# 3. International Collaboration on Helical Fusion Research — IEA Stellarator Agreement —

## 1. Overview

The world stellarator community has been promoting international collaborations under the auspices of International Energy Agency (IEA) Implementing Agreement on "Development of the Stellarator Concept". The present participating countries in this agreement are Australia, Germany, Japan, Russia, Spain, Ukraine and U.S.A. The Stellarator Executive Committee chaired by Prof.O.Motojima conducts arrangement of collaboration and endorses proposed activities. The 37th Stellator Executive Committee was held in Geneva in conjunction with the 22nd IAEA Fusion Energy Conference. In addition to summary of the status of international collaboration, development of stellarator working groups and linkage of stellarator community with ITPA was discussed.

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

## 2. JAPAN

### 2-1. LHD team at NIFS

#### 2-1-1. International Collaborations by the LHD Team

**- Collaborations with EU**

1) Igitkhanov Juri Levanovich (Max-Plank Institute fur Plasmaphysik, Germany) visited NIFS (A. Sagara and H. Chikaraishi) from 4th February 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) F.Felici (CRPP Lausanne, Switzerland) 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.

3) J. Varela Rodriguez (Universidad Carlos III, Spain) visited NIFS (K.Y. Watanabe, Y. Narushima and S. Ohdachi) from 1st March to 1st June, 2008 in order to study the characteristics of the MHD stabilities in the LHD IDB/SDC plasmas.

4) 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.

5) H. Sugama (NIFS) visited Universite de Provence (Marseille, France) as an invited Professor during 25th May through 1st June, 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.

6) Y. Suzuki (NIFS) visited Forschungszentrum Juelich GmbH (Juelich, Germany) and Max-Planck Institut fuer Plasmaphysik (Greifswald, Germany) from 9th to 29th June, 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).

7) K. Nishimura, M. Osakabe, H. Miyake, H. Hayashi, N. Suzuki, R. Kawachi and S. Nakagawa visited the Culham Science Centre (Oxfordshire, UK) from 23rd to 27th June, 2008 to inspect and to discuss about radioactive protection for D-D and D-T experiments in JET with the JET team.

8) W.Guttenfelder (Warwick Univ., UK) visited NIFS from 27th-31st July, 2008 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.

9) H. Funaba (NIFS) visited Max-Planck Institute for Plasmaphysik (Greifswald, Germany) from 16th to 28th August, 2008 and built the International Stellarator/Heliotron Profile Database with A.Dinklage and A. Kus.

10) 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 14th through 21st September, 2008 and gave lectures on gyrokinetic plasma turbulence

11) K. Aggarwal (Queen's University of Belfast, UK) visited NIFS (T. Kato and I. Murakami) from 22nd September to 23rd October, 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.

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

13) M. Yokoyama (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) from 7th to 18th October, 2008 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.

14) H. Kasahara (NIFS) visited "Centre de Recherches en Physique des Plasmas" (CRPP Lausanne, Switzerland) on 15th October, 2008 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.

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

16) E. de la Cal, CIEMAT, Spain, visited NIFS (H. Yamada and M. Shoji) from 6th to 14th November, 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.
17) A. 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.
18) C. 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.
19) O.Motojma, H.Yamada, Y.Takeiri, M.Osakabe, M.Shoji, Y.Narushima, A.Doi, K.Kimata, M.Tsuda (NIFS) visited CIEMAT from 25th to 26h February, 2009 to have a workshop to launch the collaboration program by NIFS and CIEMAT in time to conclusion of the academic exchange agreement between two institutes.

