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

# 2008 Executive Committee Annual Report to the Fusion Power Coordination Committee

**January 2009**


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# EXECUTIVE SUMMARY

The present report overviews the scientific and technical progress achieved in 2008 by the parties to the Stellarator Concept Implementing Agreement, who have greatly benefit from its international collaborative framework. The document reports the collaborations in 2008 and the parties' research plans for 2009, including technical reports on 2008 activities.

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# 1 AUSTRALIA

## 1.1 International collaborations in 2008

1) Australian Government support for the National Plasma Fusion Research Facility, centred on the H-1 Heliac, was extended until 2010 under existing funding. This includes a contract variation allowing some funding for operational costs, and visits by collaborators. The flexible Heliac H-1NF is used for fundamental experiments in magnetic configuration topology, instabilities, turbulence, flows and confinement transitions at moderate heating power, and the development of imaging spectroscopy and microwave diagnostics for broader use in the fusion program. 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 interferometry and optical multichannel spectroscopy for investigation of the radial structure of Alfven modes.

2) Collaboration on MHD and configuration studies have continued to grow: D. Pretty implemented a new version of the recently developed data mining technique in a python open-source format to be more flexible and readily adaptable to different data systems. The new implementation has been interfaced to H-1, Heliotron-J and TJ-II data, and has been successfully used to classify data into a small number of clusters of similar modes, as the first step in an automated analysis and interpretation process.

- B. Blackwell began a three month sabbatical to collaborate with Professor Nagasaki and Dr. S. Yamamoto of the Heliotron J group of the Institute of Advanced Energy, Kyoto University, to further advance this project. After submission of his PhD thesis on this subject, D. Pretty joined the CIEMAT TJ-II group to analyse MHD data and work with the Data Acquisition group.

- A collaboration between C. Nührenberg of MPIPP Greifswald, B. McMillan of CRPP Lausanne, R. Dewar, M. McGann and M. Hole of the ANU Department of Theoretical Physics, and B. Blackwell and J. Howard is comparing the experimental observations of MHD activity with eigenvalue calculations using the CAS3D code.

3) There are a number of collaborations in plasma diagnostics, in particular in the area of optical spectroscopy. One and two-dimensional coherence imaging (CI) systems have been operating successfully on H-1 for the last few years, and have led to a clearer understanding of the interaction between ions and neutrals in low-field argon discharges and between the electron and ion fluids in ECH discharges at 0.5T. The 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

- An Australian government-funded 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.

- Application of imaging birefringent interferometers for Thomson scattering on JT-60U in a collaboration with T. Hatae from JAEA. Measurements were completed successfully at JT-60U in August 2008.

4) The Australian Heliac 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 2009.

5) Collaboration between M. J. Hole (ANU) and L. C. Appel (UKAEA fusion) to complete the design of the Outboard Mirnov Array for High frequency data Acquisition (OMAHA), a high frequency magnetic probe array which has now been fully installed on the Mega Ampere Spherical Tokamak.

6) A collaboration between ANU (R. Dewar, M. Hole, M. McGann) and Princeton PPL (S. Hudson) has continued the investigation of a new formulation of the 3-D MHD equilibrium and stability problem, with the aim of developing better equilibrium codes for stellarators (with possible applications to electron transport barrier studies). Highlights included: M. McGann completed Hamiltonian studies which determined the pressure jump that a given irrational surface could support before being destroyed by chaos, R. Dewar clarified the thermodynamic aspects of the constrained energy minimization principle used to describe plasma relaxation, and related it to other Maximum Entropy principles, and M. Hole explored the nature and characterisation of unstable modes in the Multiple Relaxed Region MHD model, and compared them to tearing modes. The latter work was presented at the IAEA Fusion Energy Conference.

7) R. L. Dewar spent a 3 month research sabbatical at Department of Advanced Energy, Graduate School of Frontier Sciences, University of Tokyo, where he collaborated with Zensho Yoshida on entropy production principles, and published work on Adiabatic Wave-Particle Interaction (Plasma and Fusion Research).

8) Ongoing collaboration with UKAEA Fusion led to several publications. This included study of Compressional Alfven eigenmodes in the Mega Ampere Spherical Tokamak(Plas. Phys. Con. Fus. 50 (2008) 115011). The collaboration focused on mode identification, characterisation of mode polarisation, and a modulation model that suggested frequency splitting at the finest scale corresponds to modulation with low frequency tearing modes. Other collaboration included construction of a strong modulation model for Alfvénic and low frequency modes (Plasma Phys. Control. Fus. 51 (2009) 045002). In addition to demonstration of mode number and amplitude coupling, the work included a critical assessment of bicoherence analysis, and provided some evidence for phase coupling. In 2008 Dr Hole spent 10 days at UKAEA Fusion, collaborating toward a publication on fast magnetics diagnostic design.

Dr Hole, chair of the Australian ITER Forum, an informal association of 130 scientists and engineers, attended the 2008 meeting of the International Fusion Research Council, and was invited to become a member of the Council.

## 1.2 Research plans and activities for 2009

1) The 8th Japan-Australia Plasma Diagnostics Workshop (JAW) jointly chaired by Prof J. Howard (ANU) and A/Prof B. James (University of Sydney) will be conducted at the Australian National University during February 2009. As well as Japanese and Australian delegates, this meeting will also feature visits from a number of international experts from Korea, the USA and Europe. In conjunction with the workshop, the Australian ITER forum will undertake to identify and assess the commitment required to mount a possible Australian diagnostic system on ITER, with advice from Dr. Alan Costley and Dr H Matsumoto, who will also be briefing the Australian Government.

2) Configuration studies will focus on the effects of Alfvén-driven instabilities and turbulence which can be moderated through fine control of the H-1 magnetic configuration. Plasma density and polarimetry interferometers, and multi-channel spectroscopic detectors will provide profile information for configuration studies and mode structure of Alfvénic instabilities. International collaboration on optical systems for spectro-polarimetric imaging will continue in 2009. This work embraces the following activities

- 2D MSE snapshot imaging experiments on the TEXTOR tokamak will be undertaken in March 2009.
- A jointly funded collaboration between General Atomics and the Australian National University will see the installation of a new instrument for fast optical Doppler and Zeeman imaging of the scrape-off layer and divertor regions in the DIII-D tokamak in 2009.
- We will undertake feasibility/planning studies on the installation of 2D snapshot MSE and CXRS imaging systems for KSTAR scheduled for 2010.
- Combined with fast, gated CCD cameras, the newly developed passive 4-quadrant optical coherence imaging systems will be used to study rf-phase resolved evolution of the velocity distribution functions of particles in low field H-1 plasma discharges.

3) 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 2009.

4) A new collaborative project: “Model/data fusion: using Bayesian techniques to constrain equilibrium and stability theory of advanced magnetic confinement experiments ahead of the International Thermonuclear Experimental Reactor” will commence. The purpose of this project, which is supported by an 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.

# 2 EU

## 2.1 GERMANY

### 2.1.1 International collaborations in 2008

- **Collaborations with EU**

1) P. Helander (IPP Greifswald) to KTH Stockholm, 23.01. – 25.01.2008

2) V. Szabó (KFKI-Research Institute for Particle and Nuclear Physics, Budapest) to IPP Greifswald, 23.01. – 09.02.2008: Simulation of the temperature evolution of the video diagnostic front-end components during pulsed operation of W7-X using ANSYS.

3) T. Fülöp (Chalmers, Göteborg) to IPP Greifswald, 03.02. – 09.02.2008: Microinstabilities.

4) A. Könies (IPP Greifswald) to Culham, 12.02. – 15.02.2008: MAST research forum, stability measurement.

5) A. Weller (IPP Greifswald) participated in MAST Research Forum, Culham, England, 13.02-14.02.2008.

6) T. Klinger (IPP Greifswald) to Paris and Marseille, Université Provence, 25.02. – 27.02.2008: FPCC meeting, IEA, and CPT discussions.

7) J. Cantarini (IPP Greifswald) visited CEA Cadarache, 08.03. – 20.04.2008.

8) E. Belonohy (KFKI-Research Institute for Particle and Nuclear Physics, Budapest) to IPP Greifswald, 09.03. – 22.03.2008.

9) S. Jablonski, J. Kaczmarczyk , M. Kubkowska, L. Ryc and J. Wolowski (Institute of Plasma Physics and Laser Microfusion, Warsaw) to IPP Greifswald, 16.03. – 19.03.2008: Visit in the frame of the IPPLM-IPP Cooperation Agreement on "Spectrometry of soft X-ray emission from the W7-X Stellarator (pulse height analysis - PHA, and multi-foil spectrometry - MFS)".

10) T. Klinger (IPP Greifswald) to Warsaw University of Technology, 25.03. – 26.03.2008: Association Euratom-IPPLM Council Meeting.

11) A. Weller (IPP Greifswald) participated in EFDA MHD Topical Group Meeting, Padua, Italy, 27.03. - 28.03.2008.

12) M. Turnyanski (UKAEA Fusion Association, Culham Science Centre, Culham) to IPP Greifswald, 30.03. – 03.04.2008: Discussion of further tasks for the collaboration in the field of Charge Exchange Diagnostics. Clarification of the application of the IPP-compact neutral particle analyser CNPA inside the MAST-Physics programme and comparison with the installed Princeton NPA and CX-RS measurements.

13) P. Helander (IPP Greifswald) to Chalmers, Göteborg, 13.04. – 14.04.2008.

14) A. Weller (IPP Greifswald) participated in German-Polish Forum, Leipzig, 21.04. –

22.4.2008.

15) S. Jednorog, R. Prokopowicz, M. Scholz (Institute of Plasma Physics and Laser Microfusion, Warsaw) and K. Drozdowicz (Institute of Nuclar Physics, Krakow) to IPP Greifswald, 23.04. – 25.04.2008: Visit in the frame of the collaboration on neutron activation and MCNP calculations for W7-X.

16) F. Taccogna (University of Bari, Italy) to IPP Greifswald, 10.05. – 31.05.2008: Plasma – Wall – Interaction.

17) A. Lazaros (School of Electrical and Computer Engineering, National Technical University of Athens) to IPP Greifswald, 19.05. – 21.05.2008: Discussions with W7-X group about various aspects of plasma stability in W7-X.

18) P. Helander (IPP Greifswald) to Chalmers Göteborg, 22.05. – 23.05.2008.

19) S. Braun (IPP Greifswald) to Chalmers Göteborg, 25.05. -06.06.2008: Effect of impurities on collisional zonal flow damping.

20) A. Cooper (CRPP & EPFL Lausanne, Switzerland) to IPP Greifswald, 26.05. – 29.05.2008: Turbulence simulations.

21) T. Klinger, O. Grulke, A. Stark, J. Pfannmöller, K. Rahbarnia, H. Laqua, M. Hirsch, M. Otte (IPP Greifswald) to TU Szczecin, 11.06. – 12.06.2008: Mini-Workshop “Current topics in plasma waves”.

22) M. Jakubowski (IPP Greifswald) visited Culham Science Centre, 15.06. – 12.07.2008.

23) R. Schneider (IPP Greifswald) to University Innsbruck, 16.06. – 18.06.2008: Plasma-Wall-Interaction.

24) S. Kasilov (University Graz) to IPP Greifswald, 01.07. – 31.07.2008: Implementation of kinetic heat transport model in E3D.

25) P. Helander (IPP Greifswald) to Culham, 07.07. – 11.07.2008.

26) E. Sanchez (CIEMAT Madrid) to IPP Greifswald, 13.07. – 15.07.2008: Gyrokinetic.

27) J. Preinhaelter (IPP, Prague) to IPP Greifswald, 13.07. – 01.08.2008: Upgrade of the ray tracing code for electron Bernstein waves. Simulation of the Bernstein wave driven current at WEGA.

28) P.Carvalho (CFN, IST, Lissabon) to IPP Greifswald, 07.07. – 03.08.2008.

29) H. Smith (University of Warwick, UK) to IPP Greifswald, 31.07. – 02.08.2008: Electron kinetic

30) M. Rome (University Mailand, Italy) to IPP Greifswald, 25.08. – 16.09.2008.

31) T. Fülöp (Chalmers Göteborg) to IPP Greifswald, 07.09. – 12.09.2008: Microinstabilities.

32) J. Hastie (Culham UK) to IPP Greifswald, 07.09. – 13.09.2008: Resistive instabilities.

33) H. Maaßberg (IPP Greifswald) to University Graz, 08.09. – 10.09.2008: Benchmarking of codes in the frame of the International Collaboration on Neoclassical Transport in Stellarators – ICNTS.

34) P. Helander (IPP Greifswald) to London, 19.09. – 23.09.2008: Summer University.

35) A. Weller (IPP Greifswald) visited IPPLM Warschau, 22.09. – 25.09.2008: Visit in the frame of the collaboration on soft X-ray spectrometry, neutron activation and MCNP calculations for W7-X.

36) R. Kleiber, A. Könies (IPP Greifswald) to CRPP & EPFL Lausanne, 06.10. – 08.10.2008: Collaboration on Gyrokinetics.

37) F. Taccogna (University of Bari, Italy) to IPP Greifswald, 08.10. – 28.10.2008: Plasma – Wall – Interaction.

38) R. Burhenn, A. Dinklage, A. Weller, R. Wolf to CIEMAT, 20.10. – 22.10.2008: 4th Coordinated Working Group Meeting

39) Y. Feng (IPP Greifswald) to CIEMAT Madrid, 19. – 23.10.2008: 4th Coordinated Working Group Meeting and International Collaboration on Neoclassical Transport in Stellarators.

40) C. Beidler M. Drevlak, (IPP Greifswald) to CIEMAT Madrid, 19. – 25.10.2008: 4th Coordinated Working Group Meeting and International Collaboration on Neoclassical Transport in Stellarators.

41) J. Geiger, H. Maaßberg, N. Marushchenko, Y. Turkin (IPP Greifswald) to CIEMAT Madrid, 19. – 29.10.2008: 4th Coordinated Working Group Meeting and International Collaboration on Neoclassical Transport in Stellarators.

42) S. Schmuck (IPP Greifswald) visited CIEMAT, Madrid, 19.10. – 22.11.2008.

43) A. Weller (IPP Greifswald) collaborated with Ciemat Madrid, Ciemat Madrid, 23. – 24.10.2008 on radiation calculations with IONEQ and MHD.

44) E. Belonohy (KFKI-Research Institute for Particle and Nuclear Physics, Budapest) to IPP Greifswald, 02.11. – 29.11.2008.

45) H. Schumacher, B. Wiegel, A. Zimbal, L. Giacomelli from PTB Braunschweig, and M. Scholz, K. Drozdowicz from IPPLM Warschau and INP Krakow visited IPP Greifswald, 05. – 06.11.2008: Visit in the frame of the collaboration on neutron counters, neutron activation and MCNP calculations for W7-X.

46) T. Klinger (IPP Greifswald) to Ciemat, Madrid, 27.11. – 29.11.2008: EPS PPD Board Meeting.

47) P. Helander (IPP Greifswald) to Chalmers Göteborg, 02.12. – 04.12.2008.

48) M. Jakubowski (IPP Greifswald) visited Culham Science Centre, 09.11. – 22.11.2008 and 07.12. – 20.12.2008.

49) W. Schneider (IPP Greifswald) visited Culham Science Centre, 10.11. – 20.11.2008.

50) R. Schneider (IPP Greifswald) to University of Bari, 03.12. – 04.12.2008: Plasma-Wall-Interaction.

51) R. Schneider (IPP Greifswald) to University Innsbruck, 04.12. – 06.12.2008: Plasma-Wall-Interaction.

52) R. Warmbier (IPP Greifswald) to Culham, 07.12. – 13.12.2008: Atomic Physics for Plasma-Wall-Interaction.

53) S. Cowley (UKAEA) to IPP Greifswald, 09.12. – 11.12.2008.

- **Collaborations with Japan**

1) J. Geiger (IPP Greifswald) visited NIFS, 01.03. – 15.03.2008.

2) S. Ohdachi (National Institute for Fusion Science, Toki) to IPP Greifswald, 09.03. – 14.03.2008: Discussion of the latest results of LHD in relation to results from W7-AS and the physics program on W7-X; support for the installation of the IONEQ code on a Linux system.

3) A. Mishchenko (IPP Greifswald) visited NIFS, 21.04. – 10.07.2008.

4) Y. Suzuki (NIFS) visited IPP Greifswald, 16.06 – 27.06.2008.

5) H. Funaba (National Institute for Fusion Science, Toki) to IPP Greifswald, 16.08. – 26.08.2008: User interface for the International Stellarator/ Heliotron Confinement Database.

6) M. Yokoyama (National Institute for Fusion Science, Toki) to IPP Greifswald, 07.10. – 19.10.2008: Documentation of Central Electron Root Confinement.

7) K. Matyash, R. Schneider (IPP Greifswald) visited University of Yokohama, 30.10. – 08.11.2008: Plasma-Wall-Interaction.

8) T. Klinger, R. Wolf (IPP Greifswald) to NIFS Takayama, 11.12. – 14.12.2008: NIFS Special Review Meeting By Advisors and Foreign Researchers.

- **Collaborations with Russia**

1) J. Koshurinov and L. Lubyako (Institute of Applied Physics RAS, Nizhny Novgorod) to IPP Greifswald, 25.03. – 05.04.2008: Visit in the framework of collaborative research between IPP and IAP in the interest of international controlled nuclear fusion program and some related meetings.

