Implementing Agreement for Cooperation in Development of the Stellarator Concept

2005 Executive Committee Annual Report
to the Fusion Power Coordination Committee

Draft, February 2006

Committee Chair:

C. Alejaldre (Ministry of Education and Science, Spain)

Committee Members:

A. Iiyoshi (Chubu University, Japan)

O. Motojima (National Institute for Fusion Science, Japan)

A. Komori (National Institute for Fusion Science, Japan)

B. Blackwell (The Australian National University, Australia)

L. M. Kovrizhnikh (Institute of General Physics, Russian Academy of Science, Russia)

V. Lapshin (Institute of Plasma Physics of the National Scientific Center, Kharkov Institute of Physics and Technology, Ukraine)

N. A. Obysov (Ministry for Atomic Energy, Russia)

F. Wagner (Max-Planck-Institut für Plasmaphysik, Germany)

J. F. Lyon (Oak Ridge National Laboratory, U. S. A.)

Dr Zarnstorff (Princeton Plasma Physics Laboratory, USA)

Alternates:

R. L. Dewar (Plasma Research Laboratory, Research School of Physical Sciences and Engineering, The Australian National University)

R. McKnight (Department of Energy, U. S. A.)

J. Nührenberg (Max-Planck-Institut für Plasmaphysik, Germany)

T. Klinger (Max-Planck-Institut fur Plasmaphysik, Germany)

Guests:

S. Shchepetov (Institute of General Physics of Russian Academy of Science, Russia)

D. Grekov (Kharkov Institute of Physics and Technology, Ukraine)

C.Hidalgo (Laboratorio Nacional de Fusión, Spain)

EXECUTIVE SUMMARY

The present report overviews the scientific and technical progress achieved in 2005 by the parties to the Stellarator Concept Implementing Agreement, who have greatly benefit from its international collaborative framework. The document reports the collaborations in 2005 and the parties' research plans for 2006, including technical reports on 2005 activities.

TABLE OF CONTENTS

1 AUSTRALIA

1.1 International collaborations in 2005

The centrepiece of the National Plasma Fusion Research Facility in Australia is the flexible heliac H-1NF which 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 is able to access L-H confinement transitions at very low power (<100 kW) and can be used to study configuration effects on confinement with very rapid turnaround.

Extensive studies of plasma turbulence by M. Shats and his group in the heliac have demonstrated the role of zonal flows, spectral condensation and self-organisation in regulating the outward transport of particles and achieving enhanced plasma confinement. Collaboration with NIFS in this area is ongoing.

MHD and configuration studies have led to three 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.

- A collaboration of the ANU group with the Heliotron J group will see this technique applied to the new poloidal array data from Heliotron J, and a comparative study of the phenomena in both machines.

- A multilateral collaboration on control of edge localised mode (ELM) instabilities using stochastic magnetic fields in tokamaks was highly successful on the DIII-D tokamak, and as a result this scheme is being actively considered for implementation in ITER.

- The International Stellarator Database activity has brought together confinement data from most of the world's stellarator experiments in accessible databases hosted by NIFS (Japan) and IPP-Greifswald (Germany). Integrated studies of the unified data sets have confirmed and extended earlier confinement scaling studies for stellarators, and lend support to the configuration optimization schemes now being implemented in the next generation of stellarator experiments.

In plasma diagnostics, a traditional strength of Australian plasma physics, two collaborations are in the area of optical spectroscopy. One-dimensional modulated coherence imaging systems (J. Howard) have now been operating successfully on H-1 for some years, and have revealed a range of new physical phenomena in low-field discharges. In late 2005 a significant conceptual breakthrough realised a completely passive 4-quadrant optical system for 2-d coherence imaging. This space-multiplex approach allows instantaneous snapshots of plasma transient phenomena to be obtained.

- An Australian government-funded collaboration between the ANU, Consorzio RFX, IPP-Greifswald and Alcator/MIT has seen the installation of coherence imaging systems on RFX and WEGA stellarator, with experiments also planned for the ASDEX divertor. The systems have the unique capability to obtain high speed two-dimensional images of plasma flows and temperatures (or other spectroscopically derived quantities) and so are well suited for the study of asymmetric radiating plasma regions. A system intended for the Korean KSTAR tokamak will be initially commissioned on the Hanbit device in May 2006.

- A collaboration between B. James (Sydney University), K. Takiyama (Hiroshima), and J. Howard (ANU) has resulted in the production of a very successful highly directional pulsed supersonic beam. In conjunction with dual photomultiplier array, this provides non-perturbing, spatially localised, time resolved measurements of electron temperature and density.

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 spectroscopy systems for use in defence remote sensing and process control in steel production. For example, a variant of the 4-quadrant solid state spectrometer described above is being trialled at Bluescope Steel mills in 2006. The new system promises to be able to provide accurate surface-temperature estimates without the need for emissivity or emissivity-slope corrections.

- Theoretical collaborations:

- A collaboration between ANU, MPIPP Greifswald and University of Tokyo has analyzed the spacing statistics of eigenvalues produced with the CAS3D code for a Mercier-unstable W7-X-like equilibrium and have found strong evidence that the spectrum lies within the same universality class as chaotic quantum systems. This has implications for the numerical analysis (e,g, convergence studies) of such codes.

- A collaboration between ANU and Princeton PPL has begun investigation of a new formulation of the 3-D MHD stability problem with the aim of developing better equilibrium codes and possible applications to electron transport barrier studies in stellarators. Reciprocal visits between the two institutions took place in 2005.

- Other collaborations on fusion theory between ANU theorists and NIFS, Culham, MPIPP Garching, and the Universities of Texas, Provence and Turin have possible stellarator applications.

Finally, a group of about 100 Australian Scientists and Engineers, the Australian ITER Forum, have been promoting the ITER project locally, and exploring ways in which Australia might participate in this exciting project.

1.2 Research plans for 2006

Experiments on the H-1NF heliac (Australia) in the next years will extend studies of turbulence, flows and self organization, and extend magnetic configuration studies of instabilities driven by fast particles from ICRF and ECR heating. A glow discharge cleaning system will be trialled both prior to and during operation.

Configuration studies will focus on Alfvénic instabilities and the observation of magnetic islands and their effects on plasma, using a combination of electron beam mapping and optical and probe plasma diagnostics.

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. These will focus on the effects of Alfvén-driven instabilities and turbulence which can be moderated through fine control of the H-1 magnetic configuration. 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 particle velocity distribution functions in low field H-1plasma discharges.

- Theoretical plans

The quantum chaos style investigation of the statistics of numerically generated MHD spectra for stellarators will be completed.

Further development of the new MHD equilibrium formulation will be carried out.

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

Comparisons between numerical simulations and low-dimensional models of confinement transitions will be conducted.

2 EU

2.1 GERMANY

2.1.1 International collaborations in 2005

- Collaborations with EU

1) Roman Zagorsky, Wlodzimierz Stepriewski (IPPLMF Warsaw), to IPP Greifswald, 17.04.-22.05.2005, Plasma edge modeling for ergodic configurations

2) Guenther Eibl (Uni. Innsbruck), to IPP Greifswald, 18.04.-13.05.2005, Plasma edge modeling

3) Xavier Bonnin (CNRS U. of Paris), to IPP Greifswald, 02.05.-14.05.2005, Modelling of plasma edge transport

4) Xavier Bonnin (CNRS U. of Paris), to IPP Greifswald, 25.09.-07.10.2005, Modelling of plasma edge transport

5) Carolin Nuehrenberg (IPP Greifswald), to CIEMAT, 10.10.-11.10.2005,

ITG turbulence TORB BSC simulations

6) Heinrich Laqua (IPP Greifswald), 2 weeks, to CIEMAT,
ECRH experiments

7) WEGA: “Electron Cylcotron Waves Heating Experiments” with CIEMAT, Regular exchange, via Video

8) Dr. Mc.Carthy (CIEMAT), to IPP Greifswald, 07.-08.09.2005, Preparation of an ACORD-24 analyser for its later use in the TJ-II stellarator

9) V. Tribaldos (CIEMAT), to IPP Greifswald, 2 weeks,
Discussions of aspects of stellarator optimisation

10) C.D. Beidler, H. Maassberg (IPP Greifswald), to CIEMAT,
International Collaboration on Neoclassical Transport (IEA implementing agreement) and preparation of the International Stellarator Profile Data Base activity

- **Collaborations with Japan**

1) Yasuhiro Suzuki (NIFS), to IPP Greifswald, 10.10.-31.03.2006, 3D MHD equilibrium code benchmarking

2) Axel Koenies (IPP Greifswald), to NIFS, 07.11.-20.11.2005, Kinetic MHD modes in stellarators

3) M. Kobayashi (NIFS), to IPP Greifswald, 6 weeks, Edge plasma modelling with the EMC3-EIRENE code

4) Y. Suzuki (NIFS), to IPP Greifswald, 3 months, Implementation and benchmarking of the HINT equilibrium code

5) C.D. Beidler, A. Dinklage (IPP Greifswald), to NIFS, 2, Energy confinement time scalings

- **Collaborations with Russia**

1) Alexey Subbotin (Kurchatov Institute), to IPP Greifswald, 01.03.-28.03.2005, Investigations on balooning modes in stellarators

2) Vitaly Shafranov (Kurchatov Institute), to IPP Greifswald, 22.05.-28.05.2005, Theory of optimized stellarators

3) Mikhail Mikhailov (Kurchatov Institute), to IPP Greifswald, 22.05.-19.06.2005, Integrated optimization of stellarators

4) Alexander Zvonkov (Kurchatov Institute), to IPP Greifswald, 04.09.-02.10.2005, Investigations on toroidal mirror confinement

5) Juergen Nuehrenberg (IPP Greifswald), to Kurchatov Institute, 6.04.-08.04.2005,

29.11.-02.12.2005, Theory of optimized stellarators

6) Prof. Anatoly Kislyakov (Ioffe Physical-Technical Institute), to IPP Greifswald, 16.01.-12.02.2005, Testing of W7-AS neutral particle analysers/use for W7-X diagnostics

7) Dr. Mikhail Tournianski (UKAEA, Culham Science Centre), to IPP Greifswald, 29.03.-31.03.2005, Checking of the possibilities of testing a compact neutral particle analyser on MAST

- **Collaborations with Ukraine**

1) Ljudmilla Krupnik (1 week), Alexander Chmyga (7 weeks), Alexander Zhezhera (5 weeks) (IPP Kharkov), to IPP Greifswald, Setting up HIBP diagnostic

2) Alexander Chmyga , Alexander Zhezhera (IPP-Kharkov), to IPP-Greifswald, 2 months, Setting up HIBP diagnostic

- **Collaborations with USA**

1) Bas Braams (Emory Uni. Atlanta), to IPP Greifswald, 04.09.-16.09.2005, Plasma edge modelling

2) Ilon Joseph (UCSD), to IPP Greifswald, 04.09.-25.09.2005, Plasma edge modelling of ergodic configurations

3) Rick Moyer (UCSD), to IPP Greifwald, 22.09.-27.09.2005, Plasma edge modelling of ergodic configurations

4) Tom Rognlien (LLNL), to IPP Greifswald, 06.10.-14.10.2005, Plasma edge modelling

5) D. Mikkelsen (PPPL), to IPP Greifswald, 2 weeks, Preparation of a predictive transport code development for stellarators

2.1.2 Conference participation

1) J. Nuehrenberg (IPP Greifswald), ISW 2005 Madrid, 03.10.-07.10.2005

2) C. Nuehrenberg (IPP Greifswald), IAEA TM Madrid, 10.10.-11.10.2005

3) J. Nuehrenberg (IPP Greifswald), IAEA TM Madrid, 10.10.-11.10.2005

4) Y. Feng, R. Preuss, D. Sharma (IPP Greifswald), EPS in Tarragona (Spain), 27.06.-01.07.2005

5) Y. Feng, F. Sardei (IPP Greifswald), PET, Juelich (Germany), 16.-19.10.2005

6) R. Preuss (IPP Greifswald), MaxEnt05, San Jose (USA), 07.-12.08.2005

7) A. Kus (IPP Greifswald), 25th European Meeting of Statisticians, Oslo (Norway), 24.-28.07.2005

8) A. Dinklage (IPP Greifswald), IAEA-TM, Budapest (Hungary), 12.-15.07.2005

9) C.D. Beidler, A. Dinklage, H. Maassberg, N. Marushchenko, F. Sardei, Y. Turkin (IPP Greifswald), ISW 2005, Madrid, 03.10.-07.10.2005

10) C.D. Beidler, H. Maassberg, N. Marushchenko, Y. Turkin (IPP Greifswald), IAEA-TM Madrid, 10.10.-11.10.2005

2.1.3 Participation in joint projects

- **International Stellarator Confinement Data Base**

Contributions from C.D. Beidler, A. Dinklage, A. Kus, R. Preuss (IPP Greifswald),

- **International Stellarator Profile Data Base**

Contributions from C.D. Beidler, H. Maassberg (IPP Greifswald)

- **International Collaboration on Neoclassical Transport**

Contributions from C.D. Beidler and H. Maassberg (IPP Greifswald)

2.1.4 Planning 2006

- **Planning Stellarator Theory**

The planning for 2006 has not yet been detailed but the collaborations will comprise a similar extent with many of the researchers of the above list.

