

Implementing Agreement for Cooperation in Development of the Stellarator Concept

2009 Executive Committee Annual Report to the Fusion Power Coordination Committee

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EXECUTIVE SUMMARY

The present report overviews the scientific and technical progress achieved in 2009 by the parties to the Stellarator Concept Implementing Agreement, who have greatly benefit from its international collaborative framework. The document reports the collaborations in 2009 and the parties' research plans for 2010, including technical reports on 2009 activities.

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1 JOINT ACTIVITY: COORDINATED WORKING GROUP MEETING (CWGM) FOR STELLARATOR/HELIOTRON STUDIES

The Coordinated Working Group Meeting (CWGM) for Stellarator/Heliotron Studies has been continuously held since its 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.

Helical system research has a long history of programmatic international collaborations. One of the formalisms supporting such collaborations is the IEA Implementing Agreement for Cooperation in the development of the Stellarator Concept, concluded by the Stellarator Executive Committee (SEC) on 2nd Oct., 1992.

Extensive collaborations based on the database provided from multi-devices have led to, so to say, the landmark achievement, the International Stellarator Scaling 1995 (ISS95). Such confinement database [International Stellarator/Heliotron Confinement DataBase: ISH-CDB] activity acquired the “official” auspices of the above agreement in 2002. Since new helical devices such as Heliotron J, HSX, LHD and TJ-II (alphabetic order) came into operation after the derivation of the ISS95, the 2nd phase of ISH-CDB activity was launched, to be able to explore a wider range of configuration and plasma parameter space. The effective helicity, as the configuration-dependent quantity, was introduced to produce the ISS04. The trend, of better energy confinement in the case of smaller effective helicity, is recognized through inter-machine comparison and even in the configuration-scan experiments in one device.

As the detailed profile information of plasma parameters had become routinely available, qualitative upgrade of the database activity to include profile information is possible and expected. More physics-based discussions can be anticipated with this upgrade. One particular example was selected as its prototype project, that is, plasmas having a peculiarly steep electron-temperature gradient in the core region commonly obtained in CHS, LHD, TJ-II and W7-AS (alphabetic order) with centrally-focused ECH. The significance of the electron-root in the core region was recognized through the comparative studies. Based on this clarification, those plasmas were denoted, reflecting its physics background, as Core Electron-Root Confinement (CERC). After its presentation at the 15th International Stellarator Workshop (Madrid, 2005), discussions among volunteers with interest (coordinated mainly by Prof. H.Yamada (NIFS) and Dr. A.Dinklage (IPP-Greifswald)) led to the agreement to launch the programmatic collaboration on profile database activity [International Stellarator/Heliotron Profile DataBase: ISH-PDB]. Meanwhile it was agreed to initiate the “working-basis” meetings as the supporting body of ISH-C/P DB activities and to facilitate joint collaborations.

This is the origin of the CWGM.

The CWGMs have been held 6 times so far. In Table 1, some facts along with the topics discussed are summarized. Although the detailed discussion of each topic is not described here, presentation materials can be collectively obtained through the NIFS web site, http://www.nifs.ac.jp/en/index_cat04.html (DATABASE →International Stellarator/Heliotron Confinement/Profile Database [ISH-C/P DB]). The CWGM has evolved by identifying a person in charge from each device/institution on each possible topic, to support the steady progress.

Along with the progress of individual topics related to critical issues in helical systems, issues on reactor scenarios and collaborations in technology fields were also discussed in the 4th meeting, to draw concrete action plans towards system/reactor studies. In the 5th meeting held in Stuttgart University, sessions dealing with H mode and island dynamics were kicked-off.

One of the advanced capabilities of the stellarator/heliotron community, the computational tools rigorously dealing with the 3D nature of magnetic configurations, can be also extensively applied to critical issues in the tokamak community. One example would be the quantitative understanding of the impacts of induced ergodization of the edge field structure on ELM behaviour. The CWGM has provided suitable opportunities to discuss the strategic ways to outreach to the tokamak community and to make the understanding of helical systems to be a more comprehensive one of toroidal confinement.

The collection of profile data has been extended to construct the profile database (PDB). The PDB has been jointly hosted by IPP and NIFS, in a similar manner as the confinement database (CDB). The web site is <http://xanthippe.ipp-hgw.mpg.de/ISS/public/index.html> (IPP) and <http://ishpdb.nifs.ac.jp/index.html> (NIFS). The time trace of the shot, profile information and some key profiles are stored. In principle, published data are stored for the public use. Currently, the number of profile data has been gradually increased to make it more comprehensive.

Meanwhile, associated configuration (equilibrium) data are now intended to be stored, so that people who are interested in applying their computational codes to experimental profiles can do so. The registered profiles on ISH-PDB can also be utilized as a test bed, with the equilibrium information commonly used by a number of different computational codes.

The 5 tentative abstracts for possible joint papers to be presented at the major international conferences (such as EPS and IAEA-FEC) are now in circulation among CWGM collaborators, so that wide range of collaborations is promoted. The next (7th) CWGM has been agreed to be held in Greifswald from 30 Jun. to 2 Jul. 2010. The details of contents of the joint papers for the IAEA-FEC will be discussed along with the promotion of the collaborative research in each topic.

- [20th IAEA Fusion Energy Conference (2004)]
- H.Yamada et al., Nucl. Fusion 45 (2005) 1684.
- [15th International Stellarator Workshop (2005)]
- M.Yokoyama et al., Fusion Science and Technology, 50 (2006) 327.
 - A.Dinklage et al., Fusion Science and Technology, 51 (2006) 1
- [21st IAEA-FEC (2006)]
- M.Yokoyama et al., Nucl. Fusion 47 (2007) 1213.
 - A.Dinklage et al., Nucl. Fusion 47 (2007) 1265.
- [16th International Stellarator/Heliotron Workshop/17th International Toki Conference (2007)]
- E.Ascasibar et al., J.Plasma and Fusion Research, Vol.3 Special Issue (2009) S1004.
 - K.McCarthy et al., "Comparison of Impurity Transport in Different Magnetic Configurations"
 - Y.Feng et al., "Comparative Divertor-Transport Study for W7-AS and LHD (EMC3/EIRENE)"
 - M.Kobayashi et al., J.Plasma and Fusion Research, Vol.3 Special Issue (2009) S1005.
 - A.Weller et al., "Extensions of the International Stellarator Database by High- β Data from W7-AS and LHD"
 - A.Dinklage et al., "Status of the International Stellarator/Heliotron Profile Database"
 - H.Funaba et al., "Data Structure for LHD Plasmas in the International Stellarator/Heliotron Profile Database"
 - K.Nagasaki et al., J.Plasma and Fusion Research, Vol.3 Special Issue (2009) S1008.
- [22nd IAEA-FEC (2008)]
- Y.Feng et al., Nucl. Fusion 49 (2009) 095002.
 - R.Burhenn et al., Nucl. Fusion 49 (2009) 065005.
 - A.Weller et al., Nucl. Fusion 49 (2009) 065016.
- [17th International Stellarator/Heliotron Workshop (2009)]
- M.Hirsch et al., "Overview of LH-transition experiments in helical devices"
 - T.Akiyama et al., "Status of a stellarator/heliotron H-mode database"
 - H.Funaba et al., "Data Servers for the International Stellarator/Heliotron Profile Database (ISHPDB)"
 - S.Sakakibara et al., "Remarks on Finite Beta Effects in International Stellarator/Heliotron Scaling"
 - Y.Narushima et al., "Experimental study of effect of poloidal flow on stability of magnetic island in LHD"
 - D.Pretty et al., "Results from an international MHD data mining collaboration"
 - B.Nold et al., "Inter-machine edge turbulence data base"

Table 1. Some records on 1st to 6th CWGM.

	Place	Date	# attendants (on record) ¹	Remarks: topics discussed <i>etc.</i> (alphabetic order unless marked)
1 st	Kyoto Univ.,	19-22, Sep. 2006	41	ISS04(CDB)→PDB, possible topics on collaborations, Joint meeting with Kinetic Theory in Stellarators
2 nd	IPP-Greifswald	4-6, Jun. 2007	26	edge/3D divertor, high-beta, impurity, iota/shear, momentum transport, neoclassical (NC) transport
3 rd	NIFS	23-24, Oct. 2007	34	current drive (CD), edge/3D divertor, flow/momentum transport, high-beta, high performance, impurity, iota/shear, NC, technical issues of DB, transport codes
4 th	CIEMAT	20-22, Oct. 2008	29	<u>reactor, collaboration on technology, 3D effects,</u> CD, data access, edge/3D divertor, high-beta, impurity, iota/shear, transport codes, <u>turbulent transport codes (→ passed to discussions in expert group)</u>
5 th	Stuttgart Univ.	6-8, Jul. 2009	29	<u>H mode & ELM, turbulence studies (experiment), usage of PDB,</u> data access, high-beta, iota/shear, 3D effects
6 th	PPPL	16, Oct. 2009	27	database, US experiments, turbulence studies, H mode & ELM, high-beta, iota/shear/ <u>island</u>

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

2 AUSTRALIA

The H-1 device 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 testbed for the development of advanced active and passive imaging diagnostic technologies from microwave through to optical frequencies.

In 2009, the Australian Government awarded ~US\$6M for upgrade of the H-1 facility, now known as the Australian Plasma Fusion Research Facility. The funding, which is earmarked for infrastructure upgrades, will be spent 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 with provision for vacuum and data system enhancements. Improved configurational flexibility will deliver access to magnetic configurations suitable for development of divertor plasma diagnostics for future devices.

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 utilizes the H-1 heating and power systems, which will facilitate development of diagnostics for plasma wall interactions and for characterizing advanced high temperature materials.

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. This year, emphasis was on imaging spectroscopy and data mining for investigation of the radial structure of Alfvén modes. As a result of the upgrades, the future will see a continuation of these and other basic studies extended to new parameter regimes.

In 2009, the Plasma Theory and Modelling group, led by Prof. Dewar, joined the Plasma Research Laboratory. This closer linkage recognizes common interests and goals, provides a better foundation for exploiting the upgraded Facility and new projects of common interest (below) and aims to expand collaboration both domestically and abroad.

2.1 International collaborations in 2009

- Multilateral Collaborations

- 1) 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. 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.

- 2) One and two-dimensional coherence imaging (CI) systems developed by Prof Howard and his advanced imaging group at ANU underpin a number of international collaborations 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. This work produced fast 2D snapshot images of magnetic field pitch angle profile which will allow, for the first time, direct imaging of the internal current density profile in a 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.
- 3) In 2009, work began on the design and construction of a high frequency toroidal magnetic array for H1, in collaboration with L. C. Appel of UKAEA Fusion and Dr. S. Yamamoto of Kyoto University.
- 4) A new project with complementary stellarator compact toroidal components: "Model/data fusion: using Bayesian techniques to constrain equilibrium and stability theory of advanced magnetic confinement experiments ahead of the International Thermonuclear Experimental Reactor" commenced. The purpose of this project, which is supported by an Australian International Science Linkages grant, is to develop probabilistic techniques to extract the physics of magnetically confined plasmas from disparate data sampled from next generation UK and Australian fusion energy experiments. The project, which is a collaboration between ANU, MPIPP (J. Svensson), and the Culham Centre for Fusion Energy (L. C. Appel) builds on pioneering development of Bayesian inference for current tomography in W7-AS. In 2009, Bayesian inference of current tomography using Motional Stark Effect, magnetic pick up loops and flux coils was developed for MAST plasmas. For H-1, Bayesian inference for electron density and temperature and ion temperature measurements was developed for synthetic data of an interferometer and imaging Doppler spectroscopy system. Project leader M. J. Hole spent 4 months collaborating at CCFE, and G. von Nessi spent 2 weeks at MPIPP.
- 5) Dr Hole, chair of the Australian ITER Forum, an informal association of 140 scientists and engineers, was appointed as a member of the International Fusion Research Council (IFRC) and attended a joint meeting between the Fusion Program Consultative Committee of the IEA and the IFRC in February.
- 6) Extension of the coherence imaging collaboration to include DIII-D (GA, LLNL) and Textor (FOM), and imaging of divertor flows and internal magnetic fields
- 7) At the 2009 Stellarator Executive Committee meeting it was decided to hold the 2011 ISHW in Australia, with Dr. B. Blackwell as Chair. The APPTC committee

also agreed to host the 2011 APPTC Conference in Australia, with the suggestion that it be co-located with the 2011 ISHW meeting. Dr Hole was appointed Chair of the 2011 APPTC meeting.

- Collaborations with EU

- 1) D. Pretty is presently back with the ANU group after working with the CIEMAT TJ-II group to analyse MHD data and with the Data Acquisition group on other aspects of data analysis.
- 2) A collaboration between C. Nührenberg of MIPP Greifswald, J. Bertram, R. Dewar, B. Blackwell, M. McGann, G. Vonvon 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 also developed a cylindrical model with helical field averaging to describe a candidate basis set of discrete Alfvén Eigenmodes in H1.

- Collaborations with JAPAN

- 1) The 8th Japan-Australia Plasma Diagnostics Workshop jointly chaired by Prof J. Howard (ANU) and A/Prof B. James (University of Sydney) was conducted at the Australian National University during February 2009. As well as Japanese and Australian delegates, this meeting featured visits from a number of international experts from Korea, the USA and Europe. In conjunction with the workshop, the Australian ITER Forum met to assess commitment required to mount a possible Australian diagnostic system on ITER, with advice from Dr. Alan Costley and Dr H Matsumoto, who also briefed the Australian Government.
- 2) In a collaboration with the University of Sydney, Hiroshima University and Kyoto University a pulsed supersonic helium beam has been developed and installed on H-1NF. With the aid of a collisional radiative model, the radial electron temperature profile can be deduced from measurements of spectral line emission from the beam due to excitation by the plasma. The diagnostic is continuing to be developed.
- 3) Dr. Hatae (JAEA) on imaging birefringent interferometers for Thomson scattering
- 4) A/Prof. Blackwell spent a 3 month sabbatical at Kyoto Univ., on the application of datamining including a comparative study of MHD activity in Heliotron-J and H-1NF.

- Collaborations with USA

- 1) An existing collaboration between the ANU (R. Dewar, M. Hole, M. McGann, A. Gibson) and Princeton PPL (S. Hudson) on the investigation of a new formulation of the 3-D MHD equilibrium and stability problem (with possible applications to electron transport barrier and heat flow studies) continued and expanded in scope. In 2009, several publications were produced, development of the multi-region variational code continued and progress was made on an alternative Hamilton–Jacobi method. A new construction of almost invariant tori (imperfect magnetic surfaces) based on a unification of the quadratic-flux-minimizing (QFMIN)

surface method and the action-gradient-based ghost surface method has been formulated.

- 2) Dr. S. Hudson (PPPL) – Theory and development of improved stellarator MHD codes, initially using a stepped pressure profile code

2.2 Future Research Plans

- 1) 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.
- 2) International collaboration on CI optical systems for spectro-polarimetric imaging will continue in 2010 and beyond. In the coming year, this work will embrace the following activities
 - There will be dedicated runtime for 2D MSE snapshot imaging experiments on the TEXTOR tokamak during April 2010. The objective is to synchronously image magnetic perturbations associated with MHD activity such as sawteeth.
 - Following successful first data, a second Doppler imaging camera is planned for divertor studies on DIII-D, and a specially designed port plug will be installed on KSTAR in anticipation of 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.
- 3) In future years, we anticipate discussions with other laboratories in relation to exploiting the imaging capabilities of CI systems. In particular, 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.
- 4) In the area of coherence imaging technology development and applications, the advanced imaging group anticipates a number of developments in coming years:
 - 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 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.

- 5) Further development of the new stepped pressure 3D MHD equilibrium formulation will be carried out. It is planned a working version of the 3D MHD equilibrium solver will be produced in 2010. Methods for control of magnetic field line chaos in stellarators/heliotrons will be investigated. Alternative variational principles for equilibria to replace the Kruskal–Kulsrud energy minimization principle will be investigated to allow transport through imperfect magnetic surfaces and thus improve the flexibility of the stepped-pressure equilibrium code.
- 6) The Bayesian inference project will be progressed to obtain equilibrium profiles (T_e , T_i and n_e) and to identify wave modes in H-1, and in complementary work to validate physics models of force balance in the MAST spherical torus. For H-1 plasmas, we intend to construct a candidate basis set of discrete wave modes using a cylindrical model with helical field averaging. These candidate discrete modes will be resolved using CAS3D, and then incorporated into MINERVA in order to identify mode structures probabilistically.
- 7) A new collaborative project between CCFE (S. Sharapov, K. McClements, S. Pinches) and the ANU (M. Hole, R. Dewar) will commence in the area of burning plasma physics, as funded by ARC Discovery and an ARC Future Fellowship awarded to M. Hole. The project aims to develop an innovative multiple fluid model to model 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 collaboration with IPP and Oak Ridge, stellarator/heliotron codes and analysis will contribute to the extension of the project to 3D: investigation of the effect of 3D field structure on Alfvénic waves and energetic particle modes in tokamaks, establishing the effect on particle transport.
- 8) 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. A variant of the 4-quadrant solid-state CI system promises to be able to provide accurate surface-temperature estimates without the need for emissivity corrections and will be installed for routine operation in 2010.

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

3 EU

3.1 GERMANY

3.1.1 International collaborations in 2009

- Collaborations with EU

- 1) H. Thomsen (IPP Greifswald) visited Culham Centre for Fusion Energy, 05.01. - 25.09.2009: collaboration with EFDA-JET Taskforce E/S1 for the diagnostics start-up, calibration and data analysis of the fast IR-diagnostics in JET campaigns C26 & C27
- 2) T. Feher (IPP Greifswald) visited Chalmers University Gothenburg, 11.01. – 10.02.2009: To work on runaway losses and calculation of runaway electron generation during doped pellet injection
- 3) L. Fattorini (IST, Lisboa) to IPP Greifswald, 12.01. – 06.02.2009: the visit was part of the European Fusion Training Scheme (program microwave diagnostic engineering for ITER)
- 4) R. König (IPP Greifswald) visited CEA Cadarache, 15.02. – 19.02.2009: PETF-Technical Meeting on diagnostic movement in vacuum
- 5) T. Klinger (IPP Greifswald) visited Austria Center Vienna, 22.02. – 25.02.2009: Joint meeting IFRC/FPCC
- 6) W. Schneider (IPP Greifswald) visited Culham Centre for Fusion Energy, 24.02. – 13.03.2009: CX-measurements at MAST
- 7) J. Connor (UKAEA Culham) to IPP Greifswald, 02.03. – 15.03.2009 and 04.11. – 14.11.2009: To work on magnetic reconnection
- 8) F. Taccogna (University of Bari) to IPP Greifswald, 15.03. – 04.04.2009 and 11.07. – 01.08.2009: To work on plasma-wall-interaction with the HGF group of Dr. Ralf Schneider
- 9) G. Tracz (Institute of Nuclear Physics, Krakow) to IPP Greifswald, 08.03. – 04.04.2009: visit in the frame of the IPPLM/INP-IPP Cooperation Agreement on “Neutron Activation Diagnostics for W7-X” and on “MCNP calculations for W7-X”
- 10) T. Klinger (IPP Greifswald) visited IPPLM Warschau, 16.03. – 19.03.2009: IPPLM -IPP cooperation agreement
- 11) V. Szabó (KFKI, Budapest) to IPP Greifswald, 22.03. – 18.04.2009
- 12) D. Tskhakaya (University of Innsbruck) to IPP, 20.04. – 17.07.2009: To work on development and implementation of a new adaptive method in BIT1 code in collaboration with the HGF group of Dr. Ralf Schneider
- 13) T. Pereira (IST, Lisboa) to IPP Greifswald, 14.04. – 26.04.2009: the main topics of

the visit were the design of magnetic signals integrators for long discharges, the strategy for PCB implementation over ATCA-MIMO-ISOL modules as well as the study and selection of suitable components

