will include new heating and diagnostic systems and vacuum and data system enhancements. A new single point of contact for data access, free of firewall restrictions has been established to provide simple access to the full range of H-1 data from summary and descriptive information to raw data (<http://h1svr.anu.edu.au>).

Improved configurational flexibility will deliver access to magnetic configurations suitable for development of divertor plasma diagnostics for future devices. H-1NF has allowed studies of large-device physics on a university-scale machine, including L-H mode transitions, magnetic island studies, and the characterisation of Alfvénic modes. While this year's activities were dominated by implementation of the upgrade, research emphasis was on gas puff imaging and synchronous imaging, and investigation of the radial structure of Alfvén modes. As a result of the upgrades, the future will see these and other basic studies extended to new parameter regimes.

As part of a longer term strategy that aims for an Australian involvement with ITER, some of the funding will support the development of a small linear, high power-density satellite device that can utilize the H-1 heating and power systems. This will facilitate development of diagnostics for plasma wall interactions and for characterizing advanced high temperature materials.

A Memorandum of Understanding between The Australian National University and the Australian Nuclear Science and Technology Organisation (ANSTO) was signed in the presence of the Minister for Innovation, Industry, Science and Research, Senator Kim Carr. This enables the two institutions to collaborate across research fields. Under this arrangement, a one day workshop on potential for collaboration on materials for fusion reactors was held at the ANSTO site in Sydney.

Dr. Cormac Corr won a prestigious "Future Fellowship" to support a new experimental research program in plasma surface interaction and basic plasma physics exploiting the materials diagnostic facility. Dr. Matthew Hole of the Plasma Theory and Modelling Group, who took up his Future Fellowship earlier this year, won the IUPAP Young Scientist of the Year Award in Plasma Physics. The department is privileged to

host these fellowships, which support high achieving mid-career researchers in becoming future research leaders.

The group continues to grow following the merging the Plasma Theory and Modelling group, led by Prof. Dewar, with the Plasma Research Laboratory. This linkage recognizes common interests and goals, provides an excellent foundation for exploiting the upgraded Facility and new projects of common interest. Drs. Michael Fitzgerald and David Pretty joined the PRL this year, and the success of a joint proposal will see an additional Postdoctoral Fellow join us in 2011. Two more short term positions in diagnostic development and plasma modelling have been offered.

## 2.1 International collaborations in 2010

### - Multilateral Collaborations

International collaboration on MHD and configuration studies under the IEA agreement has grown to the point where our datamining techniques have now been implemented on five large stellarators, including the largest, LHD in Japan and is being extended to data from the JT60U flagship tokamak in Japan.

Using a new version of the data mining technique recently developed by D. Pretty, a collaboration between B. Blackwell, D. Pretty (ANU), S. Yamamoto, K. Nagasaki and S. Sakakibara (Japan), E. Ascasibar, R. Jiménez-Gómez and D. Pretty (Spain) has successfully classified data from thousands of shots data into a small number of clusters of similar modes.

One and two-dimensional coherence imaging (CI) systems developed by Prof Howard and his advanced imaging group at ANU underpin collaborations with the USA, EU members and Korea, which are supported by international agencies and the Australian Government. These include

(EU) Collaboration between the ANU and the FOM Institute for Plasma Physics (Netherlands) to undertake MSE imaging on the TEXTOR tokamak.

(US) With LLNL and General Atomics, application of Doppler CI systems for imaging flows in the DIII-D divertor and scrape-off-layer. These static systems utilise novel spatial-heterodyne interferometric techniques to capture the 2-D Doppler information.

(Korea) A 2D spatial heterodyne system installed on KSTAR in 2010 has produced very encouraging initial MSE imaging data.

In 2010, a new high frequency toroidal magnetic array was installed and first data obtained on H1, in collaboration with Drs. L. C. Appel of UKAEA Fusion and S. Yamamoto of Kyoto University who visited in April and May respectively.

A collaboration between ANU, MPIPP (J. Svensson), and the Culham Centre for Fusion Energy (L. C. Appel) has complementary stellarator and compact toroidal components. The project, which is supported by an Australian International Science Linkages grant, aims to develop Bayesian techniques for the integration of various diagnostic data, building on pioneering development of the technique on W7-AS. In 2010, implementation of the technique for current tomography on MAST was completed using

motional Stark effect and magnetic data. Work progressed on Bayesian inference of temperature, density and rotation profiles using Thomson Scattering and charge exchange recombination spectroscopy. Other work included a hybrid Tikhonoff-regularisation /cross-validation technique to remove rogue diagnostic data, a force balance verification tool, a Grad-Shafranov constraint, and use of diamagnetism data to infer poloidal current.

For H-1, a set of MHD modes with low spatial resolution was generated using CAS3D: this is being used to implement a Bayesian approach to infer mode structure in H1. Dr L. C. Appel of CCFE spent 4 weeks at ANU further developing and implementing a diamagnetic loop diagnostic, and architect of the Bayesian modelling framework MINERVA, Dr Svensson, spent 6 weeks at ANU testing force balance models, and project leader M. J. Hole spent one week at CCFE. This work featured in invited talks by Dr. Hole (ICPP, 2010) and Svensson (EPS, 2010). As part of a collaborative visit for this project, Dr Sergei Sharapov (CCFE, UK) joined Drs Hole and Corr in presenting a series of lectures at a three day Winter School on Industrial and Fusion Plasmas at the ANU.

#### **- Collaborations with EU**

A collaboration between C. Nührenberg of MPIPP Greifswald, J. Bertram, R. Dewar, B. Blackwell, J. Howard, M. McGann, G. Von Nessi and M. Hole of the ANU is comparing the experimental observations of MHD activity with eigenvalue calculations using the CAS3D code. J. Bertram has developed a cylindrical model with helical field averaging to describe a candidate basis set of discrete Alfvén eigenmodes in H1, and is completing a scan of CAS3D runs modelling H1 on the ANU supercomputer node of the Australian Computing Infrastructure Facility.

A new collaborative project between CCFE (S. Sharapov, K. M<sup>C</sup>Clements, S. Pinches) and the ANU (M. Hole, R. Dewar) commenced in the area of burning plasma physics, funded by an ARC Discovery Grant and an ARC Future Fellowship awarded to M. Hole. The project aims to non-perturbatively model the effect of energetic particles such as fusion alpha-particles on the equilibrium, wave-mode structure, and wave-mode induced confinement loss. In 2010 a postdoctoral fellow, Dr Michael Fitzgerald, was appointed in this area. To date, his initial research focus has been on the calculation of anisotropy in MAST plasmas, and computing the impact of rotation in high beta plasmas

#### **- Collaborations with JAPAN**

Prof. Howard and Dr. Hatae (JAEA) on imaging birefringent interferometers for Thomson scattering.

Dr. Satoshi Yamamoto visited H-1 in May for collaboration on datamining MHD data.

Dr. Blackwell visited the Heliotron-J group in November, presenting an invited talk to the International Symposium of Advanced Energy Science and collaborating with colleagues at Kyoto and NIFS on data mining MHD data.

### **- Collaborations with USA**

An existing collaboration between the ANU (R. Dewar, M. Hole, M. McGann, A. Gibson, G. Von Nessi) and Princeton PPL (S. Hudson) on the development of a new variational principle - multi relaxed MHD (MRXMHD) - attracted invited talks at the International Conference on Plasma Physics and the Toki Fusion meeting. In related work, progress was made on reconciling differences in almost invariant tori (imperfect magnetic surfaces) produced using quadratic-flux-minimizing (QFMIN) surface method and the action-gradient-based ghost surface method, and a project to study the ballooning stability of barrier surfaces in the MRXMHD model commenced. In 2010, work on the SPEC MRXMHD code (S. Hudson) focused on barrier selection and demonstrated calculation of multi-interface MRXMHD states for weakly toroidally asymmetric plasmas.

### **- Workshops and Conferences**

At the 2010 Stellarator Executive Committee meeting it was decided to hold the next ISHW in Australia in early 2012, with Dr. B. Blackwell as Chair. The APPTC committee agreed to host the APPTC Conference in Australia with Dr M. Hole as Chair, co-located with the ISHW meeting.

It was agreed that the 9th Japan-Australia Plasma Diagnostics Workshop be held in Japan in February 2012.

Prof. Dewar led an Australian government funded mission of seven Australian scientists to conduct a feasibility study of a multilateral collaboration on the KSTAR superconducting tokamak including POSTECH University and the Korean National Fusion Research Institute. Prof. Howard and Dr. Hole have ongoing collaborations on imaging MSE and CXRS systems and TAE excitation.

Australian research was well represented at the 21st IAEA Fusion Energy Conference, in Korea in Daejeon, with an overview poster on H1 research presented by Dr. Blackwell, and other contributed work presented as posters. An Australian (Dr Hole) also attended the 49th IFRC meeting and presented research highlights.

## **2.2 Future Research Plans**

Configuration studies will focus on the effects of Alfvén-driven instabilities and turbulence which can be moderated through fine control of the H-1 magnetic configuration. Plasma density and polarimetry interferometers, and multi-channel spectroscopic detectors will provide profile information for configuration studies and mode structure of Alfvénic instabilities.

International collaboration on CI optical systems for spectro-polarimetric imaging will continue in 2011 and beyond. In the coming year, this work will embrace the following activities:

Following successful first data, a second Doppler imaging camera is planned for divertor studies on DIII-D, and a custom designed system will be permanently installed

on KSTAR for imaging CXRS and MSE measurements.

Combined with fast, gated CCD cameras, newly developed passive spatial heterodyne CI systems will be deployed for synchronous detection of velocity distribution function perturbations associated with magnetic fluctuations in the H-1 heliac.

In the area of coherence imaging technology development and applications, the advanced imaging group anticipates a number of developments in coming years:

In future years there are plans to deploy CI imaging systems for edge physics studies in the W7-X stellarator. The recent success of Doppler imaging on the DIII-D tokamak divertor is a valuable guide in future planning

We are developing multiple-carrier spatial heterodyne CI systems that should allow extended capability for imaging of more complex spectral scenes and exploring Zeeman-assisted Doppler tomography of inhomogeneous magnetized plasma such as the tokamak divertor.

Utilizing the planned linear satellite device, we aim to trial imaging Stark effect and some new concepts in optical radar-based range sensing with the ultimate goal (subject to appropriate funding) to develop a prototype imager for monitoring tile erosion in high power fusion devices.

The collaboration with PPPL on MRXMHD will expand to include scientists from RFX-mod (Dr Dominique Escande), CCFE (Prof. Richard Dendy) and H1 (Dr Boyd Blackwell) through an Australian Research Council Discovery Grant. The new project will apply the MRXMHD code SPEC to describe helical states in RFX-mod, determine whether ELM events can be described by MRXMHD relaxation, and investigate control of magnetic surfaces between different relaxed regions via external coils. A postdoc will be appointed in this area in 2011. In related work, a Masters student, David Barmaz from CRPP in Switzerland will focus on completing the MRXMHD ballooning mode stability calculation.

In 2011 Dr Michael Fitzgerald will be seconded to CCFE to implement the effects of anisotropy and rotation into a tokamak stability code, and develop expertise with a wave-particle interaction code, HAGIS. The burning plasma project will also be extended via a DAAD ANU-IPP small grant to investigate Alfvén wave growth in H1 plasmas using the kinetic code CAS3D-K and its successor CKA/EUTERPE. A longer term objective is to expand our kinetic modelling activity to 3D.

The Australian Helic program at the ANU has produced several technological spin-offs that are now attracting support independent of the fusion program. These include technology for long distance, non-line-of-sight VHF digital wireless communications in rural Australia (the BushLAN project), and optical coherence imaging (CI) spectroscopy systems for use in process control in steel production.

Finally, the Australian fusion science community will continue endeavours to secure funding to develop prototype diagnostic concepts using the new capabilities of the H-1 facility for one or more plasma diagnostics for ITER.

## **3 EU**

### **3.1 GERMANY**

#### **3.1.1 International collaborations in 2010**

##### **- Collaborations with EU**

- 1) H. Thomsen (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 24.01. – 29.01.2010: participation in the Plenary TFS 1 Meeting
- 2) I. Ksiazek (Institute of Physics, Ople University, Opole) to IPP Greifswald, 24.01. – 05.02.2010: cooperation concerning the development of the C/O-monitor diagnostic for W7-X
- 3) W. Schneider (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 01.02. – 18.02.2010: NPA calculations at MAST
- 4) G. Papp (Budapest University) to IPP Greifswald, 01.02. – 11.02.2010: cooperation on runaway dynamics in magnetostatic perturbed fields
- 5) T. Feher (IPP) visited Chalmers Göteborg, 17.02. – 26.03.2010: Disruption mitigation with doped pellets
- 6) B. McMillan (CRPP&EPFL Lausanne) to IPP, 21.02. – 24.02.2010: Algorithms for PIC simulations
- 7) H. Thomsen (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 21.02. – 26.02.2010: TFE General Meeting
- 8) R. Koenig (IPP Greifswald) visited ITER, Cadarache, 28.02. – 04.03.2010: ITER in-vessel diagnostics meeting
- 9) B. Bieg (Akademia Morska, Szczecin) to IPP Greifswald, 04.03. – 05.03.2010: Analysis of microwave propagation in the frame of the quasi-isotropic approximation aiming at plasma diagnostics
- 10) I. Ksiazek ((Institute of Physics, Ople University, Opole) to IPP Greifswald, 03.03. – 18.03.2010
- 11) M. Jakubowski (IPP Greifswald) visited Centre for theoretical Physics, Marseille, 21.03. – 27.03.2010
- 12) R. Kleiber (IPP) visited CIEMAT Madrid, 22.03. – 31.03.2010: cooperation on the gyrokinetic code EUTERPE
- 13) M. Turnyanskiy (CCFE, Culham) to IPP Greifswald, 11.04. – 14.04.2010
- 14) B. Dudson (University of York) to IPP Greifswald, 30.04. – 08.05.2010: collaboration on fluid turbulence and stability
- 15) A. Mishchenko (IPP) visited CRPP&EPFL Lausanne, 01.05. – 05.05.2010: Gyrokinetic code development

- 16) A. Kus (IPP Greifswald) visited CIEMAT, Madrid, 01.05. – 21.05.2010
- 17) V. Szabó, S. Tulipan (Budapest University of Technology and Economics EURATOM-HAS) to IPP Greifswald, 12.05. – 12.06.2010
- 18) H. P. Laqua, T. Stange (IPP Greifswald) visited CIEMAT, Madrid, 17.05. – 21.05.2010: Electron Bernstein Wave Experiments at the TJ-II Stellarator
- 19) H. Braune (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 17.05. – 29.05.2010 and 06.06. – 19.06.2010: EC4JET Feasibility study
- 20) J. Andersson (IPP) visited Chalmers Göteborg, 24.05. – 19.06.2010: Zonal flow in drift-wave turbulence
- 21) M. Drevlak (IPP) visited Chalmers Göteborg, 06.06. – 12.06.2010: Runaway electron mitigation
- 22) P. Pedreira (University Carlos III, Madrid) to IPP Greifswald, 28.06. – 29.06.2010: 3<sup>rd</sup> Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO<sub>2</sub>-Interferometer for W7-X
- 23) L. Esteban-Hernandez, M. Sanchez (CIEMAT, Madrid) to IPP Greifswald, 28.06. – 29.06.2010: 3<sup>rd</sup> Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO<sub>2</sub>-Interferometer for W7-X
- 24) S. Kasilov (University of Graz, Austria) to IPP Greifswald, 01.07. – 31.07.2010: collaboration on kinetic modelling of plasma transport
- 25) J. Wolowski, L. Ryc, S. Jablonski, J. Kaczmarczyk, W. Figacz, M. Kubkowska, A. Czarnecka (Institute of Plasma Physics and Laser Microfusion, Warsaw), 13.07. – 14.07.2010: x-ray diagnostics for W7-X
- 26) W. Kernbichler (University of Graz, Austria) to IPP Greifswald, 17.07. – 3.07.2010: Colaboration on ECRH and ECCD
- 27) A. Werner (IPP Greifswald) visited ITER, Cadarache, 25.07. – 28.07.2010: ITER Diagnostic Conceptual Design Review
- 28) R. Wolf (IPP Greifswald) visited ITER, Cadarache, 27.07. – 30.07.2010: Concept Design Review ITER
- 29) J. Preinhaelter, J. Urban (Institute of Plasma Physics, Prague) to IPP Greifswald, 15.08. – 18.09.2010
- 30) V. Tribaldos (Universidad Carlos III de Madrid) visited IPP Greifswald, 18.08. – 02.09.2010: International collaboration on neoclassical theory
- 31) H. v. d. Brandt (Technical University, Eindhoven) visited IPP Greifswald, 01.09. – 30.11.2010: Measurement of the power flux density in a microwave stray radiation field
- 32) J. Connor (Culham Laboratory) to IPP Greifswald, 05.09. – 18.09.2010:



## Microinstability theory

- 33) L. Esteban-Hernandez (CIEMAT, Madrid) to IPP Greifswald, 05.09. – 07.10.2010
- 34) P. Carvalho (IPFN/ IST, Lissabon) to IPP Greifswald, 06.09. – 02.10.2010
- 35) J.L. Velasco Garasa (CIEMAT Madrid) to IPP Greifswald, 13.09. – 09.10.2010: cooperation on benchmarking momentum correction techniques
- 36) H. Oosterbeek (Technical University, Eindhoven) visited IPP Greifswald, 15.09. – 18.09.2010: Measurement of the power flux density in a microwave stray radiation field
- 37) N. Bertelli (FOM Rijnhuizen) to IPP Greifswald, 27.09. – 02.10.2010: collaboration on application of ECRH and ECCD for tearing mode control with a particular view on ITER
- 38) M. Krychowiak (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 29.09. – 12.10.2010: Development of diagnostic analysis software
- 39) W. Schneider (IPP Greifswald) visited RFX Padova 04.10.-15.10.2010: Optimisation and enhancement of sensitivity of an ACORD22-analyser for neutral particle diagnostics.
- 40) I. Ksiazek ((Institute of Physics, Ople University, Opole) to IPP Greifswald, 14.10. – 29.10.2010 and 01.12. – 17.12.2010: cooperation concerning the development of the C/O-monitor diagnostic for W7-X
- 41) H.P.Laqua(IPP Greifswald) visited INFN-LNS , Catania, Italy 18.-19.10.2010, ECRH in ion sources
- 42) H. Braune (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 07.11. – 19.11.2010: EC4JET Feasibility study
- 43) V. Erckmann (IPP Greifswald) visited Culham Centre for Fusion Energy, Culham, 15.11. – 20.11.2010: Project Board Meeting ECRH feasibility study
- 44) A.L. Fraguas (CIEMAT Madrid) to IPP Greifswald, 15.11. – 27.11.2010: cooperation on equilibrium calculations in TJ-II configurations
- 45) P. Helander (IPP) visited CIEMAT Madrid, 24.11. – 26.11.2010: EPS Board Meeting
- 46) H. Oosterbeek (Technical University, Eindhoven) visited IPP Greifswald, 28.11. - 30.11..2010: Measurement of the power flux density in a microwave stray radiation field

## - Collaborations with Japan

- 1) T. Akiyama (NIFS) to IPP, 28.06. – 29.06.2010: 3<sup>rd</sup> Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO<sub>2</sub>-Interferometer for W7-X.
- 2) T. Aiyama, H. Funaba, Y. Narushima, R. Seki, H. Tanaka, H. Yamada, M. Yokoyama

(NIFS) to IPP, 30.06. – 02.07.2010: 7<sup>th</sup> Coordinated Working Group Meeting/  
Cooperation within the International Stellarator Profile Database

- 3) P. Drewelow (IPP Greifswald) visited NIFS, Toki, 03.07. – 31.07.2010 and 16.09. – 31.12.2010
- 4) M. Hirsch (IPP Greifswald) visited Kyoto University and, Toki, 2.-10.10.2010 NIFS: cooperation on H-mode in Helical Devices
- 5) M. Jakubowski (IPP Greifswald) visited NIFS, Toki, 07.10. – 19.11.2010: analysis of LHD experiments
- 6) J. Geiger (IPP) Greifswald) visited NIFS, Toki, 17.10. – 30.10.2010: Development and benchmarking of the 3D equilibrium code HINT2 and his application to Wendelstein 7-AS and Wendelstein 7-X
- 7) Prof. Nagasaki (Kyoto University) visited IPP-Greifswald 21.11-27.11.2010: ECRH physics modeling and experiments.
- 8) S. Murakami (NIFS, Toki) to IPP, 14.12. – 18.12.2010: ambipolar radio-electric field

- **Collaborations with Russia**

- 1) P. Bagryansky (Budker Institute Novosibirsk) to IPP, 28.06. – 29.06.2010: 3<sup>rd</sup> Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO<sub>2</sub>-Interferometer for W7-X
- 2) U. Herbst, T. Richert (IPP) visited Budker Institute Novosibirsk, 11.04. – 16.04.2010: technical consultations, control DNBI
- 3) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 21.02. – 21.04.2010 and 27.10. – 03.12.2010: collaboration on optimized stellarators
- 4) M. Isaev (Kurchatov Institute Moscow) to IPP Greifswald, 25.04. – 16.05.2010: cooperation on benchmarking VENUS-δf PIC code against CAS3D-K and Euterpe
- 5) J. Nührenberg (IPP) visited Kurchatov Institute in Moscow, 13.09. – 16.09.2010: Optimized stellarators

- **Collaborations with Ukraine**

- 1) Y. Kolesnichenko (Institute for Nuclear Research Kyiv, Ukraine) to IPP Greifswald, 09.05. – 28.05.2010: collaboration on fast particles

- **Collaborations with USA**

- 1) P. Catto (MIT Boston) to IPP, 07.03. – 13.03.2010: Transport theory
- 2) M. Landreman (MIT Boston) to IPP, 07.03. – 26.03.2010: Transport theory
- 3) M. Jakubowski (IPP Greifswald) visited General Atomics, San Diego, 02.05. – 30.05.2010: DIII-D experiments

- 4) K. Bartschat (Drake University, Des Moines) to IPP, 17.07. – 21.07.2010
- 5) J. Hanson (Auburn University) to IPP, 25.06. – 04.07.2010: V3FIT, VMEC2000 code
- 6) A. Boozer (PPPL) to IPP, 02.07. – 05.07.2010: Stellarator development
- 7) C. Biedermann (IPP Greifswald) visited Lawrence Livermore National Laboratory, Livermore, 03.08. – 13.09.2010
- 8) J. Baumgaertel (PPPL) to IPP, 04.08. – 21.08.2010: Gyrokinetic simulations for stellarators using the GENE and GS2 code
- 9) S. Hirshman (ORNL) to IPP, 05.09. – 10.09.2010: SIESTA code
- 10) D. Mikkelsen (LLLN) to IPP, 06.09. – 1.09.2010: Transport simulation
- 11) J. Geiger (IPP) visited PPPL, 13.12. – 17.12.2010: Trim coils, equilibrium reconstruction, magnetic configuration control

