

**Implementing Agreement for Co-operation in Development
of the Stellarator-Heliotron Concept**

**2014 Executive Committee Annual Report
to the Fusion Power Coordination Committee**

January 2015

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EXECUTIVE SUMMARY

The present report overviews the scientific and technical progress achieved in 2014 by the parties to the Implementing Agreement for Co-operation in Development of the Stellarator-Heliotron Concept, who have greatly benefited from its international collaborative framework. The document reports the collaborations in 2014 and the parties' research plans for 2015, including technical reports on 2014 activities.

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1. COORDINATED WORKING GROUP MEETING (CWGM) FOR STELLARATOR-HELIOTRON STUDIES

During 2014, 13th CWGM was held to continuously facilitate the joint activities.

13th CWGM

The 13th Coordinated Working Group Meeting (CWGM13) was held from 26 to 28, February 2014 in Uji Campus of Kyoto University. The materials presented in this meeting are available at <http://ishcdb.nifs.ac.jp/> and http://fusionwiki.ciemat.es/wiki/Coordinated_Working_Group (→ CWGM13) for those of you having further interests. Below, you will find a brief summary of the meeting.

Three-dimensional (3D) Transport in divertors

Upon the proposal made in the last CWGM (12th in Padova), recent progresses were reviewed on the experimental identification and physics interpretation of 3D effects of magnetic field geometry/topology on divertor transport. This has passed the domestic (Japan) selection process towards the presentation in the coming 25th IAEA Fusion Energy Conference. Identification of key parameters for 3D effects should open new perspectives on divertor optimization for future reactors. Interactions between 3D structure of magnetic field, current in SOL/stochastic layer, parallel and perpendicular electric field should be systematically clarified through diagnostics and modelling in a range of magnetic field configurations. Issues in formulating joint experiments, potential and current measurements, 2D temperature and density measurements, are discussed among HSX, LHD and TJ-II. Comparison with linear devices “without 3D effects” is also recommended to elucidate 3D effects in a comparative manner.

Impurity

Impurity issues have been raised in several CWGM meetings, but session has not been formed unfortunately. This time, the session is formed to re-activate discussions in framework of CWGM. Experiments for impurity transport are reported from LHD (intrinsic and TESPEL-induced) and TJ-II (broad range of materials, LiF to W). In TJ-II, TESPEL injection is now under consideration with a newly installed pellet injector. In-surface variation of electrostatic potential caused by ion drift-kinetic dynamics has been put forward as potentially important for radial impurity transport. TJ-II has identified asymmetries in C⁶⁺ impurity density and floating potential, for which comparisons with EUTERPE code result has been commenced. The importance of the impurity issues calls for coordinated actions both in experiments (Heliotron J, LHD and TJ-II) and simulations (FORTEC-3D, EUTERPE, fluid codes...) to assess the existence of in-surface potential variations and its contribution to radial impurity flux. R.Burhenn et al., published the joint paper on impurity issues in 2009 [“On impurity handling in high performance stellarator/heliotron plasmas”, Nuclear Fusion 49 (2009) 065005.]. The follow-up joint papers (further developments afterwards) can be formulated by re-activating joint activities in CWGM.

Highlights in experiments, invitation to joint experiment

The recent topics in Heliotron J device were reviewed. The plasma startup, the plasma parallel flow measurement and its comparison with neoclassical prediction, fast-ion driven MHD and related particle flux studies by using several probe systems, the external control of energetic-ion driven MHD instabilities by ECCD, the fast ion distributions in ICRF experiment, high density operation through HIGP (high intense

gas puff) fueling and SMBI (supersonic molecular beam injection), transition to improved confinement in such a high density regime, etc. are emphasized to trigger proposal and discussions for joint experiments. From LHD, steady progresses of plasma parameters (ion temperature, simultaneous high temperatures, and steady state operation) were reported. New diagnostics, high dynamic-range spectroscopic measurement of Balmer- α line, has facilitated quantitative understandings on the impacts of discharge-cleaning for producing high ion temperature plasmas. RMP experiments have fertilized 3D physics, such as the magnetic island dynamics (growth/healing), and observation of peaked pressure profile inside the magnetic island after the pellet deposition. A tentative schedule of deuterium experiment was also mentioned, along with the planning of upgrade of heating and diagnostics capability. Autoplot (advanced data viewer) and TASK3D-a (integrated transport analysis suite) were introduced, which should facilitate joint experiments. Invitation to 18th campaign (in 2014) were called.

Reactor/systems code

After the kick-off session in 10th CWGM (2012, Greifswald), interaction between systems codes (HELIOSCOPE and PROCESS) and physics modellings have been successfully enhanced. Plasma operation control scenario consideration has been progressing for FFHR-d1, in which a transport model based on LHD experiment has been employed. Coupling with the TASK3D (integrated transport analysis suite) is in preparation for consistency check (time evolution of equilibrium, heating along with plasma profiles). As for PROCESS, modules for plasma geometry, modular coils and island divertor have been developed and implemented. ITG transport model is deduced based on GENE simulation results, to be included. In such a way, the common development for these 2 reactor design activities is to implement further physics models. Benchmarking activities between these developments were proposed. However, it is too difficult, at this moment, because many modules depend on the individual design. Mutual information exchange and closer link to physics modellings are anticipated.

Flows and Viscosity, Transport

Flows and viscosity strongly depend on magnetic configurations, collisionality and radial electric field etc. Variety of magnetic configurations either within a single device or covering multi-devices provides wide variety of research subjects to be challenged in experiment, theories and simulations. In terms of neoclassical transport, the neoclassical poloidal viscosity analyses for LHD biasing plasmas, the validation of stellarator optimization via extended neoclassical simulations and dedicated experiment, parallel flow in Heliotron J NBI plasmas were reported. Benchmark of a bunch of neoclassical transport codes with (FORTEC-3D)/without non-local effects has been progressing through utilizing experimental data. Setting a standard case (like "Cyclone DIII-D base case" [C.M.Greenfield et al., Nucl. Fusion 37 (1997) 1215.]) for this joint activity was proposed, utilizing the International Stellarator-Heliotron Profile Database. Uploading the simulation results was also suggested. Joint activities for the evaluation of expected potential variation on a flux surface (" Φ_1 ") based on EUTERPE and FORTEC-3D is planned in relation to the issue of the impurity transport. Neoclassical transport in tokamaks with 3D magnetic perturbation has also been progressing through collaborations among NIFS, PPPL and JAEA (Japan Atomic Energy Agency).

In addition to the neoclassical transport, correlations among flow, turbulence and transport were also discussed based on presentations from HSX (core density turbulence and plasma flows) and LHD (toroidal flows and turbulence, electromagnetic Gyrokinetic simulation in finite-beta plasmas). Because such issues have been rapidly evolving among several Stellarator-Heliotron devices, the establishment of a new session or identifying a new key person was proposed, to further activate collaborations on this topic.

Plasma startup

In Stellarator-Heliotron devices, current-free plasmas have been produced by 1st/2nd harmonic ECH or (in LHD) tangential NBI. No successful plasma startup by NBI only in mediums-size devices such as Heliotron J and TJ-II. Successful startup is required in W7-X. Reliable startup at low toroidal electric field is an important issue in superconducting tokamaks. These have been programmatically investigated in ITPA IOS (Integration Operation Scenario) topical group, and Heliotron J and TJ-II have contributed to it. Multi-device experiments and analyses have been made for detailed characterization of plasma startup, and better understanding for modelling. As the kick-off of this plasma startup session, (1) issues of plasma startup in Stellarator-Heliotron plasmas, (2) 2nd harmonic ECH breakdown in Heliotron J, LHD, WEGA and prediction for W7-X, (3) modeling of NBI startup in LHD and W7-AS and the possibility of plasma startup by NBI in W7-X, and (4) effects of Ohmic induced toroidal electric field were reported, all along with the modelling efforts. A joint paper on ECH breakdown has been in preparation.

Energetic particles, Alfvén eigenmodes

Database activity of Alfvén eigenmodes has been developing among H-1NF, Heliotron J and LHD. Data mining tool has been upgraded (updated clustering). Effects of ECH/ECCD on Alfvén eigenmodes have been programmatically investigated among Heliotron J, LHD and TJ-II. Among them, in Heliotron J, GAE (Global Alfvén eigenmode) has been targeted for comparison with TJ-II results, and it has passed domestic (Japan) selection process towards coming 25th IAEA Fusion Energy Conference as the joint paper. Anomalous transport and loss of energetic particles by MHD instabilities are also the main topic (3 devices mentioned above). STELLGAP code has been upgraded to consider the coupling between shear Alfvén wave and acoustic wave. Beta-induced Alfvén eigenmodes (BAE) including EGAM (energetic particles-driven GAM), which are observed in many devices, will be examined by STELLGAP from the viewpoints of low frequency modes in gap caused by Alfvén and acoustic waves.

3D equilibrium

The programmatic validation and cross-benchmarking initiative for 3D equilibrium calculations (involving 11 codes from 6 institutions) was introduced. Stellarator symmetric tokamak equilibrium with small non-axisymmetric perturbations (ELM suppression experiments in DIII-D, shot 146058) allows participation of wide range of equilibrium codes. Calculations have found disagreement between VMEC and linearized tokamak codes, and the source of disagreement has not yet been resolved. Dedicated run day for scanning key plasma parameters and I-coil spectral scans is under planning to widen the database for guiding validation and cross-benchmarking. Joint activity utilizing Stellarator-Heliotron experiment was recommended. The big impacts of the toroidal current on the magnetic topology especially in low magnetic

shear configurations were pointed out, and this issue has been systematically investigated in W7-X (VMEC/EXTENDER, HINT2) and TJ-II (HINT2). Some of them will be reported as the plenary talk in the coming EPS (June 2014 in Berlin) by J.Geiger (IPP-Greifswald). Comparative studies on Heliotron J should be started. Helical core in RFP and 3D displacement for tokamaks are also emerging collaborative topics in 3D equilibrium.

International Stellarator-Heliotron Confinement and Profile Database (ISH-CDB, PDB)

The long history of ISH database was reviewed, in terms of the evolutions of global energy confinement scalings (ISS95, ISS04), and from CDB to PDB with equilibrium database. Re-examination of iota dependence in ISS04 ($\sim \iota^{0.41}$) was proposed exploiting the extended TJ-II data (wide scan of ι is available) for reducing collinearity of ι with geometrical parameters such as the aspect ratio. Extension of HSX data (recent 1T operation) was also proposed. Recent TASK3D extension in LHD has enabled to sequentially produce 0D data in CDB, so that registrations from LHD are foreseen. A.Kus (IPP-Greifswald), who has devotedly contributed for ISH-CDB and PDB, will retire this September. He has used the statistical analysis software, JMP. At this occasion, he prepares his scripts to be widely available as a basis for future extension. These will be uploaded in the ISH-DB web page. Trial of the statistical approach for deducing ion and electron heat diffusivities for wide-range LHD plasmas (say, "LHD profile database") was also introduced.

Framework of collaborations

Restructuring fusion activities in Europe, EUROFUSION, was explained along with the EFDA roadmap to the realization of fusion energy (<http://www.efda.org/wpcms/wp-content/uploads/2013/01/JG12.356-web.pdf>). Stellarators are part of roadmap, as an alternative approach, and to mitigate risks such as on steady-state operation and plasma startup. Focus is put on HELIAS line. It is mentioned that work on other helical concepts (heliotron, compact stellarators) will continue as a part of international collaborations. In this regard, CWGM is highly plausible in EUROFUSION activity. TJ-II experimental plans were introduced to emphasize that plans are very much aligned with EUROFUSION work programmes. SSO CG (Steady State Operation Coordination Group) activity was also introduced. This activity has been formulated by calling the participation of related IEA (International Energy Agency) Implement Agreements and national laboratories. Among 7 work packages, there is a "roadmap to SSO", for which Stellarator-Heliotrons should contribute a lot. It was agreed to hold a brain-storming meeting (video-conference) between T.Mutoh (NIFS) and A.Dinklage (IPP) along with interested colleagues (such as the steady-state operation theme group in LHD). The outcome from that meeting will be reported in the next CWGM.

Miscellaneous

There was a proposal for setting up a "steering group" for CWGM activity, to facilitate organizational discussions such as the prioritization of topics, session organization etc. M.Yokoyama (NIFS) was appointed to initiate discussions on this issue. It was also recommended to report this setting up of the steering group to Executive Committee of the IEA Implementing Agreement on Co-operation in Development of the Stellarator-Heliotron Concept.

At the end of the meeting, there raised a proposal, from A.Dinklage (IPP-Greifswald), to hold the next 14th CWGM in Europe. CWGM activity has been recognized in EUROFUSION (see, "Framework of collaborations") as one of the international collaborative frameworks. It recommends holding the meeting, one in abroad and one in Europe, in a year. Based on recent increased interests on stellarator concept in Hungary and Poland, he will contact them for inquiring the possibility to hold the next CWGM in one of these 2 countries.

2 AUSTRALIA

2.1 International collaborations in 2014

The Australian Plasma Fusion Research Facility at the Australian National University houses the H-1 heliac and the MAGPIE linear device described below. H-1 is a three-period helical axis stellarator with a flexible magnetic topology that allows fundamental studies in plasma confinement and stability, turbulence and flows, and confinement transitions at moderate heating power. Because of its coil-in-tank construction, the device is an ideal test bed for the development of advanced active and passive imaging diagnostic technologies from microwave through to optical frequencies. The MAGPIE materials interaction device shares this infrastructure.

2014 marked the completion of the infrastructure ~US\$7M upgrade under the Australian Government's Super Science Scheme. Enhancements to the Facility included a 2x200kW 4-20MHz RF heating system, the MAGPIE device, two discharge cleaning systems and other measures for impurity control, a number of multi-channel and imaging optical diagnostics, and a simple URL-based interface to data with consistency of access from simple browsing to detailed raw data. These will enable future growth of Australian capability in fusion science and engineering, and as a focus for collaboration within the Australian community, will support the development of world-class diagnostic systems for application to international facilities in preparation for ITER.

The performance of the new 21 channel imaging interferometer was improved by incorporating specially designed sub-millimetre structures on the interfaces of several components to reduce reflections. A three-view optical emission imaging system successfully acquired data in synchronism with the MHD signals from the Mirnov coils. Using CII light as a proxy for electron density, this provided excellent two dimensional data, and some three dimensional information. The operational range of the RF was extended to 4MHz, the lower limit of the new sources, to allow ion cyclotron heating of deuterium. This, along with the 21 channel interferometer has enabled magnetic field scans over a wider range to investigate the scaling of the dispersion properties of the observed MHD modes, with minimal variation in the RF heating mechanism.

As part of a longer term strategy that aims for an Australian involvement with ITER, upgrade funding has supported the development of a prototype linear, high power-density satellite device "MAGPIE", utilizing the H-1 heating, power and diagnostic systems. This is the first device in the Materials Diagnostic Facility, led by Dr. Cormac Corr and was developed in collaboration with Oak Ridge and the Australian Nuclear Science and Technology Organisation (ANSTO), to facilitate development of diagnostics for plasma wall interactions and for characterizing advanced high temperature materials. In collaborations with the Australian Nuclear Science and

Technology Organisation, and several Australian and International Universities, materials including tungsten, its alloys, artificial diamond and carbon samples were exposed to the plasma to observe effects on both the plasma and the impinging plasma. Also, some of advanced material diagnostics available through the Australian Synchrotron and the ANU positron facility were applied to fusion wall samples exposed by our international collaborators.

Other topics advanced in 2014 included diagnosis of complex plasma flows including kHz range fluctuations, and understanding the scaling of the most fusion-relevant plasma conditions achieved ($>10^{19}\text{m}^{-3}$) in helium and hydrogen. This will inform the design of a larger device for continuous operation.

The toroidal plasma activity was strongly endorsed in a review by an international panel with expertise spanning stellarator/heliotrons, tokamaks, theoretical and basic plasma physics and material interactions. The panel recommended the tenured appointment of two mid-career researchers.

Multilateral Collaborations

Work on the international collaboration on MHD and configuration studies under the IEA Implementing Agreement for Co-operation in Development of the Stellarator-Heliotron Concept focussed on automatic mode classification, searching for unusual mode structures, and full integration of auxiliary data from Heliotron J and LHD into the new version of the data mining analysis. The datamining techniques were able to find additional examples of recently discovered mode locking in LHD. 40,000 shots were examined in one day using the new server installed for international collaborators. On H-1, von Mises clustering was applied to new magnetic field and configuration scans, combining two poloidal arrays and the new 16 element, 3 axis helical arrays, and a joint grant proposal was submitted with Spanish and Japanese partner investigators.

One and two-dimensional coherence imaging (CI) systems developed by Prof Howard at ANU underpin collaborations with USA, and EU members. These include

(EU) An imaging MSE system is installed on the ASDEX-U upgrade and first measurements obtained. The results have been validated against a standard multiple discrete channel polarimeter.

(US) With LLNL and General Atomics, application of Doppler CI systems for imaging flows in the DIII-D divertor and scrape-off-layer. A similar system has been deployed on the MAST divertor for tomographic reconstruction of divertor flows during L and H modes, and ELM events. First results were presented by Dr S Silburn at an invited talk at the High Temperature Plasma Diagnostics meeting in 2014.

Collaborations between ANU, IPP (J.Svensson), and the Culham Centre for Fusion Energy (L.C.Appel) have complementary stellarator and compact toroidal components. The project, which was supported by an Australian International Science Linkages grant, aims to develop Bayesian techniques for the integration of various diagnostic data, building on pioneering development of the technique on W7-AS. Joint publications in 2014 included a review of the subject. In an application to H-1, Dr von Nessi and Michael began developing forward models for He line ratios, for application in a Bayesian inference framework for electron temperature and density estimation.

MRxMHD Equilibrium Code: Significant progress was demonstrated in a collaboration between the ANU (R. Dewar, M. Hole, G. Dennis, B. Blackwell, M. McGann, A. Gibson, G. Von Nessi), PPPL (S. Hudson), RFX-mod (Dr Dominique Escande, David Terranova) and CCFE (Prof. Richard Dendy) on the development of a new variational approach - multi region relaxed MHD (MRxMHD) for calculating 3D plasma equilibria with islands. In 2014, Em. Prof R.L.Dewar spent 2 weeks at PPPL working with Dr. S.Hudson on theoretical issues related to development the new MRxMHD equilibrium code SPEC. Dr Dennis published two papers that extended the MRxMHD principle to include plasma flow and anisotropy. The formulation with plasma flow added constraints of flow helicity and toroidal angular momentum [Phys. Plasmas 21, 042501 (2014)], while the formulation with anisotropy added constraints of anisotropy plasma entropy and magnetic moment. A/Prof. Hole presented an invited talk on developments in both MRxMHD and anisotropy projects to the International Congress on Plasma Physics in October, and the IAEA Fusion Energy Conference in November. Prof. Dewar published calculations of plasmoid solutions of the Hahm–Kulsrud–Taylor equilibrium model, which illustrate how a magnetically sheared plasma slab driven by a resonant periodic boundary perturbation results in fully shielded (current sheet) and fully reconnected (magnetic island) responses. PhD student Craig Bowie, under the co-supervision of Prof. Richard Dendy, computed avalanche statistics from a sand pile model, and was able to reproduce characteristic waiting time statistics from JET experiments.

Collaborations with EU

An existing collaboration between C.Nührenberg and A.Koenies of IPP Greifswald, J.Bertram, R.Dewar, B.Blackwell, S.Haskey, J.Howard, M.McGann, G.Von Nessi, M.Fitzgerald and M.Hole of the ANU, which involves comparing the experimental observations of MHD activity with eigenvalue calculations using the CAS3D code and the wave-particle interaction code CAS3D-K, was expanded to commence work on continuum damping in 3D. In 2014, George Bowden spent three weeks at Greifswald funded by a DAAD grant between the Group of Eight research intensive Australian Universities and German Academic Exchange Service. During this time, he worked with collaborator Axel Koenies to include continuum damping into ideal MHD code CKA. In October Michael Cole visited the ANU for three weeks to conduct drive calculations for H-1 scenarios using the CKA-EUTERPE code suite

In 2014 the burning plasma project focused on the formulation of stability for anisotropic plasmas, and the inclusion of anisotropy into continuum mode code CSCAS-A and global mode code MISHKA-A. A paper on the configuration changes in the presence of anisotropy and a review were published.

Collaborations with JAPAN

In addition to the multilateral datamining collaboration, the following were active in 2014: Drs. C. Michael, M.Yokoyama and K Tanaka on turbulence and transport.

Collaborations with USA

In addition to the multilateral MRxMHD collaboration, and the D3D divertor studies the following were active in 2014:

- 1) A joint collaborative project with Oak Ridge National Laboratories (Dr Juergen Rapp and Dr Larry Owen) involves modeling of recycling in the MAGPIE device. The work was presented at the 21st International Conference on Plasma Surface Interactions in Controlled Fusion Devices in 2014.

- 2) ANU, PPPL, DIII-D and CCFE – The effect of 3D magnetic perturbations on edge plasma. Comprehensive parameter scans and experimental comparisons of the plasma response to a variety of applied 3D field structures, were performed with the MARS-F code, and correlated with outcomes such as ELM suppression to aid in understanding the underlying mechanism

Workshops and Conferences

Drs Blackwell and Hole presented papers which included the 3D computational collaboration at the IAEA Fusion energy conference in St Petersburg. Associate Prof. Hole represented Australia at the 53rd IFRC meeting and presented research highlights, described the successful Upgrade Launch of the Australian Plasma Fusion Research Facility, and circulated the fusion science strategic plan the Australian community released in July. The Council indicated growing support for more formal Australian participation in the International Tokamak Physics Activity.

In early December 2014 Prof. Howard chaired the Australian Institute of Physics Congress, hosted by the ANU, which attracted over 700 delegates from most areas of physics. The field of plasma physics was represented by a highly successful plenary lecture given by Prof. Steve Cowley (CEO of the Culham Centre for Fusion Energy), and four oral and two poster sessions. Associate Prof. Hole and Dr Corr convened plasma lectures at a Summer School attended by ~70 prospective graduate students.

2.2 Future Research Plans

Enabled by the upgrade, configuration studies will focus on expanded configuration scans and magnetic field scans of Alfvén-driven instabilities. Multi-channel plasma density and polarization interferometers and multi-channel spectroscopic detectors will provide profile information for configuration studies and mode structure of Alfvénic instabilities. We hope to replace the original H-1 RF antenna with a design based on the new Uragan Alfvén antennas in collaboration with that group.

International collaboration on CI optical systems for spectro-polarimetric imaging will continue in 2015 and beyond. In the coming year, this work will embrace the following activities:

Following successful first data, a second Doppler imaging camera is planned for wide field of view divertor flow and temperature tomography on DIII-D.

Combined with fast, gated CCD cameras, newly developed passive spatial heterodyne CI systems will be deployed for synchronous detection of velocity distribution function perturbations associated with magnetic fluctuations in the H-1 heliac.

In future years we hope to deploy CI imaging systems for edge physics studies in the W7-X stellarator. The recent success of Doppler imaging on the DIII-D tokamak divertor is a valuable guide in future planning.

We are developing multiple-carrier spatial heterodyne CI systems that should allow extended capability for imaging of more complex spectral scenes and exploring Zeeman-assisted Doppler tomography of inhomogeneous magnetized plasma such as the tokamak divertor.

Utilizing the linear satellite device, we aim to trial imaging Stark effect and some new concepts in optical radar-based range sensing with the ultimate goal (subject to appropriate funding) to develop a prototype imager for monitoring tile erosion in high power fusion devices.

Under the expanded collaboration on the MRxMHD project the SPEC code will be applied to MAST with an RMP field, to investigate control of magnetic surfaces between different relaxed regions via external coils. In 2015 the burning plasma project will focus on computing the impact of anisotropy on global modes. A new postdoc, Dr Brett Layden, has been appointed to compute wave-particle interactions using HAGIS in the presence of anisotropy, and thereby determine the impact of anisotropy on performance limiting global Alfvén eigenmodes.

The Australian Heliac program at the ANU has produced several technological spin-offs that are now attracting support independent of the fusion program. These include technology for long distance, non-line-of-sight VHF digital wireless communications in rural Australia (the BushLAN project), and optical coherence imaging (CI) spectroscopy systems for use in process control in steel production. A demonstration of a new type of multiple path MIMO wireless communications technology to potential investors is near completion and has attracted interest from several quarters.