- 14) H. Braune (IPP Greifswald) visited Culham Centre for Fusion Energy, May – November 2009: Feasibility studies for an ECRH system for JET
- 15) N. Marushchenko (IPP Greifswald) visited University of Graz, 03.05. – 16.05.2009: Benchmarking of the solver for Spitzer problem implemented in the ray-tracing code TRAVIS
- 16) A. Czarnecka, W. Figacz, S. Jablonski, J. Kaczmarczyk, M. Kubkowska, L. Ryc, J. Wolowski (IPPLM, Warsaw) to IPP Greifswald, 05.05. – 06.05.2009: collaboration in the field of x-ray-diagnostic for W7-X
- 17) J. Urban (IPP, Prague) to IPP Greifswald, 10.05. – 13.06.2009, and 30.07. – 01.08.2009: “ray-tracing” calculations for the electron Bernstein wave emission
- 18) A. Zocco (University of Torino) to IPP, 24.05. – 26.05.2009: To discuss about non-linear dynamical systems
- 19) T. Klinger (IPP Greifswald) visited JET, Abingdon, 13.05. – 15.05.2009: invited talk at Culham Centre for Fusion Energy
- 20) J. Cantarini (IPP Greifswald) visited Culham Centre for Fusion Energy, 07.06. – 26.06.2009: study of optical diagnostic design solutions on JET and MAST
- 21) A. Dinklage (IPP Greifswald) visited CIEMAT Madrid, 22.06.-24.06.2009: report on data analysis requirements for ITER
- 22) T. Klinger (IPP Greifswald) visited IFJ, Krakow, 25.06.2009: meeting on collaboration issues/cooperation agreement
- 23) I. Chavdorovski (University of Rome) to IPP, 01.07. – 03.07.2009: On kinetic theory of low frequency shear Alfvén waves in tokamak plasmas
- 24) L. E. Hernández, M. S. Gómez, P. Acedo, P. Pedreira (CIEMAT, Madrid) to IPP Greifswald, 06.07 - 07.07 2009: 2nd Workshop on Interferometry for Steady State Fusion Devices
- 25) G. Papp (Budapest University) to IPP, 12.07. – 15.07.2009: To calculate runaway electron drift orbits in 3D magnetostatic perturbed fields.
- 26) I. Pusztai (Chalmers University Gothenburg) to IPP, 12.07. – 19.07.2009: To discuss quasilinear theory of turbulent transport in tokamaks and its further development
- 27) T. Fülöp (Chalmers University Gothenburg) to IPP 12.07. – 22.07.2009: To discuss quasilinear impurity transport and the motion of runaway electrons in three-dimensionally perturbed magnetic equilibria

- 28) V. Erckmann (IPP Greifswald) visited JET, 15.07. – 17.07. and 11.11. – 13.11.2009: ECRH feasibility study
- 29) S. Schmuck (IPP Greifswald) visited Culham Centre for Fusion Energy, 18.07. – 21.08.2009: ECE diagnostic at JET
- 30) H. Timko, K. Nordlund und F. Djuabekova (University Helsinki) to IPP, 10.08. – 12.08.2009: Collaboration in the field of plasma-wall-interaction with the HGF group „Computational Material Science“ of Dr. Ralf Schneider
- 31) S. Braun (IPP Greifswald) visited Chalmers University Gothenburg, 13.09. – 14.10.2009: To work on effects of impurity ions on the behaviour of microinstabilities
- 32) M.-D. Hua (UKAEA Culham) to IPP, 16.09. – 18.09.2009: Comparison of rotation dumping with neoclassical theory in MAST
- 33) M. Drevlak (IPP Greifswald) visited Chalmers University Gothenburg, 27.09. – 04.10.2009: To study the runaway electron drift orbits in perturbed magnetostatic fields
- 34) M. Reshko (UKAEA Culham) to IPP, 05.10. – 07.10.2009: Gyrokinetic turbulence simulations
- 35) W. Schneider (IPP Greifswald) visited CIEMAT Madrid, 27.10. – 13.11.2009: neutral particle diagnostics at TJ-II
- 36) I. Ksiazek (Institute of Physics, Ople University, Opole) to IPP Greifswald, 18.10. – 30.10. and 15.11. – 20.11. and 13.12. – 18.12.2009: cooperation concerning the development of the C/O-monitor diagnostic for W7-X
- 37) T. Klinger, R. Wolf (IPP Greifswald) visited CEA, Cadarache, 18.10. – 20.10.2009: meeting on collaboration issues CEA/IRFM/-IPP
- 38) P. Pedreira (Carlos III University of Madrid) to IPP Greifswald, 01.11. – 11.12.2009: developing a multichannel interferometer for steady state plasma conditions
- 39)) M. S. Gómez (CIEMAT, Madrid) to IPP Greifswald, 16.11. – 20.11.2009: cooperation regarding R&D activities for developing a multichannel interferometer for steady state plasma conditions
- 40) T. Klinger (IPP Greifswald) visited Ciemat, Madrid, 19.11. – 21.11.2009: EPS PPD Board Meeting
- 41) T. Klinger (IPP Greifswald) visited IST (Instituto Superior Tecnico), Lissabon, 23.11. – 25.11.2009: SOFT-IOC meeting
- 42) L. E. Hernández (CIEMAT, Madrid) to IPP Greifswald, 16.11. – 14.12.2009: cooperation regarding R&D activities for developing a multichannel interferometer for steady state plasma conditions

- 43) K. Gal (KFKI Budapest) to IPP, 22.11. – 05.12.2009: Cooperation on pellet simulation
- 44) L. Lewerentz und R. Warmbier (IPP Greifswald) visited the University of Bari, 29.11. – 05.12.2009: Collaboration on plasma-wall-interaction
- 45) W. Guttenfelder (University of Warwick) to IPP, 07.12. – 10.12.2009: Comparison of experimental measurement with reduced transport modelling results for stellarators/heliotrons

- Collaborations with Japan

- 1) A. Kus (IPP Greifswald) visited NIFS, Toki, 11.04. – 03.05.2009: energy confinement scaling and profile data base
- 2) M. Yokoyama (NIFS, Toki) to IPP Greifswald, 29.06. – 17.07.2009: energy confinement and transport studies
- 3) M. Sato (NIFS, Toki) to IPP Greifswald, 13.07. – 17.07.2009: energy confinement and transport studies
- 4) M. Toma, K. Maeki and Y. Ishida (Keio University Yokohama) to IPP Greifswald, 06.09. – 11.09.2009: Collaboration on plasma-wall-interaction
- 5) H. Laqua (IPP Greifswald) visited NIFS, 27.10. – 01.11.2009
- 6) H. P. Laqua (IPP Greifswald) visited Kyushu University, Kyoto University and NIFS, 17.10. – 01.11.2009
- 7) R. Schneider, K. Matyash and G. Stoppa (IPP Greifswald) visited Keio University of Yokohama, 13.11. – 22.11.2009: Collaboration on plasma-wall-interaction
- 8) P. Drewelow (IPP Greifswald) visited NIFS, 14.11. – 12.12.2009
- 9) M. Otte (IPP Greifswald) visited NIFS, 28.11. – 07.12.2009: LHD experiments
- 10) J. Geiger (IPP Greifswald) visited NIFS, 05.12. – 19.12.2009: Development, application and benchmarking of 3D-equilibrium code HINT2
- 11) T. Klinger (IPP Greifswald) visited NIFS, 06.12. – 13.12.2009: Administrative council external peer review committee

- Collaborations with Russia

- 1) T. Richert (IPP Greifswald) visited the Budker Institute of Nuclear Physics, Novosibirsk, 10.05. – 15.05.2009: manufacturing control DNBI, acceptance power supplies
- 2) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 22.04. – 20.06.2009 and 27.09. – 25.11.2009: Collaboration on stellarator optimization

- 3) T. Richert (IPP Greifswald) visited the Budker Institute of Nuclear Physics, Novosibirsk, 12.07. - 17.07.2009: high voltage power supply meeting, control system discussions
- 4) F. Chernychev, A. Melnik (Ioffe Institute, St. Petersburg) to IPP Greifswald, 03.09. – 17.09.2009: collaboration in the field of neutral particle
- 5) Maxim Isaev (Kurchatov Institute Moscow) to IPP Greifswald, 25.10. – 15.11.2009: Benchmarking of momentum corrections

- Collaborations with Ukraine

- 1) A. Zhezhera (IPP Charkov) to IPP Greifswald, 10.05. – 24.05.2009: Work on the optimization of the primary beam trajectory code for the heavy ion beam probe (HIBP)
- 2) Sergey Kasilov (University of Kharkov and University of Graz) to IPP Greifswald, 01.07. – 31.07.2009: Development and implementation of algorithm with dynamic test particle weights for parallel momentum equation in Monte-Carlo fluid code E3D
- 3) N. Marushchenko (IPP Greifswald) visited the Institute for Plasma Physics of NFC Kharkov, 07.07. – 08.07.2009: Physics of RF-heating in stellarators
- 4) I. Bizyukov (Karazin Kharkiv National University) to IPP Greifswald, 01.10. – 30.11.2009: 2D-Tridyn code

- Collaborations with USA

- 1) H. Dreier (IPP Greifswald) visited General Atomics, San Diego, 06.06. – 10.06.2009: DIII-D
- 2) A. Reiman (PPPL) to IPP Greifswald, 09.07. – 10.07.2009; Nonlinear three-dimensional magnetohydrodynamics
- 3) J. Candy (General Atomics San Diego) to IPP Greifswald, 13.07. – 22.07.2009: Gyrokinetic and neoclassical transport theory
- 4) E. Belli (General Atomic San Diego) to IPP Greifswald, 13.07. – 22.07.2009: Gyrokinetic and neoclassical transport theory
- 5) A. Dinklage (IPP Greifswald) visited PPPL, 08.-09.10.2009
- 6) M. Jakubowski (IPP Greifswald) visited General Atomics, San Diego, 05.10. – 14.11.2009: DIII-D experiments
- 7) O. Grulke (IPP Greifswald/EMAU) visited MIT-PSFC, Cambridge, 01.11. – 20.11.2009: Work on cooperation programme analysis of turbulence imaging
- 8) R. Schneider (IPP Greifswald) to University of California, San Diego, 07.11. – 13.11.2009: Plasma-wall-interaction

3.1.2 Conference participation

- 1) R. Warmbier: Molecular Energy Transfer Seminar and conference, 15.01. – 23.01.2009, Ventura, USA
- 2) V. Erckmann: 5th IAEA TM on “ECRH Physics and Technology for Large Fusion Devices”, 18.02. – 20.02.2009, Gandhinagar, India
- 3) G. Kühner: Software Engineering, 02.03. – 06.03.2009, Kaiserslautern, Germany
- 4) M. Jakubowski, R. Wolf: Workshop on Stochasticity in Fusion Plasmas (SFP), 02.03. – 04.03.2009, Jülich, Germany
- 5) R. Wolf: 14. Fachtagung Plasmatechnologie, 02.03. – 04.03.2009, Wuppertal, Germany
- 6) V. Erckmann: German Microwave Conference, 16.03. – 18.03.2009, Munich, Germany
- 7) J. Baldzuhn, R. König, J. Svensson: Workshop “Active Beam Spectroscopy for plasma control”, 24.03. – 27.03.2009, Leiden, Netherlands
- 8) D. Andruczyk, A. Dinklage, P. Drewelow, O. Grulke, T. Kleinwächter, T. Klinger, S. Marsen, M. Otte, J. Pfannmöller, Y. Podoba, K. Rahbarnia, C. Rapson, S. Schmuck, T. Schröder, T. Stange, T. Windisch, R. Wolf, D. Zhang: DPG-Frühjahrstagung, 30.03. – 03.04.2009, Greifswald
- 9) A. Könies: 2nd ITPA Meeting “Energetic Particle Physics Topical Group”, 19.04. – 25.04.2009, Daejeon, Südkorea
- 10) J. Schacht: 16th IEEE Real Time Conference, 10.05. – 15.05.2009, Beijing, China
- 11) H. Braune, V. Erckmann, H. P. Laqua, G. Michel, H. Oosterbeek, Y. Podoba, T. Stange, R. Wolf: 21st Joint Russian-German Workshop on ECRH and Gyrotrons, 11.05. – 16.05.2009, Greifswald, Germany
- 12) H. Dreier, T. Klinger: 36th International Conference on Plasma Science and 23rd Symposium on Fusion Engineering, 31.05. – 05.06.2009, San Diego, USA
- 13) T. Bluhm, J. Krom, H. Laqua, H. Riemann, A. Spring, A. Werner: IAEA-TM on Control, Data Acquisition, and Remote Participation for Fusion Research, 15.06. – 19.06.2009, Aix en Provence, France
- 14) H. P. Laqua, G. Michel: 18th Topical Conference on Radio Frequency Power in Plasmas, 24.06. – 26.06.2009, Gent, Belgium
- 15) S. Braun, M. Drevlak, H. P. Laqua, S. Schmuck, W. Schneider, H. Smith, H. Thomsen: 36th EPS Conference on Plasma Physics, 29.06. – 03.07.2009, Sofia, Bulgaria
- 16) O. Mishchenko: Festival of Theory, 06.07. – 17.07.2009, Aix-en-Provence, France

- 17) T. Klinger: ICPT Summer College on Plasma Physics, 09.08. – 14.08.2009, Trieste, Italy
- 18) R. Schneider: Plasma Physics in Science and Technology, 17. – 28.08.2009, Prague, Czech Republic
- 19) T. Klinger: 2nd EFDA TTG Meeting, 15.09. – 18.09.2009, Abingdon, GB
- 20) K. Matyash and R. Schneider: 30th International Electric Propulsion Conference, 18.09. – 25.09.2009, An Arbor, USA
- 21) M. Krychowiak: 14th International Symposium on Laser-Aided Plasma Diagnostics, 21.09. – 24.09.2009, Castelbrando, Italy
- 22) A. Könies: 3rd Meeting of the ITPA Energetic Particle Physics Topical Group and IAEA TM “Energetic Particles in Magnetic Confinement Systems”, 20.09. – 26.09.2009, Kiev, Ukraine
- 23) T. Feher: IAEA TM “Energetic Particles in Magnetic Confinement Systems”, 20.09. – 24.09.2009, Kiev, Ukraine
- 24) H. Braune: 34th International Conference of Infrared, Millimetre and Terahertz Wave (IRMMW-THz), 21.09. – 25.09.2009, Busan, Korea
- 25) M. Laux, S. Marsen: 8th International Workshop on Electric Probes in Magnetized Plasmas, 21.09. – 24.09., Innsbruck, Austria
- 26) Ch. Hennig: Jahrestagung der Gesellschaft für Informatik, 28.09. – 02.10.2009, Lübeck, Germany
- 27) K. Matyash: 21st International Conference on Numerical Simulation of Plasmas, 05.10. – 09.10.2009, Lisboa, Portugal
- 28) C. Beidler, J. Geiger, . Turkin, N. Marushchenko, P. Helander, R. Kleiber and P. Xanthopoulos: 17th International Stellarator/Heliotron Workshop and International Collaboration on Stellarator Theory, 11.10. – 23.10.2009, Princeton, USA)
- 29) A. Dinklage, M. Hirsch, M. Jakubowski, M. Otte, R Wolf: International Stellarator/Heliotron Workshop 12.10. – 18.10.2009, Princeton, USA
- 30) A. Könies and A. Runov: 13th European Fusion Theory Conference, 13.10. – 15.10.2009, Riga, Latvia
- 31) R. Schneider: Workshop Math & ITER, 28.10. – 30.10.2009, Marseille, France
- 32) O. Grulke: APS-DPP Conference, 01.11. – 20.11.2009, Cambridge, USA
- 33) S. Bozhenkov, R. Schneider, R. Warmbier: 51st Annual Meeting of the APS Division, 02.11. – 06.11.2009, Atlanta, USA

34) P. Drewelow, M. Otte: 19th International Toki Conference, 08.12. – 11.12.2009, Toki, Japan

3.1.3 Participation in joint projects

- International stellarator/heliotron confinement data base

Coordinated Working Group: CWGM5, University Stuttgart, 06.07. - 08.07.2009: contributions from A. Dinklage, A. Weller, J. Geiger, M. Hirsch

Coordinated Working Group: CWGM6, PPPL (USA), 16.10.2009 contributions from A. Dinklage, M. Hirsch

- International stellarator/heliotron profile data base

Contributions from A. Dinklage, J. Geiger, M. Hirsch, A. Kus, A. Weller, Yu. Turkin

- ITPA diagnostics

Contributions from R. König:
20.04 - 24.04.2009 St. Petersburg, Russia and 12.10. - 16.10.2009 Pohang, Korea

Specialists Working Group on Reflectometry (RWG): M. Hirsch

Specialists Working Group on First Mirrors: M. Krychowiak

- ITPA pedestal and edge

Contributions from M. Hirsch

- ITPA confinement and transport

Contributions from A. Dinklage

3.1.4 Plans for 2010

- Planning stellarator/heliotron theory

- 1) Ralf Kleiber plans to visit CIEMAT Madrid to work on gyrokinetic simulations.
- 2) Ralf Kleiber plans to visit JET to work on electromagnetic gyrokinetic simulations.
- 3) Pavlos Xanthopoulos plans to visit PPPL to work on turbulence simulations.
- 4) Tamas Feher will visit Chalmers in Gothenburg to collaborate with Tünde Fülöp on runaway electrons.
- 5) Stefanie Braun will also go to Chalmers Gothenburg to work on impurity transport.
- 6) Johan Andersson will collaborate with Chalmers Gothenburg on confinement studies.

- 7) Michael Drevlak will visit Chalmers Gothenburg to work on runaway electron mitigation.
- 8) Axel Könies will go to Daejeon/Korea for the ITPA Meeting “Energetic Particle Physics Topical Group”.
- 9) Nikolai Marushchenko will visit the University of Graz to collaborate on ECRH.
- 10) Henning Maaßberg and Craig Beidler will visit the University of Graz to work on neoclassical transport.
- 11) Joachim Geiger will visit NIFS Toki to work on MHD equilibrium.

- Spectroscopic diagnostics

- 1) Rainer Burhenn, U. Herbst, E. Pasch, J. Schacht, S. Pingel (IPP Greifswald), visit of 3 days duration of TEXTOR (FZJ) planned for discussions concerning the HEXOS control and preparational work for the integration of HEXOS at W7-X.
- 2) Rainer Burhenn (IPP Greifswald) with Ireneusz Ksiazek (Institute of Physics, Opole University Poland, via Institute of Plasma Physics and Laser Microfusion (IPPLM) Poland), development of a C-, O-Monitor System for W7-X, regular communication, a visit of 1 week duration in each direction is planned.
- 3) R. König (IPP Greifswald) plans to visit KFKI Budapest, Hungary, to continue the design of the W7-X video diagnostic.
- 4) S. Zoletnik, G. Kocsis, S. Tulipan, V. Szabó (KFKI-RMKI Budapest), plan several visits to IPP Greifswald of 1-2 weeks duration to continue the design of the W7-X video diagnostic.

- SX diagnostics

- 1) H. Thomsen will visit IPPLM Warsaw in the frame of a collaboration contract on SX diagnostics to perform measurements on detectors and filters (a 1 week visit is planned).
- 2) Mutual visits between IPP and IST Lisbon are planned in the frame of the collaboration on fast online tomography and data acquisition systems (involving H. Thomsen, P. Carvalho).

- IR diagnostics / collaboration with JET taskforce S1

H. Thomsen will visit Culham Centre for Fusion Energy to collaborate in calibration improvements of the IR-camera and participate in a JET EFDA-taskforce S1 meeting (1 week).

- Neutral particle diagnostics

- 1) W. Schneider will visit Culham Centre for Fusion Energy for about 3 weeks in order to continue CX-NPA measurements at MAST and for preparing an additional shielding of the compact analyser against the magnetic stray field.
- 2) 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. The annual meeting of the project partners BINP, IPP and FZJ will take place in Greifswald in spring. 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. T. Richert (IPP Greifswald) and J. Baldzuhn plans to visit the FZ-Juelich and the Budker Institute (BINP) in Novosibirsk, Russia for this purpose.

- Neutron diagnostics

- 1) Mutual visits (about 2 per year, each about for 2-3 days) in the frame of a 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 3 weeks) to engage in development of neutron monitoring systems and in MCNP calculations.
- 2) Mutual visits (about 2 per year, each about 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) M. Hirsch will visit TJ-II (CIEMAT, Madrid) and IST (Lisboa), Microwave diagnostic development, Cooperation contract on "Development and construction of a multichannel CO₂-Interferometer for W7-X", trainee program Microwave Diagnostic Engineering for ITER and Reflectometry Workshop in Lisbon
- 2) 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.
- 3) 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.
- 4) In the framework of the European Fusion Training Scheme "Microwave Diagnostic Engineering for ITER", a Trainee from CIEMAT will visit Greifswald for a 2 months training on the Microwave Stray Radiation Launch Facility (MISTRAL) and on ECE design and calibration.

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

A. Dinklage, A. Kus, M. Hirsch will organize CWGM7 in Greifswald 30.06-02.07.2010

A. Kus will visit CIEMAT for Scaling Studies

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

M. Yokoyama will stay in Greifswald for continuation of work on the Stellarator/Heliotron Profile 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.

2) H. P. Laqua (IPP Greifswald) will visit TJ-2 CIEMAT (Spain) for 2 week: Installation of sniffer probe diagnostic and Initial experiments on 28 GHz heating at TJ-2 with the new 0.5 MW Gyrotron (shifted in from 2009).

3) T. Stange (IPP Greifswald) will visit will visit TJ-2 CIEMAT (Spain) for 2 weeks: Participation on EBW-heating experiments. EBW-emission measurement.

