

### 3. International Collaboration on Helical Fusion Research – IEA Stellarator-Heliotron Agreement –

#### 1. Overview

The world stellarator-heliotron community has been promoting international collaborations under the auspices of International Energy Agency (IEA) Implementing Agreement on “Development of the Stellarator-Heliotron Concept”. The present participating countries in this agreement are Australia, Germany, Japan, Russia, Spain, Ukraine and U.S.A. The Stellarator-Heliotron Executive Committee conducts arrangement of collaboration and endorses proposed activities. The 39th Stellarator-Heliotron Executive Committee was held in Daejeon (Korea) in conjunction with the 23rd IAEA International Fusion Energy Conference. In addition to summary of the status of international collaboration, the successful approval of the extension of this Implementing Agreement by IEA (and renamed from “Stellarator” to “Stellarator-Heliotron” as well) was reported. The 18th International Stellarator-Heliotron Workshop was agreed to be held in Australia in January/February of 2012, and development of stellarator-heliotron working groups was also reported. The link to the Steady State Operation issues in the framework of IEA was promoted to designate A. Komori as a key person from Stellarator-Heliotron community.

NIFS hosts the web page of this activity at <http://iea-shc.nifs.ac.jp/>.

The summary of international collaboration on helical fusion research is given in the following sections.

#### 2. 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 1st 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.

#### 7th CWGM

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 3-D devices. This activity is intended to link the technical documentation of tokamaks with 3-D 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 3-D 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 3-D devices, this inter-machine physics study is a new quality on the way to a comprehensive physics basis of 3-D reactor concepts.

### 8th CWGM

About 30 local and 10 remote attendees (from IPP-Greifswald, CIEMAT and Kharkov) participated in the Coordinated Working Group Meeting (CWGM8). The meeting was held from March 16-17, 2011 at NIFS. Originally, more foreign participants on site, and then, more extensive face-to-face discussions were planned as have been done in usual CWGMs. However, this could not be made this time due to the sequential tragic events triggered by the huge earthquake occurred on March 11. Consequently, we had to postpone some sessions originally planned in this meeting, such as Validation of Transport Models, and Joint Experiments. Also, some sessions were reformulated to shorter ones.

The meeting was composed of 6 sessions including the Opening, in which welcome address was given and the highlights of LHD's 14th campaign and schedule of 15th one were reported along with the call for the joint experiments utilizing the LHD (by H.Yamada).

Following the Opening, in the Magnetic Topology session, model for the interaction between the poloidal flow and the magnetic islands was presented, to be applicable to interpret the experimental findings in LHD (growth/healing). Some of experts (mainly theoreticians) on this issue in NIFS also joined to have wide-range discussions. Biasing experiment performed in Tohoku University Heliac (TU-Heliac) was also reported to actively investigate the impact of the magnetic island at the edge on the poloidal rotation as a drag term.

H mode issues were discussed along with experimental observations in LHD (edge transport barrier formation in stochastic region) and TJ-II (signature of turbulence spreading during the H-L back transition). Also, the attempt to the equilibrium reconstruction for H mode discharges in W7-AS, by utilizing VMEC2000/diagno. Equilibrium reconstruction (even including stochastic region) will enable us to more accurately investigate the role of neoclassical ambipolar radial electric field as "bias" to H mode in helical plasmas, which has been continuously discussed in CWGM collaborations.

Database Issues session dealt with the discussion on the joint paper for the coming EPS, on discriminant analysis on International Stellarator-Heliotron Confinement DataBase (ISH-CDB) to identify the

responsible variable causing the clustering in the global energy confinement data. The status and progress of Profile DataBase (ISH-PDB) were also reported, with remarks on the fast-growing edge turbulence database, requests to update data of high-beta discharges, and recent inclusion of HSX-CERC data, and so on. How to store the equilibrium data (corresponding to registered profile data) has been in discussions, and it was agreed to put them under the authentication. The example of this scheme has been prepared for a registered W7-AS high-beta discharge, and to be notified to colleagues to call an interest and participation to use PDB for joint activity.

The contribution to ITPA from Stellarator-Heliotrons (S-H) was also discussed in 3D in ITPA session. In the last ITPA Transport and Confinement (T&C) topical group meeting (Seoul, after IAEA-FEC 2010), three contributions, on H mode, impurity and flow issues, were made originated from discussions in the 7th CWGM. S-H representatives in T&C (C.Hidalgo, A.Dinklage and K.Tanaka) have had discussions to make the possible contribution list, to collect and ideas from S-H colleagues. It was pointed out in the CWGM8.0 discussion that linkages with ITPA "Energetic Particles" and "Edge & Pedestal" topical groups have been already established, even to form joint activities. Currently, 2 contributions to the coming T&C meeting (April, 2011 in San Diego) are planned, (1) Profile dynamics, flows and confinement in tokamaks and stellarators (C.Hidalgo), and (2) Turbulence and transport in ELMy and ELM-free H mode in LHD and comparison with tokamak (K.Tanaka).