Finally, the Australian fusion science community will continue endeavours to secure funding to develop plasma fusion science in Australia, including prototype diagnostic concepts using the new capabilities of the H-1 facility for one or more plasma diagnostics for ITER. In 2014, the community released a new strategic plan, "Powering Ahead: " This replaced and updated the original 2007 fusion science strategic plan, taking into account funding developments over the intervening years and changes to research funding schemes.

3 EU

3.1 GERMANY

3.1.1 International collaborations in 2014

Collaborations with EU

- 1) P. Cottier (CEA Cadarache) to IPP Greifswald, 10.01. – 14.01.2014
- 2) H. Smith (IPP) to Chalmers Göteborg (Sweden), 28.02. – 09.03.2014
- 3) P. Helander (IPP) to CCFE Culham (GB), 08.03. – 16.03.2014
- 4) A. Könies (IPP) to ENEA (Italy), 10.03. – 15.03.2014
- 5) P. Helander (IPP) to Uni Aalto (Finland), 19.03. – 21.03.2014
- 6) H. Oosterbeek (Eindhoven University of Technology) and Y. Ma (ITER) to IPP, 24.03. – 26.03.2014
- 7) S. Marsen (IPP Greifswald) visited CCFE Culham, 12.05. - 23.05.2014

- 8) J. Connor (CCFE Culham) to IPP Greifswald, 15.05. – 28.05.2014
- 9) D. Pacella (ENEA, Italy) to IPP Greifswald, 20.05. – 22.05.2014
- 10) S. Akäslompolo and T. Kurki-Suonio (TEKES, Finland) to IPP Greifswald, 26.05. – 28.05.2014
- 11) P. Holmvall (Chalmers Göteborg) to IPP Greifswald, 31.05. – 31.10.2014
- 12) M. Kubkowska, A. Czarnecka and E. Pawelec (IPPLM, Poland) to IPP Greifswald, 08.06. – 14.06.2014
- 13) M. Preynas (IPP Greifswald) visited CEA Cadarache, 16.06. – 20.06.2014
- 14) J.-P. Traverre (CEA, France) to IPP Greifswald, 23.-27.06.2014
- 15) S. Newton (CCFE Culham) to IPP Greifswald, 01.07. – 05.07.2014
- 16) J.-P. Traverre (CEA, France) to IPP Greifswald, 06.07. – 09.07.2014
- 17) S. Schmuck (CCFE Culham) to IPP Greifswald, 07.07. – 11.07.2014
- 18) R. Zagorski (IPPLM, Poland) to IPP Greifswald, 13.07. – 26.07.2014
- 19) G. Pelka (IPPLM, Poland) to IPP Greifswald, 13.07. – 09.08.2014
- 20) E. Sanchez (CIEMAT) to IPP Greifswald, 27.07. – 02.08.2014
- 21) M. de Baar (FOM Institute DIFFER and Eindhoven University of Technology) to IPP Greifswald, 28.07. – 30.07.2014
- 22) P. Helander (IPP) to CEA Cadarache (France), 08.08. – 10.08.2014
- 23) F. Manke (Imperial College London) to IPP Greifswald, 18.08. – 27.09.2014
- 24) O. Marchuk (Forschungszentrum Jülich) to IPP Greifswald, 01.09. – 05.09.2014
- 25) G. Plunk, J. Proll and P. Xanthopoulos (IPP) to University Lisbon (Portugal), 11.09. – 18.09.2014
- 26) H. Peraza (University Carlos III Madrid) to IPP Greifswald, 14.09. – 25.10.2014
- 27) A. Mollen (Chalmers Göteborg) to IPP Greifswald, 14.09. – 26.09.2014
- 28) M. Kubkowska, L. Ryc, J. Kaczmarczyk, W. Figacz and I. Ksiazek (IPPLM, Poland) to IPP Greifswald, 28.09. – 03.10.2014
- 29) W. Kernbichler (ÖAW, Austria) to IPP Greifswald, 12.10. – 25.10.2014
- 30) B. Carvalho (TECNICO, Portugal) to IPP Greifswald, 02.11 – 06.11.2014
- 31) T. Szabolics (WIGNER, Hungary) to IPP Greifswald, 09.11. – 05.12.2014
- 32) G. Cseh, T. Szepesi and G. Kocsis (WIGNER, Hungary) to IPP Greifswald, 16.11. –

05.12.2014

- 33) W. Cooper and J. Faustin (EPFL, Switzerland) to IPP Greifswald, 18.11. – 21.11.2014
- 34) M. Mantsinen (BSC, Spain) to IPP Greifswald, 18.11. – 21.11.2014
- 35) A. Mollen (Chalmers Göteborg) to IPP Greifswald, 07.12. – 19.12.2014
- 36) Collaboration with NCBJ in Swierk, Poland for the construction and installation of the NBI heating system, numerous visits between IPP, NCBJ and industry

Collaborations with Japan

- 1) E. Winkler (IPP Greifswald), delegation to NIFS, 01.01. - 31.12.2014
- 2) S. Nishimura (NIFS) to IPP Greifswald, 17.02. – 27.02.2014
- 3) A. Kus (IPP Greifswald) visited Kyoto University and NIFS, 24.02. – 07.03.2014
- 4) A. Dinklge (IPP Greifswald) visited Kyoto University, 25.02. – 01.03.2014
- 5) G. Kawamura (NIFS) to IPP Greifswald, 03.03. – 06.03.2014
- 6) H. Tanaka (NIFS) to IPP Greifswald, 03.03. – 08.03.2014
- 7) Y. Suzuki (NIFS) to IPP Greifswald, 24.03. – 28.03.2014
- 8) N. Marushchenko (IPP Greifswald) visited NIFS, 14.04. – 16.04.2014
- 9) N. Marushchenko (IPP Greifswald) visited Kyoto, 17.04. – 18.04.2014
- 10) F. Wagner (IPP) visited Kyushu University, 21.-28.05.2014
- 11) Y. Suzuki (NIFS) to IPP Greifswald, 27.06. – 04.07.2014
- 12) G. Kawamura (NIFS) to IPP Greifswald, 17.06. – 04.07.2014
- 13) S. Murakami (NIFS) to IPP Greifswald, 29.06. – 03.07.2014
- 14) M. Yokoyama (NIFS) to IPP Greifswald, 30.06. – 18.07.2014
- 15) H. Yamaguchi (Kyoto University) to IPP Greifswald, 07.09. – 20.09.2014
- 16) T. Stange (IPP Greifswald) visited Kyoto University and NIFS, 03.11. – 22.11.2014
- 17) M. Krychowiak (IPP Greifswald) visited NIFS, 03.11 – 14.11.2014
- 18) Y. Feng (IPP Greifswald) visited NIFS, 03.11. – 15.11.2014

Collaborations with Russia

- 1) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 03.03. – 18.04.2014
- 2) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 14.10. – 12.12.2014

- 3) F. Wagner (IPP) visited St. Petersburg State Polytechnical University, 14.09. - 21.09.2014

Collaborations with Ukraine

n.a.

Collaborations with USA

- 1) J.P. Allain, D. Curreli and D. N. Rasic (University of Illinois) to IPP Greifswald, 12.01. – 13.01.2014
- 2) B. Faber (University of Wisconsin, Madison) to IPP Greifswald, 19.01. – 30.01.2014
- 3) G. Wurden (LANL) to IPP Greifswald, 02.-08.02.2014
- 4) J. Proll (IPP Greifswald) to PPPL, 24.03. – 31.05.2014
- 5) H.-S. Bosch, T. Klinger, T. Sunn Pedersen (IPP Greifswald) visited University of Wisconsin, Madison (Wisconsin, USA), 06.-12.04.2014
- 6) D. Gates and N. Pablant (Princeton Plasma Physics Laboratory) to IPP Greifswald, 21.04. – 26.04.2014
- 7) J. Loizu (IPP Greifswald) to PPPL, 28.04. – 31.12.2014
- 8) J. Proll (IPP Greifswald) to University of Madison, 11.05. – 17.05.2014
- 9) G. Wurden (LANL) to IPP Greifswald, 11.06.-01.08.2014
- 10) J. Hudson (University Auburn, USA) to IPP Greifswald, 15.06. – 18.06.2014
- 11) R. Prater (General Atomics), D. Andruczyk and D. Curreli (University of Illinois) to IPP Greifswald, 29.06. – 19.07.2014
- 12) P. Fflis (University of Illinois) to IPP Greifswald, 06.07. – 12.07.2014
- 13) D. Andruczyk (University of Illinois) to IPP Greifswald, 31.08. – 20.09.2014
- 14) A. Press (University of Illinois) to IPP Greifswald, 01.09. – 12.09.2014
- 15) P. Fflis (University of Illinois) to IPP Greifswald, 07.09. – 19.09.2014
- 16) F. A. Volpe (Columbia University) to IPP Greifswald, 21.09. – 23.09.2014
- 17) D. Gates and S. Lazerson (Princeton Plasma Physics Laboratory) to IPP Greifswald, 28.09. – 03.10.2014
- 18) J. Proll (IPP Greifswald) to PPPL, 29.09. – 07.12.2014
- 19) G. Wurden (LANL) to IPP Greifswald, 10.-23.10.2014
- 20) D. Gates and N. Pablant (Princeton Plasma Physics Laboratory) to IPP Greifswald, 08.12. – 12.12.2014

Conference participation

- 1) M. Dostal, E. Foerstel, O. Ford, H. Hoelbe, H.P. Laqua, U. Hergenbahn, M. Preynas, A. Rodatos, T. Stange: DPG-Jahrestagung, Berlin (Germany), 17.03. – 21.03.2014
- 2) M. Preynas: 18th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, Nara (Japan), 22.04. – 25.04.2014
- 3) R. König: 20th Topical Conference High-Temperature Plasma Diagnostics, Atlanta (Georgia, USA), 01.06. – 05.06.2014
- 4) C. Biedermann, M. Borchardt, S. Bozhenkov, A. Dinklage, M. Drevlak, Y. Feng, J. Geiger, M. Hirsch, U. Hergenbahn, A. Kleiber, R. Kleiber, H.P. Laqua, A. Langenberg, N. Marushchenko, T. Sunn Pedersen, G. Plunk, J. Proll, J. Riemann, H. Saitoh, H. Smith, E. Stenson, H. Thomsen, Y. Turkin, F. Wagner, D. Zhang: 41st EPS Conference on Plasma Physics, Berlin (Germany), 23.06. – 27.06.2014
- 5) R. König: QIRT 2014 (Thermography Conference), Bordeaux, 07.07. – 11.07.2014
- 6) H. Braune, H.P. Laqua, T. Stange: 26th Joint Russian-German Workshop, Nizhny Novgorod (Russia), 21.07. – 31.07.2014
- 7) M. Cole, G. Plunk and A. Zocco: Joint Varenna-Lausanne International Workshop, Varenna (Italy), 01.09. – 05.09.2014
- 8) R. König: Workshop on Exploratory Topics in Plasma and Fusion Research (EPR) and US-Japan Compact Torus (CT) Workshop, 05.08. – 08.08.2014, Madison, Wisconsin, USA
- 9) F. Warmer: 28th Symposium on Fusion Technology, San Sebastian (Spain), 29.09. – 03.10.2014
- 10) B. Heinemann, P. McNeely, R. Nocentini: 4th International Symposium on Negative Ions, Beams and Sources, Garching (Germany), 06.10. – 10.10.2014
- 11) A. Dinklage, P. Helander, M. Jakubowski, A. Mishchenko: 25th Fusion Energy Conference, Saint Petersburg (Russia), 13.10. – 18.10.2014
- 12) J. Loizu, T. Sunn Pedersen, J Proll, J. Stanja: 56th Annual Meeting of the American Physical Society Division of Plasma, New Orleans (USA), 27.10. – 31.10.2014
- 13) H. Saitoh, E. Stenson: 11th International Workshop on Non-Neutral Plasmas, Takamatsu City (Japan), 31.11.-05.12.2014

Participation in joint projects

International stellarator/heliotron profile data base

Contributions from A. Dinklage, A. Kus, C. Beidler, H. Maaßberg, S. Marsen

ITPA diagnostics

- 1) R. König: 26th Meeting of the ITPA Topical Group on Diagnostics, Pohang University of Science and Technology, 19. - 22.05. 2014
- 2) R. König: 27th Meeting of the ITPA Topical Group on Diagnostics, ITER IO,

Cadarache (France), 03.11. - 07.11.2014

ITPA confinement and transport

Contributions from M. Jakubowski and A. Dinklage (3D working group within the ITPA Transport and Confinement group, TC24)

M. Jakubowski, ITPA conference, Boston (Massachusetts, USA), 07.-13.04.2014

ITPA edge and pedestal

n.a.

ITPA Fast Particles

- 1) A. Könies and M. Cole: 12th ITPA Energetic Particle Physics TG Meeting, Madrid (Spain), 30.03. – 03.04.2014
- 2) A. Könies: 13th ITPA Energetic Particle Physics TG Meeting, Padua (Italy), 20.10. – 24.10.2014

3.1.2 Plans for 2015

The 20th International Stellarator–Heliotron Workshop will take place in Greifswald 05.10. – 09.10.2015 with an expected 150 participants from across the world.

Planning stellarator/heliotron theory

- 1) J. Geiger plans to go to NIFS to work on 3D MHD equilibrium problems
- 2) J. Proll plans visit PPPL to collaborate on gyrokinetic theory for stellarators
- 3) A. Könies will participate in the 14th ITPA EP Meeting in Princeton, and in the 15th such meeting, whose location has not yet been decided.
- 4) J. Loizu plans to spend several months at PPPL to work on MHD equilibrium theory

Spectroscopic diagnostics

- 1) I. Ksiazek (Institute of Physics, Opole University, Opole) plans several visits (each about 1-2 weeks) to IPP Greifswald in the frame of the cooperation concerning the development of the C/O-monitor diagnostic for W7-X.
- 2) A. Langenberg plans to visit Alcator C-Mod for impurity diagnostic experiments using x-ray imaging spectrometer and a multi-energy x-ray camera.

Collaboration with NIFS

- 1) J. Baldzuhn plans to visit NIFS for pellet experiments (2 weeks)
- 2) A. Dinklage plans to visit NIFS for particle transport experiments (2 weeks)
- 3) F. Warmer: collaboration in systems code studies

Neutron diagnostics

Mutual visits (about 1 - 2 per year, each about for 2-3 days) in the frame of collaboration with PTB Braunschweig on the neutron counter system for W7-X are planned to discuss the progress, data analysis, MCNP calculations and the work plan of the project (involving R. Burhenn, W. Schneider).

Microwave diagnostics

H. Oosterbeek (Technical University of Eindhoven) + student(s) will visit IPP: Measurement of microwave stray radiation in the W7-X vessel.

ITPA confinement and transport

- 1) Contributions from M.Jakubowski and A.Dinklage chairs the 3D working group within the ITPA Transport and Confinement group.

ITPA diagnostics

- 1) R. König: 26th Meeting of the ITPA Topical Group on Diagnostics, Pohang University of Science and Technology, 19. - 22.05. 2014, Contributions on: Effect of neutral gas background pressure on Bolometer signals, and on Using SWCNTs for ECRH stray radiation protection of optics.
- 2) R. König: 27th Meeting of the ITPA Topical Group on Diagnostics, ITER IO, Cadarache (France), 03.11. - 07.11.2014, Presentation: Overview of the diagnostics sets available in the first Operation Phases of Wendelstein 7-X and of the EUROfusion contributions and on ECRH stray radiation protection of diagnostics

Collaboration with USA

M. Krychowiak plans to visit University of Wisconsin-Madison for 1-2 weeks to work on the development of atomic models of helium and neon for the helium beam diagnostic.

Collaboration on ECRH, ECCD and ECE Plans 2015

K.Nagasaki (Kyoto University) will visit Greifswald for the Joint research program "Optimization of high power ECRH application to helical fusion plasma confinement systems"

Conference participation 2015

- 1) M. Hirsch, R. König, H. Thomsen: 1st EPS Conference on Plasma Diagnostics, Frascati (Italy), 14.04 - 17.04.2015
- 2) R. König, H. Thomsen: 20th International Stellarator-Heliotron Workshop (ISHW), October 5 - 9, 2015, Greifswald
- 3) J. Fellingner: ISFNT-12 (Fusion Nuclear Technology Conference), Jeju Island, Korea, 14-18 September 2015

3.2 SPAIN

3.2.1 International collaborations in 2014 using TJ-II at CIEMAT

Collaborations with Russia

- 1) S. Perfilov (November-December) of the HIBP Kurchatov Institute team was visiting CIEMAT to investigate the structure of plasma potential and plasma fluctuations in TJ-II and the commissioning of the second HIBP system where secondaries have been successfully detected by the end of 2013.
- 2) Collaboration with General Physics Institute, Moscow on the characterization of the plasma reflected power on gyrotron performance. A final compilation of the experimental results as well as a conclusive data analysis have been carried out during 2014. The results will be sent for its publication. The visiting scientists of GPI involved have been: K. Sarksyian (8-22 May), V. Borzosekov (26 May-26 June), D. Malakhov (14 November-12 December), N. Kharchev (29 October-28 November).

Collaborations in Europe

Germany

- 1) Participation in Eurofusion (S1/S2) programme in the field of theory and modeling on Neoclassical transport and gyrokinetic simulations. J.L. Velasco and D. López Bruna have participated in an inter-machine validation study of neoclassical transport modelling in medium to high density stellarator-heliotron plasmas.
- 2) E. Sánchez spent one week in Greifswald working on gyrokinetic simulations.

Portugal

- 1) C. Hidalgo was visiting IST (November) to study the influence of the isotope effect on plasma confinement and fluctuations in the ISTTOK tokamak.
- 2) C. Silva was visiting CIEMAT (December) to continue our collaboration on edge studies (edge turbulence, asymmetries and transport studies and diagnostic development including RFA and probes) during 2014.

Italy

- 1) D. López-Bruna was visiting RFXmod (November) to discuss the electromagnetic nature of plasma filaments in TJ-II.
- 2) Collaboration with M. Spolaore, E. Martines and the RFXmod team to participate on edge diagnostic development and measurements in TJ-II including the design, development of electromagnetic probes and characterization of the electromagnetic nature of plasma filaments in TJ-II.

Bulgaria

T. Popov was visiting CIEMAT (November) to investigate non-Maxwellian electron distribution functions in the plasma boundary region and the influence of plasma ECRH and NBI heating.

Romania

F L Tabares and D Alegre visited the laboratories of Dr Dinescu at Magurele in the frame of the collaboration on tungsten plasma nitriding as PFC for fusion devices.

The Netherlands

D Alegre visited DIFFER and run experiments in Pilot PSI in the frame of collaboration on tungsten nitrides for PFCs.

Collaborations with USA

- 1) E. Hollmann (USCD) was visiting CIEMAT (1 week, June 2014) working on parallel / radial impurity transport studies and role of Z.
- 2) Álvaro Cappa was invited to join the experiments on the impact of ECRH on Alfvén Eigenmodes that were performed in the DIII-D tokamak in June. He spent one week in the General Atomics facilities in San Diego from June 9th to June 14th.
- 3) F Tabares was visiting the U of Illinois, Urbana, for the fabrication of LISn alloys

Collaborations with Ukraine

- 1) The Heavy Ion Beam Probe team (A.Kozachek and A.Zezhera, leaded by L. Krupnik, Institute of Plasma Physics, National Science Center “Kharkov Institute of Physics and Technology”, Kharkov) has been involved in the characterization of radial electric fields and plasma fluctuations in the TJ-II stellarator during 2013 experimental campaign. The development of the second HIBP system has been finalized and installed (injector and analyzer) in TJ-II with on-going commissioning activities in 2014.
- 2) F. Tabarés was visiting IPP Kharkov to discuss the QSPA project and contribute to the wall conditioning of Uragan 2M.

Collaborations with Japan

- 1) J.L. Velasco visited NIFS during March to discuss on the comparison between two neoclassical approaches (FORTEC-3D and DKES) for TJ-II and LHD.
- 2) F L Tabarés visited NIFS in order to plan the collaboration on the implementation of a supersonic He beam for Ti studies as well as in the characterization of 3-D effects in the plasma boundary of stellarators.

Participation in Joint Projects

Stellarator-Heliotron working groups and ITPA

The 13th Coordinated Working Group Meeting (CGWM) was held in Kyoto in February 2014. Several researchers from CIEMAT participated in the presentation and discussions in several areas such as divertor physics, impurity transport, flows and viscosity, energetic particles (remote) and scientific collaboration framework (remote). The 12th meeting of the ITPA Energetic Particles Physics Topical Group was held in Madrid (April 2014). CIEMAT participation in the meeting was mainly focused in the influence of ECRH on the Alfvén Eigenmodes observed in the TJ-II stellarator. CIEMAT scientists have been also directly involved in the ITPA (T&C and Integrated Operational Scenarios meetings) and activities along 2014. The ITPA energetic particles meeting will be held in Madrid (31 March - 4 April). E. Ascasibar was attending the ITPA Integrated Operational Scenarios meeting (MIT, April / Cadarache October); C. Hidalgo was attending the 12th ITPA Transport and Confinement meetings (April-2013, MIT, US).

3.2.2 Plans for 2015

The main research activity of Euratom – Ciemat association will remain on concept improvement development and on the fusion technology programme with special emphasis on all the different aspects of fusion materials technology. In addition, we will strengthen and continue with our long standing tradition to extend our physics studies to different confinement concepts (tokamak / stellarators), looking for common clues as a fundamental way to investigate basic properties of magnetic confinement beyond any particular concept.

The following research areas are foreseen in the 2015 research programme:

- 1) Stellarator physics: confinement data-base, neoclassical transport, magnetic topology, stellarator optimization and magnetic configuration effects on confinement. These activities are carried out within the framework of the Implementing Agreement for Co-operation in Development of the Stellarator-Heliotron Concept.
- 2) Plasma diagnostic development and engineering: Diagnostic developments for TJ-II will continue and in a wider context for ITER (with emphasis on reflectometry, VIS-IR spectroscopy) and W7-X (reflectometry, impurity transport physics, fuelling and interplay between large and short scale radial electric fields) as well a supersonic He beam for Ti edge profile measurements in LHD.
- 3) Plasma heating (NBI, ECRH) and their role on fast particles driven modes.
- 4) Physics of advanced confinement scenarios: transport barrier physics, isotope effect, impurity transport and stability (including the role of magnetic well and density limit).
- 5) Theory and modelling of plasma transport, stability and equilibrium with emphasis on island dynamics and breaking of nested surface topology (3-D effects) and Gyrokinetic theory.
- 6) Validation activities of stellarator-specific transport models will continue at TJ-II in collaboration with NIFS and IPP Greifswald.
- 7) Plasma – wall studies, exploring plasma-wall interaction scenarios with Li coating and CPS Li-liquid limiter concepts in the search for a candidate material (Li/Sn/Ga) that offers all the required properties.
- 8) Data acquisition, control and advanced data analysis techniques.

Collaborations with Russia

A. Melnikov and L. Eliseev and members of the HIBP Kurchatov Institute team will visit CIEMAT to investigate the structure of plasma potential in ECRH and NBI plasmas (in Lithium coated wall conditions) and measurements using two HIBP systems for zonal flows experiments in the core plasma region.

Collaborations in Europe

Germany

- 1) E. Sánchez will visit Greifswald (Germany) to work on gyrokinetic theory.

- 2) A. Alonso, J. L. Velasco and I. Calvo will visit Greifswald to discuss ongoing impurity studies including role of poloidal asymmetries and underlying mechanisms.
- 3) T. Estrada, E. Blanco, B. van Milligen, A. de la Peña and L. Pacios will visit Greifswald for the installation and commissioning of the Doppler reflectometry, and its control and data acquisition system. In addition, T. Estrada and E. Blanco will be involved in the first W7-X operation campaign (OP1.1).

Portugal

- 1) C. Silva and I. Nedzelskiy will visit CIEMAT to continue our collaboration on edge studies using arrays of Langmuir probes, Retarding Field Analyzers (RFA) and reflectometry.
- 2) C. Hidalgo will visit IST to study the influence of the isotope effect on plasma confinement and fluctuations in the ISTTOK tokamak

Italy

- 1) Collaboration with M. Spolaore / E. Martinez and the RFXmod team to participate on edge diagnostic development and measurements of electromagnetic turbulence and isotope physics in TJ-II.
- 2) C. Hidalgo will visit RFXmod to study the influence of the isotope effect on plasma confinement and fluctuations in the RFXmod Reversed Field Pinch.