- **International collaboration on data validation**

A. Dinklage, A. Werner contribute to VALIDATION 6 at CIEMAT

- **Conference participation**

1) G. Kühner: Software Engineering 2010, 22.02. – 26.02.2010, Paderborn, Germany

2) E. Chlechowicz, P. Drewelow, S. Marsen, E. Müller, R. Reimer, T. Stange: DPG-Frühjahrstagung, 08.03. – 12.03.2010, Hannover, Germany

3) H. P. Laqua, S. Schmuck: 16th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, 12.04. – 15.04.2010, Sanja, China

4) R. Burhenn, J. Cantarini, M. Hirsch: International Conference on Plasma Diagnostics, 13.04. – 16.04.2010, Nancy, France

5) H. Dreier, R. König, P. Kornejew, D. Zhang: 18th Topical Conference on High Temperature Plasma Diagnostics, 16.05. – 20.05.2010, Wildwood, New Jersey, USA

6) G. Michel, H. P. Laqua, V. Erckmann: Russian-German Workshop on ECRH and Gyrotrons, May/July 2010, Moscow and Nizhny Novgorod, Russia

7) M. Jakubowski, H. Thomsen: 19th Plasma Surface Interactions conference, 24.05. – 28.05.2010, San Diego, USA

- 8) M. Laux, S. Marsen, M. Otte, W. Schneider, J. Svensson: 37th European Physical Society Conference on Plasma Physics, 21.06. – 25.06.2010, Dublin, Ireland
- 9) H. Braune: International Conference on Infrared, Millimeter, and Terahertz Waves, 05.09. – 10.09.2010, Rome, Italy
- 10) G. Michel: 26th Symposium on Fusion Technology, 27.09. – 01.10.2010, Porto, Portugal
- 11) M. Hirsch, R. Wolf: 23rd IAEA Fusion Energy Conference, 11.10. – 16.10.2010, Daejeon, Korea

3.2 SPAIN

3.2.1 International collaborations in 2009 using TJ-II at CIEMAT

- Collaborations with Russia

- 1) K. Sarkisyan and the ECRH IOFAN team participated in the operation of the ECRH system of TJ-II during the 2009 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, visited at CIEMAT in March 2009 (2 weeks) and November 2009 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA and EBW current drive studies (November / December 2009).
- 4) S. Petrov (IOFFE) (June 2009) visited CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) visited Ciemat in September 2009 to discuss possible designs of a diagnostic based on scattering signals from the ECH RF power in TJ-II.
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team were visiting CIEMAT to investigate the structure of plasma potential in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP detector. The second HIBP system has been design for long-range (zoanl flows) correlation studies and the analyzer construction is foreseen during 2010.

- Collaborations in Europe

Germany

- 1) G. Müller, P. Brand and K. Schlüter IPP/IPF (Stuttgart) stayed at CIEMAT to further continue the improvements in the control system of the gyrotron anode modulators and to collaborate in the installation of the new modulator for EBW studies in TJ-II

- 2) W. Schneider (IPP, Greifswald) was visiting CIEMAT (November) on NPA experiments.
- 3) M. Sánchez visited Greifswald (November 2009) to discuss W7-X diagnostics.
- 4) E. Sánchez was visiting IPP-Greifswald (March, 2009) to discuss the development of EUTERPE gyro-kinetic code.
- 5) J. L. Velasco was visiting Julich (Germany) to work on the development of IRENE codes.

Belgium

Oleg Shyskind visited CIEMAT (March and November 2009) to work on a non-Maxwellian Coulomb collision operator, to be included in a kinetic code.

Portugal

- 1) C. Silva and I. Nedzelskiy were visiting CIEMAT to continue our collaboration on edge studies (edge turbulence studies and RFA development) during 2009.
- 2) Diana Baião is working in her PhD thesis (October – December) on soft x-ray based Te diagnostic for high density plasmas in the TJ-II stellarator (including prototypes construction and testing).

Czech Republic

Karel Kovarik was visiting CIEMAT (November 2008) to participate on edge diagnostic development and measurements in TJ-II (electromagnetic probes).

Italy

M. Spolaore was visiting CIEMAT (September 2009) to participate on edge diagnostic development and measurements in TJ-II including the development of electromagnetic probes to characterize the electromagnetic nature of plasma filaments in TJ-II.

Rita Lorenzini was visiting CIEMAT (December 2009) for studying transport in 3D magnetic confinement devices.

- Collaborations with USA

- 1) I. Calvo visited ORNL (January-February, 2009) to discuss fractional transport theory.
- 2) P. Ryan and J. Caughman (ORNL) visited CIEMAT in June 2009 to participate in the commissioning of the Electron Bernstein Emission diagnostic and discussion on NBI heating campaign.
- 3) Christopher A. Clark (UW) was visiting CIEMAT (November 2009) to participate on perpendicular impurity transport /laser blow-off experiments.

- 4) F. Tabarés was visiting HSX (UW), participating on plasma-wall (Li coating) experiments.
- 5) Erik Holdmann (USCD) was visiting CIEMAT (May 2009) working on parallel impurity transport studies.

- 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 2009 experimental campaign. The development of the second HIBP system has been design and the injector system has been constructed and delivered to CIEMAT.
- 2) S. Pavlov visited CIEMAT (December 2009) to develop a method for fast calculation of the fully relativistic dielectric tensor.

- Collaborations with Japan

- 1) D. Carralero visited Japan (November / December 2009) to participate on edge and fluctuation experiments using the 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 and the development of edge instabilities in high density regimes and beta scan studies.
- 2) C. Hidalgo visited Japan (December 2009) to discuss the joint LHD / TJ-II collaboration on edge physics (using fast visible cameras), fast particle physics (including Mach probes and HIBP measurements for the detection of Alfvén mode instabilities and related losses) and studies for test particle experiments in LHD (using fast intensified cameras and TESPEL). Planning studies for 2010 would include studies of non-diffusive transport (LHD vs TJ-II), fast particle physics, simulation studies (including impurity transport and zonal flows) and feasibility studies for test particle experiments in LHD (using fast intensified cameras and TESPEL).
- 3) A. Bustos visited Japan / NIFS (December) on fast particle confinement studies in LHD geometry.
- 4) Kenichi Nagaoka (NIFS), Takeshi Ido (NIFS), Satoshi Yamamoto (Kyoto Univ.), Takashi Minami (Kyoto Univ.) visited CIEMAT (March 2009) for participation on TJ-II experiments related to energetic particles and Alfvén modes.
- 5) The Agreement on academic and scientific cooperation between CIEMAT and NIFS was signed on CIEMAT (February 25 – 26) with the participation of a Japanese delegation led by Prof. O.Motojima and including Prof. H.Yamada , Prof.Y.Takeiri, Dr.M.Osakabe, Dr.Shoji, Dr.Narushima, Mr.A.Do, Ms.K.Kimata and Mr.M.Tsuda.
- 6) Nobuhiro Nishino (Kyoto University) was visiting CIEMAT (December 2009), working on fast camera visualization of edge physics.

7) 7) J. M. Fontdecaba was visiting NIFS (December), working on ion diagnostics.

- **Collaborations with Australia**

David Pretty (ANU) was visiting CIEMAT (until June 2009) working on data mining techniques applied to the analysis and comparison of MHD activity in stellarators and to pattern recognition in massive fusion databases.

- **Collaborations with China**

Carlos Hidalgo visited HL-2A (Chengdu) in July 2009, presenting the EU Transport Topical Group activities and joint experiments on long-range correlations and transport barrier physics in tokamaks and stellarators.

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

The 5th/ 6th Coordinated Working Group meetings (CWGM) was held in IPF (July 2009) and PPPL (October 2009) to discuss joint activities.

3.2.2 Plans for 2010

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 2010 research programme:

- Stellarator physics: confinement data-base, neoclassical transport 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 in high beta regimes.
- Theory and modelling of plasma transport, stability and equilibrium.
- Plasma – wall studies, exploring plasma-wall interaction scenarios with Li coating and divertor concepts based on flux expansion.
- Data acquisition, control and advanced data analysis techniques.

The following collaborations are planned during 2010:

- Collaborations with Russia

- 1) K. Sarkisyan and the ECRH IOFAN team participated in the operation of the ECRH system of TJ-II during the 2009 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, visited at CIEMAT in March 2009 (2 weeks) and November 2009 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA and EBW current drive studies (November / December 2009).
- 4) S. Petrov (IOFFE) (June 2009) visited CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) visited Ciemat in September 2009 to discuss possible designs of a diagnostic based on scattering signals from the ECH RF power in TJ-II.
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team were visiting CIEMAT to investigate the structure of plasma potential in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP detector. The second HIBP system has been design for long-range (zoanl flows) correlation studies and the analyzer construction is foreseen during 2010.

- Collaborations in Europe

Germany

- 1) L. Esteban and M. Sánchez will visit IPP-Greifswald in the framework of the development activities of W7-X diagnostics (CO2 interferometer).
- 2) H. Laqua will visit CIEMAT in 2010 to participate in EBW heating experiments on TJ-II.
- 3) M. Hirsch will visit CIEMAT in 2010 to participate in TJ-II L-H transition physics and Doppler reflectometry.
- 4) Participation on EFDA Topical Group activities including momentum transport, edge transport, L-H transition physics studies.
- 5) J. L. Velasco will visit Julich and IPP-Greifswald (Germany) to work on the development of IRENE code.

Portugal

C. Silva and IST team will visit CIEMAT to continue our collaboration on edge studies; Continuing the collaboration in the development of reflectometry in TJ-II (M. E. Manso,

L. Cupido, L. Guimaraes and IST team).

Czech Republic

M. Hron, I. Duran and H. Brotankova will continue their involvement on edge diagnostic development and measurements of TJ-II edge plasma diagnostics (electromagnetic probes).

JET-UK

Andrea Murari will visit TJ-II to continue our collaboration on pattern recognition techniques.

- Collaborations with USA

- 1) P. Ryan, J. Tsai and J. Caughman (ORNL) will visit CIEMAT in fall 2009 to collaborate in the scientific exploitation the Electron Bernstein Emission diagnostic and NBI heating.
- 2) I. Calvo will stay at ORNL (February 2010) to work on turbulence and transport theory.
- 3) K. McCarthy will stay at ORNL (mid-2010) 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.

- Collaborations with Ukraine

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

- Collaborations with Japan

- 1) N. Tamura, K. Ida (NIFS, Japan), S. Inagaki (RIAM, Kyushu Univ., Japan) will visit Ciemat (March 2010) to investigate the interplay between nonlocal transport effects and long-range radial correlations in TJ-II.
- 2) D. Carralero and E. de la Cal will visit NIFS to continue the investigation of fluctuations and transport using fast visible (intensified) camera experiments in LHD, including feasibility studies of test particle experiments in LHD
- 3) K. Nagaoka (NIFS) will visit CIEMAT (March) to participate on fast particle studies (radial localization of Alfvén modes and edge transport using Mach probes).
- 4) A. Bustos will visit NIFS (mid-2010) to work on fast particle confinement in LHD.

- **International stellarator/heliotron working groups**

Activities will continue with further analysis and presentations in the major conferences.

4 JAPAN

4.1 International collaborations by the LHD team at NIFS

- **Collaborations with EU**

- 1) Dr. Kubo (NIFS) from Feb. 10 to 20 and Dr. Nishiura (NIFS) from Feb. 10 to 26 will visit TEXTOR Julich Germany and RISOE Denmark to discuss the spectrum analysis of collective Thomson scattering. They will join experiment of collective Thomson scattering on TEXTOR
- 2) P. Norrington (Queen's University of Belfast, UK) visited NIFS (D. Kato and I. Murakami) from Feb. 15 to Mar. 15, 2009 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 Fe XVII which are necessary for a kinetic model of plasma spectroscopy.
- 3) Mamoru. Shoji, NIFS, Japan, visited CIEMAT, Spain from 23th Feb. 2009 to 28th Feb. 2009 to discuss measurements and analysis of the image data taken with a fast framing camera in LHD and to attend a ceremony of agreement on academic and scientific cooperation between CIEMAT and NIFS.
- 4) Y. Narushima, NIFS, Japan, visited CIEMAT, Spain from 23rd Feb. 2009 to 28th Feb. 2009 to discuss island physics in LHD and TJ-II with F. Castejon and to attend a ceremony of agreement on academic and scientific cooperation between CIEMAT and NIFS.
- 5) D. Kato visited Institute for Theoretical Physics in Vienna University of Technology (host: J. Burgdörfer) and Atomic and Molecular Data Unit in IAEA headquarter (host: R.E.H Clark) in Austria from 8th March until 15th March 2009 to discuss about physics and data on atomic processes in plasmas and fusion reactor materials.
- 6) "N.Ashikawa (NIFS) visited FOM/Rijnhuizen from May 3rd to May 10th to attend 12th ITPA meeting on SOL/divertor physics, and presented about "ICRF wall conditioning in LHD" and "Dust R&D working plan" as ITER IO urgent tasks.
- 7) T. Ido(NIFS) visited CIEMAT (Madrid, Spain) from 12th to 15th March 2008 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research. He discussed the radial electric formation mechanism in magnetically confined plasmas and technical issues on heavy ion beam probes.
- 8) K. Nagaoka(NIFS) visited CIEMAT from 15th to 22th March 2009 to join experiments on Alfvén eigenmodes study and fast ion measurement using Mach

probe. He also discussed experimental data of Directional probe utilized in CHS, LHD and Heliotron J.

- 9) Bogdan Hnat (University of Warwick, UK) visited NIFS from 22nd March to 28th March for study of generic features of edge transport mechanisms in MAST with new RMP coils and in the heliotron. He analyzed LHD data and discussed about fluctuation studies in LHD.
- 10) Prof. D. Bertin (Vice president of the University of Provence) and Prof. Benkadda (University of Provence) have visited NIFS on 13th April, 2009. The establishment of International Institute for Fusion Science (IIFS) at the University of Provence was reported, and the possible collaboration with NIFS was discussed. The ITER International Summer School 2009 was held at the University of Provence, the collaboration for which was also discussed.
- 11) Yoshio Nagayama, Hideya Nakanishi, and Takashi Yamamoto (NIFS) visited ITER-IO, France from 6th June 2009 to 21th June 2009 to test the fast data transfer technology using TCP/IP in the Internet.
- 12) Yoshio Nagayama, Hideya Nakanishi, Takashi Yamamoto, and Masahiko Emoto (NIFS) attended to the 7th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research, which was held in the "Centre des Congres" in Aix en Provence France June 15 – 19, 2009.
- 13) Valentyn Tsisar Visiting period June 19, 2009 ~ Dec. 18, 2009 Compatibility studies of liquid Li with JLF-1 were continued. Comparison was made between the corrosion of Reduced Activation Ferritic Martensitic Steel (JLF-1) in a static and a flowing Li environments. The results showed that the flowing Li enhanced erosion loss of the surface by grain boundary corrosion and detachments. Similar studies were carried out for JLF-1 in Li-Pb, which showed even stronger effects of the flowing condition on the grain boundary corrosion and detachment. The research enhanced our understanding on the means of corrosion suppression in liquid Li and Li-Pb blankets.
- 14) M. Kobayashi (NIFS) visited Institut d'Etudes Politiques in Aix en Provence, France from 21st to 26th June 2009, to give a lecture on divertor plasma transport with stochastic magnetic boundary in magnetically confined devices at third ITER International Summer school.
- 15) T. Mutoh, T. Shimozuma and H. Takahashi (NIFS) visited Forshungszentrum Karlsruhe (FZK, Germany) on 22nd June 2009 to discuss on the development and improvement of high power gyrotrons and some millimeter wave components such as a diamond window. After that, they attended "The 18th Topical Conference on Radio Frequency Power in Plasmas" held in Gent, Belgium from 24th to 26th June 2009 to give presentations and to discuss on the future collaborations with W7-X and CRPP members.
- 16) M.Yokoyama (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) to discuss and implement the strategy for developing the International Stellarator/Heliotron Profile Data Base with implementing the appropriate equilibrium information, so that users can perform their own analyses of registered

shot information. This has established the basis also for the computational code benchmarking.

- 17) M. Kobayashi visited Prof. Detlev Reiter at Forschungszentrum Juelich Germany from 28th June to 4th July, in order to collaborate and update on the version of 3D edge neutral transport code EIRENE with D. Reiter, H. Frerichs and P. Boerner. G. Kawamura (NIFS) attended 12th International Workshop on Plasma Edge Theory in Fusion Devices (PET12) at Rostov Veliky Russia from 31 Aug.
- 18) S. Ohdachi(NIFS) visited Forschungszentrum Juelich GmbH (Juelich, Germany) from 5th to 12th July. 2009 in the international collaboration on 2D imaging diagnostics in the stochastic region in the Tokamak device.
- 19) Y. Narushima, NIFS, Japan, visited Universität Stuttgart IPF from 6th Jul. to 8th Jul. 2009. 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.
- 20) Y. Suzuki (NIFS) visited Stuttgart University (Stuttgart, Germany) and Forschungszentrum Juelich GmbH (Juelich, Germany) from 6th to 10th July. 2009 in the international collaboration on 3D modeling in the tokamak configuration with the resonant magnetic perturbation field. This collaboration results were reported at EPS2009 (Sofia, Bulgaria, Jun. 2009) and ISHW2009 (Princeton, USA, Oct. 2009).
- 21) K. Tanaka (NIFS) visited Culham laboratory of UKAEA and Warwick university (England) from 8th July 2009 to 18th July 2009 to discuss the collaboration of turbulence measurements on MAST and gyro kinetic calculation for LHD. Host was Clive Michael.
- 22) M. Sato (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) from 13th July to 17th July 2009 for discussion about development of hierarchy-integrated simulation codes.
- 23) K. Ichiguchi (NIFS) visited University of Carlos III (Madrid, Spain) from July 19 to July 27 for a collaboration of theoretical research with L.Garcia (UCIII) and B.A.Carreras (BACV Solutions Inc.,USA).He also visited CIEMAT (Madrid, Spain) during the stay and started another collaboration with C.Hidalgo (CIEMAT) and CIEMAT group.
- 24) A.Nishimura took part in American Society of Mechanical Engineers (ASME) Pressure Vessel and Piping (PVP) conference held in Prague from July 26 to July 30. He gave a presentation entitled "JSME Construction Standard for Superconducting Magnet of Fusion Facility "MATERIAL". There were two technical sessions organized by Japanese Delegation on construction standard of a large scale superconducting magnet for fusion.
- 25) Murakami (NIFS) attended the IAEA Technical Meeting on "Technical Aspects of Atomic and Molecular Data Processing and Exchange (20th Meeting of the Atomic and Molecular Data Centres and ALADDIN Network)" from Sep. 7 to Sep. 9, 2009 in Vienna to discuss about atomic and molecular data and database activities for

plasma and fusion researches.

- 26) Valentyn Tsisar Visiting period Sept. 10, 2008 ~ Dec. 19, 2008 Compatibility of liquid Li with structural materials, which is the key issue of the liquid Li fusion blanket, was investigated. The effects of N impurity in Li and composition of the containing materials on the corrosion of Reduced Activation Ferritic/Martensitic Steel (JLF-1) were studied, together with the model calculation of the mass transfer. The result showed that high level of N impurity in Li enhanced grain boundary corrosion by accelerating N-Cr reaction and resulting dissolution of Cr, and that high affinity of the container materials with C can enhance C dissolution from JLF-1 inducing phase change. The research enhanced our understanding on the means of corrosion suppression in liquid Li blankets.
- 27) N. Tamura (NIFS) visited Culham Science Center, England from Sep. 15th to Sep. 20th, 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations to join the 2nd EFDA Transport Topical Group Workshop. He made a presentation entitled "Experimental verification of a non-diffusive transport mechanism under the international collaboration between Japan and EU".
- 28) Dr. Nishiura (NIFS) attended "The 14th Laser Aided Plasma Diagnostics" from Sept. 19 to 25 held in Italy. The initial result of collective Thomson scattering experiments was presented.
- 29) T. Yamamoto (NIFS), and K. Hiraki, M. Inaba and N. Tanida (Univ. of Tokyo) visited ITER-IO, France from 21st September 2009 to 25th September to demonstrate the high-speed data transfer on the wide long-distance network.
- 30) Y. Tomita (NIFS) visited University of Innsbruck (Austria) and attended the 8th International Workshop on Electric Probes in Magnetized Plasmas and the International Workshop "50 Years Plasma Physics in Innsbruck" from 20th to 28th September 2009 and gave the presentation of the international collaboration research on 'Absorption Cross-section of Plasma Particles to Spherical Probe in Weak Magnetic Field'
- 31) Prof. A. Sagara and Dr. T. Goto attended 5th Workshop on BA-DEMO Design in the IFERC activities held at Max-Planck-Institut für Plasmaphysik, Garching, Germany from Oct. 4th to 9th, 2009. The reactor design activity is now on the Phase I and is scheduled to move to Phase II in 2011 (till 2018). Beginning with the definition of the DEMO reactor, the extraction of critical issues is now in progress on the basis of past design activities mainly for Tokamak in both EU and Japan. In particular, the perspective on the steady-state operation is a focal point and helical systems is also considered to be a possible option.
- 32) R.J. Buenker (Bergische Universität Wuppertal, Germany) visited NIFS (host: D. Kato) from 26th September until 23rd October 2009 to collaborate for quantum mechanical studies on electronic states of hydrogen-tungsten systems.
- 33) Katsunori Ikeda (NIFS) attended ADAS workshop 2009 at Ringberg castle nearby Munich city from 3rd October to 8th October 2009 to discuss about the optical diagnostic technique for the estimation of neutral beam deposition used the ADAS data base.