### 3.1.2 Conference participation

- 1) A. Dinklage: 6th Workshop on Fusion Data Processing, Validation and Analysis R, 25.01. – 27.01.2010, Madrid, Spain
- 2) G. Kuehner: Software Engineering Conference, 22.02. – 26.02.2010, Paderborn, Germany
- 3) H. P. Laqua: 16th Joint Workshop on Electron Cyclotron Emission and ECRH, 12.04. – 15.04.2010, Sanja, China
- 4) R. Burhenn, J. Cantarini, H. Dreier, M. Hirsch, M. Krychowiak, J. Svensson: International Conference on Plasma Diagnostics, 12.04. – 16.04.2010, Pont-à-Mousson, France
- 5) R. Koenig, P. Kornejew, D. Zhang: 18th Topical Conference on High-Temperature Plasma Diagnostics (HTPD), 16.05. – 20.05.2010, Wildwood, USA
- 6) M. Jakubowski: 19th PSI Conference, 24.05. – 28.05.2010, San Diego, USA
- 7) S. Marsen, M. Otte, W. Schneider, J. Svensson: 37th EPS Conference, 21.06. – 25.06.2010, Dublin, Ireland
- 8) J. Nührenberg, C. Nührenberg, T. Feher, K. Kauffmann and S. Braun (IPP) participated in the 37th EPS conference, 20.06. – 27.06.2010 in Dublin
- 9) H. Braune, Y. Turkin (IPP) visited Nizhniy Novgorod, 28.06. – 06.07.2010 for the 22<sup>nd</sup> Joint Russian-German Meeting on ECRH and Gyrotrons
- 10) P. Helander and A. Mishchenko (IPP) visited Cambridge, 18.07. – 29.07.2010 and 01.08. – 14.08.2010: Workshop “Gyrokinetics in Laboratory and Astrophysical Plasmas”
- 11) P. Helander, R. Kleiber and S. Braun (IPP) visited the Joint Lausanne – Varenna Workshop, 29.08. – 03.09.2010

- 12) H. Braune: International Conference on Infrared Millimeter, and Terahertz Waves, 05.09. – 10.09.2010, Rome, Italy
- 13) G. Michel, A. Spring: 26th Symposium on Fusion Technology, 27.09. – 01.10.2010, Porto, Portugal
- 14) M. Krychowiak: Atomic Data and Analysis Structure workshop, 03.10. – 06.10.2010, Armagh, Northern Ireland
- 15) Y. Feng, J. Geiger, M. Hirsch, H. Thomsen, R. Wolf: 23rd IAEA Fusion Energy Conference, 11.10. – 16.10.2010, Daejeon, Korea
- 16) A. Könies (IPP): 5th Meeting of the ITPA Energetic Particle Physics Topical Group, 18.10. – 20.10.2010, Seoul, South Korea
- 17) P. Helander (IPP) visited Mayrhofen, Austria, 06.12. – 08.12.2010 for the 18<sup>th</sup> European Fusion Physics Workshop
- 18) N. Marushchenko (IPP): EFDA Taskforce ITM Code Camp on WP2010 cross-project activities, 06.12. – 17.12.2010, Innsbruck, Austria

### 3.1.3 Participation in joint projects

#### - International stellarator/heliotron confinement data base

Coordinated Working Group: CWGM7, IPP Greifswald, 06.07. - 08.07.2009: contributions from A. Dinklage, S. Marsen, C. Beidler, H. Maaßberg, M. Hirsch, J. Geiger, A. Kus, M. Otte, M. Jakubowski, P. Drewelow

#### - International stellarator/heliotron profile data base

Contributions from A. Dinklage, J. Geiger, M. Hirsch, A. Kus, C. Beidler, H. Maaßberg, S. Marsen

#### - ITPA diagnostics

Contributions from R. König:

11.05 - 14.05.2010, Oak Ridge, TN, USA and 18.10. - 21.10.2010 Naka, Japan

Specialists Working Group on First Mirrors: M. Krychowiak

#### - ITPA confinement and transport

Contributions from A. Dinklage

### 3.1.4 Plans for 2011

#### - Planning stellarator/heliotron theory

- 1) Alexey Mischneko plans to visit IFS Austin/USA to work on fast-particle-driven instabilities

- 2) Michael Drevlak plans to visit Chalmers/Sweden to work on confinement of runaway electrons
- 3) Per Helander plans to visit Culham/UK to work on microstability in stellarators
- 4) Josefine Proll will visit York/UK to work on gyrofluid turbulence
- 5) Joachim Geiger plans to visit NIFS/Japan to work on magnetic equilibrium
- 6) Yuriy Turkin will visit Graz/Austria to work on transport modeling
- 7) Nikolai Marushchenko will visit Graz to work on ECRH and ECCD

- **Spectroscopic diagnostics**

- 1) Rainer Burhenn (IPP Greifswald), plans several visits at TEXTOR (FZJ) for transferring the X-ray spectrometer to W7-X and for modification of the HEXOS spectrometer support structure into a W7-X compatible one.
- 2) I. Ksiazek ((Institute of Physics, Ople University, Opole) plans several visits (each about 1-2 weeks) to IPP Greifswald in the frame of the cooperation concerning the development of the C/O-monitor diagnostic for W7-X

- **SX diagnostics**

Mutual visits between IPP and IST Lisbon are planned in the frame of the collaboration on fast online tomography and data acquisition systems (involving H. Thomsen, P. Carvalho).

- **IR diagnostics / collaboration with JET taskforce E1**

H. Thomsen will visit Culham Centre for Fusion Energy to continue the collaboration on the IR-camera data analysis within the JET EFDA-taskforce (~ 4 weeks at Culham).

- **Collaboration with NIFS**

M.W. Jakubowski will visit National Institute for Fusion Science, Toki in the frame of guest professorship fellowship to continue research on transport in stochastic boundary (3 months).

P. Drewelow will visit National Institute for Fusion Science, Toki to continue research on heat and particle fluxes in LHD (3 months).

- **Neutral particle diagnostics**

- 1) W. Schneider will visit RFX in Padova for about 2 weeks in order to continue CX-NPA measurements with an ACORD22-analyser.
- 2) W. Schneider will visit the MAST team of CCFE Culham for about 2 weeks. The main focus is to complete the studies on neutron influence on the performance of neutral particle diagnostics.

- 3) The development and construction of a diagnostic high energy neutral particle injector (RuDI-X) in collaboration with the FZ-Juelich and the Budker Institute (BINP) in Novosibirsk, Russia, will continue. Test of high voltage power supply, bending magnet power supply and the grid power supplies is planned. Manufacturing of injector components will be closed and the system will be assembled. Control system has to be installed with IPP support. T. Richert and U. Herbst (IPP Greifswald) plans to visit the Budker Institute (BINP) in Novosibirsk, Russia for this purposes 3 times for a few weeks.

- **Neutron diagnostics**

- 1) Mutual visits (about 2 per year, each about for 2-3 days) in the frame of collaboration with PTB Braunschweig on the neutron counter system for W7-X are planned to discuss the progress and the work plan of the project (involving A. Weller, R. Burhenn, R. König, W. Schneider). In addition, W. Schneider will visit PTB Braunschweig (about 8 times per year for 1 to 2 weeks) to engage in development of neutron monitoring systems and in MCNP calculations.
- 2) Mutual visits (about 1 per year for 2-3 days) in the frame of collaboration with IPPLM Warsaw on the neutron activation system for W7-X and neutron transport calculations are planned to discuss the progress and the work plan of the project (involving A. Weller, W. Schneider).

- **Microwave diagnostics**

- 1) Regular meetings with cooperation partners at Akademia Morska, Szczecin (MUS) and Szczecin University of Technology (SUT) are planned, about twice per year, Analysis of Microwave Propagation and Polarization effects in an inhomogeneous plasma aiming on the analysis of polarimetry in W7-X.
- 2) H. Dreier staying predominantly at TEXTOR (Juelich) until End of April 2010 will regularly report on the progress of Dispersion Interferometry as an option for W7-X.
- 3) H. Oosterbeek (Technical University of Eindhoven) + student(s) will visit IPP: Measurement of the power flux density in a microwave stray radiation field

- **International stellarator/heliotron profile data base**

M Hirsch, et all ... will participate in the CWGM8 at NIFS 08.-10.03.2011

A. Dinklage will support organization of CWGM8 in Toki 30.06-02.07.2010

A. Kus will visit NIFS for Scaling Studies

A. Kus and A. Dinklage will cooperate with K. Thomsen (CEC) on Tokamak/Stellarator comparisons

M. Hirsch will contribute to H-mode studies.

C. Beidler, A. Dinklage and H. Maaßberg will contribute to transport model validation studies (LHD, TJ-II, W7-AS)

S. Marsen will contribute to the Edge Turbulence Database.

- **Collaboration on ECRH, ECCD and ECE**

- 1) J. Urban and J. Preinhaelter will visit Greifswald for 4 weeks: Simulation with the EBW ray-tracing-code for the calculation of the EBW driven current and EBW emission at WEGA at 28 GHz OXB-heating regime for 0.5 T and 1T. The simulation will be extended to supra-thermal electron distributions
- 2) H. P. Laqua (IPP Greifswald) will visit TJ-2 CIEMAT (Spain) for 2 week: Participation on heating experiments with electron Bernstein waves with the realigned transmission line.
- 3) T. Stange (IPP Greifswald) will visit will visit TJ-2 CIEMAT (Spain) for 2 weeks: Participation on EBW-heating experiments.
- 4) Santo Gamino (INFN-LNS , Catania, Italy) will visit Greifswald for preparation of 14 GHz electron Bernstein wave heating experiments
- 5) Joint Russian German Workshop on ECRH and ECE, Garching, Stuttgart, Karlsruhe, Germany, 23.05. – 28.05.2011

- **Conference participation**

- 1) G. Kühner: Software Engineering 2011, 21.02. – 25.02.2011, Karlsruhe, Germany
- 2) T. Stange: DPG-Frühjahrstagung, 13.03. – 18.03.2010, Dresden, Germany
- 3) P. Drewelow, S. Marsen, R. Wolf: 5th Workshop on Stochasticity in Fusion Plasmas, 11.04. – 14.04.2011, Jülich, Germany
- 4) M. Krychowiak: 11<sup>th</sup> Workshop "Frontiers in Low-Temperature Plasma Diagnostics, 09.05. – 12.05.2011, Zinnowitz, Germany
- 5) M. Hirsch: Workshop on Microwave Reflectometry, May 2011, Padova, Italy
- 6) V. Erckmann: 19<sup>th</sup> Topical Conference on Radio Frequency Power in Plasmas, 01.06. - 03.06.2011, Newport, USA
- 7) H. Dreier, A.Kus, H. P. Laqua, R. Reimer, W. Schneider, T. Stange, D. Zhang: 38<sup>th</sup> European Physical Society Conference on Plasma Physics, 27.06. – 01.07.2011, Strasbourg, France
- 8) H. P. Laqua, V. Erckmann: 8<sup>th</sup> International Workshop on Storing Microwaves: Sources and Applications, 05.07. – 12.07.2011, Nizhny Novgorod, Russia
- 9) U. Neuner: International Symposium on Fusion Nuclear Technology, 11.09. – 16.09.2011, Portland, Oregon, USA
- 10) H. Braune, G. Michel: International Conference on Infrared, Millimeter, and Terahertz Waves, 02.10. – 07.10.2011, Houston, USA

- 11) W. Schneider: International Workshop on Fast Neutron Detectors and Applications, 06.11. - 12.11.2011, Ein Gedi, Israel.
- 12) M. Jakubowski, M. Otte, R. Wolf: 18<sup>th</sup> International Stellarator and Heliotron Workshop, 2011, Australia
- 13) 8<sup>th</sup> IAEA TM on Control, Data Acquisition and Remote Participation, 2011, San Francisco, USA

## 3.2 SPAIN

### 3.2.1 International collaborations in 2010 using TJ-II at CIEMAT

#### - Collaborations with Russia

- 1) K. Sarkisyan and the ECRH IOFAN team will participate in the operation of the ECRH system of TJ-II during the 2010 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, visited at CIEMAT in March 2010 (2 weeks) and November 2010 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA, EBW current drive studies and Fokker-Planck calculations for fast ions coming from NBI (October 2010).
- 4) S. Petrov (IOFFE) (November 2010) visited CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) will visit Ciemat in September 2010 to discuss possible designs to modify the gyrotron power by means of reflected power technique
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team were visiting CIEMAT to investigate the structure of plasma potential and plasma fluctuations in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP detector. The second HIBP system has been design for long-range (zonal flows) correlation studies and the analyzer construction is in progress during 2010.
- 7) J. M. Fontdecaba was visiting IOFFE (July 2010) working on charge-exchange diagnostic.

#### - Collaborations in Europe

##### Germany

- 1) H. Laqua visited CIEMAT in May 2010 to participate in EBW heating experiments on TJ-II.



- 2) L. Estaban / M. Sánchez visited Greifswald (June / July 2010) to discuss W7-X diagnostics.
- 3) J. L. Velasco was visiting Greifswald (Germany) to work on neoclassical transport calculations. A. López Fraguas also visited Greifswald to adapt the last version of VMEC for TJ-II.
- 4) R. Klauber visited CIEMAT to work on collisions for the Gyrokinetic code EUTERPE.

### **Portugal**

- 1) C. Silva and I. Nedzelskiy were visiting CIEMAT to continue our collaboration on edge studies (edge turbulence and transport studies and RFA development) during 2010.
- 2) D. Baião is working in her PhD thesis on soft x-ray based Te diagnostic for high density plasmas in the TJ-II stellarator (including prototypes construction and testing).
- 3) Continuing the collaboration in reflectometry in TJ-II (Sylvie Da-Graça, Noviembre 2010).

### **Czech Republic**

K. Kovarik was visiting CIEMAT (June 2010) to participate on edge diagnostic development and measurements in TJ-II (electromagnetic probes).

### **Italy**

- 1) Collaboration with M. Spolaore and the RFXmod team to participate on edge diagnostic development and measurements in TJ-II including the design and development of electromagnetic probes to characterize the electromagnetic nature of plasma filaments in TJ-II.
- 2) Rita Lorenzini and Barbara Momo were visiting CIEMAT (October - December 2010) for studying transport in 3D magnetic confinement devices.

### **- Collaborations with USA**

- 1) F. Tabarés was visiting HSX (UW), PPPL and D-III-D, participating on plasma-wall (Li / B coating) experiments.
- 2) Erik Hollmann (USCD) was visiting CIEMAT (June 2010) working on parallel impurity transport studies.
- 3) Collaboration with Robert Wilcox (UW) on the influence of magnetic quasi-symmetry on zonal flows.

- **Collaborations with Ukraine**

- 1) The Heavy Ion Beam Probe team (led by L. Krupnik, Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology", Kharkov) has been fully involved in the characterization of radial electric fields in ECRH and NBI plasmas in the TJ-II stellarator during 2010 experimental campaign. The development of the second HIBP system has been design and the injector system has been constructed and delivered to CIEMAT (June 2010).

- **Collaborations with Japan**

- 1) Daniel Carralero visited Japan (November / December 2010) to participate on edge and fluctuation experiments using the TJ-II fast visible camera (loan agreement CIEMAT / LHD) in the LHD. First results, obtained in 2008, have been expanded including the investigation of parallel and radial dynamics of plasma filaments, the development of edge instabilities in high density regimes and beta scan studies and more recently the investigation of the self-similar properties of edge fluctuations during LHD beta scans.
- 2) N. Tamura and K. Ida (NIFS, Japan) visited Ciemat (March 2010) to investigate the interplay between nonlocal transport effects and long-range radial correlations in TJ-II.
- 3) Y. Narushima visited CIEMAT during one week to work on island healing in stellarators.
- 4) Kenichi Nagaoka (NIFS), Satoshi Yamamoto (Kyoto Univ.), Shinsuke Ohshima (Kyoto Univ.) visited CIEMAT (March) to participate on fast particle studies (radial localization of Alfvén modes and edge transport using HIBP / probe diagnostics).
- 5) R. Seki visited CIEMAT (May) to work on ion kinetic transport in stellarators.
- 6) Juan Arévalo was visiting NIFS (December) working on plasma spectroscopy and pellet system (TESPEL).
- 7) Tetsutarou Oishi (Nagoya University) was visiting Ciemat (March 2010) to explore the viability of Beam Emission Spectroscopy in the TJ-II stellarator.

- **International collaborations: stellarator/heliotron working groups**

The 7<sup>th</sup> Coordinated Working Group meetings (CWGM) was held in IPP-Greifswald (July 2010) to discuss joint activities. D. López Bruna attended the meeting and several Ciemat staff followed the meeting remotely.

### 3.2.2 Plans for 2011

The main research activity of Euratom – Ciemat association will remain on concept improvement development and on the fusion technology programme with special emphasis on all the different aspects of fusion materials technology. In addition, we will strengthen and continue with our long standing tradition to extend our physics studies

to different confinement concepts (tokamak / stellarators), looking for common clues as a fundamental way to investigate basic properties of magnetic confinement beyond any particular concept.

The following research areas are foreseen in the 2011 research programme:

- Stellarator physics: confinement data-base, neoclassical transport, stellarator optimization and magnetic configuration effects on confinement. These activities are carried out within the framework of the international stellarator implementing agreement.
- Plasma diagnostic development and engineering: Diagnostic developments for TJ-II will continue and in a wider context for JET, ITER and W7-X.
- Plasma heating (NBI, ECRH and studying the efficiency of Electron Bernstein Waves).
- Physics of advanced confinement scenarios: transport barrier physics, impurity transport and stability.
- Theory and modelling of plasma transport, stability and equilibrium.
- Plasma – wall studies, exploring plasma-wall interaction scenarios with Li coating and Li-liquid limiter concepts.
- Data acquisition, control and advanced data analysis techniques.

The following collaborations are planned during 2011:

- **Collaborations with Russia**

- 1) K. Sarkisyan and the ECRH IOFAN team participated in the operation of the ECRH system of TJ-II during the 2011 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, will visit CIEMAT in March 2011 (2 weeks) and November 2011 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) will visit CIEMAT to collaborate on ray-tracing and Fokker Planck studies (November / December 2011).
- 4) S. Petrov (IOFFE) (June 2011) will visit CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) visited Ciemat in September 2010 to continue the investigation of gyrotron-power control.
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team will visit CIEMAT to investigate the structure of plasma potential in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP

detector. The second HIBP system has been design for long-range (zonal flows) correlation studies and the analyzer installation is foreseen during 2011.

#### - **Collaborations in Europe**

##### **Germany**

- 1) M. Sánchez will visit IPP-Greifswald in the framework of the development activities of W7-X diagnostics (CO<sub>2</sub> interferometer).
- 2) J. L. Velasco will visit Greifswald (Germany) to work on Neoclassical transport
- 3) J. M. García-Regaña has joined Greifswald team in a pos-doc position to work on collisions for gyrokinetic theory.
- 4) A. López-Fraguas will visit Greifswald in May for two weeks to work on VMEC for TJ-II.

##### **Portugal**

Carlos Silva, Sylvie Da-Graça and IST team will visit CIEMAT to continue our collaboration on edge studies and reflectometry.

##### **Italy**

- 1) Collaboration with M. Spolaore and the RFXmod team to participate on edge diagnostic development and measurements in TJ-II

#### - **Collaborations with USA**

- 1) P. Ryan and J. Caughman (ORNL) will visit CIEMAT in 2011 to collaborate in the scientific exploitation the Electron Bernstein Emission diagnostic and NBI heating.
- 2) I. Calvo will stay at MIT working on Gyro-Kinetic Theory (October 2011)
- 3) K. McCarthy will stay at ORNL (mid-2011) to test the performance of TJ-II pellet injector.
- 4) Robert Wilcox (UW) will visit Ciemat for investigating the influence of magnetic configuration on long-range correlation (zonal flows).
- 5) Arturo Alonso and Daniel Carralero will visit UW to study driving and damping mechanisms of zonal flows and role of magnetic topology.

#### - **Collaborations with Ukraine**

L. Krupnik and HIBP team will visit TJ-II for investigation of the structure of radial electric fields using HIBP diagnostic (Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology).

S. Pavlov will visit CIEMAT for 1 month (October, 2011) to work on the fast calculation of relativistic dispersion relation.

- **Collaborations with Japan**

- 1) Kenichi Nagaoka (NIFS), Satoshi Yamamoto (Kyoto Univ.), Naoki Tamura (NIFS) will visit Ciemat (March 2011) to join TJ-II experiments.
- 2) K. Nagaoka (NIFS), S. Yamamoto, S. Kobayashi and S. Ohshima (Kyoto University) will visit CIEMAT (March) to continue the joint experiments on fast particle studies (radial localization of Alfvén modes and edge transport using HIBP / probe diagnostics). In addition two engineers (Mr. Tsuchibushi and Mr. Sato) for LHD project will join the TJ-II team.
- 3) Kieran McCarthy and Juan Arévalo will visit NIFS / Nagoya University to discuss the development of BES system in stellarators.
- 4) J. M. Fontdecaba will visit NIFS (February 2011) to work on CX plasma spectroscopy and transport.

- **International stellarator/heliotron working groups**

Ciemat staff will participate in the forthcoming CWGM to be held in Toki (March 2011).

## 4 JAPAN

### 4.1 International collaborations by the LHD team at NIFS

#### - Collaborations with EU

- 1) M. Nishiura (NIFS) from Jan. 31 to Feb. 20 will visit TEXTOR Julich Germany and RISOE Denmark to discuss the spectrum analysis of collective Thomson scattering. I joined experiment of collective Thomson scattering on TEXTOR.
- 2) K. Ida (NIFS) visited CIEMAT from 20th to 28th February 2010 to join experiments on dynamic transport study with modulated biasing. He has investigated the dynamic response of plasma parameters to the modulated edge potential using Rake probe, ECE and doppler reflectometer.
- 3) N. Yanagi (NIFS) visited Karlsruhe Institute of Technology (KIT) from March 1 to 3, 2010 for a collaborative research with Dr. Walter Fietz and his group on the development of large-current capacity high-temperature superconductors for fusion magnets.
- 4) G. Motojima (NIFS) visited Ghent university in Belgium to give a presentation of "Technology progress and physics achievements in LHD" from 11 March to 14 March 2010 within a framework of Erasmus Mundus Program.
- 5) G. Motojima (NIFS) visited CEA Cadarache in France to discuss the pellet ablation and drift modeling from 16 March to 28 March 2010 within a framework of Erasmus Mundus Program.
- 6) G. Motojima (NIFS) visited Max Planck Institute for Plasma Physics in Garching, Germany from 30 March to 6 May 2010 to discuss the high density H-mode plasma using pellet between Tokamak and stellarator/heliotron within a framework of Erasmus Mundus Program. He proposed the high density experiments by pellets in ASDEX-U.
- 7) G. Motojima (NIFS) visited Culham Science Center in England at 7 May 2010 to discuss the ELM pacing and main fueling techniques by repetitive pellet injection within a framework of Erasmus Mundus Program.
- 8) G. Motojima (NIFS) visited Dublin City University (DCU), Dublin, Ireland to attend the 37th European Physical Society Conference on Plasma Physics from 20 June to 25 June 2010 to give an oral presentation entitled "High-speed imaging spectroscopy for pellet plasmoid observation in LHD". He discussed the observation techniques of pellet ablation with the participants.
- 9) T. Akiyama (NIFS) visited Forschungszentrum Juelich GmbH (Juelich, Germany) from 21st to 27th June 2010 for discussion on mitigation of deposition and experiments of cleaning of the first mirror by chemical sputtering in TEXTOR.
- 10) Y. Suzuki (NIFS) visited Forschungszentrum Juelich GmbH (Juelich, Germany) from 26th June to 12th July 2010 in the international collaboration on 3D modeling in the tokamak configuration with the resonant magnetic perturbation field. This

collaboration results were reported at EPS2010 (Dublin, Ireland, June 2010) and ITPA2010 (Souel, South Korea, Oct. 2010).