United Kingdom

Calvo will visit the University of Oxford to work on gyrokinetic theory and optimized stellarator concepts.

The Netherlands

Exposure of Li to PILOT-PSI PSI plasma

Slovenia

Recombination constants for H atoms on lithium

Czech Republic

Implementation of a He beam diagnostic in COMPASS for edge characterization.

Collaborations with USA

- 1) E. Hollmann (USCD) will visit CIEMAT (June 2015) to work on impurity transport studies in TJ-II.
- 2) Collaboration with U. Illinois Urbana (Dr Ruzic) on Sn/Li alloys for fusion

Collaborations with Ukraine

- 1) L. Krupnik and HIBP team will visit TJ-II for investigation of the structure of radial electric fields using HIBP diagnostic (Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology). The second HIBP system has been design for long-range correlation studies (zonal flows) full operation is foreseen in 2015.

- 2) F.LTabares. Collaboration on QSPA and PWI issues in Uragan 2M

Collaborations with Japan

- 1) Collaboration on fast particle physics with Japanese institutions will continue. Joint experiments will be performed in TJ-II on March 2015. The visiting scientists likely to be involved will be K. Nagaoka (NIFS), S. Yamamoto (Kyoto Univ.), T. Ido (NIFS) and A. Shimizu (NIFS).
- 2) Based on the TJ-II experience with the pellet injector developed by ORNL, we plan to explore the viability of TESPEL system developed by NIFS (N. Tamura et al.,).
- 3) M. Shoji (NIFS) will visit CIEMAT (March) to discuss recent results on edge transport studies using fast visible cameras in TJ-II / LHD.
- 4) C. Hidalgo will visit NIFS to participate in the Workshop on the strategy of stellarator / heliotron research (March)
- 5) J.L. Velasco will visit NIFS in order to discuss on experimental results and neoclassical simulations with the code FORTEC-3D
- 6) F. Castejón and D. López-Bruna will visit NIFS to perform experiments on magnetic topology and island dynamics.
- 7) A. Alonso will visit NIFS to participate in the discussion of asymmetries as possible causes of the outward impurity convection in LHD.
- 8) Supersonic He beam for Ti profile reconstruction in LHD (Dr Morisaki)
- 9) Exposure of liquid Li to ELMs loads in the MCPG device (Dr Kikuchi)

International stellarator/heliotron working groups / ITPA

Ciemat staff will participate in the forthcoming CWGM and ITPA meetings to be held along 2015.

4 JAPAN

4.1.1 International collaborations by NIFS

Collaborations with EU

- 1) M. van Berkel (Eindhoven University of Technology) visited NIFS (N. Tamura) from November 21, 2013 November 20, 2014 with a JSPS Postdoctoral Fellowship to join the LHD experiments regarding a electron heat transport.
- 2) M.Brombin (Consorzio RFX) visited NIFS (Y.Takeiri) from 13 to 31 Jan. 2014 for collaborations on NBI.
- 3) G.Serianni (Istituto Gas Ionizzati CNR) visited NIFS (Y.Takeiri) from 13 to 24 Jan. 2014 for collaborations on NBI.
- 4) H.Nakano (NIFS) visited Institute of ionized gas (IGI) from January 27th to

February 21th, 2014 to discuss on the joint experiments performed in negative hydrogen ion sources at NIFS and IGI.

- 5) P.Veltri (Consorzio RFX) visited NIFS (Y.Takeiri) from 31 Jan. to 27 Feb. 2014 for collaborations on NBI.
- 6) G.Kawamura (NIFS) visited Forschungszentrum Julich from 3 to 15 Feb. 2014 to discuss on impurity transport simulation modeling.
- 7) G.Kawamura (NIFS) visited Max-Planck-Institut fur Plasmaphysik Greifswald from 2 to 8 Mar. 2014 to discuss on plasma simulation modeling of a linear device.
- 8) J.M.Garcia-Regaña (IPP) visited NIFS (S.Satake) from 3 to 13 Feb. 2014 for collision operator in neoclassical transport code.
- 9) P.Agostinetti (Consorzio RFX) visited NIFS (Y.Takeiri) from 9 to 27 Feb. 2014 for collaborations on NBI.
- 10) K.McCarthy, J.L.Velasco and F.L.Tabares (CIEMAT) visited NIFS (M.Yokoyama, N.Tamura, M.Kobayashi and S.Satake) from 3 to 7 Mar. 2014 for discussions on collaboration issues in the framework of CWGM.
- 11) A.Kus (IPP) visited NIFS (M.Yokoyama) from 3 to 7 Mar. 2014 for joint work on International Stellarator-Heliotron Database.
- 12) K.Nagaoka (NIFS) visited Ciemat (Madrid) from 9th March to 16th March, 2014 to join TJ-II experiments on the energetic particle driven MHD modes and the effect of ECH on the mode stability.
- 13) N.Tamura (NIFS) visited CIEMAT from to March 11, 2014 to March 22, 2014 to discuss the installation of the TESPEL injector on TJ-II device for promoting a collaborative research on the impurity transport in helical plasmas.
- 14) D.Moseev (IPP) visited NIFS (K.Tanaka) from 9 to 23 Mar. 2014 to discuss on the collective Thomson scattering measurement.
- 15) C.J.Ham and T.C.Hender (Culham Center for Fusion Energy) visited NIFS from 10 to 14 Mar. 2014 to attend the ITPA MHD meeting.
- 16) G.Pautasso (IPP) visited NIFS from 10 to 14 Mar. 2014 to attend the ITPA MHD meeting.
- 17) P.Martin (Consorzio RFX) visited NIFS from 10 to 14 Mar. 2014 to attend the ITPA MHD meeting.
- 18) A.Portone (Fusion for Energy Spain) visited NIFS from 10 to 14 Mar. 2014 to attend the ITPA MHD meeting.
- 19) C.Abellan (ICFO-The Institute of Photonic Sciences, Spain) visited NIFS (S.Satake) from 24 to 28 Mar. 2014 for tests of random parameter generator for its application.

- 20) M.Shoji (NIFS) visited to CIEMAT in Spain from 16 to 24th, March, 2014 to attend a dust trajectories observation experiment in the TJ-II and to discuss on the future international collaboration plan between NIFS and CIEMAT.
- 21) L.Antonio and M.Tomáš (Institute of Physics AS, Czech Republic, HiLASE Project) visite NIFS (R.Yasuhara) on 18 Apr. 2014 for discussions on laser for Thomson Scattering system.
- 20) T.Micolas (Institut de Recherche sur la Fusion Magnétique, IRFM) has stayed NIFS from 25 Apr. 2014 (to 24 Apr. 2016) to promote MHD simulations in LHD.
- 21) H.Yamada (NIFS) visited IPP-Greifswald in May 2014 for discussions on collaborations between NIFS and IPP.
- 22) K.Ikeda (NIFS) stayed at IPP-Garching from 19 May to 30 Nov. 2014 to study negative hydrogen behavior in RF negative hydrogen ion source for NBI.
- 23) K.Y.Watanabe (NIFS) visited Carlos III University from 25 May to 15 June, 2014 for collaborations on saturation mechanism of interchange modes.
- 24) M.Klaus (IPP) visited NIFS (H.Sugama) from 27 to 30 May 2014 for discussions on numerical scheme based on fluid and kinetic models.
- 25) C.Suzuki (NIFS) stayed at University College Dublin (Ireland) from 31 May to 9 Nov. 2014 for collaborations on atomic-molecular process. (During this stay, he also attended W7-X/LHD Joint Collaboration Workshop (Greifswald) and International Conference on atomic-molecular data and its application (Jena University))
- 26) P.Innocente (Conorzio RFX) visited NIFS (T.Morisaki) on 2 Jun. 2014 for discussions on fueling and plasma-wall interaction.
- 27) S.Satake (NIFS) visited CIEMAT, Spain from 2 to 20 June, 2014 to discuss with J. L. Velasco about inter-code verification and validation of neoclassical transport simulation for helical plasmas, and prepared an oral presentation concerning the collaboration at 41th EPS conference on plasma physics.
- 28) S. Satake (NIFS) visited IPP-Garching, Germany from 29 June to 12 July, 2014 to discuss with J. M. Garcia-Regaña about inter-code verification and validation of neoclassical transport simulation for helical plasmas
- 29) M.Kobayashi (NIFS) attended 41st EPS and EMC3 Workshop (Berlin) from 22 to 29 June 2014.
- 30) G.Kawamura (NIFS) visited Berlin from 25 to 27 Jun. 2014 to attend a workshop on development of EMC3-EIRENE code.
- 31) K.Tanaka, I.Yamada, R.Seki, T.Kobayashi and S.Okamura (NIFS) attended 41st EPS (Berlin) in Jun. 2014.
- 32) M.Yokoyama (NIFS) visited Max-Planck Institute for Plasma Physics (Greifswald) from 29 June to 20 July to attend the LHD/W7-X Joint workshop and to discuss/work on the extension of International Stellarator-Heliotron Profile Database and on statistical analysis of database.

- 33) K.Ida (NIFS) attended 41st EPS (Berlin) and W7-X/LHD Joint Collaboration Workshop (IPP-Greifswald) from 22 Jun. to 5 Jul. 2014.
- 34) B.J.Peterson (NIFS) attended 41st EPS (Berlin) and W7-X/LHD Joint Collaboration Workshop (IPP-Greifswald) from 18 Jun. to 6 Jul. 2014.
- 35) G.Kawamura (NIFS) visited Max-Planck-Institut fur Plasmaphysik Greifswald from 30 Jun. to 6 Jul. 2014 to attend a workshop on W7-X and LHD collaborations.
- 36) Y.Yoshimura (NIFS) visited IPP-Greifswald from 1 to 3, July 2014 to discuss on the collaboration between NIFS and IPP.
- 37) S.Masuzaki, T.Tokuzawa, I.Yamada, H.Tsuchiya and K.Saito attended W7-X/LHD Joint Collaboration Workshop from 1 to 3 Jul. 2014, held in IPP-Greifswald.
- 38) H.Sugama and M.Nunami (NIFS) visited CIEMAT from June 28 to July 6, 2014 to attend the Gyrokinetic Theory Working Group Meeting and discuss gyrokinetic theory and simulation of turbulent transport in toroidal plasmas.
- 39) U.Czarnetzki (RUB, Germany) visited NIFS (S.Yoshimura) from 5 to 10, Aug. 2014 to discuss the collaborative research on plasma spectroscopy using optical vortex laser.
- 40) S.Toda (NIFS) attended Varenna Workshop Theory of Fusion Plasmas (Italy) from 30 Aug. to 7 Sep. 2014.
- 41) T Goto (NIFS) visited CCFE from 1 to 5, Sep, 2014 to discuss on the improvement of the cost model in systems codes.
- 42) T.Kobayashi (NIFS) attended EU-US Transport Taskforce 2014 (Culham Centre for Fusion Energy) from 7 to 13 Sep. 2014.
- 43) K.Ichiguchi (NIFS) visited University of Carlos III in Madrid, Spain from 8 to 12 September, 2014 to discuss the MHD simulation with Dr. B.A.Carreras.
- 44) K.Ichiguchi (NIFS) attended 17th International Congress on Plasma Physics held in Lisbon, Portugal, from 15 to 19 September, 2014.
- 45) S.Yoshimura (NIFS) visited the Instituto Superior Técnico, Lisbon, Portugal to attend the 17th International Congress on Plasma Physics (ICPP2014) from 13 to 21, Sep. 2014. He gave a poster presentation entitled "Intermittent Generation of Localized Higher Electron Temperature Regions in a Weakly-Ionized Electron Cyclotron Resonance Plasma"
- 46) M.Kisaki (NIFS) visited Consorzio RFX from 14 to 29 Sep. 2014 for collaborations on beam physics.
- 47) Y.Takeiri (NIFS) visited IPP-Garching from 5 to 12 Oct. 2014 to attend the 4th International Symposium on Negative Ions, Beams and Sources NIBS2014.
- 48) H.Nakano (NIFS) joined the 4th International Symposium on Negative Ions, Beams and Sources held at Garching, Germany on October 6th to 10th, 2014.

- 49) K.Saito (NIFS) visited San Sebastian, Spain from 29, Sep to 3, Oct, 2014 to attend 28th Symposium on Fusion Technology.
- 50) S.Hamaguchi (NIFS) attended SOFT2014 (Spain) from 27 Sep. to 5 Oct. 2014.
- 51) A.Komori, K.Ida, I.Yamada and H.Tsuchiya (NIFS) attended ICPP 2014 (Lisbon, Portugal) in Sep. 2014.
- 52) K.Tsumori, H.Nakano and M.Kisaki (NIFS) visited IPP-Garching from 5 to 12 Oct. 2014 to attend the 4th International Symposium on Negative Ions, Beams and Sources NIBS2014.
- 53) K.Saito, H.Tamura, Y.Hishinuma and J.Yagi (NIFS) attended 29th Symposium on Fusion Technology (Spain) from 27 Sep. to 5 Oct. 2014.
- 54) N.Ashikawa (NIFS) is staying at IPP-Garching from 26 Oct. 2014 to 31 Jan. 2015 to investigate of hydrogen/deuterium retentions and influences of helium bombardments on ferritic steels
- 55) K.Ichiguchi (NIFS) visited Carlos III University (Spain), and then attended ICPP2014 (Portugal) from 11 to 20 Oct. 2014.
- 56) M.Osakabe (NIFS) attended ITPA Energetic Particles (Consorzio RFX, Padova, Italy) from 21 to 25, Oct. 2014
- 57) D.Kato (NIFS) visited International Centre for Theoretical Physics, Trieste, Italy, from 3 to 7, Nov, 2014 to attend and give the invited talk in 2014 Joint ICTP-IAEA Conference on Models and Data for Plasma-Material Interaction in Fusion Devices.
- 58) S.Okamura (NIFS) visited Max-Planck Society Administrative Headquarter (Germany) and Wien University (Austria) from 25 to 30 Nov. 2014.
- 59) O.Slezak (Institute of Physics AS, Czech Republic, HiLASE Project) visited NIFS (R.Yasuhara) from 6 Oct. to 12 Nov. 2014 for discussions on laser for Thomson Scattering system.
- 60) J.Geiger (Max-Planck Institute fuer Plasmaphysik, Germany) visited NIFS (Y. Suzuki) from 3rd to 22nd November 2014 to discuss applications of HINT2 code to Wendelstein 7-X.
- 61) P. Vincenzi (Consorzio RFX) is staying NIFS (M.Osakabe, M.Yokoyama) from 3 Nov. 2014 to 16 Jan.2015 for improving and applying integrated transport code, TASK3D-a.
- 62) Y. Feng (IPP, Greifswald) visited NIFS (M.Kobayashi) from 3 Nov. 2014 to 14 Nov. 2014 to discuss on the edge modeling of LHD with EMC3-EIRENE.
- 63) T.Stange (IPP) visited NIFS (Y.Yoshimura) from 17 to 22 Nov. 2014 for collaborations on RF heating.
- 64) K.Maciej (IPP) visited NIFS (T.Morisaki) from 4 to 14 Nov. 2014.

Collaborations with Russia

- 1) **The 25th IAEA Fusion Energy Conference was held in St.Petersburg from 13 to 18 Oct. 2014.** A.Komori, H.Yamada, A.Sagara, T.Mutoh, K.Ida, M.Kobayashi, W.Hao, H.Miura, T.Seki, M.Yokoyama, S.Sudo, M.Yoshinuma, Y.Narushima, S.Sakakibara, S.Ohdachi, T.Kobayashi, I.Murakami, M.Shoji, K.Mukai, A.Ishizawa, G.Kawamura, D.Kato, A.Itoh, X.Du, M.Nunami, Y.Suzuki, K.Ichiguchi, Y.Todo, K.Nagaoka, T.Shimozuma, M.Osakabe, H.Kasahara, N.Yanagi (including individual list below) participated from NIFS.
- 2) I.Tolistikhina (P.N. Lebedev Physical Institute) visited NIFS (D.Kato) from 3 to 7 Feb. 2014 for atomic process on W impurity in plasmas.
- 3) S.Konovalov, V.Lukash and V.Pustovitov (Kurchatov Institute) visited NIFS from 10 to 14 Mar. 2014 to attend the ITPA MHD meeting.
- 4) S.Kubo (NIFS) attended 9th International Workshop on Strong Microwaves and Terahertz waves (Nizhnij Novgorod Applied Physics Institute) from 23 Jul to 1 Aug. 2014.
- 5) V.N.Leonid (Budker Nuclear Physics Institute) visited NIFS (K.Tanaka) from 15 Sep. to 18 Oct. 2014 for discussions on diagnostics development for turbulence fluctuations based on CO2 laser.
- 6) S.Sudo (NIFS) discussed with I. Viniar (PELIN, Russia) about the collaboration on the TECPEL activity for LHD, and discussed with V. Sergeev (State Polytechnical University, St. Petersburg, Russia) about the collaboration on the NIOS system for LHD during the IAEA-FEC 2014 conference (13-18 October 2014) at St. Petersburg.
- 7) K.Nagaoka (NIFS) visited St. Petersburg from 12th Oct. to 20th Oct. 2014 to participate in the IAEA Fusion Energy Conference and make an oral presentation on the integration of ion and electron ITBs in the LHD.
- 8) A.Komori (NIFS) attended 25th IAEA Fusion Energy Conference and the 43rd Executive Committee Meeting of the IEA Stellarator-Heliotron Implementing Agreement from 12 to 19, Oct. 2014 (St.Petersburg, Russia).
- 9) H.Yamada (NIFS) attended 25th IAEA Fusion Energy Conference and the 43rd Executive Committee Meeting of the IEA Stellarator-Heliotron Implementing Agreement from 12 to 19, Oct. 2014 (St.Petersburg, Russia)
- 10) S.Kubo (NIFS) attended 25th IAEA Fusion Energy Conference and the SSOCG-4 from 12 to 19, Oct. 2014 (St.Petersburg, Russia).
- 11) T.Mutoh (NIFS) attended 25th IAEA Fusion Energy Conference, SSOCG-4 and the 43rd Executive Committee Meeting of the IEA Stellarator-Heliotron Implementing Agreement from 12 to 20, Oct. 2014 (St.Petersburg, Russia).
- 12) M.Yokoyama (NIFS) attended 25th IAEA Fusion Energy Conference and the 43rd Executive Committee Meeting of the IEA Stellarator-Heliotron Implementing Agreement from 12 to 20, Oct. 2014 (St.Petersburg, Russia).

Collaborations with USA

- 1) H.Miura (NIFS) visited the Institute for Fusion Studies, University of Texas at Austin from Feb. 9 to March 31, 2014 to study for numerical simulations of plasma in a heliotron device, by making use of the sabbatical leave system of NIFS.
- 2) S.Yoshimura (NIFS) visited PPPL and the University of Wisconsin-Madison to discuss basic plasma experiments related with magnetic reconnection and dynamo effects from 16 to 23, Feb. 2014. He gave a seminar presentation on intermittent local electron flux in a linear ECR plasma
- 3) A.Bader (Univ. Wisconsin-Madison) visited NIFS (M.Kobayashi) from 3 to 7 Mar. 2014 for discussions on divertor simulations.
- 4) H.Tsuchiya (NIFS) visited University of California, San Diego on 2014.3.3 to discuss the startup of collaboration study.
- 5) C.Deng (Univ. Wisconsin-Madison) visited NIFS (K.Nagaoka) on 4 Mar. 2014 to discuss on plasma flows and collaborations between NIFS and UW.
- 6) H.Tsuchiya (NIFS) visited Oak Ridge National Laboratory on 2014.3.5 to discuss the startup of collaboration study.
- 7) H.Tsuchiya (NIFS) visited Princeton Plasma Physics Laboratory on 2014.3.7 to discuss the startup of collaboration study.
- 8) M.Okabayashi (PPPL), M.J.Lanctot and E.J.Strait (General Atomics), R.Granetz (MIT), F.L.Waelbroeck (U.Texas), J.J.Koliner (U.Wisconsin) visited NIFS from 10 to 14 Mar. 2014 to attend US-Japan Workshop and the ITPA MHD meeting.
- 9) K.Tanaka (NIFS) attended ITPA Transport and Confinement (MIT) from 9 to 13 Apr. 2014.
- 10) S.Ohdachi (NIFS) visited General Atomics from 8 to 19 May 2014 for collaborations on DIII-D.
- 11) R.Yasuhara (NIFS) visited Univ. Wisconsin from 21 to 25 May 2014 for discussions on Thomson scattering diagnostics.
- 12) K.Ogawa (NIFS) visited Atlanta from 1 to 5 June, 2014 to present the design of a neutron profile monitor diagnostics in LHD.
- 13) T.Oishi (NIFS) visited Atlanta, USA from 1 to 5 June, 2014 to participate the 20th Topical Conference on High-Temperature Plasma Diagnostics (HTPD 2014).
- 14) K.Mukai (NIFS) participated in 20th Topical Conference on High Temperature Plasma Diagnostics (HTPD 2014) in Atlanta (USA) from 1 to 7, June, 2014 to present "Improvement of an infrared imaging video bolometer with a semi-tangential view in LHD"
- 15) T.Akiyama (NIFS) attended HTPD2014 (Intercontinental Hotel Buckhead) from 1 to 8 Jun. 2014 to give an invited talk.
- 16) S.Kubo, A.Shimizu, K.Ogawa and S.Kamio (NIFS) attended HTPD2014 from 1 to 7 Jun. 2014.

- 17) M.Goto (NIFS) attended 22nd emission profile workshop (Tennessee Univ.) from 1 to 8 Jun. 2014.
- 18) M. Ono (PPPL) visited NIFS from June 2, 2014 to June 3, 2014 to discuss a future plan of the collaborative research between helical plasma (LHD) and spherical torus plasma (NSTX-U).
- 19) A.S.Sabau (ORNL) visited NIFS (M.Tokitani) on 3 Jun. 2014 for discussions on heat-load tests.
- 20) D.Nishijima (UCSD) visited NIFS (S.Masuzaki) from 5 to 6 Jun. 2014.
- 21) J.W.Van Dam (DOE) visited NIFS (S.Masuzaki) on 14 Jul. 2014 for discussions on recent research in NIFS and future collaborations with US-institutions.
- 22) A.Y.Pankin (Tech-X Corporation) stayed NIFS from 16 Jun. to 16 Sep. 2014 as a JIFT visiting professor (contact: M.Yokoyama) for implementing uncertainty-quantification scheme in TASK3D-a.
- 23) S.Imagawa and Y.Hishinuma (NIFS) attended Applied Superconducting Conference 2014(Chalotte) from 10 to 16 Aug. 2014.
- 24) K.Tanaka (NIFS) visited General Atomics from 24 Aug. to 7 Sep. 2014 for US-Japan collaboration.
- 25) J.B.Caughman and C.H.Lau (ORNL) visited NIFS (S.Kubo) on 16 Sep. 2014 for discussions on RF heating physics.
- 26) T.Shimozuma, H.Kasahara and T.li (NIFS) attended Japan-US-Europe workshop on RF heating technology (Sedona, USA) from 21 to 26 Sep. 2014.
- 27) K.Ogawa (NIFS) visited PPPL from 29 Oct. to 9 Nov. 2014 for discussions on spatial profile measurement of fusion reaction.
- 28) S.Yoshimura (NIFS) visited the New Orleans Marriott Hotel, New Orleans, LA, USA to attend the 56th Annual Meeting of the American Physical Society Division of Plasma Physics (APS-DPP 2014) from 26 Oct. 2014 to 2, Nov. 2014. He gave a poster presentation entitled "Plasma Spectroscopy Using Optical Vortex Laser".
- 29) K.Ida, S.Morita, S.Sakakibara, H.Sugama and S.Toda (NIFS) attended 56th APS-DPP from 26 Oct. to 2 Nov. 2014.
- 30) S.Ohdachi (NIFS) attended 56th APS-DPP and 19th US-Japan MHD Workshop (New Orleans) from 26 Oct. to 7 Nov. 2014.
- 31) K.Ogawa (NIFS) visited Princeton Plasma Physics Laboratory from 30 Oct. to 7 Nov., 2014 to discuss the neutron calibration method in NSTX-U and get the knowledge to do the neutron calibration in LHD.
- 32) S.Hudson (PPPL) visited NIFS (Y. Suzuki) from 3rd to 11th November. He studied the chaotic coordinate system in non-axisymmetric tori and its application to the LHD. This collaboration result was reported at 24th International Toki Conference (Toki, Japan, Nov. 2013). Future plans are also discussed.
- 33) Y.Hirooka (NIFS) visited PPPL for collaboration and then attended TOFE2014 from

6 to 15 Nov. 2014.

