Implementing Agreement for Cooperation in Development of the Stellarator Concept

2007 Executive Committee Annual Report to the Fusion Power Coordination Committee

January 2008

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EXECUTIVE SUMMARY

The present report overviews the scientific and technical progress achieved in 2007 by the parties to the Stellarator Concept Implementing Agreement, who have greatly benefit from its international collaborative framework. The document reports the collaborations in 2007 and the parties' research plans for 2008, including technical reports on 2007 activities.

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1 AUSTRALIA

1.1 International collaborations in 2007

1) The National Plasma Fusion Research Facility, centred on the H-1 heliac, has been extended until 2010 under existing funding. This includes limited 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. The H-1NF heliac 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.

2) Magnetic configuration studies by S. Kumar, B. Blackwell and J. Harris (ORNL) have produced a highly refined model of H-1 geometry including error fields, and have demonstrated spontaneous appearance of the 3/2 magnetic island, accompanied by a small improvement in particle confinement, and large changes in the core electric field.

3) M. Shats and his group have applied spectral transfer analysis to plasma turbulence studies, and in a new fluid tank facility, have studied the suppression of turbulence by mean flows.

4) MHD and configuration studies have led to several collaborations: A large volume of data on Alfvén range instabilities in H-1 has been gathered following the installation of a second 20-coil poloidal Mirnov array, and extensive computer controlled configuration scans. An innovative data mining technique has been developed to classify the vast data set into a small number of clusters representing distinct phenomena.

- This technique has been successfully applied to new poloidal array data from Heliotron-J, during a visit by B. Blackwell and D. Pretty in 2007, through a collaboration on a comparative study of the phenomena in both machines.

- D. Pretty also visited CIEMAT in November 2007 to apply the technique to TJ-II data, and Greifswald for application to W7-AS data.

- 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.

5) 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 (J. Howard) 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 and their derivatives 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, Consorzio RFX and IPP-Greifswald has seen the installation of coherence imaging systems on RFX and WEGA stellarator.

- Application of a 2-d imaging system for CXRS on KSTAR (2009).

- Development of a Zeeman-assisted coherence imaging system for the plasma divertor in the DIII-D tokamak.

- Development of imaging birefringent interferometers for Thomson scattering on JT-60U in a collaboration with T. Hatae from JAEA. Measurements will be undertaken at JT-60U in April 2008.

- A collaboration between B. James (Sydney University), K. Takiyama (Hiroshima), and J. Howard (ANU) has resulted in a helium beam diagnostic producing spatially localised, time resolved measurements of electron temperature and density in H-1 via line ratios. K. Takiyama has recently demonstrated improvements in the sensitivity of the LIF technique which have improved prospects for the measurements of electric field in H-1.

6) 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 infrared 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 2008/2009.

- **Theoretical collaborations**

1) A collaboration between ANU (R. Dewar, M. Hole, M. McGann and R. Mills) 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). M. McGann visited PPPL in 2007/8, and a 3D test problem in which two Taylor-relaxed regions exhibiting islands and chaos, separated by a good magnetic surface satisfying force balance, was constructed. Also, work on the stability of a stepped-pressure plasma in the cylindrical approximation was published.

2) Collaboration with the UKAEA led to a modulational model for the frequency splitting of Alfvén eigenmodes.

3) A numerical study of resistive drift wave turbulence in a Hasegawa-Wakatani model showed the existence of a Dimits shift (upshift of the threshold for the onset of turbulence) due to the spontaneous excitation of zonal flows. The upshifted onset of turbulence was correlated with Kelvin-Helmholtz instability of the zonal flows.

The Australian ITER Forum, a group of 130 Australian scientists and engineers has developed a long-term strategy plan for fusion science and engineering, which has been submitted to the Australian Government.

1.2 Research plans for 2008

1) Over the next years, experiments will extend studies of turbulence, flows and self-organization in fluid tanks and extend magnetic configuration studies of instabilities in H-1 driven by fast particles from ICRF and ECR heating.

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. Mapping of magnetic Islands and observation of their effect on plasma will be made by a combination of electron beam mapping and optical and probe plasma diagnostics.

3) 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. A new absolutely calibrated supersonic gas injector designed for fuelling studies will be used in conjunction with the recently upgraded tomographic plasma interferometer and imaging spectroscopy systems to characterise particle transport.

- **Theoretical research plans**

1) Further development of the new stepped pressure 3D MHD equilibrium formulation will be carried out.

2) A comparison between the modulational stability theory of zonal flow generation and observations on H-1NF in H-mode will be continued.

3) Comparisons between numerical simulations and low-dimensional models of confinement transitions will be continued.

2 EU

2.1 GERMANY

2.1.1 International collaborations in 2007

- **Collaborations with EU**

1) A. Szappanos (KFKI-Research Institute for Particle and Nuclear Physics, Budapest) to IPP Greifswald, 28.01. – 31.01.2007, compose an outline of the interface specification containing the trigger signals also.

2) H. P. Laqua (IPP Greifswald) to TCV-EPFL Lausanne (CH), 29. – 30.1.07, experiments for central power deposition with electron Bernstein waves.

3) H. Thomsen (IPP Greifswald) to IST, Lisbon, 27.02. – 02.03.2007.

4) H. Fernandez (CFN, IST Lisbon) to IPP Greifswald, 28.03. – 29.03.2007, Talk: "The IST approach to steady-state fusion devices CODAC systems" and discussion of opportunities of cooperation between IST and IPP in the field of data acquisition and data analysis.

5) P. Carvalho (CFN, IST Lisbon) visited the IPP Greifswald, 01.05. – 31.07.2007.

6) S. Marczynski (Institute of Physics, Szczecin, Poland) visited the IPP Greifswald, 07.05. – 07.06.2007.

7) R. Schneider (IPP Greifswald) to DLR, Bonn, 15.05.2007.

8) H. Frerichs (FZ-Juelich) visited the IPP Greifswald, 20.05. – 25.05.2007.

9) P. Kornejew (IPP Greifswald) to CIEMAT, Madrid, 20.05. – 26.05.2007.

10) I. Ksiazek (Institute of Physics, Opole University) to IPP Greifswald, May 2007, discussion of the main topics of the cooperation program concerning the development of a fast CO-Monitor for W7-X. Moreover, the operation of the existing X-ray spectrometer used at W7-AS was trained as well as its transfer to the institute at University Opole was prepared

11) P. Helander (IPP Greifswald) to KTH Stockholm, 01.06.2007.

12) P. Helander (IPP Greifswald) to Chalmers University, Gothenburg, 29.06.2007.

13) P. Helander (IPP Greifswald) to Culham Laboratory (Summer School), 05.07. – 11.07.2007.

14) R. Leszek, S. Jablonski (IPPLM Warsaw) visited the IPP Greifswald, 15.08. – 18.08.2007.

15) H. P. Laqua (IPP Greifswald) visit IPP/CR Prague, 25.08. – 28.08.07, preparation of EBW ray-tracing calculations for WEGA.

16) T. Schwarz-Selinger (IPP Garching) visited the IPP Greifswald, 03.09. – 07.09.2007.

17) V Szabo (Budapest University of Technology and Economics) visited the IPP Greifswald, 16.09. – 06.10.2007.

18) P. McNeely (IPP Garching) and B. Schweer (FZ-Juelich), 17.09. – 21.09.2007, Meeting concerning the project „development and construction of the diagnostic injector W7-X“.

19) K. McCarthy (CIEMAT) visited the IPP Greifswald, 19.09. – 22.09.2007.

20) S. Recsei (KFKI, Budapest) visited the IPP Greifswald, 02.10. – 16.10.2007.

21) T. Fülöp (TH Chalmers, Göteborg) visited the IPP Greifswald, 07.10. – 13.10.2007.

22) S. Jablonski (IPPLM Warschau) visited the IPP Greifswald, 15.10. – 20.10.2007.

23) J. Urban, J. Preinhaelter (Institute of Plasma Physics, AS Czech Republic), 08.10. – 07.11.2007, simulation of the recently developed electron bernstein waves, power operation at the WEGA with ray-tracing code.

24) D. Tskhakaya (University Innsbruck) visited the IPP Greifswald, 31.10. – 27.11.2007.

25) N. Marushchenko (IPP Greifswald) to Forschungszentrum Jülich, 05.11. – 09.11.2007.

26) R. Zagórski, S. Glowacz (IPP&LM, Warsaw) visited the IPP Greifswald, 09.12. – 22.12.2007.

- **Collaborations with Japan**

1) M. Yokoyama (NIFS) to IPP Greifswald, 23.05. – 07.06.2007, Coordinated Working Group Meeting.

2) T. Bluhm, C. Hennig, A. Kus, S. Pingel and J. Schacht (IPP Greifswald) visited NIFS, 11.06. – 15.06.2007.

3) M. Kobayashi (NIFS) visited the IPP Greifswald, 26.08. – 08.09.2007.

4) A. Weller (IPP Greifswald) visited NIFS, 07.09. – 21.12.2007.

- **Collaborations with Russia**

1) M. Mikhailov (Kurchatov Institute, Moscow) visited the IPP Greifswald, 04.03. – 30.03.2007.

2) D. Shchegol’kov and (Institute of Applied Physics RAS, Nizhny Novgorod) visited IPP Greifswald, 13.03. – 16.03.2007.

3) M. Mikhailov (Kurchatov Institute, Moscow) visited the IPP Greifswald, 03.06. – 30.06.2007.

4) V. Davydenko, A. Ivanov, V. Kolmogorov, I. Shikhovtsev (Budker Institute Novosibirsk) to IPP Greifswald, 17.09. – 21.09.2007, Meeting concerning the project “development and construction of the diagnostic injector W7-X“.

5) M. Mikhailov (Kurchatov Institute, Moscow) visited the IPP Greifswald, 28.10. – 22.12.2007.

- **Collaborations with Ukraine**

1) Alexander Zhezhera (IPP Kharkov, Ukraine) to IPP, 12.02.–09.03.2007, experiments with heavy ion beam probe.

2) Ya. I. Kolesnichenko (INR Kiew) to IPP, 29.04. – 27.05.2007, further development and test of the theory of GAE/NGAE modes, predictive calculations for W7-X Collaborations with USA.

3) A. Simakov (Los Alamos National Laboratory, New Mexico, USA) visited the IPP Greifswald, 08.09. – 23.09.2007.

4) V. Lutsenko, Yu. Yakovenko (Institute for Nuclear Research, Kyiv) to IPP Greifswald, 07.10. – 05.11.2007.

- **Collaborations with USA**

1) I. Joseph (DIII-D, San Diego, USA) visited the IPP Greifswald, 19.02. – 02.03.2007.

2) P. Xanthopoulos (IPP Greifswald) to Emory University, Atlanta, USA, 12.03. – 21.03.2007.

3) A. R. Sharma (IPP Greifswald) to Emory University, Atlanta, USA, 06.04. – 11.05.2007.

4) L. Guazzotto (MIT, Cambridge/USA) visited the IPP Greifswald 09.05. – 11.05.2007.

5) A. Mishchenko (IPP Greifswald) to PPPL, USA, 20.05. – 02.06.2007.

6) L. Koziol (University of Southern California, USA) visited the IPP Greifswald, 08.06. – 10.06.2007.

7) B. Braams (Emory University, Atlanta, USA) visited the IPP Greifswald, 04.07. – 11.07.2007.

8) K. Bartschat (Duke University, USA) visited the IPP Greifswald, 16.07. – 22.07.2007.

9) D. Mikkelson (PPPL, USA) visited the IPP Greifswald, 24.11. – 14.12.2007.

10) J. Canik, R. Maingi (ORNL, Oak Ridge, USA) visited the IPP Greifswald, 03.12. – 14.12.2007.

11) Z. Unterberg (DIII-D, San Diego, USA) visited the IPP Greifswald, 03.12. – 14.12.2007.

2.1.2 Conference participation

1) Y. Feng, F. Sardei; Workshop Stochasticity in Fusion Plasmas, 05.03.–07.03.2007, Juelich, Germany.

2) A. Dinklage, D. Dodt, S. Marsen, Y. Podoba, S. Schmuck, A. Werner; DPG-Tagung, 19.03. – 23.03.2007, Düsseldorf, Germany.

3) G. Kühner; Software Engineering, 27.03. – 30.03.2007, Hamburg, Germany.

4) J. Schacht; IEEE NPSS 15th Real Time Conference, 29.04. – 04.05.2007, Illinois, USA.

5) V. Erckmann; 17th Topical Conference on Radio Frequency Power in Plasmas, 07.05. – 09.05.2007, Florida, USA.

6) K. Matyash, R. Schneider, F. Taccogna; 11th International Workshop on Plasma Edge Theory in Fusion Devices, 23.05. – 25.05.2007, Takayama, Japan.

7) T. Bluhm, C. Hennig, A. Kus, S. Pingel, J. Schacht; 6th IAEA TM on Control, Data Acquisition and Remote Participation for Fusion Research , 04.06. – 08.06.2007, Inuyama, Japan.

8) V. Erckmann, N. Marushchenko; IAEA TM on ECRH Physics and Technology for ITER, 06.06. – 08.06.2007, Vienna, Austria.

9) H. Dreier, M. Krychowiak, H. P. Laqua, N. Marushchenko, K. Matyash, C. Nührenberg, J. Nührenberg, M. Otte, R. Preuss, Y. Turkin, A. Weller, D. Zhang; 34th EPS Conference on Plasma Physics, 02.07. – 06.07.2007, Warsaw, Poland.

10) F. Taccogna; 43rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 08.07. – 11.07.2007, Ohio, USA.

11) D. Dodt; 27th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering, 08.07. – 13.07.2007, N.Y., USA.

12) F. Taccogna; 27th International conference on Phenomena in Ionized Gases,15.07. – 20.07.2007, Prague, Czech Republic.

13) D. Andruczyk, H. Braune, V. Erckmann, G. Michel, Y. Turkin; 19th Joint Russian-German STC Workshop, 18.07. – 24.07.2007, Karlsruhe, Stuttgart, Garching, Germany.

14) M. Laux, S. Marsen, F. Taccogna; VII IWEP International Workshop on Electrical Probes, 22.07. – 25.07.2007, Prague, Czech Republic.

15) F. Taccogna; International Conference on Ion Sources, 26.08. – 21.08.2007, Cheju, Korea.

16) H. Braune; IRMMW-THz 2007, 02.09. – 07.09.2007, Cardiff, UK.

17) P. Helander, A. Mishchenko, P. Xanthopoulos; 12th European Fusion Theory Conference, 24.09. – 27.09.2007, Madrid, Spain.

18) J. Cantarini, A. Dinklage, H.-J. Hartfuss, R. König; International Workshop on Burning Plasma Diagnostics, 24.09. – 28.09.2007, Varenna, Italy.

19) R. Wolf; 8th International Symposium on Fusion Nuclear Technology, 01.10. – 05.10.2007, Heidelberg, Germany.

20) J. Svensson; IEEE International Symposium on Intelligent Signal Processing, 03.10. – 05.10.2007, Madrid, Spain.

21) D. Eremin, A. Koenies, A. Werner; 10th IAEA TM on Energetic Particles in Magnetic

Confinement Systems, 08.10. – 10.10.2007, Kloster Seeon, Germany.

22) J. Schacht; 12. Symposium Maritime Elektrotechnik, Elektronik und Informationstechnologie, 08.10. – 10.10.2007, Rostock, Germany.

23) C. Beidler, A. Dinklage, Y. Feng, J. Geiger, P. Helander, R. Kleiber, H. Maaßberg, N. B. Marushchenko, F. Sardei, Y. Turkin, A. Weller; International Stellarator/Heliotrons Workshop, 15.10. – 19.10..2007, Toki, Japan.

24) J. Cantarini, D. Dodt, H. Dreier, H.-J. Hartfuss, M. Hirsch, R. König, M. Krychowiak, A. Kus, M. Otte, Y. Podoba, S. Schmuck, H. Thomsen, F. Wagner, R. Wolf, D. Zhang, H. Laqua; 49th APS-Conference, 12.11. – 16.11.2007, Orlando, USA.

25) A. Rai; 13th International Conference on Fusion Reactor Materials, 09.12. – 14.12.2007, Nizza, France.

2.1.3 Participation in joint projects

- **International stellarator confinement data base**

Contributions from C.D. Beidler, A. Dinklage, A. Kus, H. Maaßberg, R. Preuss, Yu. Turkin, A. Weller.