- 11) T. Akiyama (NIFS) visited IPP Greifswald from 27th June to 2nd July 2010. Coordinated Working Group Meeting for Confinement Studies in Stellarators/Heliotrons (CWGM) has been conducted under the auspices of the IEA Implementing Agreement of Development of Stellarator Concepts.
- 12) S. Yamada (NIFS) took part in 7th HTS Working Group Meeting for ITER SC feeders held in Cadarache (France) from March 2nd to March 4th for discussing the test results of 68 kA HTS current lead trial for ITER.
- 13) D. Kato (NIFS) visited Atomic and Molecular Data Unit in IAEA headquarter (host: B. Braams) in Austria from 27th April until 28th April 2010 to attend the atomic and molecular subcommittee meeting of the International Fusion Research Council (IFRC).
- 14) S. Yamada (NIFS) took part in CDR (Conceptual Design Review) Meeting of the ITER Power Supply Systems held in Cadarache (France) from June 7th to June 11th to review the conceptual design of the interlock & protection system, switching network unit, ac/dc convertor system, fast discharge unit, reactive power compensation system and so on, as one of the external reviewers.
- 15) Y. Narushima (NIFS) visited Max-Planck-Institut für Plasmaphysik (IPP), Greifswald Germany from 28th June 2010 to 1st July 2010 to attend the magnetic island session in Coordinated Working Group Meeting for Confinement Studies in Stellarators/Heliotrons (CWGM) as a chairperson.
- 16) Y. Narushima (NIFS) visited CIEMAT, Madrid Spain from 2nd July 2010 to 8th July 2010 to discuss on the contents of the joint paper presentation in the 23<sup>rd</sup> IAEA-FEC with F. Castejón, D. López-Bruna, T. Estrada and F. Medina.
- 17) T.-H. Watanabe (from Jul. 19 to Aug. 6, 2010), H. Sugama and M. Nunami (from Jul. 18 to Jun. 25, 2010) (NIFS) visited Isaac Newton Institute for Mathematical Sciences (Cambridge, UK) to attend Programme on Gyrokinetics in Laboratory and Astrophysical Plasmas and had intensive discussions on entropy transfer precesses in gyrokinetic plasma turbulence.
- 18) S. Yamada (NIFS) took part in 8th HTS Working Group Meeting for ITER SC feeders held in Karlsruhe Institute of Technology (Germany) from July 15th to July 17th for discussing the re-test results of 68 kA HTS current lead trial and design of 10 kA HTS current lead for ITER Correction Coil.
- 19) N. Tamura (NIFS) visited Palacio de Congresos, Spain from Sep. 5th to Sep. 12th, 2010 to join 15th EU-US Transport Task Force Meeting. He made a presentation entitled "Multiple states of electron heat transport inside an internal transport barrier in LHD".
- 20) D. Kato (NIFS) visited Atomic and Molecular Data Unit in IAEA headquarter (host: B. Braams) in Austria from 13th September until 15th September 2010 to attend the research coordination meeting on data for surface component dynamics

relevant to erosion processes in fusion reactor materials.

- 21) I. Murakami (NIFS) attended the 7th International Conference on Atomic and Molecular Data and Their Applications held in Vilnius, Lithuania, from Sep. 21-22, 2010 and gave an invited talk on atomic databases and related research activities.
- 22) H. Yamada (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) from 28 Jun. to 3 Jul. 2010 to attend the 7<sup>th</sup> CWGM and make an international call for joint experiments.
- 23) K. Osamu (NIFS) attended the 25<sup>th</sup> SPIG as a lecturer, and inspected Vinca Institute of Nuclear Sciences (Serbia, from 31 Aug. to 6 Sep. 2010).
- 24) R. Sakamoto (NIFS) visited CEA Cadarache (France) for the collaboration on pellet injection (from 17 May to 20 Jun. 2010, including the attendance on European Physical Society Meeting in Dublin, Ireland).
- 25) K. Ida (NIFS) participated in the TEXTOR experiment (Julich, Germany) from 10 Jul. to 25 Jul. 2010.
- 26) H. Nakanishi and S. Kubo (NIFS) attended the IAEA Technical Meeting on Steady State Operation of Magnetic Fusion Devices, held in IAEA headquarter (Austria), from 5 Dec. to 10 Dec. 2010.
- 27) H. Funaba (NIFS) attended 7<sup>th</sup> CWGM and then discussed on international stellarator-heliotron profile database issues at IPP-Greifswald from 27 Jun. to 8 Jul. 2010.
- 28) M. Yokoyama (NIFS) visited IPP-Greifswald from 21 Jun. to 8 Jul. 2010 to discuss the international stellarator-heliotron profile database (equipments and utilizations), and attended 7<sup>th</sup> CWGM to promote collaborations on the transport code validation.
- 29) C. Suzuki (NIFS) attended the 7th International Conference on Atomic and Molecular Data and Their Applications held in Vilnius, Lithuania, from Sep. 21-22, 2010, and then visited the University-College in Dublin (Ireland) for collaborations on atomic and molecular database, totally from 20 Sep. to 3 Oct. 2010.
- 30) T. Mutoh, H. Kasahara and Y. Yoshimura (NIFS) visited Como (Italy) from 11th to 16th September 2010 to attend a workshop "US-EU-JPN Workshop on RF Heating Technology of Fusion Plasmas 2010". They gave presentations about recent ICRF and ECRH results in LHD and discussed about RF Heating Technology with the participants.
- 31) N. Ashikawa (NIFS) attended the 2<sup>nd</sup> IAEA Research Coordination Meeting on Characterization of Size, Composition and Origins of Dust in Fusion Device , and joint preparation for dust-injection experiments (Austria and Germany) from 19 Jun. to 27 Jun. 2010.
- 32) The visit to Ireland and collaborative discussion on plasma physics were realized on occasion of EPS Conference on Plasma Physics. K. Itoh has discussed with G.



Hasinger, the director of Max-Planck-Institute for Plasma Physics of Germany, on the future prospect of plasma physics. This discussion is also in conjunction with the planning of ITC-2010, for which the plasma physics and fusion science in future 20 years were chosen as the theme of conference. (This visit was supported by the Grant-in-Aid for Scientific Research of JSPS.)

- 33) Bastiaan Braams (IAEA, Austria), Marie-Lise Dubernet-Tuckey (Pierre and Marie Curie University, France), Evelyne Roueff (Paris Observatory, France) visited NIFS from Mar. 23 to Mar. 26, 2010 to attend the IAEA Consultants' Meeting on XML (Extended Markup Language) Schema for Atoms, Molecules and Solids (XSAMS). I. Murakami (NIFS) served as a local organizer of the meeting.
- 34) Yusuf Celik (Ruhr University Bochum, Germany) visited NIFS (S. Yoshimura) from January 18th to January 26th for participating in the HYPER-I collaboration experiment on laser-induced fluorescence measurement of electron cyclotron resonance plasmas.
- 35) K. Aggarwal (Queen's University of Belfast, UK) visited NIFS (I. Murakami, D. Kato, and T. Kato) from Feb. 2 to Mar. 8, 2010 to promote international collaboration on "Diagnostics of non-equilibrium plasmas produced by LHD and in Solar Corona observed by HINODE" and worked on atomic data of C V and other He-like ions which are necessary for a kinetic model of plasma spectroscopy.
- 36) Giuseppe Chitarin (University of Padova and Consorzio RFX, Italy) visited NIFS (Y. Takeiri) from 8th February to 16th February to measure the magnetic field distribution inside a LHD negative ion source and to compare the measured data with the numerical models.
- 37) Nicolo' Marconato (University of Padova and Consorzio RFX, Italy) visited NIFS (Y. Takeiri) from 16th February to 23rd February to measure the magnetic field distribution inside a LHD negative ion source and to compare the measured data with the numerical models.
- 38) Ursel Fantz (Max-Planck Institute fur Plasmaphysik, Garching, Germany) visited NIFS (Y. Takeiri and K. Tsumori) from 22nd February to 5th March for study of spectroscopic measurement of a LHD negative ion source.
- 39) Pierluigi Veltri (Istituto Gas Ionizzati del CNR, Consorzio RFX, Italy) visited NIFS (Y. Takeiri) from 15th November to 14th December to participate in the LHD-NBI operation and to make benchmark between the RFX-suite of codes and the accelerators of LHD-NB injectors for developing and optimizing the simulation codes for simulating the LHD-NB injectors.
- 40) Daniel Carralero Ortiz, CIEMAT, Spain, visited NIFS (M. Shoji) from 6th Dec. 2010 to 20th Dec. 2010 to measure peripheral plasma transport and plasma-wall interactions in LHD with a fast framing camera, and to discuss the analyses of the measurements with researches concerned in NIFS.
- 41) Michael Barnes (University of Oxford, UK) visited NIFS (H. Sugama and T.-H. Watanabe) from 13th to 17th December 2010 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations to discuss the

direct multi-scale simulation using gyrokinetic turbulence codes coupled to a transport code.

- 42) M. Hirsch (IPP Greifswalt) visited NIFS from 6th to 7th October under Promotion of International Network for Scientific Collaborations to discuss on H-mode physics in helical devices and diagnostic system.
- 43) Marcin Jakubowski (Max-Planck Institute for Plasmaphysik, Germany) visited NIFS (H. Yamada and S. Masuzaki) from 9 Oct. 2010 to 12 Nov. 2010 to study the beta dependence of particle and heat flux profiles on the helical divertor in LHD. An infrared camera and a CCD camera were utilized for the study. On 4th Nov., 21 discharges were conducted in LHD for the study.
- 44) Stejner Pedersen, Morten (Riso National Laboratory, Denmark) visited NIFS from 7th Nov. 2010 to 19th Nov. 2010 joined the experiment of collective Thomson scattering in order to measure bulk and fast ion distribution function on LHD with Prof. Kubo, Dr. Tanaka and Dr. Nishiura. He installed software of bulk ion components from fast sampling digital oscilloscope.
- 45) Pierluigi Veltri (Istituto Gas Ionizzati del CNR, Consorzio RFX, Italy) visited NIFS (Y. Takeiri) from 15th November to 14th December to participate in the LHD-NBI operation and to make benchmark between the RFX-suite of codes and the accelerators of LHD-NB injectors for developing and optimizing the simulation codes for simulating the LHD-NB injectors.
- 46) Peter Drewelow (Max-Planck Institute for Plasmaphysik, Germany) visited NIFS (H. Yamada and S. Masuzaki) from 18 Sep. 2010 to 7 Jan. 2011 to study the beta dependence of particle and heat flux profiles on the helical divertor in LHD. An infrared camera and a CCD camera were utilized for the study. On 4th Nov. and 8th Dec., 21 and 37 discharges, respectively, were conducted in LHD for the study.
- 47) Ljupco R Hadzievski (Vinca Institute of Nuclear Sciences, Serbia) visited NIFS (M. Skoric) from 28 Mar. to 1 Apr. 2010.
- 48) J. Vallera Rodriguez (Carlos III Univ. Spain) visited NIFS (K. Watanabe) from 1 Sep. to 12 Nov. 2010 for MHD stability issues in LHD plasmas.
- 49) J. Arevalo (CIEMAT, Spain) visited NIFS (N. Tamura) from 24 Nov. To 11 Dec. 2010 for a collaboration research on TESPEL and charge exchange spectroscopy.
- 50) P. Veltri (RFX Consortium, Italy) visited NIFS (H. Nakano) from 22 Nov. To 14 Dec. 2010 for NBI-related technological and computational issues.

- **Collaborations with Russia**

- 1) I.Yu. Tolstikhina (P.N. Lebedev Physics Institute the Russian Academy of Sciences, Russia) visited NIFS (D. Kato) from Oct. 21 until Nov. 4, 2019 to collaborate on theoretical evaluation of isotopic effects on low-energy charge exchange processes of hydrogen collisions with carbon, beryllium and lithium atoms/ions.
- 2) Peter A. Loboda (Russian Federal Nuclear Center All-Russian Institute of Technical

Physics, Russia), Sergey A. Gagarin (Russian Federal Nuclear Center All-Russian Institute of Technical Physics, Russia) visited NIFS from Mar. 23 to Mar. 26, 2010 to attend the IAEA Consultants' Meeting on XML (Extended Markup Language) Schema for Atoms, Molecules and Solids (XSAMS). I. Murakami (NIFS) served as a local organizer of the meeting.

- 3) I. Sharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from Nov. 28th to Dec. 24th, 2010 to study a spatial structure of the ablation cloud of the Tracer-Encapsulated Solid Pellet by measuring a Stark broadening with a spatial resolution on LHD.
- 4) A.V. Melnikov (Kurchatov Institute) attended the 20th International Toki Conference from 6th to 10th December under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Supra thermal electron induced electrostatic eigenmodes with radially localized structure in TJ-II" as an oral speaker. After the conference, he visited NIFS from 13th to 17th December, and discussed the formation of electrostatic potential profiles in magnetically confined plasmas and the energetic-particle driven modes observed in LHD and TJ-II
- 5) Dr. Igor V. Vinyar, Director of the Scientific Research Laboratory of St. Petersburg State Polytechnical University, Russia visited at NIFS for collaboration with S. Sudo and N. Tamura from February 11 to February 25, 2010. The purpose was TCPEL system development including development of a fast shutter valve to prevent the He acceleration gas from flowing into the LHD vacuum vessel with closing time of less than 10 ms.
- 6) Andrey Gennadjevich Alexeev (RRC, TRINITI) visited NIFS (B.J.Peterson) from 18 Jan. to 17 Apr. 2010.
- 7) S. Moiseenko (Space Research Institute) attended the 20<sup>th</sup> International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.
- 8) N. Karchev (General Physics Institute, Moscow) attended the 20<sup>th</sup> International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.

- **Collaborations with Ukraine**

- 1) A. Shimizu visited Alushta, Ukraine from September 12th through 18th, 2010 to attend the International Conference and School on Plasma Physics and Controlled Fusion and 4th Alushta International Workshop on the Role of Electric Fields in Plasma Confinement in Stellarators and Tokamaks. He gave an invited talk on "Measurements of radial electric field and geodesic acoustic mode oscillations with heavy ion beam probe in Large Helical Device".
- 2) Dr. Oleg A. Shyshkin (Kharkiv "V.N.Karazin" National University, Ukraine) visited NIFS (A. Sagara and N. Yanagi) from 4th October 2010 to 14th January 2011 for the research on fusion reactivity enhancement by selective ICRF minority heating in D-T and D-3He plasmas, and the paper was presented in ITC-20.
- 3) V. Mykhaylenko and M. Vesnovskaya (Kharkiv "V.N.Karazin" National University,

Ukraine) attended the 20<sup>th</sup> International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.

- 4) V. Voitsenya, V. Maslov and O. Biletsky (National Science Center “Kharkov Institute of Physics and Technology”) attended the 20th International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.

- **Collaborations with USA**

- 1) Yuri Ralchenko (National Institute of Standards and Technology, USA) visited NIFS from Mar. 23 to Mar. 26, 2010 to attend the IAEA Consultants’ Meeting on XML (Extended Markup Language) Schema for Atoms, Molecules and Solids (XSAMS). I. Murakami (NIFS) served as a local organizer of the meeting.
- 2) T.Akiyama (NIFS) visited Oak Ridge National Laboratory (USA) from 10th to May 16th to attend 18th ITPA meeting on Diagnostics to present recent experimental results of new structure to prevent impurity deposition on the first mirror and developing a dispersion interferometer.
- 3) M. Nishiura (NIFS) attended the ITPA TG on diagnostics, from May 11 to 14 at Oak Ridge National Laboratory, TN, US and at 18th Topical Conference on High Temperature Plasma Diagnostics, held in Wildwood, New Jersey, US. Development and irradiation test of lost alpha detection system for ITER was reported.
- 4) D. Kato attended the 19th International Conference on Plasma Surface Interactions, which was held at Catamaran Resort and Spa in San Diego, USA, from 24th May until 28th May 2010.
- 5) N. Yanagi (NIFS) attended 19th Topical Meeting on the Technology of Fusion Energy (TOFE-19) held in Las Vegas, US, from November 8 to 11, 2010 and made an oral presentation titled "Design progress on the high-temperature superconducting coil option for the LHD-type fusion energy reactor FFHR".
- 6) H. Nakanishi (NIFS) visited General Atomics (San Diego) from 8th September 2010 to 14th September 2010 to collaborate with Dr. D.Schissel and G. Abla on the examination for "Quality of Service" effects on long-distance network on behalf of the Fusion Virtual Laboratory. The performance improvement effects have been tested by using actual long-distance tcp communications between GA and NIFS.
- 7) N. Tamura (NIFS) visited Loews Annapolis Hotel, US from Apr. 12th to Apr. 18th, 2010 to join US Transport Task Force Workshop 2010. He was given an invited talk entitled “Nonlocal Interaction of Electron Heat Transport States in LHD”.
- 8) T.-H. Watanabe, NIFS (Japan) visited Princeton Plasma Physics Laboratory (Princeton, US) from Nov. 15-19, 2010, to discuss gyrokinetic simulations of turbulent transport in toroidal plasmas with non-axisymmetry as well as efficient numerical algorithms for simulating fast parallel motions.
- 9) Y. Todo (NIFS, Japan) visited Univ. Texas at Austin from 1 to 15 Aug. 2010 to discuss nonlinear MHD effects on Alfvén eigenmodes.

- 10) Thomas J. Dolan (Univ. Illinois) visited NIFS (A.Sagara) on 8 Jun. 2010.
- 11) S.Lazerson (PPPL) visited NIFS from 5th to 10th Sep. to discuss the reconstruction of 3D MHD equilibrium in the LHD. In this visit, the benchmarking between HINT2 and PIES were discussed.
- 12) K. Hill and M. Bitter (PPPL) visited NIFS (S. Morita) to discuss X-ray spectroscopy diagnostics in LHD plasmas.
- 13) W. Horton (Univ. Texas at Austin) visited NIFS (H. Sugama) to discuss theory and simulation research based on kinetic and fluid models.
- 14) M. Shafer and A. Sontag (ORNL) visited NIFS (S. Ohdachi) from 7 Dec. to 17 Dec. , 2010 to discuss 2D imaging diagnostics in LHD plasmas.
- 15) S. Prager (PPPL) attended the 20<sup>th</sup> International Toki Conference, and made a plenary talk on the evolution and future prospects on magnetically confinement experiment.
- 16) W. Tang (PPPL) attended the 20<sup>th</sup> International Toki Conference, and made a plenary talk on the evolution and future prospects on simulations science
- 17) S. Hudson (PPPL) attended the 20<sup>th</sup> International Toki Conference, and made an oral talk on the equilibrium issues of magnetic confinement.

#### 4.1.2 Plans for 2011

- 1) M.W. Jakubowski (IPP-Greifswald, Germany) will visit NIFS in the frame of guest professorship fellowship to continue research on transport in stochastic boundary (3 months).
- 2) P. Drewelow (IPP-Greifswald, Germany) will visit NIFS to continue research on heat and particle fluxes in LHD (3 months).
- 3) T. Tatsuno (Univ. Maryland) will visit NIFS (T.-H. Watanabe) in Jan. 2010 to discuss gyro-kinetic theory and simulation.
- 4) S. Yoshimura (NIFS) will visit Ruhr-University (Germany) on the Argon-atom measurement in high-density plasmas based on collisional-radiative model, from 14 Feb. to 19 Mar. 2011.
- 5) A. KUs (NIFS) will visit NIFS (H. Funaba and M. Yokoyama) from 7. Mar to 1 Apr. 2011 for International Stellarator-Heliotron Confinement and Profile Database.
- 6) NIFS will host the 8<sup>th</sup> CWGM in March 2011, with under the auspices of NIFS/NINS project of Formation and International Network for Scientific Collaborations.

## 4.2 International collaborations by the Heliotron J team at Kyoto University

### - Collaborations with Australia

- 1) S. Yamamoto visited Australian National University on May 17 – May 27 to study the data mining technique for MHD stability of stellarator/heliotron plasmas as international research collaboration.
- 2) B. Blackwell (ANU) visited Kyoto Univ. on Nov. 15 –Nov. 17, 2009 to attend the International Symposium as an invited speaker, which was hosted by Institute of Advanced Energy, Kyoto Univ. Collaboration of the MHD analysis by using data mining technique and tomography technique and data acquisition was also performed.
- 3) Discussions with H-1NF team (ANU) were kept along the same line as in 2010.

### - Collaborations with EU

- 1) D. Tafalla and F. Tabares (CIEMAT) visited Kyoto Univ. from 21 Jan., 2010 to 26 Jan., 2010 to make detailed discussions about the application of their Li-coating technique in Heliotron J.
- 2) S. Ohshima visited CIEMAT on March 3–14 to participate in the experiments of energetic-ion-driven Alfvén eigenmodes (AEs) in TJ-II plasmas. He also discussed turbulence measurement using Langmuir probes with C. Hidalgo.
- 3) S. Kobayashi visited CIEMAT on March 7–13 to participate in the experiments of energetic-ion-driven Alfvén eigenmodes (AEs) in TJ-II plasmas. In particular, the spatial structure of AEs obtained from several spatial measurements and effects on energetic ion transport were investigated.
- 4) S. Yamamoto visited IPP, Greifswald on June 27 – July 4 to attend 7<sup>th</sup> CWGM, and discussed activities of MHD and high- $\beta$  study in stellarators/heliotrons. T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Ohshima and M. Takeuchi also participated in this meeting via a TV-conference system from Kyoto Univ.
- 5) S. Kobayashi participated in EPS conference on June 19 -27, Dublin, Ireland and discussed with Font de Cava, McCarthy (CIEMAT) about the recent results obtained in Heliotron J (study of lost fast-ions due to fast-ion driven MHD activities and NBI plasma start-up experiments).
- 6) M. Hirsch (IPP, Greifswald) visited Kyoto Univ. on Oct. 2 – 10. He presented recent collaboration activities on H-mode study among Heliotron J, LHD, CHS, TJ-II and W7-AS. A workshop on H-mode was held in his stay.
- 7) K. Nagasaki visited IPP, Greifswald on Nov. 20 – 29 to discuss ECH/ECCD physics with H. Laqua and N. Marushchenko. The ray tracing calculation code, TRAVIS, which was developed for W7-X, has been applied to Heliotron J configuration. The experimental results from Heliotron J are in quantitative agreement with the theoretical estimation. He also discussed with M. Hirsch about millimeterwave diagnostics such as reflectometer, radiometer and interferometer. Discussion with

WEGA stellarator group related to EBW heating was also made.

- 8) Imran Quaine (master degree student of École Polytechnique Fédérale de Lausanne) visited Kyoto Univ. to experimentally study MHD instability in Heliotron J plasma on 22 Feb. – 16 Aug to earn a master's degree.
- 9) Discussions with W7 team (IPP) were kept along the same line as in 2009.
- 10) Collaborations with CIEMAT were continued along the same lines as in 2009.

- **Collaborations with US**

- 1) Jeffrey Harris, Zeke Unterberg and Morgan Shafer (ORNL) visited Kyoto Univ. on July 23-25 to discuss the scheme of a high resolution soft X-ray camera for ballooning modes and imaging of the ergodic layer, and Innovative Confinement Research with strong emphasis on stellarators, 3-D divertors and materials.
- 2) Discussions with the US team (HSX (Wisconsin Univ.) team, CTH (Auburn Univ.) team, groups of ORNL and PPPL, etc.) were kept along the same line as in 2009.

- **Collaborations with Ukraine**

- 1) The effects of resonant perturbation field in the edge region have been studied through the collaboration with I. Pankratov (Kharkov, Ukraine).
- 2) Discussions with Kharkov team were kept along the same line as in 2009 and also started the discussion about the collaboration in U-2M project.

- **Collaborations with Russia**

- 1) M. Mikhailov (Kurchatov Institute) visited Kyoto Univ. on Jan. 16 – 30 to discuss optimization of quasi-isodynamic configuration for helical systems.