- 34) A.Sagara and T.Muroga (NIFS) attended 21st Topical Meeting on the Technology of Fusion Energy (TOFE) from 9 to 15 Nov. 2014 (USA).
- 35) J.W.Ahn (Oak Ridge National Laboratory, USA) visited NIFS (M.Kobayashi) from 6 to 13 Dec. 2014 to join the experiments on divertor foot print in LHD.
- 36) D.Nishijima (UCSD) visited NIFS (M.Tokitani) from 12 to 26 Dec. 2014 for joint experiment on LHD.

4.1.2 Plans for 2015

- 1) I.Yamada (NIFS) will attend the 1st EPS Plasma Diagnostic conference (Frascati, Italy) from 14 to 17, April, 2015.
- 2) I.Yamada (NIFS) will attend the 42nd EPS Plasma Physics conference (Lisbon, Portugal) from 22 to 26, June, 2015.
- 3) Y.Suzuki (NIFS) will visit General Atomics (San Diego, USA) February 2015 to discuss 3D MHD modeling of tokamaks with resonant magnetic perturbation. These collaboration results will be reported at EPS2015 (Lisbon, Portugal, Jun. 2015)
- 4) Y.Suzuki (NIFS) will visit Max-Plank Institute fuer Plasmaphysik (Greifswald, Germany) and Forschungszentrum Juelich GmbH (Juelich, Germany) in March 2015 to discuss 3D MHD equilibrium calculation of Wendelstein 7-X. These collaboration results will be reported at ISHW2015 (Greifswald, Germany, Oct. 2015)
- 5) Many NIFS researchers will attend the 20th International Stellarator-Heliotron Workshop (Oct. 2015, Greifswald)

4.1.3 Collaborations by the Heliotron J team at Kyoto University Collaborations with EU

- 1) S.Yamamoto visited CIEMAT on 9 to 17 March, 2014. He numerically analysed shear Alfvén spectra including Alfvén continua and discrete eigenfunctions of TJ-II plasma by using 3D numerical code “STELLOGAP” and “AE3D” with Francisco Castejón. He adjusted the parameters in numerical codes to analyse MHD equilibrium and magnetic field spectra in Boozer coordinate for the codes “STELLOGAP” and “AE3D” with Antonio López Fraguas.
- 2) S. Ohshima visited CIEMAT, Spain on March 9th-17th, 2014 for discussion of the joint experiment conducted in 2013 regarding the structural change of turbulence and long-range correlation observed with Langmuir probes. In this year, we discussed further analysis results for the response of long-range correlation to the radial electric field, which support a theoretical prediction for the relationship between long range correlation and neoclassical viscosity.
- 3) Nikolai Marushchenko visited Kyoto University on April 17th and 18th, 2014. He conducted a collaboration research on ECH/ECCD physics with K. Nagasaki. They have been developing a ray tracing calculation code “TRAVIS” for the Heliotron J device to calculate the EC power deposition and EC driven current efficiency. The

TRAVIS code was also applied to an interferometer system of Heliotron J to calculate the beam trajectory for designing the transmission system.

- 4) Torsten Stange (Postdoctoral fellow, Max-Planck Institute) visited Kyoto University from Nov. 4 to Nov. 17, 2014. Concerning plasma production, non-resonant heating using 2.45GHz microwaves in stellarator/heliotron devices, he joined the Heliotron J experiment. He measured gamma rays produced by high-energy electrons during 2.45GHz microwave heating, and scanned the amount and timing of gas puffing to optimize the plasma production using NBI, and compare with a simulation. He also made a presentation of recent research activities on plasma production using 2.45GHz and 70GHz microwaves in the WEGA stellarator.
- 5) Alvaro Cappa (CIEMAT, Spain) submitted a paper entitled "Second harmonic ECRH breakdown experiments in the TJ-II stellarator" to Nuclear Fusion Journal, which is related to plasma breakdown using 2nd harmonic X-mode ECH in TJ-II. K. Nagasaki discussed plasma production mechanism with him and is a co-author of this paper.
- 6) Discussions with W7 team (IPP) were kept along the same line as in 2013.
- 7) Collaborations with CIEMAT were continued along the same lines as in 2013.

Collaborations with Australia

Discussions with H-1 team (ANU) were kept along the same line as in 2013.

Collaborations with US

- 1) Chuanbao Deng (Honorary fellow, University of Wisconsin, USA) visited Kyoto University from Feb. 23 to March 6, 2014 for collaboration research on relationship between flow and turbulence in advanced helical systems such as the Heliotron J and HSX devices. He has been developing a diagnostic for density fluctuation measurement in HSX using a technique of microwave interferometry. He has reported broadband turbulent fluctuation that correlates with plasma density gradient and flow. C.B. Deng and S. Kobayashi discussed the experimental data of the density fluctuation by BES and plasma flow obtained by CXRS in Heliotron J.
- 2) K. Nagasaki will discuss reflectometer system and its application to measurement on density profile and density fluctuation with K. Likin and D. Anderson (U. Wisconsin).
- 3) Discussions with the HSX (Wisconsin Univ.) team and CTH (Auburn Univ.) team, groups of ORNL and PPPL, etc.) were kept along the same line as in 2013.

Collaborations with Ukraine

Discussions with Kharkov team about the collaboration in U-2M project were kept along the same line as in 2013.

Collaborations with Russia

Discussions with Kurchatov Institute related to development of advanced

stellarator/heliotron systems were kept along the same line as in 2014.

Others

- 1) Kyoto University hosted the 13th Coordinated Working Group Meeting (CWGM) held at Kyoto University on February 26th-28th, 2014. About 30 people attended the meeting, including Aaron Bader, Chuanbao Deng (Univ. Wisconsin), Allan Reiman (PPPL), Andreas Dinklage, Andreas Kus, Melanie Preynas, Dorothea Gradic, Felix Warmer, Robert Wolf (IPP), Enrique Ascasibar, Kieran McCarthy, Jose-Luis Velasco, Arturo Alonso, Alvaro Cappa, Francesco L. Tabares (CIEMAT) on site or through internet. They discussed database analysis for confinement and plasma profiles, three dimensional transport in divertor, impurity transport, reactor/system code, transport analysis related to flow and viscosity, plasma production, energetic-particle-driven MHD modes, three dimensional equilibrium and collaboration structure
- 2) T. Mizuuchi, S. Kobayashi, S. Yamamoto and S. Ohshima attended 25th Fusion Energy Conference held at Saint Petersburg, Russia on October 13th-18th, 2014. They presented recent experimental results on Heliotron J, especially high-density plasma sustainment using novel fuelling methods, toroidal flow measurement concerning neoclassical transport, stabilization of energetic-particle-driven MHD instabilities using ECCD and measurement of turbulence and structure at edge region using Langmuir probes. They discussed the future collaboration research with researchers from TJ-II, W7-X, H-1 and HSX.
- 3) A new gas fuelling by high-intense gas puffing (HIGP) was successfully applied to ECH/NBI plasma in Heliotron J. The core electron density reached $1 \times 10^{20} \text{ m}^{-3}$. The collaboration of fuelling control studies are being discussed with TJ-II team and NIFS.

4.1.4 Plans for 2015

- 1) The Heliotron group will participate in next international stellarator/heliotron workshop which is planned to be held at Greifswald, Germany in 2015.
- 2) Gavin Weir (Univ. Wisconsin) will join the Heliotron J group from January, 2015 for one year as a post-doctoral fellow, supported by JSPS. He will be engaged in experimental study on anomalous electron heat transport using an ECE radiometer.
- 3) Francesco Volpe and his PhD student plan to visit Kyoto University for collaboration research on the EBE diagnostic. He will develop a polarizer to measure the polarization of O-mode emitted from a Heliotron J plasma.
- 4) Manuel Garcia-Munõz (University of Sevilla, Spain) plan to visit at Kyoto University for research collaboration on the energetic ion driven MHD instabilities and their effect on energetic ion confinement in both tokamaks and stellarator/heliotron plasmas.
- 5) Plasma fluctuations and structural formation at core and edge regions will be continued to be measured with using diagnostics including a beam emission spectrometer, a reflectometer, SX array, Langmuir probes and fast CCD cameras under collaboration with CIEMAT, IPP and Stuttgart University and domestic

universities.

- 6) Confinement improvement of particle, momentum and energy, especially the role of toroidal and poloidal rotation, will be investigated by controlling particle fuelling method and magnetic field configuration under collaboration with Kharkov Institute and CIEMAT.
- 7) Confinement control of high-energy particles by using the optimized field configuration based on the quasi-isodynamic concept will be examined through Heliotron J NBI/ICRF experiments.
- 8) Internal transport barrier will be experimentally investigated in Heliotron J, which is observed in low-density ECH plasmas. The necessary conditions for forming the internal transport barrier will be clarified, and will be compared with
- 9) MHD instabilities such as interchange instabilities and Alfvén Eigenmode instabilities in low-magnetic shear configurations will be studied from the viewpoint of magnetic island control and suppression of energetic-ion loss under collaboration with CIEMAT and IPP.
- 10) Research on NBI start-up using 2.45GHz microwaves will be continued for high-beta experiments and physics study of plasma production under collaboration with IPP.
- 11) ECCD experiments using 2nd harmonic 70GHz X-mode will be performed for control of MHD instabilities through rotational transform modification under collaboration with IPP, CIEMAT and NIFS.
- 12) Electron Bernstein heating/current drive and Electron Bernstein emission diagnostics are prepared for overdense plasma heating and electron temperature profile measurement under collaboration with IPP and Columbia University.
- 13) Particle and heat transport control of edge plasmas will be investigated with regard to divertor optimization.
- 14) Kyoto University and NIFS made an application of Joint research projects related to ECRH and ECCD physics and technology between Germany and Japan to Japan Society for the Promotion of Science. If approved, personal exchange including researchers and students will be performed.

5 RUSSIA

25th IAEA Fusion Energy Conference (FEC2014) was held in St. Petersburg from 13 to 18 October 2014. (Hosted by the Government of the Russian Federation through the State Atomic Energy Corporation ROSATOM)

<http://www-pub.iaea.org/iaeameetings/46091/25th-Fusion-Energy-Conference-FEC-2014>

Collaborations with Germany

- 1) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 03.03. – 18.04.2014
- 2) M. Mikhailov (Kurchatov Institute Moscow) to IPP Greifswald, 14.10. – 12.12.2014
- 3) F. Wagner (IPP) visited St. Petersburg State Polytechnical University, 14.09. - 21.09.2014

Collaborations with Spain

- 1) S. Perfilov (November-December) of the HIBP Kurchatov Institute team was visiting CIEMAT to investigate the structure of plasma potential and plasma fluctuations in TJ-II and the commissioning of the second HIBP system where secondaries have been successfully detected by the end of 2013.
- 2) Collaboration with General Physics Institute, Moscow on the characterization of the plasma reflected power on gyrotron performance. A final compilation of the experimental results as well as a conclusive data analysis have been carried out during 2014. The results will be sent for its publication. The visiting scientists of GPI involved have been: K. Sarksyian (8-22 May), V. Borzosekov (26 May-26 June), D. Malakhov (14 November-12 December), N. Kharchev (29 October-28 November).

Collaborations with Japan

- 1) I.Tolistikhina (P.N. Lebedev Physical Institute) visited NIFS (D.Kato) from 3 to 7 Feb. 2014 for atomic process on W impurity in plasmas.
- 2) S.Konovalov, V.Lukash and V.Pustovitev (Kurchatov Institute) visited NIFS from 10 to 14 Mar. 2014 to attend the ITPA MHD meeting.
- 3) S.Kubo (NIFS) attended 9th International Workshop on Strong Microwaves and Terahertz waves (Nizhnij Novgorod Applied Physics Institute) from 23 Jul to 1 Aug. 2014.
- 4) V.N.Leonid (Budker Nuclear Physics Institute) visited NIFS (K.Tanaka) from 15 Sep. to 18 Oct. 2014 for discussions on diagnostics development for turbulence fluctuations based on CO₂ laser.
- 5) S.Sudo (NIFS) discussed with I. Viniar (PELIN, Russia) about the collaboration on the TECPEL activity for LHD, and discussed with V. Sergeev (State Polytechnical University, St. Petersburg, Russia) about the collaboration on the NIOS system for LHD during the IAEA-FEC 2014 conference (13-18 October 2014) at St. Petersburg.

Collaboration with Kurchatov Institute, Moscow, Russia

- 1) Dr. L.I. Krupnik and HIBP team (IPP NSC KIPT) in collaboration with Dr. A.V. Melnikov and T-10 team (Kurchatov Institute).
- 2) Joint development of two kinds of the probing beam diagnostics for new tokamak T-15. (two HIBP systems and Injection of the neutral atoms Li⁰ and Na⁰).
- 3) Investigation of the nature of Ti ion emission and increase intensity of the probing beam.

- 4) Study of the plasma potential and density and their fluctuations by upgraded HIBP system in regimes with high plasma density. Comparative study of the GAMs (and AEs) behavior in the T-10 tokamak and TJ-II stellarator during ECR heating with high intensity heavy ion probing beam.

6 UKRAINE

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

6.1 International collaborations of the NSC KIPT in 2014

Multilateral Collaboration

V.V.Nemov, S.V.Kasilov, V.E.Moiseenko, V.N.Kalyuzhnyj in collaboration with W.Kernbichler, A.F.Martitsch (**Technische universität Graz, Austria**) and O.Agren (**Angstrom Laboratory, Uppsala University, Uppsala, Sweden**) investigated the confinement of high energy ions for a stellarator type trap DRAKON

Collaboration with Technische Universität Graz, Austria

Direct computations of high energy particle losses in optimized stellarators solving the guiding center drift equations in real-space coordinates. (V.V.Nemov, S.V.Kasilov in collaboration with W.Kernbichler).

Collaboration with CIEMAT

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

- 1) Designing, manufacturing and installation new modification of the emitter-extraction system in the probing beam injector of the first HIBP system.
- 2) Tuning of the second HIBP system.

Collaboration with Kurchatov Institute, Moscow, Russia

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

- 1) Joint development of two kinds of the probing beam diagnostics for new tokamak T-15. (two HIBP systems and Injection of the neutral atoms Li0 and Na0).
- 2) Investigation of the nature of Tl ion emission and increase intensity of the probing beam.
- 3) Study of the plasma potential and density and their fluctuations by upgraded HIBP system in regimes with high plasma density. Comparative study of the GAMs (and AEs) behavior in the T-10 tokamak and TJ-II stellarator during ECR heating with high intensity heavy ion probing beam.

Collaboration of with Technische Universität Graz, Austria and Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

V.V.Nemov, S.V.Kasilov and V.N.Kalyuzhnyj continued collaboration aiming the application of NEO-2 to study efficiency of ECCD in tokamaks and stellarators.

6.2 Plans for 2015

Collaboration with Technische universität Graz, Austria

Study of collisionless high energy ion losses in stellarator magnetic fields produced by 3D plasma equilibrium codes.

Collaboration with Spain (CIEMAT, Madrid)

- 1) Upgrade of the first HIBP system for identity of two systems.
- 2) Tuning and start experiments with the second HIBP system.
- 3) Study of the plasma potential and electron density during ECR and NBI heating in different magnetic configurations and regimes of device operation. Study of the plasma potential evolution and its fluctuations (Alfven and non-Alfven modes) in two cross-sections of plasma column in combined NBI/ECRH plasmas by two HIBP systems on TJ-II stellarator.

Collaboration with Russian Kurchatov Institute, Moscow

- 1) Development, production and delivery of the upgraded emitter and extractor block of the accelerator of thallium ions for tokamak of T-10.
- 2) Carrying out joint experiments on receiving a long focusing beam with a high density of ionic current – $300 \mu\text{A}/\text{cm}^2$
- 3) Study of the plasma potential and density and their fluctuations by upgraded HIBP system in regimes with high plasma density. Comparative study of the GAMs (and AEs) behavior in the T-10 tokamak and TJ-II stellarator during ECR heating with high intensity heavy ion probing beam.

Conference and other meetings participation

- 1) V.E. Moiseenko: Meeting on stationary regimes and technological systems of the Thermonuclear Neutron Source (TNS) Moscow, Russia, February 17—18, 2014.
- 2) V.E. Moiseenko: 25th IAEA Fusion Energy Conference (FEC 2014) Saint Petersburg, Russian Federation. 13–18 October 2014.
- 3) V.E. Moiseenko: Second Research Coordination Meeting of the Coordinated Research Project on "Conceptual Development of Steady-State Compact Fusion Neutron Sources". 10 – 12 November 2014, IAEA Headquarters, Vienna, Austria.
- 4) 25 members of Kharkov IPP participated in the International Conference and School on Plasma Physics and Controlled Fusion (Kharkov, September 15-20 2014) with invited, oral and poster presentations.

The tasks planned for study at IPP NSC KIPT in 2015

URAGAN-3M

- 1) Optimization of RF-discharge plasma in U-3M torsatron.
- 2) Studies of plasma flow properties in the helical divertor of the Uragan-3M torsatron in different regimes of RF plasma production and heating. Studies of peripheral plasma characteristics.

- 3) A search for optimum regimes of RF plasma heating in the Uragan-3M torsatron with using the three-half-turn antenna.
- 4) Investigation of RF pre-ionization with the small frame antenna at Uragan-3M device.
- 5) Study of MHD activity of RF-discharge plasma in U-3M torsatron.
- 6) Investigation of toroidal non-uniformity of edge plasma turbulence in the Uragan-3M torsatron.
- 7) Further investigation of the high energy particles behavior in Uragan-3M RF plasmas.
- 8) Investigation of parametric instability at the periphery of plasma confinement volume in Uragan-3M.
- 9) Clearing up the mechanism of suppression of run-away electrons by supplying voltage to the RF antenna.
- 10) Study of energy characteristics of run-away electrons by means of Cherenkov detectors (in cooperation with Institute of Plasma Physics and Laser fusion, Warsaw, Poland)

URAGAN-2M

- 1) First measurements of plasma parameters via HIBP diagnostic (electric plasma potential) in Uragan-2M.
- 2) Evaluation of radial plasma density profiles using dual polarization interferometry for the U-2M plasmas.

PLASMA MODELLING

- 1) Development of a self-consistent multi-ion species model for RF plasma production (in collaboration with LPP ERM/KMS, Belgium).
- 2) Making calculations of neutron distributions in stellarator-mirror fusion-fission hybrid.

7 UNITED STATES

International collaborations in 2014

Collaborations with EU

- 1) J.P. Allain, D. Curreli and D. N. Razic (University of Illinois) to IPP Greifswald, 12.01. – 13.01.2014
- 2) B. Faber (University of Wisconsin, Madison) to IPP Greifswald, 19.01. – 30.01.2014
- 3) G. Wurden (LANL) to IPP Greifswald, 02.-08.02.2014
- 4) J. Proll (IPP Greifswald) to PPPL, 24.03. – 31.05.2014

- 5) H.-S. Bosch, T. Klinger, T. Sunn Pedersen (IPP Greifswald) visited University of Wisconsin, Madison (Wisconsin, USA), 06.-12.04.2014
- 6) D. Gates and N. Pablant (Princeton Plasma Physics Laboratory) to IPP Greifswald, 21.04. – 26.04.2014
- 7) J. Loizu (IPP Greifswald) to PPPL, 28.04. – 31.12.2014
- 8) J. Proll (IPP Greifswald) to University of Madison, 11.05. – 17.05.2014
- 9) G. Wurden (LANL) to IPP Greifswald, 11.06.-01.08.2014
- 10) J. Hudson (University Auburn, USA) to IPP Greifswald, 15.06. – 18.06.2014
- 11) R. Prater (General Atomics), D. Andruczyk and D. Curreli (University of Illinois) to IPP Greifswald, 29.06. – 19.07.2014
- 12) P. Fflis (University of Illinois) to IPP Greifswald, 06.07. – 12.07.2014
- 13) D. Andruczyk (University of Illinois) to IPP Greifswald, 31.08. – 20.09.2014
- 14) A. Press (University of Illinois) to IPP Greifswald, 01.09. – 12.09.2014
- 15) P. Fflis (University of Illinois) to IPP Greifswald, 07.09. – 19.09.2014
- 16) F. A. Volpe (Columbia University) to IPP Greifswald, 21.09. – 23.09.2014
- 17) D. Gates and S. Lazerson (Princeton Plasma Physics Laboratory) to IPP Greifswald, 28.09. – 03.10.2014
- 18) J. Proll (IPP Greifswald) to PPPL, 29.09. – 07.12.2014
- 19) G. Wurden (LANL) to IPP Greifswald, 10.-23.10.2014
- 20) D. Gates and N. Pablant (Princeton Plasma Physics Laboratory) to IPP Greifswald, 08.12. – 12.12.2014
- 21) E. Hollmann (USCD) was visiting CIEMAT (1 week, June 2014) working on parallel / radial impurity transport studies and role of Z.
- 22) Álvaro Cappa was invited to join the experiments on the impact of ECRH on Alfvén Eigenmodes that were performed in the DIII-D tokamak in June. He spent one week in the General Atomics facilities in San Diego from June 9th to June 14th.
- 23) F Tabares was visiting the U of Illinois, Urbana, for the fabrication of LISn alloys

Collaborations with Japan

- 1) H.Miura (NIFS) visited the Institute for Fusion Studies, University of Texas at Austin from Feb. 9 to March 31, 2014 to study for numerical simulations of plasma in a heliotron device, by making use of the sabbatical leave system of NIFS.
- 2) S.Yoshimura (NIFS) visited PPPL and the University of Wisconsin-Madison to discuss basic plasma experiments related with magnetic reconnection and dynamo

effects from 16 to 23, Feb. 2014. He gave a seminar presentation on intermittent local electron flux in a linear ECR plasma

- 3) A.Bader (Univ. Wisconsin-Madison) visited NIFS (M.Kobayashi) from 3 to 7 Mar. 2014 for discussions on divertor simulations.
- 4) H.Tsuchiya (NIFS) visited University of California, San Diego on 2014.3.3 to discuss the startup of collaboration study.
- 5) C.Deng (Univ. Wisconsin-Madison) visited NIFS (K.Nagaoka) on 4 Mar. 2014 to discuss on plasma flows and collaborations between NIFS and UW.
- 6) H.Tsuchiya (NIFS) visited Oak Ridge National Laboratory on 2014.3.5 to discuss the startup of collaboration study.
- 7) H.Tsuchiya (NIFS) visited Princeton Plasma Physics Laboratory on 2014.3.7 to discuss the startup of collaboration study.
- 8) M.Okabayashi (PPPL), M.J.Lanctot and E.J.Strait (General Atomics), R.Granetz (MIT), F.L.Waelbroeck (U.Texas), J.J.Koliner (U.Wisconsin) visited NIFS from 10 to 14 Mar. 2014 to attend US-Japan Workshop and the ITPA MHD meeting.
- 9) K.Tanaka (NIFS) attended ITPA Transport and Confinement (MIT) from 9 to 13 Apr. 2014.
- 10) S.Ohdachi (NIFS) visited General Atomics from 8 to 19 May 2014 for collaborations on DIII-D.
- 11) R.Yasuhara (NIFS) visited Univ. Wisconsin from 21 to 25 May 2014 for discussions on Thomson scattering diagnostics.
- 12) K.Ogawa (NIFS) visited Atlanta from 1 to 5 June, 2014 to present the design of a neutron profile monitor diagnostics in LHD.
- 13) T.Oishi (NIFS) visited Atlanta, USA from 1 to 5 June, 2014 to participate the 20th Topical Conference on High-Temperature Plasma Diagnostics (HTPD 2014).
- 14) K.Mukai (NIFS) participated in 20th Topical Conference on High Temperature Plasma Diagnostics (HTPD 2014) in Atlanta (USA) from 1 to 7, June, 2014 to present "Improvement of an infrared imaging video bolometer with a semi-tangential view in LHD"
- 15) T.Akiyama (NIFS) attended HTPD2014 (Intercontinental Hotel Buckhead) from 1 to 8 Jun. 2014 to give an invited talk.
- 16) S.Kubo, A.Shimizu, K.Ogawa and S.Kamio (NIFS) attended HTPD2014 from 1 to 7 Jun. 2014.
- 17) M.Goto (NIFS) attended 22nd emission profile workshop (Tennessee Univ.) from 1 to 8 Jun. 2014.
- 18) M. Ono (PPPL) visited NIFS from June 2, 2014 to June 3, 2014 to discuss a future plan of the collaborative research between helical plasma (LHD) and spherical torus plasma (NSTX-U).

