10. International Collaboraiton

Many research activities in NIFS are strongly linked with the international collaborations with institutes and universities around the world. These collaborations are carried out in various frameworks, such as 1) coordination with foreign institutes, 2) bilateral coordination with intergovernmental agreements, and 3) multilateral coordination under the International Energy Agency (IEA).

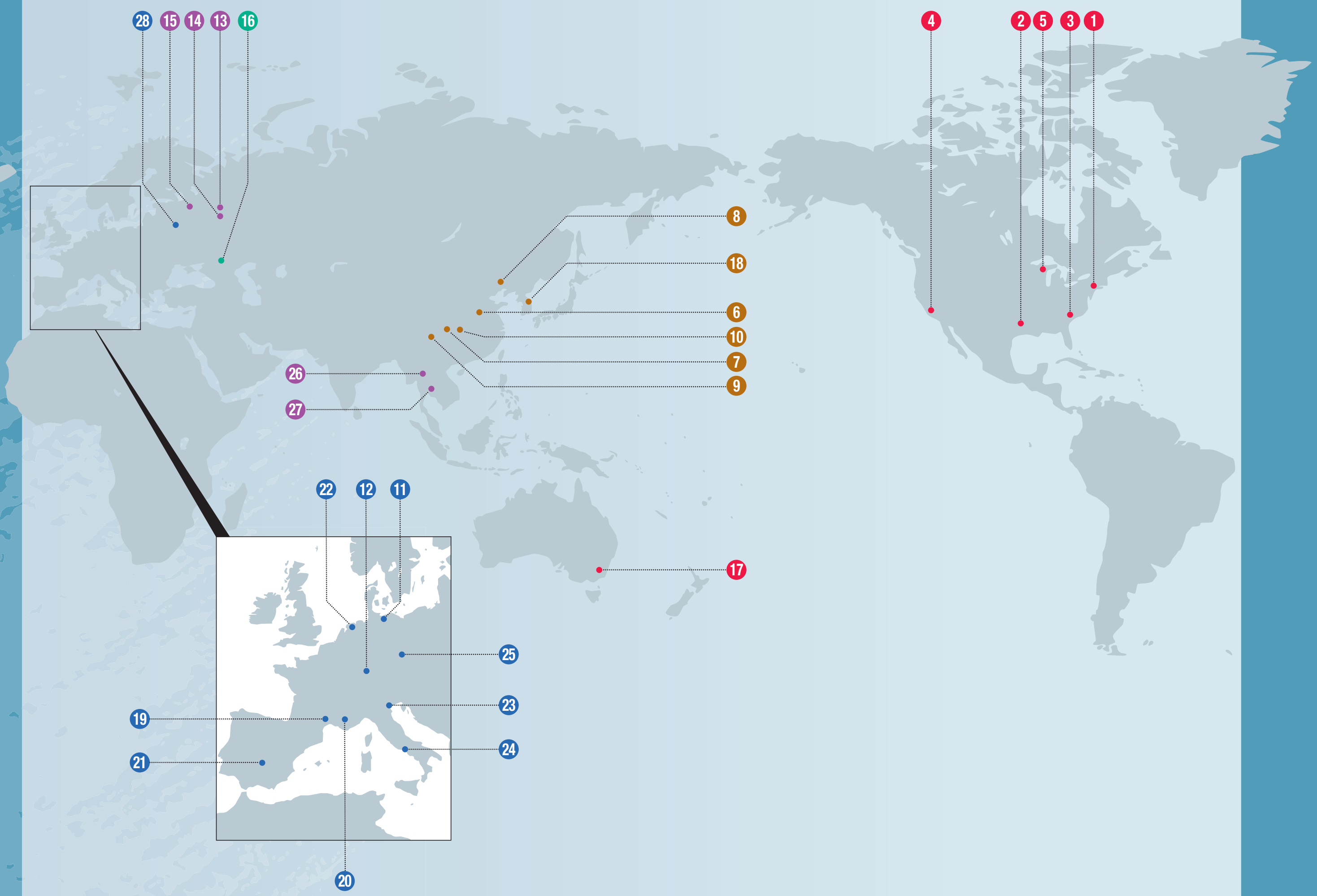
The coordination with foreign institutes is important as the basis of collaborative research. From 1991, NIFS concluded 29 coordination through FY2017. In FY2018, a new coordination was concluded between NIFS and Huazhong University of Science and Technology (China).