- 34) T.-H. Watanabe (NIFS) visited Pavilhao Atlantico, Lisbon (Portugal) from 4th to 11th October 2009 for attending the 21st International Conference on Numerical Simulation of Plasmas, and made an oral presentation in regard to application of fusion theory and simulation models to space plasmas.
- 35) Dr. Korsholm (RISOE DTU National Laboratory) visited NIFS from Oct. 10 to Oct. 31 and joined the LHD experiments related to the collective Thomson scattering (CTS) diagnostics. The experimental results of CTS in LHD and TEXTOR are discussed with LHD-CTS group.
- 36) Y. Narushima, NIFS, Japan, visited the Princeton Plasma Physics Laboratory in US from 11th Oct. to 18th Oct. 2009 to give the invited talk in 17th ISHW. 6th CWGM was held in 16th Oct. just after the ISHW, in which the joint papers for the IAEA-FEC in 2010 were discussed.
- 37) K. Saito (NIFS) visited ENEA (Frascati, Italy) from October 20 to October 23 for attending the ITPA meeting (the 3rd Integrated Operation Scenarios Topical Group Meeting) and discussed the operation scenarios for ITER.
- 38) Nishimura participated in The 7th Scientific and Technological Advisory Committee (STAC-7) for ITER held in Cadarache, France, from October 21 to October 23. The baseline documents of ITER were reviewed and evaluated.
- 39) Heike Laqua (Max-Planck Institute für Plasmaphysik, Greifswald, Germany) visited NIFS (H. Nakanishi) from 27th October 2009 to 30th October 2009 to discuss about the control and data acquisition system for both the Wendelstein 7-X and LHD. Some interviews for the density feedback control in LHD were also made.
- 40) Daniel Carralero Ortiz, CIEMAT, Spain, visited NIFS (H. Yamada and M. Shoji) from 2th Nov. 2009 to 13th Dec. 2009 to measure and analyze peripheral plasma transport and plasma-wall interactions in LHD with a fast framing camera.
- 41) Peter Drewelow (Max-Planck Institute für Plasmaphysik, Germany) visited NIFS from 15th November to 12th December to discuss mainly about divertor heat load measurement using infrared camera. He also discussed about installing a infrared camera developed by his group in LHD.
- 42) Rene Flukiger (Geneva University) visited NIFS (A. Nishimura) on November 16 to discuss the irradiation effect of fast neutron on A-15 superconducting materials properties.
- 43) Federico Felici (CRPP Lausanne, Switzerland) visited NIFS from 18th November to 5th December 2009 to apply an intelligent feedback control system of ECRH wave polarization to optimize quickly ECRH heating efficiency during one shot in LHD plasmas. He installed the polarization feedback control system based on the new algorithm in one of the LHD ECRH transmission lines and made experiments on real-time optimization of heating efficiency during long pulse discharges of LHD plasmas.
- 44) David Tskhakaya (University Innsbruck Austria) visited NIFS (Y. Tomita) from 28th

- November to 6th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research and discussion on the modelling of the boundary plasma by 3D PIC simulation. During his stay he attended the 26th Annual Meeting of the Japan Society of Plasma and Fusion at Kyoto and gave the invited talk entitled 'Kinetic modelling of the plasma edge on High Performance Computers.'
- 45) Matthias Otte (Max-Planck Institute fuer Plasmaphysik, Germany) visited NIFS (T. Morisaki, M. Shoji) from December 3rd 2009 to December 7th 2009, prior to the Toki Conference, to perform a preliminary experiment of magnetic field line visualization flux surface measurements.
 - 46) J.Geiger (Max-Planck Institute fuer Plasmaphysik, Germany) visited NIFS (Y. Suzuki) from 7th to 18th December 2009 to discuss applications of HINT2 code to Wendelstein stellarators.
 - 47) F. Wagner(IPP, Germany) attended 19th International Toki Conference in 8th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and chaired a session in the conference.
 - 48) G. Conway (IPP Garching, Germany) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Interaction of mean and oscillating plasma flows across confinement mode transitions" as an invited speaker.
 - 49) M. Otte (IPP Greifswald, Germany) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Electron Bernstein Waves at the WEGA Stellarator Heating and Emission" as an invited speaker. He also joined LHD experiments for the magnetic surface visualization for one week.
 - 50) Y. Liang (Forschungszentrum Jülich, Germany) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "ELM control by low n magnetic perturbations on JET" as an oral speaker.
 - 51) A.Sagara and T. Goto (NIFS) visited Max-Planck Institut fur Plasmaphysik (Garching, Germany) to attend 5th Workshop on BA-DEMO Design in IFERC Activities and discuss about the role of and requirement for a DEMO reactor.
 - 52) A.Kus (Max-Planck Institut fur Plasmaphysik, Greifswald, Germany) visited NIFS to discuss and establish the directory structure for easy future extension of the International Stellarator/Heliotron Profile Data Base.
 - 53) C.Hidalgo (CIEMAT, Spain, and also the chairperson of the EPS Plasma Physics Division) visited NIFS and the Institute of Advanced Energy, Kyoto University, to discuss the strategy to enhance the mutual-interrelationships between EPS and Japanese Societies (The Japan Society of Plasma Science and Nuclear Fusion Research (JSPF) and the Japanese Physical Society (JPS)). He also emphasized to enhance the international collaboration activity on magnetic

fluctuation measurement and its impact on the L-H transition, such as by extending the Pilot Program in the EFDA EU Transport Topical Group, "Long-range correlations and edge transport barrier physics".

- 54) David Tskhakaya (University Innsbruck Austria) visited NIFS (Y. Tomita) from 28th November to 6th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research and discussion on the modelling of the boundary plasma by 3D PIC simulation. During his stay he attended the 26th Annual Meeting of the Japan Society of Plasma and Fusion at Kyoto and gave the invited talk entitled 'Kinetic modelling of the plasma edge on High Performance Computers.
- 55) M.Osakabe (NIFS) visited the National Palace of Culture (Sofia, Bourgalia) to attend the 36th European Physics Society held from 29th June 2009 to 3rd July 2009, and made a presentation titled as "Fast-ion studies near neo-classically optimized configurations of LHD ". Topics on energetic particle physics were discussed with other participants.
- 56) Gianluigi Serianni (Istituto Gas Ionizzati del CNR, Padova, Italy) visited NIFS (K.Tsumori and Y. Takeiri) from 2nd September 2009 to 11st September 2009 to study the negative-ion production and optimization of the beam optics in negative-ion sources. They have analyzed the optics of the NIFS negative-ion sources, numerically. The results are discussed and compared with the experimental results at LHD.
- 57) Vanni Antoni (Istituto Gas Ionizzati del CNR, Padova, Italy) visited NIFS (K.Tsumori and Y. Takeiri) from 2nd September 2009 to 8th September 2009 to study the negative-ion production and optimization of the beam optics in negative-ion sources. They have analyzed the optics of the NIFS negative-ion sources, numerically. The results are discussed and compared with the experimental results at LHD.
- 58) Piero Agostinetti and Mauro Palma (Istituto Gas Ionizzati del CNR, Padova, Italy) visited NIFS (K.Tsumori and Y. Takeiri) from 14th September 2009 to 18th September 2009 and from 22nd November 2009 and to 5th December 2009 to study the optimization of negative-ion beam extraction in the ion-sources for neutral beam injectors and to design the thermal components of them. The numerical modeling of their beam transport are discussed. Implementation of actual acceleration grids geometry of negative-ion sources of LHD-NBI in their codes are examined.
- 59) Andres Molina De Bustos (CIEMAT, Spain) visited NIFS (M. Osakabe and Y. Takeiri) from 5th to 19th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the application of the kinetic simulation of heating and collisional transport to the interaction between the fast ions and the Alfvén eigenmode in LHD.
- 60) Jose Maria Fontdecaba (CIEMAT, Spain) visited NIFS (M. Osakabe and Y. Takeiri) from 5th to 22nd December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the evaluation of Fast-ion confinement by Fast Ion Charge exchange Spectroscopy(FICXS) in LHD and its application to TJ-II.

- Collaborations with US

- 1) H. Nakanishi (NIFS) visited Massachusetts Institute of Technology (MIT, USA) from 22nd February 2009 to 7th March 2009 to collaborate with J. Stillerman on fundamental grid design for constructing "virtual laboratory" on fusion experiments. Some acceleration schemes for long-distance tcp communications were tested between MIT and NIFS.
- 2) T. Tokuzawa (NIFS) visited the plasma diagnostic group of UCLA (Los Angeles) from 1st to 15th Mar. to discuss about the recent development results of microwave reflectometers, especially Doppler reflectometer, in DIII-D and LHD.
- 3) S. Kubo(NIFS) visited Princeton Plasma Physics Laboratory from October 12 to October 15 to attend the 17th International Stellarator/Heliotron Workshop. Here the poster entitled "Collective Thomson Scattering of 77 GHz High Power ECRH Beam in LHD" is presented and discussed the preliminary data from collective Thomson scattering in LHD.
- 4) A.Nishimura participated in International Cryogenic Materials Conference (ICMC2009) held in Tucson, AR, USA, from June 28 to July 2. He presented the scientific papers entitled "14 MeV Neutron Irradiation Effect on Critical Current and Critical Magnetic Field of Nb₃Sn and Nb₃Al Wires" and "Fission Neutron Irradiation Effect on interlaminar Shear Strength of Cyanate Ester Resin GFRP at RT and 77 K." Both papers included the world-first data and there were big discussions on these issues.
- 5) Y. Tomita (NIFS) visited UCLA, Berkeley and attended the Japan- U.S. Workshop on Heat Removal and Plasma Material Interactions for Fusion, Fusion High Power Density Components and Systems from 20th to 25th July 2009 and gave the presentation entitled 'Analysis of carbon deposition on the first wall of LHD by Monte Carlo simulation.'
- 6) Michael Shapiro (Massachusetts Institute of Technology, USA) visited NIFS (T. Shimozuma) from 13th September to 15th September 2009 for the research and discussion on a new method of improving transmission efficiency in the high power and CW ECRH transmission lines.
- 7) N. Yanagi (NIFS) visited Plasma Science Fusion Center (PSFC) at Massachusetts Institute of Technology (MIT) from October 7 to 9 for a collaborative study with Dr. Joseph Minervini, Dr. Makoto Takayasu and Dr. Leslie Bromberg on the development of large-current capacity high-temperature superconductors (HTS) for fusion magnets. After this visit, he attend 17th International Stellarator/Heliotron Workshop held at Plasma Physics Laboratory (PPPL) from October 12 to 16.
- 8) J. Stillerman (MIT, USA) visited NIFS (H. Nakanishi) from 10th October 2009 to 31st October 2009 under the support of the JSPS Invitation Fellowship for Research in Japan to collaborate on the statistical algorithm development for data access optimization in fusion experiments. Discussions about advanced data acquisition and storage system were also made.
- 9) H. Sugama (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) from

Oct.11, 2009 to Oct.22, 2009 to give an oral presentation entitled "Enhancement of Residual Zonal Flows in Helical Systems with Equilibrium Radial Electric Fields" in the 17th International Stellarator/Heliotron Workshop 2009 and International Collaboration on Stellarator Theory Meeting (ICST).

- 10) S. Ohdachi (NIFS) visited Princeton Plasma Physics Laboratory (Princeton, USA) from 11th to 18th Oct for attending 17th International Stellarator/Heliotron workshop.
- 11) N. Tamura (NIFS) visited Princeton Plasma Physics Laboratory, US from Oct. 11th to Oct. 18th, 2009 to join the 17th International Stellarator/Heliotron Workshop. He has given an invited talk entitled "Characteristics of nonlocally-coupled transition of the heat transport in LHD".
- 12) M. Sato attended "17th International Stellarator/Heliotron Workshop" held at Princeton Plasma Physics Laboratory (Princeton, USA) from 12th October to 16th October 2009 and made a poster presentation titled as "Simulation study of MHD stability beta limit in LHD by TASK3D".
- 13) Shin Nishimura attended the International Collaboration on Stellarator Theory (ICST) meeting (19-20 Oct.2009, at Princeton Plasma Physics Laboratory, Princeton,NJ,USA) for discussions on the neoclassical transport in heliotron/stellarator devices.
- 14) D. Kato visited Plasma Science and Fusion Center in Massachusetts Institute of Technology (host: B. Lipschultz) in USA from 8th November until 12th November 2009 to discuss about interaction between plasma and high-Z material towards steady state operation.
- 15) T.-H. Watanabe (NIFS) visited Hyatt Regency Atlanta, GA (USA) for discussion with Prof. W. Horton (IFS) about collaboration researches on the occasion of the 51st Annual Meeting of the Division of Plasma Physics (APS).
- 16) T. Goto (NIFS) visited University of California, San Diego (Prof. F. Najmabadi) from Dec. 1st, 2009 to Jan. 29th 2010 to discuss about the improvement of system design codes for fusion power plant within the framework of personal exchange program on Japan-US Cooperation in Fusion Research and Development.
- 17) Andres Molina De Bustos (CIEMAT, Spain) visited NIFS (M. Osakabe and Y. Takeiri) from 5th to 19th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the application of the kinetic simulation of heating and collisional transport to the interaction between the fast ions and the Alfvén eigenmode in LHD.
- 18) Jose Maria Fontdecaba (CIEMAT, Spain) visited NIFS (M. Osakabe and Y. Takeiri) from 5th to 22nd December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the evaluation of Fast-ion confinement by Fast Ion Charge exchange Spectroscopy(FICXS) in LHD and its application to TJ-II.
- 19) A.H. Reiman (PPPL) visited NIFS from December 7 to 11 to discuss the

benchmarking 3D MHD equilibrium calculation codes, HINT2 and PIES.

- 20) P.H. Diamond (UCSD, USA) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a plenary talk entitled "Wave Momentum, Potential Vorticity Mixing, Symmetry Breaking and The Physics Self-Accelerating Plasma Flows". He also chaired a session in the conference.
- 21) R. More (Lawrence Berkeley National Laboratory, USA) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Emission of Light by Hot Dense Matter" as an invited speaker.
- 22) G. Morales (UCLA, Germany) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Exponential Frequency Spectra Lorentzian Pulses and Intermittent Transport in Pressure Gradients" as an oral speaker. He also chaired a session in the conference.
- 23) Douglass S. Darrow (PPPL, USA) visited NIFS (M.Isobe) from December 12 to 22, 2009 for a collaborative work on development of lost-fast-ion diagnostic and effects of fast-particle-driven MHD instabilities on fast-ion transport in magnetically confined fusion plasmas.
- 24) N.Ashikawa (NIFS) visited UC San Diego from December 12th to December 17th to attend 13th ITPA meeting on SOL/divertor physics, and presented about "Dust injection experiment in LHD" and done a session leader for "Dust R&D working plan" as ITER IO urgent tasks. A new NIFS (N.Ashikawa) /PPPL (C.Skinner) collaboration work about dust detector was discussed during this meeting.
- 25) J. Harris(ORNL) visited NIFS for discussing 2D imaging diagnostics developed by S. Ohdachi. They keep collaboration aiming at installing it on DIII-D tokamak.
- 26) S.Usami(NIFS) attended US - Japan Workshop on Reconnection held at University of Wisconsin (USA). He presented the simulation studies on magnetic reconnection with multi-hierarchy model and discuss on the magnetic reconnection and simulation method.

- Collaborations with Russia

- 1) Sharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from May. 5th, 2009 to Feb. 28th, 2010 as a postgraduate of the Graduate University for Advanced Studies to study the spatial structure of pellet ablation cloud by measuring a Stark broadening with a spatial resolution on LHD.
- 2) A.Nishimura participated in International Cryogenic Materials Conference (ICMC2009) held in Tucson, AR, USA, from June 28 to July 2. He presented the scientific papers entitled "14 MeV Neutron Irradiation Effect on Critical Current and Critical Magnetic Field of Nb₃Sn and Nb₃Al Wires" and "Fission Neutron Irradiation Effect on interlaminar Shear Strength of Cyanate Ester Resin GFRP at RT and 77 K." Both papers included the world-first data and there were big discussions on

these issues.

- 3) N. Tamura (NIFS) visited St. Petersburg Polytechnical University, Russia from Jul. 18th to Jul. 20th, 2009 and Russian Research Center, Kurchatov Institute from Jul. 22nd, 2009 to Jul. 23rd, 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research and discussion on the TESPEL/TECPEL ablation cloud study on LHD. He has given a seminar on "Recent Results from the Large Helical Device by a Tracer-Encapsulated Solid Pellet injection" at both university and institute.
- 4) Leonid N. Vyacheslavov (Budker Institute of Nuclear Physics, Russia) visited NIFS from 30th August 2009 to 15th October 2009 and joined the developments of CO₂ laser interferometer and phase contrast imaging for density and density fluctuation measurements on LHD.
- 5) G. Kawamura (NIFS) attended 12th International Workshop on Plasma Edge Theory in Fusion Devices (PET12) at Rostov Veliky Russia from 31 Aug. to 7 Sep. 2009. Impurity redeposition simulation in LHD and divertor plasma modeling were discussed.
- 6) Y. Tomita (NIFS) visited Rostov Veliky (Russia) and attended the 12th International Workshop on Plasma Edge Theory in Fusion Devices (PET12) from from 31 August to 7 September 2009 and gave the presentation entitled 'Acceleration and Redeposition of a Dust Particle in SOL/Divertor Plasma of HL-2A tokamak.
- 7) G. Kawamura (NIFS) visited Forschungszentrum Juelich GmbH (Juelich Germany) from 4 to 18 Oct. 2009 for collaboration on impurity transport and redeposition in LHD. Development of Monte Carlo code "ERO" for LHD and future collaboration on simulation of Plasma-Surface-Interaction were discussed.
- 8) M. Nunami(NIFS) attended "21st International Conference on Numerical Simulation of Plasmas 2009" held at Lisbon, Portugal from 6th to 9th, October 2009 to give a poster presentation on "A multi-scale electromagnetic particle code with adaptive mesh refinement and its parallelization" and to discuss about developments of new plasma particle simulation methods.
- 9) Soren Korsholm (RISO National Laboratory) attended nternational Workshop on Fusion Product diagnostics for burning plasma experiments (IWFP-2009) at Chita, Aichi, from 19th October 2009 to 20th October 2009, and visited NIFS to join experiments of collective Thomson scattering on LHD from 21th October 2009 to 31th October 2009.
- 10) A.Ulantsev (Gubkin Russian State University of Oil and Gas, Russia) visited NIFS (I. Murakami and D. Kato) from Nov. 2 to Dec. 2, 2009 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 proton-impact excitation cross sections for Fe XX which are necessary for a kinetic model of plasma spectroscopy.
- 11) Ferrnando Meo (RISO National Laboratory) visited NIFS from 3rd Novemeber 2009 to 21th November 2009 and joined experiments of collective Thomson

scattering to measured ion distribution function on LHD.

- 12) I.Miroshnikov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from Nov. 29th, 2009 to Dec. 22nd, 2009 to study the spatial structure of pellet ablation cloud by measuring a Stark broadening with a spatial resolution on LHD.
- 13) P. Goncharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from Dec. 6th to Dec. 13th, 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research and discussion on the studies of fast particle and impurity transport on LHD.
- 14) Dr. Shevelko (P.N.Lebedev Physical Institute) visited NIFS from Nov. 12 to Dec. 26 and the atomic physics is studied related to the charge changing reaction to produce the high intensity heavy ion beam for HIBP in LHD. He also studied the beam-plasma interactions in high density and high temperature plasmas for LHD HIBP experiments.
- 15) A.V. Melnikov (Kurchatov Institute) visited NIFS from 12th to 19th December under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and discussed Zonal flow, L-H transition, Alfvén eigenmode, and HIBP system.

- Collaborations with Ukraine

- 1) K. Toi, M. Isobe, M. Osakabe, and Y. Todo (NIFS) visited Kiev, Ukraine from September 21 through 25, 2009 to attend the 11th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems and the 3rd ITPA Topical Physics Group Meeting on Energetic Particles. M.Osakabe gave an invited talk on "Clump and hole formation in the energetic particle spectra by the toroidicity induced Alfvén eigenmodes and their behaviors during the mode activities". K. Toi, M. Isobe, and Y. Todo gave total five oral presentations.
- 2) M.Osakabe (NIFS) visited the Kiev (Ukraine) to attend the 11th IAEA technical meeting (TM) on energetic particles held from 21st September 2009 to 23rd September 2009, and the 3rd ITPA-meeting on energetic particles. He made a presentation titled as " Clump and hole formation in the energetic particle spectra by toroidicity induced Alfvén Eigenmodes and their behavior during the mode activities " at the IAEA-TM. Topics on energetic particle physics were discussed with other participants.
- 3) V. Mykhaylenko (Kharkov National University, Ukraine) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Turbulence evolution in plasma shear flows" as an oral speaker.
- 4) V. Maslov(Kharkov National University, Ukraine) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave poster presentations on the relation between sheared flow and plasma confinement.