- **Neutral Particle Diagnostics**

W. Schneider will take part in the initial operation of the ACORD -24 analyser at TJ-II for about a week and later for a period of about one month, during an experimental campaign

- **International Stellarator Confinement Data Base**

1) R. Preuss (IPP Greifswald) plans to visit scaling studies at CIEMAT

2) C.D. Beidler, R. Preuss (IPP Greifswald) will visit NIFS/U-Kyoto

3) J.H. Harris, H. Yamada (NIFS) are expected to visit IPP Greifswald for scaling studies.

4) R. Preuss plans visits at U- Stuttgart for scaling studies

- **International Stellarator Profile Data Base and International Collaboration on Neoclassical Transport**

1) C.D. Beidler, H. Maassberg, R. Preuss will visit NIFS/U-Kyoto Stellarator Transport Code development:

2) Y. Turkin will visit NIFS/U-Kyoto

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

Y. Feng will visit NIFS for 3 months

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

N. Marushchenko will visit NIFS/U-Kyoto

- **International Collaboration on Data Validation**

A. Dinklage, J. Geiger, Joint organisation of the VALIDATION workshop at FZ Juelich

- **Implementation of the HINT equilibrium code**

Y. Suzuki (NIFS) is visiting IPP Greifswald for 3 months

- **Teaching, general cooperation**

F. Wagner (IPP Greifswald) will visit Kyushu University for a month

- **VALIDATION workshop**

Collaboration with FZ Jülich /FOM: A. Dinklage, J. Geiger are going to visit Jülich for joint organization of the workshop

- **Conference participation**

1) R. Burhenn, A. Dinklage, P. Kornejew, R. König, E. Pasch, A. Werner (IPP Greifswald), 16. Conference on High Temperature Plasma Diagnostics, Williamsburg, USA, 7.5.-11.5.2006

2) V. Erckmann, H. Laqua, N. Marushchenko (IPP Greifswald), 14. Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Heating, Santorini Islands, Greece, 9.-12.5.2006

3) Y. Feng (IPP Greifswald), 17. Plasma Surface Interactions in Controlled Fusion Devices (PSI), Hefei, China, 22.-26.5.2006

4) J. Geiger, R. König, G. Kühner, R. Preuss, A. Werner (IPP Greifswald), Data Validation Workshop, Jülich, Germany, 29.-31.05.06

5) T. Klinger, M. Schubert, Y. Turkin, F. Wagner, G. Warr (IPP Greifswald), 33. EPS Conference Plasma Physics, Rome, Italy, 19.-23.6.2006

6) H. Braune, J. Schacht, H. Laqua (IPP Greifswald), 24. Symposium on Fusion Technology (SOFT), Warsaw, Poland, 11.-15.9.2006

7) F. Wagner (IPP Greifswald), 2. International Conference on Plasma Phsics and Controlled Fusion, Alushta, Crimea, 11. - 16.09.2006

8) G. Michel, IRMMW THz 2006 (IPP Greifswald), Shanghai, China, 18.-22.09.2006

9) V. Erckmann (IPP Greifswald), 21. IAEA Fusion Ernergy Conference, Chengdu, China, 16-22.10.2005

2.2 SPAIN

2.2.1 International collaborations in 2005 using TJ-II at CIEMAT

- Collaboration with Russia

K. Sarksyan (and the ECRH IOFAN team) was participating in the operation of the ECRH system of TJ-II and in the Bernstein Waves heating project. N. Matveev (and the GUP-VEI institute team) was involved in the power supply for Bernsein modes heating system.

M. Tereshchenko (form IOFAN) visited Ciemat and collaborated in the EBW theoretical calculations involving relativistic ray tracing and Fokker Plancl calculations (October – December 2005).

S. Petrov (IOFFE) visited Ciemat (May – November 2005) to participate in the final installation a new neutral particle analyzer in TJ-II.

N. Skvortsova (IOFAN) was participating in experiments with 2 mm scattering in TJ-II (Nov 2005).

Dr. S. Shchepetov visited Ciemat and was involved in modelling of edge instabilities and Alfven modes studies (October – Nov 2005).

Melnikov and L. Eliseev (Kurchatov Institute) were visiting Ciemat to investigate the structure of plasma potential in ECRH and NBI plasmas in the TJ-II stellarator.

- Collaborations in Europe

Germany

IPF (Stuttgart). G. Müller participated in the improvement of some components of the ECRH system in 2005 (six months stay). Holtzauer was involved in reflectometry and Berstein wave simulations (May and September 2005).

IPP-Greifswald. A. Weller was visiting Ciemat (October 2005) being involved inRX studies (IONEQ code).

G. Pereverzev (IPP-Garching) visited Ciemat in February 2005 to work on the effect of geometry and electric field on transport in TJ-II plasmas, using ASTRA code.

Portugal

C. Silva were visiting Ciemat to continue our collaboration on edge studies (biasing experiments) during 2005. Horacio Fernandes has participated (November 2005) in the definition of control and software requierements for JET-EP2 diagnostic enhancement and test in TJ-II facilities (fast camera).

Hungary

G. Kocsis was visiting Ciemat (November 2005) to define the JET-EP2 diagnostic enhancement project scope and test in TJ-II facilities.

Czech Republic

M. Horn and I. Duran were visiting Ciemat to participate in the development of TJ-II edge plasma diagnostics (electromagnetic probes)

- **Collaboration with USA**

D. Rasmussen (ORNL), P. Ryan, J. Tsai and D. Schechter were visiting to Ciemat. Discussions were focused on three topics: NBI, Electron Bernstein waves and Pellet injection. The NBI activities were organized around the general status of NBI into TJ-II, NBI Electrical System, Ion Source and beam transmission. Physics issues and hardware required to install a (ORNL) pellet diagnostic in the TJ-II were discussed.

M. Murakami was visiting Ciemat (Mayo) to discuss TJ-II NBI operation issues.

G. Barber and S. Combs (ORNL) visited Ciemat to check NBI tetrode behavior and to discuss upgrades of NBI system.

PPPL: S. Zweben was visiting Ciemat in December 2005 to discuss recent 2-D visualization experiments (influence of electric fields on turbulent blobs) in the TJ-II stellarator and possible collaboration in JET tokamaks.

B. Carreras was visiting Ciemat in November 2005 to continue our long-standing collaboration between the CIEMAT, the University of Carlos III and Oak Ridge National Laboratory in the statistical description of turbulent transport in fusion plasmas.

D. Rapisarda was visiting UCSD to continue our collaboration on spectroscopy.

D. Spong was collaborating in the investigation of Alfven modes appearing NBI heated plasmas in TJ-II stellarator.

- **Collaboration with Ukraine**

The Heavy Ion Beam Probe team (leaded by L. Krupnik, Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology", Kharkov) has been fully involved in the characterization of radial electric fields in ECRH and NBI plasmas in the TJ-II stellarator during 2005 experimental campaign. In addition, an upgrade of existing HIBP system was agreed.

S. S. Pavlov (from "Kharkov Institute of Physics and Technology", Kharkov) IOFAN) visited Ciemat to work on relativistic ECRH calculations (October – December 2005).

- **Collaboration with Japan**

K. Nagasaki stayed in CIEMAT (February 2005), being involved in TJ-II operation and discussing comparative ECR studies in Heliotron J and TJ-II.

Dr. B. Zurro (July – September) and A. Baciero (December) stayed in Heliotron J, being involved in spectroscopy studies

- **International collaborations: Stellarator Implementing agreement**

During 2005 we continued with the participation in the "International Collaboration on Neoclassical Transport"§(ICNT), whose main goal is to provide a comprehensive description of the neoclassical transport processes relevant to plasma performance in stellarator experiments.

- **International Stellarator Confinement Database and profile database**

During 2005, CIEMAT has continued participating in the activities of the Internatinal Stellarator Confinement Database and in the recent group on profile database.

2.2.2 Plans for 2006

The TJ-II stellarator physics programme will be based on Phase I (ECRH: 300-600 kW) and Phase II (NBI) heating scenarios during 2006 with studies supporting international stellarator data-base, plasma –wall (including a Li-coating technique to improve density control), heating, transport and modelling

In addition, we will continue and extend our physics studies in tokamaks (in particular in JET), looking for common clues as a fundamental way to investigate basic properties of magnetic confinement including studies in plasma-wall, ELMs physics, equilibrium, transport and diagnostic development.

Activities to design a new stellarator based on magnetic configurations with reduced neoclassical transport and using the experience based on TJ-II results, showing the advantages of stellarator magnetic topology via rationals and magnetic shear to improve confinement properties, will be initiated during 2006.

Research activities in the TJ-II stellarator will be focussed in the following topics:

- **Equilibrium windows and operational limit of TJ-II.** Further investigation of the empirical confinement scaling laws in ECRH and NBI heated plasmas. The database will be extended to cover a broad range of rotational transforms and plasma volume (ripple). Continue with the international collaboration on neoclassical transport and international stellarator data –base.
- **Magnetic topology, transitions and confinement**. Further investigation of the role of low order rational surfaces and magnetic shear on radial electric fields and transport. The impact of island sizes on e-ITB will be addressed.

- **Plasma –wall.** Due to the effect of Lithium on wall conditioning (e.g. suppression of H recycling) Li coating is an attractive tool for density control in the TJ-II stellarator. The impact of Li coating on density control and TJ-II confinement will be investigated.
- **Transport, MHD and modelling**. Further characterization of effective transport coefficients (bulk and impurities) in ECRH and NBI heated plasmas including parametric evolution with magnetic configuration and investigation of the statistical description of transport processes. The impact of magnetic topology (magnetic ripple) as a tool to control ELMs-like events will be addressed. Massive orbit calculations in presence of collisions and electric field are performed to elucidate the influence of kinetic processes on confinement. ECRH pump-out is being simulated to be compared with the experimental results.
- **Momentum transport**. Investigation of core and edge plasmas rotation in ECRH and NBI plasmas. Study of the relaxation of flows and electric fields in plasma regimes with different magnetic ripple with and without rationals.

The following collaborations are planned:

- **Collaboration with Russia**

IOFAN: ECRH group (K. Sarksyan) participation in ECRH system operation and the Bernstein Waves heating project. E. Bolshakov and A. Dorofeyuk will participate in the development of a power measurement system for the EBWH project. GUP-VEI (Moscow): Power supply for Bernsein modes heating system.

M. Tereshchenko will stay in CIEMAT to collaborate in further improvement of TRUBA: including a relativistic current drive module able for EBW. He will 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.

N. Skvortsova (IOFAN) will continue her involvement in experiments with 2 mm scattering in TJ-II.

A. Melnikov and L. Eliseev (Kurchatov Institute) will visit Ciemat to participate in the characterization of radial electric fields in the TJ-II stellarator and comparative studies with T-10 tokamak.

- **Collaborations in Europe**

IPP-Greifswald. H. Laqua might participate in ECRH experiments in the TJ-II stellarator during 2006.

IPF (Stuttgart). G. Müller will collaborate in the development of a low pass filter for the high voltage power supply of the ECRH system during 2006. E. Holzhauer will visit CIEMAT in 2006 for reflectometry and studies of EBW Heating in the TJ-II stellarator.

E. Blanco will visit IPF (Stuttgart) being involved in reflectometry simulations.

Czech Republic. M. Horn and I. Duran will participate in the test and development of

TJ-II edge plasma diagnostics (electromagnetic probes).

IST-Portugal. C.Silva and IST team will visit Ciemat to continue our collaboration on edge studies during 2005. Continuing the collaboration in design and development of reflectometry in TJ-II, M. E. Manso, L. Cupido and IST team.

During 2006 the TJ-II ECRH group will collaborate with FOM Association in some ITER tasks related with ECRH Upper port measurements.

Continuing with the collaboration on neoclassical transport, V. Tribaldos will visit IPP-Greifswald to analyze recent results and propose future works.

A one month visit, scheduled for April, of a member from the Institut für Theoretische Physik, Technische Universität Graz, Graz, AUSTRIA to seek for optimized configurations of TJ-II based on a method jointly developed with CIEMAT.

A. Cooper (CRPP-Lausanne) will visit Ciemat in March to implement a Boostrap current model that works in the low collisionality regime (March).

- **Collaboration with USA**

D. Rasmussen (ORNL) will visit CIEMAT to continue with NBI, Bernstein and pellet experiments collaboration.

J. Tsai (ORNL) will stay in Ciemat in 2006 for beam conditioning at second NBI injector and to discuss beam transmission properties.

S. Zweben (PPPL-USA) will be involved on the characterization of turbulence in the TJ-II stellarator using high speed imaging. Comparative studies TJ-II NSCX (using similar aanalysis tools) are planed. In addition, a joint effort to investigate instabilities in JET is in progress.

B. A. Carreras (ORNL) will visit Ciemat to investigate statistical properties of turbulent transport.

J. Harris will visit Ciemat to discuss joint research activities on stellarator database studies and momentum transport and ballooning stability.

- **Collaboration with Ukraine**

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).

The relativistic effects study will be extended to the case of ICRH in reactor-like plasmas as well as to waves with imaginary frequency in collaboration with S. S. Pavlov (Institute of Plasma Physics, National Science Center “Kharkov Institute of Physics and Technology).