NIFS is the representative institute for the three bilateral coordination with intergovernmental agreements (J-US, J-Korea, and J-China), and for the four multilateral coordination under the IEA (Plasma Wall Interactions (PWI), Stellarator-Heliotron concept, Spherical Tori, and Steady State Operation). For the bilateral coordination, and the multilateral coordination PWI Technology Collaboration Program (TCP), NIFS coordinate the collaborative research not only for NIFS researchers, but also for researchers in universities. The activities of the bilateral and multilateral coordination activities are reported in the following subsections, respectively.

In 2018, the joint meeting of the 27th International Toki Conference on Plasma and Fusion Research and the 13th Asia Pacific Plasma Theory Conference was held on 19 – 22 November in Toki, Japan, and NIFS hosted the meeting. More than 200 researchers from 16 countries participated.

(S. Masuzaki)

Academic Exchange Agreements



U.S.A.
1. Princeton Plasma Physics Labolatory (PPPL)
2. Institute for Studies, The University of Texas at Austin (IFS)
3. Oak Ridge National Laboratory (ORNL)
4. Center for Energy Science and Technology Advanced Research, University of California, Los Angelse (UCLA)
5. College of Engineering, University of Wisconsin, Madison

China
6. Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP)
7. Southwestern Institute of Physics (SWIP)
8. Peking University
9. Southwest Jiaotong University (SWJTU)
10. Huazhong University of Science and Technology

Germany
11. Max Planck Institute for Plasma Physics (IPP)
12. Karlsruhe Institute of Technology (KIT)

Russia
13. Russian Research Center, Kurchatov Institute (KI)
14. A. M. Prokhorov General Physics Institute, Russian Academy of Sciences (GPI)
15. Peter the Great St. Petersburg Polytechnic University

Ukraine
16. National Science Center of the Ukraine Khar'kov Institute of Physics and Technology Institute of Plasma Physics (KIPT)

Australia
17. Australian National University (ANU)

South Korea
18. National Fusion Research Institute (NFRI)

France
19. Aix-Marseille University (AMU)
20. Commissariat à l'énergie atomique et aux énergies alternatives (CEA)

Spain
21. National Research Center for Energy, Environment and Technology (CIEMAT)

Netherlands
22. Dutch Institute for Fundamental Energy Reseearch (FOM)

Italy
23. CONSORZIO RFX
24. Institute of Lonized Gas (IGI)

Czech
25. HiLASE Center, Institute of Physics CAS (FZU)

Tailand
26. Chiang Mai University
27. Thailand Institute of Nuclear Technology (TINT)

Poland
28. Institute of Plasma Physics and Laser Microfusion (IPPLM)

The ITER International Fusion Energy Organization (ITER)

US – Japan (Universities) Fusion Cooperation Program

The US-Japan Joint Activity has continued from 1977. The 39th CCFE (Coordinating Committee for Fusion Energy) meeting was held on March 7, 2019 via televideo conference system. The representatives from the MEXT, the DOE, universities and research institutes from both Japan and the United States participated. At the meeting, the current research status of both countries were reported together with bilateral technical highlights of the collaborations. The FY 2018 cooperative activities were reviewed, and the FY 2019 proposals were approved. It was noted that both sides have developed significant and mutually valuable collaborations involving a wide range of technical elements of nuclear fusion. Discussion on the bilateral programs and multi-lateral activities also was conducted. Both sides agreed on the usefulness and necessity of the continuation of the Joint Activity.

Fusion Physics Planning Committee (FPPC)

In the area of fusion physics, 7 workshops (6 from JA to US, 1 from US to JA) and 13 personnel exchanges (9 from JA to US, 4 from US to JA) were carried out. Due to the funding limitation and the schedule conflict, 7 personnel exchanges (1 from JA to US, 6 from US to JA) were cancelled or postponed.