- Multi-lateral collaboration

- 1) 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. The two meetings were programmatically held in 2009, at Stuttgart University in July 6-8 (5th CWGM), and at the Princeton Plasma Physics Laboratory in October 16 (6th CWGM) just after the 17th International Stellarator/Heliotron Workshop (ISHW). The former (latter) one is mainly devoted to discuss and decide the joint papers for the 17th ISHW (the EPS and IAEA-FEC in 2010), respectively.
- 2) T. Ido(NIFS) attended Joint EU-US Transport Task Force meeting from 27th April to 3rd May 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and reported observations of Alfvén eigenmode and Geodesic acoustic mode in LHD.
- 3) “US-EU-Japan workshop on RF Heating Technology” was held at Kyushu National Museum, Dazaifu, Japan from 16th to 18th September 2009. About 36 attendants including 7 from US, 6 from EU discussed on the subjects such as the development of megawatt gyrotrons, high power millimeter-wave components and recent experimental results related with RF heating. Future R&D and collaborations among US, EU and Japan in the RF heating technology were also determined.
- 4) H.Yamada, T.Akiyama, K.Tanaka, H.Funaba, Y.Suzuki, Y.Narushima, S.Sakakibara, S.Ohdachi, M.Yokoyama (NIFS), and S.Yamamoto (Kyoto U.) attended the 5th CWGM. T.Mizuuchi, K.Nagasaki, S.Kobayashi (Kyoto Univ.) attended via the video-conference. The “H mode & ELMs” and “Turbulence Studies (experiment)” sessions were successfully kicked-off with a large potential for world-wide collaborations/outreach to tokamak community. The 7 joint papers were presented at the 17th ISHW based on extensive discussion at 5th CWGM. K.Ida, K.Toi, Y.Narushima, H.Funaba, M.Yokoyama (NIFS), and K.Nagasaki, H.Okada, T.Mizuuchi, A.Matsuyama (Kyoto Univ.) attended the 6th CWGM just after the ISHW17, and elucidated the issues for further collaboration issues with the emphasis on specifying the joint papers to be presented at the major international conferences in 2010, such as the EPS and IAEA-FEC. The introductory paper on the evolution and the progressing activity was published in the Stellarator News in October 2009 to attract more researchers to CWGM activity (M.Yokoyama is the author on behalf of all the collaborators).

4.2 International collaborations by the Heliotron J team at Kyoto University

- Collaborations with Australia

- 1) B. Blackwell (ANU) visited Kyoto Univ. for three month on December 16, 2008 – March 31, 2009 as a guest professor to participate in the Heliotron J experiment. Collaboration of the MHD analysis by using SVD method and tomography technique, ECH system and data acquisition was performed.
- 2) Discussions with H-1NF team (ANU) were kept along the same line as in 2008.

- Collaborations with EU

- 1) D. Pretty (CIEMAT, Spain) visited Kyoto Univ. for two days on January 8 – January 9. Collaboration of MHD database for improved confinement in advanced stellarator/heliotron devices was performed.
- 2) T. Minami visited CIEMAT on March 15 – March 22 to discuss the collaboration plans of improved confinement modes in advanced stellarator/heliotron devices and diagnostics for realizing the detailed profile database in those devices.
- 3) S. Yamamoto visited CIEMAT on March 15 - March 22 to discuss and participate 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) Two persons from Heliotron Team (A. Matsuyama and K. Hanatani) participated in the 36th EPS Conference on Plasma Physics (June 29 - July 3, 2009, Sofia, Bulgaria) and discussed studies of neoclassical diffusion and viscosity coefficients for stellarator/heliotron devices by the Green-Kubo approach.
- 5) S. Yamamoto participated in the 5th CWGM (Stuttgart Univ., 6-8 Jul. 2009) and discussed activities of MHD and high- β study in stellarators/heliotrons. T. Mizuuchi and K. Nagasaki also participated in this meeting via a TV-conference system from Kyoto Univ. and discussed the H-mode in stellarators/heliotrons.
- 6) H. Laqua (IPP, Germany) visited Kyoto Univ. on October 26 to discuss the collaborations on RF heating/current-drive in stellarator/heliotron devices.
- 7) C. Hidalgo (CIEMAT) visited Kyoto Univ. on December 1 to discuss the research collaborations between Heliotron J and TJ-II.
- 8) S. Benkadda (Univ. de Provence, France) has been invited to Institute of Advanced Energy (IAE), Kyoto Univ. as a guest professor for three months (Dec. 1, 2009 - Feb. 28, 2010). He participates theoretical collaboration program on turbulence and transport in fusion plasma. He also has several lectures on turbulence and transport in magnetized plasma in IAE.
- 9) Discussions with W7 team (IPP) were kept along the same line as in 2008.
- 10) Collaborations with CIEMAT were continued along the same lines as in 2008.

- Collaborations with US

- 1) Six persons from Heliotron Team (T. Mizuuchi, K. Nagasaki, H. Okada, S. Kobayashi, A. Matsuyama and K. Mukai) participated in the 17th ISHW (October 11- October 18, PPPL, U.S.A.). They presented recent experiments in Heliotron J and discussed the research collaboration program with other stellarator/heliotron teams in the world.
- 2) A. Matsuyama participated in International Collaboration on Stellarator Theory Meeting (19-20 Oct., 2009, PPPL, U.S.A.) and presented his recent study.

- 3) 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 2008.

- Collaborations with Ukraine

- 1) The effects of resonance perturbation field in the edge region have been studied through the collaboration with I. Pankratov (Kharkov, Ukraine) who visited Kyoto Univ. as a guest professor for three month (December 26, 2008 -March 31, 2009) and participated in the electrode-biasing experiment in Heliotron J.
- 2) Discussions with Kharkov team were kept along the same line as in 2008 and also started the discussion about the collaboration in U-2M project.

- Collaborations with Russia

- 1) V. Zhuravlev (Kurchatov, Russia) visited Kyoto Univ. on May 29 – June 30, 2009. Collaboration of the microwave AM reflectometer for electron density measurement was performed.
- 2) A. Melnikov (Kurchatov, Russia) visited Kyoto Univ. on Dec. 21, 2009. Possibility of collaborative studies of HIBP diagnostics was discussed.

- Others

- 1) Heliotron team has participated in CWGM (Coordinated Working Group Meeting) activity.
- 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) The details of the bulk confinement properties have been 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 discussed with TJ-II team.

4.3 Plans for 2010

- 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) PSI control by Li-coating, etc. In Heliotron J is under discussion. D.Tafalla and F. Tabares (CIEMAT) are to visit 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.
- 8) MHD activity control in higher beta plasmas through the field configuration optimization will be tested in Heliotron J.
- 9) M. Mikhailov (Kurchatov, Russia) will visit Kyoto Univ. to participate in optimization study of advanced helical configurations.
- 10) S. Yamamoto is to visit CIEMAT on March 4 - March 13, 2009 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.

5 RUSSIA

5.1 International collaborations in 2009

- Collaborations with IPP (Germany)

- 1) T. Richert (IPP Greifswald) visited the Budker Institute of Nuclear Physics, Novosibirsk, 10.05. – 15.05.2009: manufacturing control DNBI, acceptance power supplies
- 2) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 22.04. – 20.06.2009 and 27.09. – 25.11.2009: Collaboration on stellarator optimization
- 3) T. Richert (IPP Greifswald) visited the Budker Institute of Nuclear Physics,

Novosibirsk, 12.07. - 17.07.2009: high voltage power supply meeting, control system discussions

- 4) F. Chernychev, A. Melnik (Ioffe Institute, St. Petersburg) to IPP Greifswald, 03.09. – 17.09.2009: collaboration in the field of neutral particle
- 5) Maxim Isaev (Kurchatov Institute Moscow) to IPP Greifswald, 25.10. – 15.11.2009: Benchmarking of momentum corrections

- Collaborations with CIEMAT (Spain)

- 1) K. Sarkisyan and the ECRH IOFAN team participated in the operation of the ECRH system of TJ-II during the 2009 experimental campaign.
- 2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory, visited at CIEMAT in March 2009 (2 weeks) and November 2009 (one month) to maintain and improve the gyrotrons power measurement system.
- 3) M. Tereshchenko (IOFAN (at present at BIFI/ Zaragoza University)) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA and EBW current drive studies (November / December 2009).
- 4) S. Petrov (IOFFE) (June 2009) visited CIEMAT to participate on charge exchange spectrometry measurements.
- 5) N. Kharchev (IOFAN) visited Ciemat in September 2009 to discuss possible designs of a diagnostic based on scattering signals from the ECH RF power in TJ-II.
- 6) A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team were visiting CIEMAT to investigate the structure of plasma potential in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements with two slit HIBP detector. The second HIBP system has been design for long-range (zoanl flows) correlation studies and the analyzer construction is foreseen during 2010.

- Collaborations with NIFS (Japan)

- 1) Sharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from May. 5th, 2009 to Feb. 28th, 2010 as a postgraduate of the Graduate University for Advanced Studies to study the spatial structure of pellet ablation cloud by measuring a Stark broadening with a spatial resolution on LHD.
- 2) A.Nishimura participated in International Cryogenic Materials Conference (ICMC2009) held in Tucson, AR, USA, from June 28 to July 2. He presented the scientific papers entitled “14 MeV Neutron Irradiation Effect on Critical Current and Critical Magnetic Field of Nb₃Sn and Nb₃Al Wires” and “Fission Neutron Irradiation Effect on nterlaminar Shear Strength of Cyanate Ester Resin GFRP at RT and 77 K.” Both papers included the world-first data and there were big discussions on these issues.
- 3) N. Tamura (NIFS) visited St. Petersburg Polytechnical University, Russia from Jul. 18th to Jul. 20th, 2009 and Russian Research Center, Kurchatov Institute from Jul.

22nd, 2009 to Jul. 23rd, 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research and discussion on the TESPEL/TECPEL ablation cloud study on LHD. He has given a seminar on "Recent Results from the Large Helical Device by a Tracer-Encapsulated Solid Pellet injection" at both university and institute.

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structure of pellet ablation cloud by measuring a Stark broadening with a spatial resolution on LHD.

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- 15) A.V. Melnikov (Kurchatov Institute) visited NIFS from 12th to 19th December under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and discussed Zonal flow, L-H transition, Alfvén eigenmode, and HIBP system.

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

- 1) V. Zhuravlev (Kurchatov, Russia) visited Kyoto Univ. on May 29 – June 30, 2009. Collaboration of the microwave AM reflectometer for electron density measurement was performed.
- 2) A. Melnikov (Kurchatov, Russia) visited Kyoto Univ. on Dec. 21, 2009. Possibility of collaborative studies of HIBP diagnostics was discussed.

- **Collaboration with Ukraine**

(Dr. L.I.Krupnik and HIBP team (IPP NSC KIPT in collaboration with Dr. A.V.Melnikov and T-10 team (Kurchatov Institute), and with Dr..S.V. Lebedev and TUMAN-3M team (Ioffe Institute).

- 1) Installation of the special focusing system and increasing of the emitter life time; increase of the primary Tl^+ ion beam intensity up to $150 \mu A$.
- 2) Increase of the primary beam energy up to 300 keV, that enables the deeper plasma to reach.
- 3) Investigations of the plasma potential behavior with high plasma density.
- 4) Improvement of the Heavy Ion Beam Probe facility and the measurement procedure on Tuman-3M.
 - installation of the 2slit detector units in the HIBP analyzer. Entrance slits and 8-detector plates were installed exactly with trajectory calculations;
 - some trends application for friendly signal/spurious noise suppression.
- 5) Investigation of the electric field evolution in various operational modes in the

TUMAN-3M tokamak

5.2 Plans for 2010

- Collaboration with CIEMAT

- 1) K. Sarksyian and the ECRH IOFAN 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 will visit CIEMAT to further develop the gyrotrons power measurement system.
- 3) M. Tereshchenko (at present at BIFI/ Zaragoza University) will stay in CIEMAT to collaborate in further improvement of TRUBA and the development of a Fokker-Planck operator for FAFNER NBI code.
- 4) S. Petrov (IOFFE) will participate in the development / measurements with ACORD-24 charge exchange spectrometer in TJ-II.
- 5) A. Melnikov, L. Eliseev, and HIBP team (Kurchatov Institute) will visit CIEMAT to participate in the characterization of radial electric fields in the TJ-II stellarator (comparative studies with B and Li coated walls and comparative studies with T-10 tokamak).

6 UKRAINE

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

6.1.1 International collaborations of the NSC KIPT in 2009

6.1.1.1 International collaborations of the plasma theory division

- Collaboration with Technische universität Graz, Austria

- 1) Calculation of the magnetic surface function gradient and associated quantities in stellarators with broken stellarator symmetry (V.V.Nemov and S.V.Kasilov in collaboration with W.Kernbichler and B.Seiwald (Technische universität Graz, Austria)).
- 2) Fully relativistic code SYNCH (IPP Kharkov, ITP TU-Graz) for computations of the generalized Spitzer function in the long mean free path regime has been extended for general toroidal geometry with permits its use for stellarators. For calculations of the electron cyclotron current drive in tokamaks and stellarators, SYNCH has been coupled with ray tracing code TRAVIS (IPP Greifswald). This work has been performed in cooperation with W.Kernbichler (Institute of Theoretical and Computational Physics of Graz Technical University, Austria) and N.B.Marushchenko (Max-Planck-Institute of Plasma Physics at Greifswald, Germany).

- 3) Kinetic equation solver NEO-2 (IPP Kharkov, ITP TU-Graz) with solves the drift kinetic equation in arbitrary collisionality regime and general toroidal geometry has been applied for the computations of generalized Spitzer function in a tokamak with intermediate collisionality regime. New features of this function have been revealed which are of special importance for ECCD in stellarators. This work has been performed in cooperation with W.Kernbichler and G.O.Leitold (Institute of Theoretical and Computational Physics of Graz Technical University, Austria), and N.B.Marushchenko (Max-Planck-Institute of Plasma Physics at Greifswald, Germany).

6.1.1..1 International collaborations of the plasma experiment divisions

- Collaboration with CIEMAT, Madrid, Spain

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

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on TJ-II.
 - installation and tuning of the new emitter-extraction system in the HIBP injector on the TJ-II device.
 - development and installation of the system for separate probing beam focusing.
 - improvement of the primary beam focusing and increase of the secondary signal.
- 2) Providing of the experiments with the upgraded injector of the TJ-II Stellarator. Experiments were performed according to program of the potential profile evolution with two sleet energy analyzer. (two NBI1 and NBI2 injectors and Bershtain wave heating were used).
- 3) Development of the Second Heavy Ion Beam Probe diagnostic system for TJ-II. Calculations probe beam trajectories and optimisation of the installation conditions for the second HIBP line. Detailed drawing and integration of components of the primary beam injector for second HIBP. Manufacturing and testing Injector of the probing beam for the second HIBP. Shipping the second injector to CIEMAT.

- Collaboration with Germany (IPP, Greifswald)

(Dr. L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. M. Otte, Yu. Podopa and WEGA team)

- 1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on WEGA. To implement the corrections into calculations we need more information about the real beam position in WEGA. To provide this information the detector array was installed in the HIBP cross section for the primary beam position measurements.
- 2) The plasma potential and total secondary current (plasma density) profiles measurement results are measured in a comparison with Langmuir probes data.

Results of HIBP measurements agree with data from Langmuir probes.

- Collaboration with Germany (FZ-Juelich)

Together with Dr. A.Litnovsky (FZ-Juelich) the analysis was provided of the results obtained in experiments on more than 10 different fusion devices, including the largest LHD, as for the behaviour of mirrors with ITER-candidate mirror materials directed on solution of the first mirror problem. The joint paper was published in Plasma Devices and Operations, Vol. 17, No. 4, 2009, 309.

- Collaboration with Kurchatov Institute, Moscow, Russia

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

- 1) Installation of the special focusing system and increasing of the emitter life time; increase of the primary Tl^+ ion beam intensity up to 150 μA .
- 2) Increase of the primary beam energy up to 300 keV, that enables the deeper plasma to reach.
- 3) Investigations of the plasma potential behavior with high plasma density.

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

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

- 1) Improvement of the Heavy Ion Beam Probe facility and the measurement procedure on Tuman-3M.
 - installation of the 2slit detector units in the HIBP analyzer. Entrance slits and 8-detector plates were installed exactly with trajectory calculations;
 - some trends application for friendly signal/spurious noise suppression.
- 2) Investigation of the electric field evolution in various operational modes 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, and O. Motojima was finished and prepared for submission to Journal.
- 2) The manuscript "Impact of $N_2 + H_2$ mixture on carbon-containing film" by V. S. Voitsenya, S. Masuzaki, O. Motojima, and A. Sagara was modified and prepared for publication in 2010 as NIFS Report.

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

During the period January through March of 2009 Dr. I.M. Pankratov was Visiting

Professor of Institute of Advanced Energy. His activities included seminars and lectures at IAE, attendance at NIFS Workshop and collaborative experimental research in Heliotron J. The investigation of 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 is started in collaboration with Tohoku University (Dr. I.M. Pankratov, Prof. T. Mizuuchi, Prof. S. Kitajima). The more detail experiments are planed. These investigations are important for LHD (local island divertor regime) and W-7X (magnetic island divertor) devices.

- Collaborations with Sweden (Uppsala University)

V.E. Moiseenko visited Uppsala University, Uppsala, Sweden in July-August and in December to investigate theoretically fission - fusion systems, in particular based on the stellarator-mirror hybrid.

- Collaborations with Germany (Research Center, Juelich)

25-26.02.09 V.E. Moiseenko visited Research centrum Juelich, Juelich, Germany, on 27.02.09 and discussed RF plasma production and heating and RF wall conditioning in stellarator Uragan-2M. The visit was performed in frame of STCU grant 4216.

- Collaborations with Belgium (Royal Military Academy, Brussels)

27.02.09 V.E. Moiseenko visited Royal Military Academy, Brussels, Belgium, to discuss RF heating and RF wall conditioning in stellarator Uragan-2M and to give a talk on this topic. The visit was performed in frame of STCU grant 4216.

- Conference participation

- 1) V.E. Moiseenko participated in Third IAEA TM on First Generation of Fusion Power Plant: Design and Technology, 13 - 15 July 2009, Vienna, Austria.
- 2) V.E. Moiseenko participated in Fusion-Fission Research Workshop, 30 September - 2 October 2009, Gaithersburg, Maryland USA.
- 3) Dr. I.M. Pankratov gave invited talk "Studies of RF discharge plasma behavior in the Uragan-3M and Uragan-2M torsatrons" at the 17th International Stellarator /Heliotron Workshop at Princeton, USA.

6.1.2 Plans for 2010 of the IPP NSC KIPT

6.1.2..1 Plans for 2010 of the plasma theory division

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

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 Spain (CIEMAT, Madrid)**

- 1) To develop the way of fully relativistic plasma dielectric tensor evaluation for arbitrary value of the parameter $(k_{\perp} \rho_e)^2$.
- 2) To use this method for investigations of the EBW plasma heating regimes in TJ-II stellarator and other magnetic traps.

6.1.2..2 Plans for 2010 of the plasma experiment divisions

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

- 1) Investigations evolution of the plasma potential, electron density and their fluctuations in combined ECR and NBI and **Bernstein** wave modes heating regimes.
- 2) Installation of the second Heavy Ion Beam Probing diagnostic complex on TJ-II stellarator.

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

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

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

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

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

IPP NSC "KIPT" and IAE of Kyoto University are planning further collaborative research:

- 1) Series of Heliotron J biasing experiments with plasma parameter profiles measurements and detail interpretation for the investigation of the edge magnetic island plasma behavior for the field topology of the STD configuration at low magnetic field will be carried out;
- 2) Moveable magnetic probe measurements near the edge resonant magnetic surface $\iota(r_{res})/2\pi = 4/7$ with detail interpretation also are planned.

- Collaborations with Sweden (Uppsala University)

V.E. Moiseenko plans to visit Uppsala University, Uppsala, Sweden to continue theoretical investigations on fission - fusion systems, in particular based on the stellarator-mirror hybrid.

- Collaborations with Germany (IPP, Greifswald)

V.E. Moiseenko plans to visit IPP-Greifswald, Greifswald, Germany, to discuss fission - fusion systems, in particular based on the stellarator-mirror hybrid.

- Collaborations with Belgium (Royal Military Academy, Brussels)

27.02.09 V.E. Moiseenko plans to visit Royal Military Academy, Brussels, Belgium, to discuss RF heating collaboration within Wendelstein-7X program. The visit will be performed in frame of STCU grant 4216.