2) J. Nührenberg (IPP Greifswald) visited Kurchatov Institute Moscow, 21.04. –

24.04.2008.

3) A. Litvak (Institute of Applied Physics RAS, Nizhny Novgorod) to IPP Greifswald, 24.04. – 04.05.2008: Visit in the framework of collaborative research between IPP and IAP in the interest of international controlled nuclear fusion program and some related meetings.

4) M. Mikhailov (Kurchatov Institute, Moscow) visited the IPP Greifswald, 18.05. – 12.07.2008.

5) T. Richert (IPP Greifswald) visited Budker Institute of Nuclear Physics, Novosibirsk, 12.07. – 17.07.2008.

6) W. Schneider (IPP Greifswald) visited IOFFE Physico-Technical Institute, St. Petersburg, 25.08. – 11.09.2008.

7) J. Nührenberg (IPP Greifswald) visited Kurchatov Institute Moscow, 29.09. – 02.10.2008.

8) M. Mikhailov (Kurchatov Institute, Moscow) visited the IPP Greifswald, 26.10. – 20.12.2008.

- **Collaborations with Ukraine**

1) Y. Kolesnichenko (INR Kiev) to IPP Greifswald, 27.04. – 23.05.2008: Visit in the frame of the IPP-STCU collaboration on the theory of Alfvén waves and effect of fast particles in stellarators.

2) A. Zhezhera (Institute of Plasma Physics, Kharkov) to IPP Greifswald, 16.06. – 04.07.2008.

3) Yu. Yakovenko and. V. Lutsenko (INR Kiev) to IPP Greifswald, 19.10. – 06.11.2008: Visit in the frame of the IPP-STCU collaboration on the theory of Alfvén waves and effect of fast particles in stellarators.

- **Collaborations with USA**

1) T. Klinger (IPP Greifswald) to Columbia University, New York, 24.01. – 27.01.2008: Invited talk “Progress of Project Wendelstein 7-X and collaboration discussions.

2) A. Simakov (Los Alamos National Laboratory) visited IPP Greifswald, 27.01. – 03.02.2008.

3) R. Schneider (IPP Greifswald) visited Emory University Atlanta, 05.02. – 13.02.2008.

4) A. Mishchenko (IPP Greifswald) visited University of Burlington, USA, 07.03. – 22.03.2008.

5) N. Marushchenko (IPP Greifswald) visited General Atomic San Diego and MIT Boston, 09.03. – 29.03.2008.

6) H. P. Laqua and H. Laqua (IPP Greifswald) visited HSX-Madison and PPPL Princeton 17.03. – 21.03.2008.

7) T. S. Pedersen (Columbia University, New York) visited the IPP Garching and Greifswald, 18.03. – 21.03.2008.

8) M. Jakubowski (IPP Greifswald) visited General Atomics, San Diego, 06.04. – 19.04.2008.

9) P. Helander (IPP Greifswald) visited MIT Boston, 16.04 – 29.04.2008.

10) A. Könies (IPP Greifswald) visited ORNL Oakridge, 21.04. – 24.05.2008.

11) D. Eremin (IPP Greifswald) visited PPPL, 16.05 – 23.05.2008.

12) A. Boozer (Columbia University) visited IPP Greifswald, 31.05. – 06.06.2008.

13) K. Bartschat (Drake University, Iowa) to IPP Greifswald, 24.06. – 28.06.2008, Atomic Data Assessment.

14) C. Nührenberg (IPP Greifswald) visited PPPL, 22.07. – 05.08.2008.

15) R. Warmbier (IPP Greifswald) visited Emory University Atlanta, 10.08 – 29.08.2008.

16) P. Catto, F. Parra (MIT Boston) visited IPP Greifswald, 06.09 – 14.09.2008.

17) G. Kagan (MIT Boston) visited IPP Greifswald, 07.09 – 12.09.2008.

18) D. Mikkelsen (PPPL Princeton) visited IPP Greifswald, 08.09 – 14.09.2008.

19) T. Klinger (IPP Greifswald) to PPPL, Princeton, 04.10. – 07.10.2008: Invited talk and collaboration discussions.

20) A. R. Sharma (Emory University Atlanta) visited IPP Greifswald, 18.10. – 01.11.2008.

21) D. Spong (ORNL Oakridge) visited IPP Greifswald, 25.10. – 08.11.2008.

### 2.1.2 Conference participation

1) A. Dinklage, D. Dodt, S. Schmuck, H. Thomsen, A. Werner; 5th Workshop on Fusion Data Processing, Validation and Analysis, 13.01. – 16.01.2008, Culham, UK.

2) V. Erckmann, H.P. Laqua; 15th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, 10.03. – 13.03.2008, California, USA.

3) C. Brandt, A. Dinklage, D. Dodt, T. Klinger, O. Lischtschenko, J. Pfannmöller, K. Rahbarnia, A. Stark, N. Sydorenko, S. Ullrich, A. Weller, T. Windisch, DPG-Tagung, 11.03. – 14.03.2008, Darmstadt, Germany.

4) P. Helander, Hungarian Plasma Physics and Fusion Technology Workshop 25.03. – 28.03.2008 in Raab, Hungary.

5) J. Cantarini, H. Dreier, R. König, P. Kornejew, M. Krychowiak, A. Werner; 17th Topical Conference on High Temperature Plasma Diagnostics, 11.05. – 15.05.2008, Albuquerque, New Mexico.

6) D. Hildebrandt, K. Matyash, R. Schneider, 18th International Conference on Plasma Surface Interactions, 26.05. – 30.05.2008, Toledo, Spain.

7) J. Schacht, MicraTCA Conference, 02.06. – 06.06., Munich, Germany.

8) D. Eremin, Y. Feng, J. Geiger, A. Kus, S. Marsen, Y. Podoba, W. Schneider, H. Thomsen, 35th EPS Plasma Physics Conference, 09.06. – 13.06.2008, Hersonissos, Greece.

9) D. Dodt; 28th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering, 06.07. – 11.07.2008, Sao Paolo, Brazil.

10) P. Helander: Workshop “Runaway Electrons in ITER” 14.07 -17.07.2008, Cadarache, France.

11) H. Braune, V. Erckmann, N. Marushchenko, G. Michel: Participation in 7th Workshop “Strong Microwaves in Plasmas”, 27.07. – 03.08.2008, Nizhny Novgorod, Russia.

12) R. Schneider: DLR-Workshop 04. – 06.08.2008 in Schloß Rauischholzhausen, Germany.

13) A. Könies, A. Mishchenko: Joint Varenna – Lausanne Workshop 24.08. – 30.08.2008 in Varenna, Italy

14) G. Michel; 33rd International Conference on Infrared, Millimeter, and Terahertz Waves, 15.09. – 19.09.2008, Pasadena, California, USA.

15) P. Helander: Workshop “Kinetic Equations, Numerical Approaches and Fluid Models for Plasma Turbulence” at Wolfgang-Pauli-Institute 14.09. – 19.09.2008,Vienna, Austria.

16) T. Bluhm, J. Cantarini, A. Dinklage, M. Drevlak, M. Endler, V. Erckmann, T. Klinger, A. Könies, G. Kühner, M. Lewerentz, H. Riemann, J. Schacht, S. Schmuck, R. Wolf; 25th Symposium on Fusion Technology, 15.09. – 19.09.2008, Rostock, Germany.

17) J. Schacht; 5th Symposium On Automatic Control, 18.09. – 19.09.2008, Wismar, Germany.

18) C. Beidler, R. Burhenn, M. Drevlak, Y. Feng, M. Jakubowski, T. Klinger, H. Laqua, F. Wagner, A. Weller, R. Wolf; IAEA Fusion Energy Conference, 12.10. – 18.10.2008, Geneva, Switzerland.

19) K. Matyash:Project-Clic08-Workshop 15. – 17.10.2008 in CERN, Switzerland.

20) S. Braun, D. Eremin, T. Feher, J. Geiger, P. Helander, R. Kleiber, A. Könies, H. Maaßberg, N. Marushchenko, A. Mishchenko, A. Runov, Y. Turkin: Ringberg Theory

Seminar 16.11. – 21.11.2008 in Schloß Ringberg, Germany.

21) R. Wolf, 18th International Toki Conference, 09.12. – 12.12.2008, Toki, Japan.

### 2.1.3 Participation in joint projects

- **International stellarator confinement data base**

Coordinated Working Group: CWGM4, Ciemat Madrid, 20. – 22.10.2008, contributions from A. Dinklage, A. Weller, J. Geiger.

- **International stellarator profile data base**

Contributions from C.D. Beidler, R. Burhenn, A. Dinklage, Y. Feng, J. Geiger, A. Kus, H. Maaßberg, R. Preuss, A. Weller, Yu. Turkin.

- **International H-mode confinement data base**

Contributions from M. Hirsch.

- **ITPA diagnostics**

Contributions from R. König

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

Specialists Working Group on First Mirrors: R. König.

### 2.1.4 Plans for 2009

- **Planning stellarator theory**

1) J. Geiger plans to visit NIFS to work on HINT2 3D code.

2) N. Marushchenko plans to visit TU Graz to work on benchmarking momentum correction techniques.

3) J. Geiger will visit PPPL to work on comparison of PIES and HINT2.

4) C. Beidler, H. Maaßberg, Y. Turkin and N. Marushchenko plan to visit PPPL for international collaboration on neoclassical transport in stellarators.

5) Y. Feng plans to visit PPPL to work on edge physics modelling.

6) A. Runov plans to visit TU Graz to work on modelling of particle and energy transport at the tokamak edge in presence of resonant magnetic field perturbations taking into account shielding of RMSs by the plasma response currents.

7) T. Feher plans to visit Chalmers Göteborg to work on disruption mitigation with doped pellets.

8) A. Könies plans to go to ORNL Oakridge to work on fast particles.

9) P. Xanthopoulos plans to visit PPPL to work on gyrokinetic turbulence simulations.

10) C. Nührenberg plans to go to PPPL to work on MHD perturbed equilibria

11) A. Mishchenko plans to visit University of Marseille to work on gyrokinetic.

12) R. Kleiber plans to visit PPPL to work on turbulence in stellarators.

13) S. Braun plans to visit Chalmers Göteborg to work on impurity transport.

14) P. Helander will go to Culham to work on kinetic instabilities.

- **Spectroscopic diagnostics**

1) M. Krychowiak (IPP Greifswald) plans to visit the FZ-Juelich at least once for three 3 days to work on the development of the visible spectroscopy systems for W7-X.

2) Rainer Burhenn, U. Herbst, E. Pasch, J. Schacht (IPP Greifswald), S. Pingel, 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.

3) 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.

4) R. König (IPP Greifswald) plans to visit KFKI Budapest, Hungary, to continue the design of the W7-X video diagnostic.

5) S. Zoletnik, G. Kocsis, S. Recsei, Szabó Viktor (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 (several visits of about 1 week may be necessary).

2) Several progress and work visits (about 2-4 mutual visits, each 2-6 days) in the frame of a collaboration contract on SX diagnostics between IPP and IPPLM Warsaw are planned involving A. Weller and H. Thomsen of IPP.

3) 2-3 visits (1 up to 1-2 months) between IPP and IST Lisbon are planned in the frame of the collaboration on fast online tomography and data acquisition systems.

- **Neutral particle diagnostics**

1) A visit of Culham Science Centre by Wolfgang Schneider for about 3 weeks is planned in order to continue CX-NPA and CX-RS measurements at MAST with particular consideration of neutral background and magnetic stray field. At CIEMAT,

Madrid a visit of about 4 weeks is planned with respect to ion temperature measurements at TJ-II plasma using an ACORD 24 analyser and with respect to implementing further approximations into the evaluation procedures (W. Schneider).

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 autumn. H. Lambertz and B. Schweer will visit IPP-Greifswald in framework of the RuDIX project in total for about 2 weeks. Test of high voltage power supply is planned. Design of injector components will be closed. T. Richert (IPP Greifswald) 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).

2) Mutual visits (about 2 per year, each about for 2-3 days) in the frame of a 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).

- **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) 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", S. Schmuck will visit CIEMAT (Madrid) and CEA (Cadarache). Vice versa a trainee from IST, Luca Fattorini, will stay at IPP Greifswald for a 3 months training on the Microwave Stray Radiation Launch Facility (MISTRAL) and on ECE design and calibration.

- **International stellarator profile data base**

A. Weller: CWGM5 Stuttgart 2009

- **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 at WEGA at the newly developed 28 GHz OXB-heating regime.

2) A. Fernandez-Curto will visit in IPP-Greifswald for 1 week. Participation on 28GHz EBW heating experiments at WEGA.

3) H. P. Laqua (IPP Greifswald) will visit TJ-2 CIEMAT (Spain) for 1 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 2008).

4) L. Curchod from EPFL-Lausanne will visit IPP Greifswald (1 week). Participation on 28GHz EBW heating experiments at WEGA.

5) H. P. Laqua (IPP Greifswald) will visit of NIFS and Kyoto University, establish a collaboration on ECRH, ECCD and plasma start-up experiments.

- **International collaboration on data validation**

Preparation of VALIDATION 6 with CIEMAT (J. Vega)

- **Conference participation**

1) 5th IAEA TM on “ECRH Physics and Technology for Large Fusion Devices”, 18.02. – 20.02.2009, Gandhinagar, India.

2) G. Kühner: Software Engineering, 02.03. – 06.03.2009, Kaiserslautern, Germany.

3) M. Jakubowski, R. Wolf: Workshop on Stochasticity in Fusion Plasmas (SFP), 02.03. – 04.03.2009, Jülich, Germany.

4) J. Baldzuhn, R. König: Workshop “Active Beam Spectroscopy for plasma control”. 24.03. – 27.03.2009, Leiden, Netherlands.

5) D. Andruczyk, A. Dinklage, P. Drewelow, T. Klinger, S. Marsen, M. Otte, Y. Podoba, S. Schmuck, T. Stange, R. Wolf, D. Zhang: DPG-Frühjahrstagung, 30.3. – 3.4.2009, Greifswald.

6) J. Schacht: IEEE Real Time Conference, 10.05. – 15.05.2009, Beijing, China.

7) H. Dreier, D. Zhang: 36th International Conference on Plasma Science and 23rd Symposium on Fusion Engineering, 31.05. – 05.06.2009, San Diego, USA.

8) 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.

9) G. Michel: 18th Topical Conference on Radio Frequency Power in Plasmas, 24.06. – 26.06.2009, Gent, Belgium.

10) H. P. Laqua, Y. Podoba, S. Schmuck, W. Schneider, H. Thomsen, R. Wolf: 36th EPS Conference on Plasma Physics, 29.06. – 03.07.2009, Sofia, Bulgaria.

11) M. Krychowiak: 14th International Symposium on Laser-Aided Plasma Diagnostics, 21.09. – 24.09.2009, Castelbrando, Italy.

12) H. Braune: 34th International Conference of Infrared, Millimetre and Terahertz Wave (IRMMW-THz), 21.09. – 25.09.2009, Busan, Korea.

13) A. Dinklage, M. Jakubowski, T. Klinger, M. Otte, A. Weller, R Wolf: International Stellarator/Heliotron Workshop 12.10. – 18.10.2009, Princeton, USA.

## 2.2 SPAIN

### 2.2.1 International collaborations in 2008 using TJ-II at CIEMAT

#### - Collaborations with Russia

1) K. Sarksyan and the ECRH IOFAN team participated in the operation of the ECRH system of TJ-II during the autumn 2008 experimental campaign.

2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory visited at CIEMAT in March 2008 (2 weeks) and November 2008 (one month) to maintain and improve the gyrotrons power measurement system.

3) M. Tereshchenko (IOFAN) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA and EBW current drive studies (November 2008).

4) S. Petrov (IOFFE) (June and December) visited CIEMAT to participate on charge exchange spectrometry measurements.

5) N. Kharchev (IOFAN) visited Ciemat in November 2008 (two weels) 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 up-grading of the HIBP system was agreed, including a second HIBP system for long-range correlation studies.

#### - Collaborations in Europe

**Germany**

1) G. Müller and K. Schlüter IPF (Stuttgart) stayed at CIEMAT during two weeks in October 2008 to further continue the improvements in the control system of the gyrotron anode modulators and to collaborate in the installation of the new modulator

that will be transferred in January 2009 from IPP to CIEMAT.

2) Along 2008, Ángela Fernández and Javier Alonso (CIEMAT) have visited IPP-Garching two times to check the tubes and discuss the contract and the work-planning of the high power voltage modulator being built at IPF for the TJ-II Electron Bernstein Heating system.

3) W. Schneider (IPP, Greiswald) was visiting CIEMAT (May) on NPA experiments.

4) E. Sánchez visited Greisfwald (May) to discuss gyro-kinetic code development.

**Portugal**

1) C. Silva and I. Nedzelskiy were visiting CIEMAT to continue our collaboration on edge studies (edge turbulence studies and RFA development) during 2008. Carlos Silva, Andre Neto and Horacio Fernandes have also participated in the development of control and software requirements for JET-EP2 diagnostic enhancement and test in TJ-II facilities (fast camera). Diana Baião visited (October – December) CIEMAT working on soft X-ray diagnostic in TJ-II.

2) L. Guimarais was visiting CIEMAT (June 2008) to continue our collaboration on microwave reflectometry, in particular to investigate edge instabilities in the TJ-II stellarator.