- **Others**

- 1) T. Mizuuchi, K. Nagasaki and S. Kobayashi participated in 23<sup>rd</sup> IAEA Fusion Energy Conference held at Daejeon, Korea, and discussed future international collaboration research with stellarator/heliotron related persons including C. Hidalgo, E. Ascasibar, F. Castejon (CIEMAT, Spain), J. Harris (ORNL, U.S.A.), M. Hirsch (IPP, Greifswald) and B. Blackwell (Australia).
- 2) Confinement control of high energy particles by using the optimized field configuration based on the quasi-isodynamic concept was examined through NBI/ICRF experiments.
- 3) Details of bulk confinement properties were studied experimentally from the viewpoint of the bumpiness/toroidicity control, the toroidal current control, and the fuelling physics and theoretically in Heliotron J.
- 4) Advanced ECH scenarios including ECCD and EBW heating/current drive were examined through Heliotron J/LHD experiments.

- 5) New gas fuelling by supersonic molecular beam injection (SMBI) was successfully applied to ECH/NBI plasma in Heliotron J. The collaboration of fuelling control studies are being discussed with TJ-II team.

#### 4.2.2 Plans for 2011

- 1) Research on confinement improvement in ECH plasmas and development of heating and current drive using electron Bernstein waves will be performed under the collaboration with CIEMAT, IPP and NIFS.
- 2) Collaboration research will start among CIEMAT, Kharkov Institute and ANU related to the physical understanding of fluctuation induced transport in core and edge plasmas and database for concept optimization of helical systems.
- 3) Collaboration research will be continued with H-1 staff, related to the upgrade of 28GHz ECH system and the plasma production/heating using this system.
- 4) Confinement control of high energy particles by using the optimized field configuration based on the quasi-isodynamic concept will be examined through Heliotron J NBI/ICRF experiments.
- 5) Details of transition phenomena related to the high confinement mode in NBI and ECH plasmas will be investigated through configuration control, plasma current control experiments.
- 6) SMBI experiments will be performed to investigate the confinement improvement in advanced stellarators/heliotrons, especially by the collaboration with TJ-II and LHD.
- 7) MHD activity control in higher beta plasmas through the field configuration optimization will be tested in Heliotron J.
- 8) M. Mikhailov (Kurchatov, Russia) will visit Kyoto Univ. to participate in optimization study of advanced helical configurations.
- 9) S. Ohshima plans to visit CIEMAT on March, 2011 to discuss turbulence measurement by using Langmuir probe with C. Hidalgo.
- 10) S. Yamamoto plans to visit CIEMAT on March, 2011 to investigate the helicity-induced AE (HAE) with multi helicity modes and global AE (GAE) with single-helicity mode and their effect on energetic ion transport using the dynamic iota scan experiments in TJ-II.
- 11) I. Pankratov (Kharkov, Ukraine) plans to visit Kyoto Univ. on Jan., 2011 for the electrode-biasing experiment in Heliotron J.
- 12) S. Darrow plans to visit Kyoto Univ. on 2011 for collaboration research on lost-ion probe diagnostic.



## 5 RUSSIA

### 5.1 International collaborations in 2010

#### - Collaborations with IPP (Germany)

- 1) P. Bagryansky (Budker Institute Novosibirsk) to IPP, 28.06. – 29.06.2010: 3<sup>rd</sup> Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO<sub>2</sub>-Interferometer for W7-X
- 2) U. Herbst, T. Richert (IPP) visited Budker Institute Novosibirsk, 11.04. – 16.04.2010: technical consultations, control DNBI
- 3) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 21.02. – 21.04.2010 and 27.10. – 03.12.2010: collaboration on optimized stellarators
- 4) M. Isaev (Kurchatov Institute Moscow) to IPP Greifswald, 25.04. – 16.05.2010: cooperation on benchmarking VENUS-δf PIC code against CAS3D-K and Euterpe
- 5) J. Nührenberg (IPP) visited Kurchatov Institute in Moscow, 13.09. – 16.09.2010: Optimized stellarators

#### - Collaborations with CIEMAT (Spain)

- 1) K. Sarkisyan and the ECRH IOFAN team will participate in the operation of the ECRH system of TJ-II during the 2010 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, visited at CIEMAT in March 2010 (2 weeks) and November 2010 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA, EBW current drive studies and Fokker-Planck calculations for fast ions coming from NBI (October 2010).
- 4) S. Petrov (IOFFE) (November 2010) visited CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) will visit Ciemat in September 2010 to discuss possible designs to modify the gyrotron power by means of reflected power technique
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team were visiting CIEMAT to investigate the structure of plasma potential and plasma fluctuations in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP detector. The second HIBP system has been design for long-range (zonal flows) correlation studies and the analyzer construction is in progress during 2010.
- 7) J. M. Fontdecaba was visiting IOFFE (July 2010) working on charge-exchange diagnostic.

- **Collaborations with NIFS (Japan)**

- 1) I.Yu. Tolstikhina (P.N. Lebedev Physics Institute the Russian Academy of Sciences, Russia) visited NIFS (D. Kato) from Oct. 21 until Nov. 4, 2019 to collaborate on theoretical evaluation of isotopic effects on low-energy charge exchange processes of hydrogen collisions with carbon, beryllium and lithium atoms/ions.
- 2) Peter A. Loboda (Russian Federal Nuclear Center All-Russian Institute of Technical Physics, Russia), Sergey A. Gagarin (Russian Federal Nuclear Center All-Russian Institute of Technical Physics, Russia) visited NIFS from Mar. 23 to Mar. 26, 2010 to attend the IAEA Consultants' Meeting on XML (Extended Markup Language) Schema for Atoms, Molecules and Solids (XSAMS). I. Murakami (NIFS) served as a local organizer of the meeting.
- 3) I. Sharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from Nov. 28th to Dec. 24th, 2010 to study a spatial structure of the ablation cloud of the Tracer-Encapsulated Solid Pellet by measuring a Stark broadening with a spatial resolution on LHD.
- 4) A.V. Melnikov (Kurchatov Institute) attended the 20th International Toki Conference from 6th to 10th December under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Supra thermal electron induced electrostatic eigenmodes with radially localized structure in TJ-II" as an oral speaker. After the conference, he visited NIFS from 13th to 17th December, and discussed the formation of electrostatic potential profiles in magnetically confined plasmas and the energetic-particle driven modes observed in LHD and TJ-II
- 5) Dr. Igor V. Vinyar, Director of the Scientific Research Laboratory of St. Petersburg State Polytechnical University, Russia visited at NIFS for collaboration with S. Sudo and N. Tamura from February 11 to February 25, 2010. The purpose was TCPEL system development including development of a fast shutter valve to prevent the He acceleration gas from flowing into the LHD vacuum vessel with closing time of less than 10 ms.
- 6) Andrey Gennadjevich Alexeev (RRC, TRINITI) visited NIFS (B.J.Peterson) from 18 Jan. to 17 Apr. 2010.
- 7) S. Moiseenko (Space Research Institute) attended the 20<sup>th</sup> International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.
- 8) N. Karchev (General Physics Institute, Moscow) attended the 20<sup>th</sup> International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.

- **Collaboration with Kyoto University (Japan)**

- 1) M. Mikhailov (Kurchatov Institute) visited Kyoto Univ. on Jan. 16 – 30 to discuss optimization of quasi-isodynamic configuration for helical systems.

- **Collaboration with Ukraine**

(Dr. L.I.Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. A.V.Melnikov and T-10 team (Kurchatov Institute)).

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on T-10.
  - Investigations of the  $TI^+$  extraction and technology of the ion source preparation. Extracted current of  $TI^+$  ions reached  $\sim 500 \mu A$ .
  - Installation of the new modification source of  $TI^+$  ions on T-10. Increase of the primary beam energy up to 300 keV, what enables to reach the deeper plasma volume to test.
- 2) Providing the experiments with upgraded HIBP diagnostic of the T-10 Tokamak. Experiments were directed to investigations of the plasma potential behavior with high plasma density. Geodesic Acoustic modes were found on T-10 and their features were studied in the ECRH regimes for the first time.

(Dr. L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. S.V.Lebedev and Tuman-3M team (Ioffe Institute).

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on Tuman-3M tokamak.
  - Preparation of the secondary ion beam line modification to have a possibility of the HIBP processing during opposite direction of the magnetic field. Improvement of signal/spurious noise ratio.
- 2) Study of NBI-caused LH transition at low density in the TUMAN-3M tokamak

## 5.2 Plans for 2011

- **Collaboration with Russian Kurchatov Institute, Moscow**

- 1) Investigations of the plasma potential behavior and fluctuation in regimes of the high density GAM's. Comparative study of the GAM's (and AEs) behavior in the T-10 tokamak and TJ-II stellarator during ECR heating with high intensity heavy ion probing beam.

- **Ioffe Institute of Physics and Technology, St Petersburg.**

- 1) Installation of the secondary beamline of the HIBP complex for measurements with reversed orientation of the magnetic field.
- 2) Investigation of the electric field evolution in various operational modes in the TUMAN-3M tokamak with reversed magnetic fields.

- **CIEMAT. Spain**

- 1) K. Sarkisyan and the ECRH IOFAN team participated in the operation of the ECRH system of TJ-II during the 2011 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, will visit CIEMAT in March 2011 (2 weeks) and November 2011 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) will visit CIEMAT to collaborate on ray-tracing and Fokker Planck studies (November / December 2011).
- 4) S. Petrov (IOFFE) (June 2011) will visit CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) visited Ciemat in September 2010 to continue the investigation of gyrotron-power control.
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team will visit CIEMAT to investigate the structure of plasma potential in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP detector. The second HIBP system has been design for long-range (zoanl flows) correlation studies and the analyzer installation is foreseen during 2011.

## 6 UKRAINE

### 6.1 Institute of Plasma Physics of the National Science Center “Kharkov Institute of Physics and Technology” of the NAS of Ukraine (IPP NSC KIPT, NASU)

#### 6.1.1 International collaborations of the NSC KIPT in 2010

##### 6.1.1.1 International collaborations of the plasma theory division

#### - Collaboration with Technische universität Graz, Austria

Calculations of high energy particle losses for Uragan-2M taking into account the influence of the current feeds and the detachable joints of the helical winding (V.V.Nemov, S.V.Kasilov and V.N.Kalyuzhnyj in collaboration with Technische Universität Graz, Austria).

#### - Collaboration with CIEMAT, Madrid, Spain

During 2010 year Pavlov S.S., collaborating with Castejon F., A. Cappa (CIEMAT, Madrid, Spain), Tereshchenko M. (Institute of General Physics, RAS, Moscow, Russia) studied a possibility of the fast evaluation of relativistic (weakly and fully relativistic) plasma dielectric tensor for arbitrary value of the parameter  $(k_{\perp} \rho_e)^2$  and used this method for investigations of the EBW plasma heating regimes in magnetic traps.

##### 6.1.1.2 International collaborations of the plasma experiment divisions

#### - Collaboration with CIEMAT, Madrid, Spain

(Dr. L.I.Krupnik et al (IPP NSC KIPT) in collaboration with Dr. C. Hidalgo and TJ-II team (CIEMAT)).

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on TJ-II:
  - tuning of the new mode of the ionic source with increasing probing beam current up to 150- 200  $\mu$ A.
  - development of the data acquisition system to increase the bandwidth.
- 2) Providing of the experiments with the upgraded HIBP diagnostic of the TJ-II Stellarator. Experiments were directed to plasma turbulence investigations. Potential and density oscillations caused by Alfvén Eigenmodes have been found and studied in the NBI plasma. The Alfvén Eigenmode contribution into the bulk plasma turbulent particle flux was estimated to be small in comparison with the broadband turbulence flux.
- 3) Development of the Second Heavy Ion Beam Probe diagnostic system for TJ-II. Concerning with calculations of the probe beam trajectories and optimisation of the installation conditions for the second HIBP line the entering and outgoing

intermediate blocs were installed on TJ-II and vacuum test were performed. Delivered Injector was supplied the missing components of the probing beam for the second HIBP.

- **Collaboration with Kurchatov Institute, Moscow, Russia**

(Dr. L.I.Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. A.V.Melnikov and T-10 team (Kurchatov Institute)).

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on T-10.
  - Investigations of the  $TI^+$  extraction and technology of the ion source preparation. Extracted current of  $TI^+$  ions reached  $\sim 500 \mu A$ .
    - Installation of the new modification source of  $TI^+$  ions on T-10. Increase of the primary beam energy up to 300 keV, what enables to reach the deeper plasma volume to test.
- 2) Providing the experiments with upgraded HIBP diagnostic of the T-10 Tokamak. Experiments were directed to investigations of the plasma potential behavior with high plasma density. Geodesic Acoustic modes were found on T-10 and their features were studied in the ECRH regimes for the first time.

- **Collaboration with Ioffe Institute of Physics and Technology, St-Petersburg, Russia**

(Dr. L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. S.V.Lebedev and Tuman-3M team (Ioffe Institute).

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on Tuman-3M tokamak.
  - Preparation of the secondary ion beam line modification to have a possibility of the HIBP processing during opposite direction of the magnetic field. Improvement of signal/spurious noise ratio.
- 2) Study of NBI-caused LH transition at low density in the TUMAN-3M tokamak

- **Collaborations with NIFS, Japan**

The manuscript "Plasma cleaning of the surfaces from oxides: the state of the art" by V. S. Voitsenya, S. Masuzaki, O. Motojima, and J.W. Davis was modified and published in AIP Conference Proceedings, **1282** (1) pp. 96-102.

- **Collaborations with Japan Atomic Energy Agency, Japan**

V.S. Voitsenya et al. (IPP NSC KIPT) in collaboration with Drs. K. Isobe and T. Yamanishi (and Dr. V.Kh. Alimov from Institute of Chemical Physics, Moscow)

investigated the irradiation temperature effect on modification of surface morphology and optical properties of W mirrors subjected to bombardment with low energy (38 eV) ions of deuterium plasma.

- **Collaborations with Institute of Advanced Energy, Kyoto University, Japan**

(Dr. I.M. Pankratov (IPP NSC KIPT) in collaboration with Prof. T. Mizuuchi and Prof. S. Kitajima (IAE, Kyoto University)).

The first successful experiments were carried out in March of 2009. During 2010 details of the next experiments were discussed. These investigations are important for LHD (local island divertor regime) and W-7X (magnetic island divertor) devices.

- **Collaborations with Belgium**

- 1) V.E. Moiseenko 07.01.2010 visited Laboratory for Plasma Physics - ERM/KMS, for participation in discussions of ICRF heating and ICWC at Wendelstein-7X.
- 2) A. Lyssoivan, Laboratory for Plasma Physics - ERM/KMS, visited IPP NSC KIPT 04-15.10.2010 and participated ICWC experiments on Uragan-2M.

- **Collaborations with Sweden**

- 1) V.E. Moiseenko visited Uppsala University 3 times, 02-14.01.2010, 15.07.2010-30.08.2010, 16-31.12.2010 to participate theoretical studies on fission-fusion hybrids.
- 2) S.N. Chernitskiy visited Uppsala University 16-31.12.2010 to participate theoretical studies on fission-fusion hybrids.

- **Conference participation**

- 1) V.E. Moiseenko: Eighth International Conference on Open Magnetic Systems for Plasma Confinement, 5 - 9 July 2010, Novosibirsk, Russia.
- 2) V.E. Moiseenko, D.L. Grekov: Thirty-Seventh EPS Conference on Plasma Physics, 21 - 25 June 2010, Dublin, Ireland.
- 3) A.A. Beletskii, V.I. Maslov, V.S. Voitsenya: 20th International Toki Conference (ITC-20) on The Next Twenty Years in Plasma and Fusion Science December 7 - 10, 2010, Ceratopia Toki, Toki-City, Gifu, Japan.
- 4) Fifteen members of IPP NSC KIPT participated in the Alushta-2010 International Conference and School on Plasma Physics and Controlled Fusion, held in Alushta, Crimea, 13-18 September 2010.
- 5) V.V. Chechkin and V.K. Pashnev participated in the 37<sup>th</sup> Conference held in Zvenigorod 8-12 February 2010.

## 6.1.2 Plans for 2011 of the IPP NSC KIPT

Plans for 2011 of the plasma theory division

### - **Collaboration with Austria (Institut für Theoretische Physik, Technische Universität Graz)**

1) Elaboration of numerical code for a direct computation of the  $\alpha$ -particle losses in stellarators in real space coordinates using the guiding center drift equations, which is analogous to the code of W. Lotz et al., Plasma Phys. Control. Fusion, **34**, 1037 (1992), that works in magnetic coordinates. Using the real space coordinates will allow to study an influence of magnetic islands and stochastic regions on the  $\alpha$ -particle confinement. (V.V.Nemov, S.V.Kasilov and V.N.Kalyuzhnyj in collaboration with Technische universität Graz, Austria).

2) In cooperation with ITP TU-Graz (Austria) and IPP Greifswald (Germany), it is planned to study some new effects of finite plasma collisionality on the efficiency of electron cyclotron current drive in toroidal fusion devices. This study will be performed using the combination of drift kinetic equation solver NEO-2 (IPP Kharkov, ITP TU-Graz) and ray tracing code TRAVIS (IPP Greifswald).

### - **Collaboration with Spain (CIEMAT, Madrid)**

To develop the efficient algorithm of evaluation of fully relativistic plasma dielectric tensor for arbitrary value of the parameter  $(k_{\perp} \rho_{e,i})^2$  and to use this algorithm for calculation of the EBW and IBW plasma absorption in fusion and astrophysical plasmas. (Pavlov S.S., in collaboration with Castejon F., A.Cappa, CIEMAT, Madrid, Spain and Tereshchenko M., Institute of General Physics, RAS, Moscow, Russia)

Plans for 2011 of the plasma experiment divisions

### - **Collaboration with Spain (CIEMAT, Madrid)**

1) Investigation of evolution of the plasma potential and electron density during L-H transition. Study of characteristics of the Alfvén Eigenmodes (AEs) and their contribution to the turbulent particle flux.

2) Termination of preparation of the second Heavy Ion Beam Probing diagnostic line on TJ-II stellarator.

### - **Collaboration with Russian Kurchatov Institute, Moscow**

Investigations of the plasma potential behavior and fluctuation in regimes of the high density GAM's. Comparative study of the GAM's (and AEs) behavior in the T-10 tokamak and TJ-II stellarator during ECR heating with high intensity heavy ion probing beam.



- **Ioffe Institute of Physics and Technology, St Petersburg.**

- 1) Installation of the secondary beamline of the HIBP complex for measurements with reversed orientation of the magnetic field.
- 2) Investigation of the electric field evolution in various operational modes in the TUMAN-3M tokamak with reversed magnetic fields.

- **Collaborations with Institute of Advanced Energy, Kyoto University, Japan**

(Dr. I.M. Pankratov (IPP NSC KIPT) in collaboration with Prof. T. Mizuuchi and Prof. S. Kitajima (IAE, Kyoto University)). A further collaborative research is planned to be provided:

On January 2011 joint experiments are planned to continue the investigation on influence of plasma rotation on the shift of diverted plasma flux position (in like of magnetic island divertor magnetic configuration) during the biasing experiment in Heliotron J. This experiment will be in collaboration with Tohoku University

- **Collaboration with Plasma Physics Laboratory, University of Saskatchewan, Canada**

Comparative study of the SXR emissivity behavior and its fluctuations in STOR-M tokamak and URAGAN-3M stellarator.

6.1.2.3 The tasks to be solved at IPP NSC KIPT

- 1) Preparation of the review paper with description of application of the technique and manual operation of the existing heavy ion beam probing diagnostics;
- 2) Finishing the PhD thesis by A. Zhezhera, V. Bondarenko, A. Prokopenko, A. Beletskii;
- 3) Tuning on test device of the full HIBP complex designed for Uragan-2M;
- 4) Installation of the HIBP diagnostic set on the U-2M;
- 5) Continuation of investigations of the Li ion beam injector up to 100 keV and 10-15 mA.
- 6) Experiments on RF plasma production and heating using 4-strap and recently manufactured "crankshaft" antennas on Uragan-2M device to study Alfvén resonance heating and certain scenarios of ion-cyclotron heating..
- 7) Development of technique and technology of 24 hours per day RF wall conditioning operation.
- 8) Further investigation of RF wall conditioning with specially designed antennas.
- 9) Optimisation of regimes of surface cleaning in the Uragan-2M torsatron using

different combination of ECR, RF and glow discharges in H<sub>2</sub> or H<sub>2</sub>+N<sub>2</sub> mixture will be continued.

- 10) Preparation of all equipment for providing the boronization procedure in the U-2M torsatron will be finished.
- 11) Optimisation of processes of RF plasma production and heating in the Uragan-2M torsatron aiming the increase of plasma parameters will be provided.
- 12) It is planned to design and to test the B<sub>4</sub>C limiter during wall conditioning and in operating regimes of the U-2M torsatron.
- 13) It is planned to use the self-consistent numerical model for RF plasma production to explain Uragan-2M results.
- 14) Continuation of investigations of the processes accompanying ITB and ETB formation in the plasma of the Uragan-3M torsatron under the RF plasma heating. Effects of transport barrier formation on divertor flow characteristics, in particular, on fast ion loss.
- 15) Continuation of investigations of divertor plasma flow characteristics in conditions of transport barriers formation in Uragan-3M.
- 16) Elucidation of the nature of detail up-down asymmetry of characteristics of density and electric field fluctuations in the divertor region of the U-3M torsatron to check if this asymmetry is really connected with that of fast ion loss?
- 17) A search for RF plasma production and heating regimes in the U-3M torsatron with no fast ions.

## **6.2 V.N.Karazin Kharkiv National University, Kharkiv**

### **6.2.1 International collaboration in 2010**

#### **- Collaborations with Institute of Space Research of University of Toronto, Canada**

New experimental results on the reemission of C and D from tungsten during single-species and simultaneous irradiations with 6 keV C<sup>+</sup> and 1 keV D<sup>+</sup> ion beams are presented. The relatively low C fraction in the combined total beam flux (about 4.5%) was selected to prevent the formation of a carbon overlayer during C<sup>+</sup> ion irradiation. The results show that the temperature dependence of D re-emission from a mixed W-C-D surface is similar to that from pure W. In the case of a mixed W-C surface, the re-emission of C was much lower than observed for pure carbon. Post-irradiation XPS analysis of the chemical bonding states of a W specimen irradiated at 973 K with 6 keV C<sup>+</sup> shows that carbon in the mixed W-C surface is primarily in the form of single tungsten carbide.

The results of this research were published:

I.A. Bizyukov, J.W. Davis, A.A. Haasz and P. Brodersen. *C and D reemission from mixed W-C-D layers during single-species and simultaneous irradiations of W with C+ and D+//* Journal of Nuclear Materials, Volume 400 (2010) Pages 245-250

- **Collaborations with National Institute for Fusion Science, Toki, Japan**

Handling the fuel is the essential issue for the D-T and D-<sup>3</sup>He fusion realization on fusion power plants. Recent research reveals the fact that the burning ratio of D-T reaction appears in a few percent level, and a large amount of tritium should be recovered from the vacuum vessel. Additional problem at present is the limited production of tritium amount needed for valuable operation of fusion reactors.

As alternative to D-T the fuel cycle based on D-<sup>3</sup>He could be used. That gives the possibility to decrease neutron load on plasma facing components and superconducting coils. Taking into account that the thermal reactivity of D-<sup>3</sup>He is much lower than that of D-T and the amount of <sup>3</sup>He is limited as well, a new technique to handle fuel cycles should be developed.

In present study we investigate the possibility to reduce the amount of T and <sup>3</sup>He in D-T and D-<sup>3</sup>He fusion plasmas respectively and at the same time to increase the fusion reactivity rates. On this purpose we apply selective ICRF heating to plasma minorities (T and <sup>3</sup>He) to obtain catalyzed fusion. The main idea of this technique is to modify reagent distribution function in order to achieve favorable reaction rate for nuclear fusion energy production. Recent experimental results show high efficiency of ICRH acceleration of T and <sup>3</sup>He minorities in deuterium plasma and consequent increasing of fusion reactivity. The effect of transition to non-Maxwellian plasma is essential for reactor aspects studies both in tokamaks and heliotrons.