- **Collaboration with Japan**

K. Nagasaki (Institute of Advance Energy, Kyoto University) will participate in some ECRH experiments in the TJ-II stellarator and comparative studies of electron cyclotron resonance (ECR) in Heliotron J and TJ-II.

Dr. Masaki Osakabe, a member of LHD experimental group, will visit Ciemat to discuss an international colaboration of energetic particle transport in stellarators.

- **International Stellarator Confinement Database**

Activities will continue with further analysis and presentations in the major conferences. Emphasis will be paid to investigate the role of plasma volume (ripple) on iota scaling.

3 JAPAN

3.1 LHD team at NIFS.

3.1.1 International collaborations by the LHD team at NIFS.

- **Collaboration with EU**

1) M.Yokoyama (NIFS) has proceeded the international collaboration on Internal Transport Barrier Physics in helical systems such as LHD, CHS, TJ-II (CIEMAT, Spain) and W7-AS (Germany) based on the framework of the International Stellarator Profile DataBase (approved by IEA, Stellarator Exective Committe). The significance of electron root (helical-specific physics) in low collisional helical plasmas has been commonly recognized, which was reviewed in the 15th Inaternational Stellarator Workshop (Madrid, Oct. 2005).

2) M. Kobayashi visited the ITER site in Garching (Germany) from 27th Sep. 2005 to 25th Mar. 2006 to conduct the power load analysis of the ITER start-up limiter modules with Dr. G. Federici and Dr. A. Loarte. He also visited Dr. Y. Feng at Max-Planck institute in Greifswald (Germany) for implementing the 3D edge transport code for the ITER limiter configuration.

3) Dr. Arthur Weller, IPP Greifswald stayed at NIFS during 5 Jan. 2005 - 4 Apr. 2005. He and K. Toi made comparison study on MHD stability and production of high beta plasmas in LHD and W7-AS in order to improve performance of these high beta plasmas further. We focused on differences and similarities in both plasmas.

4) Dr. Yuri Igitkhanov from the Max Planck Institute for Plasma Physics in Greifswald, Germany visited NIFS (B. J. Peterson and N. Ohyabu) from April 7, 2005 to September 7, 2005 as a NIFS Guest Professor to work on the topic of "Modelling of impurity transport in helical devices". He attended and presented his results at the 19th International Conference on Numerical Simulation of Plasmas and 7th Asia Plasma Theory Conference in Nara.

5) Dr. Schubert (Max-Planck-Institut fuer Plasmaphysik) visited NIFS (K.Tanaka,) from 2005/12/10~2005/12/21 attended Japan Australian workshop for plasma diagnostics and joined LHD experiments.

6) M. Goto visited Forschungszentrum Juelich and joined the development study of an image X-ray spectrometer in collaboration with Dr. Guenter Bertschinger. The spectrometer makes use of a spherically cut crystal with which the measurement of radial distribution of spectrum becomes possible. A preliminary measurement for the helium-like argon ion has been carried out in TEXTOR and the results were presented at the 37th conference of EGAS (European Group on Atomic Systems) in 2005.

- **Collaboration with USA**

1) T.-H. Watanabe and H. Sugama (NIFS) visit Institute for Fusion Studies, The University of Texas at Austin from Jan. 29 to Feb. 4 in order to collaborate with Dr. W. Horton and Dr. J. W. Van Dam on Application of the Fusion Theory to Space Plasmas.

2) K.Ichiguchi (NIFS) visited Oak Ridge National Laboratory from June 8th to June 29th under the JIFT program. He collaborated with Dr.B.A.Carreras for the numerical study of the nonlinear MHD behavior of LHD plasmas.

3) H. Funaba and N. Tamura (NIFS) visited PPPL from Jul. 11 to Jul. 15 in order to discuss about the plan of TESPEL injection into NSTX and impuriy transport with Dr. Kugel (PPPL) and Dr. Stutman (John Hopkins Univ.).

4) L.Grisham (PPPL) visited NIFS (Y.Oka) from Jan. 10 to 15 to join the Doppler shift measurements experiment, and study the stripping spectrum and related phenomena in LHD accelerator.

5) J. Ramos (MIT) visited NIFS (T. H. Watanabe) from June 10 to September 9 as a NIFS guest researcher as well as a JIFT exchange researcher in order to advance a collaboration research on the extended MHD and generalized two-fluid equations for magnetized plasmas.

6) Tomio Y. Petrosky (Texas Univ. at Austin) stayed at NIFS from Oct. 20 to Jan. 19 as a NIFS Guest professor for collaboration research on "Dissipation structure and self-organization in plasmas".

- **Collaboration with Russia**

1) V. Sergeev (St. Petersburg Technical University, Russia) visited NIFS (S. Sudo and N. Tamura) for one month, studied the configuration of the pellet ablated cloud by measuring Stark broadening with spatial resolution on LHD.

2) I. Vinyar (St. Petersburg Technical University, Russia) visited NIFS (S.Sudo) from Nov. 6th to Dec. for the collaboration of the first TECPEL (Tracer-Encapsulated Cryogenic Pellet) operation on LHD. It was successful, and the TECPEL was injected into the LHD plasma for the first time.

3) A. V. Krasilnikov (Troitsk Institute for Innovating and Fusion Research,Russia) visited NIFS (M. Isobe) from Jan. 4 to Jan. 24, 2005. He has studied confinement

properties of co-going and counter-going beam ions measured with natural diamond detectors and made a comparison between the two cases. The results were presented in 9th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems (2005, Nov. Takayama).

4) A. Pschechinikov (General Physics Institute, Russian Academy of Science) visited NIFS (S. Kubo) for 2 weeks, continued the experiment and analysis of density fluctuations using gyrotron scattering in LHD.

5) L. N. Vyacheslavov (Budker Institute of Nuclear Physics) visited NIFS (K. Tanaka) from 2006/1/10~2006/2/12, continued developing CO2 laser imaging interferometer for density profile and fluctuation measurements on LHD.

6) Dr. Sarksyan, Dr. Arksyan, Dr. Skvortsova, and Dr. Kharchev (General Physics Insitute) visited NIFS (K.Tanaka, S.Inagaki, H.Yamada) from 2006/2/4 ~2006/2/18 and discussed with corroboration for microwave scattering experiments.

7) Dr. Neudatchin, Sergey (Russian Science Center, Moskow) has visited NIFS as a visting professor and collaborated on the problem of transient transport in LHD plasmas. By applying his detailed analysis code on the observation of the electron cyclotron emission, he and collaborators have identified the very rapid propagation of the change of effective thermal transport coefficient. In addition to it, a new transport barrier after the onset of rf heating was identified. These findings were published in a couple of scientific articles, and were reported at the H-mode workshop as well as at other international conferences.

- **Collaboration with Australia**

1) M.Yokoyama (NIFS) visited Plasma Research Laboratory (PRL) at Australian National University (ANU) as the Visiting Academic to investigate the helical-specific features on mean zonal flow - GAM oscillation properties. The significant impact of the geodesic curvature (i.e., poloidal variation of magnetic field strength) on the energy transfer from mean zonal flow to GAM oscillation has been revealed for H1-NF Heliac, which can be extended to other helical systems where the geodesic curvature effect is controllable through the three dimensionality of magnetic field. The experimental proposal has been drawn for LHD based on this finding.

2) S. Vladimirov (Univ. Sydney) visited NIFS (Y.Tomita) from Jan. 10 to 11 April 2006 for the collaboration research on the theoretical and simulation study of generation and growth of dust particles in divertor plasma.

3.1.2 Plans for 2006

1) M.Yokoyama (NIFS) will continuosly proceed International Stellarator Profile DataBase activity in collaboration with TJ-II and W7-AS. Quantitative understanding for ITB shot properties, such as the dependence of ECH power threshold on effective helicity and ripple trapped fraction, will be investigated based on a wide range of ITB discharges from LHD, CHS, TJ-II and W7-AS.

2) V. Sergeev (St. Petersburg Technical University, Russia) will visit NIFS (S. Sudo and

N. Tamura) for about one month, in order to continue the configuration study of the pellet ablated cloud by measuring Stark broadening with spatial resolution on LHD for the basis of high energy particle measurements with the pellet charge exchange.

3) L.Grisham (PPPL) will join the NB injection experiments and discuss about the improvement on negative ion system for LHD and the spectrometry.

4) A. V. Krasilnikov (Troitsk Institute for Innovating and Fusion Research, Russia) will visit NIFS (M. Isobe) for 3 weeks on Jan. 2006 and work on fast neutral particle measurements by using natural diamond detectors in LHD.

5) Yu, Wei (Prof. Shanghai Institute of Optics and Fine Mechanism) will visit NIFS (host: R. Horiuchi) from Sep. 15 to Dec. 20, 2006, for studying Microscopic self-organization in laser plasma.

3.2 CHS team at NIFS.

3.2.1 International collaborations by the CHS-team at NIFS

- **Collaborations with US**

1) T. Akiyama (NIFS) visited H.K. Park (PPPL) and E. Mazzucato (PPPL) from 20th March to 23rd March to discuss on FIR laser scattering measurement system on CHS.

2) D. A. Spong (ORNL) visited NIFS from 14th to 18th of November to discuss with M. Isobe about the particle orbit simulation study for the experimental research of fast ion loss with MHD activities.

3) S. Okamura (NIFS) visited PPPL from 23rd February to 3rd March for the discussion of future collaboration in NCSX for electron heating experiment with high power gyrotrons. He also discuss with NCSX design team for the stellarator configuration optimization work.

- **Collaborations with Germany**

S. Okamura (NIFS) visited Max-Planck-Institute in Greifswald on 10th October making discussions with Dr. Hartfuss about the advanced diagnostics for stellarator experiments.

- **Collaborations with Spain**

From Jun to September, 2005, A. Fujisawa was cooperating with F. Castejon in CIEMAT in writing the invited paper to EPS conference for the main topics of internal transport barrier formation in helical devices.

3.3 Heliotron-J team at Kyoto University

3.3.1 International collaborations by the Heliotron-J team at Kyoto University

1) The workshop on "Multi-Channel Measurements and its Tomographic Analyses in Toroidal Plasma Diagnostics" was held on January 25. A. Weller (MPI), B. Blackwell (ANU) and Liu Yi (Southwestern Institute of Physics, China) participated on the workshop.

2) B. Blackwell (ANU) visited Kyoto Univ. for two weeks on Jan. 12-29 to participate in the Heliotron J experiment. The MHD analysis by using such as SVD method and tomographic technique, ECH system and data acquisition was collaborated.

3) N. Kharchev (GPI, Russia) visited Kyoto Univ. on Feb. 21 to discuss the scattering diagnostics using strong microwaves.

4) K. Nagasaki (Kyoto) visited CIEMAT for two weeks on March 5-18 to collaborate in the plasma breakdown and ECCD experiment with A. Fernandes, A. Cappa, V. Tribaldos, F. Castejon and F. Tabares (CIEMAT). The experimental results on plasma breakdown were compared with the Heliotron and CHS data. The results were presented in APFA2005, and published in the Proceedings of Korean Physical Society.

5) B. Zurro (CIEMAT) visited Kyoto Univ. as a guest professor for three months on July 4-Oct. 3. He joined the Heliotron J experiment related to charge exchange spectroscopy, and had lectures of plasma physics for graduate students.

6) H. Laqua visited Kyoto Univ. on Oct. 31 for discussion about ECRH system and ECRH physics on Heliotron J, WEGA and W7-X.

7) A. Baciero (CIEMAT) visited Kyoto Univ. for two weeks on Dec. 3-16 to participate in the Heliotron J experiment. The data analysis software developed for TJ-II was applied to the charge exchange spectroscopy in Heliotron J.

8) Boyd Blackwell (ANU) joined the Heliotron J experiment on Dec. 14-16. He applied his MHD analysis code by using data mining technique to Heliotron J magnetic probe data.

9) Horst Punzmann (ANU) visited Kyoto Univ. on Dec. 19 for discussion about ECH system for Heliotron J and H-1.

10) The ray tracing calculation code, "TRECE" for ECH/ECCD for Heliotron J configuration was extended to some configurations under the collaboration with V. Tribaldos (CIEMAT).

3.3.2 Plans for 2006

1) The US-Japan workshop on "New approaches to advanced plasma confinement in helical system" will be held in November at Auburn University. S. Knowlton (Auburn Univ.), D. Anderson (U. Wisconsin), J. Talmadge, (U. Wisconsin), G. Neilson (PPPL) and J. Lyon (ORNL) will participate in the workshop.

2) B. Blackwell (ANU) will visit Kyoto Univ. for three weeks to participate in the Heliotron J experiment. His MHD analysis code by using data mining technique will be applied to Heliotron J magnetic probe data.

3) A. Cappa (CIEMAT) will visit Kyoto Univ. for two weeks to participate in the Heliotron J experiment. The plasma breakdown and ECCD will be analyzed.

4 RUSSIA

4.1 International collaboration in 2005

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

1) Five persons participated in the exploitation and modernisation of the TJ-II gyrotron complex (total duration of visits: 7 months-person).

2) 13 persons participated in development of the numerical code and preparation of the system for plasma heating by Bernstein mode (total duration of visits: 18 person-months).

3) One person participated on 2mm scattering diagnostic (duration: 2 months).

- **Collaboration between Kurchatov Institute and IPP**

1) Three person visited IPP to cntinue the numerical calculation on stellarators optimisation (3 person-months).