**Hungary**

G. Kocsis and G. Petravich were visiting CIEMAT to participate in the optical coupling design of the JET-EP2 diagnostic enhancement project (including an image intensifier) and testing in TJ-II facilities.

**Czech Republic**

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

- **Collaborations with USA**

1) K. McCarthy visited Oak Ridge NL (November 2008) to discuss the ongoing activities on pellet injector development for the TJ-II stellarator.

2) I. Calvo visited ORNL (March – April) to discuss fractional transport theory.

3) J. Caughman (ORNL) visited CIEMAT in February and December 2008 (one week each visit) to participate in the commissioning of the Electron Bernstein Emission diagnostic.

- **Collaborations with Ukraine**

The Heavy Ion Beam Probe team (leaded 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 2008 experimental campaign. The up-grading of the HIBP system was agreed, including a second HIBP system for long-range correlation studies.

### - Collaborations with Japan

1) E. de la Cal visited Japan (November 2008) for the final implementation of the TJ-II fast visible camera in LHD (loan agreement CIEMAT / LHD) for edge and fluctuation studies in the LHD stellarator.

2) D. Carralero visited Japan (November / December 2008) for the final implementation of the TJ-II fast visible camera in LHD (loan agreement CIEMAT / LHD) for edge and fluctuation studies in the LHD stellarator. First results have shown the parallel and radial dynamics of plasma filaments and the development of edge instabilities in high density regimes.

3) C. Hidalgo visited Japan (December 2008) to discuss the joint LHD / TJ-II collaboration on edge physics (using fast visible cameras) and fast particle physics (including Mach probes and HIBP measurements for the detection of Alfvén mode instabilities and related losses). Planning studies for 2009 would include studies on L-H transition physics and feasibility studies for test particle experiments in LHD (using fast intensified cameras and TESPEL).

4) A. Bustos visited Japan / NIFS (November / December) on fast particle confinement studies in LHD geometry.

5) J. A. Jiménez visited Japan / NIFS (March) to adapt HINT in stellarator geometry (TJ-II).

6) Yasuhiko Takeiri and Masaki Osakabe (NIFS) visited CIEMAT in March 2008 (one week) to discuss the plans for the ongoing colaboration on high-energy particle behavior and Alfven eigenmode in helical systems.

7) Koki Oba and Shigeyuki Takami (NIFS) visited CIEMAT in March 2008 (one week) to interchange operational expertise in the engineeing areas of power supplies, cooling systems and machine control.

8) K. Nagasaki (Kyoto University) visited CIEMAT to participate in ECCD experiments in TJ-II during one week, in February 2008.

### - Collaborations with Australia

David Pretty (ANU) is spending one year, between June 2008 and May 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.

### - International collaborations: stellarator working groups

The 4th Coordinated Working Group meeting (CWGM) was held in Madrid (October 2008) and organized by the “Laboratorio Nacional de Fusión” (CIEMAT National Institute for Fusion Sciences (NIFS). More than 30 experts in stellarator research from

Australia, Germany, Japan, Russia, Spain, Ukraine and the United States of America gathered at the conference to discuss joint activities on high beta physics, 3D effects, 3D divertors, turbulent transport, transport codes, heating and Current drive, impurity transport and stellarator reactor issues.

### 2.2.2 Plans for 2009

EURATOM-CIEMAT team will be involved in the area of concept improvement, thorough the scientific exploration of the Stellarator TJ-II facility. 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. Research activities in the TJ-II stellarator will be focussed in the following topics:

**Optimization and understanding of plasma characteristics and operational regimes for improved concepts:**

- Investigation of plasma conditions (density, hating power, role of magnetic configuration) for the development of edge (H-mode) and core bifurcations.

- Participation in the development of stellarator working groups, including Confinement database (ISCDB), profile Database (ISPDB) and working group for further development of stellarator divertor concepts. Continue the benchmark of Neoclassical Transport codes.

- Full lithium coating in TJ-II: Confinement studies with full lithium coating.

- MHD and fast particle interaction with transport: Characterization of fast particle losses in the TJ-II stellarator: radial localization of Alfvén modes and edge losses.

- Edge and core momentum transport studies. Poloidal and parallel momentum re-distribution mechanisms and toroidal coupling of fluctuations (zonal flow physics).

- Operational limits: Impurity accumulation and dynamics in relation to operational parameters; role of ballooning stability.

- Power and particle exhaust, plasma-wall interaction and studies of de-tritiation methods: Evaluation and design of a Li limiter for the TJ-II central coil “groove”**.**

**Development of plasma auxiliary systems:**

- **Heating:** Full operation of two NBI systems.

- **Plasma-wall:** The TJ-II stellarator was coated with Lithium during 2008. The technique used for lithiumization is evaporation using ovens and the Li is homogenised in the vessel walls by the plasma, which is seen to distribute the Li.

- **Diagnostics:** Further development of TJ-II systems including; construction and installation and first of a new reflectometer antenna system for Doppler reflectometry measurements; Design of a multi-channel filter method for electron temperature measurements; Operation of the HIBP diagnostic for fluctuation and transport measurements; Design of a second HIBP system; Design of a multi-channel filter method for electron temperature measurements Turbulence visualization using intensified fast cameras.

- **Plasma Fuelling:** Distribution of the source and fuelling efficiency in normal and divertor configurations with Li coating.

- **Real Time Measurement and Control:** Development of pattern recognition methods to identify both entire images and subset of pixels within an image. Data mining techniques. Operation of new power supply for dynamic biasing experiments.

**Theory and modelling:**

- NBI Heating: Upgrading of FAFNER2 MC code. EBW heating in TJ-II: Linear estimates (Heating, emission and current drive in 3D systems) and Quasi-Linear Estimates (development of a Fokker-Planck code).

- Modelling of kinetic effects on transport. Wave-particle interaction: Large scale simulation for ions.

- Statistical description of transport processes in fusion plasmas based on the use of probability distributions: Tracer simulations and role of magnetic topology and electric fields.

- Development of the stellarator concept. Divertor stellarator physics: Further studies on flux expension divertor and plate design: heat flux studies on divertor and toroidal limiter.

- Eirene code studies: 3-D simulation of particle sources.

- Computation developments. Grid computing for fusion: Stellarator optimization based on genetic algorithms and VMEC; Neoclassical calculations based on DKESG (DKES ported to the grid) and Global MC codes; FAFNER2 calculations in the grid.

The following collaborations are planned during 2009:

- **Collaborations with Russia**

1) K. Sarksyan and the ECRH IOFAN will participate in the operation of the ECRH system of TJ-II during the autumn 2009 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 will stay in CIEMAT to collaborate in further improvement of TRUBA: including a relativistic current drive module able for EBW. He will also collaborate in the developments of kinetic theory that are foreseen in CIEMAT. The

important point is to deal with 3D geometry using models as exact bas possible and to develop a Fokker-Planck code that can deal with plasma inhomogeneity.

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) N. Kharchev will visit CIEMAT to prepare the design of a gyrotron scattering diagnostic for TJ-II.

- **Collaborations in Europe**

**Germany**

1) G. Müller and K. Schlüter from IPF-Stuttgart will visit CIEMAT in January 2009 to assemble, install, test and start-up the high power voltage modulator built at IPF for the TJ-II Electron Bernstein Heating system.

2) L. Estaben will visit IPP-Greifswald in the framework of the development activities of W7-X diagnostics (CO2 interferometer).

3) H. Laqua will visit CIEMAT in fall 2009 to participate in EBW heating experiments on TJ-II.

4) M. Hirsch will visit CIEMAT in spring 2009 to participate in TJ-II L-H transition physics and Doppler reflectometry.

5) Participation on EFDA Topical Group activities including momentum transport, edge transport, L-H transition physics studies.

6) J. L. Velasco will visit Julich (Germany) to work on the development of IRENE codes.

**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. Guimarais 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) J. Tsai and Phillip Ryan (ORNL) will visit CIEMAT for two weeks in June 2009 to participate in the NBI plasma experiments.

2) J. Caughman (ORNL) will visit CIEMAT in fall 2009 to collaborate in the scientific exploitation the Electron Bernstein Emission diagnostic.

3) I. Calvo will stay at ORNL (January – March) to work on turbulence and transport theory.

- **Collaborations with Ukraine**

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

2) Development of the relativistic dispersion relation will be applied to ITER calculations.

- **Collaborations with Japan**

1) K. Nagasaki (Kyoto University) will participate again in the ECCD experiments in TJ-II stellarator and will continue with the comparative studies in Helical systems.

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) G. Sánchez will visit NIFS to discuss modelling of test particle experiments and its applicability to LHD experiments (using fast camera and TESPEL).

4) We will keep our collaboration on HINT code (equilibrium studies with magnetic islands).

5) K. Nagaoka (NIFS) will visit CIEMAT (March) to participate on fast particle studies (radial localization of Alfvén modes and edge transport using Mach probes).

- **International stellarator working groups**

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

# 3 JAPAN

## 3.1 LHD team at NIFS

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

- **Collaborations with EU**

1) Igitkhanov Juri Levanovich (Max-Plank Institute fur Plasmaphysik, Germany) visited NIFS (A. Sagara and H. Chikaraishi) from 4th February 2008 to 31th May 2008 as a guest professor of NIFS to contribute reactor design studies by investigations on impurity removal by controlling edge plasmas in helical reactors.

2) A. Whiteford (Univ. of Strathclyde, UK) visited NIFS (D. Kato, K. Ikeda and M. Osakabe) from Feb. 19 until Mar. 5, 2008 to study hydrogen neutral beam attenuation at LHD. Doppler shifted Balmer-line profile of the neutral beam was analyzed with ADAS atomic code and database. Electron density dependence of the beam attenuation was investigated.

3) G. O'Sullivan (University College Dublin, Ireland) visited NIFS from 12th February to 7th March to promote international collaboration on the analyses of EUV spectra from highly charged xenon and tin ions observed in LHD, and to identify spectral lines of individual charged states of these ions in the observed spectra.

4) Peter Manz (Institut für Plasmaforschung Universität Stuttgart, Germany, Germany) was awarded ‘Itoh Project Prize 2007’ for his work on experimental study of turbulence on TJ-K, and was invited to Kyushu University and NIFS from February 12 to February 13, 2008. He has given a seminar on “Experimental estimation of nonlinear energy transfer in two- dimensional plasma turbulence” at NIFS and has made a discussion on experimental study of plasma turbulence with K. Itoh and others.

5) Federico Felici (CRPP Lausanne, Switzerland) visited NIFS from 24th February to 16th March 2008 to discuss and develop an intelligent feedback control system of ECRH wave polarization to optimize quickly ECRH heating efficiency during one shot. The control programs were developed and tested at the test stand of low power millimeter-waves. He again visited NIFS from 7th to 26th December 2008. He installed the polarization feedback control system in one of the real LHD ECRH transmission lines and tested its performance during long pulse discharges of LHD experiments.

6) J. Varela Rodriguez (Universidad Carlos III, Spain) visited NIFS (K.Y. Watanabe, Y. Narushima and S. Ohdachi) from Mar. 1st to Jun. 1st in order to study the characteristics of the MHD stabilities in the LHD IDB/SDC plasmas.

7) S. Ohdachi (NIFS) visited IPP Juelich (Juelich, Germany) and discussed about the installation of the fast VUV camera which is being developed with collaboration. He also visited IPP Greifswald (Greifswald, Germany) and made a discussion about the impurity transport code IONEQ with its developer, Dr. Weller.

8) Y. Takeiri and M. Osakabe (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 and discussion on the Alfven eigenmode in TJ-II.

9) Y. Takeiri and M. Osakabe (NIFS) visited Max Planck Institut fur Plasmaphysik (Garching, Germany) from 16th to 20th March 2008 under the Japan-Germany collaboration program (JSPS) for the research and discussion on the development of the RF negative ion sources for the NBI system.

10) L. Garcia Gonzalo (Universidad Carlos III, Spain) visited NIFS (K.Y. Watanabe and N. Nakajima) from Mar. 17th to Mar. 21th in order to study the characteristics of the resistive MHD instabilities in the LHD high beta plasmas.

11) Mamoru Shoji (NIFS) visited CIEMAT, Spain from 24th March 2008 to 31th March 2008 to discuss about introduction of a fast framing camera to LHD and scientific collaboration among NIFS-CIEMAT in plasma image data analyses.

12) H .Sugama (NIFS) visited Universite de Provence (Marseille, France) as an invited Professor during May 25, 2008 through June 1, 2008 and made collaboration with Prof. Benkadda on anomalous transport in fusion plasmas in the framework of Laboratoire International Associe (LIA): France-Japan Magnetic Fusion Laboratory.

13) Y. Suzuki (NIFS) visited Forschungszentrum Juelich GmbH (Juelich, Germany) and Max-Planck Institut fuer Plasmaphysik (Greifswald, Germany) from 9th to 29th Jun. 2008 in the international collaboration on 3D modeling in the tokamak configuration with the resonant magnetic perturbation field. This collaboration results are reported at ITC18 (Toki, Japan, Dec. 2008).

14) Kiyohiko Nishimura, Masaki Osakabe, Hitoshi Miyake, Hiroshi Hayashi, Naoyuki Suzuki, Ryuzo Kawachi and Shinichi Nakagawa visited the Culham Science Centre (Oxfordshire, UK) from 23~27, June 2008 to inspect and to discuss about radioactive protection for D-D and D-T experiments in JET with the JET team.

15) W.Guttenfelder (Warwick Univ., UK) visited NIFS from July 27 to July 31 to discuss the gyro-kinetic simulation of stellarator/heliotron plasmas. The efforts towards the benchmarking between GKV and GS2 codes, and comparison with fluctuation measurements in LHD were extensively discussed.

16) H. Funaba (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) from August 16 to August 28 and built the International Stellarator/Heliotron Profile Database with A.Dinklage and A. Kus.

17) H. Sugama (NIFS) visited Wolfgang Pauli Institute (Vienna, Austria) as an invited speaker in Workshop and Minicourse "Kinetic Equations, Numerical Approaches and Fluid Models for Plasma Turbulence" during Sep.14, 2008 through Sep.21, 2008 and gave lectures on gyrokinetic plasma turbulence

18) K. Aggarwal (Queen’s University of Belfast, UK) visited NIFS (T. Kato and I. Murakami) from Sep. 22 to Oct. 23, 2008 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 XIV which are necessary for a kinetic model of plasma spectroscopy.

19) Katsunori Ikeda (NIFS) attended ADAS workshop 2008 at Forschungszentrum Jülich in Germany from September 29 to October 3 to discuss about optical diagnostic technique of neutral beam attenuation used the ADAS atomic data base.

20) M. Yokoyama (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) from October 7 to October 18 and continuously extended the international collaboration on the International Stellarator/Heliotron Profile Data Base. Sample CERC data were compiled from LHD and W7-AS, and they have been ready for open access.

21) H. Kasahara (NIFS) visited “Centre de Recherches en Physique des Plasmas” (CRPP Lausanne, Switzerland) on October 15 and discussed the progress of the newly designed high-power (2MW) gyrotron oscillator, the collaboration for R&D of RF components and RF heating system using real-time feedback control.

22) Daniel Carralero Ortiz, CIEMAT, Spain, visited NIFS (H. Yamada and M. Shoji) from 4th Nov. 2008 to 17th Dec. 2008 to support introduction of a fast framing camera to LHD and for measurement of peripheral plasma transport and plasma-wall interactions in LHD.

23) Eduardo de la Cal, CIEMAT, Spain, visited NIFS (H. Yamada and M. Shoji) from 6th Nov. 2008 to 14th Nov. 2008 to conduct introduction of a fast framing camera to LHD and for discussion about plasma image data analyses and the hard-ware setup of the camera.

24) Andres Molina De Bustos (CIEMAT, Spain) visited NIFS (M. Osakabe and Y. Takeiri) from 1st to 18th December 2008 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 Alfven eigenmode in LHD.

25) Carlos Hidalgo (CIEMAT, Spain) visited NIFS (K. Nagaoka and Y. Takeiri) from 9th to 17th December 2008 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the research and discussion on the high-energy particle behavior and its correlation with the magnetic fluctuation through the exploitation of the HIBP and the directional probe diagnostics in TJ-II and LHD.

- **Collaborations with US**

1) S. Toda (NIFS) visited University of California, San Diego (Host: P.-H. Diamond) from January 16 to February 8, in order to study the transport modelling of the role of zonal flows in the transport equations in helical and tokamak plasmas for the theoretical research of the internal transport barrier under the JIFT program.

2) A. Sagara and T. Muroga (NIFS) visited University California, San Diego from 3rd February to 10th February 2008 to promote the blanket modeling workshop as the common task coordinator in the J-US project TITAN, and discussed the next year program in the steering committee meeting of TITAN.

3) A. Shimizu (NIFS) visited the plasma physics group of university of Wisconsin (Madison) from 24th to 31st Mar. to discuss about the resent results of heavy ion beam

probe (HIBP) measurements in MST (Madison Symmetric Torus) and LHD and collaborations.

4) S. Yoshimura (NIFS) visited Massachusetts Institute of Technology (MIT, USA) from 15th February 2008 to 28th April 2008 to collaborate with B. Labombard and N. Smick on the ion flow measurement in scrape-off layer of Alcator C-mod plasma using the wall-actuated scanning probe (WASP) developed by them.