It should be remarked that "Energetic Particles (EP)" session was KICKED OFF in this CWGM8.0. Alfvén eigenmode (AE) studies in LHD, TJ-II and Heliotron J were reported with emphasis on AE-induced EP transport and EP-induced MHD instabilities, which have been based on extensive joint experiments among these three devices. The possibility to establish AE-database was mentioned, and in the mean time, similarity/differences to on-going MHD database

(<http://h1nf.anu.edu.au/collaborate/mddb/>) was discussed. It was recommended that "AE" members to contact MHD database collaborators. NB-blip experiment in LHD was introduced as a tool of investigating the energetic ion confinement. Simulation studies such as on EP transport due to AE and code benchmarking activity on AE growth rate, and on impact of re-entering particles on the NBI heating efficiency and its comparison to LHD experiment were also reported. During the session, quite extensive and wide-range collaboration opportunities were recognized to formulate joint activities. It was also mentioned that 2 ITPA joint experiments has been already started, and one more will soon start.

It should be pointed out that, during the meeting, it was agreed to facilitate the joint activities within the working groups through the occasional follow-up video conferences.

The presented materials along with summary/action plans of the sessions have been uploaded at <http://ishcdb.nifs.ac.jp/> (see CWGM8.0).

### 3. 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.

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. 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 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. 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.

#### 3.1. 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 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. 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, 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 Hole (ICPP, 2010) and Svensson (EPS, 2010). As part of a collaborative visit for this project, Sergei Sharapov (CCFE, UK) joined 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. McClements, 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, 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

Howard and Hatae (JAEA) on imaging birefringent interferometers for Thomson scattering Satoshi Yamamoto visited H-1 in May for collaboration on datamining MHD data. 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-Heliotron Executive Committee meeting it was decided to hold the next ISHW in Australia in early 2012, with B. Blackwell as Chair. The APPTC committee agreed to host the

APPTC Conference in Australia with 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.

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. Howard and 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 Blackwell, and other contributed work presented as posters. An Australian (Hole) also attended the 49th IFRC meeting and presented research highlights.

### 3.2. 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 (Dominique Escande), CCFE (Richard Dendy) and H1 (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.

## 4. EU

### 4.1. GERMANY

#### 4.1.1. 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. – 12.06.201
- 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: 3rd 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: 3rd 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: Collaboration 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: 3rd Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO2-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: 7th 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) K. 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: 3rd Workshop on Interferometry for Steady State Fusion Devices/ Cooperation in the field of development and construction of a multichannel CO2-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- $\delta f$  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 (LLN) 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

#### 4.1.2. 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

#### 4.1.3. 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 modelling
- 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

- 1) 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).
- 2) IR diagnostics / collaboration with JET taskforce E1
- 3) 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

- 1) 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).
- 2) 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) and student(s) will visit IPP: Measurement of the power flux density in a microwave stray radiation field

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

- 1) M Hirsch, et all ... will participate in the CWGM8 at NIFS 08.-10.03.2011
- 2) A. Dinklage will support organization of CWGM8 in Toki 30.06-02.07.2010
- 3) A. Kus will visit NIFS for Scaling Studies
- 4) A. Kus and A. Dinklage will cooperate with K. Thomsen (CEC) on Tokamak/Stellarator comparisons
- 5) M. Hirsch will contribute to H-mode studies.
- 6) C. Beidler, A. Dinklage and H. Maaßberg will contribute to transport model validation studies (LHD, TJ-II, W7-AS)
- 7) 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

## **4.2. SPAIN**

### **4.2.1. International collaborations in 2010 using TJ-II at CIEMAT**

#### **- Collaborations with Russia**

- 1) K. Sarksyian 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 benchmarking 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, November 2010).

#### **Czech Republic**

- 1) 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 7th 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.

#### **4.2.2. 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 (CO2 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**

- 1) 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**

- 1) 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).
- 2) 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 (Tsuchibushi and 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.

## **5. JAPAN**

### **5.1.1. 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 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 modelling 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 23rd 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 processes 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 für Plasmaphysik (Greifswald, Germany) from 28 Jun. to 3 Jul. 2010 to attend the 7th CWGM and make an international call for joint experiments.
  - 23) O. Kaneko (NIFS) attended the 25th 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 (Jülich, 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 7th 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 7th 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 2nd 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 für 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 für 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 für 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) Yu. Tolstikhina (P.N. Lebedev Physics Institute the Russian Academy of Sciences, Russia) visited NIFS (D. Kato) from Oct. 21 until Nov. 4, 2010 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) 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 20th International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.
- 8) N. Karchev (General Physics Institute, Moscow) attended the 20th 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) 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 20th 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 20th International Toki Conference, and made a plenary talk on the evolution and future prospects on magnetically confinement experiment.
- 16) W. Tang (PPPL) attended the 20th International Toki Conference, and made a plenary talk on the evolution and future prospects on simulations science
- 17) S. Hudson (PPPL) attended the 20th International Toki Conference, and made an oral talk on the equilibrium issues of magnetic confinement.

### 5.1.2. 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 gyrokinetic 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.

### 5.2.1. 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 7th 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.