- The tasks to be solved at IPP NSC KIPT

- 1) Preparation of the review paper with description of application of the technique and manual operation of the existing beam probing diagnostics;
- 2) Finishing of the PhD thesis by A. Zhezhera;
- 3) Calibration of the secondary beam analyzer for the torsatron Uragan-2M;
- 4) Integration of the U-2M HIBP units on special test device;
- 5) Manufacturing and investigation of the neutralizer with supersonic stream for Li-beam diagnostic;
- 6) Investigation of the Li neutral beam injector up to 100 keV and 10-15 mA.
- 7) Optimisation of regimes of surface cleaning in the Uragan-2M torsatron using different combination of ECR, RF and glow discharges in H₂ or H₂+N₂ mixture will be continued.
- 8) Preparation of all equipment for providing the boronization procedure in the U-2M torsatron will be finished.
- 9) Optimisation of processes of RF plasma production and heating in the Uragan-2M torsatron aiming the increase of plasma parameters will be provided.
- 10) It is planned to design and to test the B₄C limiter during wall conditioning and in operating regimes of the U-2M torsatron.
- 11) At Uragan-2M it is planned to put into operation the 4-strap Faraday-shielded antenna and study Alfvén resonance heating and certain scenarios of ion-cyclotron heating.

- 12) It is planned to use the self-consistent numerical model for RF plasma production to explain Uragan-2M results.
- 13) 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.
- 14) Continuation of investigations of divertor plasma flow characteristics in conditions of transport barriers formation in Uragan-3M.
- 15) Elucidation of the nature of 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?
- 16) A search for RF plasma production and heating regimes with no fast ions in the U-3M torsatron.

6.2 Karazin National University, Kharkov

6.2.1 International collaboration in 2009

6.2.1..1 Collaborations with Institute of Space Research of University of Toronto, Canada

Research into interaction of ions of carbon and deuterium with a surface of tungsten was carried out in collaboration with the group of studying the materials of fusion reactor of Institute of Space Research of University of Toronto, headed by Professor Haas. Application of carbon (C) and tungsten (W) as divertor materials in fusion devices results in exposure of W surface to the particle flux containing fuel and C ions. Physical sputtering is considered as a basic phenomenon responsible for erosion of W surface, but chemical sputtering of C from mixed W-C surface may be a factor increasing the erosion rate. Experimental identification of this phenomenon has been carried out using dual beam accelerator setup. W surface was simultaneously bombarded by 6 keV C ions and D ions with energy in the range of $0.1 \div 0.4$ keV/D. The chemical sputtering was detected initially as release of CD_4 (mass 20) molecules from the surface under ion bombardment. Experimental results show that chemical sputtering of C peaks at RT and decreases below the measurement error at surface temperature of 400 Celsius. The absolute values of chemical sputter yield are estimated by comparison to similar QMS measurements of leak-bottle containing D.

The results of this research were published:

I.A. Bizyukov, J.W. Davis, A.A. Haasz and P. Brodersen. *CD₄ production from mixed W-C-D surface during simultaneous irradiation of W with C+ and D+//* Journal of Nuclear Materials, Volumes 390-391, 15 June 2009, Pages 925-928

6.2.1..2 Collaborations with Max-Planck Institut für Plasmaphysik (MIPP), Germany

A new set of experiments has been carried out at MIPP on test installation in the framework of so-called manipulator experiment (Manipulator eXperiment - MXP). This installation is intended for testing the various composite coatings on radio frequency antenna for plasma heating. The research was carried out by Sandwich PhD student A. Onyshchenko in collaboration with Professor Dr. J.-M. Noterdaeme, Dr. Vi. Bobkov, W. Becker (MIPP)

6.2.1..3 Collaborations with Universite Libre de Bruxelles, Brussels, Belgium

Doctor Oleg Shishkin visited ULB in 2009 to carry out Postdoc research of island divertor with changeable geometry, and also control of impurity ions by means of a changeable electromagnetic field.

The new numerical tool, - 3-D Impurity Transport Code was developed in collaboration with Professor B. Weyssow. This numerical tool gives possibility to study impurity ions transport in different plasma configurations of modern drift optimized stellarators Wendelstein 7-X and HELIAS reactor. In the new version of the code the treatment of plasma configurations with the magnetic islands, which are the part of the divertor islands configuration, is emphasized. The code solves guiding centre equation for the test particle with the use of Runge-Kutta integrating scheme of order four. Coulomb scattering of test particle on the background plasma particles is simulated by means of discretized collision operator based on binomial distribution and presented in terms of pitch angle scattering and energy slowing down and scattering. The coronal model is used to determine the mean charge state of the impurity ion ensemble as a function of background electron temperature and density. The impurity source is simulated by additional routine that generates the impurities in vicinity of the divertor plate in accordance with the intensity parameter.

All known plasma scenarios are characterized by the transition of the background plasma from Maxwellian to non Maxwellian distribution functions. The same impurity transport characteristics should be expected in stellarator plasma of Wendelstein 7-X under the plasma heating application. In order to describe the interactions of test impurities with the background plasma characterized by non Maxwellian distribution function the Impurity Transport Code was developed. By means of the new collision operator the neoclassical transport properties of impurities in JET were studied for the non Maxwellian plasma, which is the result of NBI application.

The results of this activity were reported on the Conference:

O.A. Shyshkin, B Weyssow, Test Particle Simulations for Impurity Transport in Fusion non Maxwellian Plasma// 36th EPS Conference on Plasma Phys. Sofia, Bulgaria, June 29 - July 3, 2009.

This activity was partly supported by the regular STCU project #3685.

6.2.1..4 Plans of Karazin National University for 2010

- 1) We plan to develop our collaboration with Université Libre de Bruxelles, Association EURATOM-Etat Belge pour la Fusion, Physique Statistique et

Plasmas, Bruxelles, Belgique. The plasma physics group at ULB has always been very strong in the development of theories for particle transport (neoclassical and anomalous) and in the analysis of plasma heating scenarios. The future activities will be devoted to impurity transport and its control and transport of fusion products. The heads of this research at ULB are Dr B. Weyssow (EFDA CSU officer for Transport, Heating and Current Drive), Dr. D. Carati (head of research Unit, ULB), and Professor M. Van Schoor (Head of Physics-Department, ERM/KMS).

- 2) Future development and implementation of the results obtained in the framework of the STCU Project # 3685 are associated with collaboration with our colleagues from the INSTITUT DE RECHERCHE SUR LA FUSION PAR CONFINEMENT MAGNETIQUE, F-13108 SAINT IRFM/CEA/Cadarache, PAUL-LEZ-DURANCE, France. A team there has started the modeling activities on both impurity transport and Monte Carlo calculations of the alpha particle distribution, with the aim of integrating such important elements in the global fusion reactor simulator that we have been developing for nearly ten years. The principle investigator from French side will be Dr. G. Giruzzi (Group Leader, CRONOS Project Leader, Tore Supra Programme Coordinator). oposed to apply on the stellarator Wendelstein 7-X.
- 3) Sandwich PhD student I. Misyura (KhNU and MPIPP) will continue to test various composite coatings on radio frequency antenna for plasma heating.

7 UNITED STATES

7.1 International collaboration in 2009

- Collaborations with Germany (IPP Greifswald)

- 1) H. Dreier (IPP Greifswald) visited General Atomics, San Diego, 06.06.–10.06.2009: DIII-D
- 2) A. Reiman (PPPL) to IPP Greifswald, 09.07.–10.07.2009; Nonlinear three-dimensional magnetohydrodynamics
- 3) J. Candy (General Atomics San Diego) to IPP Greifswald, 13.07. – 22.07.2009: Gyrokinetic and neoclassical transport theory
- 4) E. Belli (General Atomic San Diego) to IPP Greifswald, 13.07. – 22.07.2009: Gyrokinetic and neoclassical transport theory
- 5) A. Dinklage (IPP Greifswald) visited PPPL, 08.-09.10.2009
- 6) M. Jakubowski (IPP Greifswald) visited General Atomics, San Diego, 05.10. – 14.11.2009: DIII-D experiments
- 7) O. Grulke (IPP Greifswald/EMAU) visited MIT-PSFC, Cambridge, 01.11. – 20.11.2009: Work on cooperation programme analysis of turbulence imaging

- 8) R. Schneider (IPP Greifswald) to University of California, San Diego, 07.11. – 13.11.2009: Plasma-wall-interaction

- Collaborations with Spain (CIEMAT, Madrid)

- 1) I. Calvo visited ORNL (January-February, 2009) to discuss fractional transport theory.
- 2) P. Ryan and J. Caughman (ORNL) visited CIEMAT in June 2009 to participate in the commissioning of the Electron Bernstein Emission diagnostic and discussion on NBI heating campaign.
- 3) Christopher A. Clark (UW) was visiting CIEMAT (November 2009) to participate on perpendicular impurity transport /laser blow-off experiments.
- 4) F. Tabarés was visiting HSX (UW), participating on plasma-wall (Li coating) experiments.
- 5) Erik Holdmann (USCD) was visiting CIEMAT (May 2009) working on parallel impurity transport studies.
- 6) H. Nakanishi (NIFS) visited Massachusetts Institute of Technology (MIT, USA) from 22nd February 2009 to 7th March 2009 to collaborate with J. Stillerman on fundamental grid design for constructing “virtual laboratory” on fusion experiments. Some acceleration schemes for long-distance tcp communications were tested between MIT and NIFS.

- Collaborations with Japan (NIFS)

- 1) T. Tokuzawa (NIFS) visited the plasma diagnostic group of UCLA (Los Angeles) from 1st to 15th Mar. to discuss about the recent development results of microwave reflectometers, especially Doppler reflectometer, in DIII-D and LHD.
- 2) S. Kubo(NIFS) visited Princeton Plasma Physics Laboratory from October 12 to October 15 to attend the 17th International Stellarator/Heliotron Workshop. Here the poster entitled “Collective Thomson Scattering of 77 GHz High Power ECRH Beam in LHD” is presented and discussed the preliminary data from collective Thomson scattering in LHD.
- 3) A.Nishimura participated in International Cryogenic Materials Conference (ICMC2009) held in Tucson, AR, USA, from June 28 to July 2. He presented the scientific papers entitled “14 MeV Neutron Irradiation Effect on Critical Current and Critical Magnetic Field of Nb₃Sn and Nb₃Al Wires” and “Fission Neutron Irradiation Effect on interlaminar Shear Strength of Cyanate Ester Resin GFRP at RT and 77 K.” Both papers included the world-first data and there were big discussions on these issues.
- 4) Y. Tomita (NIFS) visited UCLA, Berkeley and attended the Japan- U.S. Workshop on Heat Removal and Plasma Material Interactions for Fusion, Fusion High Power Density Components and Systems from 20th to 25th July 2009 and gave the presentation entitled ‘Analysis of carbon deposition on the first wall of LHD by

Monte Carlo simulation.'

- 5) Michael Shapiro (Massachusetts Institute of Technology, USA) visited NIFS (T. Shimozuma) from 13th September to 15th September 2009 for the research and discussion on a new method of improving transmission efficiency in the high power and CW ECRH transmission lines.
- 6) N. Yanagi (NIFS) visited Plasma Science Fusion Center (PSFC) at Massachusetts Institute of Technology (MIT) from October 7 to 9 for a collaborative study with Dr. Joseph Minervini, Dr. Makoto Takayasu and Dr. Leslie Bromberg on the development of large-current capacity high-temperature superconductors (HTS) for fusion magnets. After this visit, he attend 17th International Stellarator/Heliotron Workshop held at Plasma Physics Laboratory (PPPL) from October 12 to 16.
- 7) J. Stillerman (MIT, USA) visited NIFS (H. Nakanishi) from 10th October 2009 to 31st October 2009 under the support of the JSPS Invitation Fellowship for Research in Japan to collaborate on the statistical algorithm development for data access optimization in fusion experiments. Discussions about advanced data acquisition and storage system were also made.
- 8) H. Sugama (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) from Oct.11, 2009 to Oct.22, 2009 to give an oral presentation entitled "Enhancement of Residual Zonal Flows in Helical Systems with Equilibrium Radial Electric Fields" in the 17th International Stellarator/Heliotron Workshop 2009 and International Collaboration on Stellarator Theory Meeting (ICST).
- 9) S. Ohdachi (NIFS) visited Princeton Plasma Physics Laboratory (Princeton, USA) from 11th to 18th Oct for attending 17th International Stellarator/Heliotron workshop.
- 10) N. Tamura (NIFS) visited Princeton Plasma Physics Laboratory, US from Oct. 11th to Oct. 18th, 2009 to join the 17th International Stellarator/Heliotron Workshop. He has given an invited talk entitled "Characteristics of nonlocally-coupled transition of the heat transport in LHD".
- 11) M. Sato attended "17th International Stellarator/Heliotron Workshop" held at Princeton Plasma Physics Laboratory (Princeton, USA) from 12th October to 16th October 2009 and made a poster presentation titled as "Simulation study of MHD stability beta limit in LHD by TASK3D".
- 12) Shin Nishimura attended the International Collaboration on Stellarator Theory (ICST) meeting (19-20 Oct.2009, at Princeton Plasma Physics Laboratory, Princeton,NJ,USA) for discussions on the neoclassical transport in heliotron/stellarator devices.
- 13) D. Kato visited Plasma Science and Fusion Center in Massachusetts Institute of Technology (host: B. Lipschultz) in USA from 8th November until 12th November 2009 to discuss about interaction between plasma and high-Z material towards steady state operation.
- 14) T.-H. Watanabe (NIFS) visited Hyatt Regency Atlanta, GA (USA) for discussion

with Prof. W. Horton (IFS) about collaboration researches on the occasion of the 51st Annual Meeting of the Division of Plasma Physics (APS).

- 15) T. Goto (NIFS) visited University of California, San Diego (Prof. F. Najmabadi) from Dec. 1st, 2009 to Jan. 29th 2010 to discuss about the improvement of system design codes for fusion power plant within the framework of personal exchange program on Japan-US Cooperation in Fusion Research and Development.
- 16) A.H. Reiman (PPPL) visited NIFS from December 7 to 11 to discuss the benchmarking 3D MHD equilibrium calculation codes, HINT2 and PIES.
- 17) P.H. Diamond (UCSD, USA) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a plenary talk entitled "Wave Momentum, Potential Vorticity Mixing, Symmetry Breaking and The Physics Self-Accelerating Plasma Flows". He also chaired a session in the conference.
- 18) R. More (Lawrence Berkeley National Laboratory, USA) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Emission of Light by Hot Dense Matter" as an invited speaker.
- 19) G. Morales (UCLA, Germany) attended 19th International Toki Conference from 8th to 11th December 2009 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations, and gave a talk entitled "Exponential Frequency Spectra Lorentzian Pulses and Intermittent Transport in Pressure Gradients" as an oral speaker. He also chaired a session in the conference.
- 20) Douglass S. Darrow (PPPL, USA) visited NIFS (M.Isobe) from December 12 to 22, 2009 for a collaborative work on development of lost-fast-ion diagnostic and effects of fast-particle-driven MHD instabilities on fast-ion transport in magnetically confined fusion plasmas.
- 21) N.Ashikawa (NIFS) visited UC San Diego from December 12th to December 17th to attend 13th ITPA meeting on SOL/divertor physics, and presented about "Dust injection experiment in LHD" and done a session leader for "Dust R&D working plan" as ITER IO urgent tasks. A new NIFS (N.Ashikawa) /PPPL (C.Skinner) collaboration work about dust detector was discussed during this meeting.
- 22) J. Harris(ORNL) visite NIFS for discussing 2D imaging diagnostics developed by S. Ohdachi. They keep collaboration aiming at installing it on DIII-D tokamak.
- 23) S.Usami(NIFS) attened US - Japan Workshop on Reconnection held at University of Wisconsin (USA). He presented the simulation studies on magnetic reconnection with multi-hierarchy model and discuss on the magnetic reconnection and simulation method.
- 24) Six persons from Heliotron Team(T. Mizuuchi, K. Nagasaki, H. Okada, S. Kobayashi, A. Matsuyama and K. Mukai) participated in the 17th ISHW (October 11- October 18, PPPL, U.S.A.).They presented recent experiments in Heliotron J and discussed the research collaboration program with other stellarator/heliotron teams in the world.

- 25) A. Matsuyama participated in International Collaboration on Stellarator Theory Meeting (19-20 Oct., 2009, PPPL, U.S.A.) and presented his recent study.
- 26) 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 2008.

7.2 Plans for 2010

- 1) P. Ryan, J. Tsai and J. Caughman (ORNL) will visit CIEMAT in fall 2009 to collaborate in the scientific exploitation the Electron Bernstein Emission diagnostic and NBI heating.
- 2) I. Calvo will stay at ORNL (February 2010) to work on turbulence and transport theory.
- 3) K. McCarthy will stay at ORNL (mid-2010) 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.

APPENDICES: TECHNICAL REPORTS ON 2009 ACTIVITIES

APPENDIX 1: HIGHLIGHTS OF LHD EXPERIMENTS, JAPAN

Remarkable progress in the physical parameters of net-current free heliotron plasmas has been made in the Large Helical Device (LHD). The beta value has exceeded 5 % (5.1 % at $B=0.425\text{T}$) and a high beta state about 5 % from the diamagnetic measurement has been maintained for more than 100 times the energy confinement time. The density and temperature regimes also have been further extended. The central density has reached $1.2 \times 10^{19} \text{ m}^{-3}$ (1.5 atmospheric pressure) due to the feed-back control of the density by the pellet injection in a plasma with the Internal Diffusion Barrier (IDB). The ion temperature (T_i) has been increased up to 5.6 keV at the density of $1.6 \times 10^{19} \text{ m}^{-3}$, which is accompanied by the impurity-hole. The electron temperature (T_e) has reached beyond 15 keV due to the increase of the ECH power. Although these parameters have been obtained in a separated parameter regimes, efforts towards integration of high-performance has achieved the fusion triple product of $5 \times 10^{19} \text{ m}^{-3} \text{ s keV}$. The highlighted achievement in the latest experimental campaign (13th from Oct. To Dec. 2009) is described below.

The heating capability in 13th campaign was the NBI of 23 MW [16MW from 3 tangential NBIs (primarily heating electrons), and 7 MW from 1 perpendicular NBI (lower energy for ion-heating)], and the ECH of 3.5 MW. The ECH power was increased due to the installation of 77 GHz gyrotrons. The improved ICRF antenna has been in preparation. Magnetic-axis swing experiments utilizing the real-time control of the vertical field have been tried to widen the optimization knob to achieve the higher beta values. The Heavy Ion Beam Probe (HIBP) measurement has been extensively performed to clarify the weak negative radial electric field (E_r) at the core of high ion-temperature plasmas and the positive E_r at the core of high electron-temperature plasmas known as CERC (Core Electron-Root Confinement) phenomena.

The beta value has exceeded 5 %. A huge database for high beta discharges has been obtained through such as the configuration optimization, fine density control by using the pellet injection, the increase of the central beta value by utilizing the IDB scenario and so on. This database will be extensively utilized for further increase of beta value, and for clarifying the dependence of the confinement on beta value. The 3D equilibrium code, HINT2, also has been extensively applied to investigate/predict the stochastization of magnetic field lines for such high-beta LHD plasmas.

The study on IDB plasmas has been also further performed. The pellet injector was upgraded, which has allowed 20-repetitive injections to increase the capability of the feed-back density control. It has been succeeded to maintain the central density above $7 \times 10^{20} \text{ m}^{-3}$ for 1 s. Plasmas with IDB in inwardly-shifted configurations have been tried to realize for the recovery of the heating efficiency, which has resulted in a plasma achieving core T_e of 2 keV at $1 \times 10^{20} \text{ m}^{-3}$.

The impurity-hole phenomena observed in high T_i plasmas was also systematically investigated in plasmas with wide range of magnetic axis positions and with different ion species. It has revealed that the hole formation is more remarkable in impurity with higher Z number, and also in magnetic configurations with larger R_{ax} (outwardly-shifted configurations). The spontaneous toroidal flow attributed to the increase of T_i -gradient

has been also recognized.

Besides the significant progress on plasma parameters, a wide range of physics investigation on, such as, thermal and particle transport, plasma-wall interaction, MHD equilibrium and stability, energetic particles, wave heating, has been advanced by utilizing the consolidated diagnostics. The device-engineering experiment was also performed.

The LHD Experimental Technical Guide

(http://www.lhd.nifs.ac.jp/lhd/databook_2009/LHD_technical_guide2009/pdf/LHD%20Experiment%20Technical%20Guide.pdf)

was revised in 2009, to facilitate the participation of international/domestic collaborators.

APPENDIX 2: SUMMARIES FOR 2009 OF THE INSTITUTE OF PLASMA PHYSICS OF THE NSC KIPT, KHARKOV.

Plasma Theory

1) Calculation of the magnetic surface function gradient and associated quantities in stellarators with broken stellarator symmetry (V.V.Nemov and S.V.Kasilov in collaboration with W.Kernbichler and B.Seiwald (Technische universität Graz, Austria)).