5) H. Funaba (NIFS) visited Princeton Plasma Physics Laboratory (Princeton, USA) from February 23 to March 2 and discussed impurity transport on NSTX/ LHD with H. W. Kugel, R. Kaita and M. Ono.

6) US-Japan Workshop on "Development of Advanced Millimeter and Submillimete Wave Diagnostics for Fusion Plasmas" was held from 25 to 27 February 2008 at University of California, Davis, USA. About 25 attendants including 6 from Japan discussed on such subjects as the development on millimeter- to submillimeter-wave devices, circuits and detectors, the use of advanced techniques for device fabrication, the status of diagnostics techniques such as interferometry/polarimetry, reflectometry, ECE imaging, and imaging reflectometry on LHD, TEXTOR, NSTX, and TST-2. The future application plans of imaging diagnostics to DIII-D and KSTAR were also discussed.

7) Y. Yoshimura (NIFS) visited Princeton Plasma Physics Laboratory (Princeton, USA) to attend US-Japan RF Physics workshop held from 2008. 2. 27 to 28, and made a presentation titled as "EBW and ECCD activities in NIFS". Topics about ECRH physics were discussed with other participants.

8) N. Tamura (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) from Mar. 2nd to Mar. 23th to analyze and discuss the experimental data related to the TESPEL injection on NSTX with Dr. H. W. Kugel (PPPL), Dr. D. Stutman (Johns Hopkins Univ.) and other researchers.

9) H. Miura(NIFS) visited Institute for Fusion Studies (University of Texas at Austin, the United States) from March 5 to March 21 for the purpose of the collaboration research with S. Mahajan on the superimpose of nonlinear waves in the Hall-MHD system.

10) S. Nishimura (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) from March 17 to 21, 2008 for a collaborative study on the stellarator transport physics. After this visit, he attended also 21st US transport taskforce workshop held at Boulder, Colorado, USA, in March 25-28, to report this activity of the US-Japan collaboration.

11) M.Sato(NIFS) visited University of Washington from 27th March to 15th May to develop a full implicit solver in spectral finite element method code with Dr. Glasser, and University of Texas from 15th May to 31st May to discuss hierarchy-renormalized simulation approach.

12) Noah Meade Smick (MIT, USA) visited NIFS from 2nd August 2008 to 9th August 2008 to discuss the collaboration on plasma flow measurement using a pyramid-shaped Gundestrup probe which has been used at Alcator C-Mod. A preliminary experiment using a directional Langmuir probe was conducted with the HYPER-I device at NIFS.

13) Shahram Sharafat (University California, San Diego) visited NIFS (A. Sagara) from 3rd August to 7th August as a personal exchange under the J-US joint project TITAN to discuss material modeling by a helium bubble evolution code under MFE/IFE conditions.

14) Takashi Shimozuma, Tetsuo Seki and Hiromi Takahashi (NIFS) attended "US-EU-Japan workshop on RF Heating Technology" held at General Atomics, USA from 10th to 12th, September 2008 to discuss about R&D and collaborations among US-EU-Japan in the RF heating technology.

15) S. Satake (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) (Host: W. X. Wang) from Oct. 22 to Dec. 22 under the JIFT program, and discussed about the simulation method of neoclassical transport calculation in helical plasmas, and its application to neoclassical toroidal viscosity calculation in tokamak with weak toroidal magnetic ripples.

16) H. Sugama (NIFS) visited Dallas, Texas, USA during Nov.16, 2008 through Nov.23, 2008 for collaboration with Prof. W. Horton (IFS, University of Texas at Austin) on plasma turbulent transport and attended 50th Annual Meeting of the Division of Plasma Physics of the American Physical Society to give a talk on "Turbulent Transport Regulation by Zonal Flows in Helical Systems with Radial Electric Fields" as an invited speaker.

17) D. R. Mikkelsen (PPPL) visited NIFS from December 8 to 16 for attending the 18th International Toki Conference and for discussions on the stellarator transport physics with NIFS members.

- **Collaborations with Russia**

1) Dr. Vyacheslavov (Budker Institute of Nuclear Physics) visited NIFS from Jan. 7 to Mar. 9 and analyzed the turbulence in LHD measured by CO2 laser diagnostics. The rapid change of fluctuation spatial structure at the H mode transition was studied.

2) I. Miroshnikov (St. Petersburg Technical University, Russia) visited NIFS (S. Sudo and N. Tamura) from Jan. 9th, 2008 to Feb. 3rd, 2008 in order to study the configuration of the pellet ablated cloud by measuring a Stark broadening with a spatial resolution on LHD.

3) A.V. Melnikov (Russian Research Centre "Kurchatov Institute", Russia) visited NIFS (T. Ido) from January 31, 2008 to February 14, 2008 in order to discuss experimental results of zonal-flow measurement by using heavy ion beam probes (HIBPs) and to join the development of a HIBP for LHD.

4) M. Isaev (Russian Research Centre "Kurchatov Institute", Russia) visited NIFS (K.Y. Watanabe and M. Yokoyama) from Feb. 5th to Mar. 24th in order to make the comparative analysis with experimental results on the bootstrap current and install the VENUS+df code in NIFS.

5) I. Miroshnikov and I. Sharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from Dec. 6th, 2008 to Dec. 30th, 2008 to study the spatial structure of pellet ablation cloud by measuring a Stark broadening with a spatial

resolution on LHD.

- **Multi-lateral collaboration**

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, and successfully produced 4 joint papers at the 22nd IAEA-FEC (Oct. 2008). The series of CWGM has been steadily extended to become really the representative multi-lateral collaboration in Stellarator/Heliotron research.

H. Yamada, M. Kobayashi, S. Nishimura, S. Sakakibara, Masahiko Sato, Y. Suzuki, M. Yokoyama and Tomohiko Watanabe (NIFS), and T. Mizuuchi, K. Nagasaki and A. Matsuyama (Kyoto Univ.) attended the 4th CWGM (20-22, Oct. 2008 at CIEMAT, Madrid, Spain). Discussions on reactor assessment, turbulent transport, and 3D effects on confinement were newly launched based on the progress and the extension of CWGM collaboration. The importance of setting up the network of engineering researchers, information exchange with the benchmark activity of the gyro-kinetic turbulent simulation codes, and the demonstration of the powerfulness of the 3D analysis codes for the application also to tokamak plasmas, were discussed. H. Yamada acted the coordinator of the reactor session, so as T. Watanabe (turbulent transport), Y. Suzuki (3D effects on confinement), K. Nagasaki (Heating and current drive) and M.Yokoyama (Integrated/predictive transport codes). H. Yamada and M. Yokoyama involved organize this CWGM (launch of the new session, call for participants etc).

The further promotion of the collaboration was agreed and the possibility of the 5th meeting (in 2009) was also discussed.

### 3.1.2 Plans for 2009

1) Dr. Vyacheslavov (Budker Institute of Nuclear Physics) will visit NIFS and analyze the turbulence in LHD measured by CO2 laser diagnostics. The rapid change of fluctuation spatial structure at the H mode transition will be studied.

2) Dr. Michael (EURATOM/UAKEA Fusion Association, Culham Science Center) will visit NIFS and discuss with Dr. Tanaka about CO2 laser diagnostics to measure electron density fluctuation and electron density profile. He will prepare publication for fluctuation analysis during his stay.

3) M. Isaev (Russian Research Centre "Kurchatov Institute", Russia) will visit NIFS (K.Y. Watanabe and M. Yokoyama) from Feb. 25th to Mar. 30th, 2009 in order to extend the VENUS+df code to apply the LHD plasmas with the static magnetic islands and to apply the LHD experimental results.

4) Dr. Kubo (NIFS) and Dr. Nishisura (NIFS) will visit TEXTOR Julich Germany and IPP Greiswald Germany to discuss the spectrum analysis of collective Thomoson scattering. They will join experiment of collective Thomson scattering on TEXTOR.

5) Dr. Kharchev (General Physics Institute) will visit NIFS and discuss with Dr. Tanaka, Dr. Kubo and Dr. Nishiura about collective Thomson scattering. Collective Thomson

scattering is newly developing diagnostic to measure ion temperature.

6) T. Ido(NIFS) will visit CIEMAT for 1 week in March 2009 to join experiments using HIBPs and to discuss experimental data relating to electric field and its fluctuation in LHD, T-10, and TJ-II.

7) M. Yokoyama (NIFS) will visit Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) to continue and extend the collaborative work on the International Stellarator/Heliotron Profile Data Base.

## 3.2 Heliotron J team at Kyoto University

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

- **Collaborations with Australia**

1) D. Pretty (ANU) visited Kyoto Univ. for a month on January 21 – February 18 to participate in the Heliotron J experiment. Collaboration of the data analysis for the MHD instabilities was performed.

2) B. Blackwell (ANU) visited Kyoto Univ. for three month on December 16 – March 31 (2009) as a guest professor to participate in the Heliotron J experiment. Collaboration of the MHD analysis by using SVD method and tomographic technique, ECH system and data acquisition was performed.

3) Discussions with H-1NF team (ANU) were kept along the same line as in 2007.

- **Collaborations with EU**

1) K. Nagasaki visited CIEMAT on February 24 – March 4 to participate in the TJ-II experiment with A. Cappa, and A. Fernandez. Furthermore, he discussed the ECH/ECCD collaboration research program between CIEMAT and IAE Kyoto Univ.

2) T. Mizuuchi visited Spain on May 24 – June 2 to participate in 18th International Conference on Plasma Surface Interactions. He reported the recent Heliotron J experimental results and discussed the collaboration plan in the measurement of edge plasma turbulence.

3) A. Matsuyama visited CIEMAT on October 18 – October 26 to discuss his recent studies related to the stellarator kinetic theory, participating in the kinetic theory workshop (KTW) at Madrid.

4) T. Mizuuchi visited CIEMAT on October 18 – October 26 to participate in the 4th Coordinated Working Group Meeting at Madrid. He also discussed the collaboration research program between CIEMAT and IAE Kyoto Univ.

5) K. Nagasaki visited CIEMAT on October 18 – October 26 to participate in the 4th Coordinated Working Group Meeting at Madrid. He also discussed the collaboration research program between CIEMAT and IAE Kyoto Univ.

6) V. Zhuravlev (Kurchatov, Russia) visited Kyoto Univ. on September 1-September 14

and participated in the Heliotron J experiment. Collaboration of the microwave AM reflectometer for electron density profile measurement was performed.

7) D. Carralero (CIEMAT) visited Kyoto Univ. on November 28 to discuss the research collaboration for the plasma diagnostic with a high-speed video camera.

8) Collaborations with CIEMAT were continued along the same lines as in 2007.

- **Collaborations with China**

1) Chen Wei (SWIP, China) visited Kyoto Univ. as a guest researcher for three weeks (December 2-December 23). He joined the Heliotron J experiment related to the development of SMBI system and related plasma physics.

2) T. Mizuuchi visited China on November 3- November 9 to participate in the JSPS-CAS Core University Program Seminar and had a lecture of overview of recent Heliotron J experiments.

3) Gao Xiang (Chinese Academy of Sciences) visited Kyoto Univ. on December 19 to discuss the research collaboration for fusion and plasma studies.

- **Collaborations with US**

1) H. Okada visited PPPL to participate in the RF workshop on February 26 – March 3. He discussed the research collaboration program of RF current-drive experiment and theory.

2) K. Nagasaki visited US to participate in the Electron Cyclotron Emission and Electron Cyclotron Heating on March 9 – March 16. He discussed the research collaboration program of ECCD/ECH .

- **Others**

1) Confinement control of high energy particles by using the optimized field configuration based on the quasi-isodynamic concept was examined through NBI/ICRF experiments.

2) The details of the bulk confinement properties were studied experimentally from the viewpoint of the bumpiness control, the toroidal current control, and the fuelling physics and theoretically in Heliotron J.

3) Advanced ECH scenarios including ECCD and EBW heating/current drive were examined through Heliotron J/LHD experiments.

4) New gas fuelling by supersonic molecular beam injection (SMBI) was successfully applied to ECH/NBI plasma in Heliotron J. The optimization studies of this fuelling method are in progress.

5) Discussions with U-3M team (Kharkov) were kept along the same line as in 2007 and also started the discussion about the divertor plasma energy analyzer.

### 3.2.2 Plans for 2009

1) I. M. Pankratov (Kharkov) will visit Kyoto Univ. as a guest professor for three month (December 26, 2008 -March 31) to participate in the Heliotron J experiment. The divertor design studies and high-energy particle confinement studies in Heliotron J will be carried out with a viewpoint of the collaboration with U-3M team.

2) B. Blackwell (ANU, Australia) will participate in the Heliotron J experiment until March 31 (three months). Collaboration of the MHD analysis by using SVD method and tomographic technique, ECH system and data acquisition will be performed.

3) D. Pretty (ANU, Australia) will visit Kyoto Univ. to participate in the Heliotron J experiment. The MHD activity in the Heliotron J plasma will be discussed using data mining technique with SVD method.

4) 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.

5) 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.

6) 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.

7) Comparable study on ECCD will be experimentally carried out among TJ-II, Heliotron J, CHS and LHD.

8) Transition phenomena related to the high confinement mode in NBI and ECH plasmas will be investigated using current control by NBCD, ECCD and bootstrap currents.

9) SMBI experiments will be performed to investigate the confinement improvement in Heliotron J especially by the collaboration with SWPI.

10) MHD activity control in higher beta plasmas through the field configuration optimization will be tested in Heliotron J.

11) The divertor study in the helical-axis heliotron configuration is to be started in Heliotron J.

# 4 RUSSIA

## 4.1 International collaborations

- **Collaboration between General Physics Institute (GPI) and CIEMAT (Spain)**

Five persons participated in joint GPI-CIEMAT works
(total duration of visits :7.5 month-persons)
Kovrizhnykh ( 1 month.)
Sarksyan ( 1 month)
Kharchev ( 1,5 months)
Bondar (2 months)
Dorofeyuk (2 months)

In 2008 in accordance with agreed program of joint activity next tasks were fulfilled:

**1) Scattering on plasma density fluctuations diagnostic on TJ-II with the use of ECRH gyrotron radiation.**

a) The proposal of new system for scattering diagnostic with the use of first and second harmonic of gyrotron radiation was developed. The proposal was considered in CIEMAT and approved with its realization in 2009.
b) Technical part of measurements of gyrotron radiation second harmonic was prepared.

**2) Gyrotron power modulation experiment**.

The investigations of gyrotron response on small-reflected signal were continued. New results were got. These results were presented in joint report on International Workshop "Strong microwave sources and applications "2008, N.Novgorod, Russia. Two articles were prepared for publication in corresponding journal in 2009.

**3) Exploitation of gyrotron complex. Participation in exploitation of gyrotron complex on TJ-II.**

**4) Maintenance works on the Microwave Energy Measurement Device on TJ-II**

- **Collaboration between GPI and NIFS (Japan)**

**1) Preparing and publication of the joint report on Control of Gyrotron by Modulated Remote Reflector and article in the journal Review of Scientific Instruments.**

**2) Preliminary agreement on participation of GPI scientists in the new Thomson scattering diagnostic experiment on LHD.**

**Joint publications**
As a result of this collaboration some joint papers were published:

[1] J.A.Jimenez, E. De la Luna, I.Garcia-Cortes, *S.V.Shchepetov*.

Localized Electromagnetic modes in MHD stable regime of the TJ-II Heliac.
Plasma Phys.Control. Fusion, v. 48, № 5, 515-526 (2006)
[2] A.Cappa, F.Castejon, D.Lopez-Bruna, A.Fernandez, *M.Tereshchenko*, E.Holzhauer, A.Kohn, S.Pavlov.
Summary of EBW theoretical calculations in the TJ-II stellarator.
Proc. of 15th Joint Workshop on ECE and ECRH, Yosemite National Park, USA, 2008.
[3] F.Castejon, A.Cappa, *M.Tereshchenko*, A.Fernandez.
Computation of EBW heating in the TJ-II stellarator.
Nuclear Fusion, 2008, Vol.48, 075011.
[4] J.M.Garcia-Regana, F.Castejon, A.Cappa, *M.Tereshchenko*.
Linear estimation of Electron Bernstein Current Drive (EBCD) in inhomogeneous plasmas.
35th EPS Plasma Physics Conference, Hersonissos, 2008, ECA Vol.32, P-1.107
[5] S.S.Pavlov, F.Castejon, A.Cappa, *M.Tereshchenko*.
Fast computation of the exact plasma dispersion functions.
Proc. of Int. Conference and School on Plasma Physics and Controlled Fusion, Alushta, 2008.
[6] A. Fernandez, *N. Kharchev, G. Batanov* et al.
VII Jnt. Workshop, “Strong microwave sources and applications”
N.Novgorod, Russia . 2008 ,
17th Technical Conf. on High-Temp Plasma Diagn. Albuquerque, New Mexico, May 2008.
[7] *N. Kharchev*, K. Tanaka, S. Kubo et al.
Review of Scientific Instruments. <u>79</u>, 10E721 (2008)

- **Collaboration between Kurchav Institute (Russia), Max-Planck (IPP, Germany) and Centre de Recherches en Physique des Plasmas (Switzerland)**

**Topic:** Numerical steady of stellarator optimization.

**Visits:**
Prof. J. Nuehrenberg, IPP, Greifswald, two visits to Kurchatov Institute, 4 days each (April, October).
M.I. Mikhailov, Kurchatov, two visits to IPP, Greifswald, two month each (June-July, November-December).