- 19) A.S.Sabau (ORNL) visited NIFS (M.Tokitani) on 3 Jun. 2014 for discussions on heat-load tests.
- 20) D.Nishijima (UCSD) visited NIFS (S.Masuzaki) from 5 to 6 Jun. 2014.
- 21) J.W.Van Dam (DOE) visited NIFS (S.Masuzaki) on 14 Jul. 2014 for discussions on recent research in NIFS and future collaborations with US-institutions.
- 22) A.Y.Pankin (Tech-X Corporation) stayed NIFS from 16 Jun. to 16 Sep. 2014 as a JIFT visiting professor (contact: M.Yokoyama) for implementing uncertainty-quantification scheme in TASK3D-a.
- 23) S.Imagawa and Y.Hishinuma (NIFS) attended Applied Superconducting Conference 2014(Chalotte) from 10 to 16 Aug. 2014.
- 24) K.Tanaka (NIFS) visited General Atomics from 24 Aug. to 7 Sep. 2014 for US-Japan collaboration.
- 25) J.B.Caughman and C.H.Lau (ORNL) visited NIFS (S.Kubo) on 16 Sep. 2014 for discussions on RF heating physics.
- 26) T.Shimozuma, H.Kasahara and T.Ii (NIFS) attended Japan-US-Europe workshop on RF heating technology (Sedona, USA) from 21 to 26 Sep. 2014.
- 27) K.Ogawa (NIFS) visited PPPL from 29 Oct. to 9 Nov. 2014 for discussions on spatial profile measurement of fusion reaction.
- 28) S.Yoshimura (NIFS) visited the New Orleans Marriott Hotel, New Orleans, LA, USA to attend the 56th Annual Meeting of the American Physical Society Division of Plasma Physics (APS-DPP 2014) from 26 Oct. 2014 to 2, Nov. 2014. He gave a poster presentation entitled "Plasma Spectroscopy Using Optical Vortex Laser".
- 29) K.Ida, S.Morita, S.Sakakibara, H.Sugama and S.Toda (NIFS) attended 56th APS-DPP from 26 Oct. to 2 Nov. 2014.
- 30) S.Ohdachi (NIFS) attended 56th APS-DPP and 19th US-Japan MHD Workshop (New Orleans) from 26 Oct. to 7 Nov. 2014.
- 31) K.Ogawa (NIFS) visited Princeton Plasma Physics Laboratory from 30 Oct. to 7 Nov., 2014 to discuss the neutron calibration method in NSTX-U and get the knowledge to do the neutron calibration in LHD.
- 32) S.Hudson (PPPL) visited NIFS (Y. Suzuki) from 3rd to 11th November. He studied the chaotic coordinate system in non-axisymmetric tori and its application to the LHD. This collaboration result was reported at 24th International Toki Conference (Toki, Japan, Nov. 2013). Future plans are also discussed.
- 33) Y.Hirooka (NIFS) visited PPPL for collaboration and then attended TOFE2014 from 6 to 15 Nov. 2014.
- 34) A.Sagara and T.Muroga (NIFS) attended 21st Topical Meeting on the Technology of Fusion Energy (TOFE) from 9 to 15 Nov. 2014 (USA).
- 35) J.W.Ahn (Oak Ridge National Laboratory, USA) visited NIFS (M.Kobayashi) from 6

to 13 Dec. 2014 to join the experiments on divertor foot print in LHD.

- 36) D.Nishijima (UCSD) visited NIFS (M.Tokitani) from 12 to 26 Dec. 2014 for joint experiment on LHD.
- 37) Chuanbao Deng (Honorary fellow, University of Wisconsin, USA) visited Kyoto University from Feb. 23 to March 6, 2014 for collaboration research on relationship between flow and turbulence in advanced helical systems such as the Heliotron J and HSX devices. He has been developing a diagnostic for density fluctuation measurement in HSX using a technique of microwave interferometry. He has reported broadband turbulent fluctuation that correlates with plasma density gradient and flow. C.B. Deng and S. Kobayashi discussed the experimental data of the density fluctuation by BES and plasma flow obtained by CXRS in Heliotron J.
- 38) K. Nagasaki will discuss reflectometer system and its application to measurement on density profile and density fluctuation with K. Likin and D. Anderson (U. Wisconsin).

APPENDICES: TECHNICAL REPORTS ON 2014 ACTIVITIES

APPENDIX 1: HIGHLIGHTS OF LHD EXPERIMENTS

In 2014, the Large Helical Device (LHD) comes to its 18th experimental campaign (Plasma experiment till 5 Feb. 2015). Progress being made in this experimental campaign will be reported after it finishes and detailed analyses are conducted.

Record parameters newly achieved in 2013 are summarized as follows; (1) Ion temperature (T_i) of 8.1 keV at density (n_e) of $1 \times 10^{19} \text{ m}^{-3}$, and the parameter was extended for integrated high-temperature plasmas having comparable ion and electron temperature, to about 6 keV. In such extension of temperature regime, ICRF wall conditioning and increased ECH power were effectively utilized as discharge scenario in addition to the confinement improvement. (2) Steady state operation of about 48 min. with the temperature of 2 keV and the density of $1.2 \times 10^{19} \text{ m}^{-3}$ was successfully sustained with the heating power of 1.2 MW. The total injected energy reaches 3.36 GJ, which broke LHD's own previous world record. This has been made possible by the ensured stable heating capability and reliable real-time density control. The termination of the discharge was due to the radiation collapse induced by impurity contents such as carbon in plasma.

[Below quoted from the summary section of proceeding for the IAEA-FEC (Overview of transport and MHD stability study and impact of magnetic field topology in the Larger Helical Device, K.Ida et al., OV2/3)]

The non-diffusive terms of the momentum transport and impurity particle transport has been studied in the ion-ITB plasmas. The flip of intrinsic torque and convection of impurity was found. The time scale of the flip is much shorter than the time scale of the change in mean plasma parameters, which imply the sign of the non-diffusive term is directly affected by the turbulence state.

The modulated ECH (MECH) has been applied in order to study the transport in particular focusing on the dynamic response to the perturbation. The dynamic transport analysis for the heat pulse by MECH shows the nonlinear and non-diffusive characteristics of transport. The high frequency component of the perturbation propagates much faster than the fundamental component of the modulation. The toroidal rotation at the LCFS, which has been considered to be zero, is found to be affected by the electron temperature gradient near the LCFS. This fact suggests the change in residual stress associated with the modulation of electron temperature gradient.

The impacts of magnetic topology, in particular, the magnetic island and stochastic magnetic field on the MHD and transport have been extensively studied. A significant reduction of magnetic perturbation without the change in pressure gradients is observed when the magnitude of the RMP field is increased. This shows the direct effect of magnetic topology on MHD instability, which gives a clue for the mechanism of ELM suppression by RMP in tokamaks.

The peaked pressure is observed inside the magnetic island after the pellet injection to the O-point of the magnetic island, which shows the reduction of transport inside the magnetic island. In general, the temperature or density profile is flat. However, this flattening is due to a lack of heat and particle flux inside the magnetic island not due to

the enhancement of transport. The transport itself is found to be even better inside the magnetic island than that outside the magnetic island, which gives a new insight for understanding the transport and MHD stability when RMP is applied, because the RMP produced many magnetic islands near the plasma periphery.

The impacts of stochastization on plasma flow and impurity flux have been studied. In LHD plasmas, good impurity shielding due to the stochastic magnetic field has been experimentally confirmed. In the low-collisional regime, the impurity is shielded by the positive radial electric field, while the frictional force outside the LCFS contributes to the impurity shielding in the high-collisional regime. Therefore, the impurity accumulation takes place only in the narrow parameter space in LHD plasmas. The understanding in physics of the impurity shielding by the stochastic magnetic field can contribute to the prediction of impurity behavior in the plasmas with RMP in future devices.

Such progresses of physics understandings and concurrent parameter extension were presented in the 25th IAEA Fusion Energy Conference (St. Petersburg, Oct. 2014, as listed below), and further progress in 18th campaign will be reported in 20th International Stellarator-Heliotron Workshop (Greifswald, Oct. 2015).

List of presentations from NIFS, 25th IAEA-FEC (2014)
(Only related to this Implementing Agreement)

PAPER#	AUTHOR	TITLE
OV/2-3	K. Ida	Overview of transport and MHD stability study and impact of magnetic field topology in the Large Helical Device
OV/4-4	M. Kobayashi	3D effects of edge magnetic field configuration on divertor/SOL transport and optimization possibilities for a future reactor
EX/7-3	H. Kasahara	Progress of High-Performance Steady-State Plasma and Critical PWI issue in the LHD
EX/P6-27	M. Yokoyama	Comprehensive understandings of energy confinement in LHD plasmas through extensive application of the integrated transport
EX/P6-29	S. Ohdachi	Pressure Driven MHD Instabilities in Intrinsic and Externally Enhanced Magnetic Stochastic Region of LHD
EX/P6-30	M. Yoshinuma	Abrupt Reversal of Convective Flow of Carbon Impurity during Impurity-Hole Formation on LHD
EX/P6-35	Y. Narushima	Experimental Observation of Response to Resonant Magnetic Perturbation and Its Hysteresis in LHD
EX/P6-37	S. Sakakibara	Characteristics of MHD Instabilities Limiting Beta Value in LHD
TH/6-2	K. Ichiguchi	Three-dimensional MHD Analysis of Heliotron Plasma with RMP
TH/P6-38	S. Murakami (Kyoto U.)	Integrated Heat Transport Simulation of High Ion Temperature Plasma of LHD
TH/P6-39	G. Kawamura	Transport simulation analysis of peripheral plasma with the open and the closed LHD divertor
TH/P7-9	M. Nunami	Reduced Model for Gyrokinetic Turbulent Transport in Helical Plasmas
FIP/P7-16	T. Goto	Integrated Physics Analysis of Plasma Operation Control Scenario of Helical Reactor FFHR-d1
PPC/2-1	K. Nagaoka	Integrated discharge scenario for high-temperature helical plasma on LHD
EX/P3-47	M.W. Jakubowski (IPP-Greifswald)	Influence of Magnetic Perturbations on Particle Transport in magnetic fusion devices

APPENDIX 2: PROGRESS REPORT ON WENDELSTEIN 7-X CONSTRUCTION

The Wendelstein 7-X project coordinates human resources, technical activities, the technical part of industry contracts and the contributions from other research centres, and takes care of the interfaces between physics and engineering.

The collaboration with other institutions is of utmost importance for the Wendelstein 7-X project. KIT, FZJ and CEA provide immediate support via the supply of technical components and tests for Wendelstein 7-X subsystems. EURATOM continues to support the project with senior experts consulting on key project tasks. The cooperation with KIT on the ECRH system is running well. The collaboration with ERM/KMS and FZJ for the ICRH has been further intensified. FZJ/TEC, the Wigner Institute Budapest, the consortium RFX Padua, and the Polish Association are strongly involved in the development of diagnostics. The CEA IRFM Cadarache is collaborating on actively cooled in-vessel components, device control and diagnostics. The Polish institute NCBJ Swierk has successfully completed its contribution on the Neutral Beam Injection (NBI) system for W7-X. Within the collaboration with US laboratories, PPPL provided the trim coils for W7-X and the respective power supplies. All five coils and the power supplies have been delivered to Greifswald, installed on W7-X, and are currently being commissioned. In addition, PPPL provides a new type of X-ray imaging spectrometer (XICS). ORNL develops the design for the divertor scraper element, being an additional high-heat-flux component to protect the divertor during plasma start-up with high power discharges. LANL is developing a fast infrared camera system for divertor monitoring.

- Wendelstein 7-X construction (preferential support activity)

The project Wendelstein 7-X has entered the phase of parallel assembly and commissioning. The main focus is now the successful cool-down of the machine, the timely start of the commissioning of the magnet system, and the major project milestone MST 30, "Start of OP 1.1 plasma tests", which is scheduled for July 2015.

Magnet system

In April 2014, the current lead installation for the superconducting coil system was successfully concluded and the cryostat was closed. The integration of the power supplies has been completed as well and the installation of the quench detection system is nearing completion.

In-vessel component manufacturing

All in-vessel components for the first operation phase OP 1.1 are assembled (see below). The manufacturing of the remaining in-vessel components is proceeding according to schedule. The production of the last components for OP 1.2 is being pursued with high priority. The detailed design of the high-heat-flux divertor for OP 2 has been completed and the procurement and manufacturing progresses. Due to the discovery of a leak in one target element after testing in GLADIS, it was decided to apply a reinforcement procedure to this specific type of elements. From the current perspective, this will not affect the start of OP 2.

Assembly

The tedious and time consuming assembly of the in-vessel components for OP 1.1 has been completed in all five modules. The remaining work focuses now on the completion of the periphery assembly, in particular the assembly of the cooling circuits and the installation and connection of more than 6000 cables. The cooling circuits for the trim coils and plasma vessel/ports are already installed and have undergone hydraulic adjustment. The assembly of the cooling water distribution network for heating system, pumps and diagnostics is slightly delayed but should be completed within the first quarter of 2015. The installation of the quench-gas system is almost finished and the installation of the complex fire protection system has been concluded. The installation of electronic cubicles and the cabling works are performed with high priority in order avoid delays to the commissioning plan.

Device Control, Data Acquisition and Communication (CoDaC)

Through strict prioritisation of tasks, significant progress was achieved for the CoDaC work packages. The programming and implementation of local and central controls is proceeding as planned. For the central safety control, a system based on industry standards is being implemented. Safety functions for the cool-down of the cryostat have been defined and the emergency stop system has been installed. The device control room has been set up and is already operational. Extensive efforts are made to ensure the timely completion of interfaces and controls for the integral commissioning of each component.

Commissioning

Despite initial delays during the start-up of the vacuum systems, the commissioning of Wendelstein 7-X is proceeding mostly on track. The first steps, the local and integral commissioning of the vacuum system were performed successfully. The commissioning of the cryostat vacuum started in mid-July with two pump units. In the course of one weekend, the cryostat was pumped to 0.3 mbar. Several leaks were found and fixed after the first venting. In the beginning of August, the re-evacuation of the system started now with all five pump units, including the turbo molecular pumps. In November, the pressure in the cryostat measured below $1 \cdot 10^{-4}$ mbar, with a combined leak- and outgassing rate of about $0.1 \text{ mbar} \cdot \text{l/s}$, including approx. $1 \cdot 10^{-3} \text{ mbar} \cdot \text{l/s}$ air leaks. This will be further reduced after the repair of one larger leak in a bellow during the next venting of the cryostat.

The tests of the normal conducting trim coils are proceeding according to the plan. The commissioning of the cryo systems has started as well with the leak testing and purging of cryo-lines and the restarting of the cryo plant. The cool-down of the cold mass of 425t (coils, bus bars, central ring, and support elements) is the next big step in commissioning and is scheduled to start in the beginning of January 2015.

- Wendelstein 7-X physics

Wendelstein 7-X heating systems (preferential support activity)

Electron Cyclotron Resonance Heating (Project PMW at KIT)

After a successful factory acceptance test at the Karlsruhe Institute of Technology (KIT),

the gyrotron SN2i has passed the site acceptance test (SAT) at IPP Greifswald and was accepted. The repaired and improved gyrotron SN7i was also successfully tested at KIT with good results and will be delivered to Greifswald for the SAT. If the gyrotron is accepted, seven gyrotrons will be available. Six gyrotrons with approximately 5 MW of ECRH power will be taken into operation for OP 1.1. Negotiations about the repair of SN5R are ongoing. The replacement for the defective CPI gyrotron is expected to be delivered in mid-2015. A cryo free magnet has been ordered. The procurement of individual helium liquefiers for the Thales gyrotrons is proceeding as planned. Inside the torus hall, the four ECRH beam launchers have been completely installed and have been vacuum tested with success. The installation of the final components of the transmission systems is ongoing. The hardware for the remote steering (high field side) launchers is being developed and fabricated in the frame of a joint project with industry support by the ministry of education and research.

Ion Cyclotron Resonance Heating (ICRH)

The development and construction of the ICRH system is performed in the frame of a collaboration between IPP, FZJ and the ERM/KMS in Brussels. It is planned to install one double strap antenna which can be moved radially for about 30 cm by remote control. The electromagnetic configuration of the antenna has been finalized, the design of the antenna head progresses well. Assembly details for the transmission lines and the matching network are yet to be worked out. The high frequency generators, transmission lines, and the electromagnetic components of the antenna and the matching network will be contributed by ERM/KMS, while FZJ is partially responsible for the manufacturing and assembly of the antenna. It is the aim of the project to provide the operational system in time for OP 1.2.

Neutral Beam Injection (NBI)

The procurement and assembly of NBI components is progressing as planned. The pre-assembly of the neutral beam injector boxes in the NBI hall has been completed and both injectors have been positioned inside the torus hall. Most components for the connection between the injector box and the torus beam duct have been delivered and already installed. The Procurement of components for the Ti-getter pumps has started. It is intended to have the system operational until OP 1.2.

Wendelstein 7-X diagnostics

In order to cope with limited capacities for the diagnostics development, all activities are governed by the priorities derived from the schedule for commissioning and operations. It is expected that a substantial set of start-up diagnostics will be ready for the first plasma operation in 2015. In fact, many diagnostics are now being fabricated and prepared for installation. Below follows a status report for selected key diagnostics.

Neutron counters

The in-vessel railway system for calibration of the neutron counters has been pre-assembled, tested and is now ready for assembly. The support structures for the external monitors have been installed and the support for the central monitor is ready for installation. The monitors have been tested and certified at PTB Braunschweig, and are currently being prepared for installation.

Flux surface measurement

Procurement and construction of the components for the magnetic flux surface measurement have been completed. The two manipulators for OP 1.1 have been installed and are being commissioned. The e-gun has been integrated in one manipulator and tested.

Single Channel Dispersion interferometer

The two granite plates that constitute the vertical interferometer bench together with their massive support structure were installed in the torus hall. The system is in preparation for installation.

Video diagnostics

All in vessel components for the video diagnostics system have been installed. The vacuum windows and the holders have been installed in all 10 AEQ ports. The cameras for the visualisation of the magnetic flux surfaces in OP 1.1 have been installed in two ports. The remaining eight immersion tubes will be handed over to AS in the beginning of December 2014.

Electron cyclotron emissions diagnostic

All in-vessel components have been installed. The plug-in with the ECE Gauss-antenna has been assembled and tested.

Limiter diagnostics

The limiter for OP 1.1 has been equipped with thermo couples and the Langmuir arrays have been installed. All ten simplified infrared/H-alpha immersion tubes each with two cameras for the visible spectral region and one infrared camera have been installed.

Thomson scattering

All in-vessel components have been installed. The design for the laser beam path in the torus hall was confirmed, the respective components and catalogue items are under procurement.

HEXOS

The calibration sources for the HEXOS-spectrometer, which has been installed at its final location in the torus hall, have been prepared.

In-vessel magnetic diagnostics

All magnetic diagnostics for OP 1.1 have been installed inside the vacuum barrier and have been successfully tested.

APPENDIX 3: TECHNICAL REPORT ON TJ-II ACTIVITIES

TJ-II is a medium-size Helic-type stellarator operating at low magnetic shear. The results achieved in the TJ-II stellarator during 2014 were obtained in plasmas created and heated by Electron Cyclotron Resonance Heating (ECRH) (2 x 300 kW gyrotrons, at 53.2 GHz, 2nd harmonic, X-mode polarisation) and Neutral Beam Injection (NBI). Two beams of 700 kW port-through (H0) power at 34 kV, were injected on TJ-II. Recently plasma operation scenarios with NBI have been successfully developed. The TJ-II research programme has been focussed on Transport, Stability and Plasma Control Studies including the understanding of the plasma flow dynamics in relationship with TJ-II confinement transitions and isotope effect physics, impurity transport, stability and fast particle physics. All the results have been obtained under Li coated wall conditions. Biasing experiments of carbon and lithium limiters were initiated.

Particle, energy and Impurity transport: Observations of asymmetries in parallel impurity flows in TJ-II ion-root plasmas have been interpreted in terms of a compressible variation of the impurity flow field and hence of impurity density asymmetries within a flux surface. In addition, first observations of electrostatic potential variations within the same magnetic flux surface are presented, modelled on the basis of neoclassical Monte-Carlo calculations. The dependence of impurity confinement time on charge and mass has been also studied.

TJ-II has participated in an inter-machine validation study of neoclassical transport modelling in medium to high density stellarator-heliotron plasmas. The goal of this study was to compare neoclassical predictions (of non-local NC codes) for radial particle and energy transport with experimental estimates in selected discharges at high ion collisionality (i.e., NBI-heated). With some exceptions, reasonable agreement was found between experimental and neoclassical particle and heat fluxes in the core region ($r/a < 0.5$). Similar results were obtained in ECH-heated TJ-II plasmas.

Momentum transport and isotope physics: TJ-II provides evidence that three-dimensional magnetic structures have a significant impact on plasma confinement and L-H transitions. Recent observations of the temporal ordering of the limit cycle oscillations at the L-I-H transition emphasize the leading role of the plasma turbulence. Comparative studies between tokamaks and stellarators have provided direct experimental evidence for the importance of multi-scale physics to unravel the impact of the isotope effect on transport.

Power exhaust physics: Novel solutions for plasma facing components based on the use of liquid metals like Li and alloys have been developed on TJ-II. The TJ-II liquid metals programme addresses fundamental issues like the self-screening effect of evaporating liquid lithium, protecting plasma-facing components against heat loads, and tritium inventory control, using the recently installed Li-liquid limiters (LLL).

Plasma stability studies: Magnetic well scan experiments suggest that traditional stability criteria, on which the optimizations of stellarator configurations are based, may miss some stabilization mechanisms.

Fast particle control: Moderate off-axis ECH power deposition modifies the continuous nature of the Alfvén eigenmodes (AEs) significantly, and frequency chirping sets in. This result shows that ECH can be a tool for AE control that might be ITER and reactor-relevant, if confirmed.

APPENDIX 4: TECHNICAL REPORT ON HELIOTRON J ACTIVITIES

Particle fuelling control, effects of the magnetic configuration on toroidal flow, fast ion confinement, bulk thermal confinement, MHD stability and edge fluctuation have been investigated in a flexible helical-axis heliotron, Heliotron J, with special regard to the optimization study of helical systems with spatial magnetic-axis and vacuum magnetic well. To attain the drift optimization of the L=1 helical-axis heliotron, the bumpiness control is essential to reduce the neoclassical transport (or the effective helical ripple). The experiments have been performed in several configurations. The Heliotron J activities in 2014 are summarized as follows:

- 1) Several gas-fuelling techniques have been developed to expand the plasma operational region in Heliotron J into higher-density domain under NBI heating. When the plasma density is increased with conventional gas-puff fuelling (GPF), the stored energy W_p becomes saturated or decreased at a density level, probably due to the edge cooling caused by excess neutrals. A short pulse high-intensity gas fuelling (HIGP) opens a higher density and stored-energy operation regime for NBI plasma especially at the low- ε_t configuration in Heliotron J. Experiments indicate that an important effect of the HIGP scenario is the decrease of the power loss due to the charge exchange and/or radiation, which is caused by a low neutral density state in the periphery after the HIGP pulse. With careful control of HIGP scenario, high-density ($n_e \sim 10^{20} \text{ m}^{-3}$) NBI plasma with $T_e(0)$ and $T_i(0) = 0.2\text{-}0.3 \text{ keV}$ is realized, where the enhancement of increasing-rate of diamagnetic energy accompanied the drop of $H\alpha/D\alpha$ emission intensity and the reduction in the edge fluctuation indicate the transition to a improved confinement mode after HIGP. Since the SMBI fuelling is also useful from this point of view, it is interesting to compare these two fuelling methods. Preparation of a small pellet injection system for Heliotron J is also in progress. In order to more detailed discussion about (1) the relation between these fluctuations and the expected confinement improvement and (2) the effect of HIGP pulse on the fluctuation behaviour, preparation for more precise measurement of fluctuation structure with enough time and spatial resolution is in progress.
- 2) A Nd:YAG Thomson scattering system started its operation for measurement of electron temperature and density profiles with high spatial and temporal resolution. The laser beam is injected obliquely from outer downward to inner upward side of the Heliotron J, and the backscattered light (the scattering angle of 160°) is obliquely detected to avoid interference with a coil and a supporting structure. The scattered light is collected with a large concave mirror ($D=800\text{mm}$, $f/1.25$) with a solid angle of $\sim 80\text{-}100 \text{ mstr}$. It has 25 spatial points with $\sim 10\text{mm}$ resolution by interference polychromators and an optical fiber bundles. The system can measure a wide range of an electron temperature and density ($T_e: 10\text{eV} - 10\text{keV}$, under $n_e > 5 \times 10^{18} \text{ m}^{-3}$). Two high repetition Nd:YAG lasers ($> 550\text{mJ}@50\text{Hz}$) realize the measurement of the plasma profile with $\sim 10\text{ms}$ time intervals. A time evolution of electron temperature and density profiles was measured for the high-density neutral-beam-injection plasma with a high-intensity gas-puff (HIGP) fuelling. The profiles reveal that not only large increases of core n_e but also increases of peripheral T_e contribute to the increase of the stored energy after the HIGP by increasing both the core and the peripheral pressures. It was found that HIGP could improve the global thermal confinement especially in the peripheral.
- 3) The effect of the magnetic ripple strength on the parallel flow was investigated in

NBI plasmas of Heliotron J. The dependence of the magnetic ripple strength γ ($= \langle (\partial B / \partial s)^2 / B^2 \rangle^{1/2}$) on the parallel flow velocity is investigated by changing the bumpy magnetic field component, being the toroidal mirror ratio in the Boozer coordinate system. In the plateau regime, the parallel flow velocity of carbon impurity at the core region of the high γ configuration is measured to be 2-3 times smaller than that in the standard γ case. The dependence of the flow velocity on γ shows that the damping force by the neoclassical (NC) parallel viscosity is much higher in the high γ case. On the other hand, in the region of $r/a > 0.6$, the flow velocity was measured to be around 2-4km/s for both the co- and counter-NBI plasmas. The flow velocity outside the core region was not sensitive to the ripple strength and the NBI direction, which implies that importance in the thermodynamic force to the plasma flow to interpret the spontaneous flow. The measurement results are compared with a NC transport calculation based on the Sugama-Nishimura method with taking the external NBI force into account. The experimentally observed flow velocity is generally consistent with that predicted based on the NC prediction.