Each personnel exchange was performed successfully in the research fields of steady-state operation, high-beta physics, confinement and transport, diagnostics and the high density physics related to the inertial fusion and its application. Fruitful discussions were conducted in the workshops with many participants from both sides. These programs were productive and beneficial for the progress of fusion physics, and were recommended to be continued.

In the category of the high density physics related to the inertial fusion, experiments were performed to obtain the scaling of the laser-generated intense magnetic field towards ignition-scale targets in the OMEGA-EP facility in Laboratory for Laser Energetics in the University of Rochester. In this method, the intense magnetic field is generated by current running along the periphery of the hohlraum wall surface, as shown in Figure 1. Dependencies of the generated magnetic field on laser pulse length and target-size were studied with the proton deflectometry method.

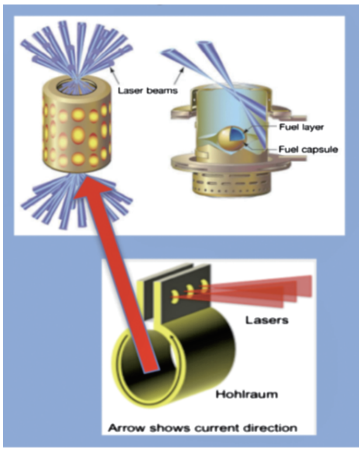


Fig. 1 Schematic of intense magnetic field generation with laser.

Joint Institute for Fusion Theory (JIFT)

Most of the activities in the two categories, workshops and personnel exchanges, that had been scheduled for the 2018–2019 JIFT program were carried out during the past year. Three workshops were successfully held, in addition to the JIFT Steering Committee meeting. In the workshops, multiscale methods in plasma physics, co-designs of fusion simulations for extreme scale computing, and simulation of the high field and high energy density physics were discussed as main topics (Figure 2). In the category of personnel exchanges, two Visiting Professors and eight Visiting Scientists made exchange visits for the purpose of collaborations on theoretical modeling and simulation of magnetic and inertial confinement fusion plasmas. At the JIFT Steering Committee meeting that was held in Portland, on November 7, 2018, the status of JIFT activities for 2018–2019 was reviewed and the recommenda-

Fig. 2 Workshop on “US-Japan collaborations on co-designs of fusion simulations for extreme scale computing” which was held in PPPL from July 30-31, 2018.

tion plans for 2019–2020 were discussed. The JIFT discussion meeting was held at Toki on September 14, 2018, in the Plasma Simulator Symposium.

Fusion Technology Planning Committee (FTPC)

In this category of the US-Japan Collaboration, personnel exchange programs were continued in six research fields, i.e., superconducting magnets, low-activation structural materials, plasma heating related technology, blanket engineering, in-vessel/high heat flux materials and components, and others (power plant studies and related technologies). Of the 14 originally planned items, 10 were completed including 3 workshops/technical meetings and 7 personnel exchanges.

One of the highlights was the joint experiment of a large-current high-temperature superconductor (HTS) as shown in Figure 3. A coiled sample of a Twisted Stacked-Tape Cable (TSTC) HTS conductor was prepared by Massachusetts Institute of Technology (MIT) and installed into the superconducting magnet testing facility at NIFS, equipped with a 13-T magnetic field, 700-mm-bore superconducting solenoid magnet and a temperature control capability at 4.2–50 K for the sample area. A sample current of 9 kA was measured at the bias magnetic field of 5 T with an inlet temperature of ~5 K.

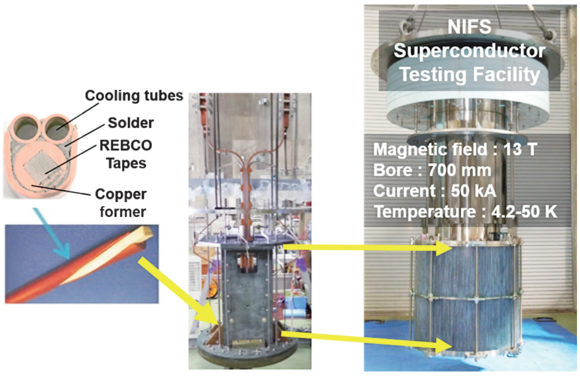


Fig. 3 TSTC-type HTS conductor sample fabricated at MIT and tested at NIFS.