**Joint publications**

[1] V.R. Bovshuk, *M.I. Mikhailov*, *V.D. Shafranov*, J.N. Nuehrenberg, W.A. Cooper.
Exploration of Configurational Space for QI Stellarators with Poloidally Closed Contours of B.
22 IAEA Fusion Energy Conference, Geneva, 2008.
[2] J. Nuehrenberg, R. Zille, *M.I. Mikhailov, V.D. Shafranov*,
Neoclassical Transport in Stellarators without Collisionless Ion Losses.
Plasma Phys. Reports, 2008, (34) 525-527.
[3] V.R. Bovshuk, W.A. Cooper, *M.I. Mikhailov*, J. Nuehrenberg, *V.D. Shafranov*.
Search for Very-High-β Stable Quasi-Isodynamic Configurations.
Plasma and Fusion Research, vol. 3 2008, pp. S1046-1 -- S1046-5.

### 4.2 Research plans for 2009

- **GPI**

1) Carrying out ECRH experiments on plasma creation and confinement in the L-2M stellarator at high heating powers up to 0.6 MW (at average specific powers up to 2.2 $MW/m^3$).

2) Assembling, adjustment and test of a new submillimeter twin-wave (0.22 mm and 0.118 mm) Michelson interferometer in ECRH experiments at high heating powers up to 0.6 MW. Carrying out first measurements of the radial density profiles at multichord plasma probing.

3) Updating of diagnostic equipment for studying turbulence characteristics by collective scattering of radiation of the second gyrotron harmonic by plasma density fluctuations. Carrying out first measurements in experiments with gyrotron heating powers up to 0.6 MW.

- **Kurchatov Institute**

To continue the exploration of the stellarator configurational space. Study of stability in systems with more elaborated structure of period. Study of N=4 stellarator with poloidally closed contours of the magnetic field strength.

# 5 UKRAINE

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

#### 5.1.1 International collaborations of the NSC KIPT in 2008

#### 5.1.1.1. International collaborations of the plasma theory division

- **Collaborations with Technische Universität Graz, Austria**

1) Study of the velocity of the poloidal motion of trapped particle orbits for stellarators in real-space coordinates (V.V. Nemov and S.V. Kasilov in collaboration with W. Kernbichler and G.O. Leitold (Technische universität Graz, Austria)).

2) Calculations of 1/v transport for Uragan-2M in the regime of $k_\varphi$ =0.295 taking into account the influence of the current-feeds and detachable joints of the helical winding. (V.V. Nemov, V.N. Kalyuzhnyj, S.V. Kasilov, G.G. Lesnyakov in collaboration with B. Seivald and W. Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria) and N.T. Besedin (Kursk State Technikal University, Russia)).

3) Study of the coefficients of diffusion and heat conductivity in the long-mean-free-pass regimes for the Uragan-2M torsatron (S.V. Kasilov, V.N. Kalyuzhnyj and V.V. Nemov in collaboration with W. Kernbichler (Technische universität

Graz, Austria)).

### - Collaborations with NIFS, Japan

Development of the new method of selective cold alpha-particles removal from the fusion helical plasma (A. Shishkin in collaboration with O. Motojima and A. Sagara).

### - Collaborations with CIEMAT, Madrid, Spain

1) Pavlov S.S., collaborating with CIEMAT (Madrid, Spain) team (Castejon F., Cappa A., D. Lopez-Bruna, A. Fernandez, Tereshchenko M.) and E. Holzhauer, A. Kohn (Institute of Plasmaphysics, Stuttgart University, Stuttgart, Germany) went on to study influence of relativistic effects on the Electron Cyclotron plasma heating in conditions of stellarator.

2) An overview of the main Electron Bernstein Wave (EBW) plasma heating theoretical results obtained for conditions of the TJ-II stellarator is presented. CIEMAT team and E. Holzhauer, A. Kohn , S.S. Pavlov // $15^{th}$ Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonanse Heating, March 2008, Yosemite National Park, California, USA, fusion.gat.com/conferences/ec-15, Book of abstracts.

3) The general method to evaluate the fully relativistic plasma dispersion functions on the base the theory of Cauchy-type integrals, related to the Reactor plasma conditions, is presented. F. Castejon, S.S. Pavlov // Nuclear Fusion, 48, №5, 2008, 48 054003. The method of fast calculations of the weakly relativistic and fully relativistic plasma dispersion functions on the base of Jacobi continued fractions is presented. Pavlov S.S. and CIEMAT team. Alushta-2008 International Conference-School on Plasma Physics and Controlled Fusion, Alushta (Crimea), 2008, Book of abstracts, p. 103.

## 5.1.1.2 International collaborations of the plasma experiment divisions

### - Collaborations with NIFS, Japan

1) The of surfaces of SS and Cu mirrors exposed in LHD during 7th experimental campaign and in He glow discharge (in collaboration with S. Masuzaki and N. Ashikawa) were investigated with the use of SEM and XPS methods. The results are being analyzed in comparison with those obtained in previous joint experiment on LHD.

2) Basing on results of joint paper published in 2006, (V. Voitsenya in collaboration with S. Masuzaki, O. Motojima, and A. Sagara), the preparation was began to provide in 2009 the experiments on application of ECH+RF discharges in the mixture of hydrogen with nitrogen for the wall conditioning of the Uragan-2M torsatron when preparing the device to plasma experiments in working regimes.

### - Collaborations with CIEMAT, Madrid, Spain

1) Improvement of the Heavy Ion Beam Probe facility and measurement procedure on TJ-II: installation and tuning of the two-slit detector units in the HIBP analyzer on the TJ-II (entrance slits and 8-detector plates were installed exactly with trajectory calculations); some trends application for friendly signal/spurious noise suppression; increasing the primary probing beam intensity up to 80-100 mkA (Dr. L.I. Krupnik et al

(IPP NSC KIPT) in collaboration with Dr. C.Hidalgo and TJ-II team (CIEMAT)).

2) Providing of the experiments with the upgraded analyzer on the TJ-II Stellarator. Experiments were performed according to the program of the potential profile evolution with density rise (two injectors (NBI1 and NBI2) were used). It was investigated: $E_r$ evolution with density; Core turbulence reduction at ECRH/NBI transition; ECRH+NBI - peculiarity in potential – Te profiles; Alfven mode characterization; B/Li discharges - experimental comparison.

3) Development of the Second Heavy Ion Beam Probe diagnostic system for TJ-II: Calculations of the probe beam trajectories and optimisation of the installation conditions for second HIBP; Designing of the primary beam injector for the second HIBP (Dr. L.I. Krupnik et al).

- **Collaborations with IPP, Greifswald, Germany**

The first plasma potential and total secondary current profiles measurements results are presented in comparison with Langmuir probes data. Results of HIBP measurements are in good agreement with Langmuir probes data (Dr. L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. M. Otte, Yu Podopa and WEGA team).

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

Investigations of the plasma potential behavior in the plasma edge. Measurements of the plasma fluctuation in regimes of the GAM. Comparative study of the plasma electric fields behavior in the T-10 tokamak and TJ-II stellarator during ECR heating (Dr. L.I. Krupnik and HIBP team (IPP NSC KIPT in collaboration with Dr. A.V. Melnikov and T-10 team (Kurchatov Institute).

### 5.1.2 Plans for 2009 of the IPP NSC KIPT

#### 5.1.2.1. Plans for 2009 of the plasma theory division

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

1) Elaboration of a new technique of the $\nabla\psi$ calculation in real space coordinates for a stellarator magnetic field with the broken stellarator symmetry (V.V. Nemov and S.V. Kasilov in collaboration with Technische universität Graz, Austria).

2) Numerical study of a bootstrap current in Uragan-2M in the 1/v regime for the case of the magnetic field with a broken stellarator symmetry (V.V. Nemov, S.V. Kasilov, G.G. Lesnyakov and V.N. Kalyuzhnyj in collaboration with Technische universität Graz, Austria).

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

1) Usage of the fast algorithm computing the weakly relativistic and exact relativistic plasma dispersion functions for investigations of the EBW plasma heating in the TJ-II stellarator and other traps. (S.S. Pavlov in collaboration with F. Castejon).

2) Investigation of relativistic effects in the ICR frequency range in the regime of conversion of fast mode of fast magnetosonic wave into ion cyclotron plasma waves near resonances $\omega = n\omega_{ci}$. (S.S.Pavlov in collaboration with F.Castejon).

### 5.1.2.2. Plans for 2009 of the plasma experiment division

- **Collaborations with NIFS, Japan**

1) The work on the draft of paper “Plasma cleaning of the surfaces from oxides: the state of the art” by V. S. Voitsenya and S. Masuzaki is planned to be finished with possible printing as a NIFS Report in 2009.

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 is planned to be modified and printed as NIFS Report in 2009.

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

Investigation of effects of helical ripples on confinement of plasma in helical fusion devices (I.M. Pankratov and Kyoto Univ. team).

- **Collaborations with Spain (CIEMAT, Madrid) and Russia (Kurchatov Institute)**

Preparation of the equipment for providing the boronization procedure in the U-2M torsatron.

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

1) Investigations of the evolution of plasma potential, electron density and their fluctuations in combined ECR and NBI heating regimes and in various operational modes in the TJ-II stellarator with two sleet energy analyzer.

2) Manufacturing and installation of the Primary beam injector for the second HIBP system of the TJ-II stellarator.

- **Collaborations with Germany (IPP, Greifswald)**

1) Investigations of the ECRH power deposition (with using modulated gyrotrons) by the HIBP diagnostic. Studies of the plasma potential fluctuations.

2) Investigations of the plasma parameters and their fluctuations inside the magnetic islands and in the X-point of WEGA magnetic configurations without changing the magnetic configuration itself.

- **Collaborations with Russia (Kurchatov Institute, Moscow)**

1) Development and installation of the multiply cell array detector.

2) Investigations of the plasma potential behavior and its fluctuations in regimes of the

GAM. Comparative study of the plasma electric fields behavior in the T-10 tokamak and TJ-II stellarator during ECR heating.

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

1) The review paper with analysis of the results of measurements of magnetic surfaces in Uragan-2M torsatron will be finished and prepared for publication.

2) Optimisation of regimes of surface cleaning in Uragan-2M torsatron using different combination of ECR, RF and glow discharges in $H_2$ or $H_2$+$N_2$ mixture will be continued.

3) The preparation of all equipment for providing the boronization procedure in the U-2M torsatron will be finished.

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

5) It is planned to test the pumped limiter vacuum system in work regimes of U-2M torsatron and to design the limiter head plate system.

6) Continuation of investigations of the processes accompanying the ITB and ETB formation in plasma of Uragan-3M torsatron under the RF plasma heating. Effects of transport barrier formation on divertor flow characteristics, in particular, on fast ion loss due to outflow to the divertor.

7) Continuation of investigations of divertor plasma flow characteristics in conditions of transport barriers formation.

8) 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. Is this asymmetry really connected with that of fast ion loss?

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

10) It is planned to carry out the experiments with the use of the W limiter with controlled hydrogen recycling in order to estimate the influence of the hydrogen state (desorbed from metal and usual molecular hydrogen) on plasma characteristics in the U-3M torsatron.

11) Investigations of the new HIBP injector with addition pre-injector system up to 150-200 keV of the primary beam energy for Uragan -2M at the HIBP test-stand.

12) Development and calculation of the Li-beam injector for Beam Emission Spectroscopy diagnostic for U-2M.

## 5.2 Karazin National University, Kharkov

### 5.2.1 International collaboration in 2008

- **Collaborations with Max-Planck Institut für Plasmaphysik**

**(MPIPP), Germany**

1) For simulating the processes of plasma-wall interaction in fusion reactors high-current stationary ion source of Hall type with ballistic and reversible magnetic focusing is developed. The coefficient of beam compression in the respect of current reaches 40 if diameter of the beam in the plane of the crossover is of 1 mm. If the current of the ion beam is equal to 200 mA and average energy of ions is 2 KeV then it corresponds to power density of nearly 20 $Mw/m^2$ that is close to parameters of ion flows on a wall in modern stelalrators.

The results of this research were published in the following papers and reported at the conferences:

1. I.A. Bizyukov, A. Mutzke, R. Schneider, A. Gigler, K. Krieger, *Morphology and changes of elemental surface composition of tungsten bombarded with carbon ions*// Nuclear instruments and methods in physics research. b. Vol. 266, p. 1979-1986, (2008).
2. M. Gutkin, I. Bizyukov, A. Bizyukov, V. Sleptsov, K. Sereda, *Focused anode layer ion source with converged and charge compensated ion beam (falcon)*// Patent application publication. Pub. No. Us 2008/0191629 a1.
3. I.A. Bizyukov, A. Mutzke, R. Schneider, A. Gigler, K. Krieger, *Morphology and changes of elemental surface composition of tungsten bombarded with carbon ions*// Nuclear instruments and methods in physics research. b. Vol. 266, p. 1979-1986, (2008).
4. A.A. Bizyukov, A.I. Girka, K.N. Sereda, E.V. Romaschenko, *High-intensive Hall-type ion source with ballistic and magnetic beam focusing*// p. 164.

2) A number of experiments have been carried out at MPIPP 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. It has been upgraded for further experiments which are planned for the period of the next visit of sandwich PhD student A.Onishchenko to MPIPP since January, 15th 2009 till July, 14th, 2009. During his training A. Onyshchenko has written some computer programs and has carried out statistical calculations.

Complex researches of influence of an irradiation of composite thin-film structures of tungsten and copper which are deposited on stainless steel are carried out at Problem Laboratory of Ion Processes of the University (the manager - Professor V.V.Bobkov) by ions of deuterium of average energies on their physical properties:

- accumulation of the implanted particles of deuterium;
- structure-phase changes of the irradiated materials.

The system of controlling the work function of electrons during the ion bombardment of the solid surface is developed.

The results of the experiments carried out in the collaboration with physicists of the Technologie Division (in which PhD student A. Onyshchenko studies) have been reported:

R. D'inka, A. Onyshchenko, F. Braun, G. Siegel, V. Bobkov, H. Faugel, J-M. Noterdaeme, *Characterization of arcs in ICRF transmission lines*// 25th Symposium on Fusion Technology (SOFT 2008), 15-19 September 2008, Rostock, Germany.

- **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 in the temperature range 300÷1500 °K 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. The radiation enhanced sublimation of carbon and formation of methane (with subsequent volatilization) on mixed carbon - tungsten surface were studied. Temperature dependence of intensity of methane radiation was found out which resulted in the decrease of carbon losses from the surface with the temperature increase. The radiation enhanced sublimation of carbon has been detected out.

- **Collaborations with Colorado School of Mines (CSM), USA**

The investigation of mechanisms of optical emission and optical absorption of complex oxides prospective for devices of plasma diagnostics subjected to ionizing irradiation. Research was carried out by University group (V. Gritsyna, V. Bobkov, Yu. Kazarinov, A. Moskvitin) in collaboration with the group from CSM (I. Reimanis).

There were provided investigations of processes of optical emission from complex oxides under ion bombardment. As complex oxides there were chosen magnesium aluminates spinel crystals and ceramics which is highly radiation resistant material. Photon emission was stimulated by bombardment with mass-separated $Ar^+$-ion beam at an energy of 20 keV and density current of 10 µA/cm$^2$. The lay-out of equipment allowed to measure emission of photons from sputtered exited atoms and ions. The yield of particles in different exited states was defined as the flux of excited particles divided by the flux of incident ions. There were observed in excited states Mg and Al atoms, $Mg^+$, $Al^+$ and $Al^{2+}$ ions spontaneous decay of which leads to optical emission. No emission from oxygen atoms or ions was registered. The dependences of yield of all particles in different excited states on the composition of spinel crystals quantitatively do not reflect the variation of the calculated bulk concentration of constituent ions in the targets. In general, we found two types of particles excited in definite states the yield of which depends on the dose of ion bombardment and composition of targets and these could be used as *in-situ* indicators for modification of surface properties of complex oxides during ion bombardment.

There were investigated the radiation induced optical centers in magnesium aluminates spinel ceramics doped with LiF at different types of irradiation: (1) UV-light, which provides only charge exchange between nearest neighbor defects or defects and impurities; (2) X-rays, which provides also generation of free charge carriers in conduction band of this insulator and subsequent capture them by different defects or impurities and (3) gamma-rays (maximal energy Eγ~7 MeV) which ensure also formation of new lattice defects. The differential absorption bands demonstrate that gamma-rays generate some additional lattice defects, which could be activated into optical centers by subsequent irradiation with UV-light or X-rays. Because UV-irradiation causes charge transfer between near neighbor defects the appearance of low intensity bands at 3.8 eV and 4.2 eV indicate the formation of additional concentration of closely located anti-site defects in spinel lattice. Much more anti-site defects become apparent at X-irradiation, which were formed at spatially separated defects capturing free charge carriers generated by X-rays. These centers give contribution to optical absorption in the spectral range of 2.2÷4.2 eV.

These data can be used for choice of optimal materials of specific transparency and photon emission to avoid the interference of emission radiation induced from materials and signal from plasma.