- **Collaborations with U.S.A.**

1) M.Sato(NIFS) visited University of Washington from 27th March to 15th May, 2008 to develop a full implicit solver in spectral finite element method code with Dr. Glasser, and University of Texas from 15th to 31st May, 2008 to discuss hierarchy-renormalized simulation approach.
2) N. Meade Smick (MIT, USA) visited NIFS from 2nd 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.
3) S. Sharafat (University California, San Diego) visited NIFS (A. Sagara) from 3rd to 7th August, 2008 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.
4) T. Shimozuma, T. Seki and H. 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.
5) S. Satake (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) (Host: W. X. Wang) from 22nd October to 22nd December, 2008 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.
6) H. Sugama (NIFS) visited Dallas, Texas, USA during 16th through 23rd November, 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.
7) D. R. Mikkelsen (PPPL) visited NIFS from 8th to 16th December, 2008 for attending the 18th International Toki Conference and for discussions on the stellarator transport physics with NIFS members.

- **Collaborations with Russia**

1) I. Miroshnikov and I. Sharov (St. Petersburg Polytechnical University, Russia) visited NIFS (S. Sudo and N. Tamura) from 6th to 30th December, 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 (20th-22nd October, 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.

### 2-1-2. Plans for 2009

1) 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) C.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) S. Kubo (NIFS) and Y.Nishiura (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.
4) 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.

### 2-2. Heliotron J Team at Kyoto University

### 2-2-1. International Collaborations by the Heliotron J Team at Kyoto University

**- Collaborations with Australia**

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

**- Collaborations with EU**

1) T. Mizuuchi visited Spain on 24th May – 2nd June, 2008 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.
2) A. Matsuyama visited CIEMAT on 18th – 26th October, 2008 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 18th – 26th October, 2008 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 18th – 26th October, 2008 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 1st – 14th September, 2008 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 28th November, 2008 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.

**- 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.

### 2-2-2. Plans for 2009

1) 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.
2) 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.
3) 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.
4) Confinement control of high energy particles by using the optimized field configuration based on the quasi-isodynamic concept will be examined through Heliotron J NBI/ICRF experiments.
5) Comparable study on ECCD will be experimentally carried out among TJ-II, Heliotron J, CHS and LHD.
6) 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.
7) SMBI experiments will be performed to investigate the confinement improvement in Heliotron J.
8) MHD activity control in higher beta plasmas through the field configuration optimization will be tested in Heliotron J.
9) The divertor study in the helical-axis heliotron configuration is to be started in Heliotron J.

## 3. EU

### 3-1. GERMANY

### 3-1-1. International Collaborations in 2008

**- Collaborations with EU**

1) J. Cantarini (IPP Greifswald) visited CEA Cadarache from 8th March to 20th April, 2008.
2) M. Turnyanski (UKAEA Fusion Association, Culham Science Centre, Culham) to IPP Greifswald from 30the March to 3rd April, 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.
3) P. Helander (IPP Greifswald) to Chalmers, Göteborg from 13th to 14th April, 2008.
4) A. Weller (IPP Greifswald) participated in German-Polish Forum, Leipzig, from 21st to 22nd April, 2008.
5) 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 from 23rd to 25th April, 2008: Visit in the frame of the collaboration on neutron activation and MCNP calculations for W7-X.