2) Two persons visited NIFS to studythe turbulence of near-wall plasma (3 persons-months).

3) As a result of this collaborations 9 papers was published.

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

Three persons participated in the analysis of experimental data of plasma fluctuation in LHD with the aide of the new statistical method (total duration of visits:5 months).

4.2 Research plans for 2006

1) Close collaboration between GPI and CIEMAT (Spain) will be continued along the same line as in 2005.

2) The collaboration GPI and NIFS (Japan) will be continued on analysis of experimental data of plasma fluctuation in LHD

3) The collaboration between Kurchatov Institute and IPP (Greisvald, Germany) will be continued on development of the numerical optimization of advanced stellarators , and to study quasi-isodinamic stellarators with large number of periods and calculations of real winding for same optimized configurations

4) In GPI work on the L-V project will be continued in order to optimize the magnetic field configuration. The problems of plasma equilibrium and stability will be studied by using currently available computer codes (in collaboration with Kurchatov institute and IPP (Greiswald, Germany))

5) In GPI one will continue experiments on studying how modifications to the stellarator magnetic topology that are achieved by generating ohmic currents influence confinement of ECRH plasma in L-2M.

6) Fabrication of the power supply system for a new ECR heating system for L-2M (GPI).

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)

5.1.1. International collaboration of the NSC KIPT in 2005

5.1.1.1. International collaborations of the plasma theory division

- **Collaboration with Technische universität Graz, Austria**

1) Optimization of stored energy for URAGAN-2M is carried out in the 1/v regime with applying the fast field line tracing NEO code (V.V.Nemov, S.V.Kasilov and V.N.Kalyuzhnyj in collaboration with B. Seiwald and W.Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria)).

2) New target functions which are related to collision-less α–particle confinement are introduced. They are based on specific averages of the bounce averaged ∇B drift velocity of trapped particles across magnetic surfaces (V.V.Nemov and S.V.Kasilov visited Institut für Theoretische Physik, Technische universität Graz, Austria, and worked with W. Kernbichler and G.O.Leitold)

3) The electron cyclotron heating in a stellarator has been modeled using the Monte Carlo method and taking into account the nonlinear wave-particle interaction effects and non-Maxwellian distribution function of electrons. These effects are shown to cause broadening of radial power deposition profiles at low plasma densities in the heating scenario using the second harmonic resonance for the extraordinary wave (S.V.Kasilov in collaboration with W.Kernbichler, R.Kamendje and M.F.Heyn (Institut für Theoretische Physik, Technische universität Graz, Austria)).

- **Collaboration with NIFS, Japan**

1) Neoclassical transport for LHD in the 1/v regime was analyzed by the NEO code (mainly for inward shifted configurations). The results are benchmarked with the corresponding results obtained recently with the GIOTA code as well as with Monte-Carlo calculations from the DCOM code. (V.V.Nemov and S.V.Kasilov in collaboration with W.Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria), M.Isobe, M.Matsuoka and S.Okamura (National Institute for Fusion Science, Japan)).

2) Removal of Cold Alpha-Particles from Fusion Helical Reactor. The conditions when He ions can escape from the confinement volume of the helical reactor due to the drift of the drift island, while D and T ions are confined. (Prof. Dr.Alexander Shishkin (NSC KIPT), O. Antufyev (Kharkov V.N.Karazin National University) in collaboration with Prof.Dr. O. Motojima and Prof. Dr. A. Sagara (NIFS, Japan).Two joint reports (PS 2-24 and PS 2-25) were presented at 15th International Toki Conference "Fusion and Advanced Technology" , 2005, Japan, with the following submission to Fusion Engineering and Design.

- **Collaboration with PPPL, USA**

V.A.Rudakov continued collaboration with A.V.Georgiyevskiy, E.Fredrickson and M.Zarnstorff (Princeton Plasma Physics Laboratory, USA). E-beam mapping simulation program on the NCSX stellarator was studied.

- **Collaboration with Uppsala University, Sweden**

V.E.Moiseenko continued collaboration with O.Ågren, N.Savenko and S.Jonansson from Uppsala University, Sweden. The study of fundamental properties of the charged particle motion in stationary magnetic and electric fields is carried out. The study relates both for open-ended and toroidal magnetic traps.

5.1.1.2. International collaborations by the plasma experiment divisions

- **Collaboration with NIFS (Japan)**

1) Investigation of the transport barrier formation in the core and edge plasmas (V.Chechkin and E.Volkov in collaboration with S.Masuzaki and K.Yamazaki).

2) The study of the behavior of fast ions during formation of transport barriers (V.Chechkin and E.Volkov in collaboration with S.Masuzaki, K.Yamazaki and T.Mizuuchi).

3) Investigations of electrostatic turbulence in the edge and divertor plasmas (V.Chechkin and E.Sorokovoy in collaboration with S.Masuzaki and T.Mizuuchi).

- **Collaboration with Cadarache, France**

Problems of in-vessel mirrors in ITER (V.Voitsenya and V.Konovalov in collaboration with NIFS (Japan), Cadarache (France), RNC "Kurchatov Institute" (Russia)).

- **Collaboration with Argonne National Laboratory, USA**

The use of W-Pd bimetallic systems for hydrogen recycling control (G.Glazunov in collaboration with A.Hassanein and R.Causey (USA)).

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

1) Modernisation of the HIBP secondary beam detection system in TJ-II (Dr. L.I.Krupnik et al (IPP NSC KIPT) I collaboration with Dr. C.Hidalgo and TJ-II team (CIEMAT)).

2) Studies of the radial electric fields end confinement in the TJ-II stellarator with NBI heating in variety of magnetic configurations (Dr. L.I.Krupnik and HIBP team in collaboration with C.Hidalgo and TJ-II team).

- **Collaboration with IPP, Greifswald, Germany**

1) Development and manufacturing the system of the Heavy Ion Beam Probe (HIBP) diagnostic for WEGA Stellarator (Dr. L.I.Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr.M.Otte and WEGA team.

2) Delivery and integration of the HIBP diagnostic system in IPP Greifswald (Dr.L.I.Krupnik and HIBP team in collaboration with Dr.M.Otte and WEGA team).

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

Study of the radial electric field end GAM during ECR heating by HIBP diagnostic in T-10 tokamak in comparative regimes with TJ-II stellarator (Dr. L.I.Krupnik and HIBP team (IPP NSC KIPT in collaboration with Dr.A.V.Melnikov and T-10 team (Kurchatov Institute)

5.1.2. Plans for 2006 of the IPP NSC KIPT

5.1.2.1. Plans for 2006 of the plasma theory division

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

1) Continuation of optimization of stored energy for URAGAN-2M for the 1/v regime.

2) Using worked out new target functions which are related to collision-less α–particle confinement. A number of optimized stellarator configuration will be analyzed with respect to trapped particle confinement.

3) A numerical method will be developed for fast evaluation with the help of integration along the magnetic field lines of the bootstrap current and current drive efficiency in stellarators with arbitrary collisionality.

- **Collaboration with Japan (National Institute for Fusion Studies)**

New physics mechanisms for removal of cold alpha-particles from fusion helical reactor with simultaneous confinement of the main plasma, which appropriate the constructive advantages of Force Free Helical Reactor, will be studied.

- **Collaboration with USA (Princeton Plasma Physics Laboratory))**

Numerical studies of the NCSX stellarator vacuum magnetic configuration will be continued.

- **Collaboration with Sweden (Uppsala University)**

The investigation of the charged particle motion in stationary magnetic and electric fields will be continued.

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

1) Using existing in KIPT code for calculating the magnetic surfaces of URAGAN-2M with taking into account the current-feeds and detachable joints of the helical winding. The base of coil data will be transformed to a new form which will be valid for the NEO code runs for URAGAN-2M with taking into account the current-feeds and detachable joints of the helical winding.

2) Using the developed numerical model. The study of Alfvén resonance heating in the URAGAN-2M will be carried out.

3) Further development of the reactor concept on the basis of the stellarator system.

5.1.2.2. Plans for 2006 of the plasma experiment divisions

- **Collaboration with NIFS (Japan)**

1) The study of the role of stochastic magnetic field line layers near rational surfaces on a formation of inferior and edge transport barriers (E.Volkov, V.Chechkin and A.Skibenko in collaboration with S.Masuzaki and T.Mizuuchi).

2) The influence of losses of fast ions on a formation of edge transport barriers (V.Chechkin and A.Slavnyj in collaboration with S.Masuzaki and T.Mizuuchi).

3) V.Voitsenya's visit to NIFS (90 days) with aims: 1) Optimization of wall conditioning procedure (V.Voitsenya and D.Naidenkova in collaboration with J.Kubota, Masuzaki and A.Sagara); 2) Environment effect on in-vessel mirrors (V.Voitsenya and Konovalov in collaboration with A.Sagara).

- **Collaboration with ANL, USA**

Hydrogen permeability and erosion behaviour of the W-Pd bimetallic systems

(G.Glazunov in collaboration with R.Causey and A.Hassanein (USA)).

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

1) Development and creation of the upgrading high voltage power supply system for HIBP diagnostic in TJ-II stellarator.

2) Study of the plasma potential and density and their fluctuations in combined ECR and NBI heating regimes in TJ-II stellarator. Comparative study of the electric fields behavior in TJ-II stellarator (Spain) and T-10 tokamak. (Russia).

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

1) Development and manufacturing of the control and data acquisition systems for Heavy Ion Beam Probe (HIBP) diagnostic in WEGA Stellarator.

2) Installation and launching of the HIBP diagnostic in WEGA stellarator.

3) Starting up of the experiments on electric potential measurements in WEGA stellarator

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

1) Modernization of the HIBP hard ware system for T-10 tokamak

2) Calibration of the new electrostatic energy analyzer developed for T-10.

3) 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) Works in support of putting into operation of the Uragan-2M torsatron during 2005-2007. The manufacture of the systems (central desk, ICRH system, vacuum system) for the Uragan-2M torsatron.

2) Starting of works on development of the new stage of the HIBP diagnostic for stellarator Uragan-2M (IPP NSC KIPT, Kharkov). Calculations and optimization of the HIBP implementation for the Uragan-2M device. Development of the HIBP hard ware structure for the U-2M.

3) Development and designing of the new probing beam injectors for HIBP diagnostic in stellarators. Study of the Tl and Cs ion emitters of the high intensity. Development of the Li injector with current intensity of up to 10 mA.

5.2 Karazin National University, Kharkov

5.2.1 International collaboration in 2005

- Collaboration with Max-Planck-Institut für Plasmaphysik, Germany

1) Impurity transport and electromagnetic waves in the plasma periphery of a HELIAS reactor configuration and WENDELSTEIN 7-X (Prof.Dr. I.Girka (University) and Prof.Dr. A.Shishkin (NSC KIPT) in collaboration with Prof.Dr. F.Wagner, Dr. H.Wobig, Dr. R.Schneider, Dr. Yu.Igitkhanov and Dr. C.Beidler (MPIPP)).

2) Sandwich Fellowship Program was established between the University and MPIPP since 2001. In brief it means education of PhD students from the University by both supervisors from the University and MPIPP with the following PhD thesis defense at the University. The first PhD thesis ⌈Stochasticity of impurity ion trajectories and particles flows in high temperature plasma of stellarators was defended by former Sandwich PhD student O.Shyshkin (University) on December, 2005 (supervisor from MPIPP side was Dr. R.Schneider).

3) Erosion of tungsten layers by deuterium bombardment (Sandwich PhD student I.Bizyukov under the supervision of Dr. K.Krieger (MPIPP)).

4) The experiments on the pulsed plasma diagnostics, proofing the RF plasma source design and improving the data analisis in the plasma diagnostic methods (Dr. K.Polozhiy (University), who occupied the Postdoctoral position at the IPP under the supervision of Prof.Dr.h.c. V. Dose).

5) Designing the new diagnostic methods in area of the plasma reactive processes at the plasma-wall interaction (during the visit of Dr. Th.Schwarz-Selinger (MPIPP) to the University, November, 2005).

6) Testing the ICRF antenna of new geometry (junior researcher A.Onyshchenko University) during his visit to MPIPP in collaboration with Dr. J.-M.Noterdaeme, Dr. Vl.Bobkov, W.Becker (MPIPP)).

7) University graduate O.Mishchenko defended PhD thesis carried out at the Stellarator Theory Division MPIPP under the supervision of Dr. A.Koenis, academic supervisor was Prof. Dr. J.Nuehrenberg.

- Collaboration with National Institute for Fusion Studies, Japan:

1) Dynamics of D+D fusion products in LHD geometry (Prof.Dr. A.Shishkin, A.Eremin, A.Moskvitin and Yu.Moskvitina (University) in collaboration with Prof. Dr. O.Motojima and Dr. S.Sudo (NIFS)).

2) The conditions when 42He ions can escape from the confinement volume due to the drift of the drift island, while 21D and 31T ions are confined are found by Prof.Dr. A.Shishkin, O.Antufyev (University), and Prof.Dr. O. Motojima, Dr. A. Sagara (NIFS).

- **Collaboration with Los Alamos National Laboratory, USA:**

The development and investigation of radiation resistant materials for optical windows in devices of plasma diagnostics. Research was carried out by University group (Dr. V.Gritsyna, Dr.V.Kobyakov, Yu.Kazarinov (University) and Dr. K.Sickafus (LANL)).