In our simulations the calculation of modified distribution function of plasma minorities is provided by means of particle code based on test-particle approach. This code solves the guiding center equations for T and <sup>3</sup>He test particles taking into account Coulomb collisions of these species with the background deuterons and electrons by means of a discretized collision operator. A simple Monte Carlo model for ICRF heating is implemented in this code as well.

New values for reactivity rates are calculated basing on the obtained distribution function profiles for different RF heating scenarios. It is demonstrated that non-Maxwellian shape of the minorities distribution function plays an important role for reactivity enhancement. The increase of reactivity rate is an important issue for the performance of fusion reactors.

The results of this research were presented on International Toki Conference (ITC20):

1) O.A. Shyshkin, Yu.K. Moskvitina, A.O. Moskvitin, N. Yanagi, A. Sagara. *Ignition Analysis for D Plasma with non-Maxwellian  $^3\text{He}$  Minority in Heliotron Reactor* // 20<sup>th</sup> International Toki Conference (ITC-20), Toki-City, Gifu, Japan, December 7-10, Book of Abstracts, p. 92, Poster Presentation P1-56 (2010)

2) N. Yanagi, O.A. Shyshkin, T. Goto, H. Kasahara, J. Miyazawa, A. Sagara. *Reduced tritium circulation in the heliotron reactor by enhancing fusion reactivity using ICRF* // Ibid. p. 213, Poster Presentation P2-65 (2010)

- **Collaborations with National Science Center «Kharkiv Institute of Physics and Technology », Kharkiv, Ukraine**

Both linear and renormalized nonlinear kinetic theory of drift instability of plasma shear flow across the magnetic field, which has the Kelvin's method of shearing modes or so-called non-modal approach as its foundation, was developed with applications to the regimes of the enhanced plasma confinement in stellarators. The developed theory proves that the time-dependent effect of the finite ion Larmor radius is the key effect, which is responsible for the suppression of drift turbulence in an inhomogeneous electric field. This effect leads to the non-modal reducing of the frequency and growth rate of the unstable drift perturbations with time. We found that turbulent scattering of the gyrophase of ion Larmor orbit is the dominant effect, that determines extremely rapid suppression of drift turbulence in shear flow.

These results were reported on Conferences:

1) Mikhailenko V.S., Mikhailenko V.V., Stepanov K.N., Azarenkov N.A. *Renormalized non-modal theory of turbulence of plasma shear flows* // "Alushta-2010" International Conference-School on Plasma Physics and Controlled Fusion and 4-th Alushta International Workshop on the Role of Electric Fields in Plasma Confinement in Stellarators and Tokamaks Alushta (Crimea), Ukraine, September 13-18, 2010

2) Mikhailenko V.S., Mikhailenko V.V., Stepanov K.N. *Integrated Non-modal Linear and Renormalized Nonlinear Approach to the Theory of Drift Turbulence in Plasma Shear Flow* // 23rd IAEA Fusion Energy Conference, 11–16 October 2010, Daejeon, Republic of Korea, Report THS/P8-03 (8 pages)

3) Mikhailenko V.S., Mikhailenko V.S., Stepanov K.N. *Non-modal approach to kinetic theory of plasma shear flows* // 20th International Toki Conference (ITC-20) on The Next Twenty Years in Plasma and Fusion Science December 7 - 10, 2010, Ceratopia Toki, Toki-City, Gifu, Japan

and were published in articles

1) Mikhailenko V.S., Mikhailenko V.V., Stepanov K.N. *Renormalized theory of drift turbulence in plasma shear flow* // Plasma Phys. Control. Fusion 52, 055007 (2010)

2) Mikhailenko V.S., Mikhailenko V.V., Stepanov K.N. *Turbulence evolution in plasma shear flows* // Plasma and Fusion Research (Japan): Volume 5, S2015 (2010)

**- Collaborations with Max-Planck-Institute fuer Plasmaphysik, Munich, Federal Republic of Germany**

Testing installation is upgraded at MPIPP to study composite coatings with the further goal to utilize them for constructional elements of HF antennas of plasma heating. Sandwich PhD student A. Onyshchenko (KhNU) took part in this work during his visit to MPIPP in collaboration with Dr. J.-M. Noterdaeme, Dr. VI. Bobkov, W. Becker (MPIPP).

**6.2.2 Plans of National University for 2011**

1) We plan to develop our collaboration with National Institute for Fusion Science, Toki, Japan. The future activities will be devoted to D-T and D-<sup>3</sup>He catalyzed fusion realization conditions with reduced amount of T and <sup>3</sup>He respectively in FFHR - 2m3 heliotron configuration. The heads of this research at National Institute for Fusion Science are Prof. Dr. Akio Sagara (Executive Director of Fusion Engineering Research Project) and Dr. Nagato Yanagi (Device Engineering and Advanced Physics Research Division, Department of Helical Plasma Research).

2) Strength of materials and coatings will be studied in collaboration with MPIPP with respect to bombardment by charged particles. The following targets are planned to be tested:

- bulk stainless steel;
- tungsten coating of various thicknesses on stainless steel;
- tungsten coating of various thicknesses on stainless steel with an interlayer of copper.

3) Research in the non-modal kinetic and hydrodynamic low-frequency turbulence of the plasma shear flows will be continued in collaboration with NSC KhIPhT, Ukraine.

## 7 UNITED STATES

### 7.1 International collaboration in 2010

#### - Collaborations with Germany (IPP Greifswald)

- 1) P. Catto (MIT Boston) to IPP, 07.03. – 13.03.2010: Transport theory
- 2) M. Landreman (MIT Boston) to IPP, 07.03. – 26.03.2010: Transport theory
- 3) M. Jakubowski (IPP Greifswald) visited General Atomics, San Diego, 02.05. – 30.05.2010: DIII-D experiments
- 4) K. Bartschat (Drake University, Des Moines) to IPP, 17.07. – 21.07.2010
- 5) J. Hanson (Auburn University) to IPP, 25.06. – 04.07.2010: V3FIT, VMEC2000 code
- 6) A. Boozer (PPPL) to IPP, 02.07. – 05.07.2010: Stellarator development
- 7) C. Biedermann (IPP Greifswald) visited Lawrence Livermore National Laboratory, Livermore, 03.08. – 13.09.2010
- 8) J. Baumgaertel (PPPL) to IPP, 04.08. – 21.08.2010: Gyrokinetic simulations for stellarators using the GENE and GS2 code
- 9) S. Hirshman (ORNL) to IPP, 05.09. – 10.09.2010: SIESTA code
- 10) D. Mikkelsen (LLLN) to IPP, 06.09. – 1.09.2010: Transport simulation
- 11) J. Geiger (IPP) visited PPPL, 13.12. – 17.12.2010: Trim coils, equilibrium reconstruction, magnetic configuration control

#### - Collaborations with Spain (CIEMAT, Madrid)

- 1) F. Tabarés was visiting HSX (UW), PPPL and D-III-D, participating on plasma-wall (Li / B coating) experiments.
- 2) Erik Hollmann (USCD) was visiting CIEMAT (June 2010) working on parallel impurity transport studies.
- 3) Collaboration with Robert Wilcox (UW) on the influence of magnetic quasi-symmetry on zonal flows.

#### - Collaborations with Japan (NIFS)

- 1) Yuri Ralchenko (National Institute of Standards and Technology, USA) visited NIFS from Mar. 23 to Mar. 26, 2010 to attend the IAEA Consultants' Meeting on XML (Extended Markup Language) Schema for Atoms, Molecules and Solids (XSAMS). I. Murakami (NIFS) served as a local organizer of the meeting.
- 2) T.Akiyama (NIFS) visited Oak Ridge National Laboratory (USA) from 10th to May 16th to attend 18th ITPA meeting on Diagnostics to present recent experimental results of new structure to prevent impurity deposition on the first mirror and

developing a dispersion interferometer.

- 3) M. Nishiura (NIFS) attended the ITPA TG on diagnostics, from May 11 to 14 at Oak Ridge National Laboratory, TN, US and at 18th Topical Conference on High Temperature Plasma Diagnostics, held in Wildwood, New Jersey, US. Development and irradiation test of lost alpha detection system for ITER was reported.
- 4) D. Kato attended the 19th International Conference on Plasma Surface Interactions, which was held at Catamaran Resort and Spa in San Diego, USA, from 24th May until 28th May 2010.
- 5) N. Yanagi (NIFS) attended 19th Topical Meeting on the Technology of Fusion Energy (TOFE-19) held in Las Vegas, US, from November 8 to 11, 2010 and made an oral presentation titled "Design progress on the high-temperature superconducting coil option for the LHD-type fusion energy reactor FFHR".
- 6) H. Nakanishi (NIFS) visited General Atomics (San Diego) from 8th September 2010 to 14th September 2010 to collaborate with Dr. D.Schissel and G. Abla on the examination for "Quality of Service" effects on long-distance network on behalf of the Fusion Virtual Laboratory. The performance improvement effects have been tested by using actual long-distance tcp communications between GA and NIFS.
- 7) N. Tamura (NIFS) visited Loews Annapolis Hotel, US from Apr. 12th to Apr. 18th, 2010 to join US Transport Task Force Workshop 2010. He was given an invited talk entitled "Nonlocal Interaction of Electron Heat Transport States in LHD".
- 8) T.-H. Watanabe, NIFS (Japan) visited Princeton Plasma Physics Laboratory (Princeton, US) from Nov. 15-19, 2010, to discuss gyrokinetic simulations of turbulent transport in toroidal plasmas with non-axisymmetry as well as efficient numerical algorithms for simulating fast parallel motions.
- 9) Y. Todo (NIFS, Japan) visited Univ. Texas at Austin from 1 to 15 Aug. 2010 to discuss nonlinear MHD effects on Alfvén eigenmodes.
- 10) Thomas J. Dolan (Univ. Illinois) visited NIFS (A.Sagara) on 8 Jun. 2010.
- 11) S.Lazerson (PPPL) visited NIFS from 5th to 10th Sep. to discuss the reconstruction of 3D MHD equilibrium in the LHD. In this visit, the benchmarking between HINT2 and PIES were discussed.
- 12) K. Hill and M. Bitter (PPPL) visited NIFS (S. Morita) to discuss X-ray spectroscopy diagnostics in LHD plasmas.
- 13) W. Horton (Univ. Texas at Austin) visited NIFS (H. Sugama) to discuss theory and simulation research based on kinetic and fluid models.
- 14) M. Shafer and A. Sontag (ORNL) visited NIFS (S. Ohdachi) to discuss 2D imaging diagnostics in LHD plasmas.
- 15) S. Prager (PPPL) attended the 20<sup>th</sup> International Toki Conference, held in Toki,

Japan, and made a plenary talk on the evolution and future prospects on magnetically confinement experiment.

- 16) W. Tang (PPPL) attended the 20<sup>th</sup> International Toki Conference, and made a plenary talk on the evolution and future prospects on simulations science
- 17) S. Hudson (PPPL) attended the 20<sup>th</sup> International Toki Conference, and made an oral talk on the equilibrium issues of magnetic confinement.

- **Collaborations with Japan (Heliotron J team)**

- 1) Jeffrey Harris, Zeke Unterberg and Morgan Shafer (ORNL) visited Kyoto Univ. on July 23-25 to discuss the scheme of a high resolution soft X-ray camera for ballooning modes and imaging of the ergodic layer, and Innovative Confinement Research with strong emphasis on stellarators, 3-D divertors and materials.
- 2) Discussions with the US team (HSX (Wisconsin Univ.) team, CTH (Auburn Univ.) team, groups of ORNL and PPPL, etc.) were kept along the same line as in 2009.

## 7.2 Plans for 2011

- 1) Alexey Mischneko (IPP-Greifswald, Germany) plans to visit IFS Austin/USA to work on fast-particle-driven instabilities
- 2) P. Ryan and J. Caughman (ORNL) will visit CIEMAT in 2011 to collaborate in the scientific exploitation the Electron Bernstein Emission diagnostic and NBI heating.
- 3) I. Calvo (CIEMAT) will stay at MIT working on Gyro-Kinetic Theory (October 2011)
- 4) K. McCarthy (CIEMAT) will stay at ORNL (mid-2011) to test the performance of TJ-II pellet injector.
- 5) Robert Wilcox (UW) will visit CIEMAT for investigating the influence of magnetic configuration on long-range correlation (zonal flows).
- 6) Arturo Alonso and Daniel Carralero (CIEMAT) will visit UW to study driving and damping mechanisms of zonal flows and role of magnetic topology.



## **APPENDICES: TECHNICAL REPORTS ON 2010 ACTIVITIES**

### **APPENDIX 1: HIGHLIGHTS OF LHD EXPERIMENTS**

In 2010, the Large Helical Device (LHD) comes to its 14th experimental campaign. Remarkable progress in the physical parameters of net-current free heliotron plasmas has been made in LHD.

To explore physics in higher temperature heliotron plasmas, heating capability of LHD has been further strengthened.

Neutral Beam Injection (NBI) system delivers the total power of 29 MW (16 MW from 3 tangential beams (180 keV), and 13 MW from 2 perpendicular beams (one with 40 keV and the other with 60 keV).

ICRF antenna was renovated to accommodate two straps in the toroidal direction. This allows us to control the toroidal wave number by phase control of current, to improve the electron heating efficiency, and to suppress the impurity contamination by the reduction of sheath potential as well as high wave-number excitation. Especially, latter feature is appropriate for long-pulse discharge experiments.

The gyrotron with the world-record value of the output power (1.8 MW for > 1s by one tube, 77 GHz) was set up for the LHD experiment, and has realized the electron temperature beyond 20 keV in the currently on-going 14th campaign. Based on these strengthened heating capability, experiments for improving ion and electron heat confinement has been on-going.

The partial modification of divertor system provides critical data to finalize the design of closed divertor. Two toroidal sections (out of 10) of inboard side have been modified, although the pumping facility is not yet available. The identification of neutron compression capability has been pursued in this 14th campaign, which provides us to a firm physics basis towards helical closed divertor system in LHD.

LHD has provided flexible opportunities for international (as well as domestic) collaborations by providing plasmas with their parameters' extension. Examples of such collaborative experiments "with setting up their own equipments" in 14th campaign are described below. Daniel Carralero Ortiz (CIEMAT) set up a fast framing camera to measure peripheral plasma transport and plasma-wall interactions in LHD. P. Drewelow (IPP-Greifswald) set up an infrared camera to investigated divertor heat load distribution. As such, international joint experiments in the LHD have been always welcome, as emphasized through the CWGM activity. Final design and fabrication of an imaging crystal spectrometer has been done by the PPPL initiative led by M.Bitter. The spectrometer will be installed in LHD immediately after the 14th experimental campaign.

(cf., The LHD Experimental Technical Guide is available as follows.

[http://www.lhd.nifs.ac.jp/lhd/databook\\_2009/LHD\\_technical\\_guide2009/pdf/LHD%20Experiment%20Technical%20Guide.pdf](http://www.lhd.nifs.ac.jp/lhd/databook_2009/LHD_technical_guide2009/pdf/LHD%20Experiment%20Technical%20Guide.pdf) )

The special issue on LHD achievements was published in Fusion Science and Technology, Vol. 58, No.1 (Jul/Aug) 2011. It is composed of 60 papers all of which are based on 12-years LHD experiments with substantial contributions from international/domestic collaborators as well as from LHD experiment and technical groups. This is the milestone of LHD, having provided extensive opportunities for the world-wide collaborative research. The LHD will be providing further opportunities for collaborative research by extending machine capability, database, and associated information (like Technical Guide as above mentioned).

The Special issue is available at Fusion Science and Technology Website, [http://www.new.ans.org/pubs/journals/fst/v\\_58:1](http://www.new.ans.org/pubs/journals/fst/v_58:1).

## APPENDIX 2: PROGRESS REPORT ON WENDELSTEIN 7-X CONSTRUCTION

*(from Stellarator News: Oct. 2010 )*

### Status

Two modules are already in their final position on the machine base in the Torus Hall. A third module was transferred there in August 2010. Soon this module, too, will undergo final positioning. Work on the first module is concentrating on the difficult installation of about 50 ports. The ports provide access for the heating and diagnostics systems required for scientific measurements, and for cooling of in-vessel components. Assembly of half-modules, where the coils were threaded onto the plasma vessel, has been completed. This workstation has been freed up for prepare the ports for assembly. Two further extremely challenging work packages were completed: all of the special coil slide bearings have been manufactured, and the serial production of helium piping is complete. Both required innovation and expertise to employ novel manufacturing techniques.

### Bus bar systems for Wendelstein 7-X completed

At the heart of W7-X are 70 superconducting coils, which generate the stellarator's magnetic field. At the end of June 2010, the team at the Forschungszentrum Jülich celebrated the successful development and construction of the bus bar system for Wendelstein 7-X. This milestone ensures that the magnetic field coils can be supplied with high currents. The bus bar system provides electrical connections between the coils and to external power supplies. Ten coils of each type are connected in series and then to one current lead. The production was extremely complex, due to the three-dimensional design of the bus bars and the large forces that they must withstand. Components in the stellarator will move as much as a few centimetres and the bus bars have to absorb these stresses. Furthermore, the bus bars are installed in cramped space. This all results in extremely high accuracy requirements for the design and assembly. The bus bars are made from copper-niobium-titanium, the same material as the coils. Specially woven wires are placed in an aluminium jacket. Liquid helium will flow through the jacket to cool the wires down to 4 K. Since the coils are designed to be switched off very quickly, the electrical insulation was tested to 13000 V. Such a high level of performance is achieved by using two layers of Kapton foil embedded in a fibreglass reinforced epoxy resin. On the surface, a conductive lacquer prevents build-up of static charge and helps to detect short circuits. The comprehensive expertise and specialized equipment at the Forschungszentrum Jülich were utilized for the bus bar manufacture. A computer-controlled manufacturing line was specially built for the machining and bending of bus bars. After the first bus bars were produced, they were checked on a 1:1 mock-up of a Wendelstein 7-X module. The first bus bars were installed on a real module in 2009 while the rest were still in production. Currently, four of the five modules are equipped with their bus systems, and preparation for the last module is in progress. In total, the Forschungszentrum Jülich has produced and delivered 140 bus bars up to 14 m long. In addition, 400 brackets and 700 clamps have been made to attach the bus bars to the modules, and 240 joints to connect the modules to the coils. After the bus bars were bent to shape with millimeter accuracy, special transport racks were used to deliver them to Greifswald to prevent any in-transit distortion. Prior to assembly the ends were cut and bent precisely, transition pieces were welded on, the ends were insulated electrically, and detector wires were mounted. For the final assembly the technicians used a technique learned from Jülich production:

the bus bars hang from helium balloons as they are positioned delicately and precisely on the modules.

Cf.,

Wendelstein 7-X Newsletter:

<http://www.ipp.mpg.de/ippcms/eng/for/publikationen/w7xletters/index.html>

On Youtube:

<http://www.youtube.com/plasmaphysik>

## APPENDIX 3: SUMMARIES OF THE INSTITUTE OF PLASMA PHYSICS OF THE NSC KIPT, KHARKOV

### Plasma Theory

**1) Calculations of high energy particle losses for U-2M (Uragan-2M) taking into account the influence of the current feeds and the detachable joints of the helical winding** (V.V. Nemov, S.V.Kasilov and V.N. Kalyuzhnyj in collaboration with Technische universität Graz, Austria).

Because of the non-symmetric arrangement of the current feeds and the detachable joints of the helical winding of U-2M the stellarator symmetry of the magnetic field of U-2M is broken. This requires a special approach for the computation of the gradient of the magnetic surface function,  $\nabla\psi$ , in the numerical particle confinement study. Such an approach has been elaborated recently in the paper V.V. Nemov et al., Physics of Plasmas **17**, 052512 (2010). To assess particle losses, target functions are used, which have been introduced in Refs. V.V. Nemov et al., Phys. Plasmas, **12**, 112507 (2005) and Phys. Plasmas, **15**, 052501 (2008), in combination with the indicated approach for the  $\nabla\psi$  computation. For the calculation of the magnetic field the Biot-Savart code as well as the Lagrange polynomial interpolation are used.

Results for two magnetic configurations of U-2M are obtained for the rotational transform  $i$  within  $1/3 < i < 1/2$  and  $0.31 < i < 0.383$ . Because of broken stellarator symmetry island magnetic surfaces of significant sizes are formed for  $i=2/5$  and  $i=1/3$ . Calculations are also performed for the cases when the influence of the current feeds and the detachable joints is neglected and the indicated islands are very small. It follows from the results that for the considered conditions the particle confinement properties in presence of islands are approximately the same as in the absence of the magnetic islands. The results are published in V.V. Nemov et al., 37<sup>th</sup> EPS Conference on Plasma Phys, 21-25 June, 2010, Dublin, Ireland, ECA Vol. 34A, P1.1088.

**2) Weakly relativistic plasma dispersion functions computation using superasymptotic and hyperasymptotic series** / Pavlov S.S., Castejon F., Tereshchenko M. // Problems of Atomic Science and Technology, 2010, № 6, Series: Plasma Physics (16), p. 73-75. (On the base of superasymptotic and hyperasymptotic series there was given a general method of fast calculations of the weakly relativistic and fully relativistic plasma dispersion functions in the complex region.)

**3) Power-flow formulation of a ray approach to the modeling of inhomogeneous waves** / M. Tereshchenko, F. Castejon, S. Pavlov, A. Cappa / Submitted for publication. (An axiomatic approach to the formulation of a ray-based method is consistently presented, in which the ray trajectories are defined in a real phase space as the pathways of the wave power transport.)

**4) The calculations of parameters of reactor-stellarator** were provided with the use of a one-dimensional numerical code, giving the spatio-temporal behavior of DT-plasma in supposition of neoclassical transport. For basis of construction of the reactor the construction of the experimental device Uragan-2M is accepted ( $l=2$  helical winding together with the additional longitudinal magnetic field).

It is assumed that electron diffusion corresponds to dependence  $v^{-1}$  and ions – to  $v^{1/2}$ . The model of transport takes into account the ambipolarity of diffusive fluxes of plasma. The stationary burning is provided by dissipation of energy of alpha-particles, appeared due to fusion reaction of deuterium and tritium ions. The plasma density is maintained by the injection of fuel pellets as soon as plasma density in the volume of reactor decreases by 5%.

It was shown that the ion root of transport is realized ( $E_r < 0$ ) in the whole plasma volume. The steady state of the thermonuclear burning can be realized at the temperature of plasma  $\sim 12$  keV and density of plasma of  $(3-4) \cdot 10^{20} \text{ m}^{-3}$ . (V.A. Rudakov).