- 4) A moment method taking account of the external momentum from neutral beam (NB) is proposed. In order to treat the external momentum source, the field particle portion of the collision operator between fast ion and background particles are included in the conventional moment method. This method is applied for the estimation of parallel ion flows in the Heliotron J plasmas. The C6+ flow velocities which are calculated by this method are generally consistent with those measured by CXRS in NB heated plasma. This method also shows that parallel flow velocity of bulk ions which are difficult to be measured directly are almost identical with the C6+ flow velocity in the collisional plasma we investigated. These facts suggest that the moment method calculation is useful to estimate the parallel plasma flows.
- 5) Energetic-ion-driven MHD instabilities such as Alfvén Eigenmodes (AEs) and energetic particle modes (EPMs) were studied in NBI-heated Heliotron J plasmas with low magnetic shear. We clarified the characteristics of the observed EPMs. The observed EPMs has low- m/n (m and n are poloidal and toroidal mode number) such as $m/n=2/1$ or $4/2$ with a single helicity, and localizes at plasma edge region $\rho \sim 0.8$ where frequency of passing particle in toroidal direction intersects with shear Alfvén continua of $m/n=2/1$ or $4/2$. We scanned plasma current by the parallel refractive index N_{\parallel} in order to vary the magnetic shear which is a key parameter for continuum damping rate of EPM. We demonstrated that EPMs could be controlled by means of both positive and negative magnetic shear induced by electron cyclotron (EC) driven plasma current.
- 6) The physical mechanism of interaction between fast-ion and fast-ion-driven magnetohydrodynamic (MHD) instabilities is studied. We developed a Faraday-cup-type lost fast-ion probe (FLIP) to detect the lost fast-ions induced by MHD instabilities. Information including both the energy and the pitch angle of the lost fast ions is obtained simultaneously by using the FLIP. The lost fast-ions have energy close to the injection energy of neutral beams (E_b), and pitch angles of 100~110 degree. Comparison between experimental results and full-orbit calculations indicates that the lost fast-ions come from the plasma edge region.
- 7) ICRF minority heating has been performed for the investigation of the fast ion confinement and bulk ion heating. The effectiveness of the toroidal ripple is

confirmed in the measurement of the accelerated fast ions and positional dependences of the fast ions is observed. The Monte-Carlo simulation is performed to understand fast minority ion behaviour. For the toroidal distribution of fast ions, the dependence is not so large since the mirror ratio is small. However, in the high bumpiness, the largest fast ions are observed in the corner section and the fast ions become smaller towards the straight section. There is little change in the toroidal direction for the medium and low bumpiness. The large fast ion flux is observed in the experiment that the line-of-sight of the CX-NPA is directed to the corner section in the high bumpiness as the calculation result.

- 8) A toroidally symmetrical electric field fluctuation with radially elongated structure is found inside the last closed flux surface (LCFS) in low-density ECH plasmas of Heliotron J. The fluctuation has dominant frequency components less than 4 kHz, and shows electrostatic characteristics without density perturbation. These characteristics are quite similar to those of zonal flows, however, its radial wavelength is, unlike those in other devices, comparatively large. The electric field fluctuation generates the velocity shear synchronized with the fluctuation around LCFS since the fluctuation amplitude sharply increases inside LCFS. Nonlinear coupling between the radial and poloidal electric field fluctuations exists in the low frequency range. Cross-correlation analysis indicates that turbulence structure drastically changes at the boundary of LCFS, which results in the steep increase of Reynolds stress inside LCFS. Consequently, radial shape of the Reynolds stress is similar to that of the symmetric fluctuation amplitude. These observation implies that the generation of the symmetric fluctuation is coupled with the Reynolds stress.
- 9) A new far infrared (FIR) interferometer has been developed on Heliotron J for high density plasma measurement. This interferometer adopts heterodyne detection system and realizes 1 μ s-time-resolution by super rotating grating as a frequency shifter. The system was applied to practical experiment and successfully obtained temporal development of line-averaged density. The time trace of \bar{n}_e measured with FIR interferometer is similar to that obtained with a microwave-interferometer being used in Heliotron J, however, is greater than the measured value of the microwave-interferometer. This difference can be attributed to the different chords of each interferometer system placed at different toroidal section. The influence of different chords is evaluated based on the density profile obtained with Thomson scattering measurement, and the result explains the discrepancy between these two interferometer quantitatively.
- 10) A novel reconstruction method is developed for acquiring the electron density profile from multi-channel interferometric measurements of strongly asymmetrical toroidal plasmas. It is based on a regularization technique, and a generalized cross-validation (GCV) function is used to optimize the regularization parameter with the aid of singular value decomposition (SVD). The feasibility of method could be testified by simulated measurements based on a magnetic configuration of the flexible helical-axis heliotron device, Heliotron J, which has an asymmetrical poloidal cross section. And it makes possible to construct a multi-channel Far-infrared (FIR) laser interferometry on this device. The advantages of this method are demonstrated by comparison with a conventional method. The factors which may affect the accuracy of the results are investigated, and an error analysis is carried out. Based on the obtained results, the proposed method is highly

promising for accurately reconstructing the electron density in the asymmetrical toroidal plasma.

- 11) Beam emission spectroscopy (BES) has been used to measure local density fluctuations. To obtain the two-dimensional structure of the density fluctuation, the sightlines are improved in radial and poloidal direction from 16×1 to 16×2 . The density fluctuation with a frequency of 15–20kHz was measured in the core ($r/a < 0.4$) region of the ECH+NBI plasma. The propagation direction of the fluctuation was estimated to calculate the frequency-wavenumber spectra by two-point correlation analysis. As a result, the poloidal propagation of the fluctuation was the ions diamagnetic shift direction.
- 12) Internal transport barrier formation is observed in T_e profiles of low-density ECH plasmas using a Nd:YAG Thomson scattering system. The ECH power dependence on the electron temperature profile is investigated. The absorbed ECH power depends on the power ratio of the X-mode in the injected EC waves, which can be changed by a polarizer. Formation of steep electron temperature gradient is observed, depending on the absorbed ECH power.
- 13) Electron Bernstein Emission (EBE) diagnostic is under development for electron temperature profile measurement in helical-axis heliotron device, Heliotron J. Ray-tracing calculation results using KRAY code show that the X-O mode conversion window is accessible with the existing ECH/ECCD antenna system, and the radiation profile is possible to measure at the core region. A multi-channel radiometer has been assembled and tested.
- 14) Edge density fluctuation has been measured simultaneously with a high-speed video camera and a Langmuir probe, in a medium-sized heliotron device – Heliotron J. Poloidally propagating, parallel elongating filamentary structures were observed by camera, with the frequency of 20-30 kHz and poloidal wavelength of ~ 14 cm. However, radial position of this density mode is not well known with only camera data, because camera lens axis is perpendicular to the torus plane. To identify the span of this density mode, plasma-surface interaction (PSI) between probe and plasma has been analyzed. As probe being scanned into the plasma, enhanced brightness due to PSI was clearly observed in camera images. By comparing this enhanced brightness among different probe positions, the outmost margin of the 20-30 kHz mode observed by the camera, has been identified to be within 10mm outside from the last closed flux surface (LCFS). This conclusion is supported by the spectrum of the probe data.
- 15) Three SX detector systems are installed into Heliotron J for tomographic analyses of MHD phenomenon. The main purpose of the study is to analyze the MHD equilibrium and stability by using SX Computer Tomography (SXCT) plasma image reconstruction. We observed MHD instabilities and modification of MHD equilibrium, so called Shafranov shift, but two SX detector systems were not used for CT but for measurement of MHD instabilities. The SX detector systems were improved, and the reconstruction plasma image was obtained.
- 16) To deepen the understanding of the configuration effects on confinement, the following new diagnostics are being designed and/or installed; an improved CXRS system for the measurement of ion temperature and toroidal rotation, VUV spectrometer, upgraded Langmuir probes, magnetic probes and fluctuation

measurement by using an SX tomography and a reflectometer for density fluctuation. Advanced wall conditioning method using a Li coating is under development.

APPENDIX 5: SUMMARIES OF THE INSTITUTE OF PLASMA PHYSICS OF THE NSC KIPT, KHARKOV

Plasma Theory

1) Calculations of confinement of high energy ions for a stellarator type trap

DRAKON. The equilibrium stellarator configuration DRAKON (V.M.Glagolev et al, in Proceedings of 10-th European Conference on Controlled Fusion and Plasma Physics, Moscow, 1981, Vol. 1, paper E-8.) consists of two rectilinear regions which in fact represent two mirror traps. The magnetic system is closed by two curvilinear elements (known as CREL). Here, for high energy ions of tritium with energy 70 keV comparative computations of collisionless losses in the mirror part of a specific model of such a trap are carried out. A recently developed technique is applied for direct computations of particle losses solving the guiding center drift equations in real-space coordinates. The results show that high energy ions obtained as a result of the neutral beam injection can be satisfactorily confined in the mirror part during $0.1 \div 1$ s in the case of sufficiently small value of $|v_{\parallel}/v|$ (V.V.Nemov, S.V.Kasilov, W.Kernbichler, V.E.Moiseenko, O.Agren, V.N.Kalyuzhnyj, A.F.Martitsch, 41st EPS Conference on Plasma Physics, Berlin, 23 - 27 June 2014, P2.069). The results can be, in particular, of interest for studies of plasma neutron sources based on stellarator type magnetic configurations in which neutrons are produced in the mirror part due to fusion reactions of the hot ion component (tritium) with the cold background plasma ions (deuterium).

2) Direct computations of high energy particle losses in optimized stellarators solving the guiding center drift equations in real-space coordinates.

Collisionless high energy particle losses are calculated in real-space coordinates for a number of optimized stellarator configurations. The calculation technique based on solving the guiding center drift equations in real-space coordinates is described. It is found that the life time of fast particles obtained in real-space coordinates can be smaller than that obtained in magnetic coordinates. The results are presented in the work: V.V.Nemov, S.V.Kasilov, and W.Kernbichler, Phys. Plasmas **21**, 062501 (2014).

3) Drift kinetic equation solver NEO-2 has been applied for the studies of ECCD efficiency in tokamaks and stellarators.

For this purpose code NEO-2 has been parallelized, and a new interface has been developed for fast interpolation of the generalized Spitzer's function in stellarator geometry where this function is 4D in contrast to tokamaks where it is 3D. The code has been applied first for the studies of ECCD in tokamaks with finite plasma collisionality.

It has been shown that finite collisionality may have a significant effect on current drive efficiency in the plateau regime at the onset of the banana regime in the advanced ECCD scenarii (O2 and X3). Namely, the sign of the driven current for off-mid-plane launches of the microwave beam becomes independent of the toroidal injection angle in a wide range of angles and determined then by the sign of the vertical displacement of the launch plane from to the mid-plane. The result of this study have been reported at 18th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating (Nara, Japan, 22-25 April 2014), and the respective paper, W.Kernbichler, S.V.Kasilov, G.Kapper, N.B.Marushchenko, Computation of the Spitzer function in stellarators and tokamaks with finite collisionality, is due to be published in the European Physical Journal Web of Conferences.

4) A quasilinear version of the NEO-2 code has been developed, which allows for the fast computation of the non-ambipolar particle transport in tokamaks with small

non-axisymmetric perturbations of the magnetic field. Via the flux-force relation, these computations directly provide the density of the toroidal torque acting on the plasma from these perturbations ("Neoclassical Toroidal Viscosity"). Quasilinear approximation used in the code includes most transport regimes relevant for present day and future tokamaks and excludes only the regimes with relatively high perturbation amplitudes. Code has been benchmarked against few analytical and numerical models, in particular, against the code DKES and analytical models of K.C.Shaing. The results have been reported at the 41st EPS conference (Berlin, Germany, 23-27 June 2014) and published as paper, S.-V.Kasilov, W.Kernbichler, A.-F.Martitsch, H.Maassberg, M.F.Heyn, Evaluation of the toroidal torque driven by external non-resonant non-axisymmetric magnetic field perturbations in a tokamak, Phys. Plasmas, 21 (2014) 092506.

5) Numerical modelling of plasma production with radio-frequency heating using four-strap π -phased antenna. Calculations of RF plasma production in the ion-cyclotron range of frequencies (ICRF) in the Uragan-2M stellarator using four-strap π -phased antenna were provided. The analysis was carried out with usage of a self-consistent model that simulates plasma production with ICRF antennas. It includes the system of the particle and energy balance equations for the electrons and neutrals and the boundary problem for the Maxwell equations. The model uses the neoclassical diffusion and the basic elementary processes of plasma interaction with the neutral gas are taken into account. The Maxwell equations are solved in 1D using the Fourier series in the azimuthal and the longitudinal coordinates. Discretization in radial direction was performed with the method of weighted residuals using finite elements of the second and third orders. The equations are solved each time moment for the current plasma density and temperature distributions. The calculated value of the local RF power, deposited to the electron component of plasma, is used in the energy balance equation. This value influences on the electron temperature and, in this way, on the ionization rate which determines the evolution of plasma density. The model for the stellarator plasma column is the plasma cylinder with identical ends. The plasma is assumed to be azimuthally symmetrical and uniformly distributed along plasma column. Discretization in time and radial coordinate of operators with diffusion and thermal conductivity was performed using the Crank-Nicholson method which, as it is known, is absolutely stable. To achieve second-order accuracy in time, refinement of the solution was carried out by Runge-Kutta second order scheme.

The results of calculations for Uragan-2M stellarator indicate that plasma density can be increased by an order of magnitude during the pulse of the four-strap antenna. The generated plasma density profile has a maximum in the center of the plasma column. Optimal value of the initial neutral gas density is $n_{a0} = 2 \cdot 10^{12} \text{ cm}^{-3}$. The power deposition occurs within the plasma volume in this case. As in the case of the frame-type antenna, with the four-strap antenna in use, the peripheral plasma is also heated to high temperatures. It can be explained by the Landau damping of the slow wave at the plasma periphery. Unlike the frame-type antenna slow wave is excited by the conversion of the fast wave field in the Alfvén resonance layer. When the neutral gas density increases, the resulting plasma density is somewhat higher, the power deposition profile is shifted toward the antenna, whereby the electron temperature within the plasma column decreases.

6) Fast trapped particle motion in Uragan-2M stellarator with embedded magnetic mirror. In paper [V E Moiseenko, K.Noack, O.Ågren 2010 *J. Fusion Energy* **29** 65], a concept of fusion-fission hybrid based on the stellarator with embedded magnetic mirror is proposed. The hybrid comprises a fusion neutron source and a powerful sub-critical fast fission core. It is aimed at transmutation of spent nuclear fuel and safe fission energy

production. In its fusion part neutrons are generated in deuterium-tritium plasma confined magnetically in a stellarator-type system with embedded magnetic mirror. The stellarator confines the warm background deuterium plasma while the hot sloshing tritium ion minority population is sustained at the magnetic mirror part of the device by means of the neutral beam injection or the ion cyclotron heating. For the reason of tritium ion trapping at the mirror part, the fusion neutron generation is strongly localized which is the principal point of this concept of a fusion-fission hybrid. The magnetic configuration of a stellarator with embedded mirror may be arranged in the Uragan-2M experimental device since in addition to the helical coils it has the coils of the toroidal field. Switching off one toroidal coil or lowering the electric current in the pair of neighboring coils results in appearance of the magnetic mirror with the mirror ratio about 1.5. Under certain conditions, the system of nested magnetic surfaces can exist in such a combined magnetic trap [V.G.Kotenko, V. E. Moiseenko, and O.Ågren 2012 AIP Conf. Proc. **1442** 167]. The aim of the study is to investigate the trapped ion motion in the mirror part of the device. The investigation is based on Biot-Savart calculations of the magnetic field of the device and the analysis of the parallel adiabatic invariant J_{\parallel} . The influence of the static radial electric field is taken into account in the calculations. The calculations are performed for the case of one toroidal coil switched off and for the case of lowered electric current in the pair of neighboring coils. In both cases, without the electric field, the drift trajectories of ions are disclosed. Because of quick escape of hot ions the plasma acquires the negative charge. This helps to confine ions with the energy below certain threshold energy which value is discussed.

Plasma Experiment

1) Synchrotron radiation spectra and synchrotron radiation spot shape of runaway electrons in experimental advanced superconducting tokamak (2014 PHYSICS OF PLASMAS 21, 063302). The synchrotron radiation is a powerful tool for investigation of fundamental physical phenomenon of runaway electron generation. A detailed analysis of the spectra of synchrotron radiation emitted by runaway electrons, and an analysis of synchrotron radiation spot shapes were studied for the EAST tokamak. The investigated discharge was an Ohmic discharge and was performed in the limiter configuration, with toroidal magnetic field $B_0 = 2$ T, plasma current $I_p = 250$ kA, central line-averaged density $\langle n_e \rangle = 2.2 \times 10^{19} \text{ m}^{-3}$, plasma major radius $R = 1.86$ m and minor radius $a = 0.45$ m. The shape of the synchrotron radiation spots emitted by runaway electrons was analyzed. The shape was detected by the CMOS camera in EAST (the operation wavelength range of this camera is $(0.38 - 0.75) \mu\text{m}$). The influence of large drift orbit shift of high energy runaways on the camera record possibility was the main reason why an asymmetrical ring-like synchrotron radiation spot was observed in EAST and also several tokamaks. In EAST the runaway energy $E \approx 30$ MeV and pitch angle $\theta_p \approx 0.16$ were deduced from joint analysis of the synchrotron radiation spectra and synchrotron radiation spot shape.

2) First results of multi-chord soft x-ray detection array on the U-3M torsatron. A miniature pinhole camera array for spatially and temporally resolved measurements of soft X-ray plasma emission has been recently installed inside the U-3M vessel from high field side in the "A-A" cross section. The system has been tested in different types of the U-3M discharge. In the low density frame antenna (FA) discharges with so-called "H-mode-like" transition, fast SXR emission modification is observed. The SXR emissivity decay in some channels is observed simultaneously with its rise in different channels during the 0.5 ms transition time. A phase shift of the perturbation and different shapes of the perturbation are observed in different channels. A comparison of the SXR emissivity, measured by different channels, as well as transient nature of the modification, indicate that the transition can be

associated with MHD instability. In this type of the discharge significant SXR signal rise is observed in the plasma center after RF heating power turning off, although signals of the edge channels decay immediately. Different shapes of the SXR emission profile has been observed in different discharge conditions, even during one discharge. A narrow emissivity profile is observed during low power FA plasma breakdown stage, but a wide profile with shifted center is observed during medium density stage of the three-half-turn (THT) antenna discharge; the profile becomes narrow and unshifted again in the high density colder plasma stage. The 10 kHz SXR electronics bandwidth in U-3M limits frequency range of the MHD activity under consideration. Different types of the low frequency MHD activity have been observed in the U-3M torsatron. A localized in the central region MHD activity with inverted phase of the perturbation in the opposed from the center plasma side is observed in the THT antenna discharges. These fluctuations can be associated with the MHD perturbation rotation or vertical shift of the central part of the plasma column. In different types of the THT antenna discharges, with higher RF heating power, similar fluctuations are observed without phase inversion. Smaller amplitude edge fluctuations are observed in the FA discharges. Thus, the recently installed SXR diagnostics opens opportunity of detailed studies of the MHD activity together with its driver – the plasma pressure gradient.

3) On the issue of shielding properties of the plasma outside the separatrix region in U-3M. In the $l = 3$ U-3M torsatron, the hydrogen plasma is produced and heated by introduction of RF power in the frequency range $\omega \leq \omega_{ci}$ by the use of two types of unshielded antennas: a frame type (FT) antenna and a three-half-turn (THT) antenna. A very specific feature of U-3M, distinguishing it from many other fusion devices, is: the whole magnetic system is placed inside a large vacuum tank, thus the ratio of plasma volume to a gas filled volume is $\sim 1/200$.

Usually the experiments were organized with continuous gas (hydrogen) feeding, and when experimenting with FT antenna it was found out recently that a fast increase of RF power during the RF pulse (e.g., anodic voltage from ~ 5.5 kV by ~ 9 kV) results not in plasma density increase, but in a significant (about twofold) decrease of density. One of possible explanations of this phenomenon could be the decrease of gas inflow due to stronger gas ionization outside the plasma confinement volume (outside the separatrix).

On the base of results of electrical probe measurements of $n_e(r)$ and $T_e(r)$ outside the plasma confinement volume, the shielding factor for working gas molecules (H_2) was estimated as a few percent at the plasma border. The attenuation of H atoms reflected from the helical coil casing amounts $\sim 0.1\%$. For carbon and iron atoms leaving the casing surface with energy of a few eVs the values of attenuation factor amount $\sim 0.6\% \sim 3.0\%$, accordingly. Thus it is shown that in regimes of RF discharges produced by FT antenna (with mean density of confined plasma several units of 10^{12} cm^{-3}) there is no any significant shielding effect for incoming particles. Therefore the reason of opposite correlation between injected RF power and the density of confined plasma should be looked for in the processes inside the plasma confinement volume.

4) Values of the stray environment fields-to-toroidal-coil magnetic field ratio were determined in the URAGAN-2M torsatron. The fraction of the additional toroidal magnetic field of 16 coils (with a casing internal radius $a_c = 0.54$ m) in the total toroidal field of the U-2M torsatron can vary between 60% and 76% and depends on the chosen structure of magnetic surface configuration (the current configuration). In similar devices a significant influence on the quality of magnetic surfaces is exerted by the impact of stray magnetic fields, the value of which is determined by the accuracy of the magnetic system assembly,

magnetization of coil casings, power framework, elements of the toroidal vacuum chamber, and diagnostics. The values of stray environment magnetic fields of the installation were determined using local magnetic sensors and behavior of injected electron beam into the toroidal magnetic field B_T . Comparison showed that the stray environment fields measured by these two methods have very close values. In the stationary toroidal magnetic field, the visualization of turns of the electron beam was performed by scanning the poloidal vacuum chamber cross-section with a luminescent rod. The purpose of these measurements was to determine vertical and horizontal displacements of the electron beam during its drift along the torus in magnetic field $B_T = 0.0225 \div 0.15$ T and to estimate the ratio of stray environment magnetic fields-to-toroidal-coil magnetic field (mfttcmf). For the fields with $B_T = 0.1 \div 0.15$ T the value of the stray environment (mfttcmf) ratio in the U-2M is $\bar{B}_z/B_T \approx 1 \times 10^{-3}$, \bar{B}_z is the vertical component of the stray environment magnetic fields. It has been shown also that the values of the stray environment (mfttcmf) ratio have a level confirming a high quality of the assembly of additional toroidal magnetic field coils and measured magnetic surfaces. According to the measurement data and their extrapolation the stray environment (mfttcmf) ratio decreases and, probably, will be reduced by an order of magnitude else to $\bar{B}_z/B_T \approx 1 \times 10^{-4}$ when the toroidal magnetic field will be increased up to $B_T \geq 0.45 \div 0.5$ T.