In the elaborated technique the quantity $\nabla\psi$ is represented as a linear combination of gradients of two conveniently chosen independent integrals of the magnetic field line equations. The corresponding coefficients of this combination are determined in preliminary computations of these gradients in real-space coordinates using the field line following code for a sufficiently large integration interval. In the bootstrap current study the geometrical factor of this current, λ_b , is calculated. The magnetic field and its spatial derivatives are computed with help of the Biot-Savart law code as well as using the Lagrange polynomial interpolation or the decomposition into toroidal harmonic functions. It follows from the computations that for the island magnetic surfaces of $\iota=2/5$ and $\iota=1/3$ which arise because of the violation of the stellarator symmetry the values of λ_b are essentially higher than for adjacent non-island magnetic surfaces. For non-island magnetic surfaces λ_b is rather close to the corresponding factor of an equivalent tokamak. (36th EPS Conference on Plasma Phys., Sofia, June 29-July 3, 2009 ECA Vol. 33E, P-4.127 (2009).)

2) Fully relativistic code SYNCH (IPP Kharkov, ITP TU-Graz) for computations of the generalized Spitzer function in the long mean free path regime has been extended for general toroidal geometry with permits its use for stellarators. For calculations of the electron cyclotron current drive in tokamaks and stellarators, SYNCH has been coupled with ray tracing code TRAVIS (IPP Greifswald). This work has been performed in cooperation with W.Kernbichler (Institute of Theoretical and Computational Physics of Graz Technical University, Austria) and N.B.Marushchenko (Max-Planck-Institute of Plasma Physics at Greifswald, Germany).

Currently, in ECCD computations, the most often used models for the generalized Spitzer function in the long mean free path regime are the high speed limit or momentum corrected models based on Taguchi approximation where pitch angle scattering part of the collision operator is treated exactly while the energy scattering part and the integral part of the linearized collision operator are taken into account by means of the first Legendre harmonic of the pitch-angle expansion of distribution function. Exceptions are codes ADJ (Princeton, USA, author C.F.F.Karney) and CQL3D (General Atomics, USA, author R.W.Harvey), where energy scattering is treated accurately, as well in the code SYNCH which has been developed in 1995 by S.V.Kasilov and W.Kernbichler in cooperation between IPP NCS KhIPT (Kharkov, Ukraine) and ITP/CP TU-Graz (Graz Austria) for the modelling of passive synchrotron current drive in tokamaks with relativistic plasma temperatures. In the year 2009, code SYNCH has been generalized from the circular tokamak model to the general toroidal geometry, including the stellarator geometry, and has been implemented as a module in a ray tracing code TRAVIS (IPP Greifswald, Germany, authors N.B.Marushchenko et al). This new version of SYNCH uses the magnetic field data in flux coordinates which are the standard output of the equilibrium codes such as VMEC. This work would allow more accurate computations of the ECCD in the long mean free path regime in the

W-7X stellarator, in particular, more accurate description of the Okhawa effect connected with particle trapping in the inhomogeneous magnetic field.

3) Kinetic equation solver NEO-2 (IPP Kharkov, ITP TU-Graz) which solves the drift kinetic equation in arbitrary collisionality regime and general toroidal geometry has been applied for the computations of generalized Spitzer function in a tokamak with intermediate collisionality regime. New features of this function have been revealed which are of special importance for ECCD in stellarators. This work has been performed in cooperation with W.Kernbichler and G.O.Leitold (Institute of Theoretical and Computational Physics of Graz Technical University, Austria), and N.B.Marushchenko (Max-Planck-Institute of Plasma Physics at Greifswald, Germany).

At the present time the generalized Spitzer function which serves as the current drive efficiency in linear current drive computations is well studied in the asymptotical collisionality regimes such as high collisionality regime (homogeneous magnetic field limit) and long mean free path regime. At the same time, in the intermediate collisionality regimes such as plateau and neighbouring regions of the banana regime and Pfirsch-Schlueter regime, the adequate model for this function is still not available. In the year 2009, the drift kinetic equation solver NEO-2 (developed in cooperation between IPP NCS KhIPT, Kharkov, Ukraine and ITP/CP TU-Graz, Graz Austria, authors S.V.Kasilov, W.Kernbichler, G.O.Leitold and V.V.Nemov) which has been used earlier for calculations of neoclassical transport coefficients in stellarators and tokamaks in arbitrary collisionality regimes has been applied for calculations of the generalized Spitzer function in these regimes. At the first stage, tokamak geometry has been considered. It has been found that in the confinement regimes where finite collisionality is important, a combined effect of collisions and magnetic mirroring force appears which destroys the anti-symmetry of this function with respect to the parallel velocity. This new feature of the generalized Spitzer function makes a difference in ECCD efficiency between the microwave beam launches in the upper and lower tangential planes with respect to a given magnetic surface. In stellarators, this effect will be more pronounced because finite collisionality is important there in a wider velocity space region than in tokamaks. This is connected with the fact that the length of trapped orbits tends to infinity in stellarators when approaching the passing particle region, while in tokamaks this length does not exceed the poloidal connection length.

4) Based on supposition about the neoclassical transport of plasma, a one-dimensional numerical code, intended for the design of space-temporal behavior of plasma in a stellarator type fusion reactor, was adapted for modeling of the experimental regimes of plasma in the torsatron Uragan-2M. The feature of the code is an accounting of equality of ion and electron diffusive fluxes of plasma due to an ambipolar electric field.

In the accepted model, the fluxes of electrons correspond to the modes of $1/v$, and ions – to $v^{1/2}$ of the neoclassical theory of transport for the stellarator-type systems. The system of equations, i.e., two equations for thermal conductivity and a diffusion equation for plasma density, were solved numerically. The solution of task starts with finding the radial electric field taking into account the condition of equality of diffusive fluxes $\Gamma_e = \Gamma_i$ at every step of spatial grid. There are three roots of the equation in general case, and the problem of finding the root being realized is defined by the choice of the initial conditions. The steady distributions of plasma parameters were obtained, including distributions of temperatures, density and radial electric field. The

found solutions allow to compare the calculated and experimental plasma parameters, what can give more reliable prognostication of parameters of experimental devices of the next generation and a thermonuclear reactor. (V.A. Rudakov).

5) *Pressure perturbation resonant excitation by an external helical field near tokamak edge plasma.* In the toroidal geometry equations for the investigation of pressure perturbation resonant excitation by an external low frequency helical field are derived. The plasma conductivity and rotation are taken into account. These pressure perturbations may be responsible for ELMs (edge localized modes) suppression in tokamaks. (I.M. Pankratov, A.Ya. Omelchenko)

6) *Stellarator-mirror based fusion driven fission reactor.* In a sub-critical fast fission reactor the neutron multiplication factor k_{eff} , is less than unity. The coefficient k_{eff} is the average number of neutrons from a single fission that causes another fission. To sustain the fission reactions in a sub-critical system an external neutron source is therefore required to drive the fission power production. One option for the neutron source is an accelerator driven system (ADS) with a spallation neutron source. Another option is a fusion plasma neutron source, i.e. a fusion driven system (FDS). In sub-critical driven systems the fission rate is proportional to the external neutron flux intensity. In this way the fission chain is fully controlled that provides a superior safety for the sub-critical systems.

The version of fusion driven system (FDS), a sub-critical fast fission assembly with the fusion plasma neutron source based on a stellarator with a small mirror part, was theoretically investigated. The combination of a stellarator and mirror is beneficial to localize the fusion neutron flux to the mirror part of the device which is surrounded by a fission mantle. In the magnetic well of the mirror part, fusion reactions occur from collision of an RF heated hot ion component (tritium), with high perpendicular energy, with cold background plasma ions. The hot ions are assumed to be trapped in the magnetic mirror part. The stellarator part which connects to the mirror part provides confinement for the bulk (deuterium) plasma. Calculations based on a power balance analysis indicate the possibility to achieve a net electric power output with a compact FDS device.

Two scenarios could be realized in the machine: hot tritium in warm deuterium plasma and vice versa, and both scenarios were found to be efficient with some advantage of the first. The design and operation of all plasma device systems is facilitated with a localization of the neutron emission. The calculations indicate promising potentials for the studied FDS scheme. Namely, for representative thermal power output of a power plant ($P_{th} \approx P_{fis} = 0.5 - 2 GW$) the computed electric Q-factor is in the range $Q_{el} = 8 - 14$, which indicates high efficiency of the FDS scheme. Important that in a power plant scale the plasma part of the considered FDS machine is rather compact with a size comparable to existing fusion devices.

An experimental device could be built in small scale for a proof-of-principle purpose, and even under these conditions it may have a positive power output. Besides the commercial potential, a practical usage of such FDS would contribute to the knowledge of fusion plasma handling. (V.E. Moiseenko, K.Noack, O.Ågren)

Plasma Experiment

1) Investigation of plasma confinement in torsatron Uragan-3M (U-3M). According to present conception, the fusion reactor based on the stellarator magnetic configuration will operate in regime of rare collisions. This regime was not investigated sufficiently experimentally up to now, and therefore in the program of torsatron Uragan-3M much attention is paid just to experiments with plasma having low collision frequency. In spite of this, plasma confinement time is not bad, i.e., the collision frequency is much greater than the plasma confinement time, and the electron energy distribution is Maxwellian.

In such conditions the transition to the regime of improved confinement of plasma occurred. The transition takes place at about same plasma density, after absorbed power per every particle reaches the level $(W/n_e V) \approx 0.22 \cdot 10^{-19}$ MW/particle (n_e – mean plasma density and V – plasma volume). This level of specific power is characteristic for other stellarator-type fusion devices (L-2, CHS) on reaching the transition to regime of improved confinement.

After transition, a significant increase of energy confinement time is observed from $\tau_E = 2.5$ ms up to 4.5 ms. The last value is 2.3 times greater than the value estimated by application of the scaling ISS95, and exceeds a little (~20%) the scaling of LHD.

It was found that the reconstruction of plasma pressure profile takes place during transition to the regime of better confinement. The time of reconstruction is rather short, ~80 μ m, what indicates that the heat flux providing the reconstruction of pressure profile, is probably connected with electron plasma component. (V.K. Pashnev, P.Ya. Burchenko, E.D. Volkov, V.G. Konovalov, V.L. Berezhnyi, A.V. Lozin, Yu.K. Mironov, .A. Petrushenya, V.S. Romanov, Ed.L. Sorokovoy, S.A. Tsybenko)

2) Suppression of the edge turbulent transport by fast ion loss in the U-3M torsatron. In the U-3M torsatron, as a result of plasma heating in the multi-mode Alfvén resonance regime ($\omega \lesssim \omega_{ci}$), a two-temperature ion energy distribution with a suprathermal tail sets in. With this, the hotter and suprathermal ions (common name “fast ions”, FI) are in the LMFP regime, a part of them is trapped into the wells of the toroidal and helical non-uniformities of the magnetic field.

If the RF power absorbed by the plasma exceeds some threshold value, spontaneous changes of plasma parameters occur which are interpreted as a transition to the H-like confinement mode (a rise of the energy content, average electron density n_e , ECE, etc.). These changes are typical for all stellarators and tokamacs. The H-transition in U-3M is also synchronized with a rise of FI content and a short-time enhanced FI outflow to the divertor. On this basis, it was hypothesized that the transition in U-3M was triggered by the FI loss.

The objective of investigations carried in 2009 was to find out in more details the real effect of FI loss on formation of the enhanced edge E_r shear (and, consequently, the enhanced shear of the poloidal $E \times B$ velocity) resulting in reduction of the edge turbulent transport and formation of the H-like confinement mode. To fulfill this, such a transient regime of the RF discharge has been chosen and considered where with n_e changing, two H-like mode states are realized separated by an L-like mode state, and time evolution is followed of the FI content, FI outflow to the divertor, on the one hand,

and of the edge potential, its radial profile, and the edge turbulent particle flux, on the other hand.

Beginning with some threshold RF power, the discharge passes three phases in its evolution. In phase 1, after discharge ignition, the density rises, and at a certain its value $n_e = n_{e1}$ the FI content passes over a maximum and a short-time burst of FI outflow to the divertor is observed. As last studies show, this phase is characterized by a relatively high value of $|\nabla E_r|$ and a low level of the edge turbulent transport. At the density $n_{e2} > n_{e1}$, the value of n_{e2} increasing with RF power, the phase 1 is terminated by a hard E_r bifurcation toward a smaller absolute value and by a reduction of $|\nabla E_r|$. In phase 2, the turbulent flux increases and probably this is the reason for start of the observed density decay. When the density falls to $n_{e3} \approx n_{e1}$, the FI content passes over a maximum again and a short-time burst of FI outflow to the divertor occurs by analogy with the phase 1. The increased FI loss results in a bifurcational transition to a more negative E_r , a higher $|\nabla E_r|$ and return to the state with reduced turbulent flux (phase 3 – an H-like mode). (A. Beletskii, P.Ya. Burchenko, V.V. Chechkin, L.I. Grigor'eva, A.Ye. Kulaga, A.V. Lozin, Yu. K. Mironov, I.M. Pankratov, V.K. Pashnev, V.S. Romanov, A.S. Slavnyj, Ye.L. Sorokovoy, S. A. Tsybenko, N.V. Zamanov, Ye.D. Volkov)

[1] Plasma Phys. Rep. 35 (2009) 926.

[2] Presented at XXXVI Int. Zvenigorod Conf. 2009, Zvenigorod, Russia.

[3] Presented at 17th ISHW 2009, Princeton, NJ, USA.

3) Study of nonlinear effects during RF plasma heating in Uragan-3M. The plasma in U-3M torsatron is created and heated by RF fields in the frequency range $\omega \leq \omega_{ci}$. However the estimation of the efficiency of energy transfer from antennae to plasma requires some specification. With this purpose special investigations were carried out with taking into account nonlinear effects. The essence of this phenomenon is as follows. It is known, the application of RF voltage to electrode results in plasma creation near the electrode surface. In this plasma the positive space charge is formed with the separate layer which has a nonlinear current-voltage characteristic (nonlinear element – NE). It is possible to show that in such a case the interaction between the RF wave and the NE leads to appearance of not only main component, but its second harmonic and the time-independent term indicating that the rectification of alternating voltage occurs. Also the interaction between two waves, ω_1 and ω_2 , leads to appearance of the combination frequencies ($n\omega_1 \pm m\omega_2$). For example, when ω_1 and ω_2 are multiple the new harmonics do appear, which do again interact with NE, thus the process of higher harmonics generation can continue without limit. In such a case the effect of rectification of U_{\perp} into U_{\parallel} is proportional to the sum of the squares of harmonics' amplitudes interacting with NE, i.e., $\Delta \propto (A^1 + A^2 + A^3 + \dots + A^n)$.

Thus, some part of energy of the original RF mode can be transformed into higher harmonics and constant component. During the experimental investigations on U-3M torsatron the number of disturbed harmonics of RF-field was up to eleven. The generation of modes with combinative frequencies was also detected during the injection of two waves for plasma creation and heating. The positive potential occurring in the vicinity of RF antenna is strong enough to provide the plasma ions acceleration. These ions bombard the surface of RF antenna and supply the metallic atoms into plasma. This fact was approved experimentally. (V.L. Berezhnyj, I.V. Berezhna, I.B.

Pinos, A.V. Prokopenko, A.I. Skibenko, D.A. Sitnikov, I.K. Tarasov, M.I. Tarasov)

4) Dynamics of electrostatic fluctuations in the edge plasma of the Uragan-3M torsatron. The investigations of the electric field fluctuations in the edge plasma (outside of the confinement volume) were carried out during the 2009 year experimental campaign on U-3M torsatron. For plasma production and heating the RF power in the frequency range $\omega \leq \omega_{ci}$ was applied to antenna, and in these investigations special attention was paid to the oscillations detected in the vicinity of harmonics of the ion cyclotron frequency. The measurements were carried out using a set of electrostatic probes which were held under floating potential. The signals were processed to obtain the spectra and the amplitude dynamics in selected frequency ranges.

A number of spectra were obtained in different U-3M operating modes. In particular, the measurements were carried out at different values of RF power or different modes of plasma confinement.

The obtained results were compared with those of numerical simulation of ion Bernstein wave generation in the edge plasma of U-3M during RF heating. The comparison has shown a good consistency in the fluctuation spectral distributions. The values of increments in different points of the frequency spectrum of fluctuations were significantly lower in comparison with numerically computed values.

It was found, that the increase of RF power leads to the reorganization of fluctuation spectra. Namely, the spectra become to widen and the energy to transfer to a higher frequency range of spectrum. Similar effect was observed after transition to the enhanced plasma confinement mode. In the framework of the chosen theoretical model such effect can be interpreted as the transition of fluctuations dynamics into the mode with pronounced nonlinearity. (K.N. Stepanov, V.V. Olshansky, M.I. Tarasov, I.K. Tarasov, D.A. Sitnikov, A.I. Skibenko)

5) Scattering of plasma particles by turbulent fluctuations in plasma of the Uragan-2M torsatron. In the torsatron Uragan-2M for the wall conditioning the hydrogen plasma produced in stationary RF discharges was used. The RF power was ~ 1 kW in the frequency range 4-9 MHz and the strength of magnetic field 0.1-0.7 kOe. With hydrogen pressure varied in a wide interval, the plasma density was $n_e \leq 10^{10} \text{ cm}^{-3}$. To measure such density the cavity method was applied, based on excitation of the toroidal vacuum chamber at frequency 10 GHz with sawtooth modulation. After plasma creation, there was observed the shift of the resonance relatively its initial position (i.e., without plasma) along the sawtooth voltage, which was proportional to averaged plasma density. Besides, significant resonance broadening occurred what pointed out some increase of the effective collision rate.

When looking for the optimal conditions of wall cleaning, the RF power, working gas pressure, and magnetic field strength were varied with measuring plasma density and particle collision rate [1]. It was found from the resonance broadening that the observed collision rate ($\nu > 10^9 \text{ s}^{-1}$) much exceeds any possible particle collision rates. Such high collision rate can correspond to scattering of particles by turbulent plasma fluctuations, in particular by ion-sound fluctuations [2].

If we suppose such a mechanism for increasing the effective collision frequency, then the latter has to be proportional to Langmuir electron frequency and energy of

fluctuations (\tilde{W}), and inversely proportional to the plasma electron temperature (T_e). With the value of measured mean plasma density $n_e=5\cdot 10^9\div 10^{10}$ cm⁻³ and with maximal plasma density factor 1.5-2 higher, the observed v_{eff} values can be achieved at $(\tilde{W}/T_e)\sim 0.1\div 0.2$. These estimations can be continued to obtain the portion of RF power needed for maintaining the collision frequency $\nu \approx \nu_{\text{eff}}$. The full energy of plasma, with $n_e=5\cdot 10^9\div 10^{10}$ cm⁻³ and $T_e\approx 10$ eV, created in the whole volume limited by the last closed magnetic surface, is $\sim 10^{-2}$ J, i.e., $\tilde{W} \approx 2\cdot 10^{-3}$ J. The estimated energy confinement time of plasma is $\tau\sim 10^{-4}$ s, that is, about 2% of power of the RF generator used for plasma production has to be consumed for maintaining the energy of fluctuations at the level $2\cdot 10^{-3}$ J. (A.V. Prokopenko and A.I. Skibenko)

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

6.1) to study directly with a good spatial (up to 1cm) and temporal (up to 1 μ s) resolution the plasma electric potential and density, poloidal component of electric field $E_p=(\varphi_1-\varphi_2)/\Delta r$ [V/cm] and to extract radial turbulent particle flux $\Gamma_r = \Gamma(E_{\text{pol}}\times B_{\text{tor}}) = \Gamma(\text{ExB})$, for the first time in stellarators.

6.2) Energetic ion driven Alfvén Eigenmodes (AE) are believed to be an important element disturbing the transport in a future reactor. The study of the properties of the AE in modern toroidal devices is the crucial contribution into the reactor relevant physics. AE are conventionally studied by Mirnov coils, which provides the poloidal m and toroidal n mode numbers and their spectral characteristics. Heavy Ion Beam Probing (HIBP) becomes a new tool to study AE with the high spatial and frequency resolution. HIBP in the TJ-II heliac observed the locally (~ 1 cm) resolved AE at radii $-0.8 < \rho < 0.9$. The set of low m ($m < 8$) branches, detected with the high frequency resolution (< 5 kHz) is supposed to be Toroidicity Induced Alfvén Eigenmodes (TAE). TAE are pronounced in the local density, electric potential and poloidal magnetic field oscillations, detected simultaneously by HIBP in the frequency range $50 \text{ kHz} < \omega_{\text{AE}} < 300 \text{ kHz}$. AE are visible in the NBI-heated plasma; the high coherency between Mirnov and HIBP data was found for specific branches of AE. The mode location is close to the plasma center for co-NBI (< 450 kW), and to the mid radius for counter- (< 450 kW) and balanced NBI (< 900 kW), indicating the deformation of the rotational transform profile by NBI current drive. When the density rises, AE frequency is decreasing, $\omega_{\text{AE}} \sim n e^{-1/2}$, the cross-phase between the plasma density and potential remains permanent. Poloidally resolved density and potential measurements provides the AE poloidal wavelength and AE contribution to the turbulent particle flux Γ_{ExB} . Typically, $\Gamma_{\text{ExB}}(\text{AE})$ was found to be comparable with the broadband turbulence flux $\Gamma_{\text{ExB}}(\text{BB})$ from the same frequency domain.