- **International stellarator profile data base**

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

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

Contributions from A. Kus.

2.1.4 Plans for 2008

- **Planning stellarator theory**

1) P. Helander will visit the MIT Plasma Science and Fusion Centre to initiate collaboration on kinetic transport theory.

2) A. Mishchenko plans to visit NIFS to work on gyrokinetic theory.

3) A. Könies is going to visit Oak Ridge National Laboratory to initiate a new collaboration with Donald Spong in the field of fast-ion-driven instabilities.

4) J. Nührenberg plans to visit the Kurchatov Institute once or twice for collaboration on stellarator optimisation.

5) M. Marushchenko will visit General Atomics and MIT to work on problems relating to electron cyclotron heating and current drive.

- **Spectroscopic diagnostics**

1) M. Krychowiak (IPP Greifswald) plans to visit the FZ-Juelich at least once for three weeks to work on the development of the spectrometer system for W7-X. Also a one week visit to JET is planned for testing a spectrometer system on the JET plasma.

2) D. Zhang will visit MAST (Culham Science Centre) bolometer team for cooperation and discussion about the tomographic reconstruction method.

3) D. Zhang will visit IPP Garching for cooperation with the AUG-team and ITER bolometer team.

4) Rainer Burhenn, U. Herbst, E. Pasch, J. Schacht (IPP Greifswald), visit of 3 days duration of TEXTOR (FZJ) planned for discussions concerning the HEXOS control and preparational work for the integration of HEXOS at W7-X.

5) 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, several visits of 1 week duration in each direction planned.

6) M. Laux and L. Mollwo will participate in the construction and commissioning of the fast actuator at FZ-J in preparation for the design of the movable Langmuir probes for W7-X.

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

8) 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) Wolfgang Schneider plans to visit the Culham Science Centre for 3 weeks in order to carry out CX-NPA measurements with the former IPP-CX-NPA from W7-AS in comparison with results of CXRS diagnostics on MAST. Further he will take part in the operation of an ACORD-24 analyser at TJ-II in CIEMAT, Madrid and will provide contributions to a specific solution for the new prototype of data acquisition for NPA

measurements for about 4 weeks (2 x two weeks). With respect to the upgrading of an old 10-channel analyser into an ACORD 24-type analyser he will take part in the calibration procedure of this analyser and determination of the features and especially to the energy resolution after modernisation for 3 weeks at IOFFE-Institute St. Petersburg.

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), Microwave diagnostic development, Cooperation contract on "Development and construction of a multichannel CO2-Interferometer for W7-X", trainee program Microwave Diagnostic Engineering for ITER.

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, IST (Lisbon) and CEA (Cadarache). Vice versa trainees from IST and CIEMAT will be hosted at Greifswald.

- **International stellarator profile data base**

1) A. Dinklage (IPP Greifswald) plans to visit CIEMAT for scaling studies.

2) Contributions from C.D. Beidler, R. Burhenn, A. Dinklage, Y. Feng, A. Kus, H.

Maaßberg, Yu. Turkin.

- **International stellarator profile data base and international collaboration on neoclassical transport**

Topical Group Workshop in Madrid (Fall 2008).

- **EMC3-EIRENE code for edge plasma modelling**

Y. Feng (IPP Greifswald) will visit Ciemat (Spain): edge physics modelling and 3D divertors.

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

1) H. P. Laqua (IPP Greifswald) visit HSX-Madison, 17.3 – 19.3.08: Establish collaboration on 28GHz ECRH, diagnostic development and neoclassical transport investigation on HSX and WEGA with comparative experiments.

2) J. Urban and J. Preinhaelter to Greifswald 4 weeks: Implementation of a Fokker-Planck-Code into the EBW ray-tracing-code for the calculation of the EBW driven current at WEGA.

3) H. P. Laqua (IPP Greifswald) to TJ-2 CIEMAT (Spain) 1 week: initial experiments on 28 GHz heating at TJ-2 (shifted in from 2007).

4) H. P. Laqua (IPP Greifswald) to IPP/CR Prague 1 week: interpretation of 3-dimensional ray-tracing calculation for Bernstein waves current drive at Wega.

5) H. P. Laqua (IPP Greifswald) visit NSTX and NCSX Princeton, 20.3 – 22.3.08: establish collaboration on Bernstein wave heating and current drive at NSTX, establish collaboration on the preparation of the 70 GHz ECRH for NCSX.

- **International collaboration on data validation**

Preparation of VALIDATION 6 with CIEMAT (J. Vega), preparation of common fusion software repository (J. Storrs, UKAEA).

- **VALIDATION Workshop**

A. Dinklage and A. Werner are going to visit CIEMAT for joint organization of the workshop conference participation.

- **Conference participation**

1) H. Thomsen, A. Werner; 5th Workshop on Fusion Data Processing, Validation and Analysis, 14.01. – 16.01.2008 Culham, UK.

2) A. Junge; 10 AICON 3D Forum, 06.03.2008, Braunschweig.

3) T. Klinger; DPG-Frühjahrstagung, 10.3. – 14.3.2008, Darmstadt.

4) V. Erckmann, H. Laqua; EC-15, 15th Joint Workshop on Electron Cyclotron Emission and Electron, 10.03. – 13.03.2008, Yosemite, USA.

5) J. Müller; 9. Norddeutsche Fachtage der Hochschule Neubrandenburg, 12.-13.04.2007 Neubrandenburg.

6) M. Schröder, R. Vilbrandt; DACH Jahrestagung, 28.04. – 30.04.2008, St. Gallen, Schweiz.

7) R. König, P. Kornejew, Werner, R. Wolf; 17th High Temperature Plasma Diagnostics Conference, 11.05. – 15.05.2008, Albuquerque, New Mexico, USA.

8) D. Hildebrandt, W. Schneider, U. Wenzel; PSI-18 Plasma Surface Interactions in Controlled Fusion Devices, 26.05. – 28.05.2008, Toledo, Spain.

9) H.-S. Bosch; Jahrestagung Kerntechnik, 27.05. – 29.05.2008, Hamburg.

10) T. Klinger, M. Krychowiak, A. Kus, H. Thomsen, A. Weller, R. Wolf; 35th EPS Conference on Plasma Physics, 09.06. – 13.06.2008, Hersonissos, Crete.

11) C. Dhard, M. Nagel; ICEC22 - ICMC2008 International Cryogenic Engineering Conference and 22 International Cryogenic Materials Conference 2008, 21.07. – 25.07.2008, Seoul, Korea.

12) H. Braune, V. Erckmann; 7th SMP (+dt.-russ.WS), 27.07. – 01.08.2008, Nizhnij Novgorod, Russia.

13) T. Andreeva, C. Baylard, T. Bluhm, D. Birus, J. Boscary, R. Brakel, H. Braune, T. Bräuer, V. Bykov, D. Chauvin, P. Czarkowski, M. Czerwinski, A. Dudek, A. Dübner, K. Egorov, G. Ehrke, M. Endler, J. Fellinger, D. Gustke, D. Hathiramani, C. Hennig, A. Jung, J. Kallmeyer, T. Klinger, T. Koppe, R. Krause, M. Köppen, G. Kühner, F. Kunkel, Heinrich Laqua, Heike Laqua, M. Lewerentz, T. Mönnich, M. Nagel, M. Pietsch, D. Pilopp, J. Riemann, K. Riße, T. Rummel, P. Sanchez, J. Schacht, F. Schauer, W. Schneider, M. Schrader, A. Spring, H. Viebke, A. Tereshchenko, P. van Eeten, A. Vorköper, S. Weber, L. Wegener, M. Ye, D. Zacharias; 25th Symposium on Fusion Technology, 15.09. – 19.09.2008, Rostock, Germany.

14) G. Michel; IRMMW, 15.09. – 19.09.2008, Pasadena, USA.

15) T. Klinger; ICPP- International Conference on Plasma Physics, 8.09. – 12.09.2008, Fukouka, Japan.

16) H. Viebke, B. Missal; TOFE 2008, 18th Topical Meeting on the Technology of Fusion Energy, 28.09. – 02.10.2008, San Francisco, USA.

17) R. Burhenn, M. Jakubowski, V. Tomarchio, Weller, Wolf; 22nd IAEA Fusion Energy Conference - 50th Anniversary of Controlled Nuclear Fusion Research, 13.10. – 18.10.2008, Geneva, Switzerland

18) C. Dhard; DKV-Tagung 2008, Deutsche-Kälte-Klima-Tagung 2008, 19.11. – 21.11.2008, Deutschland.

19) H.-S. Bosch; 18th International Toki Conference (ITC18) on Development of Physics and Technology of Stellarator/Heliotrons December 9 – 12, 2008, Ceratopia Toki, Toki-City, Gifu, Japan.

2.2 SPAIN

2.2.1 International collaborations in 2007 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 2007 experimental campaign.

2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory visited at CIEMAT in November 2007 to carry out new developments in the gyrotrons power measurement system.

3) M. Tereshchenko (form IOFAN) visited CIEMAT and collaborated in the improvement and bench-marking of the ray-tracing code TRUBA. The current drive calculations are under development to be included in the code. (October – December 2008).

4) S. Petrov (IOFFE) (Oct) and D. Makarin (St. Petersburg University) (May) visited CIEMAT to participate on charge exchange spectrometry measurements.

5) N. Skvortsova (IOFAN) was participating in experiments with scattering signals from the ECH RF power in TJ-II (Nov 2007).

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 (comparative studies in B and Lithium coated wall conditions) and first measurements with two slit HIBP detector.

- Collaborations in Europe

Germany

1) G. Müller IPF (Stuttgart) stayed at CIEMAT during six months in 2007. He participated in the start-up of the new high voltage power supply for the ECRH system. -K. Schlüter IPF (Stuttgart) visited CIEMAT in July 2007. He improved some parts of the gyrotron modulators in order to allow their remote control in the near future.

2) W. Schneider (IPP, Garching) was visiting CIEMAT (October) on NPA experiments.

3) Y. Podoba (IPP-Greifswald) has participated in the HIBP experiments in the TJ-II (November – December 2007) stellarators (measurements with two slit detector and improving HIBP capabilities reducing signal to noise ratio).

4) E. Sánchez visited IPP-Greifswald to advance in the gyrokinetic TORB code development.

Portugal

1) C. Silva and I. Nedzelskiy were visiting CIEMAT to continue our collaboration on edge studies (biasing experiments and RFA development) during 2007. Carlos Silva, Andre Neto and Horacio Fernandes have also participated (November 2007) in the definition of control and software requirements for JET-EP2 diagnostic enhancement and test in TJ-II facilities (fast camera).

2) L. Cupido was visiting CIEMAT (Feb-Mar 2007) to continue our collaboration on microwave reflectometry, in particular to install and test a second channel for the Hopping reflectometer installed at TJ-II stellarator.

3) L. Guimarais was visiting CIEMAT (April, June and Oct-Nov 2007) to continue our collaboration on microwave reflectometry, in particular to investigate the parametric dependence of the perpendicular velocity shear layer formation in TJ-II stellarator.

Hungary

1) G. Kocsis and G. Petravich were visiting CIEMAT (May / November 2007) to participate in the optical coupling design of the JET-EP2 diagnostic enhancement project and testing in TJ-II facilities.

2) András Szappanos visited CIEMAT in the last quarter of 2007 to discuss a collaboration on pattern recognition in images and its application to real-time conditions.

Czech Republic

H. Brotankova was visiting CIEMAT (May 2007) to participate in the analysis of edge plasma fluctuations and I. Duran (November 2007) in the installation of magnetic sensors in TJ-II.

- **Collaborations with USA**

1) J. Tsai and Philip Ryan visited CIEMAT to collaborate with the NBI Group in the period 1st-15th July 2007. The NBI activities were organized around three main problems: Ion Source maintenance, Commissioning of injector #2, and High Voltage Power Supplies.

2) J. Caughman (ORNL) visited CIEMAT in July and September 2007 to participate in the installation of the antenna for the Electron Bernstein Emission diagnostic.

- **Collaborations with Ukraine**

1) 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 2007 experimental campaign.

2) S. S. Pavlov (Kharkov Institute of Physics and Technology) visited CIEMAT to introduce complex frequencies in the dispersion relation in order to study plasma

instabilities and to develop a fast way to calculate the plasma dispersion function in order to use it in the fully relativistic estimations for the ray tracing code TRUBA (October – November 2007).

- Collaborations with Japan

1) A. Cappa visited Japan in February 2007 to participate in the ECRH experiments in Heliotron-J and to discuss comparative ECR studies with TJ-II.

2) A. Fernández visited Japan in September 2007 to carry out ECCD experiments in the Heliotron-J and to compare the results with the TJ-II experiments.

3) S. Kobayashi (Institute of Advanced Energy, Kyoto University) was visiting CIEMAT (March) to collaborate on plasma spectroscopy.

4) K. Nagaoka (National Institute for Fusion Science) visited CIEMAT in the week 5-9 March 2007 to give a talk (Fast ion measurements in LHD) and discuss fast ion flux measurements, in the framework of an international collaboration for the study of energetic particle transport in stellarators.

5) S. Yamamoto (National Institute for Fusion Science) visited CIEMAT in the week 5-9 March 2007 to give a talk (Energetic ion-driven MHD instabilities in LHD and Hel-J) and discuss the interaction of fast ions with MHD activity, in the framework of an international collaboration for the study of energetic particle transport in stellarators.

6) T. Mizuuchi visited CIEMAT in the period 25-26 October 2007 to discuss with the members of the Experimental Group about hardware and analysis tools needed for the 2-D visualization of plasma turbulence.

7) G. Motojima spent three weeks in CIEMAT in April 2007 discussing issues related with EC current drive and MHD activity in TJ-II. He also gave lectures in the Erasmus Mundus PhD Programme and a seminar in the Fusion Lab entitled "Toroidal Current Control in ECH Plasmas on Heliotron J".

- Collaborations with Australia

David Pretty (ANU) spent three weeks in CIEMAT, in November 2007. A collaboration agreement on data mining techniques applied to the analysis and comparison of MHD activity in stellarators was launched during his visit.

- International collaborations: stellarator working groups

1) Three members of the CIEMAT TJ-II team (C. Hidalgo. D. López-Bruna and E. Ascasíbar) participated in the 2nd Coordinated Working Group Meeting (CWGM) held in Greifswald. Germany, in June 2007 on the topics of: ISCDB (iota dependencies), impurity transport, edge physics, neoclassics and high beta physics.

2) The 3rd CWGM took place in Toki in October 2007, right after the celebration of the ISHW 2007and dealt with the same issues discussed in the previous 2nd CWGM. Again, three members of the CIEMAT TJ-II team (C. Hidalgo. D. López-Bruna and F. Castejón) attended the meeting.

2.2.2 Plans for 2008

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 power threshold for core transition development with and without rationals and role of magnetic shear (dynamic variation of the magnetic configuration).

- 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. Influence of electric fields on transport and MHD stability. ELM physics.

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

- Power and particle exhaust, plasma-wall interaction: Studies of de-tritiation methods.

Development of plasma auxiliary systems:

- **Heating:** Commissioning and first tests of the EBWH system. Port-Through Power (400 kW) measurement by Infrared Thermography for NBI-2 system.

- **Diagnostics:** Further development of TJ-II systems including; design of a new reflectometer antenna system for Doppler reflectometry measurements; First measurements of EBW emission at 28 GHz; Expand Diagnostic Neutral beam measurements to toroidal capabilities; Up-grade of HIBP diagnostic for fluctuation and transport measurements; Development of a new ion temperature edge diagnostic; 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:** First experiments of the main power supply control system looking for vertical coil current modulation (aiming to dynamic control of magnetic well) and helical coil current modulation (aiming to dynamic control of low order rational location). Dynamic investigation of the influence of rationals on transport. Data mining techniques (pattern recognition).

Theory and modelling:

- 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.

- Theoretical EBW studies in TJ-II: Linear estimation of EBW Current Drive; Link between particle transport and heating, using TRUBA and ASTRA codes.

- Development of the stellarator concept. Divertor stellarator physics: Investigation on the feasibility of the flux expanded divertor concept for TJ-II. Optimization of stellarator configurations and equilibrium studies: Search for optimized stellarator configurations compatible with a blanket.