5) Experimental and numerical arguments for creation of the island divertor in the Uragan-2M torsatron. The island divertor concept appears to be the only suitable approach that may be helpful to make up for the absence of a natural helical divertor in the magnetic configuration. Finding appropriate divertor solutions of plasma exhaust for stellarators is a relatively new research area. In this context, the work presents and discusses the measured and calculated magnetic surface structures of different configuration modes, where large magnetic islands or their remains at the edge of the plasma volume may be used for both the experimental implementation of the island divertor, and its performance control. Based on magnetic structure measurements and field calculations, the work surveys the edge configurations in the Uragan-2M and shows which low-order islands can be potentially explored for island-divertor. The analysis of typical iota-profiles shows operational iota-windows at the edge of the Uragan-2M and magnetic shear there. The point of this work is to show the exploration of magnetic configuration and the retrieval of the necessary conditions for the island divertor; besides, there were given the island sizes, etc., in cases under consideration/study. It is given calculation result under the same conditions with the experiment, in order to compare the result of calculation and the experimental observation. The knowledge of the phase shifts at the 1/3 and 2/5 island chains in different field periods helps to take out a fitting place of divertor targets. The edge dynamics of islands along the torus has pointed to the possibility of additional spatial modulation of the divertor properties. The data obtained on the magnetic configuration surface structures provide a sufficient experimental versatility in further studies of the island divertor in Uragan-2M.

6) Investigation of processes accompanying H-like mode transition in the helical divertor of the Uragan-3M torsatron. Important distinctions of the $\ell=3/m=9$ Uragan-3M (U-3M) torsatron are: (i) a natural open helical divertor; (ii) RF plasma production and heating in the Alfvén range of frequencies ($\omega \lesssim \omega_{ci}$); (iii) an unshielded frame-like antenna in use; (iv) indications of the H-like mode transition takes place.

Plasma characteristics in the divertor region were studied with the use of plane Langmuir probe arrays arranged poloidally in the spacing between the helical coils in two symmetric poloidal cross-sections of the U-3M torus. Similar to the Heliotron E and Heliotron J devices, a distinct vertical (up-down) asymmetry of the diverted plasma flows

(DPFs) is inherent to U-3M, and it has been shown that the asymmetry results from the direct (non-diffusional, collisionless) ion loss.

The objectives of the recent work were to find out:

- effects of the electron loss on characteristics of the DPF vertical asymmetries in U-3M;
- effects of the H-like mode transition in U-3M on diverted plasma parameters.

The measured poloidal distributions of the electron density n_e in the divertor region confirm the effect of the DPFs up-down asymmetry with the denser DPFs outflowing on the ion ∇B drift side due to the direct ion loss. A newly revealed asymmetry characteristic is that the electron temperature T_e in the DPFs on the electron ∇B drift side is substantially higher than that on the ion side, in part, indicating the direct electron loss. In both cross-sections DPFs on the electron ∇B drift side with higher T_e undergo a short-time rise after RF off consistently with the start of the density n_e rise. This means that the predominant part of the plasma in these flows escapes from the confinement volume, so that the hotter electrons in these flows really occur due to the direct loss from the confinement volume. The n_e reduction with the H-mode-like transition in DPF maxima on the electron ∇B side combined with the DPF rise after RF off is an evidence of high temperature electron loss reduction and improvement of plasma confinement in the electron channel.

7) Characteristic properties of the three-half-turn-antenna-driven RF-discharge. In the Uragan-3M (U-3M) torsatron a hydrogen plasma is produced and heated by RF fields in the Alfvén range of frequencies, $\omega \lesssim \omega_{ci}$. The initial plasma with the mean density \bar{n}_e units of 10^{12} cm^{-3} is produced by the frame-like antenna (FA). This plasma is used as a target to produce and heat a denser plasma (up to $\bar{n}_e \sim 10^{13} \text{ cm}^{-3}$) with the help of another, shorter wavelength antenna with azimuthal currents (three-half-turn antenna, THTA) [3, 4]. In the reported work characteristics of the THTA-driven discharge were studied depending on the RF-power P_K fed to the antenna (anode voltage U_K of the oscillator) and initial plasma (target plasma) parameters, such as $\bar{n}_e = \bar{n}_{e0}$ and T_{e0} (the latter by 2nd harmonic ECE).

- With target plasma parameters fixed, at low values of P_K (voltage U_K), the THTA-driven discharge is in the regime with a relatively high density \bar{n}_e up to $8.5 \times 10^{12} \text{ cm}^{-3}$, low T_e ($< 100 \text{ eV}$) and low plasma loss (by the value of divertor plasma flow, DPF, on the electron $\mathbf{B} \times \nabla B$ drift side). In these conditions, a predominant fraction of P_K is spent for ionization of the neutral hydrogen continuously entering the confinement volume from the ambient space. With a further P_K increase, heating of the plasma (in part, of electrons) results in a loss increase evidenced by slowing down of the \bar{n}_e rise and DPF increase. Finally, the plasma loss is no more compensated by ionization of the inflowing neutrals, and the slowing down of the density rise turns into the density decay to $\bar{n}_e \sim 4 \times 10^{12} \text{ cm}^{-3}$ with the radiation temperature T_e^{rad} becoming ~ 2 times as high as the initial temperature. Some new effects here are indications of a hot plasma confinement improvement during evolution of the THTA-driven discharge.

- With the RF voltage being applied to THTA at different values of the initial ECE, it was shown that the resultant heating of the electrons weakly depends on their initial temperature.

- Basing on results of studies of the \bar{n}_{e0} effect on the density and temperature of the THTA-driven plasma with using available diagnostics, we can state with confidence that a plasma with higher radiation temperature and the density up to $\bar{n}_e \sim 5 \times 10^{12} \text{ cm}^{-3}$ can be produced within the range of $\bar{n}_{e0} \sim (3.5-5) \times 10^{12} \text{ cm}^{-3}$ against $\bar{n}_e \sim (1-3) \times 10^{12} \text{ cm}^{-3}$ in the FA only-produced discharge. With $\bar{n}_{e0} > 5 \times 10^{12} \text{ cm}^{-3}$, the mean density supported by THTA can be brought up to $\sim 8 \times 10^{12} \text{ cm}^{-3}$, and indirect measurements evidence electron heating at such density too.

- Speaking about optimum parameters of the FA-driven target plasma to produce denser and hotter plasmas with using THTA, we can argue that there is no need in production of a hot initial plasma, and even an afterglow plasma can be used. This enables to produce the initial plasma using an ultimately low RF-power where a stable discharge ignition by FA still is realized.

8) Peripheral plasma characteristics in the Uragan-3M torsatron. In the $\ell=3/m=9$ Uragan-3M (U-3M) torsatron ($R_0 = 100$ cm, $\bar{a} \approx 12$ cm, $r(\bar{a})/2\pi \approx 0.3$, $B_\phi \lesssim 1$ T) a hydrogen plasma is produced and heated by RF fields in the Alfvén range of frequencies ($\omega \lesssim \omega_{ci}$). In the work reported, to introduce RF power into the plasma, an unshielded frame-like antenna with a broad spectrum of generated parallel wavelengths is used. Close to radial distributions of plasma parameters (electron density n_e , electron temperature T_e , floating potential V_f) were studied with the use of movable Langmuir probes in the space between the helical winding cases and the last closed flux surface in a poloidal torus cross-section far from the antenna and in two cross-sections in the region of antenna disposition, one of them crossing the area bounded by the antenna frame. The measurements were carried out in two discharge regimes, one of which (regime 1) was characterized by a low average density $\bar{n}_e \sim (1-3) \times 10^{12}$ cm⁻³, a high electron temperature (T_e^{rad} up to 800 eV) and a large plasma loss from the confinement volume (by the diverted plasma flow magnitude), while a higher density, $\bar{n}_e \lesssim 7 \times 10^{12}$ cm⁻³, a lower temperature ($T_e \lesssim 100$ eV) and a low plasma loss were inherent to another regime (regime 2). Due to characteristic properties of the device, such as enclosing the whole magnetic system into a large vacuum chamber, a specific structure of the edge field lines ensuring the helical divertor magnetic configuration and the method of RF plasma production and heating with the antenna disposed in a short section of the torus, strong toroidal and radial inhomogeneities are inherent to the peripheral plasma in U-3M. Unlike the V_f , n_e and T_e spatial distributions far from the antenna, the distributions of these parameters as well as their absolute values are strongly disturbed by the near antenna field. Near the antenna the absolute values of V_f , T_e and n_e considerably exceed those measured far from the antenna at similar distances from LCFS. Presumably, a considerable part of the RF power fed to the antenna is spent for peripheral plasma production and heating near the antenna with a further fast loss of this plasma.

9) Control of the runaway electron flow in torsatron. The possibilities of stimulation and, on the contrary, complete suppression of the runaway electrons flow in the experiments at Uragan-2M torsatron were investigated. The flow stimulation was carried out by producing additional free charged particles during the runaway electrons flow formation. The runaway electrons flow suppression was carried out using the peripheral electrode with fixed negative or positive potential. The qualitative agreement of experiment results and the results of simple theoretical consideration was found.

10) Decreasing water concentration in the Uragan-3M device with UHF discharge. The first stage of procedure of wall conditioning at torsatron Uragan-3M by low temperature plasma of UHF discharge at ECR frequency allows to use low power (less than 3 kW) for effective chamber cleaning from water vapor and oxygen after closing chamber and vacuum pumping start. After this, higher impurities removal rate from inner torsatron vacuum chamber surfaces is provided at second stage (RF cleaning) of wall conditioning. At the first stage, the important role is played by the chemically active neutral hydrogen atoms that are produced during UHF wall conditioning. Water vapor, CO, CO₂, and hydro carbonates are generated during wall conditioning and removed by vacuum pumping. For

effective water vapor removal chamber walls should be heated to high temperatures (200-400 C) or hydrogen atoms flow should be increased together with low temperature plasma density as soon as H₂O desorption should be higher than its adsorption by chamber walls. Optimal plasma density is 10¹⁰ cm⁻³ for chamber walls at 150 C. Plasma density should be obviously higher at room temperature. UHF wall conditioning was realized by *continuous wave* power input regime. Plasma with the density $n_e \sim (4 \div 8) \cdot 10^{10}$ cm⁻³ and temperature T_e up to 10 eV was created at generator frequency $f_0 \sim 2,375$ GHz, magnetic field $B_0 \sim 700 \div 1200$ Gs and hydrogen pressure $p_{H_2} \sim 5 \cdot 10^{-5}$ Torr. Concentration of water vapor in the vacuum chamber decreases for 45-50% during first 4-5 hours of UHF wall conditioning regime, further dynamics of water vapor decrease is slower.

11) Hydrogen recycling during RF plasma heating in the U-3M torsatron. The hydrogen recycling behavior has been studied during the plasma experiments in torsatron U-3M. For this purpose, the time dependence of the molecular hydrogen pressure in the U-3M torsatron vacuum chamber in the modes of RF wall conditioning and RF plasma heating has been measured. The experimental results show that hydrogen recycling is observed in all plasma experiments. During the RF discharge for each mode the hydrogen pumping from the vacuum chamber runs at about constant rate. This rate is much exceeds the rate of an external pumping rate. After RF power switching-off the inverse desorption of hydrogen, accumulated during the RF discharge in the vacuum chamber walls and helical coil surfaces, is observed. When the antenna anode voltages and the RF pulse duration in both modes are increasing, the character of the time dependences of hydrogen pressure does not change significantly. The obtained results indicate on the fact that the mechanism of hydrogen absorption from the vacuum chamber is related with the RF discharge activation of hydrogen pumping by the vacuum chamber and helical coil wall surfaces.

12) Creation of low density starting plasma with small frame antenna at Uragan-3M device. During RF plasma creation and heating experiments at torsatron Uragan-3M (U-3M) RF power was transferred to antenna in a programmable way (power increase in three steps) to keep minimal idle time of discharge and protect antenna from high voltage that can appear without load. The voltage at the first stage of the RF impulse is not sufficient to provide minimal time for starting phase of RF plasma creation. But even programmable stages of RF power launching do not guarantee stable plasma creation (approximately every 30th impulse fails): idle time of each discharge is not stable and varies from 3 to 7 ms that impedes pulse to pulse measurements. The solution is to provide pre-ionisation before RF power start-up, i.e. to create low density and low temperature plasma. The main function of this discharge is to create plasma with approximately two orders of magnitude less electron density comparing with the regular discharge plasma density. The requirement is that the pre-ionising discharge shouldn't influence the level of impurities during the main part of the impulse. It is also important to make time stable gas breakdown during the discharge and eliminate idle time influence upon main characteristics of the discharge.

The pre-ionising discharge is driven by a small frame antenna (14x14 cm) placed in D-D cross section of U-3M stellarator and fed by RF power during 35 ms. The RF power (under 2 kW) is generated by a special RF generator based on GU-4 tube at the frequency of 6-8 MHz. The results of first experiments showed that small frame antenna can create low density pre-ionisation plasma.

13) New quasioptical receiving system for electron cyclotron emission diagnostics in Uragan-3M stellarator. Electron cyclotron emission (ECE) measurement is a powerful diagnostic for electron temperature profile measurement of high temperature plasmas confined in a magnetic field. For many years Uragan stellarators were equipped with conventional single antenna heterodyne radiometer. The antenna and waveguide system utilize mostly X-band ($\lambda = 3$ cm) components to deliver EC radiation from plasma to the detection system. The direction of the conical horn is fixed in the equatorial plane of the plasma and shifted in the direction of low field side to the distance which correspond the position of the inner surface of the helical coil. Recently the design of the quasioptical antenna system for the use in U-3M was suggested.

The ECE, with a frequency of more than 30 GHz, is transported according the quasi-optical (QO) phenomenon. The antenna consists of four stainless steel mirrors. Three of them are plane mirrors and the fourth is the concave elliptical one. This is done to optimize the mirrors layout, which is determined by the spot size of the QO beam at the plasma center and the beam is passed through the vacuum window, matching it to the size of the horn detection antenna. In order to select X-mode beam a wire grid polarizer is used. To improve the measured microwave intensity, it is desirable to enlarge elliptical mirror, which faces the plasma. To enhance the spatial resolution of the QO system in comparison to the present conical horn antenna the plasma spot size must be set as small as possible. This is done by optimization of the elliptical mirror depth (or it focuses). To manufacture concave QO mirror with elliptical surface special numerical code to operate computerized milling bore machine have been developed. The surface is polished with metal polishing compound (PIKAR) by hand so that the alignment is enabled using the laser beam.

To extend the ability of the ECE system to operate with any other microwave diagnostics (reflectometry or interferometry) in the same or lower frequency range, a quasi-optical splitter (dichroic plate) is used. For frequencies below the cutoff frequency, the dichroic filter acts as a plane mirror with a very low leakage rate.

The other advantage of large aperture optics for ECE (or other microwave diagnostics) is to form an image of the reflecting/emitting layer onto an array of detectors (instead single antenna) located at the image plane, enabling localized sampling of small plasma areas and to become a microwave imaging diagnostics, thus, to have a potential for visualization the 3D plasma turbulence.

14) Behavior of the radiation of the suprathermal electrons at the Uragan-3M stellarator after RF heating off from electron cyclotron emissions measurements.

The runaway electron (RE) phenomenon is one of the severe problems for fusion plasmas experiments. It was reported that at most tokamaks and some stellarators the present of such suprathermal electrons leads to sudden plasma disruptions. The impact of RE on the first wall or inner components is well localized due to their very small pitch angle. Thus the energy deposition may be huge and plasma facing components damages are often reported.

During previous experimental campaigns (2010-2013) for the central magnetic field of 0.7 T some evidence of the presence of the runaway electron was observed. It was found a strong radiation in the frequency range of an extraordinary mode second harmonic of electron cyclotron emission (32...39 GHz) after RF pulse switched off. A recently installed (2012) new microwave superheterodyne radiometer was used to confirm such phenomenon at the extended frequencies (57...75 GHz), which corresponds to third harmonic of the same wave.

It was found that during frame ICRF antenna plasma production/heating plasma scenario a strong runaway electron radiation has very distinct threshold on plasma density

of $(0.95...1.05) \cdot 10^{12} \text{ cm}^{-3}$. It has almost no dependence on operational magnetic field. Furthermore, it is possible that a beam of relativistic electrons can be slowed down by the combined effects of pitch-angle scattering and slowing down at more dense plasma by collisional friction against the plasma ions and electrons. New strategies for plasma discharge scenario have been recently tested in the Uragan-3M torsatron to mitigate the runaway electrons radiation which is routinely used for the initial plasma breakdown enhancement.

15) Spectral analysis of antenna RF-current in the torsatron U-2M. Plasma production and heating by RF techniques involve two major tasks. The first task implies that the RF generator should provide the required power in the necessary frequency range, a high quality of radiated waves and their optimum transmission to the antenna during the plasma discharge. The second task consists in reducing nonlinear interactions of ion-cyclotron antenna-radiated frequencies with the near-antenna plasma, which impair the efficiency of RF power input from the antenna to plasma.

Frequency-domain analysis of RF current excited on the screenless frame antenna in the U-2M has been performed. At an early stage of plasma discharge, only the first RF generator (K_1) was switched on. At this stage of the discharge, harmonics of type $f_n = nf_1$ (where $n=1, 2, \dots, 6$; $f_1=3.6875$ MHz is the generator K_1 frequency) as well as harmonics of type $\Omega = mf_1/2$ (with $m=1, 3, 5, \dots, 13$) were registered. At the initial stage of the discharge (≈ 10 ms), all lines of the two harmonic series show the side frequencies ($f_n - F, f_n, f_n + F$) and ($\Omega_m - F, \Omega_m, \Omega_m + F$), where $F \approx \pm 0.1875$ MHz. During the discharge with two generators K_1 and K_2 switched on, the following harmonics were observed: $f_n = nf_1$ and $f_n = nf_2$, where $f_2 = 4.75$ MHz is the frequency of the second section K_2 of the generator system. The combined frequencies ($nf_2 \pm nf_1$) were identified in the whole received frequency range up to 25 MHz. In the final stage of plasma discharge, the harmonics of type $f_n = nf_2$ were detected only from the section K_2 .

The observed effects may result from nonlinear wave interactions. As regards the generator system, here the non-optimal circuit, mismatch between the circuits and the presence of components with nonlinear characteristics may account for the effects. On the other hand, the edge plasma-antenna system is a strongly nonlinear coupled system. Therefore, even if the pumping waves come to the plasma through the near-antenna layers of the volume positive spatial charge having a nonlinear CVC, the formation of harmonics occurs, which are combination frequencies and rectification of some part of applied RF voltage. In an electrostatic field, plasma ions get acceleration with the result that the antenna surface degrades and gives rise to a flux of heavy impurities arriving to the plasma, as is the case with U-2M. With the use of the same generator system, similar nonlinear interactions took place in the torsatron U-3M. The present results show that the improvement of the efficiency of RF power input into the plasma calls for upgrading of both the generator system and the design of the RF antenna and its protection in order to reduce nonlinear interaction of RF waves with the near-antenna plasma.

16) Update of radiometry of RF complex kaskad-1 and measurements of RF parameters. The electromagnetic fields in ion cyclotron frequency range are applied for plasma production and heating in the Uragan-2M torsatron. Different types of antennas are used for RF power launching into the plasma. Matching of generator, antenna and plasma is among the most important tasks in the process of plasma heating. The measurements of frame-type antenna impedance during a RF discharge were provided. Such measurements are rather challenging due to high level of nonlinear effects, which are produced both the generator and the plasma. So, it is necessary to apply high selective filters. But due to

variety of generator operational regimes these filters could not be all-purpose. Moreover, it is very difficult to construct the selective filter with high inhibition and the same group delay in the passband for frequencies of the order of several MHz. Considering this, fast-acting ADC with frequency 200 MHz and buffer memory 16 Ms was applied to detect the real shape of RF signals during a RF discharge.

RF antenna current was measured using the noiseproof detector. For RF voltage detection on antenna the capacitive divisor with big inlet impedance was applied and voltage in the middle point of matching device was measured with the help of resistive divisor. The antenna impedance was determined using the Ohm's law.

As the results:

- in the course of RF generator operation antenna impedance was measured and the relative levels of main frequency harmonics were set;
- the antenna voltage measurements confirmed the effect of potential jump formation in the near antenna sheath;
- RF system was modified after that the harmonics, generated by the plasma, were defined with acceptable accuracy;
- the dynamic of power input into the room of device was determined; this is especially important for further understanding of physics of RF plasma discharge.

17) Effect of plasma on the radiotechnical characteristics of the Uragan-2M torsatron matching RF system. Uragan-2M (U-2M) has antennas with a matching device based on one oscillatory circuit. During the U-2M RF cleaning campaign with the use of helium as a working gas the qualitative assessment of the effect that plasma created and retained in torsatron has on changes in oscillation circuit Q-factor was carried out. The loop antenna was chosen for research purposes. Oscillatory circuit resistance is characterized by loss resistance R , which consists of antenna and connecting circuits active loss resistance r_{ant} , and of contributed load resistance created by the influence of plasma (antenna loading resistance) r_{pl} . During the discharge antenna loading resistance is changed. These changes r_{pl} cause corresponding changes in the oscillatory circuit current I_k . Q-factor of the circuit is determined from the ratio $I_k = I_f \cdot Q$, where I_f - is current supplied to the circuit (feeder current). The influence of the magnetic field in the range of 200-700 Oe and working pressure from $3.2 \cdot 10^{-5}$ Torr to $7.8 \cdot 10^{-5}$ Torr on the Q-factor of the oscillation circuit was studied. There are several areas of the maximum load of the antenna, i.e. maximum power input into the plasma with $B = 200, 400$ and above 600 A. A sharp circuit Q-factor increase was detected starting from pressure $5.8 \cdot 10^{-5}$ Torr. The relations of oscillatory circuit voltage under the absence of discharge and under loading circuit with plasma, as well as relations of corresponding currents in antenna are provided. The effect of the helical field on antenna load was studied separately. It was noted that oscillatory circuit Q-factor decreases with increasing current in U-2M helical winding.

18) Concerning Neutral Flux Shielding in the U-3M Torsatron. The volume of the torsatron U-3M vacuum chamber is about 70 m^3 , whereas the plasma volume is about 0.3 m^3 . The large buffer volume of the chamber serves as a source of a substantial neutral flux into the U-3M plasma. A fraction of this flux falls onto the torsatron helical coils located in front of the plasma, due to which the dynamics of neutral influx into the plasma modifies. The shielding of the molecular flux from the buffer volume into the plasma is estimated using numerical calculations. Only about 10% of the incident flux reaches the plasma volume. Estimates show that about 20% of atoms escape beyond the helical coils without colliding with them. Under these conditions, the helical coils substantially affect the neutral flux. A discharge regime with a hot low-density plasma produced by a frame antenna is

considered. The spatial distribution of the molecular density produced in this regime by the molecular flux from the chamber buffer volume after it has passed between the helical coils is calculated. The contributions of the fluxes emerging from the side and inner surfaces of the helical coils are considered. The calculations show that the shape of the spatial distribution of the molecular density differs substantially from the shape of the magnetic surfaces.

19) Features of Regular Discharges in Uragan-3M Torsatron. The Uragan-3M device is equipped with two antennas which are fed by RF power with the frequency below ion cyclotron. The frame antenna was used for pre-ionization and the three-half turn (THT) antenna makes plasma heating. In this experimental series, the radial profiles of CV and H α lines intensity and the second cyclotron harmonic emission are measured using a pulse-by-pulse technique. The results of these measurements and Biot-Savart calculations could be explained by existence of a small central area with relatively good plasma confinement surrounded by a zone where the confinement is poor. If so, the relatively low average electron temperature and high RF power needed to sustain plasma are the consequences.