5.2.2 Plans of National University for 2006

1) The new numerical tool: 3-D Impurity Transport Code, - will be developed by O.Shyshkin on the base of the 1-D Impurity Transport Code. This numerical tool will allow studying the impurity ions transport in different plasma configurations of modern drift optimized stellarators such as Wendelstein 7-X and HELIAS reactor. In the new version of the
code, the treatment of the plasma configurations with the magnetic islands, which are the part of the divertor islands configurations, where the stochastic behavior of the magnetic field lines is observed, would be emphasized. That would be the principal new feature of the code.

2) Excitation of the second chain of the islands, overlapping of adjacent island chains and stochastization of the magnetic field lines as the result of finite plasma pressure in the magnetic field configuration of the stellarator Wendelstein 7-X.

3) New physics mechanisms for removal of cold alpha-particles from fusion helical reactor with simultaneous confinement of the main plasma, which appropriate the constructive advantages of Force Free Helical Reactor, Japan, will be studied. Namely the small magnetic islands at the plasma periphery will be proposed to make use of.

4) Sputtering of tungsten, accumulation of deuterium in tungsten, blistering and growth of a carbonic film at irradiation of tungsten by ions of carbon and deuterium. Simulation of sputtering and growth of a film in a zone of the implantation by Monte-Carlo method (code TRIDYN). The next Sandwich PhD student I.Bizyukov (University) will defend his thesis (supervisor from MPIPP is Dr. K. Krieger).

5) Coating technologies related to plasma facing materials and components. Operation testing of the coatings (including multilayer) aimed for protection of the ICRF antennas. New Sandwich PhD student A.Onyschenko (University) will start his research ⌈Influence of the coating on the dielectric rigidity of the ICRF antenna at Technology Division (MPIPP).

6) Erosion of the carbon surfaces under effect of the hydrogen (neutral and charged) spices from plasma: designing the bright plasma sources with the high density plasma fluxes for an experimental modelling of the conditions at the wall and for testing of the materials for the fusion applications; diagnostics of pulsed low-temperature plasmas; investigation of basic deposition mechanisms of hydrocarbon coatings; determination of time-resolved data for the electrical characteristics, such as the resulting mass- and energy-resolved ion fluxes to the wall as well as plasma potential, floating potential, and electron density and temperature; improving the data analisis in the existing diagnostic methods at using

Bayesian probability theory.

7) Collaboration with Colorado School of Mines (Colorado, USA) on the development, fabrication and characterization of optical magnesium aluminate spinel ceramics transparent in the wide range of spectral region for RF heating and optical diagnostics of plasma.

5.3 Kyiv Institute for Nuclear Research (Ukraine)

5.3.1 International collaboration in 2005

- Collaboration with Germany

A collaboration between the Kyiv Institute for Nuclear Research (KINR) and Max-Planck-Institut für Plasmaphysik (IPP) was continued. The main research topics were the following. (i) Equilibrium features and transport of the energetic ions produced during NBI and ICRH in Wendelstein 7-X. (ii) Alfvén instabilities driven by the energetic ions in Wendelstein 7-X, including a study of theoretical aspects of Alfvén instabilities in stellarators and modelling Alfvén instabilities in Wendelstein-line stellarators. The main results were as follows.

A new Alfvén mode called "non-conventional global Alfvén eigenmode" (NGAE) is predicted. It is shown that NGAE can be transformed to a kinetic Alfvén wave (KAW), which results in enhancement of the thermal conductivity of the plasma. The enhancement is shown to be strongest when the electron collision frequency exceeds the particle transit frequency in the wave field. The developed theory is applied to explaining experimental observations of thermal crashes during bursting Alfvénic activity in Wendelstein 7-AS.

An invariant of the motion of well-circulating particles in stellarators with a large number of the field periods is derived. The mode structure in weak-shear systems is determined by solving an eigenmode equation analytically. The results were used in the development of a theory of Alfvén instabilities driven by fast ions with finite orbit width.

A general expression for the growth rate of Alfvén instabilities driven by circulating and semi-trapped energetic ions in stellarators is derived, which generalizes that obtained in a recent work (Kolesnichenko Ya.I. et al., Phys. Plasmas **11** (2004) 158) by taking into account the finite orbit width of the energetic ions. It is found that the finite orbits typically reduce the growth rate, but in some cases they enhance instabilities, leading to additional resonances. The developed theory is applied to a particular shot in Wendelstein 7-AS, where Alfvénic activity had a bursting character, being strongest at the end of each burst. It is concluded that finite orbits in the mentioned shot are actually a trigger of instability bursts; on the other hand, they weaken a strong instability at the burst end, which justifies the perturbative approach used. A detailed analysis of destabilized Alfvén eigenmodes in W7-AS precedes the stability analysis. An explanation of the frequency chirping observed is suggested.

Effects of the radial electric field, , on the confinement of trapped fast ions in the

Wendelstein-line stellarators are studied. It is shown that negative electric field improves the confinement; in particular, a radially localized field can play the role of a transport barrier for ions escaping from the plasma when . In contrast to this, a positive electric field can deteriorate the ion confinement. Such a field accompanied by the plasma rotation with the frequency around a certain magnitude, which we refer to as the resonance rotation frequency, leads to a quick particle loss. A possibility to use the plasma rotation with the resonance frequency for the ash removal in a Helias reactor is considered. The mentioned results are obtained analytically and numerically. The analytical consideration was done on the basis of the derived bounce-averaged equations of the particle motion. The numerical calculations were carried out for Wendelstein 7-X and a Helias reactor by the guiding centre code ORBIS (ORBits In Stellarators) developed in this work.

The properties of the Alfvén continuum (AC) and the Alfvén eigenmodes (AE) in stellarators in the high-frequency range (that of the helicity-induced and mirror-induced gaps) are elucidated. With this aim the AC in the vicinity of two close gaps is studied, including the case when the gaps cross at a certain radial point. It is shown that the gaps “annihilate” at the crossing point, i.e., the width of the joint gap at the crossing point is the difference of the widths of the two separate gaps. The AC wave functions are shown to be trapped in narrow bands of the flux surfaces, which are located on either the inner or the outer circumference of the torus. To investigate the structure of AEs of the discrete spectrum in this frequency range, the ballooning formalism is employed. It is shown that the high-frequency AEs are also localized in narrow poloidal sectors.

Publications that resulted from the collaboration in 2005:

[1] Ya.I. Kolesnichenko, Yu.V. Yakovenko, A. Weller, A. Werner, J. Geiger, V.V. Lutsenko, and S. Zegenhagen, “Novel mechanism of anomalous electron heat conductivity and thermal crashes during Alfvénic activity in Wendelstein 7-AS”, Phys. Rev. Lett. **94** (2005) 165004.

[2] Ya.I. Kolesnichenko, V.V. Lutsenko, A. Weller, A. Werner, H. Wobig, Yu.V. Yakovenko, J. Geiger, and S. Zegenhagen, “Effects of fast-ion-orbit width on Alfvén instabilities in stellarators: a general theory and its application to a W7-AS experiment”, submitted to Nucl. Fusion.

[3] Ya.I. Kolesnichenko, V.V. Lutsenko, A.V. Tykhyy, A. Weller, A. Werner, H. Wobig, “Confinement of fast ions in Wendelstein 7-X in the presence of the radial electric field”, submitted to Nucl. Fusion.

[4] Ya.I. Kolesnichenko, V.V. Lutsenko, A. Weller, A. Werner, Yu.V. Yakovenko, J. Geiger, A.V. Tykhyy, and S. Zegenhagen, “Analysis and interpretation of observations of Alfvénic activity in Wendelstein 7-AS”, 32nd EPS Conf. on Plasma Physics, Tarragona, 2005, Abstracts, Rep. P2.125, http://eps2005.ciemat.es/database/abstracts/contributed/P2_125.pdf.

[5] Ya.I. Kolesnichenko, V.V. Lutsenko, A. Weller, A. Werner, H. Wobig, Yu.V. Yakovenko, J. Geiger, A.V. Tykhyy, and S. Zegenhagen, “Novel physics involved in interpretation of Alfvénic activity accompanied by thermal

crashes in W7-AS", Report at the 15th International Stellarator Workshop, Madrid, October 2005; 15th Int. Stellarator Workshop, Madrid, 2005, IAEA Tech. Comm. Mtg, 2005 (CIEMAT, Madrid, 2005), p. 15; http://www-fusion.ciemat.org/cgi-bin/sw05/dir_talks.cgi.

[6] Ya.I. Kolesnichenko, V.V. Lutsenko, A. Weller, A. Werner, H. Wobig, Yu.V. Yakovenko, J. Geiger, and S. Zegenhagen, "Effects of fast-ion-orbit width on Alfvén instabilities in stellarators: a general theory and its application to a W7-AS experiment", Report at the IAEA Technical Meeting on Innovative Concepts and Theory of Stellarators, Madrid, October 2005; 15th Int. Stellarator Workshop, Madrid, 2005, IAEA Tech. Comm. Mtg, 2005 (CIEMAT, Madrid, 2005), p. 163.

[7] Yu.V. Yakovenko, Ya.I. Kolesnichenko, A. Weller, H. Wobig, and O.P. Fesenyuk, "Properties of the high-frequency part of the Alfvén continuum and eigenmodes in stellarators", Ibid., p. 162.

6 UNITED STATES

6.1 International collaborations in 2005

- Collaborations with Australia

S. Hudson (PPPL) visited Bob Dewar (ANU) to collaborate on developing a new 3D equilibrium code.

- Collaborations with Japan

1) C. Hegna (U. Wis.) attended the US/Japan JIFT Workshop on Stellarator Theory - Jan 26-28, 2005 Kyoto, Japan - gave talk "Finite Larmor Radius Stabilization of Ballooning Instabilities in 3-D Plasmas". He also collaborated with N. Nakajima (NIFS) and DY. Nakamura (Kyoto) on ideal stability calculations relevant to LHD plasmas - this directly lead to parts of two papers: S. R. Hudson, C. C. Hegna and N. Nakajima "Influence of pressure-gradient and shear on ballooning stability in stellarators," Nuclear Fusion 45, 271 (2005), and N. Nakajima, S. R. Hudson, C. C. Hegna and Y. Nakamura, "Boundary modulation effects on MHD instabilities in heliotrons," Nuclear Fusion 46, 177 (2006).

2) J. Lyon (ORNL) visited NIFS to discuss results from the ORNL neutral particle analyzer on LHD and to repair one of the detector channels.

3) D. Mikkelsen (PPPL) visited Sadayoshi Murakami at Kyoto University discuss modeling of neutral beam orbits in stellarators. He also visited NIFS to discuss recent experimental turbulence results, and the further collaborations with PPPL to model results CHS and JIPP-TII.

4) D. Spong (ORNL) presented a talk at the 9th IAEA Technical Meeting on "Energetic

Particles in Magnetic Confinement Systems" in Takayama, Japan and gave a talk at the mini-conference on "Energetic ion driven MHD modes in CHS and LHD" at NIFS. He also visited NIFS to collaborate on modeling fast ion losses associated with frequency sweeping Alfvén modes in the CHS stellarator.

5) Prof. H. Himura (Kyoto) visited the CNT experiment (Columbia) in September and participated in experiments investigating the stability of electron plasmas with a significant ion fraction, inspired by non-neutral experiments on the CHS.

6) K. Ichiguchi (NIFS) visited ORNL to work on a multi-scale code that combines the slow increase in plasma beta by heating with the stellarator equilibrium developing stable path to high beta. This led to a paper "Multi-scale approach to the solution of the nonlinear MHD evolution of Heliotron plasmas" by K. Ichiguchi and B. A. Carreras that was accepted for publication in J. Plasma Physics.

7) Prof. S. Okamura (NIFS) visited PPPL in February to work on optimization codes and discuss future plans for collaboration on NCSX. NIFS, the University of Tokyo, PPPL, and other collaborating institutions proposed a long term collaboration on ECH for NCSX.

- **Collaborations with Germany**

1) I. Joseph (UCSD) visited MPI-Griefswald to develop a coupled TRIP3D/E3D numerical model for the boundary of the DIII-D tokamak in the presence of error fields and externally applied magnetic perturbations.

2) D. Mikkelsen (PPPL) visited MPI-Greifswald to discuss simulation of neutral beam heating and discuss benchmarks against the tokamak code TRANSP. An analytic representation of neoclassical mono-energetic diffusion coefficients appropriate for NCSX was developed, and a plans made for testing the adequacy of this approximation. Plans were discussed for future collaboration on comprehensive modeling and hybrid analysis of Alfvenic modes.

3) M. Zarnstorff (PPPL) visited MPI-Greifswald and collaborated with A. Weller (IPP) and the W7AS group to continue the analysis of parametric scans of W7AS high-beta data. This resulted in three conference papaers.

4) V. Erckmann (IPP) visited PPPL to discuss possible collaborations on NCSX.

- **Collaborations with Spain**

1) G. Barber and S. Combs (ORNL) visited CIEMAT to improve the performance of the TJ-II NBI and to discuss the design of a pellet injector for TJ-II. Improvements were made to the NBI electrical system and the modulator vacuum tubes were conditioned to 45 kV. Decisions were made on the ORNL/CIEMAT interfaces and design for the pellet injection system.