6) F. Taccogna (University of Bari, Italy) to IPP Greifswald from 10th to 31st May, 2008: Plasma – Wall – Interaction.
7) A. Lazaros (School of Electrical and Computer Engineering, National Technical University of Athens) to IPP Greifswald from 19th to 21st May, 2008: Discussions with W7-X group about various aspects of plasma stability in W7-X.
8) P. Helander (IPP Greifswald) to Chalmers Göteborg, from 22nd to 23rd May, 2008.
9) S. Braun (IPP Greifswald) to Chalmers Göteborg from 25th May to 6th June, 2008: Effect of impurities on collisional zonal flow damping.
10) A. Cooper (CRPP & EPFL Lausanne, Switzerland) to IPP Greifswald from 26th to 29th May, 2008: Turbulence simulations.
11) T. Klinger, O. Grulke, A. Stark, J. Pfannmöller, K. Rahbarnia, H. Laqua, M. Hirsch, M. Otte (IPP Greifswald) to TU Szczecin from 11th to 12th June, 2008: Mini-Workshop "Current topics in plasma waves".
12) M. Jakubowski (IPP Greifswald) visited Culham Science Centre from 15th June to 12th July, 2008.
13) R. Schneider (IPP Greifswald) to University Innsbruck from 16th to 18th June, 2008: Plasma-Wall-Interaction.
14) S. Kasilov (University Graz) to IPP Greifswald from 1st to 31st July, 2008: Implementation of kinetic heat transport model in E3D.
15) P. Helander (IPP Greifswald) to Culham from 7th to 11th July, 2008.
16) E. Sanchez (CIEMAT Madrid) to IPP Greifswald from 13th to 15th July, 2008: Gyrokinetic.
17) J. Preinhaelter (IPP, Prague) to IPP Greifswald from 13th July to 1st August, 2008: Upgrade of the ray tracing code for electron Bernstein waves. Simulation of the Bernstein wave driven current at WEGA.
18) P.Carvalho (CFN, IST, Lissabon) to IPP Greifswald from 7th July to 3rd August, 2008.
19) H. Smith (University of Warwick, UK) to IPP Greifswald from 31st July to 2nd August, 2008: Electron kinetic
20) M. Rome (University Mailand, Italy) to IPP Greifswald from 25th August to 16th September, 2008.
21) T. Fülöp (Chalmers Göteborg) to IPP Greifswald from 7th to 12th September, 2008: Microinstabilities.
22) J. Hastie (Culham UK) to IPP Greifswald from 7th to 13th September, 2008: Resistive instabilities.
23) H. Maaßberg (IPP Greifswald) to University Graz from 8th to 10th September, 2008: Benchmarking of codes in the frame of the International Collaboration on Neoclassical Transport in Stellarators – ICNTS.
24) P. Helander (IPP Greifswald) to London from 19th to 23rd September, 2008: Summer University.
25) A. Weller (IPP Greifswald) visited IPPLM Warschau from 22nd to 25th September, 2008: Visit in the frame of the collaboration on soft X-ray spectrometry, neutron activation and MCNP calculations for W7-X.
26) R. Kleiber, A. Könies (IPP Greifswald) to CRPP & EPFL Lausanne from 6th to 8th October, 2008: Collaboration on Gyrokinetics.
27) F. Taccogna (University of Bari, Italy) to IPP Greifswald from 8th to 28th October, 2008: Plasma – Wall – Interaction.
28) R. Burhenn, A. Dinklage, A. Weller, R. Wolf to CIEMAT from 20th to 22nd October, 2008: 4th Coordinated Working Group Meeting
29) Y. Feng (IPP Greifswald) to CIEMAT Madrid from 19th to 23rd, 2008: 4th Coordinated Working Group Meeting and International Collaboration on Neoclassical Transport in Stellarators.
30) C. Beidler M. Drevlak, (IPP Greifswald) to CIEMAT Madrid from 19th to 25th October, 2008: 4th Coordinated Working Group Meeting and International Collaboration on Neoclassical Transport in Stellarators.
31) J. Geiger, H. Maaßberg, N. Marushchenko, Y. Turkin (IPP Greifswald) to CIEMAT Madrid from 19th to 29th October, 2008: 4th Coordinated Working Group Meeting and International Collaboration on Neoclassical Transport in Stellarators.
32) S. Schmuck (IPP Greifswald) visited CIEMAT, Madrid from 19th October to 22nd November, 2008.
33) A. Weller (IPP Greifswald) collaborated with Ciemat Madrid, Ciemat Madrid from 23rd to 24th October, 2008 on radiation calculations with IONEQ and MHD.
34) E. Belonohy (KFKI-Research Institute for Particle and Nuclear Physics, Budapest) to IPP Greifswald from 2nd to 29th November, 2008.
35) 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 from 5th to 6th November, 2008: Visit in the frame of the collaboration on neutron counters, neutron activation and MCNP calculations for W7-X.
36) T. Klinger (IPP Greifswald) to Ciemat, Madrid from 27th to 29th November, 2008: EPS PPD Board Meeting.
37) P. Helander (IPP Greifswald) to Chalmers Göteborg from 2nd to 4th December, 2008.
38) M. Jakubowski (IPP Greifswald) visited Culham Science Centre from 9th to 22nd November, 2008 and from 7th to 20th December, 2008.
39) W. Schneider (IPP Greifswald) visited Culham Science Centre from 10th to 20th November, 2008.
40) R. Schneider (IPP Greifswald) to University of Bari from 3rd to 4th December, 2008: Plasma-Wall-Interaction.
41) R. Schneider (IPP Greifswald) to University Innsbruck from 4th 6th December, 2008: Plasma-Wall-Interaction.
42) R. Warmbier (IPP Greifswald) to Culham from 7th to 13th December, 2008: Atomic Physics for Plasma-Wall-Interaction.
43) S. Cowley (UKAEA) to IPP Greifswald from 9th to 11th December, 2008.