- Eirene code studies. Simulation of particle fluxes and neutral pressure distribution in TJ-II H_2 and He plasmas.

- Computation developments: Grid computing for fusion. Introduction of a simple 3D Geometry in TORB code. Porting of VMEC and DKES to the Grid.

The following collaborations are planned during 2008:

- **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 2008 experimental campaign.

2) E. Bolshakov and A. Dorofeyuk, from the IOFAN laboratory will visit CIEMAT in autumn 2008 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) and D. Makani (St. Petersburg University) 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).

- **Collaborations in Europe**

Germany

1) IPP-Garching / IPF-Stuttgart

During 2008 a high power voltage modulator for the Electron Bernstein Heating system will be installed at CIEMAT in collaboration with IPP-Garching and IPF-Stuttgart. The IPP will lend to CIEMAT 4 high voltage vacuum tubes. These tubes will be tested and two of them will be modified and upgraded in the IPF-Stuttgart to be used with the 28 GHz-gyrotron. The modulator will be assembled and shipped to CIEMAT, where it will be installed and tested with the high voltage power supply and the gyrotron. These activities will require visits of several persons of the three laboratories during 2008 to supervise and carry out all the tasks. In January 2008 two persons from CIEMAT will visit IPP-Garching to check the tubes and discuss the contract and the work-planning. When the modulator is assembled in Stuttgart, persons from CIEMAT will participate in the tests. Finally, persons from IPF-Stuttgart will visit CIEMAT to assemble the modulator and carry out the tests and the start-up of the system.

2) IPP-Greifswald

G. Müller will visit CIEMAT during one month to further continue the improvements in the control system of the gyrotron anode modulators and to collaborate in the installation of the the new modulator that will be transferred from IPP to CIEMAT.

K. Schlüter will also visit CIEMAT in 2008 to collaborate in the installation of the new modulator that will be transferred from IPP to CIEMAT.

3) M. Sánchez will visit IPP-Greifswald to continue the collaboration on infrared interferometry.

4) E. Sánchez will visit IPP-Greifswald to continue with the adaptation of TORB code to 3D geometry.

Portugal

C. Silva and IST team will visit CIEMAT to continue our collaboration on edge studies during 2007 continuing the collaboration in design and development of reflectometry in TJ-II (M. E. Manso, L. Cupido, L. Guimarais and IST team).

Hungary

András Szappanos will visit CIEMAT to further discuss the collaboration on pattern recognition in images and its application to real-time conditions.

Czech Republic

M. Hron, I. Duran and H. Brotankova will participate in the 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.

Finland

F. Ogando will visit TEKES in Helsinki for collaborating in the development of ELMFIRE code.

Austria

J. L. Velasco will visit Graz University (Austria) to work on the development of Global Montecarlo codes.

- **Collaborations with USA**

1) J. Tsai and Phillip Ryan (ORNL) will visit in CIEMAT in 2008 to participate in the beam conditioning of the injectors and to discuss beam transmission properties.

2) J. Caughman (ORNL) will visit CIEMAT in summer 2008 to participate in the final commissioning of the Electron Bernstein Emission diagnostic.

3) K. McCarthy will visit ORNL to perform final test on the TJ-II pellet injector. If necessary, S. Comb (ORNL) may visit CIEMAT to commission the pellet experimental set-up.

4) I. Calvo will stay at ORNL (January – April 2008) for statistical transport studies in non-equilibrium systems and phase transition model with impact in understanding transport barrier physics.

- **Collaborations with Ukraine**

1) Further 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 during the first half of 2008 in the ECCD experiments in TJ-II stellarator and will continue with the comparative studies in Helical systems.

2) S. Yamamoto (National Institute for Fusion Science) will visit CIEMAT in March 2008 to continue the collaboration on the interaction of fast ions with MHD activity.

3) D. Carralero will visit NIFS to discuss fast visible (intensified) camera experiments in LHD.

4) J. A. Jiménez will visit NIFS to work on the application of HINT code (equilibrium

studies with magnetic islands) to TJ-II stellarator.

- **International stellarator working groups**

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

3 JAPAN

3.1 Joint Conference of the 17th International Toki Conference and the 16th International Stellarator/Heliotron Workshop

The Joint Conference of 16th International Stellarator/Heliotron Workshop (ISHW) and 17th International Toki Conference (ITC) was held in Toki (Japan) October 15-19 2007 and organized by the National Institute for Fusion Sciences (NIFS). More than 200 experts in stellarator/heliotron research from Australia, Austria, Belgium, Germany, Japan, Russia, Serbia, Spain, Ukraine and the United States of America gathered at the conference. The International Advisory committee chaired by O. Motojima, the International Program Committee (IPC) chaired by C. Hidalgo and the Local Organizing Committee (LOC) chaired by H. Yamada have played the leading role in the elaboration of the scientific programme of the joint conference. This series of Stellarator Workshops is organized biennially in the framework of the International Energy Agency (IEA) Implementing Agreement on the Stellarator Concept. NIFS has organized the ITC as an annual meeting for fusion related sciences since its establishment in 1989. The IPC arranged 2 plenary talks, 1 review talk, 2 tutorial talks, 23 invited talks in addition to 202 contributed presentations.

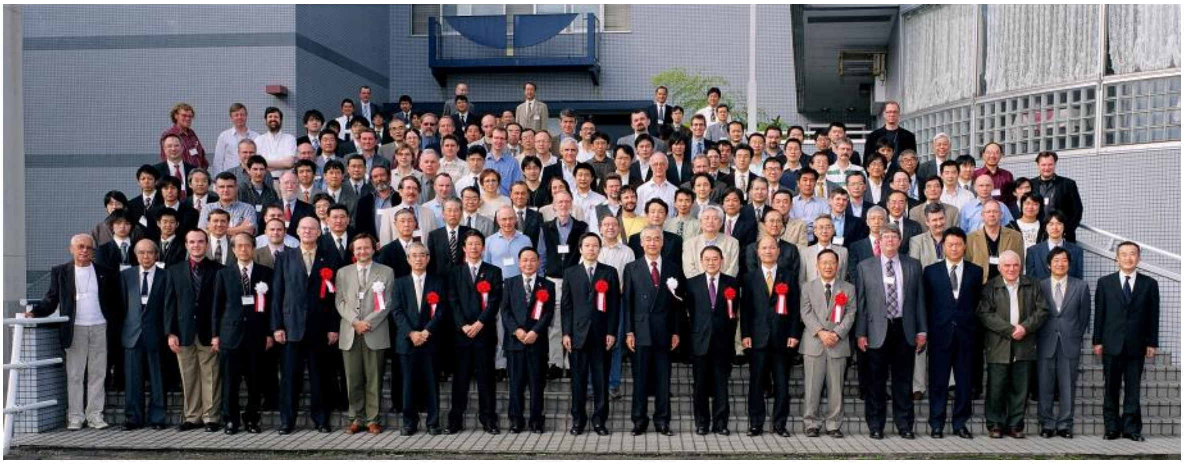
The driving force behind magnetically confined fusion research is the design of magnetic traps to confine high temperature plasmas of deuterium and tritium in reactor relevant conditions (i.e. to produce self-sustaining fusion reactions to release useful energy). Although next step magnetic confinement devices, such as ITER, will be based on the tokamak idea, it is not clear that a unique magnetic configuration will be the answer to the various possible applications of fusion energy and hence other magnetic confinement concepts should be explored. The stellarator is an alternative magnetic confinement concept, with the specific advantages of an intrinsically steady state magnetic field and disruption free operation. The 3D magnetic field geometry in stellarators needs an elaborate optimization to guarantee confinement properties which meet the basic requirements of a fusion reactor plasma. Development of stellarators as an alternative fusion reactor concept is a key issue confronting the stellarator community. This issue was addressed in the meeting by including special sessions on topics which are particularly relevant in the stellarator line as reactor concepts (e.g. divertor physics).

From the perspective of the basic understanding of systems far from thermal equilibrium, fusion plasma studies are a fully multi-disciplinary area of research. The joint ISHW/ ITC conference has emphasized the topical area of "*Flows and Turbulence*" which are seen widely in nature and are also becoming a high priority research area in magnetically confined plasmas.

Stellarators and tokamaks are complementary magnetic confinement concepts, but nevertheless share many common aspects. Thus, we should exploit synergies with the tokamak wherever meaningful. The International Stellarator/Heliotron Workshop benefited greatly from the presence of invited talks from the tokamak community, as in previous stellarator workshops.

The development of stellarator/heliotron working groups, including confinement database and profile database working groups, has been very a successful activity to fully promote international collaboration. Invited talks reporting on these key activities in the stellarator community were included in the programme. In addition, the workshop has been an adequate forum to trigger discussion on possible additional stellarator/heliotron working groups. This discussion has been fully welcomed and stimulated by the IEA Stellarator Executive Committee. Considering that a fusion reactor stellarator should operate at high beta with control of particle and energy exhaust, it was agreed to promote the development of a new stellarator/heliotron working group for further development of helical divertor concepts.

Slides of some oral presentations as well as the proceedings are available at http://itc.nifs.ac.jp/. Extended papers of major contributions will be also published in the special issue of Plasma and Fusion Research (http://www.jspf.or.jp/PFR/).



3.2 LHD team at NIFS

3.2.1 International collaborations by the LHD team at NIFS

- **Collaborations with EU**

1) Y. Feng, Max-Planck Institute (IPP Greifswald), visited NIFS (H. Yamada and M. Kobayashi) from 19th Sep.2006 to 22nd Dec. 2006 as a NIFS guest Professor to conduct 3D edge transport modeling of LHD. The analysis focused on the effect of magnetic structure in the ergodic layer on plasma transport, and of the impurity transport/radiation on thermal.

2) Kobayashi (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) from 25th Aug. 2007 to 8th Sep. 2007 and continuously proceeded on the international collaboration on divertor transport study of helical devices, based on the

framework of the International Stellarator Profile Data Base. The collaboration results are reported as an invited talk at ITC/ISHW2007 (Toki, Japan, Oct. 2007).

3) M. Yokoyama (NIFS) visited Max-Planck Institut fur Plasmaphysik (Greifswald, Germany) and continuously extended the international collaboration on the International Stellarator/Heliotron Profile Data Base.

4) H. Maassberg (IPP-Greifswald), C.D. Beidler (IPP-Greifswald), Y. Turkin (IPP-Greifswald) and W. Kernbichler (Tech. Univ. Graz, Austria) visited NIFS to promote international collaboration on neoclassical transport code benchmarking and to discuss the benchmarking modules in the developing integrated/predictive transport code.

5) N. B. Marushchenko (IPP Greifswald, Germany) visited NIFS to discuss ECRH heating efficiency by using their ray-tracing code “TRAVIS” which has been developed in IPP Greifswald. In the 3D LHD magnetic configuration, comparative study between NIFS code and their code was performed for harmonic resonance heating experiments in LHD.

6) Takashi Mutoh (NIFS) and Ryutaro Minami (Univ. Tsukuba) attended “US-EU-Japan workshop on RF Heating Technology” held at Heidelberg, Germany from 10~12, September 2007 to discuss about R&D and collaborations among US-EU-Japan in the RF heating technology.

7) Shin Kubo (NIFS) attended “US-EU-Japan workshop on RF Heating Technology” held at Heidelberg, Germany from 10~12, September 2007 to discuss about R&D and collaborations among US-EU-Japan in the RF heating technology and visited TEXTOR (Juelich, Germany) on 13 September and ASDEX-U (Garching, Germany) on 14 September to discuss mainly on ECRH physics and collective Thomson scattering diagnostics using gyrotron.

8) K. Ikeda (NIFS) visited the NBI development facility in Max-Planck Institut fur Plasmaphysik (Garching, Germany) from 1st Feb. 2007 to 2nd May 2007 to study a long life RF negative ion source for NBI and an optical measurement method. The collaboration results are reported in the 12th international conference on ion source (Jeju, Aug. 2007).

9) K. Nagaoka (NIFS) visited Max Planck Institut fur Plasmaphysik (Garching, Germany) from 18th February 2007 to 9th March 2007 and from 10th June 2007 to 8th August 2007 under the Japan-Germany collaboration program (JSPS) for the research on the optical measurement in the RF negative ion sources for the NBI system.

10) S. Yamamoto (Kyoto Univ., Japan) visited CIEMAT from 3rd March 2007 to 11th March 2007 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.

11) Jimenez Gomez Ruben (CIEMAT, Spain) visited Heliotron-J and NIFS (M. Osakabe, K. Nagaoka and Y. Takeiri) from 7th October 2007 to 27th October 2007 under the NIFS/NINS project of Formation and International Network for Scientific Collaborations for the joint experiments of the interaction between the fast ions and the

Alfven eigenmode in Heliotron-J and LHD.

- **Collaborations with US**

1) M. Yokoyama (NIFS) visited Princeton Plasma Physics Laboratory (Princeton, USA) and discussed the plasma flows in helical plasmas and its implications on LHD/NCSX.

2) K. Ichiguchi (NIFS) visited B. A. Carreras (BACV Solutions Inc., Oak Ridge, USA) from June 24 to July 1, 2007 based on the US-Japan collaboration program, and discussed nonlinear MHD behavior of heliotron plasma, mainly the effect of beta increase.

3) S. Nishimura (NIFS) visited Princeton Plasma Physics Laboratory (PPPL) from March 4 to May 19, and Oak Ridge National Laboratory (ORNL) from May 20 to June 31 for a study of neoclassical transport in stellarators with D.R.Mikkelsen, M. C .Zarnstorff (PPPL), D. A. Spong (ORNL), and the other members on design studies of NCSX and QPS.

4) S. Toda (NIFS) will visit University of California, San Diego (Host: P.-H. Diamond) for about three weeks, 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.

5) H. Sugama and T.-H. Watanabe visited UCSD during Jan.10 through 12 in 2007 in order to attend the JIFT Workshop "Gyrokinetic Simulation of Ion and Electron Temperature Gradient-Driven Transport" as its co-organizers.

6) N. Ashikawa (NIFS) visit GA for 1 week in Sep. 2007 to discus about boronized wall and deposited layer and select exposed material samples in DIII-D for analysis with C. Wong (GA).

7) N. Tamura (NIFS) visited PPPL from Mar. 17th to Mar. 31st to implement the TESPEL injection experiment on NSTX with Dr. H. W. Kugel (PPPL) and Dr. D. Stutman (Johns Hopkins Univ.). The TESPEL has been injected successfully into the NSTX plasmas during his stay.

- **Collaborations with Russia**

M. Isaev (Russian Research Centre "Kurchatov Institute", Russia) visited NIFS (K.Y. Watanabe and M. Yokoyama) from Feb. 3rd to Feb. 22nd in order to study the bootstrap current in LHD configurations and make the comparative analysis with experimental results.

- **Multi-lateral collaboration**

H. Yamada, H. Funaba, K. Ida, S. Sakakibara, Y. Suzuki and M. Yokoyama [M. Kobayashi and K.Y. Watanabe (remote participation)] attended the 2nd Coordinated Working Group Meeting (CWGM) for Confinement Studies in Stellarators/Heliotrons (4-6, Jun. 2007 at Max-Planck Institut fur Plasmaphysik, Greifswald, Germany), and H. Yamada and M. Yokoyama (NIFS) coordinated the following 3rd CWGM (23-24 Oct. 2007 at NIFS) in cooperation with international collaborators. These meetings were conducted under the auspices of the IEA Implementing Agreement of Development of Stellarator Concepts and based on the preparatory discussion at the 15th International Stellarator Workshop in Madrid in 2005. The main issues for discussions were progress of the International Stellarator/Heliotron Confinement & Profile Database (ISHCDB and ISHPDB) activities on several physics issues, development of transport codes and their integration. The participants from several countries covered almost all institutions where helical system research has been promoted. The further promotion of the international collaboration on these issues was agreed and the possibility of the 4th meeting was also discussed.

3.2.2 Plans for 2008

1) The several NIFS researches will attend the 4th CWGM (Madrid, Oct. 2008 as a tentative plan) to further lead the multi-lateral collaborations on the International Stellarator/Heliotron Confinement & Profile Database (ISHCDB and ISHPDB) activities.

2) K.Ichiguchi (NIFS) will continue the collaboration with B. A. Carreras (Oak Ridge) concerning with turbulent transport in nonlinear evolution of interchange mode in heliotron plasmas.