2) B. Carreras (ORNL) visited TJ-II to continue work on analysis of experiments at TJ-II to study a possible transition at the plasma edge that is responsible for the creation of the edge shear flow layer, and new experiments were planned. Work was done on a transport model in collaboration with B. van Milligen and R. Sanchez.

A paper was completed and published in European Journal of Physics. During a separate visit, he worked on the development of a two-equation version of the model based on continuous time random walk (CTRW) and critical gradients and on application of an approach based on the CTRW to neoclassical stellarator transport.

3) M. Murakami (ORNL) visited CIEMAT to participate in NBI experiments in TJ-II and make suggestions for experiments based on the experience from the Advanced Toroidal Facility stellarator results.

4) D. Rasmussen (ORNL) visited CIEMAT and participated in discussions on the status and plans for the two ORNL NBI systems (one operating and one to be installed on TJ-II in 2006), an ORNL pellet injection system (to be installed in the fall of 2006), and an electron Bernstein wave emission diagnostic (to be installed in the spring of 2006).

5) P. Ryan and C-C. Tsai (ORNL) visited Culham Laboratory and CIEMAT to decide on the eventual disposition of ORNL NBI equipment that is on loan to Culham and to improve the performance of NBI #1 prior to the start of the TJ-II 2006 campaign. Improvements to the electrical system and repair of the beam line #2 bending magnet were discussed.

6) D. Schechter and C-C. Tsai (ORNL) visited CIEMAT to enhance the performance of the TJ-II NBI and to transfer NBI assembly, maintenance, conditioning and repair skills to CIEMAT staff. The ion source was reassembled with appropriate gap spacing and aperture alignment of the grids of the ion accelerator and the vacuum leak of the ion source for NBI #2 was repaired.

7) D. Spong gave a talk at the IAEA Technical Meeting on Innovative Concepts and Theory of Stellarators at CIEMAT.

8) S. Zweben (PPPL) visited TJ-II to continue the collaboration on gas-puff imaging of edge turbulence, analyzing past data and preparing for the coming run period. This collaboration is being broadened to include JET.

- International Stellarator Workshop

A.Boozer (Columbia U.), J. Canik (U. Wisconsin), K.L. Ku (PPPL), J. Lyon (ORNL), D. Spong (ORNL), and W. Reiersen (PPPL) gave invited talks at the 15th International Stellarator Workshop at CIEMAT in Madrid, Spain, and a total of twelve contributed papers were presented from all the US stellarator groups.

6.2 Program Plans for 2006

- CNT

Full characterization of pure electron plasma equilibria. Further investigations of instabilities and waves driven by a finite ion fraction. Installation of external mesh probes and retractable emitter and operation without internal probes.

- **CTH**

The key activities for 2006 include:

- Diagnostic commissioning
- Field-mapping and correction of vacuum field errors with full equilibrium coil set. The 15-coil error correction system has not yet been fully proven.
- Measurement of edge islands & stochasticity in plasma with emphasis on edge temperature and density gradients measured by probes
- Experimental equilibrium determination and 3-D reconstruction attempts with magnetic measurements from external probes and loops, and later with input from SX arrays
- Initial characterization of stability of current driven stellarator plasmas

The Compact Toroidal Hybrid laboratory plans to host a US/Japan workshop in November 2006 at Auburn University. An official request has been submitted to OFES by Prof. F. Sano of Kyoto University and PI of the Heliotron J experiment. The proposed title of the workshop is “New approaches to advanced plasma confinement in helical systems”.

- **HSX**

HSX activities for CY2006 emphasize increased heating power through installation of a new transmission line (in progress) and increasing the operating magnetic field to the designed B=1.0 T level. Modifications needed for these goals should be completed by April 2006. Fundamental heating will double the attainable plasma density and reduce the non-thermal electron population. A DNB is being installed to measure plasma flows and infer the radial electric field for transport studies. Physics studies wll emphasize differences in electron thermal conductivity between symmetric/non-symmetric operation, the influence of magnetic islands on plasma flow, bootstrap current measurements and modeling, fluctuation-induced/anomalous transport, and further clarification of observed MHD activity which appears Alfvenic in nature. Expanded collaborations with the TJ-II group will be pursued.

- **NCSX**

Construction of the National Compact Stellarator Experiment (NCSX) will continue during 2006. The three vacuum vessel sectors will be delivered to PPPL and assembly operations begun. Delivery of modular coil winding form deliveries will continue throughout the year, supplying the coil winding operations at PPPL. A contract will be placed for fabrication of the planar TF coils. The physics design of the external trim coils, magnetic alignment, and plasma facing component will be developed.

PPPL will host a US/Japan workshop on US/Japan JIFT Workshop on March 14-16, 2006 titled "Issues in the theoretical analysis of three dimensional configuration". The workshop is being organized by N. Nakajima (NIFS) and S. Hudson and D.

Monticello (PPPL).

- **QPS**

A test coil will be wound with the internally cooled cable conductor to test the winding, vacuum canning and potting techniques for larger, more complex shaped coils. Additional test coils will be wound to determine their thermal, mechanical and fatigue properties. The prototype casting of the modular coil winding form will be machined to the needed tolerance prior to winding the full-size prototype coil with the internally cooled cable conductor.

APPENDICES: TECHNICAL REPORTS ON 2005 ACTIVITIES

APPENDIX 1: TECHNICAL REPORT ON 2005 ACTIVITY, GERMANY

Wendelstein 7-X

In 2005, the project Wendelstein 7-X has started with coil assembly. Design and manufacturing of the different machine components of the basic device has progressed considerably. Power supplies and plasma vessel are complete and delivered. ECRH has progressed and the first series gyrotrons have demonstrated the specified qualification (920 kW for 30 min). The coils, however, are still a problem, specifically the non-planar coils from the quality and from the mechanical stability point of view to meet all forces with acceptable deviations and strain.

Major reorganisation of the project has happened in 2005. Dr. Rem Haange, originally working with JET in England and at the ITER-site in Naka, Japan, in the last years as its head, has joined the W7-X project and is Technical Director since September 1. Prof. Klinger has succeeded Prof. Wagner as head of the project.

The collaboration with FZJ, mostly in the field of the bus-bar system and the SC joint-housing for W7-X and diagnostic development and with FZK, predominantly in the area of ECRH and quench detection, continued successfully. The cooperation with CEA Saclay, where the coils are tested at low temperature, has intensified owing to the larger rate of coil production.

CEA has and CIEMAT will send personnel to W7-X/Greifswald to help the realisation of the project but also to train personnel for ITER.

The development of the diagnostics continued as planned. Cooperation contracts with Russia (Budker) and Charkov (Heavy-ion-beam) in the field of plasma diagnostics exist. New contracts are under preparation in the field of diagnostics with several Polish institutions.

Tests with the 2 MeV accelerator sub-systems provided by Text-U Austin, Texas which is foreseen as an energetic thallium ion source in a heavy ion beam probe diagnostic has been started.

A Magnetic Configuration Data Base (MCDB) for relevant W7-X equilibria (with respect to pressure and toroidal current density profiles) together with visualisation tools and magnetic co-ordinate transforms was installed.

The newly developed ray-tracing code for ECRH, ECCD and ECE simulations as well as the stellarator predictive transport code (under development) are linked to the MCDB.

For W7-AS HDH-scenarios, the impurity screening within the edge plasma was simulated with the EMC3-EIRENE code. For W7-X, the efficiency of the divertor pumping was analysed depending strongly on the position and size of the islands (indicating the need of a control of the edge magnetic topology).

The International Stellarator Profile Data Base activity was initiated with neoclassical "electron-root" discharges (density and power scans for different W7-AS configurations). In addition, the effect of ECRH in O1- and X2-mode was analysed.

The neoclassical theory was extended to include self-consistently density and potential variations on the flux surfaces. The impact of this extension on the particle and energy fluxes was analysed both for LHD and for W7-X configurations.

Stellarator Theory

In 2005, work of the stellarator theory division was concentrated on widening the scope of theoretical work of the Greifswald branch institute and on further development of the stellarator concept. Main areas were

1) MHD theory of stellarators (progress with PIES equilibria, coil optimization, stability analysis of W7-X, stability including kinetic effects)

2) gyrokinetic simulations (progress with electromagnetic PIC simulations at small scales, global itg turbulence in screw-pinch geometry, global itg modes in stellarators, gyrofluid turbulence modeling) and

3) plasma edge physics (progress with the code BoRiS for 3d but non-ergodized topology, application of E3D to the ergodized DIII-D, a local-magnetic-coordinates finite-differences code in parallelization).

WEGA

At WEGA stellarator experiments on the properties of ECR heated plasmas at 2.45 GHz have been continued. The microwave heating scenarios have been studied experimentally and theoretically using probes in the vicinity of the antennas. Furthermore, experiments on the detection of super thermal electrons and on the polarisation of the plasma edge have been realised.
The setup of a new microwave heating source operating at 28GHz gyrotron with a power of 10kW cw, the transmission line and the appropriate infrastructure started. It is planned to operate this gyrotron at WEGA at an increased magnetic field strength of B0=0.5T. Within the framework of a cooperation with the IPP-Kharkov the setup Heavy Ion Beam Probe (HIBP) diagnostic has been started.

APPENDIX 2: HIGHLIGHTS OF LHD EXPERIMENTS, JAPAN

In the high-density regime, complete detachment takes place when the edge density reaches a threshold and the hot plasma boundary shrinks below the last closed flux surface. The completely detached state is self-sustained in some cases with appearance of a rotating helical radiation belt. This is called the Serpens mode. The effective fueling efficiency improves at complete detachment and continued gas-fueling leads to radiative collapse. The threshold edge density for complete detachment determines the operational density limit of attached plasmas. For pellet-fueled plasmas, this threshold edge density is similar and thus significantly higher central density plasma is maintained since the density profile is peaked. The maximum central density of 6 x 1020 m-3 is obtained by applying pellet injection.

A new transport barrier (SDC-mode) has been observed in the pellet fuelled Local Island Divertor (LID) discharge in the Large Helical Device (LHD). The key feature of the new barrier is a steep rise (barrier) in density, which leads to Super Dense Core plasma (3×1020m-3, 0.8 keV). Radius of the dense core increases with increasing magnetic axis (Rax) and increasing β. It is about 60% of the minor radius for the Rax=3.75m configuration with β(0) =3.4%. The function of the LID divertor appears to be pumping of the recycled particles. For a fixed core density, maintained by the pellet fueling, the efficient pumping by LID reduces the density in the outer region, allowing higher temperature gradient there and higher temperature at the barrier. Furthermore, Low outer density is advantageous in avoiding the radiative collapse which determines the operational limit of the outer density and hence leads to higher core density. Our results are very promising for design of the helical reactor since very high core density as high as 5×1020m-3 can be achievable while keeping the edge density relatively low.

Production of high beta plasma has been performed in the configuration with optimal coil pitch parameter γ of 1.2. Volume averaged beta of 4.5 % has been achieved by pellet injection. MHD activities excited in periphery are observed in such high-beta regime, whereas they are not crucial for an expansion of high-beta regime. Clear dependence of saturation of MHD modes on magnetic Reynolds number has been found and the dependence is close to that predicted by linear theory on resistive interchange mode. While the reduction of γ is better for maintaining high heating efficiency and good neoclassical transport, it leads to the reduction of magnetic shear, especially, at ι/2π = 1 resonance. It is important to verify the beta-limit due to ideal stability and to investigate significance of magnetic shear. Strong ι/2π = 1 resonant mode causing minor collapse has been observed in configurations with low-γ and/or large plasma currents reducing magnetic shear which correspond to ideal unstable configuration.

We injected hydrogen pellets or a tracer encapsulated solid pellet and obtained improved heat transport states transiently. The core electron temperature increases from ~4 to~5keV in response to the small perturbation. The transient analysis indicates an abrupt reduction in the heat flux without significant change in local plasma parameters, particularly local temperature gradient, hence exhibiting a non-local behavior of the heat transport.

APPENDIX 3: TECHNICAL REPORT ON 2005 ACTIVITY, RUSSIA

1) GENERAL PHYSICS INSTITUTE (GPI)

1. We began to upgrade the ECR heating system for the L-2M. A new 75-GHz gyrotron was manufactured last year by GYCOM and was put through tests. The gyrotron possesses an output power of 0.7 MW and unsurpassed efficiency (70%) of microwave conversion. A supply system for two such gyrotrons is now under construction. The fabrication of a multi-frequency gyrotron with similar parameters is scheduled for 2007. .

2. The confinement regimes with edge localized transport events (ELE) were discovered in low-beta ECRH plasmas of L-2M. Each ELE is identified by a sudden fast (~200 μs) drop in total plasma energy measured by plasma diamagnetism that correlates with a significant drop in floating potential measured by Langmuir probes. The most drastic changes in floating potential are observed near a rational magnetic flux surface where the rotational transform is equal to 2/3. After the ELE the plasma energy grows monotonically to the end of the discharge, so does the average plasma density. It is reasonable to suggest that the ELE indicates the transition to the regime of better confinement. A theoretical analysis of plasma stability by using two-fluid approach showed that, under relevant experimental conditions, ideal modes can be unstable but only as the result of coupling ion-temperature-gradient modes to Alfven and acoustic modes.