20) Dynamics of longitudinal plasma current during RF plasma heating in torsatron U-3M was measured by a set of 15 magnetic sensors installed in one poloidal cross section for measuring spatial-temporal structure of the poloidal component of the magnetic field produced by toroidal plasma current. It was found that the poloidal component of plasma current magnetic field is not constant on the measuring surface. At the quasi-stationary discharge stage and after switching off the RF power the poloidal distribution of the registered magnetic field has a pronounced triangular shape (note, U-3M is $l=3$ device). At an initial stage of current rise the distribution is closer to circular with some shift outward relatively to geometrical torus center. The vertexes of triangle are located just under the helical coils.

At the time of transition into the improved confinement (to an H-like mode) the plasma current distribution becomes more peaked and with that the current is a little shifted inward. During the transition, the rapid increase of growth rate of plasma energy content is observed; the ratio of toroidal plasma current to plasma energy content becomes constant and is fixed at this level up to 1.5 ms after the end of RF pulse.

21) Heavy Ion Beam Probe diagnostic at the U-2M. The Heavy Ion Beam Probing (HIBP) diagnostic system is operated now at the Uragan-2M torsatron for the first time in Ukraine. The probing ion beam injector and energy analyzer, primary and secondary beam-lines, computer control and data acquisition systems were mounted and put into operation. The cesium ion beam with energy of 17-120 keV and ion current of 10-150 μ A was used in the first experiment for probing beam tracing through torsatron magnetic field (0.4 T). The secondary ion beam of 30-100 μ A was detected on the first deflecting plate of the secondary beam-line according to preliminary calculations using primary beam energy of 60-90 keV an ion current of 30-100 μ A. The primary beam ionization was held without plasma with hydrogen pressure in torsatron chamber of $5 \cdot 10^{-6}$ - $9 \cdot 10^{-5}$ Torr. The primary beam-line with energy 17-20 keV (12 μ A) was traced through torsatron magnetic field towards the analyzer detecting plates.

The X-ray radiation with energy above 1 MeV produced by electrons flow was detected during the magnetic field increasing and decreasing. These accelerated runaway electrons were produced by interaction between HIBP probing ion beam with the torsatron constructive elements.

22) Investigation of the Alfvén modes in TJ-II by Heavy Ion Beam Probe diagnostic.

Excitation of modes in the Alfvénic frequency range, $30 \text{ kHz} < f_{\text{AE}} < 300 \text{ kHz}$, was observed in hydrogen plasma heated by hydrogen NBI in the TJ-II heliac. Co-field and counter-field NBI were realized, and the components of the poloidal magnetic field were varied one-by-one and in combinations in order to investigate the beam-driven modes over an extended range of the rotational transform values, $1.51 < i(0) < 1.67$. Taking advantage of the unique TJ-II capabilities, a dynamic magnetic configuration experiment with $i(\rho, t)$ variation during discharges has shown strong effects on the mode frequency via both vacuum i changes and induced net plasma current. A drastic frequency increase from 50 to 250 kHz was observed for some modes when plasma current as low as $\pm 2 \text{ kA}$ was induced by small (10%) changes in the vertical field. A comprehensive set of diagnostics including heavy ion beam probe, magnetic probes and multi-chord bolometer made it possible to identify the spatial spread of the modes and deduce internal amplitudes of their plasma density and magnetic field perturbations. A simple analytical model for f_{AE} , based on the local AE dispersion relation was proposed to characterize the observation. It was shown that all the observations, including vacuum i and plasma current variations may be fitted by the model, so the linear mode frequency dependence on i (plasma current) and one over square root density dependence present the major features of the NBI-induced AEs in TJ-II, and provide the framework for further experiment-to-theory comparison.

23) The multichannel energy analyzer was installed on T-10 Tokamak. It makes heavy ion beam probing an effective tool to study the poloidal structure of geodesic acoustic modes with two-point correlation technique. GAMs were mainly pronounced on the plasma electric potential. It was shown that GAM potential oscillations have the poloidal mode number $m=0$ in the core plasma. This experimental result agrees with theoretical predictions.

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Research within the University

Ion beam interaction with composite structures

Radiation resistance of tungsten coatings deposited on multilayer functional units for fusion devices units to consecutive irradiation by He^+ and D^+ ions is determined. Tungsten coatings of different thicknesses are deposited on stainless steel with a copper layer (stainless steel + Cu + W). The effect of prior implantation of He^+ and D^+ ions on the accumulation of deuterium and helium and their thermal desorption into vacuum from tungsten coating of composite structure after consecutive irradiation by ions ($\text{He}^+ - \text{D}^+$) or ($\text{D}^+ - \text{He}^+$) is studied by methods of thermo-desorption mass spectrometry and electron microscopy. Types of radiation damages produced in the result of consecutive irradiation by D^+ and He^+ ions in a different sequence and, for a comparison, separately are determined. The influence of these damages on the structural properties of W coatings are found.

The results are published:

1) V.V. Bobkov, R.I. Starovoitov, L.P. Tishchenko, Yu.I. Kovtunencko, L.A. Gamayunova. Deuterium-Ion Implantation into Composite Structures with Tungsten Coatings. J. Surface Investigation. X-ray, Synchrotron and Neutron Techniques. 2014, V.8, No 5. p. 853-858.

Minutes of 43rd Stellarator-Heliotron Executive Committee Meeting

16 October, 2014

12:10 – 13:40

Room Red No.8, Hotel Park Inn Pribaltiyskaya

(Venue of 25th IAEA Fusion Energy Conference)

St.Petersburg, Russian Federation

Attendees

Australia	B.Blackwell
EU	Per Helander (substitute for R.Wolf /T.Klinger) A.Dinklage (substitute for R.Wolf/T.Klinger) (R.Wolf (partly through web-meeting)) J.Sanchez C.Hidalgo
Japan	A.Komori (Chair) H.Yamada T.Mutoh (as SSOCG chair) M.Yokoyama (secretary)
Ukraine	S.Moiseenko (substitute for I.E.Garkusha and V.S.Voitsenya)
USA	M.C.Zarnstorff (vice chairperson, web-meeting participation)
IEA	C.Pottinger (web-meeting participation)

Proposed Agenda

- 1) Approval of agenda
- 2) Approval of minutes of 42nd S-H ExCo meeting
- 3) Confirmation of membership of S-H ExCo (in addition, on chairmanship)
- 4) 20th International Stellarator-Heliotron Workshop (Greifswald, Germany)
- 5) Preparation for the IA Extension (due: 1 November 2015)
- 6) Status of domestic activities and international collaborations
- 7) Development of Stellarator-Heliotron working groups
- 8) Miscellaneous and final remarks

(Participants' titles are omitted in the minutes)

Meeting was opened by Komori. The participants are introduced by Yokoyama. It was mentioned that there was no participant from Russia this time. 7 members are attending, and thus a quorum is satisfied.

1. Approval of Agenda

The proposed agenda was approved.

2. Approval of minutes of the 42nd S-H ExCo meeting

(handout 2) No corrections and comments were raised. The minutes were approved as they are.

3. Confirmation of membership of S-H ExCo (in addition, on chairmanship)

The membership listed on the handout 3 (participants for this ExCo is also included) was confirmed to have no changes.

Komori: Please mention about the chairmanship.

Yokoyama: As some of you attended 40th ExCo (Jan.2012, Australia) might remember, there was a discussion for passing the chairmanship from NIFS to IPP. Klinger mentioned that NIFS (as a flagship) should hold the chairmanship till the beginning of W7-X operation, and now NIFS (Komori) holds a chairmanship. As you know, mid next year the W7-X will begin the operation, and considering the Thomas's statement in 40th ExCo, we may consider to succeed the chairmanship from NIFS to IPP next year.

Robert: (cannot be heard from web microphone, unfortunately).

Helander: Given the background, we discussed this issue in IPP scientific board, and Wolf declared to be willing to become a next chairmanship. Peter Kurz (background: reactor economy study) has been identified to be a secretary.

Yokoyama: This is the interim status of the next chairmanship. Unfortunately, Wolf is not here (although he is on-line), and upon the Klinger's statement ("after the W7-X operation begins"), the next ExCo should be the good timing for actually succeeding the chairmanship from NIFS to IPP, if you all agree.

→ *agreed by all the attendees. Yokoyama will confirm Russian representative's opinion.*

(postscript: it was agreed by Russian representative (L.M.Kovrizhnykh) by e-mail on 20 Dec.2014→ unanimous agreement)

4. 20th International Stellarator-Heliotron Workshop 2015

Komori: Please report the preparation status of 20th ISHW.

Helander: In the last ExCo (Sep. 2013, Padova), we were asked to organize the next 20th ISHW, and I was asked to chair the local organizing committee (LOC). We have done lot of work. I have sent out the pre-announcement to all the possible participants we could think about. It takes place from 5 to 9, October, 2015. The venue is close to downtown Greifswald (not IPP), and convenient in many ways. The only possible disadvantage of the venue is there are only up to 180 seats in the hall, but there have never been more than 180 participants. We will have an excursion to W7-X experiment. We have agreed on the preliminary schedule to be uploaded to web-site. 1 May: Start of registration, 15 May: Abstract submission deadline, 30 May: Accommodation booking deadline (block reservation agreed with Greifswald tourist office). Booking should be made directly with them. I also was asked by Yamada to contact journals for publications. For the last two ISHW, publication was made in PPCF. It is good to establish tradition. The reception will be in the university building on Monday, and the conference dinner will be on Thursday. For more scientific parts of the organization, they should be done in the international program committee (IPC).

Blackwell: We did selection of papers in ISHW in Australia (2012). (only invited, oral)

Dinklage: I would like all the participants have chance to publish, which strongly enhance the quality of presentations.

→ *This issue will be discussed in IPC.*

Hidalgo: It may be interesting to take an action to have the web-link to all the ISHW publications.

Dinkluge, Blackwell: Fusion-wiki has. (IA web)

Hidalgo: Then, publicity of the Fusion Wiki should be increased.

Komori: It was agreed in the last ExCo that the chair of IPC should be appointed from NIFS. In this case, we recommend K.Ida as a chair.

Yokoyama: According to the appointment of K.Ida as the IPC chair, we also ask each county to appoint one member to PC. May I ask you to do it in October? Please send the name of the appointed person to me.

Yamada: Let me propose Helander and Yokoyama to be involved in PC as well, to enhance communication between IPC, LOC and ExCo. → agreed

Moiseenko: Due to the severe situations (also on financial) in Ukraine, we would like to ask ExCo to find a way to support a few participants to ISHW from Ukraine.

Helander: How to decide and how to support should be decided.

(An experience on the successful preparation of IAEA support (although not used) was introduced by Blackwell.)

Helander: One thing LOC could do is to increase a conference fee a bit. How many participants should be supported?

Moiseenko: At least one. If possible, two or three.

→ A bit increase of conference fee and the support for two persons are the consensus in ExCo.

5. Preparation for the IA Extension (due: 1 November 2015)

Komori: In 30 June 2016, our IA will expire. We must determine whether our IA should be extended or not. Are there any opinions? → There were no objections.

Yokoyama: (handout 5) we should submit supporting documents to Pottinger till November 1, 2015 (we have more than 1 year). Letter to the FPCC Chair, CERT Criteria, End-of-Term Report (~10 pages) and Strategic Plan (~5 pages) should be submitted. As a secretary, I need your contributions for preparing these documents. I have example documents from the previous secretary, Yamada. Then, IA representative should attend FPCC (January 2016) in person to present the request for extension. At some point (mid-) 2015, I will distribute requests to you for this preparation. By default, 5 year extension will be made.

Blackwell: Do you have previous examples?

Yokoyama: Yes. It might be too early to distribute. Please just be prepared. → minutes will be distributed to Russian representative for asking their opinions for IA extension. *(postscript: it was agreed by Russian representative (L.M.Kovrizhnykh) by e-mail on 20 Dec.2014 → unanimous agreement)*

6. Status of domestic activities and international collaborations

Komori: Mutoh-sensei, could you report on status of SSOCG activity?

Mutoh: (Viewgraph) This group is formally organized on the last IAEA-FEC. The first term is three years, until this December. The next term is three years from 2015. The main object is to organize and coordinate the steady-state (SS) operation research, important for fusion research. The first meeting was held in Aix-en-Provence on 16 May 2013. At that occasion, we decided 7 working packages and contact persons listed in the viewgraph. In the last year, we received the report from each contact person, and we sent the report to IEA, FPCC this January. The second meeting was held at Kyushu University at the last ITPA meeting. Today, we held the third meeting (just before SH ExCo), and we discussed on the status of SS activity in each major institute, and how we continue this activity in the next term. We will propose the extension of this activity for next three years from next February. Key physics and technological area are listed in the viewgraph. Today, we discussed to add another items: modelling of IR system (heat flux to wall, SOL), SSOCG-6 to be divided to

shorter and longer term activities, and we will make another new workpackage (SSOCG-8) on the exhaust: divertors and active heat flux control to be led by A. Dinklage. We will request three-year extension to FPCC.

Komori: Next item is the report of domestic activities and international collaborations.

Australia

Blackwell: 2013-14 has been a busy year of publicity and politics, with all Australian Facilities undergoing evaluation as part of a drive to renew funding on longer timescales. Funding is still in 'bridging' mode for operations and maintenance only, until such renewed funding eventuates. This limited funding appears to be safe until July 2016. The ANU plasma fusion research activity, including the Australian Plasma Fusion Research Facility was also reviewed quite favourably by an international panel. (mentioned later) As for international collaboration, one thing we found positive that the implementing agreement was that we stimulated government to attend the FPCC. That is a progress. We are getting good support from nuclear authority and government, and we have a MOU with IPP waiting to be signed.

Hidalgo: How is the funding for facilities?

Blackwell: We have A\$450,000 per year. That's enough just to keep us alive without losing more people. All facilities in Australia are funded by the scheme so-called National Collaborative Infrastructure. That scheme is more or less on hold with the new government, and I heard they are starting a longer-term funding in approximately one year.

Spain

Sanchez: We have had a severe crisis in public finances in the last years. However, CIEMAT, in particular, fusion group, could overcome this situation relatively easily. Probably, the most affected part of the budgets was travelling. But, we did not lose any stuff, and even could hire new stuff. We could operate device without any problems. The budget for running TJ-II is national and some European money (EUROfusion research workpackage). Obviously, we are looking W7-X, and as soon as W7-X getting full-swing. I am sure CIEMAT scientists are more interested to do science in W7-X than in TJ-II. We will manage this transition in coming years.

Hidalgo: We keep very long-standing collaboration on diagnostics with Ukrainian colleagues. We are just starting commissioning the second HIBP in TJ-II, unique capability to explore such as zonal flows in the whole plasma cross section as well as looking for the plasma potential asymmetry. Topics are growing to the whole community, such as impurity transport in collaboration with Greifswald colleagues. The W7-X is the key point, diagnostic development, particularly emphasis in reflectometry, to be ready for the first plasmas in 2015. Not only physics, supporting experiments in TJ-II, very close collaboration with IPP-Greifswald, areas of modelling experiments is the key topics for all of us. We keep our link with Japan in last years, successful in area particularly of fast-particle physics, many colleagues visiting CIEMAT. How to control empirical actuators on Alfvén modes, we know we can do although we don't know the details. We really hope we keep this activity in coming years. I had a pleasure to join the last campaign of LHD experiment for joint experiments on area of zonal flows. We are looking forward DD operation in 2016. All these physics might be particularly relevant. We are happy with this interaction. With US, I will highlight the pellet system, just starting operation. We have a successful interaction on impurity transport with a US colleague visiting CIEMAT from California University. We hope to keep this successful international interaction in coming years.

Ukraine

Moiseenko: The gradual decrease of the budget started from 2010. One also should take into account that the value of our currency dropped by 40 %. But the budget remains the same. The nearest plan is to prepare to close our activity by December,

and we expect no heating till then and renew it until next March. It could turn better, but we have to prepare to the worst scenario. Experiments in both devices (U2-M, U3-M): one device to another device by chain basis. Last year, both devices worked by collecting all the scientific materials. We continue theoretical work mainly for stellarator-based fusion-fission hybrid reactor. We have successful collaboration with Spain, and we want to even extend this collaboration for wall-conditioning scenario especially with Tabares. We also have international collaboration with Slovenia and Belgium for wall-conditioning, Austria for stellarator theory and Sweden for reactor issues.

Germany

Helander: At IPP, we had a big funding review this March for previous 5 years. We were given the very highest marks of all the energy research in Germany, but we were not given the increase of the funding because of the political situation (one of the coalition parties is not very keen to fusion). We would have stable situation in next 5 years. Of course, we collaborate just like everybody. I can speak mostly about theory. We send a PhD student to ANU, two post-docs to PPPL at the moment. Within EU, Dinklage will describe situation since he is coordinating European support for towards W7-X. Former post-doc in IPP theory division from CIEMAT, he is now coordinating EUROfusion funding for stellarator research within Europe. For the first time, we have a stellarator physicist doing that. It is good.

Komori: How about conditioning of W7-X?

Dinklage: The status of assembly and commissioning of W7-X, the closure of cryostat began at the beginning of May, for finalization of main device, those were major milestone achieved this year. Since we continue device commissioning, still there are assembly works to be done particularly in-vessel and periphery. With regard to commissioning plan, status is that cryostat vacuum has been achieved, leak search has been performed. Installation of heating components, recently first ECH launcher was installed. There are no major delays on commissioning plan. First plasma is foreseen summer 2015. As for organizational restructuring in Europe, former EURATOM laboratories are now called EUROfusion labs. Stellarator is part of the mission-oriented roadmap with its own mission to the generation of fusion electricity. There are two stellarator workpackages, which are coordinated on European scale. The scheme has been already implemented. We are very happy to observe that there are strong European interests on stellarator program, and stellarator community is growing such as Poland and Hungary, Finland. This is a promising progress. There are still discussions going on the final funding, but this is another story.

Japan

Yamada: (handout 6-1) I would like to thank for your participation to the last campaign of LHD experiment (FY2013). We had 90 participants from abroad. The cooling down process for the coming 18th campaign is going well, on-schedule. We will have experiment from 6 Nov. 2014 to 5 Feb. 2015 (13 weeks), and expect 7000 plasma shots. In 18th campaign, we will have a new gyrotron with the frequency of 154 GHz, and we will increase ECH power to 5.6 MW from 4.6 MW in the last campaign. We rearrange injection alignment of two 77 GHz-gyrotrons to inject horizontally (so far we have injected vertically) to improve the coupling with plasma. Therefore, we expect substantial improvement of central heating with ECH. I hope you enjoyed Ida's talk this Monday. He mentioned we have achieved ion temperature of 8.1 keV and simultaneous high ion and electron temperature of 6 keV. We achieved 7.5 keV in the previous campaign. Although the progress was not so significant, the operational scenario to achieve high ion-temperature plasma has been established. This means we have got the high reliability and reproducibility to produce this kind of

discharges. We can accumulate large database for these plasmas, and many papers related to improved confinement are reported in this IAEA FEC. We have also successfully extended steady-state operation: 48 minutes long discharges with 1.2 MW of wave heating (1 MW of ICH and 0.2 MW of ECH), temperature of 2 keV and density of $1.2 \times 10^{19} \text{ m}^{-3}$. We have established this kind of steady state operation, with the improvement of fueling and heating control. This kind of discharges is often terminated by the invasion of a large fragment of co-deposited materials. This is also reported in this IAEA-FEC. We are making big efforts to prepare deuterium experiment, prospected hopefully from April 2016. Before that, we have to finish all the preparation perfectly, to secure the reliability based upon the agreement with the local government and local residents.

Hidalgo: I found that Ida's presentation on LHD overview was very interesting. My comment to him after his presentation was indeed that the impurity transport is priority issue to everybody. I found in his presentation that the impurity hole is still a mystery. I still wonder we could consider joint actions in our community, a kind of research proposals including main actors in this table. If we assume that impurity hole is connected to the asymmetry of plasma potential on flux surfaces, very difficult to measure but can be computed, we may put some pieces together from experiments (ex., TJ-II) and modelling (ex., IPP-Greifswald). Then, I wonder whether LHD might try to look impurity hole from this perspective (potential asymmetry measurement is too difficult, though). This may be an action we might consider with many actors.

Yamada: Let me make sure you are talking about the neoclassical picture, or shock formation?

Hidalgo: Our colleagues in IPP-Greifswald are looking into the neoclassical mechanisms why we have poloidal asymmetry of plasma potential. Whole story may include turbulence as well.

Yamada: Let me introduce next International Toki Conference (4-7, Nov. 2014). The title is "Expanding horizons of plasma and fusion science through cross-fertilization". In these several years, we have aimed at more or less upward direction toward realization of fusion energy from the present status. In contrast, the motif of this Toki conference is the horizontal extension including wide variety of plasma science including fusion science. Some introductions on plenary speakers are made.

USA

Zarnstorff: HSX and CTH are both operating well, and funding is stable. They will have to re-propose for continuing support roughly in one year's time. This is also usual pattern, since the funding is three-year cycle. HSX is evaluating possible upgrades for that proposal, including island divertor capability. For collaborations: for W7-X collaborations DoE called proposals from universities. Reports have been evaluated and funding decision has not been announced. Unfortunately, LHD-specific funding was cancelled by DoE. We were very surprised by this and are still trying to get this reversed. But the resolution depends on the uncertainty of the overall budget. We do not know exactly what is going on. You heard about collaborations with TJ-II. Overall, the budget in the US is still basically under pressure because of ITER funding. The domestic non-ITER programs are in substantial uncertainty, driven by ITER funding. The uncertainty would be resolved till early parts of next year. As a part of that, DoE has been asked to make the strategic plan for next ten years. They are very controversial and lot of discussions going on at the moment. The report has not been adopted unanimously. On the other hand, the report specifically mentions stellarators, better than I expected.

Dinklage: Question about the implementation of the DoE proposals to W7-X. I did not get exactly what procedure would be.

Zarnstorff: DoE called proposals specifically from universities. They are now evaluating referees reports for these proposals. They have not announced which proposals would be funded.

IEA

Pottinger: We had the very first cross-cutting session in 2014 FPCC. The topic was on communicating with society. We had very interesting cross-cutting discussions. They are anticipating ITER as a potential for fusion. We had delegates from including delegates from European space agency, large collider and so on. It was very interesting to have Dr. R.Aymer, who has been DG of CERN for a number of years, to hear his experiences. Reports on implementing agreements were made to the governing board of IEA in 2013, basically highlighting what IAs are all about, evolution in about 40 years (from 1975). They were very pleased to have this report and pretty much amazed. They had a couple of requests to CERT, committee just above FPCC: 1. More ways for awareness, 2. Improvements for process of the request of IA extension. Next cross-cutting session (next meeting of FPCC) will be 28-29 Jan. 2015. We will be having a special session for materials. If you are willing to contribute that special session, please let me know.

6. Development of Stellarator-Heliotron working groups

Yokoyama: (handout 7-1) We had 13th CWGM in Feb. 2014 in Kyoto (Uji). We had several participants from abroad, and remote-participation. The report was already published in Stellarator News, and all the presentation files are available in the web. In addition to usual scientific discussion, we had a session for frame of collaborations: EUROfusion (Dinklage) and SSOCG (Mutoh). What kind of issues have been discussed, and how we can contribute and lead this kind of framework of collaborations based on CWGM activities. Some highlights in 13th CWGM were, 3D transport in divertors (led by Kobayashi, he successfully made the overview talk in IAEA-FEC) and impurity (led by McCarthy, considering joint actions including modelling activities). We are considering holding the next one, 14th CWGM. (handout 7-2) We had LHD/W7-X joint collaboration workshop in Greifswald, July 2014. Discussions for collaborations on diagnostics, heating and theory/simulation were made. We successfully compiled 15 LOI (Letters of Intent) for possible collaborations between LHD and W7-X. We should proceed to follow-up meeting.

7. Miscellaneous and final remarks

- Komori proposed to hold the next ExCo in Greifswald during 20th ISHW (Oct.2015), and agreed by attendees.
- 2014 Annual Report: the deadline of submission to IEA secretary is 1 Dec. (according to C.Pottinger). Yokoyama will send around the e-mail asking contributions from each party (due will be mentioned in the request e-mail).
- Closing remark by Komori.

(After the closing)

- *The will of IA SH extension was conveyed to Pottinger, to confirm the documents submission due is 1 Nov. 2015.*
- *Discussion was raised from Pottinger on Russian participation status. Some trials will be made for a progress. (Inquiry to B.Kuteev etc..)*