Results of these investigations were published in:

1. V.T. Gritsyna, V.V. Bobkov, S.P. Gokov, V.V. Gritsyna, D.I. Shevchenko. *Effects of argon ion bombardment on the properties of surface layer in spinel crystals of different compositions*// Vacuum, Vol. 82, 2008, pp. 888-894.
2. V.T. Gritsyna, Yu.G. Kazarinov, A.A. Moskvitin, I.E. Reimanis. *Radiation induced optical centers in magnesium aluminate spinel ceramics*// Proc. of the XVIII Internat. Conf. on Phys Radiation Phenomena and radiation material science, September 8-13, 2008, Alushta, Ukraine, pp.248-249.

- **Collaborations with Universite Libre de Bruxelles, Brussels, Belgium**

In the framework of particle transport problem study for the toroidal plasma configurations related to Stellarator devices the Test Particle Transport Code (TransPar), created by Dr. Oleg A. Shyshkin (University) in collaboration with Dr. R. Schneider and Dr. C. Beidler (MPIPP), was extended to trace particles in the real geometry in cylindrical and toroidal coordinates. This code simulates the particle transport in terms of test particle fraction transport. In was used to analyse tungsten transport for the HELIAS reactor with five periods of the magnetic field and stellatrator Wendelstein 7-X.

In order to upgrade the transport model reproduced by TransPar Code, a comprehensive picture of particle motion in plasmas is under study. The model is extended by including the Monte Carlo equivalent of collision operator extended for the non Maxwellian plasmas often observed in fusion devices due to magnetic resonant structures, particle injection or plasma heating.

The results of this activity were presented on 35th EPS Conference on Plasma Physics, June 9-13, 2008, Hersonissos, Crete, Greece under the title - MONTE CARLO COLLISION OPERATOR FOR THE TEST PARTICLE TRACING IN FUSION NON MAXWELLIAN PLASMA, by Dr. Oleg A Shyshkin and Prof. Dr. Boris Weyssow, and on TEC Theory topic group meeting on November 26 at Université Libre in Brussels, hosted by Daniele Carati, under the title - Non Relativistic Collision Operator for the Test Particle Tracing in Fusion non Maxwellian Plasma, by Dr. Oleg A Shyshkin and Prof. Dr. Boris Weyssow.

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

## - Collaborations with NIFS, Japan

Evolution in time of the plasma density, temperature and thermal alpha-particle density is considered under modeling of the helium ash removal. It was shown that slow changing in time of the helium ash density can be used for the operation path changing in fusion plasma. There is considered also the effect of different scenarios of fueling rates on the plasma operation path and steady state parameters. The temporal evolutions of the operating point during the ignition access and ignited operation phases were analyzed analytically and numerically. The main target of the study is the optimization of the plasma operation scenario in LHD. Here the effect of the removal of the helium ash on the achieving of the steady state and plasma parameters in steady state is considered. We model the removal of helium ash taking into account the rule of the helium ash confinement time changing during the plasma discharge. We suppose that $\tau_E$ is not constant but is a harmonic function of the time. We obtain that operation paths with and without helium ash removal reach ignition region in different ways. While the operating point approaches the final point slowly with the increase of the plasma density from the higher temperature side after switching off the heating power, the ignition boundary also shifts up with the increase in the helium ash density. The effect of the removal of helium ash on the plasma parameters is demonstrated. We see some reduction of the bremsstrahlung losses and that in the steady state the plasma parameters are more stable in time under the removal of the helium ash. The fusion power does not change in time so rapidly. The effect of the change of the fuel source $S_{DT}$ in time on the plasma parameters in the steady state was found. In the case of the smaller fuel rate the steady state is established on the level of the lower value of the helium ash (approximately 12% instead of 15%). The fusion power is smaller too, namely $P_{fusion} \approx$ 1GW in the case of the smaller fuel rate in comparison with the $P_{fusion} \approx$ 1.5GW in the other fueling case. We expected that plasma operation paths on the background of POPCON can distinguish noticeably under the different scenarios of fueling. The plasma operation path leads to lower value of temperature and plasma density for the desired value of the output fusion power $P_{fusion}$. It means that we can operate at lower densities, so we can use simpler fuel and power injection system, magnetic confinement system, and have easier plasma operation. Some work was devoted to finding optimal operation windows for plasma burning. It allows using simpler and faster methods of diagnostic and feedback control.

The results of this activity were published:


1. A.V. Eremin and A.A. Shishkin, *Particle and Power Balance in Fusion Plasma with Different Fueling Scenarios and Helium Ash Removal//* 23rd Symposium on Plasma Physics and Technology, June 16-19, 2008, Prague, Czech Republic.
2. A.V.Eremin, A.A.Shishkin, *Fusion D+T and D+D products dynamics for the different fueling scenarios in toroidal magnetic reactors//* Ukrainian Physical Journal, 2008. Vol. 53, No. 5, p. 428-437.
3. Zh.S.Kononenko, A.A.Shishkin, *Impurity ion dynamics near magnetic islands in the drift optimized stellarator configuration of Wendelstein – 7X//* Ukrainian Physical Journal, 2008. Vol. 53, No. 5, p.438-442.
4. Zh.S.Kononenko, A.A.Shishkin*, Effect of magnetic islands on impurity ion dynamics in drift optimized stellarator//* Problems of Atomic Science and Technology. 2008. No. 4. Series: Plasma Electronics and New methods of Acceleration (6), p. 95-98.
5. Yu.K. Moskvitina, A.A. Shishkin*, Resonant interaction of fusion products with*

perturbations of magnetic field in toroidal magnetic trap with rotational transform// Problems of Atomic Science and Technology. 2008. No. 4. Series: Plasma Electronics and New methods of Acceleration (6), p. 104-108.
6. A.A.Shishkin, O. Motojima, A. Sagara, Yu.K. Moskvitina, A. Eremin, Jun-ichi Miyazawa, S. Masuzaki, H. Yamada, O. Mitarai, T. Morisaki, N. Ohyabu, *Control of $\alpha$ -particles confinement in fusion trap with helical magnetic field with the use of "magnetic axis oscillation"//* Problems of Atomic Science and Technology. 2008. No. 4. Series: Plasma Electronics and New methods of Acceleration (6), p. *109-113.*
7. Yu.K. Moskvitina, A.A. Shishkin*. Effect of the resonance phenomena on high energetic particle losses in closed magnetic trap with the rotational transform of the magnetic field//* Alushta-2008. International Conference – School on Plasma Physics and Controlled Fusion. Book of abstracts. Alushta (Crimea), Ukraine, September 22-27, 2008. 1-25. P.45.

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

### 5.2.2 Plans of National University for 2009

1) The implementation of the extended version of Monte Carlo equivalent of collision operator presented in terms of pitch-angle scattering and energy slowing down and scattering in the TransPar Code should be done. This work is planed to be performed in the framework of collaborations with Prof. Dr. Boris Weyssow (Universite Libre de Bruxelles, Brussels, Belgium) and under the partial support of regular STCU project #3685.

2) Regular STCU project # 3685 "Impurity transport in 3D magnetic field for the stellarator Wendelstein 7-X and tokamaks" supported by European Union will be finished. AC electromagnetic field control of impurity ions at periphery of the confinement volume will be studied both analytically and numerically. New method of the impurity ion control (removal out from the volume of confinement) in drift optimized configuration with the use of AC field will be developed and proposed to apply on the stellarator Wendelstein 7-X.

3) Collaboration with Colorado School of Mines (Colorado, USA) will be continued on the development of methods for determination of point defects, impurities, and their complexes in spinel ceramics doped with lithium fluoride which is responsible the formation of defects under irradiation.

4) Sandwich PhD student A. Onishchenko (KhNU and MPIPP) will continue to test various composite coatings on radio frequency antenna for plasma heating.

# 6 UNITED STATES

## 6.1 ORNL IEA stellarator activities, 2008-2009

- **Alfven modes driven by fast particles in LHD**

In 2008, extensive studies of fast-particle-driven Alfven modes were made in LHD configurations having non-monotonic rotational transform profiles produced by counter neutral beam injection. Analysis of the fluctuation data and comparison with the results of the AE3D code developed jointly by NIFS and ORNL allowed the observed fluctuations to be identified as Reverse-Shear Alfven Eigenmodes. Validation of the theoretical model supports the use of these fluctuations as a tool to measure the rotational transform profile in reversed-shear tokamaks. Because of the importance of this area of physic for all large fusion experiments, we anticipate this work continuing in 2009, and would also like to look in more detail at Alfven-like fluctuations that have been seen in lower parameter plasmas in TJ-II, HSX, and H-1. Key contributors to work in this area are D. A. Spong of ORNL, K. Toi, M. Isobe, M. Nishiura of NIFS, and A. Könies of IPP-Greifswald.

1. K. Toi, F. Watanabe, T. Tokuzawa, K. Ida, S. Morita, T. Ido, A. Shimizu, M. Isobe, K. Ogawa, D.A. Spong, Y. Todo, T. Watari, S. Ohdachi, S. Sakakibara, S. Yamamoto), S. Inagaki, K. Narihara, M. Osakabe, K. Nagaoka, Y. Narushima, K.Y. Watanabe, H. Funaba, M. Goto, K. Ikeda, T. Ito, O. Kaneko, S. Kubo, T. Minami, J. Miyazawa, Y. Nagayama, M. Nishiura, Y. Oka, R. Sakamoto, T. Shimozuma, Y. Takeiri, K. Tanaka, K. Tsumori, I. Yamada, M. Yoshinuma, K. Kawahata, A. Komori and LHD Experimental Group, "Alfvén Eigenmodes and Geodesic Acoustic Modes Driven by Energetic Ions in an LHD Plasma with Non-monotonic Rotational Transform Profile," presented at IAEA Conference on Plasma Physics and Nuclear Fusion, Geneva, 2008, and submitted to Nuclear Fusion (2008).

2. K. Toi, F. Watanabe, T. Tokuzawa, K. Ida, S. Morita, T. Ido, A. Shimizu, M. Isobe, K. Ogawa, D.A. Spong, Y. Todo, T. Watari, S. Ohdachi, S. Sakakibara, S. Yamamoto), S. Inagaki, K. Narihara, M. Osakabe, K. Nagaoka, Y. Narushima, K.Y. Watanabe, H. Funaba, M. Goto,K. Ikeda, T. Ito, O. Kaneko, S. Kubo, T. Minami, J. Miyazawa, Y. Nagayama, M. Nishiura, Y. Oka, R. Sakamoto, T. Shimozuma, Y. Takeiri, K. Tanaka, K. Tsumori, I. Yamada, M. Yoshinuma, K. Kawahata, A. Komori and LHD Experimental Group, " Observation of Reversed Shear Alfvén Eigenmodes Excited by Energetic Ions in a Helical Plasma," submitted to Phys. Rev. Lett., (2008).

3. Y. Todo, N. Nakajima, M. Osakabe, S. Yamamoto, and D. A. Spong, "Simulation Study of Energetic Ion Transport due to Alfvén Eigenmodes in LHD Plasma," Plasma and Fusion Research, 3, (2008) S1074.

4. D. A. Spong, Y. Todo, M. Osakabe, L. Berry, B. N. Breizman, D.L. Brower, C. B. Deng, A. Konies, “Energetic particle physics issues for three-dimensional toroidal configurations,” presented at IAEA Conference on Plasma Physics and Nuclear Fusion, Geneva, 2008, and submitted to Nuclear Fusion (2008).

### - Heating and fueling of TJ-II

In 2003, TJ-II became the first heliac device to make use of neutral beam heating when a CIEMAT-ORNL team commissioned one of two ORNL neutral beam injectors for use in the TJ-II complex. This task was particularly challenging in TJ-II because of its extremely wide magnetic axis excursion (15% of the major radius (R = 1.5 m) and 120% of average plasma radius (⟨a ⟩= 0.22 m)) and the relatively small size of the device. During the following years the NBI provided 200 to 400 kW of additional heating power with its neutral $H_0$ beam operating at 31 kV and opened the way to a wide range of plasma studies. In summer 2008 the NBI heating capability at TJ-II was doubled with the successful commissioning of the second system. NBI heating combined with lithium conditioning of the TJ-II vacuum chamber led to production of plasmas showing H-mode transitions to enhanced confinement with increases in both density and stored energy. These developments open the path to high density, high beta experiments in this device. ORNL continues to collaborate actively with TJ-II in the development of a four-shot, variable size pellet injector to perform additional plasma fuelling and in the implementation of a electron Bernstein wave heating system to overcome the density limit of the electron cyclotron heating. We look forward to contributing to high beta experiments on TJ-II in 2009 and beyond, and hope to have the pellet injector working in the ORNL laboratory setup by late 2009/early 2010. Key contributors to work in this area are P. M. Ryan, S. K. Combs, J. Caughman, and J. H. Harris of ORNL, and M. Liniers, K. McCarthy, A. Fernandez, C. Cappa, and E. Ascasibar of CIEMAT.

- **High β confinement in stellarators**

The key finding of the 2008 CWGM assessment of high beta results for stellarators is that macroscopic instabilities originally expected to be active do not dramatically limit the achievable plasma betas (which reach nearly 5% in LHD), but rather equilibrium configuration changes induced by the increasing plasma pressure result in confinement degradation that "softly" limits the plasma beta achievable with a given heating power. Configuration optimization for high beta by advanced design techniques (such as those developed for W7X and NCSX) or by external changes in coil currents as beta increases (such as those planned for LHD) appears to be the appropriate way forward to improving the high-beta performance of stellarators. In 2009, we would like to see an international effort to use stellarator design tools to assess possible techniques for improving the high-beta equilibria using external fields as well as further work on a high-beta fluctuation database.

1. A Weller, K. Y. Watanabe, S. Sakakibara, A. Dinklage, H. Funaba, J. Geiger, J. H. Harris, S. Ohdachi, R. Preuss, Y. Suzuki, A. Werner, H. Yamada, M. C. Zarnstorff, W7-X Team and LHD Experimental Group, "International Stellarator/Heliotron Database Activities on High-Beta Confinement and Operational Boundaries," submitted to Nuclear Fusion (2008).

- **Configuration design/verification**

Stellarator coil sets are constructed to millimeter accuracies, but there are inevitably uncertainties about the effective parameters of the final "as-built" configuration as compared with the designed configuration. Australian National University (ANU) and ORNL researchers developed techniques to determine the effective configuration of the H-1 heliac (ANU) by studying the behavior of magnetic islands that appear in the flux surfaces as the rotational transform is varied. Contributors include S. Kumar (ANU/Wisconsin), B. D. Blackwell (ANU), and J. H. Harris (ORNL).

1. S. T. A. Kumar, B. D. Blackwell and J. H. Harris, "Accurate determination of the magnetic geometry of the H-1NF heliac," Nuclear Fusion (2009, in press).

### 6.2 PPPL IEA stellarator activities, 2008-2009

1) D. R. Mikkelsen (PPPL) visited IPP Greifswald form September 8 to 14 to discuss

gyro-kinetic simulation in stellarators. He also visited NIFS from December 8 to 16 for attending the 18th International Toki Conference and for discussions on the stellarator transport physics with NIFS members.

2) M. Z. Zarnstorff (PPPL) visited NIFS twice to discuss the reconstruction of the 3-D equilibria and high-$\beta$ experiments in LHD. His experimental proposal to achieve the high central $\beta$ was executed as a joint experiment.

# APPENDICES: TECHNICAL REPORTS ON 2008 ACTIVITIES

## APPENDIX 1: HIGHLIGHTS OF LHD EXPERIMENTS, JAPAN

Remarkable progress in the physical parameters of net-current free plasmas has been made in the Large Helical Device (LHD). The beta value reached 5 % and a high beta state beyond 4.5% from the diamagnetic measurement has been maintained for longer than 100 times the energy confinement time. The density and temperature regimes also have been extended. The central density has exceeded $1.2\times10^{21}$ $m^{-3}$ due to the formation of an *Internal Diffusion Barrier* (IDB). The ion temperature has reached 5.2 keV at the density of $1.6\times10^{19}$ $m^{-3}$, which is associated with the suppression of ion heat conduction loss. Although these parameters have been obtained in separated discharges, each fusion-reactor relevant parameter has elucidated the potential of net-current free heliotron plasmas. The highlighted achievement in the latest experimental campaigns (11th from Oct.2007 to Feb.2008, 12th from Sep.2008 to Dec.2008) is the extension of high ion temperature, high $\beta$ and high density.

The heating capability of neutral beam injection (NBI) has been significantly upgraded in these two years. A new perpendicular NBI with a low accelerating voltage of 40 keV (7 MW) enables efficient ion heating. Confinement of trapped particle used to be a great concern and indeed this is the reason why the tangential NBI was chosen at the beginning of the LHD project. However, this issue has been resolved by geometrical optimization and demonstration of the confinement of highly energetic trapped particles up to 1.6 MeV in an ICRF experiment has motivated the choice of perpendicular NBI. Combined with the three existing tangential beams (180 keV), the heating capability of the NBI has exceeded 20 MW. The upper limit of the magnetic field is improved by adding the subcooling system to lower the inlet liquid helium temperature from 4.4 K to 3.2 K. The increase in magnetic field is certainly small (4 %) but very beneficial to the resonance condition of the ECH.

Ion temperature has increased to 5.2 keV due to the perpendicular NBI. This is associated with confinement improvement which shares commonalities with the ITB. Also this high ion temperature regime is accompanied by a large toroidal flow and an extremely hollow impurity profile which is called “Impurity Hole”.