#### **- 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 23rd 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.

#### **5.2.2. 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.

## 6. Russia

### 6.1. International collaborations in 2010

#### - Collaborations with IPP (Germany)

- 1) P. Bagryansky (Budker Institute Novosibirsk) to IPP, 28.06. – 29.06.2010: 3rd 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 benchmarking 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) Yu. Tolstikhina (P.N. Lebedev Physics Institute the Russian Academy of Sciences, Russia) visited NIFS (D. Kato) from Oct. 21 until Nov. 4, 2010 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) 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 20th International Toki Conference, held in Toki, Japan from 7 to 10 Dec. 2010.
- 8) N. Karchev (General Physics Institute, Moscow) attended the 20th 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**

- 1) L.I.Krupnik and HIBP team (IPP NSC KIPT) in collaboration with A.V.Melnikov and T-10 team (Kurchatov Institute). 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  $\sim 500 \mu\text{A}$ . 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.
- 3) L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with S.V.Lebedev and Tuman-3M team (Ioffe Institute). 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. Study of NBI-caused LH transition at low density in the TUMAN-3M tokamak

## **6.2. Plans for 2011**

### **- 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.**

Installation of the secondary beamline of the HIBP complex for measurements with reversed orientation of the magnetic field. 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 (zonal flows) correlation studies and the analyzer installation is foreseen during 2011.

## **7. Ukraine**

### **7.1. Institute of Plasma Physics of the National Science Center "Kharkov Institute of Physics and Technology" of the NAS of Ukraine (IPP NSC KIPT, NASU)**

#### **7.1.1. International collaborations of the NSC KIPT in 2010**

##### **7.1.1.1. 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 and used this method for investigations of the EBW plasma heating regimes in magnetic traps.

#### **7.1.1.2. International collaborations of the plasma experiment divisions**

##### **Collaboration with CIEMAT, Madrid, Spain**

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

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.

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**

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

- 3) L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with S.V.Lebedev and Tuman-3M team (Ioffe Institute). 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. Study of NBI-caused LH transition at low density in the TUMAN-3M tokamak

##### **- Collaborations with NIFS, Japan**

- 1) 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**

- 1) V.S. Voitsenya et al. (IPP NSC KIPT) in collaboration with K. Isobe and T. Yamanishi (and 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**

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

### 7.1.2. Plans for 2011 of the IPP NSC KIPT

#### 7.1.2.1. 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)

- 1) To develop the efficient algorithm of evaluation of fully relativistic plasma dielectric tensor for arbitrary value of the parameter 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)

#### 7.1.2.2. Plans for 2011 of the plasma experiment divisions

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

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. 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.

Installation of the secondary beamline of the HIBP complex for measurements with reversed orientation of the magnetic field. 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

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

##### - The tasks to be solved at IPP NSC KIPT

Preparation of the review paper with description of application of the technique and manual operation of the existing heavy ion beam probing diagnostics; Finishing the PhD thesis by A. Zhezhera, V. Bondarenko, A. Prokopenko, A. Beletskii;

Tuning on test device of the full HIBP complex designed for Uragan-2M; installation of the HIBP diagnostic set on the U-2M; continuation of investigations of the Li ion beam injector up to 100 keV and 10-15 mA.

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.

Development of technique and technology of 24 hours per day RF wall conditioning operation. Further investigation of RF wall conditioning with specially designed antennas.

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.

Preparation of all equipment for providing the boronization procedure in the U-2M torsatron will be finished.

Optimisation of processes of RF plasma production and heating in the Uragan-2M torsatron aiming the increase of plasma parameters will be provided.

It is planned to design and to test the B4C limiter during wall conditioning and in operating regimes of the U-2M torsatron.

It is planned to use the self-consistent numerical model for RF plasma production to explain Uragan-2M results.

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.

Continuation of investigations of divertor plasma flow characteristics in conditions of transport barriers formation in Uragan-3M.

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?

A search for RF plasma production and heating regimes in the U-3M torsatron with no fast ions.

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

### **7.2.1. 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.

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

Handling the fuel is the essential issue for the D-T and D-3He 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-3He 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-3He is much lower than that of D-T and the amount of 3He 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 3He in D-T and D-3He 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 3He) 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 3He 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 3He 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.

#### **- 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.

**- 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 J.-M. Noterdaeme, Vl. Bobkov, W. Becker (MPIPP).

**7.2.2 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-3He catalyzed fusion realization conditions with reduced amount of T and 3He respectively in FFHR - 2m3 heliotron configuration. The heads of this research at National Institute for Fusion Science are Akio Sagara (Executive Director of Fusion Engineering Research Project) and 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 KhPhT, Ukraine.

**8. United States of America**

**8.1. 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, VMCC2000 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 (LLNL) 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 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 20th 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 20th International Toki Conference, and made a plenary talk on the evolution and future prospects on simulations science
- 17) S. Hudson (PPPL) attended the 20th International Toki Conference, and made an oral talk on the equilibrium issues of magnetic confinement.

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

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. 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.

**8.2 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.

(Yamada, H.)