- **Collaborations with Japan**

1) A. Mishchenko (IPP Greifswald) visited NIFS from 21st April to 10th July, 2008.
2) Y. Suzuki (NIFS) visited IPP Greifswald from 16th to 27th June, 2008.
3) H. Funaba (National Institute for Fusion Science, Toki) to IPP Greifswald from 16th to 26th August, 2008: User interface for the International Stellarator/ Heliotron Confinement Database.

4) M. Yokoyama (National Institute for Fusion Science, Toki) to IPP Greifswald, from 7th to 19th October, 2008: Documentation of Central Electron Root Confinement.
5) K. Matyash, R. Schneider (IPP Greifswald) visited University of Yokohama from 30th October to 8th November, 2008: Plasma-Wall-Interaction.
5) T. Klinger, R. Wolf (IPP Greifswald) to NIFS Takayama from 11th to 14th December, 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 from 25th March to 5th April, 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 from 21st to 24th April, 2008.
3) A. Litvak (Institute of Applied Physics RAS, Nizhny Novgorod) to IPP Greifswald from 24th April to 4th May, 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 from 18th May to 12th July, 2008.
5) T. Richert (IPP Greifswald) visited Budker Institute of Nuclear Physics, Novosibirsk from 12th to 17th July, 2008.
6) W. Schneider (IPP Greifswald) visited IOFFE Physico-Technical Institute, St. Petersburg from 25th August to 11th September, 2008.
7) J. Nührenberg (IPP Greifswald) visited Kurchatov Institute Moscow from 29th September to 2nd October, 2008.
8) M. Mikhailov (Kurchatov Institute, Moscow) visited the IPP Greifswald from 26th October to 20th December, 2008.

- **Collaborations with Ukraine**

1) Y. Kolesnichenko (INR Kiev) to IPP Greifswald from 27th April to 23rd May, 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 from 16th June to 4th July, 2008.
3) Yu. Yakovenko and. V. Lutsenko (INR Kiev) to IPP Greifswald from 19th October to 6th November, 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 U.S.A.**

1) M. Jakubowski (IPP Greifswald) visited General Atomics, San Diego from 6th to 19th April, 2008.
2) P. Helander (IPP Greifswald) visited MIT Boston from 16th to 29th April, 2008.
3) A. Könies (IPP Greifswald) visited ORNL Oakridge from 21st April to 24th May, 2008.
4) D. Eremin (IPP Greifswald) visited PPPL from 16th to 23rd May, 2008.
5) A. Boozer (Columbia University) visited IPP Greifswald from 31st May to 6th June, 2008.
6) K. Bartschat (Drake University, Iowa) to IPP Greifswald from 24th to 28th June, 2008, Atomic Data Assessment.
7) C. Nührenberg (IPP Greifswald) visited PPPL from 22nd July to 5th August, 2008.
8) R. Warmbier (IPP Greifswald) visited Emory University Atlanta from 10th to 29th August, 2008.
9) P. Catto, F. Parra (MIT Boston) visited IPP Greifswald from 6th to 14th September, 2008.
10) G. Kagan (MIT Boston) visited IPP Greifswald from 7th to 12th September, 2008.
11) D. Mikkelsen (PPPL Princeton) visited IPP Greifswald from 8th to 14th September, 2008.
12) T. Klinger (IPP Greifswald) to PPPL, Princeton from 4th to 7th October, 2008: Invited talk and collaboration discussions.
13) A. R. Sharma (Emory University Atlanta) visited IPP Greifswald from 18th October to 1st November, 2008.
14) D. Spong (ORNL Oakridge) visited IPP Greifswald from 25th October to 8th November, 2008.