3. For the steady-state case, a relatively simple model of transport processes in stellarators is constructed based on neoclassical theory with allowance for anomalous particle and heat losses. From mathematical standpoint this model is equivalent to a system of first-order nonlinear equations. At given sources of particles and energy, the radial profiles of density N, temperatures Te, Ti and ambipolar electric field Ea can be uniquely determined from this system. Results of calculations performed using this model for the L-2M, ATF, CHS and LHD stellarators over a wide range of average densities N = (5×1012 - 5×1014) cm-3 and absorbed power P = (0.1 - 10) MW showed that the calculated energy lifetime τE, to within a factor on the order of unity, agrees with predictions of the ISS95 and, better still, of the LHD scaling (see related plots in the attachment).

4. In 2005, we have come to agreements about prolongation of the scientific cooperation for 2006-2007 both with the Spanish Scientific Center (CIEMAT) and with the National Institute for Fusion Science (NIFS). The main directions of cooperative research are the continuation of experiments and theoretical studies of strong plasma turbulence, the development of microwave methods for plasma diagnostic, the participation in experiments on plasma heating by high-power gyrotron radiation.

2) KURCHATOV INSTITUTE

It is shown that a boundary magnetic flux surface of an integrally optimized six-period configuration with beta limit <β> = 8.4% in respect to stability of global modes. This configuration is practically free of collisionless losses of fast particles at reactor parameters (B = 5 T, M = 1000 m3), the bootstrap current is minimal (the change produced by the current in the rotational transform is about 1-2% of its initial vacuum value), and the neoclassical diffusion coefficients for 1/ν regime do not exceed their values for the W7-X stellarator. Besides, the optimization of configurations of the same type but with a large number of periods was undertaken. It is shown that in the systems with a large number of periods, when limitations on the longitudinal current become more severe, the bootstrap current can be made negligible, even though the plasma pressure limit in respect to stability increases substantially with increasing number of periods. At the same time, the configurations retain all good confinement properties. It is expected that with further increase of the number of periods it will possible to clear up the structure of a “straight” stellarator whose properties are no longer dependent on the number of periods.

A comparative analysis was performed for the quality of confinement of trapped particles in various stellarators with improved particle confinement – in systems with axial and helical symmetry and in quasi-isodynamic stellarators. It is shown that the size of trapped-particle bananas is minimal for quasi-isodynamic stellarators with the same values of plasma volume and magnetic field, because particles are trapped within the period. The banana size is maximal for stellarators with axial quasi-symmetry.

APPENDIX 4: SUMMARIES FOR 2005 OF THE INSTITUTE OF PLASMA PHYSICS OF THE NSC KIPT, KHARKOV.

Plasma Theory

1) Optimization of stored energy for URAGAN-2M is carried out in the 1/ν regime with applying the fast field line tracing NEO code (V.V. Nemov, S.V. Kasilov and V.N. Kalyuzhnyj in collaboration with B.Seiwald and W.Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria))

A realistic model of the magnetic field is used. In particular, the magnetic field produced by the helical coils and its spatial derivatives are calculated on the basis of the Biot-Savart law, where each helical coil is modeled with 24 current filaments distributed in two layers. Some possibilities for improving the 1/ν confinement properties using optimization procedure for a set of three varying parameters have been presented. The parameters are connected to the toroidal field coil currents , the difference of these currents in adjacent groups of coils and the changes in the vertical magnetic field. In particular, it follows from the obtained results that for the configuration corresponding to $k\varphi$=0.31 ($k\varphi$ is the ratio of the helix and the total toroidal fields) the optimized maximum in stored energy can be made in 1.65 times higher than for $k\varphi$=0.375 (standard configuration). According to energy content corresponding to energy source localized at the magnetic axis and zero temperature at the boundary the same increase in the stored energy for a standard configuration would require 9.5 times higher input power. The results are reported at the 15th International Stellarator Workshop (Madrid, Spain, October 2005).

2) Neoclassical transport for LHD in the 1/ν regime was analyzed by the NEO code. The results are benchmarked with the corresponding results obtained recently with the GIOTA code as well as with Monte-Carlo calculations from the DCOM code. (V.V.Nemov and S.V.Kasilov in collaboration with W.Kernbichler (Institut für Theoretische Physik, Technische universität Graz, Austria), M.Isobe, M.Matsuoka and S.Okamura (National Institute for Fusion Science, Japan))

The results obtained with NEO confirm recent conclusions from GIOTA and DCOM calculations that for LHD the optimum configuration corresponds to the inward shifted configuration with Rax close to Rax=3.53 m. At the same time for inward shifted configurations εeff3/2.values obtained from NEO are somewhat bigger than those obtained from GIOTA. The difference may be partly connected with the different treatment of the contributions of various classes of trapped particles to the transport. In contrast to GIOTA, the NEO code takes all classes of trapped particles into account. The benchmark with Monte-Carlo results from DCOM shows essentially smaller differences for NEO than for CIOTA. The results are reported at the 32nd EPS Conference on Plasma Phys., Tarragona, 27 June-1 July 2005, ECA Vol. 29C, P-1.110 (2005).

3) New target functions which are related to collision-less α–particle confinement are introduced. They are based on specific averages of the bounce averaged ∇B drift velocity of trapped particles across magnetic surfaces (V.V.Nemov and S.V.Kasilov visited Institut für Theoretische Physik, Technische universität Graz, Austria, and worked with W.Kernbichler and G.O.Leitold)

The main optimization target proposed here is the mean-square average over the pitch angle and over the magnetic surface of the bounce averaged ∇B drift velocity of trapped particles across the magnetic surfaces. The role of specific magnetic field is manifested in this quantity by the dimensionless factor Γv, which is calculated using field line tracing code. For a specific configuration, this factor is only a function of the minor radius. Minimization of Γv corresponds to the optimization of the trapped particle collision-less confinement.

Computation of the poloidal drift velocity for the trapped particles is discussed also. A numerical analysis of velocities of the radial drift as well as the poloidal drift allows for a quick assessment of J|| contours in the vicinity of a given magnetic surface. The results are reported at the 32nd EPS Conference on Plasma Phys., Tarragona, 27 June-1 July 2005, ECA Vol. 29C, P-1.109 (2005).

4) Modeling of the electron cyclotron heating in a stellarator with the non-thermal electrons. (S.V.Kasilov in collaboration with W.Kernbichler, R.Kamendje and M.F.Heyn (Institut für Theoretische Physik, Technische universität Graz, Austria)).

A numerical method has been developed for the fast Monte Carlo modeling of the electron distribution function in a stellarator during the electron cyclotron heating by the wave with the finite amplitude. With the help of this method, ECRH in the Wendelstein-7AS stellarator has been modeled in the case of the second harmonic resonance for the extraordinary wave launched perpendicularly to the magnetic field in the elliptic cross-section of this device. It has been shown that the nonlinear wave-particle interaction effects and, partly, distortion of the electron distribution function from the Maxwellian cause the reduction of wave absorption and, therefore, the increase of the absorption length of the microwave beam. This results in broadening of radial power deposition profiles at low plasma densities (1013 cm-3 and less) while at high densities such a broadening is insignificant because radial power deposition profiles are determined mainly by the perpendicular beam width which is larger than the absorption length at these densities. Preliminary results have been reported in October 2005 in Madrid, Spain, as a poster at the 15th International Stellarator Workshop and as an oral presentation at the IAEA Technical Meeting on Innovative Concepts and Theory of Stellarators.

5) E-beam mapping simulation program on the NCSX stellarator. (V.A.Rudakov in collaboration with A.V.Georgiyevskiy, E.Fredrickson and M.Zarnstorff (Princeton Plasma Physics Laboratory, USA).

The primary object of the e-beam mapping simulation program on NCSX is to develop requirements for the hardware and machine capabilities necessary for the actual e-beam mapping experiments. The magnetic flux surface configuration was constructed using a numerical code, based on the Biot-Savart law, to calculate the magnetic field components and trace the field line trajectory many times around the torus. Magnetic surfaces are then mapped by recording the field line intersections with toroidal cross-sections of the magnetic system, much as in an actual e-beam mapping experiment. In the course of these calculations, a catalog of many hundreds of vacuum magnetic configurations was compiled, each with varying sensitivity to poloidal, toroidal and modular coil displacements. NCSX is not a classic stellarator in that the coils were designed to provide good magnetic surfaces in the presence of significant current in the plasma; roughly half of the transform will be generated by current in the plasma. Thus, many of the vacuum field configurations with low order rational surfaces also have finite, stellarator-symmetric islands present. Nevertheless, despite the presence of these islands, configurations have been found which will allow, we believe, the identification of modular and poloidal field coil displacements of < 0.5 mm. There was generally less sensitivity to toroidal field coil displacement, and a novel approach of energizing a subset of the toroidal field coils at higher current is proposed. By using half of the toroidal field coils, at twice the current, it is possible to detect alignment errors of less than approximately 1 mm. These results assume that the spatial resolution of the e-beam mapping apparatus is of order 5 mm, a previously achieved result for the luminescent rod method. The results are reported at the 15th International Stellarator Workshop (Madrid, Spain, October 2005).

6) For theoretical study of Alfvén resonance heating in stellarators a numerical model and the computer code have been developed. A distinguishing feature of the model is the account of non-local effects associated with the ion gyration and electron longitudinal motion. For discretization it uses the recently developed method of weighted residuals with uniform finite elements. The method provides the numerical stability of the numerical scheme and resolves the problem of stiffness of the Maxwell's equations caused by the significantly different plasma response on the electric perturbation along and perpendicular to the magnetic field lines. First calculations have shown the possibility for usage of portable antennas for Alfvén resonance heating in the URAGAN-2M stellarator. (V.E.Moiseenko)

7) V.E.Moiseenko participated in examining the charged particle motion in magnetic traps performed by O.Ågren, C.Johansson and N.Savenko (Uppsala University, Sweden). It is found that the gyro center radial Clebsch coordinate r_0 is an exact invariant in confining fields where the gyro center is restricted to move on a magnetic flux surface, and r_0 could also be expected to be a useful approximating invariant in other confining magnetic fields. A radial drift invariant I_r generalizes the invariance of r_0 if there are oscillatory gyro center radial displacements off the magnetic surface. Expressions for $r_0(\mathbf{x},\mathbf{v})$ and $I_r(\mathbf{x},\mathbf{v})$ are obtained for gyrating particles in the drift ordering. An exact energy integral is proven to exist for the first order drift motion of the gyro center. A modification of the parallel invariant $J_\parallel$ is derived which leads to an exact (not only adiabatic) invariant to first order. By using r_0 in solutions of the Vlasov equation, it is demonstrated that the approximating gyro center invariant r_0 determines the perpendicular plasma diamagnetic current. It is also shown that a fourth stationary motional invariant is required to calculate the parallel plasma current. Several systems with four time independent invariants are identified, and the general solution for straight cylindrical Vlasov equilibria with adiabatic particle motion is determined. A set ($\varepsilon, \mu, J_\parallel, I_r$) of four invariants is proposed for adiabatic equilibria in general geometry, including systems where single valued flux surfaces may not exist. The resutls of this study are published in Phys. Plasmas 12, 122503 (2005).

Plasma Experiments

8) In the Uragan-3M torsatron were investigated characteristics of edge plasma turbulence and space-time dynamics of low frequency plasma density fluctuations during the transition to improved confinement regime. (Publications: "Problems of Atomic Science and Technology, Series: Plasma Physics", 2005, N1, p. 21-23 and

“Problems of Atomic Science and Technology, Series: Plasma Physics”, 2005, N1, p. 27-29).

9) It was shown that the formation of high radial electric field shear regions during the transition to the improved confinement regime take place in the vicinity of stochastic magnetic field line layers near rational surfaces. (Publications: 10th IAEA Technical Meeting on H-mode Physics and Transport Barriers, 2005, St. Petersburg, Rep. 3.1 and Rep. 3.11; Report on 15th Stellarator Workshop, Madrid, 2005, Book of Abstracts, p. 77).

10) The excitement of ion Bernstein waves during Alfven wave plasma heating was observed in the Uragan-3M torsatron. (Report on 15th Stellarator Workshop, Madrid, 2005, Book of Abstracts, p. 76).

11) There was carried out analysis of magnetic configuration with plane magnetic axis in l=2 torsatron with additional toroidal magnetic field (Report on IAEA Technical Meeting on Innovative Concept and Theory of Stellarators, Madrid, 2005, Book of Abstracts, p. 159).

12) The study of hydrogen permeability and erosion behavior of the W-Pd bimetallic system (Report on 7th Simposium on Fusion Nuclear Technology, 2005, Book of Abstracts., p. 216).

13) The measurements of radial plasma potential and density as well as their fluctuations by Heavy Ion Beam Probe (HIBP) diagnostics and study of their influence on the plasma confinement in helical axis Stellarator TJ-II (CIEMAT, Spain) with ECR and NBI heating were carried out. Behavior of the plasma potential in variety of magnetic configurations and plasma parameters was studied.(simultaneously with the TJ-II team).

A number of experiments were devoted to variation of the ECRH input power density (gyrotron modulation regime). The evolution of the electric potential in a wide range of regimes of ECR heating, with using the upgraded Heavy ion Beam Probing diagnostic in TJ-II, is investigated. Discharges with shift of plasma column by limiter were observed also. The potentials in SOL of plasma were measured simultaneously with multi-pin Langmuir probes.