3) Federico Felici (CRPP Lausanne, Switzerland) will visit NIFS to discuss and develop an intelligent feedback control system of ECRH wave polarization to optimize quickly ECRH heating efficiency during one shot.

4) Miroshnikov and V. Sergeev (St. Petersburg Technical University, Russia) will visit 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.

5) N. Tamura (NIFS) will visit PPPL for 2-3 weeks in Mar. 2008 to continue the TESPEL injection experiment on NSTX with H. W. Kugel (PPPL) and D. Stutman (Johns Hopkins Univ.).

3.3 CHS team at NIFS.

3.3.1 International collaborations by the CHS team at NIFS

- **Collaborations with US**

1) S. Okamura visited PPPL from February 25th to March 4th for the discussion of the collaboration program on NCSX experiment for the study of electric field and turbulence using a heavy ion beam probe (HIBP). He also worked on the magnetic configuration optimization with auxiliary saddle coils for Heliotron J machine using the STELOPT program developed by ORNL and PPPL team.

2) S. Okamura visited PPPL from September 14 to September 18 to attend the NCSX Review Committee appointed by the Fusion Energy Sciences Advisory Committee for the purpose of making scientific and programmatic reviews focused on evaluating the NCSX program. The discussions in the committee continued after the meeting for about one month with the internet communication and finally gave a report to FESAC

on October 17.

3.3.2 Plans for 2008

M. Isobe (NIFS) will visit Princeton Plasma Physics Laboratory (Host: Dr. D.S. Darrow) from 24 February to 8 March to perform experiment on fast-ion driven MHD instabilities in NSTX and discuss about common physics of those instabilities between helical and spherical toroidal plasmas.

3.4 Heliotron J team at Kyoto University

3.4.1 International collaborations by the Heliotron J team at Kyoto University

- **Collaborations with Australia**

1) B. Blackwell (ANU) visited Kyoto Univ. for a week on October 27 – November 3 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.

2) D. Pretty (ANU) visited Kyoto Univ. for a week on October 28 – November 2 to participate in the Heliotron J experiment. Collaboration of the data analysis for the MHD instabilities was performed.

3) Discussions with H-1NF team (ANU) were kept along the same line as in 2006.

- **Collaborations with EU**

1) A. Cappa (CIEMAT) joined the Heliotron J experiment for two weeks on January 28 – February 10. He analyzed ECCD experimental results on Heliotron J and compared them with TJ-II results.

2) S. Kobayashi visited CIEMAT on February 27-March 11 to participate in the TJ-II experiment. He discussed the operation and conditioning of the NBI system and diagnostic systems (CXRS and NPA) in TJ-II.

3) P. Scarin (RFX consortium) joined the Heliotron J experiment on March 30 to discuss the edge turbulence in magnetic confinement plasma with the Heliotron J group.

4) D. Escande (Provance Univ.) visited the Heliotron J group on March 30 to discuss the collaboration research program between Provance Univ. and IAE Kyoto Univ.

5) A. Fernandez joined the Heliotron J experiment for two weeks of September 18-28. The ECCD experimental collaboration was performed and a seminar was held.

6) J. Ruben joined the Heliotron J experiment for two weeks of October 8-12. He participated in the Heliotron J experiment related to the MHD instabilities.

7) T. Mizuuchi visited Portugal and CIEMAT on October 21-29 to participate in IAEA technical meeting and TJ-II experiment. He reported the recent Heliotron J

experimental results and discussed the collaboration plan in the measurement of edge plasma turbulence with fast-video cameras.

8) Collaborations with CIEMAT were continued along the same lines as in 2006.

- **Collaborations with China**

1) Q. Yang (SWIP, China) visited Kyoto Univ. as a guest professor for three months (January-March). He joined the Heliotron J experiment related to development in diagnostic systems, and had lectures of plasma physics for graduate students.

2) H. Okada visited to SWIP (Chengdu, China) on March 11-18 to discuss the development of ICRF heating system in the HL-2A.

3) K. Nagasaki visited to SWIP (Chengdu, China) on November 4-17 to join the HL-2A experiment related to the development of the ECH/ECCD system.

4) T. Mizuuchi visited to SWIP (Chengdu, China) on December 9-15 to participate in the HL-2A experiment related to the supersonic molecular beam injection (SMBI), and had a lecture of overview of recent Heliotron J experiments.

- **Collaborations with US**

F. S. B. Anderson visited Kyoto Univ. for two weeks on January 23 – February 11 to join the Heliotron J experiment. He analyzed the MHD fluctuations driven by interchange instabilities.

- **Collaborations with India**

K. Nagasaki visited the Institute for Plasma Research (India) to participate in APFA conference and discuss the plasma research.

- **Others**

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

2) The details of the H-mode were studied experimentally from the viewpoint of the toroidal current and theoretically in Heliotron J.

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

4) Discussions with U-3M team (Kharkov) were kept along the same line as in 2006 and also started the discussion about the divertor plasma energy analyzer.

3.4.2 Plans for 2008

1) Pretty (ANU, Australia) will visit Kyoto Univ. for one month 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) S. Yamamoto will visit CIEMAT for a week of March to join the MHD experiment of TJ-II.

3) 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.

4) 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.

5) 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.

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

7) 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.

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.

10) The development of SMBI system and its application for fueling and/or plasma diagnostics are in progress under the collaboration with CIEMAT and SWIP.

11) A heavy Ion Beam Probe will be designed for measuring the radial electric field and fluctuations in Heliotron J.

4 RUSSIA

4.1 International collaborations

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

Six persons participated in joint GPI-CIEMAT works
(total duration of visits: 9 month-persons):
Kovrizhnykh (2 weeks)
Sarksyan (2 weeks)
Kharchev (2 months)

Kolik (1 month)
Bondar (2.5 months),
Skvortsova (2 weeks)
Tereshchenko (2 months)

In 2007 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 technical possibilities of the use of gyrotron second harmonic in the scattering diagnostic were considered,
b) The recever system for scattering diagnostic was prepared and adjusted,
c) The first measurements and analysis of preliminary data were fulfilled; the results were presented on SIEMAT seminar.
d) The design of the new version of scattering diagnostic was fulfilled

2) Gyrotron power modulation experiment.

The investigations of gyrotron response on small-reflected signal were continued and the article on this item was presented to publication.

3) Participation in planned experiment on TJ-II with additional plasma heating by Bernstein waves.

Theoretical task-further development of “TURBA” code.

4) Exploitation of gyrotron complex.

Participation in exploitation on gyrotron complex on TJ-II.

5) Maintenance works on the Microwave Energy Measurement Device (MEMD) on TJ-II

Maintenance development and improvement of MEMD for measurements of microwave power.

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

Three persons participate in joint works (Kharchev- 2 months, Kovrizhnykh and Skvortsova participated on Toky conference)

The measurements of high k (up to 40 cm^{-1}) plasma density fluctuations by the use of 82 GHz ECRH heating gyrotron radiation (first harmonic) in scattering diagnostic on LHD:

a) Preparing and adjustment of corresponding tools
b) Measurements in several plasma regimes
c) Analysis of the obtained fluctuation data.
d) Preparing of the corresponding report for NIFS seminar.

As a result of this collaboration some joint papers were published [1-7]

- **Collaboration between Kurchav Institute and Max-Planck Institute (IPP) (Greifswald, J.Nuhrenberg group) and CRPP (Switzerland)**

Topic: The theoretical works on optimization of stellarators, in collaboration with IPP (Germany) and CRPP (Switzerland)

Visits:
M. Mikhailov (stellarator optimization): visits to CRPP, Lausanne,Switzerland, February (1 week), Greifswald, IPP, Gernmany: February (1 month), June (1 month), November-December (2 months);
Prof. J. Nuehrenberg, visit to Kurchatov Institute, September, 3 days.
M. Isaev, visit to NIFS, Toki, Japan, 2.02.07-22.02.07, topic “MHD equilibrium and transport study in helical plasmas”, visit to Greifswald, FRG, 15.07.07-15.08.07, topic “International Collaboration on Neoclassical Transport in Stellarators”.

As a result of this collaboration some joint papers were published [8-14]

Joint publications

[1] F.Castejon, I. Campos, M. Tereshchenko et al
2nd EGEE User Forum, Manchester, UK, 2007
[2] J. Vazquez-Poletti, E. Huedo, R. Montero et al
2nd EGEE User Forum, Manchester, UK, 2007
[3] F. Castejon, A. Capa, M. Tereshchenko at al
Fusion Science and Technology 2007, vol. 52, 3 2 p.230-239
[4] A. Cappa, E. Holzhauer, F. Castejon et al
34th EPS Conference on Contr. Fusion and Pl. Phys.
Warsaw, 2-6 July, 2007
[5] A. Cappa, F. Castejon, D. Lopez-Bruna, Tereshchenko
Proc. of 12th European Fusion Theory Conference, Madrid, 2007
[6] F. Castejon, S. Pavlov, M. Tereshchenko
Proc. of 12th European Fusion Theory Conference, Madrid, 2007
[7] A. Fernandez, N. Kharchev, A. Pshenichnikov et al
Inter. Journal of Inrared and Millimeter waves, vol.28, # 9, 2007
[8]. V. R. Bovshuk, W.A. Cooper, M.I. Mikhailov, et al
Report on 34 EPS Conference on Plasma Physics, ECA Vol 31 F, P-4.103 (2007).
[9]. V. R. Bovshuk, M.I. Mikhailov, V. D. Shafranov, et al
Report On 17 International Stellarator/Heliotron Workshop, Toki, Japan, Oct. 2007.
[10]. G. Y. Fu, M. Yu. Isaev, L.P. Ku, M.I. Mikhailov, et al
Fusion Science and Technology, v.51, N2, p.218-231 (2007).
[11]. G.A. Cooper, M. Jucker, W.A. Cooper, J.P
Physics of Plasmas, v.14, p.102506-102513 (2007).
[12]. K. Allmaier, C. D. Beidler, M. Yu. Isaev,et al
Proc. of Joint Conf. 17th Int. Toki Conf. On Physics of Flow and Turbulence in Plasmas and 16th Int. Stellarator/Heliotron Workshop 2007, Toki, Japan, 2007, itc.nifs.ac.jp/abstracts/Poster2/P2-029.htm.
[13]. M. Yu. Isaev, K.Y. Watanabe, M. Yokoyamaet al
submitted to the Journal of Plasma and Fusion Research, 2007.
[14]. V.M.Kulygin, V.V. Arsenin, V.A. Zhil'tsov,
Nuclear Fusion, 47 (2007) 738-745.

4.2 Research plans for 2008

- **GPI**

1) Experiments on ECR heating of plasma in the L-2M stellarator with the use of a new high-power gyrotron (P=800 kW, f=75 GHz) begin in 2008.

2) Work will be continued on the application of advanced statistical methods to studies of stochastic properties of plasma fluctuations in the resonance region with high ECR heating power density.

3) The available interferometer based on an HCN laser will be replaced by the new interferometer based on a water-vapor laser generating orthogonal polarizations of different frequency simultaneously at the two wavelengths for measuring the electron density profile in the stellarator.

4) Experiments on combined ECR and ICR heating of plasma begin in 2008.

5) Continuation of the theoretical modeling of transport processes in stellarators.

- **Kurchatov Institute**

To optimize the stellarator with zero secondary dipole current and very- high-β toward the small neoclassical transport and bootstrap current. It is planned also to investigate the effect of the number of periods on the properties of the considered configurations.

VENUS+δf code is planned to be applied for the plasma islands effects on equilibrium, stability and transport analysis in the ITER, LHD, W7X configurations as well as for another tokamaks and stellarators. Detailed comparison of the VENUS+δf transport simulations with the LHD experiments will be made. Development and applications of new powerful tools for equilibrium, stability, transport and optimization calculations with pressure anisotropy will be carried out.

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 2007

5.1.1.1. International collaborations of the plasma theory division

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

1) Study of the 1/v neoclassical transport for Uragan-2M with 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, W. Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria) and

N. T. Besedin (Kursk State Technical University, Russia)).

2) Calculations of an effective ripple for a stellarator magnetic field computed by the HINT2 code (V. V. Nemov and S. V. Kasilov in collaboration with B. Seivald and W. Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria), Y. Suzuki (NIFS, Japan) and J. Geiger (Max-Planck-Institut für Plasmaphysik Physik, Germany)).

3) Studies of the neoclassical transport for CNT (V. V. Nemov in collaboration with B. Seivald and W. Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria) and T. Sunn Pedersen (Columbia University, USA)).

4) Development of the delta-f Monte Carlo method for the computation of bootstrap current with improved convergence in the low collisionality regime. (S. V. Kasilov, V. V. Nemov in collaboration with W. Kernbichler, G. O. Leitold and K. Allmaier (Institut für Theoretische Physik, 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**

Development of TRUBA beam/ray tracing code for the exact fully relativistic calculations (S. S. Pavlov in collaboration with F. Castejon, A. Cappa, A. Fernandez (CIEMAT, Madrid, Spain) and M. Tereshchenko (General Physics Institute, Moscow, Russia)).

5.1.1.2 International collaborations of the plasma experiment divisions

- **Collaborations with NIFS, Japan**

1) As a result of activity on investigation of possibilities to decrease the oxygen concentration in LHD plasma the draft of the paper “Plasma cleaning of the surfaces from oxides: the state of the art” by V .S. Voitsenya and S. Masuzaki was prepared for further corrections.

2) The partial analysis 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) was provided.

- **Collaborations with Germany (FZ-Juelich)**

Together with Dr. A. Litnovsky (FZ-Juelich) the analysis was provided of the results obtained in experiments on different fusion devices, including published earlier data on the joint mirror experiment in LHD, with ITER-candidate mirror materials directed on solution of the first mirror problem. The paper will appear in Proceedings of the International Conference on Burning Plasma Diagnostics, Villa Monastero, Varenna, September, 24-28, 2007.

- Collaborations with CIEMAT, Madrid, Spain

1) Development and creation of the two sleet detector system in the TJ-II HIBP energy analyser. (Dr. L. I. Krupnik et al (IPP NSC KIPT) in collaboration with Dr. C. Hidalgo and TJ-II team (CIEMAT)).

2) Assembling and installation of a new high voltage power supply system for HIBP injector. (Dr. L. I. Krupnik et al (IPP NSC KIPT) in collaboration with Dr. C. Hidalgo and TJ-II team (CIEMAT)).

3) Calibration and test experiments with two sleets energy analyser on TJ-II stellarator and Kharkov test device.

4) Measurements of the plasma potential profile, electron density and their fluctuations with two-slit energy analyzer. Investigation of the signal/noise situation up to 200 kHz. (Dr. L. I. Krupnik et al (IPP NSC KIPT) I collaboration with Dr. C. Hidalgo and TJ-II team (CIEMAT)).

5) Development of suggestions on installation of the second heavy ion beam line at the TJ-II device (Dr. L. I. Krupnik and V. S. Voitsenya (IPP NSC KIPT) in collaboration with Dr. A. Melnikov (RNC Kurchatov Institute)).

- Collaborations with IPP, Greifswald, Germany

1) Testing of the full control and data acquisition systems and calibration of the energy analyser of the Heavy Ion Beam Probe (HIBP) diagnostic on WEGA Stellarator. (Dr. L. I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. M. Otte and WEGA team.

2) Measurements of the electric plasma potential by HIBP diagnostic in WEGA stellarator. (Dr. L. I. Krupnik and HIBP team in collaboration with Dr. Yu. Podopa and WEGA team).

- Collaborations with Kurchatov Institute, Moscow, Russia

1) Upgrade of the data acquisition system up to 150-200 kHz for plasma fluctuation measurements in T-10 tokamak.

2) Investigation of the plasma potential behavior during Internal and Edge barrier formation. Measurements of the plasma fluctuations. Investigation of Geodesic Acoustic Modes (GAM). Comparative study of the plasma electric fields behavior in the T-10 tokamak and TJ-II stellarator during ECR and NBI heating in the stellarator (Dr. L. I. Krupnik and HIBP team (IPP NSC KIPT in collaboration with Dr. A. V. Melnikov and T-10 team (Kurchatov Institute).

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

Investigation of the electric field evolution in various operational modes in the TUMAN-3M tokamak (Dr. L. I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. S. V. Lebedev and Tuman-3M team (Ioffe Institute).