### 3-1-2. Conference Participation

1) J. Cantarini, H. Dreier, R. König, P. Kornejew, M. Krychowiak, A. Werner; 17th Topical Conference on High Temperature Plasma Diagnostics from 11th to 15th May, 2008, Albuquerque, New Mexico.
2) D. Hildebrandt, K. Matyash, R. Schneider, 18th International Conference on Plasma Surface Interactions from 26th to 30th May, 2008, Toledo, Spain.
3) J. Schacht, MicraTCA Conference from 2nd to 6th June, 2008, Munich, Germany.
4) D. Eremin, Y. Feng, J. Geiger, A. Kus, S. Marsen, Y. Podoba, W. Schneider, H. Thomsen, 35th EPS Plasma Physics Conference from 9th to 13th June, 2008, Hersonissos, Greece.
5) D. Dodt; 28th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering, from 6th to 11th July, 2008, Sao Paolo, Brazil.
6) P. Helander: Workshop "Runaway Electrons in ITER" from 14th to17th July, 2008, Cadarache, France.
7) H. Braune, V. Erckmann, N. Marushchenko, G. Michel: Participation in 7th Workshop "Strong Microwaves in Plasmas" from 27th July to 3rd August, 2008, Nizhny Novgorod, Russia.
8) R. Schneider: DLR-Workshop from 4th to 6th August, 2008 in Schloß Rauischholzhausen, Germany.
9) A. Könies, A. Mishchenko: Joint Varenna – Lausanne Workshop from 24th to 30th August, 2008 in Varenna, Italy
10) G. Michel; 33rd International Conference on Infrared, Millimeter, and Terahertz Waves from 15th to 19th September , 2008, Pasadena, California, USA.
11) P. Helander: Workshop "Kinetic Equations, Numerical Approaches and Fluid Models for Plasma Turbulence" at Wolfgang-Pauli-Institute from 14th to 19th September, 2008, Vienna, Austria.
12) 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 from 15th to 19th September, 2008, Rostock, Germany.
13) J. Schacht; 5th Symposium On Automatic Control, 18th to 19th September, 2008, Wismar, Germany.
14) C. Beidler, R. Burhenn, M. Drevlak, Y. Feng, M. Jakubowski, T. Klinger, H. Laqua, F. Wagner, A. Weller, R. Wolf; IAEA Fusion Energy Conference from 12th to 18th October, 2008, Geneva, Switzerland.
15) K. Matyash:Project-Clic08-Workshop from 15th to 17th October, 2008 in CERN, Switzerland.
16) 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 from 16th to 21st November, 2008 in Schloß Ringberg, Germany.
17) R. Wolf, 18th International Toki Conference from 9th to 12th December, 2008, Toki, Japan.

### 3-1-3. Participation in Joint Projects

1) International stellarator confinement data base
Coordinated Working Group: CWGM4, Ciemat Madrid from 20th to 22nd October, 2008, contributions from A. Dinklage, A. Weller, J. Geiger.
2) 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.
3) International H-mode confinement data base
Contributions from M. Hirsch.
4) ITPA diagnostics
Contributions from R. König
Specialists Working Group on Reflectometry (RWG): M. Hirsch.
Specialists Working Group on First Mirrors: R. König.