The $\beta$ value has reached 5 % which is the demanding target required for a fusion reactor and it should be emphasized that this high $\beta$ state is maintained for more than 100 times the energy confinement time.

The innovative scenario of high density by means of an *Internal Diffusion Barrier* (IDB), which was discovered in the *Local Island Divertor* configuration, has been extended to a helical divertor configuration. The central density has exceeded $1\times 10^{20}$ $m^{-3}$ at the moderate magnetic field of 2.5 T. Although plasmas with an IDB and ITB are located in different density regimes, it is found that impurity contamination is significantly reduced for both cases. In plasma with an IDB, impurity screening due to the friction force exerted by the background plasma flow on impurities suppresses impurity influx in the ergodic layer. The outward convection which cannot be explained by neoclassical theory is pronounced when turbulent driven radial flux is suppressed in plasma with an ITB.

Control of heat and particles is becoming a critical issue in the high-performance and steady state plasmas. A pulse length of 800 s was achieved with the RF heating power of 1.1 MW. The plasma of $\bar{n}_e$ of $6 \times 10^{18}$ $m^{-3}$ and $T_{e0}$ = 1.5 keV was sustained with $P_{ICH}$ = 1.0 MW and $P_{ECH}$ = 0.1 MW, employing the magnetic axis swing to disperse the plasma heat load to the graphite divertor tiles. Based on experimental knowledge and performance requirements, the closed helical divertor system which enables much better control of heat and particles is being designed.

In addition to these major achievements, important progress has been made in various areas. Properties of anomalous transport have been discussed with respect to the effect of magnetic shear, dependence on collisionality and long radial correlation. Wave physics in Electron Bernstein wave heating, electron cyclotron current drive and high harmonic fast wave heating has been investigated. The physics of energetic particles has been discussed with emphasis on its radial profile and TAE mode. LHD has provided a good platform for the study of PWI. Co-deposition, behavior of dust and damage on in-vessel mirrors have been evaluated.

Experimental observation with detailed diagnostics in LHD promotes theoretical and simulation studies. Validation of the advanced physical models for integrated transport simulation including bootstrap currents and MHD equilibrium/instabilities, TAE modes and gyro-kinetic simulation of anomalous transport has progressed. Extension of the plasma parameters and the advantage of steady-state operation accelerate the deepening of diversified physical understandings of net current free helical plasmas.

For the next stage of LHD experiments, the constructions of a closed helical divertor and a perpendicular NBI with an accelerating voltage of 80 keV have been started this fiscal year. Experiments handling deuterium gas are also planned and will begin in a few or several years to achieve final LHD targets.

## APPENDIX 2: TECHNICAL REPORT ON 2008 ACTIVITY, RUSSIA

### 1) A.M. PROKHOROV GENERAL PHYSICS INSTITUTE (GPI)

1. Interesting transport transitions to the regime with improved confinement in the L-2M stellarator were studied. During the transition the edge plasma has definite sandwich structure being subdivided by moderate order rational magnetic surfaces (where the rotational transform take the values 2/3 and 3/4) into three smaller zones with different dynamics of plasma parameters. It is shown that the role of plasma instabilities in this transition can be twofold. The improved confinement is caused by the reduction in turbulent transport because of mode stabilization. On the other hand, transition is triggered by local disturbances of plasma parameters that are caused by non-MHD instabilities in the vicinity of moderate order rational magnetic surfaces.

2. Experiments were carried out in the L-2M stellarator during ECRH with heating powers of 100 kW - 200 kW for studying plasma turbulence by collective scattering of radiation at the second harmonic of the gyrotron operating frequency. A quasioptical receiving system allowed measurements of scattered radiation from plasma regions $r/a \leq 0.6$ at scattering angles $\pi/4 \leq 0 \leq \pi/2$ ($24\ cm^{-1} \leq k_{\perp} \leq 44\ cm^{-1}$). The short-wave turbulence was studied for two radial positions of the scattering region: r/a=0.3-0.4 and r/a= 0.5-0.6. Short-wave turbulence observed in the core plasma of the L-2M stellarator is assigned to the ETG mode instability. This type of turbulence exhibits features of strong plasma turbulence. The role of such short-wave turbulence in anomalous transport can appear important for conditions of a thermonuclear reactor.

### 2) KURCHATOV INSTITUTE

Study of the possibilities of stellarators with poloidally closed contours of magnetic field strength and study of the configurations with large number of periods and search for more elaborated geometry of the period were carried out.

## APPENDIX 3: SUMMARIES OF THE INSTITUTE OF PLASMA PHYSICS OF THE NSC KIPT, KHARKOV, FOR 2008

### Plasma Theory

1) Study of the velocity of the poloidal motion of trapped particle orbits for stellarators in real-space coordinates (V.V. Nemov and S.V. Kasilov in collaboration with W. Kernbichler and G.O. Leitold (Technische universität Graz, Austria)).

A method is elaborated to compute the bounce averaged poloidal drift velocity of trapped particles for stellarators in real space coordinates through integration along magnetic field lines. Combining studies of the poloidal drift as well as the radial drift one can conveniently assess the character of contours of the second adiabatic invariant in the neighborhood of a magnetic surface and indicate the poloidally closed or unclosed contours. This is important in particular for assessment of collisionless α-particle confinement using the magnetic field produced by coil currents or the results of three dimensional finite beta equilibrium codes, such as PIES and HINT. (Phys. Plasmas, 15(5):052501-1-052501-13, 2008; 35th EPS Conference on Plasma Phys., Hersonissos, 9-13 June 2008, ECA Vol.32D, P-5.021 (2008).)

2) Calculations of 1/v transport for Uragan-2M in the regime of k_phi=0.295 taking into account the influence of the current-feeds and detachable joints of the helical winding. (V.V. Nemov, V.N. Kalyuzhnyj, S.V. Kasilov, G.G. Lesnyakov in collaboration with B.Seivald and W.Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria) and N.T.Besedin (Kursk State Technikal University, Russia)).

Recently a numerical study of the influence of current-feeds and detachable joints of the helical winding of Uragan-2M has been carried out for the magnetic field parameters corresponding to the rotational transform, ι, within the limits 1/3<ι<1/2 ($k_\varphi$=0.31). Now an analogous study is performed for the case of somewhat increased toroidal magnetic field ($k_\varphi$=0.295) for which the resonant magnetic surfaces corresponding to ι=1/3 can be present in the confinement region. Results are presented in the Alushta-2008 International Conference-School on Plasma Physics and Controlled Fusion, Alushta (Crimea), 2008, Book of abstracts, p. 30.

3) Study of the coefficients of diffusion and heat conductivity in the long-mean-free-pass regimes for the Uragan-2M torsatron (S.V. Kasilov, V.N. Kalyuzhnyj and V.V. Nemov in collaboration with W. Kernbichler (Technische universität Graz, Austria)).

Mono-energetic diffusion coefficient and coefficient of the bootstrap current generation are calculated for Uragan-2M in the in the long-mean-free-pass regimes with taking into account finite collisionality. The magnetic system parameters are considered corresponding to $k_\varphi$=0.31 without taking into account the influence of the current-feeds and detachable joints. For the calculations the NEO-2 code is used (W. Kernbichler, S.V. Kasilov, G.O .Leitold, V.V. Nemov, 32nd EPS Conference on Plasma Phys. Tarragona, 27 June-1 July 2005, ECA Vol.29C, P-1.111 (2005)). In the code the drift-kinetic equation is solved for a separate magnetic field line by integration along this line using third order conservative finite-difference scheme for a discretization of the distribution function in the velocity space. It follows from the computational results obtained in case of small radial electric field for the magnetic surface with the mean radius, *r*, of *r*=5.9 cm that in the limit of small collision frequency the diffusion coefficient is in good agreement with the asymptotical results in the 1/v regime. For the intermediate collision frequencies (the plateau regime for which $2\pi R \sim l_c$, $l_c$ is the mean free pass) the diffusion coefficient coincides practically with the diffusion coefficient for an equivalent tokamak. A maximum value of the normalized coefficient of the bootstrap current generation, $\lambda_{bb}$, is obtained for $2\pi R/l_c=10^{-4}$. The difference of this value from the asymptotic value is of approximately 30%. So, the asymptotic value gives a satisfactorily estimation of $\lambda_b$ for the regime of very small collision frequencies.

4) Theoretical investigations of the possibilities of the microwave reflectometry in stellarators (D.L. Grekov).

It was shown that using the two-polirized reflectometry (plasma probing in the equatorial plane) let us possibility to define the value of the plasma center shift with respect to the geometrical axis of the chamber. For plasma with relatively low density this method provides to restore the plasma density profile not assuming the density constancy at the magnetic surfaces.

## Plasma Experiments

1) Experiments in stellarator-torsatron Uragan-2M.

1.1) The investigations of the structure of magnetic surfaces were carried out in the Uragan-2-M torsatron by the use of the luminescent rod method (the photographing was carried out by digital camera). The measurements were done for wide range of the $K_\varphi$ values ($K_\varphi$ =0.295 ÷ 0.4) and the vertical magnetic field amplitude.

It was shown that the magnetic configurations have magnetic surfaces with high enough area of the cross-sections: $a \approx$ 20,5 cm for $K\varphi$ = 0.31, $\langle B \rangle/B0 \approx 1.14\%$, 1.85%, 2.55%. Configurations with no magnetic islands, with $K\varphi$ =0.31 и $K\varphi$ =0.32, are recommended for plasma confinement investigations. The influence of the vertical magnetic field value on the magnetic field structure and the shift of the magnetic axis was analyzed.

It was shown a good agreement of radial positions and islands with *i* =1/3 size ($K\varphi$ =0.31, $\langle B \rangle/B0 \approx 1.8\%$) measured both in 1994 and 2007 and numerical simulation results (for $K\varphi$ =0.295, $\langle B \rangle/B0$ =1.85%).

1.2) Wall conditioning in the Uragan-2M torsatron was made with the ECR and RF discharges in the atmosphere of hydrogen in continuous mode at low toroidal magnetic field $B_T$ = (0.02-0.1) T. It was accompanied by the local heating of the vacuum vessel elements up to 100 $^0$C.

The RF discharge wall conditioning was performed both in pulsed and continuous regimes. In pulse operation both frame antennas were used. In continuous regime the RF frequency was 4.7 MHz and RF power launched was up to 1 kW. No special antenna was designed for this type of wall conditioning. As the wave launcher, the frame antenna was used. It was fed by RF power with disconnected ground contact. In this way the electrostatic wave excitation was realized. For neutral hydrogen pressure $P_H$ = 4.8x10$^{-5}$ Torr the breakdown was observed for the magnetic field value at the stellarator axis ~ 160 Gs and higher. Plasma fills up whole volume of the vessel. Its maximum density, determined from the probe measurements, was 4x10$^9$ cm$^{-3}$. The electron temperature was surprisingly high ~ 55 eV. The plasma parameters varied weakly with the steady magnetic field.

In the discharge in hydrogen the cleaning is associated with chemical reactivity of the atomic hydrogen that can create volatile substances. To produce the atoms efficiently, electron temperature should have a value order of the dissociation threshold of hydrogen molecule (~ 4.4 eV) that is an order lower than in the RF discharge. The plasma density should be an order higher. In future experiments it is planned to optimize the RF discharge to come close to the required parameters.

1.3) Uragan-2M torsatron is equipped with two compact RF antennas of frame type. The first antenna has a broad $k_{||}$ spectrum and is used for plasma production. The second one with narrower $k_{||}$ spectrum heats plasma in the Alfven range of frequencies. Two generators with RF power 0.5 MW and frequency in the range of 10 MHz are used.

The antenna with the broad $k_{||}$ spectrum provides reliable gas break-down in the pressure range of ($3.10^{-6}$ - $8.10^{-5}$) torr and produces plasma with density (1-2).$10^{12}$ $cm^{-3}$. Combined usage of two antennas with RF power $P_{RF}$~100 kW (after preliminary short time wall conditioning) results in increase of the plasma density up to $6\times10^{12}$ $cm^{-3.}$ The increase of the carbon line intensity in time indicated that for improving the plasma parameters there is a need to perform a more careful wall conditioning.

2) Continuation of investigations of processes accompanying ITB and ETB formation in the plasma of the Uragan-3M torsatron under RF plasma heating.

**2.1) Study of the link between H-mode transition and fast ion loss in RF discharge plasmas of the U-3M torsatron.** As a result of RF heating ($\omega\lesssim\omega_{ci}$), a two-temperature ion distribution in perpendicular energies with a suprathermal tail is formed in the U-3M plasma, the hotter and suprathermal ions (“fast ions”, FI) being in the LMFP regime and can be toroidally and helically trapped. With the heating power high enough, a spontaneous transition to an H-like mode occurs, caused by a hard edge $E_r$ bifurcation toward a more negative value with an enhancement of the $E_r$ shear.

Earlier it was supposed that the bifurcation is initiated by the ion orbit loss. To verify this hypothesis, the link between FI loss and H-transition has been studied. It is shown that the transition is always preceded by a short-time, burst-like enhanced FI outflow to the divertor. This burst is clamped to a certain density $\bar{n}_e = \bar{n}_{e1}$ due to the resonance character of RF heating, and so, the $E_r$ bifurcation also occurs close to this density. As $\bar{n}_e$ increases with time, the H-mode state is terminated by reverse bifurcational transition toward an L-like mode at some density $\bar{n}_{e2} > \bar{n}_{e1}$ (hysteresis). The value of $\bar{n}_{e2}$ decreases with RF power reduction and becomes close to $\bar{n}_{e1}$ at some threshold power, so that the H-mode does not occur. Accordingly, there exists a threshold amplitude of the burst-like FI loss, but the burst itself stays even at the power lower than the threshold one, being a primary effect in the causality between enhanced FI loss and H-transition. Thus, the H-mode transition in U-3M is really initiated by FI loss. To the mechanism of toroidally trapped ion loss the loss caused by radial drift of helically trapped ion orbits that is inherent to stellarators should also be added.

The results of investigations were reported at Alushta-2008 International Conference & School on Plasma Physics and Controlled Fusion (Alushta (Crimea), Ukraine, Sept. 22-27, 2008) and at 18th IAEA Technical Meeting on Research Using Small Fusion Devices (Alushta (Crimea), Ukraine, Sept. 25-27, 2008) and are to be published in corresponding IAEA proceedings.

**2.2) Studies of fast ion outflow to the helical divertor of the U-3M torsatron.** The presence of the helical divertor in the l=3/m=9 Uragan-3M torsatron with RF-produced and heated plasmas offers new opportunities for studying FI loss by measuring ion fluxes and energies in the divertor plasma. Ion energy distributions were measured in divertor flows in two symmetric poloidal cross-sections of the U-3M torus belonging to 4 helical field periods, with both directions of the magnetic field. It is shown that FIs outflow to the divertor predominantly on the ion $B\times\nabla B$ side in full accordance with the assumption on the determinative FI contribution to the divertor flow up-down asymmetry inherent to torsatrons/heliotrons.

Strong toroidal non-uniformities in flows and energies of ions outflowing to the divertor have been observed. The large-scale island structure of the U-3M magnetic configuration and locality of RF power injection are considered as possible reasons for these non-uniformities.

These measurements were carried out in the L-like phase of discharge time evolution, prior to the transition into the H-like mode of confinement, and are the first part of more general investigations aimed at elucidation of H-transition effects on FI loss in a torsatron/heliotron.

The results of investigations were reported at Alushta-2008 International Conference & School on Plasma Physics and Controlled Fusion (Alushta (Crimea), Ukraine, Sept. 22-27, 2008) and published in Plasma Devices and Operations 16 (2008) 299.

**2.3) Studies of statistical characteristics of density and turbulent particle flux fluctuations in the SOL and divertor plasmas of the Uragan-3M torsatron.** Earlier, a substantial reduction of the level of edge electric field fluctuations in the low-frequency part of the spectrum and of the fluctuation-induced radial turbulent particle flux has been observed in the U-3M torsatron with spontaneous transition to the H-mode confinement, resulting from ITB and ETB formation. In 2008 investigations of statistical characteristics of edge density and electric field fluctuations and of corresponding radial turbulent particle flux were carried out in the L- and H-modes of confinement, and the link was found out between these fluctuations and the density fluctuations in the divertor plasma. It is shown that a layer arises in the SOL plasma where the 3rd moment (skewness) S of PDF of density and turbulent flux fluctuations is reduced with H-transition, in particular, indicating a reduction of the anomalous particle transport directed outward. A considerable deviation of S from the Gaussian value (S=0) is observed. In the divertor plasma a rise of the 3rd and 4th (curtosis) moments of PDF are observed on the ion toroidal $B\times\nabla B$ drift side with H-transition, while these moments stay practically unchanged on the electron drift side. Therefore, it is natural to suppose that the rise of PDF moments is associated with the rise of fast ion outflow to the divertor observed in the given poloidal cross-section during the H-transition.

The results of investigations were presented at Alushta-2008 International Conference & School on Plasma Physics and Controlled Fusion (Alushta (Crimea), Ukraine, Sept. 22-27, 2008) and at 18$^{th}$ IAEA Technical Meeting on Research Using Small Fusion Devices (Alushta (Crimea), Ukraine, Sept. 25-27, 2008) and are to be published in corresponding IAEA proceedings.

3) The measurements of the 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).

3.1) The direct measurements of an electric potential and its fluctuations in a core plasma are of a primary importance for the understanding of the mechanisms of the confinement improvement in toroidal plasmas and the role of the electric field in plasma confinement.