**5) Fission-fusion hybrid studies was continued.** Neutron distribution calculations in the fission blanket of the sub-critical fusion driven system are going on. For such calculations, a deterministic model is developed. In parallel, the Monte-Carlo calculations using MCNP-X code are involved. (V.E. Moiseenko, S.P. Fomin, S.N. Chernitskiy, O. Ågren, K. Noack)

**6) The self-consistent model of RF plasma production** includes the system of the balance equations of particles and energy and the boundary problem for the Maxwell equations. The balance of the electron energy includes the RF heating, energy losses for the electron impact excitation and ionization of atoms and losses caused by the heat transport. The balance of the charged particles includes accounts for the ionization and diffusion losses of particles. In the model it is assumed that the neutral gas is uniformly distributed in the vacuum chamber volume, including the plasma column. Besides plasma build-up inside the confinement volume, the RF field produces plasma outside it. The losses of the charged particles in this region have a direct character: the particles of plasma escape to the wall along lines of force of the magnetic field. This effect is accounted in the model. To make the system of the balance equations closed it is necessary to determine the single external quantity in it, RF power density. This quantity can be found from the solution of the boundary problem for the Maxwell's equations. The Maxwell's equations are solved at each time moment for current plasma density and temperature distributions. (V.E. Moiseenko, Yu. S. Stadnik, A.I. Lyssoivan)

**7) The adiabatic motion of charged particles in static electromagnetic fields is analyzed.** The equation for the corrected magnetic moment is obtained in coordinate-independent form. The derived local corrections to the magnetic moment invariant are oscillating and are associated with the particle drift. They have no influence on conservation of the magnetic moment in average, but they make the higher order magnetic moment invariant consistent with the other invariants such as the generalized momentum. The right-hand side of the equation determines the slow variation of the magnetic moment in time, and is associated with the magnetic field vorticity in current-carrying plasma. (V. E. Moiseenko, M. A. Surkova, O. Ågren)

## Plasma Experiment

### 1) Edge turbulence and its effect on anomalous transport in the Uragan-3M

### **torsatron**

In the  $l=3/m=9$  Uragan-3M (U-3M) torsatron/heliotron ( $R_0=100$  cm,  $\bar{a} \approx 12$  cm,  $\iota(\bar{a})/2\pi \approx 0.3$ ,  $B_\phi=0,72$  T) under conditions of RF plasma production and heating ( $\omega=0.8\omega_{ci}(0)$ ,  $\bar{n}_e \sim 10^{12}$  cm $^{-3}$ ,  $T_e(0) \sim 600$  eV) with a two-temperature ion distribution ( $T_{i1} < 100$  eV,  $T_{i2} \sim 250-400$  eV + suprathermal tail) at the heating power high enough, indications of transition to an H-like confinement mode are observed. Earlier, it has been shown experimentally that the transition in U-3M is connected with a bifurcation of the edge  $E_r$  toward a more negative value and an  $E_r$  shear enhancement, this being triggered by the fast ion loss (the  $T_{i2}$  group + suprathermal ions are meant). It is commonly believed that the  $E_r$  shear amplification results in damping of the edge turbulence and the turbulence-induced anomalous transport, this eventually explaining the H-mode transition.

Spectral and statistical characteristics of the edge turbulence and its effect on the edge transport in U-3M have been studied using movable arrays of Langmuir probes.

- The probability distribution function (PDF) of the edge plasma density fluctuation strongly differs from the Gaussian one. The analysis of results obtained in U-3M and included into the International Stellarator/Heliotron Edge Turbulence Data Base (<http://xanthippe.ipp-hgw.mpg.de/ISS/public>) shows that the 3rd (skewness, S) and 4th (kurtosis, K) moments of the PDF obey the universal parabolic relation  $K=1.54S^2+2.68$  [F. Sattin *et al.*, Phys. Scr. **79** (2009) 045006].

- A distinct correlation exists between the time behavior of the radial turbulent flux in the boundary plasma and the average plasma in the confinement volume. (A.A. Beletskii, V.V. Chechkin, I.M. Pankratov, L.I. Grigor'eva, Ye.L. Sorokovoy, Ye.D. Volkov, P.Ya. Burchenko, A.Ye. Kulaga, S.A. Tsybenko, A.V. Lozin, A.S. Slavnyj, N.V. Zamanov, V.K. Pashnev, V.L. Berezhnyj)

### **2) Studies of electron loss contribution to the asymmetry of plasma flows in the helical divertor of the Uragan-3M torsatron**

In the Uragan-3M (U-3M) device with an open natural helical divertor under conditions of RF plasma production and heating with a two-temperature ion energy distribution ( $T_{i1} < 100$  eV,  $T_{i2} \sim 250-400$  eV + suprathermal tail up to several keV), a strong up-down asymmetry of the plasma divertor flows (PDF) has been observed. In particular, the asymmetry displays in the larger ambipolar PDF outflowing on the ion  $\nabla B$  side ("ion side") and in an excess of ions in the corresponding non-ambipolar flow. On this basis a conclusion has been drawn that the asymmetry is caused by the direct (collisionless, non-diffusional) ion loss. This has been validated by a numerical modeling of charged particle loss and direct comparative measurements of energies of ions outflowing to the divertor on the ion side and on opposite ("electron") side. However, the role of electrons in forming the asymmetry has not been cleared up before.

Experiments have been undertaken to find out the electron contribution to the PDF up-down asymmetry. To do this, arrays of plane Langmuir probes are used arranged poloidally in the divertor region in the gaps between the helical coils in two symmetric poloidal gross-sections of the U-3M torus. As a result of IV characteristic processing, it is shown that the hotter electrons outflowing to the PDF on the electron side make a more significant contribution to the flow up-down asymmetry than fast ions escaping to the PDF mainly on the ion side.

Changes in the density and temperature of hotter electrons that escape to the PDF

have been studied with the H-like mode transition. These changes occur much more substantial than those on the ion side and indicate a considerable reduction of particle and energy loss through the electron channel. Thereby, a similar conclusion based on other independent measurements in U-3M has been confirmed. (V.V. Chechkin, L.I. Grigor'eva, Ye.L. Sorokovoy, A.A. Beletskii, A.S. Slavnyj, V.S. Voitsenya, Ye.D. Volkov, V.K. Pashnev, N.V. Zamanov, A.Ye. Kulaga, R.O. Pavlichenko, F.I. Ozherel'ev, P.Ya. Burchenko, A.V. Lozin, S.A. Tsybenko, Yu.K. Mironov, V.S. Romanov)

### **3) Development of the soft X-ray diagnostics and its measurement techniques**

A novel technique of rotating MHD modes localization is proposed; criteria have been established numerically and tested experimentally in the STOR-M tokamak. This technique provides significant noise reduction, effectively isolating the MHD oscillations from other interfering components. The radial location of the 20-30 kHz MHD mode has been determined in the STOR-M tokamak by this technique. (M.Dreval, A. Hirose, C.Xiao)

### **4) An energy sweeping technique has been developed and applied for charge exchange**

(CX) neutral particle diagnostics in the URAGAN-3M torsatron. The presence of ions with energies up to 4 keV was confirmed in the low-density ( $n_e=(0.5-1)\cdot 10^{12} \text{ cm}^{-3}$ ) frame antenna radio frequency (RF) plasma discharges. Fast ion energy rise was observed in the plasma buildup stage. The ion energy distribution is close to the Maxwellian one in the energy range 0.4-2.5 keV. The ion temperature  $T_i=300-600 \text{ eV}$  in this energy range was determined. This is an indication of a direct RF energy deposition into the ions due to the negligible ion-electron energy exchange. It has been established that the ion temperature distribution investigated is flat in the range of  $p=0.5-1$ . Also, the edge RF energy deposition into the ions is expected. (M. Dreval, A.S. Slavnyj)

### **5) The U-3M torsatron discharge scenario without continuous gas puffing has been proposed**

for study of a role of hydrogen atoms and molecules flux on the plasma build-up, heating and confinement. The U-3M magnetic system is enclosed into a large vacuum chamber and such role may be critical. A system of arbitrary gas puffing set using a computer has been proposed, designed and manufactured. This system can be used for optimisation of THT antenna discharges, in particular for the plasma density control. (M.Dreval)

### **6) Electron temperature evaluation from the second harmonic electron cyclotron resonance radiation**

Radial profile of X-mode second harmonic electron cyclotron emission (ECE) was observed for optically thin plasma produced by Alfvén resonance heating in Uragan-3M (U-3M) torsatron. At present, one channel receiver measures at a single frequency per plasma shot. For the ECE frequency range 31-37 GHz the reconstruction of electron temperature profile was done for several consecutive shots in assumption of the constant plasma parameters. Radial electron temperature profile was derived from "radiation temperature" profile using approximation formula for the plasma optical thickness. The applied conversion procedure ignores multiple reflections from the walls (due to "open magnetic system" of



the U-3M device) of the vacuum chamber, but nevertheless has sufficiently small errors according to estimation. For special plasma production conditions (additional gas-puffing) an ECE “cut-off” phenomena (rapid signal losses) due to the overdense plasma is clearly observed. Thus, it is possible to estimate the value of the local “threshold” electron density. In the absence of Thomson scattering system the temperature data were cross-checked with other electron temperature related diagnostics (SXR, optics, etc.). (R. Pavlichenko, A. Kulaga, N. Zamanov, O. Pavlichenko and U-3M team)

### **7) Microwave plasma diagnostics**

Two new microwave diagnostics were prepared for operation on Uragan-2M and Uragan-3M stellarator-type fusion devices. One of them is six channel super-heterodyne radiometer operating within frequency range 57-74 GHz that optimized for the central magnetic field 0.95-1.15 T. This diagnostic will measure electron temperature radial profile in a single plasma discharge. A new 140 GHz, 40 mW compact interferometer system has been developed to diagnose average density of the bulk plasmas on Uragan-2M and Uragan-3M. It will replace the old system that was under operation for more than 25 years. To minimize signal losses a new optimized waveguide transmission line have been installed. System is equipped with I-Q detection system with phase deviation accuracy of 0.1 degree, that corresponds to minimal detectable relative density fluctuations level of 0.001 percent. Preliminary data which shows good system instrumental characteristics and measurement capabilities were obtained at small plasma device “MAKET”. (R. Pavlichenko, A. Kulaga, A. Skibenko, O. Pavlichenko in collaboration with State Scientific & Research Institute “ORION”, Kiev)

### **8) Limiter for Uragan-2M torsatron**

A movable B<sub>4</sub>C-limiter has been designed, manufactured and installed in the Uragan-2M torsatron. The first experiments with low density plasma produced at RF and UHF wall conditioning regimes have shown no cutoff of the plasma column (excepting the zone behind the limiter plate) after crossing the last closed magnetic surface with the limiter plate and its moving to the plasma column axis. Because B<sub>4</sub>C is a moderate conducting material, the limiter can be used for providing biasing experiments. In addition, an essential ion currents might be extracted during the RF plasma pulsed-discharge cleaning regime and supplied to the head B<sub>4</sub>C-plate, what can be used for partial solid-target boronization of the Uragan-2M vacuum vessel walls. (G.P. Glazunov, D.I. Baron, M.N. Bondarenko, P.Ya. Burchenko, V.V. Chechkin, V.Ya. Chernyshenko, L.I. Grigor'eva, V.G. Konovalov, A.L. Konotopskiy, V.G. Kotenko, A.V. Lozin, S.M. Maznichenko, V.E. Moiseenko, V.K. Pashnev, N.P. Ponomarenko, S.I. Solodovchenko, E.L. Sorokovoy, A.V. Shapoval, V.I. Tereshin, V.S. Voitsenya).

**9) Experiments on RF heating below ion-cyclotron frequencies in Uragan-3M torsatron** were provided using a compact strap antenna (THT antenna). The experiments demonstrate electron plasma heating within the Alfvén resonance heating scenario. Initial plasma density  $\langle n_e \rangle \approx 10^{12} \text{ cm}^{-3}$  is increased by the order of magnitude

during the THT antenna pulse and is controlled by the pulsed gas puff. Electron heating is dominant. Some ion heating is also observed. The plasma with the density  $\langle n_e \rangle \approx 0.5 \times 10^{13} \text{ cm}^{-3}$  and electron temperature  $T_e(0) \approx 0.5 \text{ keV}$  obtained in the experiments have a highest energy content as compared with earlier experiments on Uragan-3M device. (V.E. Moiseenko, M.B. Dreval, P.Ya. Burchenko, A.V. Losin, V.L. Berezhenyj, V.N. Bondarenko, V.V. Chechkin, L.I. Grigor'eva, D. Hartmann, R. Koch, V.G. Konovalov, V.D. Kotsubanov, Ye.D. Kramskoi, A.E. Kulaga, A.I. Lysoivan, V.K. Mironov, R.O. Pavlichenko, V.S. Romanov, A.N. Shapoval, A.I. Skibenko, A.S. Slavnyi, V.I. Tereshin, V.S. Voitsenya.)

**10) Continuous RF discharges for wall conditioning in Uragan-2M** were sustained in the first experimental series by the 1 kW RF oscillator in the frequency range 4.5-8.8 MHz. This power is coupled to plasma by a frame antenna which is used for plasma production in regular discharges. Plasma with low density up to  $2 \cdot 10^9 \text{ cm}^{-3}$  is sustained. The dissociation degree of hydrogen given by the optical measurements for such a discharge is about 1%. To increase it, higher plasma density is necessary. To achieve higher discharge performance, a higher frequency RF heating at 135 MHz is chosen. A new small frame antenna is manufactured and installed in Uragan-2M. With this antenna the dissociation degree ranges in 6-10%. (V.E. Moiseenko, P.Ya. Burchenko, V.V. Chechkin, L.I. Grigor'eva, D. Hartmann, R. Koch, Ye.D. Kramskoi, A.V. Losin, A.I. Lysoivan, I.N. Misiura, A.N. Shapoval, V.I. Tereshin, V.S. Voitsenya)

**11) The measurements of radial plasma potential and electron density** as well as their fluctuations by Heavy Ion Beam Probe (HIBP) diagnostic and study of their influence on the plasma confinement in helical axis Stellarator TJ-II with ECR and NBI heating were continued in the frame of the collaboration of IPP NSC KIPT with CIEMAT (Madrid).

**11.1)** Low density ECRH plasmas ( $n_e = (0.3-1.1) \times 10^{19} \text{ m}^{-3}$ ) are characterised by positive potential up to  $\varphi(0) = +1200 \text{ V}$  at the centre of plasma column. The minor area of the negative potential may appear at the edge depending on the plasma density. The density rise is accompanied by the decrease of potential, which evolves to the less absolute values becoming fully negative if  $n_e > 1.5 \times 10^{19} \text{ m}^{-3}$ . Contrary, the rise of  $T_e$  due to  $P_{\text{ECRH}}$  increase leads to the linear potential rise. NBI plasma is characterized by fully negative potential up to  $\varphi(0) = -600 \text{ V}$  for higher densities. The density rise is accompanied by increase of an value of absolute potential. However, if density approaches  $n_e = (2.0-2.5) \times 10^{19} \text{ m}^{-3}$ , the potential saturates. L-H transition spontaneously happening in NBI plasma is characterized by further potential drop  $\sim -100 \text{ V}$ , formation of the edge layer of the negative  $E_r \sim -100 \text{ V/cm}$ , strong suppression of the density oscillations and turbulent particle flux at the edge and bulk plasma. Thus, potential behaviour in TJ-II shows clear link between the negative electric field formation, turbulence suppression and rise of the plasma density and plasma confinement. Similar trend has been observed in tokamaks.

**11.2)** Energetic ion driven Alfvén Eigenmodes (AE) are believed to be an important element disturbing the transport in a future reactor.

HIBP becomes a new diagnostic tool to study Alfvén Eigenmodes directly in the bulk plasma with the high spatial ( $\sim 1 \text{ cm}$ ) and frequency resolution ( $< 5 \text{ kHz}$ ); NBI induced AEs in the TJ-II stellarator are pronounced in all three HIBP parameters:

potential/density/ $B_{pol}$  due to their intrinsic electric and magnetic fields and pressure (density) oscillations; all three quantities present high coherency and finite cross-phase between each other, while the AE frequency varies strongly due to the density variation. NBI induced AEs in the TJ-II stellarator are characterized by potential oscillations in a range of  $\delta\phi \sim 10$  V,  $\delta E_{pol} \sim 10$  V/cm. This is the first direct observation of the electrostatic potential /  $E_{pol}$  oscillations of AEs in toroidal plasmas. AE contribution to the turbulent particle flux was found to be both outward and inward, having same level as the broadband turbulence flux in the NBI heated regimes of TJ-II.

**12) The measurements of radial plasma potential and electron density** and also their fluctuations by Heavy Ion Beam Probe diagnostic and study of their influence on the plasma confinement in tokamak T-10 with ECR and OH heating were continued in the frame of the collaboration of IPP NSC KIPT with Kurchatov Institute (Moscow).

**12.1)** Plasma electric potential in T-10 has negative sign and scale about several hundred Volts depending on plasma conditions:  $\phi(6\text{cm}) \sim -1300 -1500$  V; Potential profile has nearly linear shape,  $E_r \sim \text{const} < 0$ , directed towards the plasma centre;  $E_r \sim -50-90$  V/cm. The absolute value of potential is decreasing with the rise of PEC, negative  $E_r$  decreases in the whole observation area till the very edge (limiter). The absolute value of potential is increasing with the rise of density, negative  $E_r$  increases. Stronger negative  $E_r$  is associated with higher  $t_E$ .

Within the achieved experimental accuracy, the broadband drift-wave turbulence tends to rotate with the  $E \times B$  rotation velocity in OH and ECRH plasmas.

**12.2)** Geodesic Acoustic modes (GAMs) were found in T-10 and their features were studied in the ECRH regimes for the first time. They are: GAM amplitude reaches 100 V and the satellites were found. The long range density-potential correlations were observed, the intermittent character of GAM, and GAM modulation by sawteeth were detected.

**13) Investigations of the electric field by the Heavy Ion Beam Probe** diagnostic have been continued on the Tuman-3M (St-Petersburg): to study potential evolution during L-H transition caused by HBI heating.

**14) Development of the Heavy Ion Beam Probe diagnostic for torsatron Uragan-2M** have been continued in the frame of Ukrainian Academy of Science assignment.

**14.1)** To implementation HIBP diagnostic to Uragan-2M ( $B_t$  up to 2 T) it is necessary to have a probing beam of heavy ion. Thallium ions obtained by thermoionic source is more preferable for resolving this problem. It was developed technology of the thallium solid state emitter manufacturing and the detailed characteristics of the emission of thallium ions were investigated. As a result of this efforts, the ion current up to 500  $\mu\text{A}$  has been obtained.

**14.2)** Measurements of the electric plasma potential require of the energy probing beam measurements with very fast response. Development, manufacturing and investigation of the energy analyser of the Proca-Greena kind have been done. Tuning and calibrations of the analyser show the energy resolution  $\Delta E/E = 10^{-4}$ .

**14.3)** Diagnostic HIBP complex for Uragan-2M is advanced for tuning and testing. It is ready for installation on the machine.

### **15) Modification of morphology and optical properties of W surface due to exposure to low-energy, high flux deuterium plasma ions**

The investigations of temperature effects on modification of surface morphology and optical properties of tungsten mirror samples exposed to low energy deuterium ions (38 eV) up to ion fluence  $10^{26}$  D/m<sup>2</sup> were performed. It was found that the surface state weakly depends on the exposure temperature in the range 320-695 K with the exception of a quite narrow region around 535 K, which is characterized by active blistering and drastic change of all optical characteristics. It is worthy to note that for sample exposed at 535 K, the reflectance found in direct measurements at normal incidence drops in the wavelength interval 220-650 nm, whereas the estimations of reflectance demonstrate some increase when the optical indices  $n$  and  $k$  found from ellipsometry data are used.

The reason of this difference is that both methods are based on different physical effects. In reflectometry of specular reflection, the full energy specularly reflected from the sample is measured, thus the surface defects result in decrease of the specular reflectance. The ellipsometry is based on investigation of changing the polarization state of the specular component only, without taking into account the parts which scatter the light. Thus the strong modification of ellipsometric characteristics means, probably, significant modification of the electronic structure for the specimen exposed at 535 K as distinct from those exposed at other temperatures. (V.S.Voitsenya, V.G.Konovalov, S.I.Solodovchenko, W.Kh.Alimov, K.Isobe, T.Yamanishi)

### **16) Simulating study of plasmachemical erosion of a-C:H films in a ECR discharge plasma**

It is suggested to control *in situ* the quality of cleaning the walls of vacuum chamber of the stellarator type fusion device Uragan-2M by means of mirrors installed into the vacuum chamber. The idea of this suggestion is as follows. Before mirror installation, the carbon-containing film is deposited (e.g., a-C:H film) on its surface, and the *in situ* measurements of reflectance (e.g., at the He-Ne laser wavelength) during the conditioning procedure can give possibility to make conclusion about the cleaning efficiency.

To estimate the prospect of such method, preliminary simulating experiments on the special stand DSM-2 were carried out, where ECR plasma was produced by UHF power ( $\approx 400$  W at frequency 2.37 GHz). The electron temperature did not exceed 5 eV, and the plasma density in the place of mirror location was  $\sim 1 \cdot 10^{10}$  cm<sup>-3</sup>. No any voltage was applied to the mirror holder thus the ion energy was  $\leq 15$  eV, i.e., the mechanism of film was etched by chemical erosion. In experiments the SS and Cu mirror were coated with a-C:H film in a non-self-maintained discharge in a propane-butane mixture. The amorphous film was semitransparent in visible light. From the time dependence of spectral reflectance change during cleaning procedure the thickness of the film and efficiency of mirror cleaning were estimated. (V.G.Konovalov, M.N.Makhov, I.V.Ryzhkov, A.N.Shapoval, A.F.Shtan', S.I.Solodovchenko, A.I.Timoschenko, V.S.Voitsenya)

**Some of joint presentations at different conferences and joint publications:**

- 1) I. Bondarenko, A. Chmyga, G. Deshko, A. Komarov, A. Kozachek, L. Krupnik, S. Khrebtov, Yu. Tashev, A. Zhezhera, "Investigations of Thermo-Ionic Emitters of Heavy Alkali Metals for Diagnostic Injector of URAGAN-2M Stellarator", accepted for publication in Atomic Science and Technology, series Plasma Physics, 2011, #1, 173-175.
- 2) I. Bondarenko, A. Chmyga, G. Deshko, A. Komarov, A. Kozachok, L. Krupnik, S. Khrebtov, Yu. Tashev, A. Zhezhera. "Hibp Diagnostic Injectors for Uragan – 2M and TJ-II stellarators" Problems of Atomic Science and Technology, series Plasma Physics, 2010, #6 211-213.
- 3) L.I. Krupnik, A.V. Melnikov, C. Hidalgo, A.A. Chmyga, L.G. Eliseev et al. "Plasma turbulence and local electric field investigations of the dense plasma on TJ-II stellarator and T-10 tokamak by HIBP diagnostic" submited to Problems of Atomic Science and Technology.
- 4) A.V. Melnikov, V.A. Vershkov, S.A. Grashin, L.G. Eliseev, S.E. Lysenko, V.A. Mavrin, V.G. Merezkin, S.V. Perfilov, D.A. Shelukhin, R.V. Shurygin, L.I. Krupnik, A.D. Komarov, A.S. Kozachek, A.I. Zhezhera. "Study of plasma potential, its fluctuations and turbulence rotation in the T-10 tokamak". Atomic Science and Technology, series Plasma Physics, 2010, #6 40-42.
- 5) L.I. Krupnik, A.V. Melnikov, C. Hidalgo, A.A. Chmyga, L.G. Eliseev, E. Ascasibar, A. Zhezhera et al. "Heavy Ion Beam Probe (HIBP) diagnostic as a tool for plasma turbulence and local electric field investigations of the dense plasma" Plasma Diagnostics Conference "PLASMA 2010", Pont-à-Mousson, Nancy, France, 12-16 April 2010.
- 6) A.V. Melnikov, V.A. Vershkov, S.A. Grashin, L.G. Eliseev, S.E. Lysenko, V.A. Mavrin, S.V. Perfilov, R.V. Shurigin, D.A. Sheluchin, L.I.Krupnik, A.I. Zhezhera, A.D.Komarov, Measurements of Plasma Potential, Radial Electric Field and Turbulence Rotation Velocity in the T-10 Tokamak" 37-th EPS Conference on Plasma Physics, Dublin, Ireland O5.128, June 21 - June 25, 2010.
- 7) L.G. Askinazi, F.V. Chernyshov, M.A. Irzak, A.D. Komarov, L.I. Krupnik et al. "Study of NBI-caused LH transition at low density in the TUMAN-3M tokamak" 37-th EPS Conference on Plasma Physics, Dublin, Ireland P1.1005, June 21 - June 25, 2010.
- 8) A.V. Melnikov, S.V. Perfilov, L.G. Eliseev, S.E. Lysenko, V.A. Mavrin, R.V.Shurygin, D.A. Shelukhin, V.A. Vershkov, G.N. Tilinin, S.A. Grashin, L.I. Krupnik, A.D. Komarov, A.S. Kozachek et. al. "Study of the GAM Characteristics in the T-10 Tokamak 37-th EPS Conference on Plasma Physics, Dublin, Ireland P1.1065, June 21 - June 25, 2010.
- 9) K.I. Krupnik, A.V. Melnikov C. Hidalgo, A. Alonso A.D. Komarov, A.S. Kosazek et al, "Plasma Potential Profiles and Oscillations in the ECRH and NBI Plasmas in the TJ-II Stellarator" 376th EPS Conference on Plasma Physics, Dublin, Ireland P1.1066, June 21 - June 25, 2010.
- 10) A.V. Melnikov et al. "Direct plasma potential and turbulence measurements by HIBP in toroidal devices" EFTSOMP2010 - 13<sup>th</sup> Workshop on Electric Fields, Turbulence and Self-Organization in Magnetized Plasmas, Satellite meeting of the 37<sup>th</sup> EPS Plasma Physics Conference, Dublin, Ireland, June 28 – 29, 2010.
- 11) L.I. Krupnik et al, "Development of the accelerating beam probe diagnostic for plasma turbulence and local electric and magnetic field investigations of the dense fusion plasmas" EFTSOMP2010 - 13<sup>th</sup> Workshop on Electric Fields, Turbulence and

Self-Organization in Magnetized Plasmas, Satellite meeting of the 37<sup>th</sup> EPS Plasma Physics Conference, Dublin, Ireland, June 28 – 29, 2010.