5.1.2 Plans for 2008 of the IPP NSC KIPT

5.1.2.1. Plans for 2008 of the plasma theory division

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

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

2) Version of NEO-2 with a full linearized Coulomb collision operator will be used for the benchmarking of various momentum correction techniques currently employed for the computation of transport coefficients and bootstrap current. This benchmarking will be performed within the collaboration on stellarator transport modelling between IPP Greifswald, CIEMAT, NIFS, ORNL, ITP TU-Graz and IPP NSC KIPT.

3) Elaboration of numerical tools for a 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 Technische Universität Graz, Austria).

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

1) Development of the fast algorithm computing exact relativistic plasma dispersion functions and a study of the electron Bernstein waves plasma heating in fusion magnetic traps on the base of this algorithm (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 waves into ion plasma waves near resonances $\omega = n\omega_{ci}$ (S. S. Pavlov in collaboration with F. Castejon).

- **Collaborations with NIFS, Japan**

It will be developed the analysis of the new helical reactor schemes with the use of the modulation of the helical winding in FFHR 2m, which can provide the reduction of the neoclassical transport and enlargement of the blanket space. Kharkov idea of the application of “negative” modulation coefficient of the helical winding in FFHR 2m (Nuclear Fusion 24 (1984) 1195) will be advanced (A. Shishkin in collaboration with O. Motojima and A. Sagara).

5.1.2.2. Plans for 2008 of the plasma experiment division

- **Collaborations with NIFS, Japan**

1) Basing on results of joint paper published in 2006, (V. Voitsenya and A. Shtan in collaboration with S. Masuzaki, O. Motojima, and A. Sagara), it is planned in 2008 to use 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.

2) The analysis of surfaces of SS and Cu mirrors exposed in LHD (V. S. Voitsenya in collaboration with S .Masuzaki and N. Ashikawa) will be continued in 2008.

3) 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 will be continued with possible printing as a NIFS Report in 2008.

4) The manuscript “Impact of N_2 + H_2 mixture on carbon-containing film” by V. S. Voitsenya, S. Masuzaki, O. Motojima, and A. Sagara was accepted for printing as NIFS Report in 2008.

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

1) Upgrade of the Injector and Secondary Beam Detector Systems of the Heavy Ion Beam Probing (HIBP) diagnostic on TJ-II stellarator.

2) Improvement of the data acquisition system up to 150-200 kHz for plasma fluctuation measurements in TJ-II stellarator.

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

4) Calculations and development of the project for the second beam line of the HIBP diagnostic for TJ-II stellarator.

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

Measurements of the plasma potential, electron density and their fluctuations in various operational modes in the WEGA stellarator.

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

1) Increasing the primary beam Tl^+ ion intensity up to 80-100 μA.

2) 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.

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

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

2) Optimisation of regimes of surface cleaning in Uragan-2M torsatron using different combination of ECR, RF and glow discharge will be continued.

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

4) Design and development of a pumped limiter for Uragan-2M torsatron.

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

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

7) Designing and manufacturing Uragan-3M torsatron of the W limiter with controlled recycling of hydrogen due to a by-metal system W-Pd having the high-porosity of a W coating for Uragan-3M torsatron.

8) Investigations of the HIBP injector up to 150- 200 keV of the primary beam energy for Uragan -2M at the HIBP test-stand.

9) Development and designing of the energy analyzer for U-2M.

5.2 Karazin National University, Kharkov

5.2.1 International collaboration in 2007

- **Collaborations with MPIPP, Germany**

1) With the aim to study the behaviour of impurity ions in plasma configuration of Wendelstein 7-X stellarator including island divertor configuration in real geometry, the 3D Impurity Transport Code was developed by Dr. Oleg Shyshkin (University) in collaboration with Dr. R. Schneider and Dr. C. Beidler (MPIPP) in the framework of the regular project of Science and Technology Centre in Ukraine (STCU) #3685. The code is the upgrade version of 1D Impurity Transport Code developed during the regular STCU project #2313. The code solves guiding center equations for the test particle with the use of Runge-Kutta integrating scheme of order four. This code could be used for the calculation in parallel for the HELIAS reactor with five periods of the magnetic field and is the direct extrapolation from Wendelstein 7-X stellarator and for the Wendelstein 7-X as well. The outcomes are published in the paper:
O. A. Shyshkin, R. Schneider, C. D. Beidler, *Numerical analysis of tungsten transport in drift optimised stellarator with ergodic and nonergodic plasma configurations*// Nuclear Fusion, 2007, vol. 7, p. 1634-1643.

2) The collaboration with the groups carrying out the research in the field of ion-surface interactions in fusion devices has been started by Dr. I. Bizyukov (University) in collaboration with Dr. K. Krieger and Dr. J. Roth (MPIPP) and Prof. Hass (Toronto). Currently, experimental program running in fusion laboratory of University of Toronto Institute of Aerospace Studies is coupled to one running on Dual-Beam Setup in MPIPP. This program is aimed on study of processes eroding the tungsten surface exposed to simultaneous C and D ion bombardment at elevated surface temperatures. Both laboratories own similar experimental equipment, but the diagnostic is different: UTIAS setup provides detection of sputtered particles, while IPP setup is capable to measure atomic concentrations on surface. The collaboration allows obtaining both on-surface data (a real densities, depth profiles, etc.) with data on fluxes of sputtered atoms and molecules at the same bombarding conditions. It is expected that the program will provide comprehensive picture of processes on surface being under multi-species bombardment. These data can be used to validate numerical codes; after the validation application of these codes can be extended to the fusion conditions.

3) The theory of surface extraordinarily polarized electromagnetic waves propagating in fusion devices was developed in the framework of the STCU regular project #3685. The effect of the shape of the chamber cross-section on the waves' dispersion properties was studied:

1. I. O. Girka, O.I. Girka, V.O. Girka, I. V. Pavlenko. *Effect of the Shape of the Cross Section of a Plasma-Dielectric Interface on the Dispersion Properties of Azimuthal Surface Modes*// Plasma Physics Reports, 2007, vol. 33, No. 2, p. 91-101.
2. I. O. Girka, O.I. Girka, V.O. Girka, I. V. Pavlenko. *Resonant Effect of the Noncircular Shape of the Plasma Surface on the Dispersion Properties of Extraordinary Azimuthal Surface Modes in Magnetoactive Waveguides* // Ibid, No. 7, p. 543-552.

4) Sandwich Fellowship Program was established between the University and MPIPP since 2001. Sandwich PhD student I. Bizyukov had defended his thesis "Experimental study of tungsten sputtering by simultaneous carbon and deuterium bombardment at Dual-Beam Experiment facility" that was carried out under the supervision of Dr. K. Krieger (MPIPP) and Prof. N. Azarenkov (University). The outcomes of joint research are published in the paper:

I. Bizyukov, K. Krieger, N. Azarenkov, S. Levchuk, Ch. Linsmeier. *Tungsten sputtering and accumulation of implanted carbon and deuterium by simultaneous bombardment with D and C ions*// Journal of Nuclear Materials, 2007, vol. 363-365, p. 1184-1189.

5) Sandwich PhD student A. Onyshchenko (University) continued his course at the Technology Division of MPIPP under the supervision of Dr. J.-M. Noterdaeme (MPIPP) and Dr. V. Bobkov (University). The experiments for testing different protection composition coatings of the ICRF antennas for the plasma heating were carried out in collaboration with J.-M. Noterdaeme, Vl. Bobkov, W. Becker (MPIPP).

- **Collaborations with NIFS, Japan**

1) A new concept for the selective removal of cold α-particles is developed by Alexander A.Shishkin (Kharkiv Institute of Physics and Technology, UKRAINE and the University) in collaboration with Akio Sagara, Osamu Motojima, Osamu Mitarai, Tomohiro Morisaki, and Nobuyoshi Ohyabu (NIFS). which is specific to the helical devices (heliotron/torsatron system). It includes escape of trapped cold α-particles due to enhanced drift in the helical magnetic field under finite β and resonant removal of passing cold α-particles trough the island structure created by drift resonance. For both mechanisms, control of the perturbation field coil current is the key issue. There is proposed to include the perturbation poloidal field coils in the design of the Force Free Helical Reactor 2m1 /FFHR 2m1/. The results are published in the paper:

Alexander Shishkin, Akio Sagara, Osamu Motojima, Osamu Mitarai, Tomohiro Morisaki, and Nobuyoshi Ohyabu. *Controlling the cross-field flux of cold α-particles with resonant magnetic perturbations in a helical fusion plasma device*// Nuclear Fusion, 2007, Vol. 47, No. 8, p. 800-808.

2) There is developed the new scenario of the plasma heating in Force Free Helical Reactor 2m1 /FFHR 2m1/ to minimize the external heating power and prolong the fusion power rise-up time over 300 seconds:

O. Mitarai, A. Sagara, H. Chikaraishi, S. Imagawa, K. Watanabe, A. A. Shishkin and

O. Motojima. *Minimization of the external heating power by long fusion power rise-uptime for self-ignition access in the helical reactor FFHR 2m*// Nuclear Fusion, 2007, Vol. 47, No. 11, p. 1411-1418.

5.2.2 Plans of National University for 2008

1) The analysis of the new helical reactor schemes with the use of the modulation of the helical winding in FFHR 2m, which can provide the reduction of the neoclassical transport and enlargement of the blanket space, will be developed. Kharkiv idea of the application of “negative” modulation coefficient of the helical winding in FFHR 2m (Nuclear Fusion, Vol. 24, 1984, p.1195) will be advanced. The base of this work is reported in the recent paper:

A. Sagara, O. Mitarai, T. Tanaka, S. Imagawa, Y. Kozaki, M. Kobayashi, T. Morisaki, T. Watanabe, K. Takahata, H. Tamura, Y. Nagaki, K. Nisihimura, H. Chikaraishi, Y. Yamada, S. Fukuda, S. Masuzaki, A. Shishkin, Y. Igitrkhanov, T. Goto, Y. Ogawa, T. Muroga, T. Mito, O. Motojima and FFHR design group. *Optimization Activities on Design Studies of LHD-type Reactor FFHR//* 8th International Symposium on Fusion Nuclear Technology, Heidelberg, Germany, September 30-October 5, 2007, paper PS3-1017, ID#227 is submitted t*o* Fusion Engineering and Design.

2) Regular STCU project # 3685 “Impurity transport in 3D magnetic field for the stellarator Wendelstein 7-X and tokamaks” will be continued. Plasma transport control with the use of drift resonances: drift islands transfer and estafette of drift resonances, will be studied. AC electromagnetic filed control of impurity ions at periphery of the confinement volume will be studied both analytically and numerically.

6 UNITED STATES

6.1 International collaborations in 2007

- **Collaborations with Australia**

1) S. Hudson (PPPL) collaborated with Prof. Dewar et al. (ANU) on development of stepped pressure equilibrium code.

2) R. Nazikian (PPPL) visited H-1 (ANU) for three weeks in August 2007 to conduct and analyze experiments on Alfven eigenmodes driven by fast particles.

- **Collaborations with Japan**

1) D. Spong (ORNL) served as JIFT Visiting Professor NIFS, Toki, Japan from Feb. 18 - May 19, 2007 - sponsored by Yasushi Todo. While there, he worked on the computational study of Alfven eigenmode structure in LHD and other stellarators, self-consistent neoclassical plasma flows in LHD super dense core regime, and development of particle based MHD closure relations.

2) Prof. S. Okamura (NIFS) visited PPPL in February to collaborate on stellarator optimization and for planning of long-term collaborations on NCSX.

3) S. Nishimura (NIFS) visited PPPL for two months, during which he made calculations of neoclassical transport diffusivities in NCSX using his rapid method. He extended his method to handle the complexity of the NCSX field, and further modifications are planned.

4) S. Sakakibara (NIFS) visited PPPL in March, and discussed MHD stability issues in LHD and possible collaboration activities.

5) J. Harris (ORNL), D. Mikkelsen (PPPL), D. Spong (ORNL) attended the International Collaboration on Neoclassical Transport in Stellarators (ICNTS) working meeting (22 Oct. 2007) and the 3rd Combined Working Group Meeting to coordinate stellarator transport research (23-25 Oct. 2007), at NIFS, Japan. Progress was made in plans for scalar and profile confinement databases were advanced, as well as transport code benchmarks and coordination of research on high beta and enhanced-confinement plasmas. D. Mikkelsen also discussed collaborative research on microinstabilities in LHD.

6) S. Anderson (Wisconsin) participated in fluctuation studies on Heliotron-J.

7) The HSX group collaborated with S. Murakami (NIFS) on the use of the GNET code.

8) T. Pedersen (Columbia) visited Prof. H. Himura (Kyoto Inst. Tech.) and gave a talk on CNT. They co-wrote and submitted for publication a letter describing a global non-resonant instability in CNT.

- **Collaborations with Germany**

1) A. Boozer (Columbia) and S. Hudson (PPPL) collaborated with C. Nuehrenberg (IPP-Greifswald) on 3D perturbed equilibrium analysis, expanding about a VMEC approximate equilibrium. The magnitude of singular currents on rational surfaces is calculated, and from this the size of magnetic islands, including the effects of finite plasma pressure and current.

2) M. Zarnstorff and A. Reiman (PPPL) continued to collaborate with A. Weller (IPP) and the W7AS group on the analysis of the W7AS high-beta plasmas. Papers were presented at the Third Workshop on Stochasticity in Fusion Plasmas (Juelich, Germany). A paper on the PIES analysis was published in Nucl. Fusion.

3) D. Mikkelsen(PPPL) visited Frank Jenko (IPP) at IPP-Garching to develop plans for coordinated work (at IPP, PPPL, U. Md., U. Wisc.) on gyrokinetic stability calculations for a variety of stellarator configurations, including benchmarks of two codes used in the US and Germany.

4) H. Mynick (PPPL) and A. Boozer(Columbia) in 2007 began a collaboration with F. Jenko's gyrokinetic group (IPP-Garching) to analyze the data GENE produces to better understand issues in stellarator turbulent transport & zonal flows.

5) D. Mikkelsen (PPPL) and J. Harris (ORNL) participated in the 2nd Coordinated Working Group meeting at IPP-Greifswald in June, planning stellarator research collaborations in several topics. After the meeting, D. Mikkelsen participated in

discussions on the design of an international stellarator profile database, and began benchmarking the GENE (IPP) and GS2 (U. Md.) gyrokinetic codes.

6) D. Spong (ORNL) attended the International Collaboration on Neoclassical Transport in Stellarators (ICNTS) working meeting on codel benchmarking July 9 - 13, 2007 at IPP-Greifswald, Germany.

7) D. Mikkelsen (PPPL) visited P. Xanthopoulos at IPP-Greifswald for two weeks starting in November, working on systematic benchmarks of the gyrokinetic stability codes GS2 and GENE (IPP). The two codes' geometrical quantities matched closely in a tokamak case; the geometrical quantities were calculated in very different ways from the same EFIT equilibrium. The benchmarks are proceeding to comparison of frequency and growth-rate k-spectra for the tokamak case, followed by geometrical and k-spectra comparisons with an NCSX configuration.

8) An agreement was negotiated and signed between PPPL and IPP-Greifswald for long-term collaboration on ECH research on NCSX. This included transfer of W7-AS 70 GHz equipment to PPPL.

9) R. Maingi and J. Canik (ORNL) began a collaboration with J. Feng and F. Sardei (IPP-Greifswald) on applying the EMC3-EIRENE code to NCSX. This included a two week visit to Greifswald in December 2007. Initial calculations were presented by F. Sardei at the 2007 Toki Conference/ISTW.

- **Collaborations with Spain**

1) R. Sanchez and the ORNL group collaborated with C. Hidalgo, Ivan Calvo, Bowdewijn van Milligen, Victor Tribaldos, Juan A. Jimenez and Maria A. Pedrosa of TJ-II on: 1) interpretation of edge fluctuation probe data (from TJ-II and JET); 2) development of simple models to understand turbulent transport in turbulent plasmas (not only stellarators, but also tokamaks); 3) development of simple models for the formation of the edge shear layer at TJ-II; 4) stellarator MHD stability studies. This work produced one paper in Phys. Rev. Letters, three in Phys. Plasmas, and one in Nucl. Fusion. Several related posters were presented at the EPS Plasma Conference.

2) I. Calvo (CIEMAT) visited ORNL for three months (03/07-05/07).