### 3-1-4. 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) D. Andruczyk, A. Dinklage, P. Drewelow, T. Klinger, S. Marsen, M. Otte, Y. Podoba, S. Schmuck, T. Stange, R. Wolf, D. Zhang: DPG-Frühjahrstagung, 30th March to 3rd April, 2009, Greifswald.
2) J. Schacht: IEEE Real Time Conference from 10th to 15th May, 2009, Beijing, China.
3) H. Dreier, D. Zhang: 36th International Conference on Plasma Science and 23rd Symposium on Fusion Engineering, 31st May to 5th June, 2009, San Diego, USA.
4) T. Bluhm, J. Krom, H. Laqua, H. Riemann, A. Spring, A. Werner: IAEA-TM on Control, Data Acquisition, and Remote Participation for Fusion Research, 15th to 19th June, 2009, Aix en Provence, France.
5) G. Michel: 18th Topical Conference on Radio Frequency Power in Plasmas, 24th to 26th June, 2009, Gent, Belgium.
6) H. P. Laqua, Y. Podoba, S. Schmuck, W. Schneider, H. Thomsen, R. Wolf: 36th EPS Conference on Plasma Physics, 29th June to 3rd July, 2009, Sofia, Bulgaria.
7) M. Krychowiak: 14th International Symposium on Laser-Aided Plasma Diagnostics, 21st to 24th September, 2009, Castelbrando, Italy.
8) H. Braune: 34th International Conference of Infrared, Millimetre and Terahertz Wave (IRMMW-THz), 21st to 25th September, 2009, Busan, Korea.
9) A. Dinklage, M. Jakubowski, T. Klinger, M. Otte, A. Weller, R Wolf: International Stellarator/Heliotron Workshop 12th to 18th October, 2009, Princeton, USA.

## 3-2. SPAIN

### 3-2-1. 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 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 U.S.A.**

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).

- **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.

### 3-2-2. 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 focused in the following topics:

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

1) Investigation of plasma conditions (density, hating power, role of magnetic configuration) for the development of edge (H-mode) and core bifurcations.
2) 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.
3) Full lithium coating in TJ-II: Confinement studies with full lithium coating.
4) 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.
5) Edge and core momentum transport studies. Poloidal and parallel momentum re-distribution mechanisms and toroidal coupling of fluctuations (zonal flow physics).
6) Operational limits: Impurity accumulation and dynamics in relation to operational parameters; role of ballooning stability.
7) 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:
8) Heating: Full operation of two NBI systems.
9) 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.
10) 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.
11) Plasma Fuelling: Distribution of the source and fuelling efficiency in normal and divertor configurations with Li coating.
12) 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:**

1) 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).
2) Modelling of kinetic effects on transport. Wave-particle interaction: Large scale simulation for ions.
3) 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.
4) 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.
5) Eirene code studies: 3-D simulation of particle sources.
6) 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.

- **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**
1) 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**
1) 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**
1) A. Murari will visit TJ-II to continue our collaboration on pattern recognition techniques.

- **Collaborations with U.S.A.**

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.

## 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.

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

### 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/ν 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)).
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 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) 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 $1/\nu$ 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 . (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 N2 + H2 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 H2 or H2+N2 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/m2 that is close to parameters of ion flows on a wall in modern stelalrators.
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.

**- 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), U.S.A.**

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 $\mu$A/cm2. 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 Al2+ 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.

**- 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.

- **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 SDT 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 Pfusion. 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.

## 6. UNITED STATES

### 6-1. ORNL IEA Stellarator Activities, 2008

- **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.

- **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 H0 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.

- **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).

### 6-2. PPPL IEA Stellarator Activities, 2008

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-β experiments in LHD. His experimental proposal to achieve the high central β was executed as a joint experiment.

## 7. AUSTRALIA

### 7-1. 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 Z. 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.

### 7-2. 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.

(Yamada, H.)