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

7.1) Major tasks were of the primary beam energy growth to dipper penetration of the probing beam in the plasma column and increase dynamical range of the secondary

current measurement. The probing energy have been increase up to 300keV. Especial external focusing system ensures of the wide dynamical range.

7.2) The study together with a good intensity probing beam up to 200 Ma TI+ (the best among the inter parents HIBP) and flexible focusing the plasma electric potential and density in range of plasma column $r=15\div 30$ cm. and densities up to $5 \times 10^{19} \text{ m}^{-3}$.

7.3) Investigations of the plasma potential evolution with plasma density show proportional increasing of the electric field and negative plasma potential.

8) Investigations of the electric field by the Heavy Ion Beam Probe (HIBP) diagnostic have been continued on the Tuman-3M (St.Petersburg).

8.1) Measurements were started with new double detector of the secondary beam.

9) Development and installation of the Heavy Ion Beam Probe (HIBP) diagnostic on WEGA Stellarator have been continued in frame of the collaboration with IPP (Greifswald).

9.1) Verification of the calculated trajectories of the probing beams was done by special detector of the primary beam. Good agreement calculated and experimental data was done.

9.2) In the experiments, helium plasma was heated non-resonantly with microwaves at 2.45 GHz. The obtained with the HIBP results are consistent with Langmuir probe potential measurements.

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

10.1) On the base of the calculations according optimized HIBP installation on U-2M the general form of diagnostic hardware have been designed, which includes primary beam injection of Cs^+ and TI^+ ions with energy range between 100 and 950 keV, and the ion energy analyzing units.

10.2) Development, manufacturing and investigation of the probing beam injector for torsatron have been done.

APPENDIX 3: TECHNICAL REPORT ON TJ-II ACTIVITIES IN 2009

The results achieved in the TJ-II stellarator during 2009 were obtained in plasmas created and heated by Electron Cyclotron Resonance Heating (ECRH) (2 x 300 kW gyrotrons, at 53.2 GHz, 2nd harmonic, X-mode polarisation) and Neutral Beam Injection (NBI). Two beams of 400 kW port-through (H0) power at 30 kV, were injected on TJ-II. The inherently strong plasma wall interaction of TJ-II has been successfully reduced after Lithium coating by vacuum evaporation. The main conclusions can be summarized as follows.

Considerable improvement of plasma particle control has been observed in the TJ-II stellarator after Li-coating, in comparison with the operation under Boron coated walls. The beneficial Li properties for plasma-wall interaction have a strong effect on this device that presents a helical limiter very close to the magnetic axis, which receives the strongest particle and heat fluxes. The outstanding results are the density control due to very low recycling conditions in formerly collapsing NBI discharges and the access to improved confinement regimes. A key ingredient for understanding the operational improvement is the change of profile radiation under Li coated wall. The edge radiation is observed to fall, which avoids the local power unbalance that produces the low radiation collapse.

Confinement studies in ECH plasmas show that the lowest values for the effective electron heat diffusivity are found in regions where the lowest order magnetic resonances are located, while Alfvén eigenmodes destabilized in NBI plasmas, also related to low order resonances, can degrade fast ion confinement. A transition from kinetic effect-dominated to a more collisional regime is found in ECRH plasmas. The electric field, positive all over the plasma in the low ECRH plasma regime, starts developing negative values at the maximum density gradient region when the collisionality reaches a threshold value. For given heating power and magnetic configuration, this translates into a line-density threshold to restore particle confinement. Further increments in the density extend the region with negative electric fields towards the centre of the plasma.

During the high density NBI operation, a transition to an improved confinement regime is observed, characterised by the increase of diamagnetic energy, the decrease of H α emission, the drastic reduction of turbulence, and the development of steep density gradients. High temporal and spatial resolution measurements indicate that turbulence reduction precedes the increase in the mean sheared flow, but is simultaneous with the increase in the low frequency oscillating sheared flow. So far, the H-mode has been obtained in a transient way and the estimated NBI absorbed power is comparable to the power threshold calculated using the empirical scaling obtained for tokamaks. This type of spontaneous transitions is added to the ones that happen at lower densities, which correspond to the shear flow development and can be also provoked by biasing. Regression analysis of the energy confinement time (up to 14 ms in NBI discharges) indicates stronger degradation with power (power exponent – 0.8) and weaker density dependence (power exponent 0.4) than ISS04.

During both low and high density plasma bifurcations, the correlation length of the plasma potential becomes of the order of the machine size during the edge bifurcation itself, quite unlike the density fluctuations. These results show that the increase in the degree of long-range correlation is strongly coupled to the presence of radial electric

fields.

Future TJ-II experiments will be focussed on studying the efficiency of Electron Bernstein Waves (EBW) heating system using the OXB mode conversion scenario, whose heating capability has been preliminary tested by EBE measurements, physics of bifurcations and stability in high beta regimes and exploring plasma-wall interaction scenarios with Li coating and divertor concepts based on flux expansion.

APPENDIX 4: TECHNICAL REPORT ON HELIOTRON J ACTIVITIES IN 2009

Effects of the confinement configuration on the fast ion confinement, the bulk thermal confinement, the plasma current control, and the particle fuelling control have been investigated in Heliotron J, a flexible helical-axis heliotron, with special regard to the optimization study of the helical system with a spatial magnetic-axis and a vacuum magnetic well. To attain the drift optimization of the L=1 helical-axis heliotron, the bumpiness control is essential to reduce the neoclassical transport (or the effective helical ripple). The experiments have been performed by changing the bumpiness with keeping plasma volume, plasma axis position, and edge rotational transform almost constant. The Heliotron J activities in 2009 can be summarized as follows:

- 1) Fast ion velocity distribution has been investigated using fast protons generated by ICRF minority heating with special emphasis on the effect of the toroidal ripple of magnetic field strength and heating position. In the standard configuration in Heliotron J, the larger fast minority protons are observed in the on-axis resonance case than in the inner-side resonance case. However, the increase of the bulk ion temperature in the inner-side resonance case is larger. The change of the absorption ratio is one candidate for the explanation of the experimental result. The three-dimensional wave analysis using TASK/WM code predicts that the absorption ratio of the majority deuteron in the inner-side case is almost doubled comparing with the on-axis case.
- 2) In Heliotron J, a bursting global Alfvén eigenmode (GAE) has been observed in NBI plasmas under the condition that the energetic particle confinement was fairly good. The response of fast ion fluxes to the Alfvén eigenmodes was measured with a hybrid directional Langmuir probe (HDLP) system. A high coherent response of the ion flux to the GAE bursts has been observed. The experiments indicate that the fast ion response is considered to be a resonant convective oscillation.
- 3) Electron cyclotron current drive (ECCD) experiments have been made in Heliotron J by using an upgraded EC launching system, where a focused Gaussian beam is injected with the parallel refractive index, $N_{||}$, ranging from -0.05 to 0.6. Ray tracing calculation shows that EC power is more localized than that in the previous launching system. The EC driven current flows in the Fisch-Boozer direction for the standard configuration, and it increases largely as the resonance moves to the high field side (the inside of the torus) rather than on-axis resonance. This may indicate that the ECCD depends not only on plasma parameters but also the magnetic field structure where the EC power is deposited.
- 4) The investigation of configuration effects on the energetic ion and the bulk thermal confinement in the neutral beam injection (NBI) plasmas have been continued expanding the parameter range of $\varepsilon_b/\varepsilon_h$ and $\varepsilon_t/\varepsilon_h$.
- 5) An amplitude modulation (AM) type system of reflectometer (the frequency ranges of carrier waves: 33 - 56 GHz, the modulation frequency: 200 MHz.) has been developed for electron density profile measurement in Heliotron J. The X-mode propagation makes it possible to measure a hollow density profile, which is typically observed in ECH plasmas.
- 6) Details of the effect of a gas fuelling by supersonic molecular beam injection (SMBI)

has been investigated in Heliotron J. Measuring of the characteristic parameters of SMBI (the beam speed, the penetration length, etc.) and change of the density/temperature profile were tested. The optimization of this fuelling method is in progress.

- 7) Design/installation of new diagnostics (such as an YAG laser Thomson scattering system for temporal temperature/density profile measurement, a BES system, an improved CXRS system, etc.) is in progress in Heliotron J to get profile data.

MINUTES OF 38TH STELLARATOR EXECUTIVE COMMITTEE MEETING

14th October, 2009

7:00 pm – 10:10 pm

Salt Creek Grill, Princeton, NJ, U.S.A.

Attendees

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

Observer

D.A.Gates (PPPL, USA)

M.Yokoyama (NIFS, Japan)

Agenda

- 1) Approval of Agenda
- 2) Confirmation of membership of SEC
- 3) Approval of minutes of the 37th Stellarator EC meeting
- 4) Extension of IEA IA
- 5) 18th International Stellarator/Heliotron Workshop 2011

- 6) Status of domestic activities and international collaborations
- 7) Development of stellarator working groups
- 8) Miscellaneous and final remarks

Meeting was opened by Motojima, chair and he welcomed all participants to the 38th Stellarator Executive Committee (SEC) meeting. It was also mentioned that there was no participant from Russia this time.

1. Approval of Agenda

The proposed agenda was approved. We have two important agenda tonight. One is the continuation of IA, and the other is the decision on the 18th ISHW.

2. Confirmation of membership of SEC

Motojima introduced and confirmed all the participants. A SEC member from Russia was not available, unfortunately.

3. Approval of minutes of the 37th SEC meeting

The minutes were approved as they are.

4. Extension of IEA -IA

Motojima: There are several necessary process and documents. I would like to ask Yamada to explain the required process.

Yamada: The present IA is valid for 5 years from 2005 to 2010. The current term is due to expire on 30 July, 2010. We would like to propose the extension of IA if unanimous agreement is obtained. The process along with required documentations for the extension is summarized in the attached letter from Ms.C.Pottinger.

Zarnstorff: Are there any examples for such documents?

Hidalgo: I have an experience of the previous extension in May 2005 with Alejandre.

Yamada: Electronic files are available, and will be distributed. These documents should be sent to IEA 3 weeks before the review (23-24 Feb., 2010) at FPCC. Thus, I would like to propose to set the deadline at the end of December (before 1 Jan, 2010) at the SEC level.

Motojima put the decision to the vote and the unanimous agreement was obtained on the continuation of IA, and the proposed deadline was also agreed.

Motojima: Before moving to the next item, I hope to suggest Dr.Komori to make some proposals.

Komori: My proposal is to amend the name of the IA a little bit. How about using “Stellartor/Heliotron concept” instead of the present “Stellarator concept” ?

Hidalgo: So, you are proposing to have a name which is similar to the words we are using for the stellarator/heliotron workshop?

Komori: Yes, we are.

Harris: In fact, it makes things easier.

Hidalgo: I think it makes sense to have a similar name and we fully understand your proposal. I do not see any problems.

Zarnstorff: So, we agree.

Komori’s proposal was unanimously supported by all the attendees. Since the representative from Russia was absent, Motojima will send the minutes to obtain their agreement. Yamada will distribute the End-of-Term report (2005-2010) and the copy of Annual Report in these 5 years together with requirements to each party.

[Supplemental note]

On Oct.23rd, Motojima sent the letter via E-mail to the Russian representatives : Prokhorov and Kovrizhnykh, who was absent from the 38th Stellarator ExCo, to ask the opinion on this agenda. This process follows the procedure described in IA Article 3 (e). Prokhorov and Kovrizhnykh replied with agreement to the decision at the 38th SEC, on Oct.26th and Oct.23rd, respectively. Consequently, a unanimous vote and agreement on the extension of IA and amending the title to “FOR CO-OPERATION IN DEVELOPMENT OF THE STELLARATOR/HELIOTRON CONCEPT” has been completed and fulfilled the requirement when amending the IA text which is described in IA Article 11 (d).

5. 18th International Stellarator/Heliotron Workshop (ISHW) 2011

Motojima: The 17th ISHW this week has been successful. We would like to express our thanks to US colleagues, especially the PPPL colleagues to organize it. We would like to decide the host of the next 18th ISHW in 2011.

Yamada: The history of ISHW was summarized in the attached document.

Blackwell: Australia can be a candidate, although there are some conditions. We are small group, so we would like to jointly host it with, for example, APPTC (Asia-Pacific Plasma Theory Conference), and Japan-Australia diagnostics workshop. We might have some joint sessions.

Hidalgo: Do you have any numbers in mind how many people will attend?

Blackwell: Considering the participants for these workshop/conferences and the geographic nature, a fewer than 100 people are anticipated. The venue should also be considered (Sydney, near Canberra, along the coast).

Hidalgo: Are you proposing parallel sessions?

Blackwell: APPTC mainly deals with tokamak issues. Disruption issue might be held separately, but, some other issues can be combined (such as the current drive, heating, reactor designs, divertor, ELMs). So, 50-75% joint sessions might be considered.

Zarnstorff: How about 19th ISHW (2013)?

Hidalgo: A bit early to decide.

Although Greifswald was mentioned (and supported by Wolf), it will be discussed in the next SEC.

Motojima: I would like to encourage Ukrainian colleagues to host ISHW in the near future.

Pankratov: I should discuss with Tereshin. But, in principle, it is possible. This time, I do not have a problem on Blackwell's proposal.

The proposal from Blackwell, Australia to host the 18th ISHW, was unanimously supported.

Blackwell: For considering joint workshop, a couple of people are needed to sort out issues. Can Yamada-san help us?

Yamada: I am pleased to help you as a secretary of the SEC. And then the SEC should assign program committee.

Blackwell: We should have some mechanism to discuss with APTC and AJDW people.

6. Status of domestic activities and international collaborations

USA

Anderson: HSX group has been collaborating, for example, with Murakami (Kyoto Univ.) on GNET code analysis on HSX, and with TJ-II on impurity, zonal flow and wall-conditioning (boronization) issues.

Zarnstorff: PPPL has a large collaboration with ORNL, LHD, W7-AS(X) and TJ-II. The cancellation of NCSX has strengthened the collaboration, stimulating strategic planning.

Motojima: Congratulations for the Nobel prize for President Obama. Nuclear fusion research will contribute to reduce the number of atomic weapons.

Blackwell: What fraction of governmental representatives has seen the coils of NCSX?

The construction site is quite impressive, and I guess it may alter their decision of the cancellation.

Zarnstorff: We have invited essentially everybody of DOE, but only a few have visited us.

Hidalgo: In case you get the approval, what would be the time scale and budget for completion?

Zarnstorff: It would be closed to 4 years. We estimate the total cost to be 172 M\$, and we spent 92, so we need another 80. DOE is not ready for such a decision and no funding.

Australia

Harris: Before coming to report from Australia, I would like to mention on the on-going transnational collaboration: observation of Alfvénic modes in LHD, TJ-II and H-1, and early data from W7-AS, along with ORNL-Kiev-Greifswald theory collaboration. Further extension of collaborations is expected.

Blackwell: We have some good news. The new government is favor on science, and we've got the increased funding. The funding for post-graduate students has doubled and mid-career fund which M.Hole received guaranteed tenure of 4 years. We also received 7 MA\$ for the upgrade of H-1, but there is a restriction that this should be used only for infrastructure. One of the aims of the funding is to increase the researchers for fusion including material science, and to use H-1 as a symbolic facility for a test bed for diagnostic development/edge physics for some involvements to ITER. Science minister visited H-1 and fired the discharge, I hope, which will make him to be more familiar with fusion research. Couple of international collaborations is on-going, Blackwell-Kyoto, Howard-TEXTOR and DIII-D, Dewar-Japan etc.

Motojima: It is good to have new funding. Education of young people is important with variety of funding support.

Spain

Hidalgo: From the European perspective, the completion of the W7-X is the internal priority. Collaboration in diagnostics development has been strengthened with

Greifswald. We have tried to increase the number of researchers on plasma physics in European Physical Society, and it has succeeded with universities. In Feb.2009, we concluded the collaboration agreement with NIFS, which has been fruitful for both sides. Many scientists exchanged on e.g., fast particles, impurity and diagnostics. Collaborations with US colleagues have been done for heating issues such as NBI and Bernstein wave (experiments in a few weeks) for increasing the density. Very recently, we have some links to HSX colleagues. Russian and Ukrainian colleagues are visiting CIEMAT for many years on HIBP and heating issues. This has made progress on duplication of HIBP (hopefully in 2 years) on zonal flow studies. Collaboration on data mining with Pretty has been continued. We have a very good perspective to 2010.

Motojima: We understand the active international collaboration. How about the internal collaboration with universities in Spain?

Hidalgo: CIEMAT has tried to increase the link with universities. So far, a limited number. There is special funding for university colleagues to work in CIEMAT. We are now considering how to organize such a huge man-power (not only students, but also senior scientist) from universities in a productive way.

Blackwell: What is the “break-even” time for such collaborations to gain “something”?

Hidalgo: From the statistics, 1/3 visitors are successful to establish stable collaborative links. That is a good number. We offer openly the joint experiment, and we need “minimum budget” to gain “something”.

Motojima: This is a question from university side, right?

Blackwell: Yes.

Japan

Komori-Yamada: We have distributed detailed information on LHD in handouts. We are very pleased to present more than 20 papers at the 17th ISHW. You all have recognized our recent activity. As mentioned in the plenary talk, LHD is the experimental platform for collaboration worldwide. We appreciate the experimental proposals in this experimental campaign from international colleagues such as Hidalgo, Otte and Zarnstorff. The machine time is so limited, but we try our best.

Zarnstorff: What is the cause of the limitation of machine time?

Komori: We need a time for the installation of new NBI and divertor.

Harris: When will be the divertor installed? I know the new NBI will be in 1 year.

Yamada: We will install 2/10 section, inboard side by 2010.

Harris: In succeeding years, step by step?

Komori: We require 3 or 4 years to complete.

Germany

Wolf: We have a PhD student to be sent to LHD for magnetic measurement by using the infrared camera. We also have collaboration with PPPL especially on theory and general plasma physics, (Zarnstorff) forming the joint institute based on the special program of the Max-Planck society. We have contacts with Wisconsin on OXB heating (a PhD student) and with CIEMAT on diagnostics. Everybody is invited for the opportunities of joint research on the W7-X once it approaches. Workshop on DEMO was held in the framework of EFDA.

Zarnstorff: Can you say more on the DEMO workshop?

Wolf: Many people attended for 2-days meeting. Very open discussions on problems, such as islands, divertor developments etc., and how ITER is relevant to DEMO.

Finally a few remarks on W7-X, 5-year review by the Helmholtz society finished with favorable evaluation. We got the proposal for the increased funding first time more than in 10 years.

Motojima: There is still a severe argument left on the definition of DEMO.

Wolf: Official version of DEMO is to show the power plant capability. 4 models were discussed in DEMO-WS, with high over-all efficiency.

Motojima: As for DEMO, flexibility should be kept as wide as possible, where stellarator/heliotrons can contribute to.

Ukraine

Pankratov: Fast ion studies have progressed in Uragan-3M. On the 2nd HIBP installation on TJ-II, we have a strong collaboration with CIEMAT. Collaboration with NIFS and Heliotron-J has progressed on plasma-wall conditioning and divertor issues. In the theory area, there is collaboration with Austria (Technical Univ. Graz) on bootstrap current estimate in Uragan-2M.

Motojima: Thank you for telling us a wide range international collaboration. Ukraine should be a core member of Stellarator/Heliotron research.

Hidalgo: How about new-generation scientists? There are few young scientists visiting to CIEMAT from Ukraine.

Pankratov: There is a small group of young scientists. One reason of your pointing-out might be they go abroad, like Germany, for research.

Motojima: To encourage young researchers, it is important to tell them future career-pass. We need more efforts on that.

7. Development of stellarator working groups

Yamada: Please have a look at the ITPA membership list. There are members assigned from stellarator/heliotron community. Dr.Hidalgo attended the ITPA meeting last week.

Hidalgo: On topic of L-H transition, it has been extensively discussed how magnetic configuration affects the transition. We have to intensify our presence in specific topics like this. It will be our contribution to ITER.

Harris: I am on the MHD topics. They concern disruptions occurring all the parameter space of tokamaks, and yet to see programming avoidance of disruption. There is a lot of interest of using RMP to mitigate ELMs. I wonder, more substantial helical intervention to be investigated at some point.

Gates: Implementation of 3D codes for calculating neoclassical toroidal viscosity has been discussed, where stellarator/heliotron community can do a lot.

Wolf: HINT2 code has been applied to 3D.

Harris:EMC3-EIRENE code has been applied to ITER.

8. Miscellaneous and final remarks

Closing remarks by Motojima.

Next EC will be held at Daejon (Korea) during IAEA-FEC 2010 (Oct. 2010).