The plasma potential behaviour showed the clear link between the core plasma potential and ECRH power: the stronger power leads to the higher (more positive) absolute potential value. The electric potential was in strict dependence on the electron temperature. Potential in the plasma core and edge depended on the plasma density. The negative plasma potential was observed when ne was above some threshold value.

The quasicoherent oscillations were observed in TJ-II plasma. Some different diagnostic: Heavy Ion Beam Probe (HIBP), 2 ω ECR emission, Langmuir and Mirnov probes were used. A resent improvement in the signal to noise ratio of the HIBP diagnostic has allowed to observe the radial structure of these oscillations from the edge to the plasma core regions. The obtained experimental results indicate that the quasi-coherent modes associated to the rational surface that triggers the formation of e-ITBs in TJ-II are modified by the electric fields developed at the transition. These results show the importance of ExB flows in the evolution of MHD instabilities linked to low order rationals in the TJ-II stellarator. Present findings suggest the importance of clarifying the role of electric fields and sheared flows in the stability of MHD modes (e.g. tearing modes) in fusion plasmas. The magnetic configuration scan shows evidence of quasicoherent oscilations (≅ 20kHz) in the plasma edge. When rational surface is located at the edge gradient region (8/5 rational) HIBP shows a strong correlation with the Langmuir probes and Mirnov coils. (Publications: L.Krupnik, A.Alonso, A.Chmyga, N.Dreval, G.Dezgko, L.Eliseev, C.Hidalgo, S.Khrebtov, A.D.Komarov, A.S.Kozachok, A.V.Melnikov, M.A.Pedrosa, J.L.de Pablos, V.I.Tereshin “Electron internal transport barriers, rationals and fluctuations in the stellarator TJ-II” In Proc.32nd EPS Conf. on Plasma Physics and Controlled Fusion, Tarragona, 27 June-3July 2005.CD-ROM; T.Estrada, L.Krupnik, A.Alonso, F.Castejon, A.Chmyga, N.Dreval, L.Eliseev, C.Hidalgo, S.Khrebtov, A.Komarov, A.Kosachok, A.Melnikov, J.L.de Pablos, V.Tereshin. “Electron Internal Transport Barrier, and Magnetic Topology inStellarator TJ-II“15th International Stellarator Workshop, Madrid, October 3-7, 2005, Spain, Rep..IT-01, CD-ROM; L.Krupnik, A.Alonso, A.Chmyga, N.B.Dreval, G.N. Dezgko, L. Eliseev, C.Hidalgo, S.M. Khrebtov, A.D. Komarov, A.S. Kozachok, A.V.Melnikov, M.A. Pedrosa, J. L. de Pablos, V.I. Tereshin. “Characterization of the quasi coherent oscillatins in the TJ-II plasma“, 32nd EPS Conf. on Plasma Physics and Controlled Fusion, Tarragona, 27 June-3July 2005.CD-ROM).

14) The global confinement and plasma parameters were modified with biasing. The basic features of the HIBP data show some similarities for two kind of biasing: limiter- and electrode biasing. Potential response jD_{pl} has the same polarity and scale as U_{bias} and the fluctuations are suppressed near electrode/limiter regions.

Other features of plasma response to biasing are different: in the limiter biasing both edge and core change potential. in electrode biasing changes are mainly localized near the biased electrode (L.Krupnik, A.Alonso, E.Ascasibar A.Chmyga, N.Dreval, G.Dezgko, L.Eliseev, T.Estrada, C.Hidalgo, S.Khrebtov, A.Komarov, A.Kozachok, A.Melnikov, B. vn Milligen, M.Ochando M.Pedrosa, J.L.de Pablos, C.Silva, V.Tribaldos, V.Tereshin. “Radial electric fields and confinement in the TJ-II stellarator” Cheh. J. of Physics v.55, (2005) p.317-335).

15) The main attention in the experiments on TJ-II was devoted to the plasma potential behavior during combined ECRH+NBI and NBI heating. The negative plasma potential was measured at the final NBI regime. The observation of the decay in plasma potential with density increase is in agreement with previous experiments. (A.V.Melnikov, C.Hidalgo, A.A.Chmyga, LG.Eliseev, A.D.Komarov, A.S.Kozachok, L.I.Krupnik, M.Liniers, M.A.Pedrosa, S.V.Perfilov, K.McCarthy, M.A.Ochando, S.Ya.Petrov, Yu.N.Dnestrovskij, S.E.Lysenko, V.I.Tereshin, A.Alonso, J.L. de Pablos, J.M.Fontdecaba, R.Balbin and TJ-II team. “Plasma potential evolution study by HIBP diagnostic during NBI experiments in TJ-II stellarator”. 15th International Stellarator Workshop, Madrid, October 3-7, 2005, Spain, Rep. **Or-09**, CD-ROM. 16) Taking into account that the role of the electric fields in the neoclassical analysis of the plasma confinement in tokamaks and stellarators is not the same, and drawing the attention to recent experimental investigations on similar behavior of electric fields in different regimes of tokamaks and stellarators we can assert that comparative examinations of the electric fields in these devices are rather actual task. Similar results on electric potential behaviour in stellarator/torsatron TJ-II and tokamak T-10 in a comparable

regimes of device operation were obtained. Both machines were equipped with systems of ECR heating and a Heavy Ion Beam Probing diagnostic (HIBP). (A.V.Melnikov, L.G.Eliseev, S.A.Grashin, A.V.Gudozhnik, S.E.Lysenko, V.A.Mavrin, S.V.Perfilov, V.A.Vershkov L.I.Krupnik, A.A.Chmyga, A.D.Komarov, A.S.Kozachok, C.Hidalgo, A.Alonso, J.L. de Pablos, M.A.Pedrosa. "Study of the plasma potential evolution during ECRH in the T-10 tokamak and TJ-II stellarator" Cheh. J. of Physics, 2005, in print).

17) The Heavy Ion Beam Probe (HIBP) diagnostic for WEGA Stellarator have been tasted at IPP NSC KIPT and deliveried to IPP in Greifswald.(L.I.Krupnik and HIBP team in collaboration with Wega team). The optimized probing scheme for C+C- port combination was found. The radial range of volume (for 0.5 T, 40 keV) is $0.3 < \rho < 1$, the geometrical limitations were not permited to reach the plasma column center. Toroidal focusing of the secondary trajectories will lead to necessity to construct rather complex secondary beamline.

Control and data acquisition systems were developed and completed for WEGA experimental conditions. (L.I.Krupnik, G.N.Deshko, A.I.Zhezhera, A.A.Chmyga, A.D.Komarov, A.S.Kozachek A.V.Melnikov, S.V.Perfilov, M.Otte, M.Shubert. "The Heavy Ion Beam Probing Development for WEGA Stellarator". Proc.15th International Stellarator Workshop (Madrid, Spain, 3-7 Oct. 2005), Rep. **P2-11**, CD-ROM).

18) Geodesic Acoustic Modes (GAM) were investigated on the T-10 tokamak using Heavy Ion Beam Probe (HIBP), Correlation Reflectometry (CR) and Multi-pin Langmuir Probe (MLP) diagnostics. Regimes with Ohmic heating and with on- and off-axis ECRH were studied. It was shown that GAMs are mainly the potential oscillations. Typically, the power spectrum of the oscillations has a form of a solitary quasi-monochromatic peak with the contrast range of 3-5. They are the manifestation of the torsional plasma oscillations with poloidal wavenumber m=0, called as the Zonal Flows (ZF). The frequency of GAMs changes in the region of observation and decreases towards the plasma edge. After ECRH switch-on, the frequency increases, correlating with growth of the electron temperature T_e. The frequency of the GAMs depends on the local T_e as: $f_{GAM} \sim c_s/R \sim T_e^{1/2}$ which is consistent with a theoretical scaling for GAM, where c_s is the sound speed within a factor of unity. The GAMs in T-10 are found to have the density limit, some magnetic component and intermittent character. They tend to be more excited near low q magnetic surfaces.(A.VMelnikov, V.A.Vershkov, LG.Eliseev, S.A.Grashin A.V.Gudozhnik, L.I.Krupnik, S.E.Lysenko, V.A.Mavrin, S.V.Perfilov, D.A.Shelukhin, S.V.Soldatov, M.V.Ufimtsev, A.O.Urazbaev, G.Van Oost and L.G.Zimeleva. Investigations of the geödesic acoustic mode oscillations in the T-10 tokamak". J of Sciense and Technology, in press).

APPENDIX 5: SUMMARIES OF KARAZIN NATIONAL UNIVERSITY, KHARKOV FOR 2005.

1) Science and Technology Center in Ukraine Project # 2313 "Impurity transport and electromagnetic waves in the plasma periphery of a HELIAS reactor configuration and WENDELSTEIN 7-X" (manager Prof.Dr. I.Girka) was successfully finished in 2005. The results of the studies were published in 2 journal papers and were presented in 4 reports on scientific conferences. Six manuscripts more were submitted to journals. In particular, the reports ⌈Electromagnetic Field Effect on Impurity Ion Transport in Helical Plasma] and ⌈Comparative Numerical Analysis of the Tungsten Transport in Drift Optimized Stellarator Ergodic and Nonergodic Plasma Configuration] were presented at the 32-nd European Physics Society Conference on Plasma Physics and Controlled Fusion, Spain, 2005. The latter was presented by O.Shyshkin (University) in collaboration with Dr. R.Schneider and Dr. C.Beidler (MPIPP). The report ⌈Surface flute modes in the bumpy magnetic field] was presented at IEA 15-th International Stellarator Workshop, Spain, 2005.

2) The experiment for testing the ICRF antenna of new geometry was carried out. The software for graphical signal processing for each shot was made. This software has also an opportunity to characterize lagging after the ELMs take place. This activity was carried out by junior researcher A.Onyshchenko (University) during his visit to MPIPP in collaboration with Dr. J.-M.Noterdaeme, Dr. V.I.Bobkov, W.Becker (MPIPP).

3) Erosion of tungsten layers by deuterium bombardment was studied by PhD student of Sandwich Fellowship Program I.Bizyukov (University) in collaboration with Dr. K.Krieger (MPIPP). Two journal papers by I.Bizyukov, K. Krieger, et al were published. The report by I.Bizyukov, K.Krieger, et al was presented at 17th International Conference on Plasma-Surface Interactions, 2005.

4) Luminescence technique of nondestructive monitoring of property changes in silica exposed to charged particle irradiation was developed at the Research Laboratory of Radiation Electronics (RELAB, University). The use of silica as insulators and windows in thermonuclear facilities is widespread. Angular and spectral characteristics of silica luminescence include important information about instantaneous dynamic equilibrium of the defect distribution in the solid and are unique channel of radiation process remote monitoring. The technique was applied for monitoring of silica absorption dose during hydrogen ion bombardment (the report S.I.Kononenko et al. ⌈Remote monitoring of silica absorption dose by means of ion – luminescence] was presented at the 14th International Toki Conference on Plasma Physics and Controlled Nuclear Fusion, 2004).

5) Two joint reports were presented at 15th International Toki Conference Fusion and Advanced Technology], 2005, Japan, with the following submission to ⌈Fusion Engineering and Design]: O.Motojima, S.Sudo (NIFS), A.Shishkin (NSC KIPT), A.Eremin, A.Moskvitin and Yu.Moskvitina (University), ⌈Dynamics of Fusion Products in LHD Geometry], PS 2-24; A.A.Shishkin, A.Yu.Antufyev (University), O.Motojima, A.Sagara (NIFS), ⌈Removal of Cold Alpha-Particles from Fusion Helical Reactor], PS 2-25.

APPENDIX 7: TECHNICAL REPORT ON TJ-II ACTIVITIES IN 2005

Significant improvements in characterising the confinement and stability properties of TJ-II stellarator plasmas have been achieved in 2005. The main conclusions can be summarized as follows:

1) Global data-base has been extended confirming the positive dependence of energy confinement on rotational transform and density. Impact of fuelling and electric field on spontaneous confinement transitions has been addressed.

2) Magnetic configuration scan experiments have highlighted the interplay between magnetic topology, transport (kinetic effects) and electric fields. Quasi-coherent modes are observed with maximum amplitude close to the foot of the e-ITB, where the E_rxB shear flows develop at the e-ITB formation. Experiments with different low order rationals show a dependence of the threshold density (and also of the barrier quality) on the order of the rational.

3) The structure of radial electric fields and plasma (impurity) rotation has been compared in ECRH and NBI plasmas. Low density ECRH plasmas are characterised by core positive electric fields up to 50 V/cm. Edge radial electric fields remain positive at low densities and became negative at the threshold density that depends of plasma configuration. NBI plasmas are characterized by negative electric potential in the full plasma column and negative radial electric fields (in the range of 40 V/cm). It has been observed that the poloidal rotation direction changes sign depending on the auxiliary heating method used in consistency with neoclassical calculations.

4) EBW modelling has also experienced a large advance. TRUBA ray tracing code is ready to perform relativistic calculations to be compared with the non-relativistic ones. Also, a new form for the full relativistic dielectric tensor is obtained.

5) Comparative plasma break-down studies among several stellarators have been performed, showing a clear dependence of break-down properties on magnetic configuration and wave polarization.