3) P. M. Ryan and colleagues (ORNL) continued their collaboration with the TJ-II team on modification and optimization of the two ORNL neutral beam injectors. In July, 2007 they successfully injected two beams simultaneously into the TJ-II plasma with a combined power of approximately 1 MW.

4) J. Caughman (ORNL) worked with the TJ-II to complete installation of the electron Bernstein wave emission diagnostic on TJ-II. These studies will prepare for future experiments with EBW gyrotron heating.

5) S. K. Combs and colleagues (ORNL) completed design and placed orders for component fabrication for the four-shot pellet injector for TJ-II.

6) S. Zweben collaborated with TJ-II on analysis of gas puff turbulence imaging, with results published in Nuclear Fusion.

- **International Stellarator Workshop**

D. Anderson (U. Wisc.), P. Garabedian (NYU), W. Guttenfelder (U. Wisc.), S. Knowlton (Auburn), J. Lyon (ORNL), H. Mynick (PPPL), R. Sanchez (ORNL), and M. Zarnstorff (PPPL) gave invited talks at the 16th International Stellarator Workshop at Toki, Japan, and a total of eighteen contributed papers were presented by the US stellarator groups.

6.2 Program Plans for 2008

- **CTH**

CTH activities in 2008 will center on fundamental studies of disruption immunity of current-driven discharges as a function of external rotational transform. These studies will lead into equilibrium reconstruction of current driven discharges using the V3FIT code. They also intend to investigate the effect of controlled islands on edge plasma parameters and transport, and determine what role they may be playing in unstable plasma behavior observed to-date.

- **HSX**

HSX will extend their study of the effect of quasi-symmetry on plasma transport to higher magnetic field (B=1 T) and higher heating power. These studies are focusing on the effect of symmetry on anomalous transport and turbulence. New diagnostics to measure plasma flows and electric fields are being installed.

- **NCSX**

Construction of the National Compact Stellarator Experiment (NCSX) will continue during 2008. The final modular coils and TF coils will be completed, and the contract for the poloidal field coils and trim coils will be placed. Assembly of the coils for the first field period will be completed.

- **QPS**

Machining of the prototype casting of the modular coil winding form will be completed prior to winding the full-size prototype coil with the internally cooled cable conductor.

APPENDICES: TECHNICAL REPORTS ON 2007 ACTIVITIES

APPENDIX 1: HIGHLIGHTS OF LHD EXPERIMENTS, JAPAN

The 10th campaign of the LHD experiment has been executed successfully. We have made significant progress in three physics research areas, achievement of hot ion temperature plasma, exploration of high density plasma with an Internal Diffusion Barrier (IDB) in the expanded parameter space and achievement of the average beta of 5.0 %.

The production of high-ion-temperature hydrogen plasma was successfully demonstrated in the Large Helical Device (LHD) experiment. The ion temperature (T_i) exceeded 6.8 keV (the record high value of T_i in helical plasmas) at the plasma density (n_e) of $2\times10^{19}m^{-3}$ and also achieved 3 keV at $n_e\tilde{}4\times10^{19}m^{-3}$. This achievement demonstrated the capability of high-ion-temperature plasma confinement in helical devices. The total power of neutral beams as much as 20 MW (3 parallel-injections and 1 perpendicular-injection) and ion cyclotron heating power of about 2 MW contributed to make this realize.

The radial profiles of the toroidal rotation (V_t) as well as T_i were measured by means of the charge exchange recombination spectroscopy (CXRS) with the toroidal-view. The CXRS measurement has clarified that high-T_i plasmas typically have large V_t (as large as several tens of km/s) at the core region accompanied by an increase of T_i gradient. This observation indicates that the ion heat confinement is improved in high-T_i discharges associated with the presence of a large V_t.

It is also interestingly observed that the emission intensity from carbon-impurity ions (for CXRS measurement) at the core region strongly drops as the core-T_i becomes higher. It implies that the carbon-impurity ions are expelled from the core region. This phenomenon has been dubbed as “impurity hole”. This unique feature may provide the efficient knob to avoid the impurity accumulation in reactor-relevant helical plasmas.

We have also initiated the relevant transport analysis. The ions are in 1/v regime for these high-T_i plasmas, and neoclassical (NC) ambipolar Er is predicted to be negative (ion-root). This prediction indicates that the hollow impurity profile (usually anticipated from the positive E_r (electron-root)) must be due to effects beyond the NC transport theory. The theoretical study to clarify the role of large V_t for the improved ion heat confinement has also been performed from the viewpoint of plasma viscosity structure in three-dimensional magnetic configurations. It is anticipated that systematic theoretical study may provide fruitful experimental scenarios for pushing the T_i-record higher in LHD.

An experimental study is performed to explore the operational space of super dense core plasmas due to an IDB, which was originally found in pellet fueled high density discharges with the local island divertor configuration, in Large Helical Device (LHD). The internal diffusion barrier with steep gradient has been produced at an intrinsic helical divertor configuration in LHD by optimizing the pellet fueling and magnetic configuration.

Core fueling by multiple pellet injections is essential for the internal diffusion barrier formation. Nine-barrels in-situ pneumatic pipe-gun was employed to inject solid hydrogen pellets, which contain 1.5 - 2.0×10^{21} hydrogen atoms, at a velocity of ~ 1100 m/s every several 10 ms.

A global confinement property reach a maximum performance at an inward shifted magnetic configuration (R_{ax}= 3.65 m) which give a maximum plasma volume. The internal diffusion barrier, on the other hand, easily appears in the outward shifted magnetic configurations (R_{ax} > 3.75 m) in which magneto hydrodynamic stability properties are considered to be favorable. A central pressure of the super dense core plasma increases with density and the central pressure exceeds atmospheric pressure. The super dense core plasma is, therefore, characterized by very large Shafranov shift (Δ/a_{eff} ~ 1/2), even at high magnetic field (B_t> 2.54 T).

Maximum central density reaches 1×10^{21} m^{-3} just after pellet injection at R_{ax}= 3.9 m and above. Central pressure reach its greatest value at the neighborhood of R_{ax}= 3.85 m. The maximum central pressure is limited by a core density collapse (CDC) event

Core density collapse (CDC) is a relaxation events observed in the SDC plasmas. When the magnetic axis exceeds about 4.1m and 4.0m at the horizontally and vertically elongated section, respectively, the CDC events happen. From the time evolution of the soft X-ray (SX) radiation intensity, the time scale of the events (typically 0.1-1 ms) is studied. Two stages are identified in the events, the pre-cursor phase and the rapid drop phase. The time scales become shorter when the core electron temperature increases. From the SX radiation profile, rapid movement towards outboard side just before the events is often observed. Magnetic reconnection from the movement is one possible scenario to explain this rapid loss.

The average beta of 4.8 % has been obtained with increasing NBI power. With pellet injection, we have achieved the average beta of 5.0 %, which is the target value in the conceptional design phase of the LHD.

APPENDIX 2: TECHNICAL REPORT ON 2007 ACTIVITY, RUSSIA

1) GENERAL PHYSICS INSTITUTE (GPI)

1. A series of investigations was made of the excitation and damping of fast magnetosonic waves at the ion cyclotron resonance frequency in hydrogen plasma in the L-2M stellarator. The longitudinal wavenumber and damping length of these waves was determined. The dependence of the loading resistance of a poloidal antenna on the plasma density was measured. The measurements have shown that strong damping of fast magnetosonic waves takes place when the ion cyclotron resonance region is located at the plasma axis.

2. Mounting of a power supply system for the new ECRH system is completed, which allows for independent operation of two high-power (800 kW) gyrotrons. Because of some technical problems, the L-2M experiments with the high-power gyrotron have to be postponed to the first of the year 2008.

3. The performance of the new submillimeter interferometer based on a water-vapor laser was tested at a test bench at the Institute of Physical Problems. This interferometer should take the place of the HCN interferometer used at present in L-2M experiments. The water-vapor laser is capable of generating orthogonal polarizations of different frequency simultaneously at two operating wavelengths. The new interferometer, owing to this capability, may do much to upgrade sensitivity, accuracy and reliability of the electron-density profile measurements.

4. Further development of the theoretical model of transport in stellarator using the different form of anomalous losses.

2) KURCHATOV INSTITUTE

In quasi-isodynamic configurations earlier considered, the divergence of the current perpendicular to the magnetic field lines is equal to zero in the cross-sections of maximal magnetic field strength B and changes the sign only once along the magnetic field within one period. Thus, the parallel to the magnetic field current density has nonzero dipole component which effects on MHD stability at very high β. During this year the new structure of the period was found in which the B-contours change their inclination with respect to the lines ς_B = const within half a period. This makes it possible to eliminate the dipole component of the parallel current density in quasi-isodynamic configurations [8]. The described in [8] configuration has a magnetic hill. Thus, the next step was to study the compatibility of the conditions of quasi-isodynamicity, zero dipole parallel current and creation of the magnetic well in the associated vacuum magnetic field. In Ref. [9] the geometry of the configuration was found with closed contours of the second adiabatic invariant, zero dipole secondary current and Resistive, Mercier and strong ballooning modes stable at very-high-β.

New version of the 3D VENUS+δf code to calculate the neoclassical diffusion and the bootstrap current has been developed by M. Isaev with co-authors for an arbitrary collisionality, with the experimental density profiles and with the magnetic islands structure of the magnetic surfaces. The bootstrap current coefficients calculations have been performed with the VENUS+δf code for stellarators/heliotrons LHD, W7X, NCSX, the successful benchmark with the DKES code and MC tools have been obtained in the frame of the International Collaboration on Neoclassical Transport in Stellarators. Qualitative coincidence of the simulations has been obtained for the LHD experiments. Calculations have been performed on the different computational platforms, including several clusters and supercomputers as well as a new cluster in the Kurchatov Institute.

EPSILON project is developed to create closed magnetic mirror trap with extremely low rotation transform and with poloidal pseudosymmetry of the magnetic field geometry for high pressure plasma confinement. Device consists of two straight multi-mirror traps closed with curvilinear equilibrium elements. Mirror field, MHD stability and plasma purity are provided by axisymmetric divertors with zero magnetic field at the separatrix. Divertors are situated along the multi-mirror traps. Prof-of-principle experiment is suggested.

APPENDIX 3: SUMMARIES OF THE INSTITUTE OF PLASMA PHYSICS OF THE NSC KIPT, KHARKOV, FOR 2007

Plasma Theory

1) Study of the 1/v neoclassical transport for Uragan-2M with 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, W. Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria) and N. T. Besedin (Kursk State Technical University, Russia)).

The device parameters are considered for which the rotational transform (within the vacuum chamber) is larger than 1/3 (near the magnetic axis) and smaller than 1/2 (for the outer surfaces) (k_φ=0.31). Because of non-symmetric arrangement of the current feeds and of the detachable joints the stellarator symmetry of the resulting magnetic field of U-2M is violated. As a result a preliminary computation of each magnetic surface is necessary to find the starting conditions for the transport computation using the NEO code. The lack of the stellarator symmetry leads to formation of new island surfaces for some rational values of the rotational transform. The obtained transport coefficients for such island surfaces can be markedly different from those for the non-island surfaces. For non-island surfaces the transport coefficients turn out to be sufficiently close to the corresponding results obtained formerly in case of neglecting the influence of the current-feeds and detachable joints. 34th EPS Conference on Plasma Physics, Warsaw, Poland, 2-6.Jul. 2007.

2) Calculations of an effective ripple for a stellarator magnetic field computed by the HINT2 code (V.V.Nemov and S.V.Kasilov in collaboration with B.Seivald and W.Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria), Y. Suzuki (NIFS, Japan) and J.Geiger (Max-Planck-Institut für Plasmaphysik Physik, Germany)).

The effective ripple, ε_{eff}, as measure of $1/\nu$transport is computed for W7-AS and W7-X equilibria with various average β-values. Those equilibrium data are provided as output from the HINT2 code. The ε_{eff} computations are performed using the code NEO. Some peculiarities of the transport are found for the regular and island magnetic surfaces. The obtained results demonstrate the possibility of using HINT2 data for study of neoclassical transport in stellarators. 34th EPS Conference on Plasma Physics, Warsaw, Poland, 2-6.Jul. 2007.

3) Studies of the neoclassical transport for CNT (V. V. Nemov in collaboration with B. Seivald and W. Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria) and T. Sunn Pedersen (Columbia University, USA).

The Columbia Nonneutral Torus (Columbia University, USA) is a device of the stellarator type. To asses its general confinement properties the 1/v neoclassical transport is studied. Possibilities of decreasing this transport are analyzed. Although a strong ambipolar electric field should be present in CNT the transport estimates and optimizations are performed for the zero electric field. So, the transport estimates provide an upper bound on the neoclassical transport of the bulk plasma. Also, an ambipolar electric field will not appreciable affect the confinement of the 3.5 MeV alpha particles and the transport estimates will have relevance to alpha-particle confinement. 34th EPS Conference on Plasma Physics, Warsaw, Poland, 2-6.Jul. 2007; Plasma Physics and Controlled Fusion, Vol.49, p. 2063-2073 (2007).

4) Development of the delta-f Monte Carlo method for the computation of bootstrap current with improved convergence in the low collisionality regime. (S. V. Kasilov, V. V. Nemov in collaboration with W. Kernbichler, G. O. Leitold and K. Allmaier (Institut für Theoretische Physik, Technische universität Graz, Austria)).

The new delta-f Monte Carlo method has been developed for the computation of neoclassical transport coefficients and bootstrap current which has improved convergence in the long mean free path regime. In order to reduce large variance in bootstrap coefficient of the standard delta-f Monte Carlo method which is caused by a finite bounce-averaged drift of trapped particles, the driving term is separated into the sources of trapped and passing particles in this method. Source of passing particles is treated using a standard delta-f scheme because the contribution of the driving term to the bootstrap coefficient has low variance similar to that in the tokamak, while the source of trapped and barely trapped particles is treated with the help of a re-discretization scheme which assumes calculation of the perturbed distribution function on the grid. Due to annihilation of test particles with opposite signs of the weight and due to the importance samping of test particle distribution the variance in boostrap coefficient scales for this new method linearly with the mean free path (in contrast to the quadratic scaling in the standard delta-f scheme without filtering). In addition, due to the annihilation of test particles on the grid the number of test particles is exponentially decreasing during the run. As a result, total CPU time required for the computation of bootstrap coefficient with given accuracy scales as the mean free path in the power 3/2 which is much better than cubic scaling of the standard delta-f scheme without filtering. In contrast to delta-f schemes with filtering which also have an improved convergence in the long mean free path regime, the new method does not introduce a bias (systematic error) in the result.

5) New method of selective cold alpha-particles removal from the fusion helical plasma have been developed. (A. Shishkin in collaboration with O. Motojima and A. Sagara (NIFS, Japan)).

A new concept for the selective removal of cold α-particles is developed which is specific to the helical devices (heliotron/torsatron system). It includes escape of trapped cold α-particles due to enhanced drift in the helical magnetic field under finite β and resonant removal of passing cold α-particles trough the island structure created by drift resonance. For both mechanisms, control of the perturbation field coil current is the key issue. There is proposed to include the *perturbation* poloidal field coils in the design of the Force Free Helical Reactor 2m1 /FFHR 2m1/. The results are published in the recent paper by A. Shishkin, A. Sagara, O. Motojima, O. Mitarai, T. Morisaki, and N. Ohyabu, Nuclear Fusion 47 (2007) N8, p. 800-808.

6) Development the new scenario of the plasma heating in Force Free Helical Reactor. (A. A. Shishkin, in collaboration with O. Mitarai, A. Sagara, H. Chikaraishi, S. Imagawa, K. Watanabe and O. Motojima).

There is developed the new scenario of the plasma heating in Force Free Helical Reactor 2m1 /FFHR 2m1/ to minimize the external heating power and prolong the fusion power rise-up time over 300 seconds (See paper by O.Mitarai, A.Sagara, H.Chikaraishi, S.Imagawa, K.Watanabe, A.A.Shishkin and O.Motojima, Nuclear Fusion 47 (2007) N11, pages 1411-1418.

7) Pavlov S.S., collaborating with Castejon F., Cappa A., Fernandez A. (CIEMAT, Madrid, Spain) and Tereshchenko M. (Institute of General Physics, RAS, Moscow, Russia), studied on the base TRUBA beam/ray tracing code influence of relativistic effects on conversion of O-waves into the electron Bernstein waves near the fundamental ECR in conditions of the TJ-II stellarator and on conversion of the fast mode of magnetosonic wave into the ion plasma wave near the fundamental ICR.