- 12) V.S. Voitsenya, S. Masuzaki, O. Motojima, and J. Davis. "Plasma cleaning of the surfaces from oxides: the state of the art". AIP Conference Proceedings, **1282** (1) pp. 96-102.
- 13) V.E. Moiseenko, K. Noack, O. Agren. "Stellarator-mirror based fusion driven fission reactor" J Fusion Energy **29** (2010) 65–69.
- 14) V.Kh. Alimov, A.I. Belyaeva, A.A. Galuza, K. Isobe, V.G. Konovalov, A.A. Savchenko, K.A. Slatin, S.I. Solodovchenko, V.S. Voitsenya, T. Yamanishi. "Modification of optical properties of tungsten exposed to low-energy, high flux deuterium plasma ions". Atomic Science and Technology, series Plasma Physics, 2011, #1, 179-181.

#### **APPENDIX 4: TECHNICAL REPORT ON TJ-II ACTIVITIES IN 2010**

The results achieved in the TJ-II stellarator during 2010 were obtained in plasmas created and heated by Electron Cyclotron Resonance Heating (ECRH) (2 x 300 kW gyrotrons, at 53.2 GHz, 2<sup>nd</sup> harmonic, X-mode polarisation) and Neutral Beam Injection (NBI). Two beams of 400 kW port-through (H0) power at 30 kV, were injected on TJ-II.

We have continued with the characterization of plasmas under Li-coating walls, which has allowed to enlarge the operational density range and to reach H-mode customarily. The energy confinement time increases substantially for high density plasmas even in L mode. The properties of Li on the wall have been studied including the Li sputtering under H and He plasmas. The sputtering and desorption characteristics of H and He plasmas on a Li surface have been investigated in TJ-II, showing in particular that the threshold for Li sputtering and for H desorption are very similar in He plasmas, which suggests that both species could obey to the same release mechanism. However, a higher mass than that of LiH would be still required to explain the experimental energy values. Laboratory experiments in progress to check the influence of the underlying B layer on these findings. The properties of fast ion confinement are also described, showing the appearance of Alfvén modes, as well as the effects of impurities on radiation profiles, showing two types of emissivity profiles the “bell” and the “dome” shape, being the latter more robust under radiative collapse. The transition from one type of profile to another has been provoked dynamically in a single discharge by impurity puffing.

The L-H transitions have shown the development of long range correlations of the turbulent floating potential in the plasma edge coupled to the presence of mean and fluctuating radial electric fields. These findings provide a new guideline for understanding the trigger mechanisms of the L-H transition, pointing out the importance of low frequency fluctuating sheared ExB flows. These long-range toroidal correlations are modulated during fine dynamical scans in the magnetic configuration in the proximity of low order rational surfaces, which is consistent with the theory of zonal flows linked to the magnetic topology. The low order rational surfaces located in the edge also provoke a better quality H-mode. Close to the transition threshold, a coupling between sheared flows and turbulence level is measured which reveals a characteristic predator-prey behaviour consistent with L-H transition models based on turbulence driven flows.

## APPENDIX 5: TECHNICAL REPORT ON HELIOTRON J ACTIVITIES IN 2010

Effects of the confinement configuration on the fast ion confinement, the bulk thermal confinement, the plasma current control, and the particle fuelling control have been investigated in Heliotron J, a flexible helical-axis heliotron, with special regard to the optimization study of the helical system with a spatial magnetic-axis and a vacuum magnetic well. To attain the drift optimization of the L=1 helical-axis heliotron, the bumpiness control is essential to reduce the neoclassical transport (or the effective helical ripple). The experiments have been performed by changing the bumpiness with keeping plasma volume, plasma axis position, and edge rotational transform almost constant. The Heliotron J activities in 2010 are summarized as follows:

- 1) The SMBI fuelling has been successfully applied to Heliotron J plasma. A supersonic H<sub>2</sub>-beam is effective to increase fuelling efficiency and make a peaked profile. Local fuelling with a short pulse by SMBI can increase the core plasma density avoiding the degradation due to the edge cooling. A large increment of plasma stored energy after a short pulse intense gas fuelling from a conventional piezoelectric-valve system has been observed in NBI (or NBI+ECH) plasma. The physics under the observation would give us a new insight into more preferable plasma operation conditions.
- 2) Edge plasma behavior during supersonic molecular-beam injection (SMBI) has been measured with fast camera. The bright stripe observed at SMBI appears to be very dense neutral clouds expanded along the magnetic field line. After ~1ms, the bright stripe seems to be rotating, and then the rotation stops and the bright stripe seems to move along the magnetic field line.
- 3) Fast ion velocity distribution has been investigated using fast protons generated by ICRF minority heating. In the standard configuration in Heliotron J, the larger fast minority protons are observed in the on-axis resonance case than in the HFS resonance case. However, the increase of the bulk ion temperature in the HFS resonance case is larger. The change of the absorption ratio is one candidate for the explanation of the experimental result. The three-dimensional wave analysis using TASK/WM code suggests that the change of the absorption ratio among the minority and majority ions is one candidate for the explanation of the experimental result.
- 4) Second harmonic ECCD experiments have been performed. A focused Gaussian beam is injected with a wide range of parallel refractive index,  $-0.05 \leq N_{\parallel} \leq 0.6$ . The experimental results show that the EC driven current is determined not only by  $N_{\parallel}$  but also by local magnetic field structure where the EC power is deposited. A large increase in ECE signals has been observed when the EC current was driven, indicating the important role of high-energy electrons on the ECCD. The experimental results on the  $N_{\parallel}$  and  $B$  dependences are in quantitative agreement with a ray tracing simulation using TRAVIS code.
- 5) A bursting global Alfvén eigenmode (GAE) has been observed in Heliotron J NBI plasmas under the condition that the energetic particle confinement was fairly good. The response of fast ion fluxes to the Alfvén eigenmodes was measured with a hybrid directional Langmuir probe (HDLP) system. A high coherent response of the ion flux to the GAE bursts has been observed. The experiments



indicate that the fast ion response is considered to be a resonant convective oscillation.

- 6) An amplitude modulation (AM) type system of reflectometer (the frequency of carrier waves: 33-56 GHz, the modulation frequency: 200 MHz.) has been developed for electron density profile measurement in Heliotron J. Electron density profile has been measured by using the AM reflectometer in a plasma where the performance is improved by using SMBI as a fuelling method. The measurement suggests that the SMBI affects the particle confinement and transport, leading to the increase in plasma stored energy,  $W_p$ .
- 7) The investigation of configuration effects on the energetic ion and the bulk thermal confinement in the neutral beam injection (NBI) plasmas have been continued expanding the parameter range of  $\varepsilon_b/\varepsilon_h$  and  $\varepsilon_t/\varepsilon_h$ .
- 8) To deepen the understanding of the configuration effects on confinement, design and installation of new diagnostics such as an YAG laser Thomson scattering system for temporal temperature/density profile measurement, a BES system, an improved CXRS system, far-infrared interferometer, upgraded Langmuir probes and magnetic probes (saddle coils) and fluctuation measurement by using an SX tomography and an AM reflectometer is in progress in Heliotron J to obtain profile data. Advanced wall conditioning method using a Li coating is under development.

## Minutes of 39th Stellarator-Heliotron

### Executive Committee Meeting

12th October, 2010

11:30 am – 2:20 pm

Room 105, Daejeon Convention Center, Daejeon, Rep. Korea

#### Attendees

Australia	B.Blackwell
	J.H.Harris
EU	R.Wolf
	J.Sanchez
	C.Hidalgo
Japan	O.Motojima (chairperson)
	A.Komori
	H.Yamada (secretary)
Ukraine	I.Garkusha (substitute for V. I. Tereshin)
USA	M.C.Zarnstorff (vice chairperson)

#### Observer

C.Pottinger (IEA)  
D.A.Gates (PPPL, USA)  
M.Yokoyama (clerk, NIFS, Japan)  
H.Kataoka, T.Matsumoto, I.Amagasa (MEXT, Japan)  
T.Oshitani, A.Tonouchi, A.Kato (NIFS, Japan)

#### Agenda

- 1) Approval of Agenda
- 2) Approval of minutes of the 38th S-ExCo meeting
- 3) Chairmanship and membership of SH-ExCo
- 4) Report of extension of IEA-IA
- 5) Status of domestic activities and international collaborations
- 6) Development of stellarator/heliotron working groups
- 7) 18<sup>th</sup> International Stellarator/Heliotron Workshop 2011
- 8) Cooperation on Steady State Operation
- 9) Miscellaneous and final remarks

Meeting was opened by Motojima, chair and he welcomed all participants to the 39<sup>th</sup> Stellarator-Heliotron Executive Committee (SH-ExCo) meeting.

Motojima: Today, we have a special guest from IEA, Ms. C.Pottinger. She has contributed a lot to establish the continuation of this IA. From Ukraine, the director of the Kharkov institute, Prof, Tereshin passed away. We are very sorry for it. He had contributed a lot. Dr. Garkusha was introduced as a substitute from Ukraine.

Mr. Kataoka, Director of International Nuclear and Fusion Energy Affairs Division of MEXT, was introduced. Mr.Matsumoto and Ms.Amagasa (MEXT) were also introduced. Dr.Yokoyama, Mr.Oshitani (Director of Research Support Division of Department of Administration), Mr.Tonouchi and Ms.Kato (NIFS) were also introduced. It was also mentioned that there was no participant from Russia this time. 8 members are attending, and thus a quorum is satisfied. Dr.Gates from PPPL is also attending.

### **1. Approval of Agenda**

The proposed agenda was approved.

### **2. Approval of minutes of the 38th S-ExCo meeting**

No comments were raised. The minutes were approved as they are.

### **3. Chairmanship and membership of SH-ExCo**

Motojima: I am now the DG of ITER organization in Cadarache. The reason for this appointment would be the enough experience in stellarator-heliotrons, and I am happy and ready to continue this very important position, SH-ExCo, if you agree. I have a strong secretary, Dr.Yamada, and this ExCo is keeping a good relation to contribute international activity. I hope to hear your frank ideas.

Wolf: I think this is a very good continuation what we have done in the past. The present situation is that the LHD is the largest operating heliotron device worldwide. It is a very good link to ITER and tokamak activities. Hence, this proposal is very welcome.

Sanchez: We all congratulate Dr. Motojima to become a DG of ITER. This is a personal achievement, and also an achievement of SH community. We will be in very good hands of your chairmanship with the help of Yamada.

Komori: I also recommend Motojima-sensei to continue. He must be very busy, but I hope it is possible for Motojima-sensei to continue the chairperson of the ExCo.

Motojima: It's my great honor to complete my responsibility as the chairman of the IA. I just want you to make sure is there any conflicts of interests?

Harris: I see only a positive conflict. As you said in you talk yesterday, ITER is the major

commitment. That also involves stellarator people. All the talks I heard yesterday raised the issues of 3D physics over and over again. There is a role for people doing stellarator research in a broader toroidal physics community, and more over, to an increasing extent, support for stellarators is going to involve making commitments to apply knowledge and tools that we have to resolve difficult issues they are facing. So, that's why it's not of conflict of interests, and it's a coincidence of interest. So, I see no problems on this proposal.

Motojima: I found my increased responsibility. I will do my best. From IEA side, is there a conflict of interest?

Pottinger: I just want to make sure all the parties unanimously agree. *(Please refer postscript)*

Garkusha: I cannot make some decision here, but, of course, I think it's very good.

Blackwell: Same as Australia.

Pottinger: I, of course, am very positive and supportive. I very much look forward to see your results in ITER. I do not see any conflicts of interests.

Yamada: We have to hear the opinion from the US.

Zarnstorff: This is a very positive thing. Stellarator community well connected to ITER.

Motojima: At next day of 27 Jul, after the ITER council designated me as DG, I organized all-staff meeting, 750 already. I said several important messages, and then I come here to make ITER project successful with you. What I attached is that I have no idea to change ITER to a stellarator. I expect and ask more contributions in physics, engineering and science. Always open to anybody, any institutions to come to Cadarache. Thank you very much.

Motojima: As for the membership, I hope to here a proposal from Ukraine.

Garkusha: We would like to propose Prof. Voitsenya as a member of ExCo. Also, I want to report that an election of new DG of plasma physics institute is going on. Probably he will be the second representative from our team. During a previous meeting, Prof. Pankratov attended as a substitute, I propose him as a substitute. One more person is Prof. Checkin. Election will be at the beginning of the next year. I can report after election in more details to Dr. Yamada.

Motojima: Thank you very much. We welcome new membership from Ukraine.

Yamada: We know Prof. Voitsenya very well. He visited us for a long time.

Motojima: Article 3 is the list of member. Dr. Voitsenya and new director will be new member from Ukraine. Let me make sure there are no other changes.

#### **4. Report of extension of IEA-IA**

Article 4: Agreement on cooperation of development of stellarator-heliotron concepts

Article 5: A letter from Directorate for Sustainable Policy and Technology of IEA, Mr. Bo Diczfalusy

Motojima: We are already aware of the contents. This was approved for the extension till July 30, 2015, and the name was changed adding "Heliotron". So, this is Stellarator-Heliotron IA (SH-IA). I strongly appreciate Dr. Ascasibar on his attendance on CERT meeting. This will be valid until June 30, 2016, and the reason is written on article 5. I need some explanation from Prof. Yamada, and then *I hope to hear unanimous agreement. (Please refer postscript)*

Yamada: One thing is that a valid date will be extended. Article 5 shows that review system of IEA has been changed, in particular, in the CERT, and they requested us to extend validation period until Jun 30, 2016. This means we have another extra 11 months for the present IA.

Pottinger: It's very complicated seen from the outside. CERT has made some decision of disciplines, IAs to do more cutting-edge, more strategic discussions. In order to do that, they have requested IAs to align the dates of end-of-terms, all aligned to one month, rather than being all around the year. Fusion is always in June. There are two things IAs to do, (1) to put forward cross-cutting issues that we could discuss in the CERT, very interesting topic not only for the fusion community, but could be also to the other IAs as well, and (2) *to vote to unanimously approve the alignment of the date of end-of-terms, as outlined in the letter (article 5). (Please refer postscript)* In addition, there are some other administrative issues we have to deal with, 30 Jun 2016, when the IA goes another extension, there's nothing else needs to be done now.

Zarnstorff: Discussions on any cross-cutting issues, in regular CERT meeting?

Pottinger: Yes, with involving working parties and outside expertise,

Zarnstorff: IAs are fusion, renewables. What else?

Pottinger: We have buildings, transport, industrial electricity, fossil fuels, cross-cutting IAs on modelling, information exchange, climate technology initiative... There is a workshop in France this year that will bring together the transport-related and material-related IAs.

Wolf: What does the information exchange mean?

Pottinger: It's called the science and technology data exchange. The member countries collect all the energy science and technology research in the country, and then create the database. It's a focused research database.

Motojima: I hope to confirm your agreements. Some members are absent. First of all, I hope to make sure all of you are agreeable at this point. There is essentially no problem. It's welcome for 1 year extension. It is 3 years before 1<sup>st</sup> plasma in ITER. *We could confirm unanimous agreement here, and please communicate Russian representatives on this information. (Please refer postscript)*

Yamada: I will communicate with Prof. Prokhorov and Dr. L.M. Kovrizhnykh.

Yamada: *I need unanimous agreement in the different issue.* In article 4, you see the name of IA is the Stellarator[-]Heliotron. In the last ExCo, we agreed to change the

name to Stellarator[/]Heliotron. But, we had message from IEA administration office that they cannot use [/] in the name of IA in regulation. Also, [/] means "or", and [-] is "both". In that sense, [-] is much better than [/]. Then, Prof. Motojima and I agreed to the request from the IEA for the time being. We need another unanimous agreement to this name. *"The unanimous understanding is obtained."*

I'm going to communicate with Russian representatives on this matter as well.  
(Please refer postscript)

## 5. Status of domestic activities and international collaborations

Please summarize domestic and international activities in 2010, and plans in 2011, in inverse-alphabetic order.

### USA

Zarnstorff: HSX is doing well. Recently, we had a competition within the US on funding between fossils, non-tokamak activities. I would say the stellarator activity evaluated quite well. This resulted in funding on the start of a long-term collaboration with W7-X, on ELMs and the edge activity. I think all that good. Design effort has been started up in Wisconsin. In the mean time, we have enjoyed collaborations with all the facilities and programs as we had had for a couple years.

Motojima: Are there any changes or the progress related to the NCSX? Small possibility, I believe.

Zarnstorff: We continue to hold all hope. We have all components of NCSX. Fundamental problem is the budget for supporting the facility in the US. This was the real problem at the end even before NCSX was cancelled. The largest problem at this point, doing anything in fusion research, is the funding. Until that really changes, I don't see any prospects. Biggest issue, the same as for all the parties, is funding for ITER.

Yamada: Recently, the DoE secretary, Steven Chu, visited the PPPL. Did you have any consequences?

Zarnstorff: It was an extremely short visit. We showed him the NCSX. There was a certain size of interest. It's very hard to tell what he thinks on the program. We showed both NCSX and NSTX as well, such as lithium wall program.

Pottinger: Is he also doing visits to other major labs?

Zarnstorff: He supposed to visit all the major labs. He used to visit all labs once a year. I should say also we have other interactions to those not with their visiting, there are opportunities periodically.

Hidalgo: Because the HSX is rather unique in our community with the symmetric configuration, do you have any future plans for pushing forward diagnostics, heating power etc.?

Zarnstorff: They also had proposals, part of the competition. They did reasonably well. I think the budget for diagnostics and increasing heating is waiting for a final version of

approval. This effort includes design money, that's start looking options for modifying HSX. It secures hopefully for 3 years.

Pottinger: What's the program in MIT?

Zarnstorff: That was only ex-proposal, did not actually very well. That is so-called levitated dipole experiment.

Motojima: NIF experiments started. Do you expect any changes or effects in the near future? What is the situation in the fusion community for starting up of NIF?

Zarnstorff: This is extremely hard to tell. NIF is indeed starting up, as you heard J.Lindl's talk yesterday, pushing IFE to ignition. Without a question, we wish they succeed, as it is good for fusion everywhere. If they succeed, they plan to have a fairly visible event. I think they believe highly likely they will achieve the ignition in the next 2 years, sometime in next year. There are many political aspects. They are funded from the defense side, not funded for energy reasons. Everybody knows there is energy possibility of IFE. So, they are funding so-called "ICF", not funding "IFE" for fusion energy. They, members of the program, are pushing DoE to consider funding if NIF does get ignition, DoE then consider funding for energy mission. Claims are so strong that worry many of us. On the other hand, Steven Knud, undersecretary of DoE, is very much in favor, has been part of the program for one time, large degree of familiarity, is very interested in hoping the program if it does succeed. That's dominant reason why a large amount of political interests being generated to potentially act upon the success. I think, if they do this, one of the problems we have in the US right now, is that, in general, DoE is not interested in fusion as any source of energy, either MFE or IFE, and is interested in fusion as science. If DoE decides to engage fusion for energy, even it is IEF, this could also be the positive step for MFE. We have to wait see what exactly will happen cautiously.

Motojima: Thank you for your important information.

Hidalgo: In the last EPS conference, in session on NIF experiments and perspective in IF, assuming that ignition will be obtained in 2 years time scale, and I fully agree this will be a great achievement for all of us. However, there was also a discussion it's important for scientists to claim to community and society where we are, and what we are prospecting. Sometimes, there is a tendency to focus our own results. This is a risk. Getting the ignition is a great success, but this is very far from the reactor. We have to explain a great success in our hands and at the same time also very far from a reactor.

Zarnstorff: The distance to a reactor needs to be carefully assessed. On the one hand, we want it to be understood that fusion is potentially to be useful, and therefore is worth investing it. On the other hand, it is a reality that there a lot of issues to be solved. In the US, what is happening in IF side, because of the prospects of NIF getting ignition, will be a study by the National Academy about what are the next steps necessary for IF. We have had some discussions with the Department to launch a similar study for MF, but it not yet clear. The need and importance of such a study is raised by a large cost of ITER. One of the issues in our meeting today, is discussions how S-H are interested in outstanding MFE issues, possible solutions, strategy for resolving them, and given push for ITER, what is the right strategy, and what is allowed strategy?

Pottinger: What I find very interesting with the fusion research is, because of the high cost of fusion research, it needs to have some kind of return to investments and governments. Timelines have been always set up and always slipped, because such an area of science is so unpredictable. I'm wondering if fusion community is setting themselves goals.

Zarnstorff: We all set goals.

Pottinger: If you look at NIF, until now, goals and timelines set seem to be reasonable. But then, it always slipped inevitably. This is the other end of the spectrum if they set ridiculous goals. I'm wondering if other areas of science, if you look at, some of the outlined area, like hydrogen-mass production, storage issues, and other major physics issues, do they have to put the incredible timelines, or is there still funding on the programs?

Zarnstorff: Scales are not so large.

Wolf: From German perspective, exactly the discussion that those people funding to us, is to stop fusion research all together. At least in Europe, there is a misconception that fusion needs a lot of money, more money than the others. In Germany, renewables, what we call the energy conservation or saving, more money that all public funding in fusion together. Big difference is, even if in some areas that are far away from the technical solutions, they are producing energy now, if you could argue it's inefficient whatever, but they demonstrate to produce energy. The public perception is very important.

Pottinger: Also, for funding issues, we need to have some kind of a table that shows what has been spent on each of technology and research. If you compare fusion to fission research, fusion is nothing compared to the total amount spent for fission.

Zarnstorff : Related to that, there is a general misunderstanding, people, say, congress man and politicians in our case, just what it costs for making a new energy system.

Wolf: In German laws, for instance, photovoltaic is subsidized by guaranteeing a price far above the market price. Now opposition starts, people are starting calculations what this accumulated costs, in next 5 or 10 years, it would be hundred billion Euros. People realize is this worth investing?

Pottinger: But, my answer to that is no matter what it costs, given the challenges can be afford not to. Regardless of the cost, we are going to have to keep up.