The significant improvement in the beam control system and the acquisition electronics of the HIBP system leads us to the increase of the possibilities of the diagnostics. The most crucial one is the extension of the signal dynamic range, which allows us to have the reliable profiles from the plasma center to the very edge. Low density ($n = 0.3\text{-}0.5\times10^{19}$ $m^{-3}$) ECRH plasma in TJ-2 is characterized by positive plasma potential ($\varphi(0)$ = + 600 - + 400 V). At higher densities the minor area of the negative electric potential appears at the edge. This area increases with the density, finally makes potential fully negative. This tendency is affected by ECRH power and deposition area. The NBI plasmas are characterized by negative electric potential in the fill plasma column from the center to the edge, ($\varphi(0)$ = - 300 - 600 V. These results show the clear link between plasma potential, temperature, density and particle confinement.

Density rise (particle confinement, energy confinement) is associated with the rise of the negative $E_r$ suppression of the turbulence. These observation lies inside the paradigm of the turbulence suppression of by $E_r$ as a mechanism of confinement improvement.

3.2) Alfven modes were observed by HIBP. Correlation studies with reflectometry, magnetic probes and Langmuir probes can give an insight to spatial structure and properties of the Alfven modes.

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

5) <u>Development of the HIBP diagnostic for Uragan-2M torsatron.</u>

The numerical calculations of the heavy ion ($Cs^+$ and $Tl^+$) beams with different energies and different values of the torsatron magnetic fields were carried out for optimization of the HIBP experiment: choice of the relevant ports and particle energy providing the measurements in the main part of a plasma column form the edge to the axis. It was found the most appropriate position of the heavy ions accelerator and the secondary particles analyzer providing to use the minimum energy of the primary beam particles. It was shown that using the thallium beam with the energy of 100-150 keV will provide adequate measurements of a plasma potential in U-2M plasma confined in toroidal magnetic field with the value up to 0.8 T. For the second stage of experiments with magnetic field > 2 T the primary thallium beams with energy 500-900 keV will provide potential and other plasma parameters measurements in the main part of a plasma cross-section.

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**APPENDIX 4: TECHNICAL REPORT ON TJ-II ACTIVITIES IN 2008**

The results achieved in the TJ-II stellarator during 2008 were obtained in plasmas created and heated by Electron Cyclotron Resonance Heating (ECRH) (2 x 300 kW gyrotrons, at 53.2 GHz, 2$^{nd}$ 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. Recently 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:

1) Considerable improvement of plasma particle control, in comparison with operation under boron coated walls, has been observed in the TJ-II stellarator after Li-coating. The beneficial Li properties for plasma-wall interaction have a strong effect on this device that has a helical limiter very close to the magnetic axis, which receives the strongest particle and heat fluxes. The outstanding results are density control in formerly collapsing NBI discharges and access to higher plasma pressures. The properties of Li as a plasma facing material in fusion devices are explored in these experiments, which are relevant for future fusion reactors, where Li could be used for liquid divertor or for coating some in-vessel components.

The technique used for lithiumnization is evaporation using ovens where the Li is homogenised about the vessel walls by the plasma itself. The wall properties after Li coating are strongly changed and, remarkably, they increase the H retention capability, thus improving the density control. Oxygen gettering is still maintained by the boron layer that is deposited under the Li one. 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 power unbalance that produces the low radiation collapse.

2) 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 Alfven eigenmodes destabilized in NBI plasmas, also related to low order resonances, can influence fast ion confinement. A transition from kinetic effect-dominated –with very low particle confinement times– to a more collisional regime is found in ECRH plasmas. The electric field, positive across the whole plasma in the low confinement regime, starts developing negative values at the maximum density gradient region when the collisionality reaches a threshold value. For a given heating power and magnetic configuration, this translates into a line-density threshold to improve particle confinement. Further increments in the density extend the region with negative electric fields towards the centre of the plasma.

3) During high density NBI operation, a transition to an improved confinement regime is observed, characterised by an increase of diamagnetic energy, a decrease of Ha emission, a drastic reduction of turbulence, and the development of steep density gradients. In some discharges, edge instabilities detected by Ha emission monitors, reflectometry and Langmuir probes, are triggered several milliseconds after the transition. So far, the H-mode has been obtained in a transient way, and though it is subject to uncertainties, the estimated NBI absorbed power is comparable to the power threshold calculated using the empirical scaling obtained for tokamaks. This type of spontaneous transitions adds to those that occur at lower densities, which correspond

to the shear flow development and can be also provoked by biasing. During these lower density transitions, an increase in the cross-correlation in floating potential signals measured by probes located at distant toroidal positions is found. These results show that the increase in the degree of long-range correlation (for potential fluctuations) is strongly coupled to the presence of radial electric fields. The appearance of the L-H transition, at present under investigation, makes TJ-II a unique experiment to study the two-step process in the development of edge sheared flows in fusion plasmas, since both types of transitions are present in this device.

## APPENDIX 5: TECHNICAL REPORT ON HELIOTRON J ACTIVITIES IN 2008

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 $\varepsilon_{eff}$). The experiments have been performed by changing the bumpiness with keeping plasma volume, plasma axis position, and edge rotational transform almost constant. The results achieved in Heliotron J during 2008 can be summarized as follows:

1) By using ICRF minority heating, the fast ion formation and confinement was investigated in the low density condition of 0.4 x $10^{19}$ $cm^{-3}$. The fast ion flux (up to 30 keV) measured by CX-NPA was largest in the high bumpy configuration under the experimental conditions of ICRF power 200-300 KW. Thus, the high bumpy configuration was found to be most favourable. The model calculation results using Monte Carlo method was in general agreement with the experimental data, indicating the existence of the loss region around the perpendicular direction. In addition, the observed asymmetry of the fast ion energy spectra on the pitch angle against 90 deg remains to be studied.

2) The electron cyclotron current drive (ECCD) experiments have been carried out, focusing on the effects of the magnetic field ripple in Heliotron J. The EC driven current decreased as the power was deposited at the deeper magnetic field ripple bottom. The reversal of the driven current direction was observed as the power was deposited at ripple bottom, indicating that the amplitude and direction of EC current are determined by the balance between the Fisch-Boozer effect and the Ohkawa effect. The measurement results and the calculation of electron loss in velocity space indicate that the reduction in EC driven current is related to the generation and confinement of trapped particles. Low efficiency compared to tokamaks may be due to the strong Ohkawa effect enhanced by the toroidal and helical ripples.

3) The configuration effects on the energetic ion and the bulk thermal confinement in the neutral beam injection (NBI) plasmas have been investigated with regard to the bumpiness control. It was found that the 1/e decay time of high energy CX flux after the NB turned-off has increased with bumpiness. The co-going ion flux induced by energetic-ion-driven MHD modes has been observed by installing the hybrid directional Langmuir probe system. The preferable thermal confinement time to the international stellarator scaling law ISS95 has been obtained in the high and medium-bumpy configurations. The improvement in the electron temperature mainly contributes to the enhancement of the plasma performance in the high- and medium-bumpy configurations.

4) A gas fuelling by supersonic molecular beam injection (SMBI) was successfully applied to ECH/NBI plasmas in Heliotron J, showing the unique characteristics such as increase (or decrease) of electron temperature and its target density dependence for ECH plasmas. For ECH(0.35 MW)+NBI(0.6 MW) plasmas, the stored energy has reached about 4.5 kJ, which is about 50% higher than the

maximum value achieved so far under the conventional gas-puffing control. The optimization of this fuelling method is in progress.

5) Data mining technique, which automatically extracts useful knowledge from large dataset, was applied to multichannel magnetic probe signals in order to identify and classify MHD instabilities in Heliotron J. MHD instabilities were successfully classified using the criterion of phase differences of each magnetic probe and identified as the energetic-ion-driven modes (GAE) from the related parameter studies in Heliotron J plasmas.

# MINUTES OF 37$^{TH}$ STELLARATOR EXECUTIVE COMMITTEE MEETING

12th October, 2008
4:00 pm – 6:00 pm
Valeriane room, Hotel Epsom, Geneva, Switzerland

<u>Attendees</u>

| | |
|---|---|
| Australia | B. Blackwell |
| EU | T. Klinger |
| | J.Sanchez |
| | R.Wolf |
| Japan | O. Motojima (chairman) |
| | A. Komori |
| | H. Yamada (secretary) |
| Ukraine | V. I. Tereshin |
| USA | M. C. Zarnstorff (vice chairman) |
| | J. N. Talmadge (substitute for D.T.Anderson) |

<u>Guests</u>

C. Pottinger (International Energy Agency)
H.Yamamoto (Ministry of Education, Culture, Sports, Science and Technology, Japan)

<u>Observers</u>

K.Tanaka, Y.Fukui, K. Kimata, K.Shimizu (National Institute for Fusion Science)

## Agenda

1) Approval of Agenda
2) Approval of minutes 36th Stellarator EC meeting
3) Membership of SEC
4) 17th International Stellarator/Heliotron Workshop
   September 2009, Princeton, USA
5) Status of domestic activities and international collaborations
   Australia, EU(Germany, Spain), Japan, Russia, Ukraine, USA
6) Development of stellarator working groups
7) Link of stellarator community with ITPA working groups
   New membership
8) Miscellaneous and final remarks

Meeting was opened by Motojima, chair and he welcomed all participants to the 37th Stellarator Executive Committee (SEC) meeting. At the beginning, Motojima introduced C.Pottinger with appreciation to her support for the IEA Implementing Agreement (IA) and H.Yamamoto with appreciation to the support to NIFS from MEXT.

Motojima also referred participation of K.Tanaka for clerical work, and Y.Fukui, K. Kimata and K. Shimizu from the administrative office of the National Institute for Fusion Science (NIFS) as observers to the SEC members. Their participation was accepted by the memebers.

H. Yamada pointed out that quorum was met according to page 8 (d) 6 of IA.

## 1. Approval of Agenda

The agenda was approved

## 2. Approval of minutes 36th Stellarator EC meeting

The minutes were approved as they are.

## 3. Membership of SEC

New members of SEC are proposed by each corresponding party;

EU: R.Wolf from IPP, C.Hidalgo (not attended) from CIEMAT

USA: D.T.Anderson (J.N.Talmadge substituted Anderson at this meeting) from Wisconsin University.

The new membership was confirmed and the updated list of the membership was distributed.

## 4. 17th International Stellarator/Heliotron Workshop (at PPPL in 2009)

Zarnstorff proposed the week of September 21st or the week of October 12th. In between them, H-mode workshop in the week of September 28th and ITPA will be organized in the week of October 5th by PPPL as well. Although the basic idea was to organize in the week of 21st of September, Zarnstorff suggested communication with Yamada.

Yamada recommended the week of October 12th because the linkage between ITPA and ISHW should be emphasized. If ISHW is organized in the week of September 21st, our workshop will be isolated from ITPA.

Zarnstorff said that we can push the schedule in the week of October 12th.

Motojima confirmed that we agree October 12th as the starting day and ask Zarnstorff to inform of this arrangement to ITPA program committee. Zarnstorff will do.

Yamada proposed to decide the chairman of International Program Committee (IPC). He explained the procedures which SEC did on this matter. SEC has designated the chairman of IPC in one year advance. Last time (2007), the chairman was C.Hidalgo. Previous time (2005) Yamada was the chairman. More previous time (2003), J. Harris was the chairman. He also suggested the chairman should be from Europe this time.

Zarnstorff recommended R.Wolf to be a chairman and Yamada supported it. Motojima confirmed that every member agrees to this recommendation and SEC designated Wolf as the chairman of IPC for ISHW2009.

Motjima asked an idea of special topics for the ISHW and Zarnstorff mentioned that it is a good choice to have a three dimensional toroidal physics as a special topic. This would be a hard topic but it could be commonality.

Yamada posed the issue of the publication of the proceedings. Last time, the proceeding was published in the Plasma Fusion Research, which is the Japanese Journal. The previous time, it was published in the Fusion Science Technology. Zarnstorff suggested that we can choose from Fusion Science Technology or Plasma Physics and Controlled Fusion and published as a special issue. He will discuss with Wolf.

## 5. Status of domestic activities and international collaborations

<u>Australia</u> :

Blackwell - There are some international collaboration in the stellarator community with Heliotron-J for MHD study and TJ-II. Also, there are collaborations with tokamak. These are about diagnostic developments done by John Howard on TEXTOR and

DIII-D. We try to H-I results to compare with edge divertor physics, since the parameter is comparable. H-I group is not big enough to be one independent institute and will be one group of the institute of environment. Recently, Australian governments doubled the scholarship for post Doctoral and PhD students.

Motojima - Do you mean doubling of the number of post Doc. and PhD students?

Blackwell - No. Our governments doubled the founding. Recently, scholarship from industry is increasing.

Motojima - I expect contribution of Australian fusion scientist.

Germany :

Wolf - W-7X is making a good progress. Some technical issues remain, but these should be solved. All coils were manufactured and everything was O.K. Recently, we have contract with astrophysics faculty of Berlin Technical University. In Europe, now main issue is facility review. All European facilities including experimental device, test device and computer are now in discussion for next 20 years.

Zarnstorff - Does Europe decide priority of facilities?

Sanchez - In the end of October, EU will decide the priority. W-7X and TJ-II are 100% secure. JET is planned to operate till 2010, but they plan to extend 2014. DT experiments with Q=1 are planned but these plans are not clear. TJ-II will continue till 2014. After 2014, decision will be made.

Motojima - What is the effect of over-cost of ITER?

Sanchez - Funding of fusion program of European countries are partly from EU and partly from their own governments. For example, 20% of the funding is from EU and 80% are from each government. 80% of funding of JET is from EU while 100% of funding of ITER is from EU. If ITER cost becomes higher, the funding from EU will be spent for the ITER instead of domestic program. For some countries, this situation will be severe.

Spain :

Sanchez - There are several international collaboration with USA (Oak Ridge National Laboratory (ORNL), Princeton Plasma Physics Laboratory (PPPL)), Germany (IPP), Japan (NIFS, Kyoto Univ.), Russia (Kurchatov for ECH), Ukraine (Kharkov for HIBP) and Australia (H-I). These collaborations are experimental works and theoretical works. Recent topic of TJ-II is Lithium coating. With Lithium coating, density control was improved. Density and confinement became twice higher.

Japan :

Komori - I show the list of guest professors and invited researchers during Japanese Fiscal year 2008. The details of results of LHD will be reported in tomorrow session. I will explain some remarkable results. One is high ion temperature with central impurity hole. Central density reached to $1.1x10^{21}m^{-3}$ with internal diffusion barrier. We have started the real time control of magnetic axis. About a future plan, we construct another positive ion based NBI, and we plan to start deuterium experiments and install helical closed divertor. Also, we are doing design study of Free Force Helical Reactor.

Motojima - Real time feedback control will help further achievement beta.

Ukraine :

Tereshin - URGAM-3M in now under operation at 0.7T. There are many problems of equipments. RF power is 0.7MW but impurity is high. International collaboration are done with CIEMAT ( for HIBP), IPP Greifswald, NIFS (in theory field by Prof. Shishkin), PPPL and General Physics Institute (GPI).

Motojima - We are very sorry about Prof.Shishkin's passing away.

USA :

Zarnstorff - NCSX was terminated in September 2008. Assemble of 1/6 of the system was demonstrated. Now, whole stellarator program is under re-planning. In June 2008, new program of stellarator will be proposed. Now, highest propriety of stellarator program is easier construction not physics. The question is how possible it will be to maintain such a complicated system for future reactor.

Talmadge - ORNL and PPPL are now making a joint report to explain the problem of NCSX project.

Motojima - NCSX project showed the technical feasibility of the construction at some stage.

Sanchez - Complexity is now problem, but when the stellarator becomes commercial one, complicated construction will be easier due to mass production.

Klinger - We have considered physics optimization, but now we need to consider engineering optimization.

## 6. Development of stellarator working groups

Yamada report the current status of Coordinated Working Groups. In last ISHW last year, six joint papers appeared. In this FEC 2008, three joint papers are presented. These are outcome of this work in the last one year. This activity organizes the 4th CWGM (Coordinated Working Group Meeting) in Madrid. This time it is pity that the schedule is conflict with ITPA. Two new important issues will be discussed at the 4th CWGM, which are reactor assessment and turbulent transport study. The latter can be exercise of 3-D tokamak physics.

## 7. Link of stellarator community with ITPA working groups

SEC is requested to rearrange the representatives to reorganized ITPA working groups. Yamada sorted out the issues by a handout of the list. Yamada explained that one person represents the stellarator community for each ITPA topical group according to the ITPA Charter. Motojima suggested that representative parties other than Japan can take priority since NIFS has already sent substantial number of people as regular members. Wolf requested that some people from IPP will be sent to diagnostics, pedestal, and SOL and Divertor groups. Zarnstorff requested that people from USA will be sent to MHD stability group. Motojima proposed to continue the discussion by circulating circulate the information to SEC members by e-mail. Zarnstorff mentioned that NIFS contribution to ITPA is quite successful.

## 8. Miscellaneous and final remarks

Yamada introduced the 18th International Toki Conference in December. The topic will be stellarator programs on the way to a DEMO reactor.

Closing remarks by Motojima,
Next SEC will be held at PPPL during ISHW2009 (12-16 Oct. 2009).