On the base the theory of Cauchy type integrals it is given an analytic continuation of the exact relativistic plasma dispersion functions from real axis into the complex region and studied their analytical properties in this region (Pavlov S.S., Castejon F., Dreval N.B., Problems of Atomic Science and Technology. Ser. “Plasma Physics” (11), 2007, N1, p. 66).

It was shown that a theoretical study of EBW heating at the fundamental ECR in the TJ-II conditions requires taking into account relativistic effects (Castejon F., Cappa A., Tereshchenko M, Pavlov S.S., Fernandez A., Weakly, Fusion Science and Technology, Vol. 52, 2007, p. 230).

It was shown that in plasmas with the JET tokamak parameters in the regime of conversion of fast mode of fast magnetosonic wave into ion plasma wave near fundamental ICR can arise relativistic effects (Castejon F., Pavlov S.S., Tereshchenko M., 12th Europ. Fus. Theor. Conf., Madrid, Spain, September 2007, Book of abstracts, p. 83).

8) Poloidal plasma shear flows in the SOL regions of stellarators (V.S.Mikhailenko, K.N.Stepanov et al.).

The effects of strong poloidal plasma shear flows in the SOL region of tokamaks and stellarators on the processes of the anomalous transport were investigated analytically. The large variations of the flow velocity in real toroidal systems are limited to the same small edge layer in which the velocity shear length L_v is found to be much less than the magnetic shear length L_B. In fact, the shearing rate, dv_0/dr, in this region is of the order of or even larger than the typical drift wave frequency. Under such conditions the conventional modal approach to drift and drift Alfven turbulence, incorporating local approximation, is principally invalid because the evolution of drift--type disturbances due to flow shear occurs in times much less than the period of the modal drift waves in the shearless plasma. Our investigations are grounded on the non--modal approach in which spatial dependence, connected with the shear flow, was excluded by transformation of spatial coordinates to coordinates convected with sheared flow. That gives the possibility to obtain the initial value problem solution for the waves and instabilities considered for any desired times of interest and for any magnitude of the velocity shear.

In the case of the flow with homogeneous shear we find, that the suppression of the drift resistive instability in the case of sufficiently strong flow shear is a non--modal process, during which the initial amplitude of the perturbed electrostatic potential decreases with time as t^{-2}. In the case of the flow with homogeneous shear we find, that for the conditions of shear flow in SOL in ASDEX Upgrade drift and interchange modes have not the oscillatory dependence in time in convective set of reference. The instabilities suppression process is non-modal one with power-like time dependencies and of the electrostatic potential. The anomalous transport is of the subdiffusive nature with reducing with time as t^{-2} diffusion coefficient.

The analysis of the effect of the flow shear non-uniformity on the temporal evolution of the drift modes, performed on the bases of the Hasegawa-Wakatani system of equations, have shown, that flow curvature contained terms decay more rapidly with time, as compared with only shearing rate contained terms. Therefore the linear "hydrodynamic" effect of the non-uniformity of the flow shear appears to be subdominant. The same conclusion is valid for Rayleigh-Taylor modes evolution in flow with inhomogeneous shear. The local kinetic analysis proves that the non-uniformity of the flow shear is a source of the kinetic mechanism of the resonant damping of waves across the magnetic field due to their interaction with ions, which is akin to the finite-beta resonance in the curved magnetic field. This damping may be exceptionally strong, but at such condition the non-modal effects also may be dominant, and additional efforts are necessary for the development the non-modal kinetic theory for the non-local investigation the effect of the flow shear non-uniformity on the anomalous plasma transport.

Plasma Experiments

1) The investigations of the structure of magnetic surfaces were carried out in the Uragan-2-M torsathon by the use of the luminescent rod method. The method is based on the photographing of the luminescence of the rod when electrons with energy ≤100 eV, generated by a compact electron source, hit the rod surface. The photographing was carried out either by a Polaroid camera or by a digital photo-camera.

Magnetic surfaces were investigated for 9 different regimes of magnetic configurations, which differ by the value of the portion of toroidal magnetic field produced by the l=2 helical coils variation in a quite wide range, K_φ =0.295 ÷ 0.4, with corresponding variation of the vertical magnetic field amplitude.

Using the results of measurements of magnetic configuration, the most interesting for the plasma experiments configurations with K_φ near 0.31 and 0.32 were chosen. The influence of the vertical magnetic configuration was studied in details, in particular, it was found that depending on the value of the vertical magnetic field, the principally different magnetic configurations are realized: with 3 magnetic islands near the last magnetic surface or without magnetic islands. In both cases the mean minor radius of the last closed magnetic surface is $\bar{a} \approx 20{,}5$ cm.

The locations of islands and their size found are in good agreement with the results of computer calculations.

2) By means of electrostatic probes the comparative behaviour of fluctuations of plasma density above and below central plane of the torus was for the first time studied in two poloidal cross sections of the Uragan-3M torsatron before and after transition to the H-mode. It was found out a new type of the vertical asymmetry of the divertor plasma flows (DPF), namely, the lack of coincidence of power spectra and coherency of fluctuations in symmetrically disposed divertor channels.

According to results of measurements of coherency between fluctuations in the SOL and in DPF, two SOL regions may be distinguished: the one with the predominance of ions is located nearby the LCMS (last closed magnetic surface), and the one located further from LCMS with the predominance of electrons. Basing on the corresponding spectral characteristics of fluctuations, one may assert that on the ion $B\times\nabla B$ drift side the DPF is formed mainly by particles that are going out from the SOL region being adjacent to LCMS. At the same time, on the electron $B\times\nabla B$ drift side the DPF is formed mainly by particles that are going out from the SOL region, a little remote from LCMS.

Important, that the changes of spectral characteristics of DPF fluctuations at the H-mode transmission do support the measured earlier peculiarities of dynamics of ion and electron losses during such transmission.

Important, that the changes of spectral characteristics of DPF fluctuations at the H-mode transmission do support the measured earlier peculiarities of dynamics of ion and electron losses during such transmission, and are in agreement with results of measurements of effects of the H-mode transmission on the equilibrium DPF properties, measured previously.

3) The contribution of the fast ions (FI) into the divertor plasma flows (DPF) was measured by means of ion grid analyzers disposed in two poloidal cross sections of the Uragan-3M torsatron. It was found that the mean energy of ions that are registered on the $B\times\nabla B$ vertical drift side is higher than on the opposite side. Thus, for the first time it was shown a significant FI contribution into a vertical (up-down) asymmetry of DPFs in the helical divertor of torsatron/heliotron. The results are very different for two identical poloidal cross sections, what indicates on the lack of toroidal homogeneity of DPFs and the $B\times\nabla B$ drift effects.

One of the possible reasons of such toroidal homogeneity can be existence of the island structure of the real magnetic configuration in Uragan-3M, with the angle of magnetic field lines transformation close to $2\pi/4$ (at present, the existence of islands was shown only by computer calculations but not experimentally). With magnetic islands, the real magnetic configuration could have only a single-period structure instead of nine-period structure in the case of no magnetic islands (as this device is three-period construction of the helical coils). Due to magnetic islands, the local helical wells are different in different poloidal cross sections, leading to difference in the portion of locally-trapped ions along the torus, and correspondingly their contribution into DPFs because $B\times\nabla B$ drift.

Another reason – the local input of a RF power into plasma from the RF antennae located only along one period of magnetic coils. The efficiency of RF power absorption in plasma probably decreases with decreasing the minor plasma radius, what evidently results in poloidal and toroidal symmetry of the heating efficiency.

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

4.1. The link between edge sheared flows and turbulence was investigated in the plasma edge region of the TJ-II stellarator. In the TJ-II stellarator is a threshold density to trigger the development of edge shear flows. During sheared flow development the degree of the turbulence anisotropy is modified. The fact that different quadratic terms in fluctuating velocities (radial-parallel/radial poloidal) change during edge sheared flow generation means that sheared flow physics involves 3-D physics phenomena. A new strategy has been recently applied to plasma physics to quantify the local energy transfer between flows and turbulence by computing the production term. Experimental results show that turbulence can act as an energy sink and energy source for the mean flow near the shear layer. Measurements of the turbulence production show the importance of 3-D effects on the energy transfer between flows and turbulence.

4.2. The correlation measurements of the plasma density and the potential fluctuations in the plasma core are possible by simultaneous registration of the secondary ions, coming from the different plasma points. Such simultaneous measurements of the plasma potential make possible the direct calculation of the electric field E, its mean and oscillating components. In its turn, poloidal electric field oscillations correlated with the density ones open the way to the direct study of the convective turbulent particle flux Γ_r.

To perform the *E* measurements the two-slit energy analyzer was created and calibrated in order to unify the analyzer gains *G* and dynamic factors *F* for the both entrance slits. Hitherto obtained accuracy for both analyser slits is ΔG – $2x10^{-3}$ and ΔF – $3x10^{-3}$, which is limited by the existing step motor accuracy of 0.1 mm for entrance slits moving. The presented study work is considered as a first step to the multi-slit analyzer elaboration.

4.3. Direct measurements of the electric potential, electric fieald E, plasma density and their fluctuations by HIBP diagnostic with two-slit energy analyser have been investigated in different combinations of gas puffing, ECR+NBI heating and edge conditioning scenarios (biasing) .

5) The measurements of radial plasma potential and density as well as their fluctuations (GAM) by Heavy Ion Beam Probe (HIBP) diagnostics and study of their influence with ECR heating were continued in the frame of the collaboration with Kurchatov Institute (Moscow).

5.1. The geodesic acoustic modes (GAM) were investigated on the T-10 tokamak in OH and ECRH regimes. Regimes with Ohmic heating and with on- and off-axis ECRH were studied (B = 2.2–2.5 T, I_p = 180-330 kA, n_e = 1.3 – 2.5 x 10^{19} m^{-3}). Experimental layout is as follows: one CR antenna is located at the same cross section as HIBP at the Low Field Side, another one has a toroidal shift of one quarter of the torus, it is located at the High Field Side. Multipin movable and fixed limiter Langmuir probes are located at the CR diagnostic cross-section. This layout is oriented to the future study of the toroidal and poloidal mode structure of the GAM. This report is dedicated to the first result of the correlation measurements of the HIBP, CR and MLP diagnostics. HIBP is a convenient diagnostic to study GAMs. It is able to get simultaneously the oscillatory components for plasma electric potential and density by total secondary beam current, I_{tot}, if the beam attenuation does not affect the signal (path integral effect). This is the case of low density, which was studied here.

5.2. It was shown the GAMs are more pronounced in the plasma potential rather than density. The GAM peak is dominant in the potential spectra while MHD m=2 peak dominates the density spectra.

It was shown that GAM might have a complex structure, not similar to conventional periodical oscillations with a single frequency. GAM has an intermittent character presenting the stochastic sequence of the wave packages. For the observed T-10 conditions the “lifetime” of the package lies in a range of 0.5 -2 ms. So, the most direct tool to study the GAM properties looks to be the wavelet analysis. GAM is more pronounced in ECRH plasmas, where the typical frequencies of the wave packages are observed in a narrow interval from 22-27 kHz at the outer one third of the plasma column. The clear correlations between potential and density are seen at the spectra of HIBP signals. The phase shift is $\pi/2$ for GAMs. In contrast, for MHD m=2 peak, the phase shift is zero.

5.3. The power spectra of $\Delta\varphi$ looks like a narrow dominant coherent peak between 9 – 33 kHz with a high contrast to the noisy background. The GAM frequency depends on the electron temperature as $T_e^{1/2}$. The absolute values of the frequencies are close to the theoretical ones.

5.4. Along with the above mentioned features, predicted for GAM, there were found some additional characteristics: GAM tends to be more exited near low-q magnetic surfaces; along with being mainly electrostatic, GAM also has some magnetic component; GAM amplitude has an intermittent character; GAM has a density limit.

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

6.1. Spatial structure and temporal dynamics of the radial electric field in the small tokamak TUMAN-3M (R=0.55 m, a=0.22 m, I_p^{max}= 0.16 MA, B_{tor}^{max}=0.8 T, $n_e<5\times10^{19}$ cm^{-3}, T_e<500 eV, T_i<200 eV, q_{lim}~ 2.3-2.6) was studied in different modes of plasma heating and confinement, namely, in the ohmic L- and H-modes and NBI, with and without low frequency MHD oscillations. Central plasma potential was measured by heavy ion beam probe (HIBP), which gives a rare possibility of direct measurement of hot dense plasma potential. Due to the geometrical limitations, only a region of 0<r<16 cm (i.e. 0<r/a<0.73) is typically covered by the HIBP. Peripheral radial electric field was measured using Langmuire probes. Thanks to the proper design and materials used (and of course, moderate electron temperature and density of the TUMAN-3M peripheral plasma), the probes may have been inserted up to 2 cm (r/a= 0.91) inside LCFS, thus allowing E_r measurement in the peripheral region of the core plasma. So, range 0.73<r/a<0.91 is still unreachable for both Langmuire probes and HIBP, and obtaining information on E_r structure in this region is a challenge for future experiments. Useful information on plasma rotation in this region, qualitatively corresponding to E_r evolution measured with probes and HIBP has been obtained using microwave reflectometry.

6.2. Strong positive perturbation of the core plasma potential was registered by the HIBP during the burst of peripheral MHDs with low m, n. If such a burst takes place in the H-mode (both ohmic and counter-NBI heated), the positive potential perturbation leads to H-mode termination. The most probable mechanism of the positive field build-up during MHD burst is though to be a loss of fast electrons along partly disturbed magnetic field lines near the island's separatrix. This mechanism is similar to the ergodic divertor's action on the TEXTOR, where radial electric field modification by the electron loses was also discussed. A quantitative analysis of the subject may be found in. Similar mechanism may be responsible for a positive perturbation of central plasma potential registered in the saw-tooth crashes. The positive radial electric field caused by MHD activity is capable of H-mode termination, most probably through the canceling the H-mode "natural" negative radial electric field.

In a scenario with Counter-NBI it was found using HIBP that, due to the NBI effect (most probably, orbit loss with some heating and momentum impact), core plasma potential plasma gradually became more negative (by ~200V).

The GAM with $\delta\phi/\phi$~0.3 and $\delta\phi/\phi >> \delta n/n$~0.05 were observed with HIBP in a core region of the TUMAN-3M r/a~0.33 in the current ramp phase. Further studies are planned to reveal a possible connection between the GAM properties (localization, plasma condition dependence) and plasma confinement in the TUMAN-3M.

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

The WEGA HIBP operates with a beam of singly charged sodium ions with an energy of up to 50 keV, ion current up to 199 μA, and beam diameter of 5-6 mm in the confined plasma region. Plasma expertiments with the HIBP diagnostic system were carried out at a magnetic field strength of B=0.45 T. In the experiments, helium plasma was heated non-resonantly with microwaves at 2.45 GHz. The first single point plasma potential measurements V_{pl}=42 V obtained with the HIBP is consistent with Langmuir probe potential measurements.

8) The calculations of the trajectories were made for Uragan-2M stellarator using singly charged cesium and thallium (Cs^+ and Tl^+) primary ions in the energy range of 100÷950 keV. URAGAN-2M HIBP project uses entrance port 12 for an injection of primary ion beam inside the plasma vessel and exit port 15 for a detection of the secondary ions beams, coming out of the plasma. These ports placed on a toroidal angle $\varphi=54^0$ and are almost opposite to each other. Two variants of HIBP diagnostic for different magnetic field values were calculated. The operation of the URAGAN-2M at the first stage: the magnitude of the toroidal magnetic field will be not more than 0.8 T, at the second stage - up to 2.4 T.

Detector grid calculated for the first stage covers quite large area of the plasma. It is possible to get the plasma potential profile by fast electrostatic deflection scanning system and beam energy variation in the range of $0<\rho<1$ using the Tl^+ beam with an energy from 100 to 150 keV. For the second stage of the operation it will be necessary to increase the Tl^+ beam energy up to 950 keV in order to reach the plasma center.