Wolf: Researchers say, this is spending to get something into the market. Then you have to ask yourself is this a feasible solution.

Sanchez: Spain spent 6 billion Euros every year for subsidizing renewables.

Zarnstorff: Robert's point is correct. Making energy with any source is extremely important in perceptions. This is part of motivations for an effort PPPL having a wide range of collaborations across the US, looking at power plants for advanced tokamaks, stellarators and STs. We have been looking various advantages, challenges and risks in all three. But, part of the motivations is to ask ourselves what we will have to do to produce electricity, Qengineering greater than 1. It will change perceptions somewhat.



Wolf: One important strategy would be comparing IF and MF is to really get a consensus amongst scientists and energy researchers. This is naive to believe it can be achieved, but at least, should be attempted, because, people start arguing each other, rather than having a consensus for challenges in all these fields. A next step would be go to public to explain this.

Motojima: We have spent on this point for several years already, but we do not have a solution yet. US is starting NIF experiment, it may have the effect as a locomotive.

(lately mentioned from US.)

Gates: I wrote the paper in this IAEA conference to summarize US collaboration activity. I like to submit it as a US collaboration activity.

## Ukraine

Garkusha: We have two devices, Uragan-2M and Uragan-3M. In both devices, we tried to do experiments related to plasma heating and also wall conditioning. U-3M, we have continued studies of edge turbulence, anomalous transport, and tested some new limiter of B4 (2M). We tried to find some support from our Academy of Sciences for continuation and extension of our experiments. Therefore, we are advertising our stellarator activity in our Nuclear Department of Ukrainian ministry of Science, and they provided some funding for development of HIBP diagnostics on U-2M. We have started developments despite we have some experiences of such diagnostic in CIEMAT. We have had no operating diagnostics in Kharkov for potential measurements. We will use  $Ti^+$  beam of 200 keV, it will be enough for our torus.

We continue our international collaborations with, first of all, CIEMAT on potential, electron density, fluctuation measurements, and now assembling 2nd HIBP system on TJ-II. We continue collaborations with Belgium and IPP-Greifswald on implementation of specially designed RF antenna for wall conditioning on U-2M. As to collaboration with Germany, Alfvén resonance heating by the use of a compact strap antenna on U-3M, and the modelling of RF plasma production. With Sweden, concept of stellarator-mirror based fission-fusion hybrid has been studied. We have contributed to International Stellarator-Heliotron Data Base group on discussion U-3M data on joint EPS paper (participation in the 7th CWGM). With Kurchatov, development of magnetic diagnostics for torsatron U-2M.

Also, plasma theory division, collaboration with Japan (influence of plasma rotation on the shift of diverted plasma flux position in Heliotron J), and Austria (Graz technical Univ., on the development of kinetic equation solver NEO-2, and fully relativistic code SYNCH for computations of the generalized Spitzer function.)

Yamada: I would like to remind you that Dr. Shyshkin Jr. is visiting NIFS as a guest professor. He stays for 3 months, and he is engaged in the study of effect of non-Maxwellian distribution in a reactor condition.

Motojima: Thank you very much for the report in detail. We are very glad to hear very high level of collaboration.

## Spain

Hidalgo: I should say we have organized a national plasma physics group under the umbrella of Spanish Physical Society, including formally more than 100 scientists from universities, and national labs. This has been a good way to bridge between university and different labs, hopefully also to trigger many activities in fusion, stellarators, helping young scientists. As for the international level, long standing collaboration with IPP-Greifswald, Laqua on Bernstein wave heating, a CIEMAT scientist visiting Greifswald on magnetic equilibrium. We have intensified interactions with community of reversed field pinch, in the area of 3D physics, a scientist visiting CIEMAT. I have to emphasize strong interaction with HSX on how magnetic configuration is affecting the development of zonal flow how symmetry is playing a role on transport. As for Ukraine, I have to mention plasma diagnostics; in 2011 we will install 2nd HIBP with collaboration with Kharkov and Kurchatov. Long standing links with NIFS, many scientists moving both sides, we had visitors from NIFS, Tamura and Ida in the area of on non-local transport how the LHD experiments might be connected to zonal flow, on Alfvén modes triggered by fast particles (Nagaoka). Young scientist, Cavallero, in the area of edge physics, he will come to LHD this campaign. In the area of heating, diagnostics, TESPEL edge transport as well. We keep our strong involvement with S-H Working group. Based on our discussions in last CWGM in July, we have a visibility in this IAEA meeting with very nice joint work presentations as well in the next week ITPA transport/edge pedestal physics, we have a number of 3D contributions coming from S-H community, agreed and triggered by last CWGM.

Sanchez: In the framework of fusion research in Spain, particular plans for TJ-II, in the European program, costs other than ITER, we are suffering some cuts. That means EURATOM will not fund experimental devices (operation costs) from next year. But, they will fund physics activities, so basically people doing physics use the devices. On the Spanish side, we passed the evaluation in national system in spring last year, and it was very positive. We plan to keep the machine in operation irrespective of EURATOM funding, at least, for 3-5 years. Next 2-3 years, our full effort and then in W7-X experimental activities there. We plan to start the study the design of a future TJ-III machine, being discussed in European system, because we first have to be clear to Framework program 8, starting in a year from now. We are talking about the project, hypothetical first plasma by the time that ITER is running. We believe that it is important to keep the effort in this line, starting to look for configurations, for after TJ-II. This would not be a device close to W7-X in terms of size, but it would be reactor-relevant in physics.

On the European program, how the stellarators get in position. There was a discussion last year on DEMO program in Europe on the power plant activities, physics and technology. We have created in Europe a group to work for DEMO under EFDA structure. The present DEMO working group considers a stellarator as a possible candidate for DEMO. But we believe that the scenarios for DEMO-stellarator in parallel to DEMO-tokamak make sense. Also, W7-X in operation in couple of years, stellarators will be a big part of European program.

Motojima: Thank you very much for reporting big achievements and progress.

Harris: We are assembling the pellet injector for TJ-II. It has been very slow because of only have a certain amount of money. Hopefully it will be in completion soon.

Motojima: Recently, I met the minister of science and technology of Spain. I think she is very supportive to fusion research in Spain.

Sanchez: She has to run a full process to finding a new finance.

## Japan

Yamada: Article 6 is the summary of recent LHD results. I hope you enjoyed my talk yesterday. I would like to thank your contributions again. I would like to mention that new experimental campaign will start on 14 Oct., and we will continue experiment until 24 Dec. Hopefully, we would like to extend the campaign until the end of January, which depends on the available budget. We have a lot of intense collaborations, in particular, David stayed NIFS for 3 months as a guest professor. Also, CIEMAT provided a fast camera on LHD, IPP will install (not arrived yet) IR camera for divertor physics. Anyway, it will be installed on LHD soon, and also PPPL provides a crystal imaging spectroscopy meter by their fund, it is a fairly large budget. It will be available from the next exp. campaign. We have such an intensive and substantial collaboration. In the coming experiment we expect very exciting exp. with new facilities, which I mentioned yesterday, closed divertor, new NBI and new ICRF antenna.

Komori: At first, I would like to thank you for your support to LHD budget when I asked last year. This year, the budget was cut by about 10 %, but on the contrary, next year budget will increase for deuterium experiment, I hope. (But it depends on ministry of treasury.) There are many complicated procedure to determine the next year budget. One is the public comment, and also some committee will determine the excellent political items. Next year budget of LHD is still not clear, and it's unstable like a ball on the hill. Then, there is a possibility to increase and decrease. As you know, LHD wants to start the deuterium experiment, and as for the safety agreement between NIFS and local governments, some neighboring area in Tajimi city has been against the deuterium experiment. So, we have persuaded them to accept the deuterium experiment. This summer, they accepted the deuterium experiment, and we are asking the local governments to approve the safety agreement. It will take a about a half of the year for local governments to call the necessary procedure, but I think the agreement will be concluded within this Japanese fiscal year. We can start, at least, the preparation for the deuterium experiment from the next Japanese fiscal year.

Pottinger: Is it something new to have local governments impose the safety agreement? Or, is that the usual procedure?

Komori: Procedure itself is not new. It depends on cities. There are three cities around us. City council must say yes to start the deuterium experiment. Prefecture as well. There are councils and also the meeting of representative of citizens, such procedure is necessary. Public comment is also necessary. These are not determined by law, but they will do such procedures. (If something happens, they do not want to take responsibilities. There must be concluded.)

Motojima: Thank you very much for the important reports. I have a question to Mr.Kataoka on the expectations of the budget.

Kataoka: It is the ministry of finance, who is going to decide. Regarding the deuterium experiment, we put the request of the budget for the next fiscal year. Also, the

government developed supplementary budget for 2010. It also includes a supplementary budget. If things go OK, we can get the budget.

Harris: Given all the reports, the laboratory is having to deal with political uncertainties and down-pressure of the budgets. I was in Japan at the time of one of the big crisis, down-pressure of the budget. Obviously things are better now, what has contributed this improvement of the situation?

Yamada: It has not been improved yet. We have a fighting chance to get the extra budget. It is the initiative of the present government. Roughly speaking, all the entire budget is cut by 10 % to ensure the extra budget, and then we will compete extra budget.

Harris: That is not so bad. You have a chance.

Komori: Japanese government has recognized fusion is necessary.

Gates: There must be extraordinary efforts.

Motojima: This activity, Stellarator-Heliotron, has a long history and its achievement is well understood in Japan.

Yokoyama: Just a brief announcement, we have some a memorable 20<sup>th</sup> International Toki Conference, ITC20. Some of you have been working as international advisory and program committee members. Thank you so much for the efforts. We have totally 250 presentations on ITC20. Unfortunately, the abstract submission has been closed, but your participation is still highly anticipated.

## **Germany**

Wolf: Let me start with W7-X. Construction status is going very well. The time has not been shifted, completion of the assembling in 2014, one year commissioning for device operation. We are installing ports, total of 254, any small delays may multiply, but we are rearranging the schedule. Having operations coming closer, we increasingly get pressure for those aspects, which have not been in high-priority, heating systems and diagnostics. We have shortage of designers on diagnostics, lot to do. We still have not solved ECRH system problem, and replacement has been working, but other problems appear. We have to solve them with high priority.

On the collaboration, I would specially thank NIFS to support of our PhD student, and the other scientists going there now. We also are very happy on the approval from the US side, discussion how to proceed. In Germany, in our last review, there was a recommendation to take more initiative on the DEMO side. On this regard, we will have a first workshop in November, where important issues will be discussed between technology-oriented and physics-oriented institutes in Germany, which corresponds to the European activity in German level.

We are not sure what's the consequence of the budget increase on ITER will be on European funding. JET operation, there will be funding secured to 2014, but not decided. Beyond 2014, other discussions in Europe about ITER-satellite and Italian proposal, FAST. There has been a roadmap of future fusion activities, where stellarator is mentioned.

A few remarks on German policy, we are happy to have our Chancellor in Greifswald. Thomas gave a presentation about W7-X, and she started asking specific question, like how ITER colleagues consider this competitive concept? Germany government is, in principle, pro-fusion, but more on pro-renewable. They have produced the paper on energy policy for next 40 years, which does not mention fusion explicitly. We are not very happy about this. Considering discussions, extending lifetime of our fission plants, they did not want to open other Pandora's box. And they left out fusion discussions in this paper. Next spring, paper about energy policy will be published.

Finally, the movie of the W7-X is shown to the ExCo members.

## **Australia**

**Blackwell:** In the last meeting, I announced that we were allocated funding to upgrade the facility. We managed to increase funding to \$7M, and the contract was signed in December. We have approximately 12 milestones each year, and so far we have successfully met 11. Milestones are basically engineering ones. The objective of the upgrade is to improve heating systems, data access and collaboration. The problem is, under the special legislation, expenditure must be on infrastructure and not for research. However, we are still happy to have the funding.

Recently, we have let a contract for radio-frequency heating systems to total 200 kW. We chose it emphasizing the flexibility rather than ECH. Part of this upgrade is the material diagnostics facility. A small linear machine, which we will help us to develop diagnostics looking at plasma-material interaction, using a high-density hydrogen helicon source. A prototype will be in operation late this year or early next year. The objective there is to improve the connection to the rest of Australian fusion science, a large part of which is materials.

The new director of the Australian Nuclear Science and Technology Organization is very positive about fusion. We are having a workshop next month for institutions to look at the collaboration. Out of the funding, we are able to have a new 3-year technical-physics position. As for new work (on my poster presentation), basically synchronous imaging of Alfvén fluctuations, using new toroidal Mirnov array, and international data-mining collaboration.

Looking at the politics side, the government is more favorable to science than the previous government. However, as a consequence of recent large investments in science such as our upgrade funding beginning this year, the Science Minister told us at a meeting on infrastructure, to expect no further applications for facility funding until 2012. We are hoping that the International Science Linkages Research Grants Scheme, which has supported several of our collaborations, will be renewed next year.

The Government is now developing a policy for very large infrastructure, which will include any connection with ITER. However, there has been no discussion of funding. On the local front, the Australian National University (ANU) is announcing the launching of its Energy Change Institute (ECI), which will be about 12 members, this month.

**Pottinger:** Could you tell us more about the ECI?

Blackwell: ANU covers a number of different fields of energy research, brought together in the Institute, which will improve visibility. The government has changed a policy on energy research to include more than just coal, a major export. Now, the government recognizes a wider range of energy sources. ECI is designed to promote alternative energy sources in Australia. Initially, it is not expected that institute will have any significant funding.

Wolf: We heard a presentation on “Desert-Tec”, European activity to install solar plants in North-Africa. Other areas in the world to do this, would be south of the US and Australia. Is there anything in this direction in Australia?

Blackwell: We have research on solar voltaic and thermal, including hydrogen generation.

Motojima: Thank you for the report on activities, including future prospects.

## **6. Development of stellarator/heliotron working groups**

Yokoyama: (article 7) a brief summary of WG evolution. It comes to 7<sup>th</sup> one this year, which was held in June in Greifswald. Thank Robert for hosting the meeting. Some brief summary session in wide range of session with a lot of participants. Joint papers from CWGM activity in this IAEA conference, M.Hirsch (H mode in helical devices), Narushima (island physics). Also, we have the outreach to the ITPA on 3D physics based on CWGM discussion (H mode, flow, impurity). We are considering 8<sup>th</sup> one will be held in Japan (probably at NIFS) in next February or March. We will announce it soon. Along with discussions with A.Dinklage (IPP), we will be using the Stellarator News for call for the participants and report of CWGM. The report of 7<sup>th</sup> CWGM appeared as shown. Please keep watching Stellarator News for CWGM developments.

Motojima: I want to express thanks for contributions from members of CWGM. Please continue the high level collaborations.

(lately mentioned)

Zarnstorff: Last time when I attended the 4<sup>th</sup> CWGM, things struck me that CWGM has been getting crowd. We are not having much working time. That is the sign of success, we should be glad in some sense. But one question is whether we still have a combined meeting of all the working groups at the same time, or to split them more like ITPA. I think we should figure out strategy for the working purpose.

Hidalgo: The CWGM should go on one-year time scale. People directly involve in one task communicate each other. Meeting every year is good to see a perspective, how the different areas are evolving.

Zarnstorff: That is certainly a character of workshop.

Hidalgo: We should keep this spirit of working together.

Harris: A group should be very small, totally aiming specific progress on specific

activities.

Zarnstorff: Number of them has been successful. There are so many The meeting seems to have mainly just a reporting function, just like a workshop.

Harris: Maybe what you would do is to have a separate “working” session, and have a plenary session to limit the progress report.

Yamada: Certainly CWGM is evolving; but involved people is not huge. Therefore, we can get together at once, and we can arrange parallel sessions, for example. The essential point is not the presentation, “Work together”.

Motojima: It is very important subject on how to organize CWGM, should be discussed in the next CWGM

## **7. 18th International Stellarator-Heliotron Workshop (ISHW) 2011**

Blackwell: We have looked up three options of location, Cairns (no local representative: too difficult), Sydney, and combination of ANU and south coast (Murrumurang) along with its cost. I have a question from R.Wolf why considering two places, and the reason is the ANU is the cheapest option. We can take two large buses (2 hours) to/from south coast. Some of you may have experienced the coast in Japan-Australia workshop on diagnostics.

Motojima: We see several possibilities. Please decide the dates and venue.

Many of ExCo members voted February 2012: the warmest month, university is still empty, cheap accommodation.

Yamada: IEA-IA requested us to have an ExCo meeting once a year. If we choose February 2012, the interval is more than 1 year. Is it OK?

Pottinger: That's fine.

Motojima: Chairperson of the international program committee needs to be decided (history: article 8).

Harris: F.Wagner was the chairperson in 2002 workshop in Australia.

Motojima: I propose from the US. Mike, can you be a chairperson?

Zarnstorff: OK.

Motojima: Also, a brief communication after Australia. Any ideas?

Yamada: If we think about the rotation, the next would be in Germany. But, it depends on decision on Ukraine or Russia. Is it possible or not?

Harris: I have been in Russia. A problem is that, in Moscow, hotel prices are astronomical. How about other places in Ukraine?

Garkusha: I should say it is less expensive than in Moscow. But, nevertheless, prices

have been expensive in Kiev and Kharkov.

Harris: How about in Zvenigorod? That's for annual plasma physics conference?

Motojima: I hope to hear some comments from Germany, since W7-X will be completed in 2014. Do you want to have a workshop after that?

Wolf: I would not be so strict. We are ready after 2011. If there are other candidates, we can wait another two years.

Zarnstorff: The other idea would be to interchange Spain and Germany.

Hidalgo: We are also ready.

Harris: It is worthwhile to ask Russia or Ukraine.

Garkusha: I need to talk with my colleagues.

Yamada: It also depends on new DG of your institute.

Motojima: Possible candidates for 2013: Ukraine or Russia, 2015: Germany or Spain.

Hidalgo: Maybe one more place in Europe might be Padova, where RFP community gets interested in 3D physics. I'm pretty sure that they will be happy to have ISHW. We can use this proposal as European one if Russian and Ukrainian colleagues are not ready.

Motojima: We will continue the discussion of the ISHW after the next.

## **8. Cooperation on Steady State Operation (SSO)**

Motojima: As for the cooperation on the steady state operation, in the framework of IEA, Dr. J.Jacquinot is proposing a meeting on 14 Oct. This is very important item to combine several activities. We need to cooperate to this activity. From this ExCo, I hope to send the representative to this activity. May we raise the name, or any volunteers?

Wolf: What does the cooperation mean here? More specific ideas like having workshop in this direction? We have already workshops, IAEA-TM on the same issue.

Motojima: Objective of this activity is to form the new IA, combining tokamaks and stellarator-heliotrons. Right now, SSO is the key issue on fusion research. That is the origin of this discussion in the FPCC (Fusion Power Co-ordinating Committee).

Zarnstorff: Is this the first meeting?

Motojima: Already some written material has been prepared. We have spent more than 2 years for discussion on this theme. It is strongly coupled to reduce the number of activities in IA.

Wolf: If this is a new IA, it sounds like replacing existing IA by new IA?



Pottinger: It's accepted. It's the relevance of all the IA, One person in IA participates and shares results how they could work together on a specific topic. Do you mean specifically on steady state?

Wolf: For instance, IAEA-TM on SSO in December.

Pottinger: There was a question in INFRC that is not actually necessary anymore, because of this IA. Do they have any CRPs (Criteria Review Process) on that, or just put it in a global program of work?

Harris: It's definitely an interesting area.

Wolf: Because I'm somewhat skeptical.

Motojima: Up to now, three key persons, J.Jacquinot, E.Oktay and myself, we create this document (article 9).

Harris: What is your opinion? You need to have a separate grouping? Is this the best way to do it?

Motojima: I think separate meeting is needed to keep the independence of this activity. If we try to combine tokamaks and S-H, especially related to SSO, then some parts of S-H activity will be shifted.

Harris: In that case, let me support you. When you finally face SSO, then people becomes more open to things in S-H. It is properly right to do. It takes a time.

Motojima: Coming back to ITER and ITER-BA, there are ITER-oriented, ITER-DEMO-oriented, DEMO-oriented activities, this activity will be coupled to ITER-DEMO-oriented. We need a longer view.

Harris: In that case, I think it's a good idea.

Motojima: Including the communication between tokamaks and S-H. I will retire a key person, and hope to pick up another name. Anybody can attend, but at least, a key person should be nominated. I hope to nominate Dr. Komori. Are you ready to accept?

Komori: Yes.

Motojima: Any volunteers are welcome to attend to see what is going on. The scope is shown in article 9 (3), what we reached after 2-3 years discussion.

Motojima: Are there any other issues?

Yamada: This morning, Carrie sent me the secretary report. I distributed as a file to all the members via e-mail.

Pottinger: The most important would be items we discussed earlier about the CERT session. But also, the report goes into a couple of other areas that I would like you to see explore IEA IA on fusion, that is, finding a way to more systematically and proactively think about outreach to the non-fusion community, including policy makers and policy messengers, that always put fusion energy on the context of the other energies. Device-specific fusion science in general, and then compare to the

other energies. If fusion wants to be continued to be considered as a future energy source, it needs to be considered in the context of the other energies. We had a communications workshop recently for all of the IAs, and several of fusion-IA had participated. I was pleased to see that. One of the first steps in that direction would be to systematically have a website with information on (1) general information about what IA is trying to achieve, and then (2) perhaps technical page for those want to know your experiments and your technical cooperation.

Also a little bit detail on the publication, that is, every 2 years, this year, called "Energy Technology Initiative", I have sent copies to Mr.Yamada. That is a starting to a right direction. For all the IAs, what is your agreement within that framework, and how is that fit in the IEA framework and energy in general. That is one publication only comes out once every two years. There needs to be something that happens in between that. We have another means about reach for you, that is an open bulletin, which is a regular news letter. Editors are more than happy to publish an article on your scientific results, but she has to have a website to point readers. We come back to the fact that we need to diffuse information more and reach out to other audience than just a fusion community.

Last but not least, visit by IEA Executive Director, Mr.Tanaka to the ITER site last April. He is very keen to support fusion because the IEA member governments support fusion. This is a very important step.

Harris: We already have a newsletter, "Stellarator News" (as example shown in article 7). It does not have to be an only solution, but we already have a material.

Pottinger: IEA technology homepage, "three click" reaches your IA. It takes an effort, but it's important.

Motojima, Yamada: As for the annual report, please submit till 17 Dec. before Christmas holidays.

Motojima: Next ExCo will be held in Australia during 18th ISHW (Feb. 2012).

Pottinger: If it is not possible to have an ExCo meeting before then, as Mr.Yamada rightly pointed out, all of you have to agree he is the best operating agency in all of the IA members. So, you thank him for his fantastic jobs. *Agreed.*

Your specific text in your IA (IEA does not say so), you have to have a meeting every year, and if next one will be in Feb.2012 and you cannot do it in next year, just be sure you have a vote (and have an unanimous agreement).

Possibilities to have a meeting during next CWGM (Feb, or Mar. 2011, probably at NIFS), or video-meeting was also mentioned.

## **9. Miscellaneous and final remarks**

Closing remarks by Motojima.

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(Postscript)

On 15 Dec., Russian representative, Dr. D.Prokhorov (ROSATOM) agreed the following administrative issues. This has resulted in unanimous agreements on all items discussed in 39th Executive Committee Meeting.

1) Prof. O.Motojima continues to serve as a chairman of the IEA Implementing Agreement on Development of Stellarator-Heliotron Concept.

2) The title of the agreement is confirmed as "Development of Stellarator-Heliotron Concept" instead of "Development of Stellarator/Heliotron Concept"

3) The valid term of the agreement is extended to June 30, 2016 instead of our original request; July 31, 2015 due to the change of administrative process in IEA.