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APPENDIX 4: SUMMARIES OF KARAZIN NATIONAL UNIVERSITY, KHARKOV FOR 2007

1) With the aim to study the behaviour of impurity ions in plasma configuration of Wendelstein 7-X stellarator including island divertor configuration in real geometry, the 3D Impurity Transport Code was developed by Dr. Oleg Shyshkin (University) in collaboration with Dr. R. Schneider and Dr. C. Beidler (MPIPP) in the framework of the regular project of Science and Technology Centre in Ukraine (STCU) #3685. The code is the upgrade version of 1D Impurity Transport Code developed during the regular STCU project #2313. The code solves guiding center equations for the test particle with the use of Runge-Kutta integrating scheme of order four. This code could be used for the calculation in parallel for the HELIAS reactor with five periods of the magnetic field and is the direct extrapolation from Wendelstein 7-X stellarator and for the Wendelstein 7-X as well. The outcomes are published in the paper:

O. A. Shyshkin, R. Schneider, C. D. Beidler, *Numerical analysis of tungsten transport in drift optimised stellarator with ergodic and nonergodic plasma configurations*// Nuclear Fusion, 2007, vol. 7, p. 1634-1643.

2) The collaboration with the groups carrying out the research in the field of ion-surface interactions in fusion devices has been started by Dr. I.Bizyukov (University) in collaboration with Dr. K. Krieger and Dr. J. Roth (MPIPP) and Prof. Hass (Toronto). Currently, experimental program running in fusion laboratory of University of Toronto Institute of Aerospace Studies is coupled to one running on Dual-Beam Setup in MPIPP. This program is aimed on study of processes eroding the tungsten surface exposed to simultaneous C and D ion bombardment at elevated surface temperatures. Both laboratories own similar experimental equipment, but the diagnostic is different: UTIAS setup provides detection of sputtered particles, while IPP setup is capable to measure atomic concentrations on surface. The collaboration allows obtaining both on-surface data (a real densities, depth profiles, etc.) with data on fluxes of sputtered atoms and molecules at the same bombarding conditions. It is expected that the program will provide comprehensive picture of processes on surface being under multi-species bombardment. These data can be used to validate numerical codes; after the validation application of these codes can be extended to the fusion conditions.

3) The theory of surface extraordinarily polarized electromagnetic waves propagating in fusion devices was developed in the framework of the STCU regular project #3685. The effect of the shape of the chamber cross-section on the waves' dispersion properties was studied:

I. O. Girka, O. I. Girka, V. O. Girka, I. V. Pavlenko. *Effect of the Shape of the Cross Section of a Plasma-Dielectric Interface on the Dispersion Properties of Azimuthal Surface Modes*// Plasma Physics Reports, 2007, vol. 33, No. 2, p. 91-101.

I. O. Girka, O. I. Girka, V. O. Girka, I. V. Pavlenko. *Resonant Effect of the Noncircular Shape of the Plasma Surface on the Dispersion Properties of Extraordinary Azimuthal Surface Modes in Magnetoactive Waveguides*// Ibid, No. 7, p. 543-552.

4) A new concept for the selective removal of cold α-particles is developed by Alexander A.Shishkin (Kharkiv Institute of Physics and Technology, UKRAINE and the University) in collaboration with Akio Sagara, Osamu Motojima, Osamu Mitarai, Tomohiro Morisaki, and Nobuyoshi Ohyabu (NIFS). which is specific to the helical devices (heliotron/torsatron system). It includes escape of trapped cold α-particles

due to enhanced drift in the helical magnetic field under finite β and resonant removal of passing cold α-particles trough the island structure created by drift resonance. For both mechanisms, control of the perturbation field coil current is the key issue. There is proposed to include the *perturbation* poloidal field coils in the design of the Force Free Helical Reactor 2m1 /FFHR 2m1/. The results are published in the paper:

Alexander Shishkin, Akio Sagara, Osamu Motojima, Osamu Mitarai, Tomohiro Morisaki, and Nobuyoshi Ohyabu. *Controlling the cross-field flux of cold α-particles with resonant magnetic perturbations in a helical fusion plasma device//* Nuclear Fusion, 2007, Vol. 47, No. 8, p. 800-808.

5) There is developed the new scenario of the plasma heating in Force Free Helical Reactor 2m1 /FFHR 2m1/ to minimize the external heating power and prolong the fusion power rise-up time over 300 seconds:

O. Mitarai, A. Sagara, H. Chikaraishi, S. Imagawa, K. Watanabe, A. A. Shishkin and O. Motojima. *Minimization of the external heating power by long fusion power rise-uptime for self-ignition access in the helical reactor FFHR 2m//* Nuclear Fusion, 2007, Vol. 47, No. 11, p. 1411-1418.

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APPENDIX 5: TECHNICAL REPORT ON TJ-II ACTIVITIES IN 2007

The results achieved in the TJ-II stellarator during 2007 were obtained in plasmas created and heated by Electron Cyclotron Resonance Heating (ECRH) (2 x 300 kW gyrotrons, at 53.2 GHz, 2nd harmonic, X-mode polarisation) and Neutral Beam Injection (NBI). Two beams of 400 kW port-through (H0) power at 30 kV, were injected on TJ-II. Recent improvements in plasma diagnostics have led to a better understanding of the confinement properties of TJ-II, including operation of a dedicated neutral beam injection system and charge-exchange diagnostic, fast ion detector and spectroscopy. The main conclusions can be summarized as follows:

1) The TJ-II stellarator has been operated under several first wall conditions until now, including full metallic scenario, with He glow discharge conditioning and full boronized walls and, in the 2007 experimental campaign, lithium coating by several techniques. Lithium coating, tested for the first time in a stellarator, has proven a very effective method for particle control in TJ-II. Changes in the shot by shot fuelling have been recorded as well as in the total particle inventory compatible with good density control have been recorded after the Li coating. Thus, a factor of four increases in the fuelling rate at constant density compared with the B-coated walls was recorded and even a higher value was estimated for the allowed H inventory in the puffing-controlled ECRH discharges.

2) Rotational transform and magnetic shear remain among the key reactor-relevant issues in the stellarator studies. Recent results obtained in the TJ-II low beta, low collisionality plasmas indicate that the low order resonances lower locally the local electron heat diffusivity. The effect is apparently smaller the higher the order of the rational number and stronger the higher the plasma density but it survives even for the low magnetic shear values typically fond in TJ-II. Regions of lower and higher relative electron heat diffusivity are found to lie adjacent to each other in TJ-II but the rational values can be clearly tracked over lower heat diffusivity grooves.

   Transitions to improved core electron root transport (CERC) triggered by low order rational is a well established area of research in the TJ-II stellarator. Latest results have been focussed in the CERC triggered by the 4/2 rational. The rational 4/2 positioned in the plasma core region can have a favourable effect on the confinement provided a moderate magnetic sear is established. Transitions triggered by the 4/2 rational surface show an increase in the ion temperature (about 10 %) synchronized with the increase in the electron temperature. In these experiments the magnetic island associated to the 4/2 rational surface is detected by SXR tomography as a flattening in the SXR profiles with an m=2 structure.

3) The investigation of momentum transport mechanisms in the core and edge region remains as a key area of research in the TJ-II stellarator. Experiments in the TJ-II stellarator showing that the generation of spontaneous sheared flows at the plasma edge requires a minimum plasma density open a unique possibility to characterize the dynamics of sheared flow development in fusion plasmas. The effective viscosity at the plasma edge can be deduced by means of the decay of the perpendicular flow and radial electric field measurements once the external driving force (via electrode biasing) has been removed. Recent measurements of the (fast) decay time (in the range 10 – 50 microseconds) suggest an increase in decay time above the threshold

edge gradient to trigger the emergence of the edge shear flow. These findings can be explained using a second order phase transition model in which the basic mechanisms assumed is the shear flow amplification by the turbulence-induced Reynolds stress with the associated shear flow suppression of the turbulence.

First active charge-exchange recombination spectroscopy (CXRS) systematic measurements of ion impurity (C VI) poloidal rotation and temperature profiles have been obtained, showing (in agreement with previous results) a change of sign in rotation from ion diagmatic to the electron diamagnetic as density increases and the impact of ECRH power on rotation.

4) The quest for the stellarator divertor needs a robust divertor concept to guarantee low plasma-wall interaction and power exhaust. In order that the island divertor concept (already tested in different stellarators) works it is necessary that the island positions and widths do not change substantially during plasma operation, which makes it not suitable for devices which rely their configuration on the bootstrap current like NCSX or devices that present high flexibility in their rotational transform values, like TJ-II. In these cases, the flux expansion concept could be a good candidate to control power and particle exhaust. First studies of ion guiding centre orbits have been done for TJ-II configurations (considering ion-ion and ion-electron collisions together with the electric field) using the ISDEP code to investigate the fluxes in ECRH and NBI plasmas. It has been observed that the poloidal distribution of the flux is weakly dependent on the toroidal angle.

MINUTES OF 36TH STELLARATOR EXECUTIVE COMMITTEE MEETING

17th October, 2007
4:00 pm – 6:15 pm
Meeting Room, Ceratopia Toki, Toki-city, Gifu, Japan

Attendees

Australia	B. Blackwell
	J. H. Harris
EU	J. Sanchez
	P. Helander (substitute for F.Wagner)
	C. Hidalgo (ex-secretary)
Japan	O. Motojima (chairman)
	A. Komori
	H. Yamada (secretary)
Russia	L. M. Kovrizhnykh
Ukraine	C. Chechkin (substitute for V.I.Tereshin)
USA	J. F. Lyon
	M. C. Zarnstorff

Meeting was opened by Motojima, chair and he welcomed all participants to the 36th Stellarator Executive Committee (SEC) meeting. He referred participation of Peterson for clerical work, and Kimata and 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.

Yamada pointed out that quorum was met according to page 8 (d) 6 of the Implementing Agreement (IA)

1. Approval of Agenda

Lyon has two miscellaneous items to be brought up at the end of the meeting. Agenda was approved

2. Approval of minutes 35th Stellarator EC meeting

Minutes were approved.

3. Chairmanship and membership of SEC

The membership from each party was confirmed:

Australia	B. Blackwell
	J. H. Harris
EU Germany	F. Wagner is replaced by R. Wolf (represented by P. Helander)
	T. Klinger (alternate)
Spain	C. Alejaldre is replaced by J. Sanchez
	C. Hidalgo (alternate)
Japan	O. Motojima (chair)
	A. Komori
	H. Yamada (secretary)
Russia	N. A. Obysov *

	L. M. Kovrizhnykh
Ukraine	V. I. Tereshin
	C. Chechkin
	(provisionally, V. I. Tereshin suggests Volkov as representative)
USA	J. F. Lyon
	M. C. Zarnstorff

Sanchez suggested that the change of EU members should be approved in EURATOM. The parties with changes will make a required action.

Vice Chairman election: Since no candidates were suggested from the members, Motojima suggested that Vice Chairman comes from USA. Lyon nominated Zarnstorff. This assignment was approved by committee consensus.

* PS The message from Alexey N. Kalashnikov of ROSATOM on 23 Oct., 2007 told that Dmitry Yu. Prohorov replaces N.A.Obysov.

4. Confirmation of changes of contracting party

Yamada explained the letter from the administration office of IEA which requests the discussion about renewal of the contracting party of Russia. Kovrizhnykh will take this issue to Russia and Motojima will send the inquiry to Obysov.

5. Status of domestic activities and international collaborations

<u>Australia</u> (Blackwell)
Contract has been extended from Dec. 2005 – 2010
    Covers operation of H-1 and collaboration
Plasma Fusion strategic plan is 63MA$ over 10 years
    Experimental program for H-1
    Basic fusion science
    Includes 8 universities with matching funding
    ITER diagnostic – optically based edge diagnostic
    Recent strong encouragement form Ikeda ITER director
    Proposed to government, no response yet

<u>Germany</u> (Helander)
MPIPP Executive Committee is undergoing a generational shift with retirements by Behringer, Lackner and Nuremberg, soon to be followed by Wagner. Nuremberg has been replaced by P. Helander and Wagner will be replaced by R. Wolf.

W7-X is moving forward. 80% (56/70) of superconductiong coils have been manufactured and half have been tested. Insulation problem with non-planar coils has been rectified. All coils in one toroidal field period segment have been assembled and mounted on a central support structure. 299 ports have been delivered, VV has been delivered, cooling pipes for the first segment have been installed. ECH is on track, diagnostics on track Machine should be finished in mid 2014.

<u>Spain</u> (Sanchez)
TJ-II replaced ECH gyrotron, currently commissioning
Lithium wall coating in last campaign

2nd NBI commissioning, next week operation
Technical support of ITER growing without taking away from plasma activity. Want to reinforce theory and studies of new machines.

With regard to European program
Review being carried out by European Commission of facilities and programs. Review panel consist of Europeans from outside the fusion community and Non Europeans from inside the fusion community. Topics are new facilities, closing facilities and what is road map to reactor. Will meet by the end of the year and report due by middle of next year.

With regard to strategic energy technologies
If money is not limited, what is offered and when. Opinion of European experts: Scaled back DEMO earlier to involve industry and reduce time lag from ITER.

<u>Japan</u> (Komori)
11th campaign targets and achievements in LHD
Guest Professors and visits
Plan of future upgrade including deuterium, NBI upgrade and closed divertor.

<u>Russia</u> (Kovriznykh)
L-2: Buying 2 gyrotrons 500kW/each, one in possession, one comes in one month. Now making power supply. Experiments to focus on ECH. 11 – 12 ms pulse length should be extended. Need to upgrade the power supply of magnetic coil, must reconstruct machine. 15 year ambitious program is being discussed. If approved then machine may be reconstructed. Goal is power plant by 2050.

<u>Ukraine</u> (Chechkin)
Uragan 3-M l = 3 torsatron: emphasis on ICRF and fast ions – fast particle los and RF wall conditioning
Urgan 2-M l = 2 torsatron: small helical ripples, fast ion behaviour, compare with 3-M, study wall conditioning by RF

<u>USA</u> (Lyon, Zarstorff)
CTH, HSX results reported in meeting
QPS, NCSX
Study in US on what capabilities are needed for DEMO

DOE plan – accompanying program strategic plan to ITER and beyond. No commitment by government for DEMO. Stellarator recognized as having role in additional facilities. Stellarator is seen as solution to disruptions, but no discussion of current drive. More recognition in DOE as new arises study is tokamak based, but includes stellarator case. Industry advisory group says that disruptions are unthinkable in a reactor and are considering economics. Tokamak supporters are getting realistic about the feasibility of current drive.

NCSX – Due to 2.5 year delay and $40M overrun being reexamined by various panels about 1/month, Princeton, DOE, FESAC – What will compact stellarator contribute to world fusion program? Cancellation remote, budget submitted to Office of management and budget.

6. Development of stellarator working groups

Harris and Yamada reported the current activity of working groups. The coordinated working group meeting was launched last year in Kyoto and then the second meeting was held in June 2007 in Greifswald. The third meeting is planned in the next week in NIFS. Theory responding to experiments is discussed as well. Issues in the working group had been limited to confinement&transport, however groups are now expanding even out of confinement issues. Kovryznykh mentioned necessity to publish results for explanation. Motojima promoted Web page. Zanstorff and Lyon suggested multiple working groups are needed, in particular, for reactor assessment and divertor issues.

7. Link of stellarator community with ITPA working groups

Hidalgo suggested that ITPA Stellarator members should be revised and working group leaders should be ITPA representatives. The committee member exchanged their opinion.
- disappointed that there is no feedback Stellarators need presence in ITER.
- representation should be reexamined regularly, ITPA is being reorganized into ITER and ITER may not welcome stellarator representatives.
- ITER may not welcome stellarator representatives
- Representatives should be held responsible

Representatives from stellarators are to be reconsidered along with this communication.

8. Title of the Stellarator IA

NIFS proposed that the name of the IA be changed to include the word Heliotron at the next extension. The committee members exchanged opinion with regard to its significance and procedure.

9. IEA Ad-Hoc Group on Science & Energy Technology (AHGSET) Work Plan

The document from IEA was distributed and the committee members consider a plan to be discussed next time.

10. Miscellaneous and final remarks

Lyon proposed two items which were confirmed.

i) Next ISHW at Princeton in 2009
   No objections, be careful about conflicting dates
   Program committee chair will be chosen from German party.
ii) Annual report due by the end of year.

Closing remarks by O. Motojima.
Next SEC will be in Geneva during the IAEA FEC in October 2008.