US-Japan Joint Project: PHENIX

FY2018 was the last year of the six-year project of PHENIX. A number of experiments were successfully carried out to reach the project's goals.

Task 1 derived a new and simplified configuration of He-cooled gas divertor, named "flat design", from both results of the high pressure and the high temperature multi-nozzle impinging jet heat transfer experiments conducted in the past five years at the Georgia Institute of Technology with the He loop and of the numerous downselection studies by means of numerical simulation. The fundamental physics for heat flow of the He-cooled divertor was understood, and its cooling performance of each component of He-cooled divertor was demonstrated. Heat load tests were also performed for neutron-irradiated W and K-doped W-3%Re.

Task 2 examined mechanical and thermal properties of W and W alloys irradiated in the RB-19J capsule in the High Flux Isotope Reactor (HFIR), ORNL at around 500°C, 800°C, and 1100°C. K-doped W-3%Re developed during PHENIX project showed good ductility even after neutron irradiation, though significant irradiation embrittlement was observed for pure W.

Task 3 exposed neutron-irradiated W specimens to high flux deuterium (D) plasma and D+He plasma at 400°C in Tritium Plasma Experiment at Idaho National Laboratory. The retention of D was evaluated using thermal desorption spectrometry. The mixing of He in D plasma resulted in orders-of-magnitude decrease in D retention in neutron-irradiated W, as shown in Figure 4. This observation indicates that tritium inventory in W divertor can be significantly reduced by controlling He concentration in edge plasma.

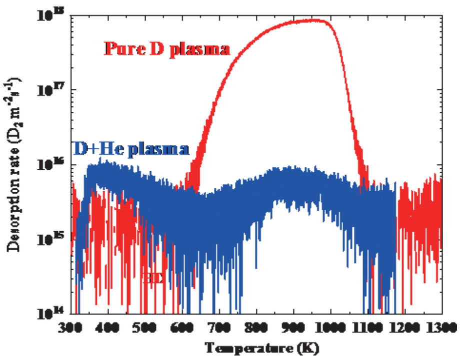


Fig. 4 Thermal desorption spectra of D_2 from neutron-irradiated W exposed to pure D and D+He plasma.

(T. Muroga, S. Okamura, H. Kasahara and K. Yaji)

Plasma Wall Interaction (PWI) Collaboration

This collaboration is based on the IEA Technical Collaboration Programme (TCP) of the “Development and Research on Plasma Wall Interaction Facilities for Fusion Reactors” (in short, PWI TCP). The objective of this TCP is to advance physics and technologies of the plasma-wall interaction research by strengthening cooperation among plasma–wall interaction facilities (in particular, by using dedicated linear plasma devices), to enhance the research and development effort related to the first wall materials and components for fusion reactor. In this fiscal year, collaborations on PWI experiment such as the impact of impurities on tungsten erosion, tritium retention analysis, plasma diagnostics and mechanical examination of tungsten alloys, and edge plasma simulation were conducted. All the collaborations are listed in Table I. Highlight of each activity is described in this report.

Condition of generation of supersonic plasma flows and its effect on impurity transports and radiation losses in advanced divertors

The super-X divertor, one of advanced divertors, has a total flux expansion and, thus, can drive supersonic plasma flows by the magnetic nozzle effect. In this study, we investigate effects of particle recycling on supersonic plasma flows by using a 2D plasma fluid code B2 which is based on the Braginskii’s equations.

(S. Togo, University of Tsukuba)

Impact of impurity on tungsten erosion expose to helium plasma

Impact of impurity and incident energy on the surface erosion in helium plasma exposed tungsten has been investigated on the linear device; PSI-2. The typical flux and fluence were 1×10^{22} /m^2/s and 1×10^{26} /m2, respectively. In order to investigate the effect of incident energy on the surface erosion, the incident helium energy was surveyed crossing the threshold energy of the sputtering, namely, within the range 30 eV and 130 eV applying bias on the sample holder. The sample temperature is actively controlled at 773 K by a combination of water cooling and electric heating, based on an infrared (IR) camera temperature measurement. Neon doped plasma exposure experiments are also carried out in order to investigate the effect of impurity on the surface erosion.

(R. Sakamoto)

Collaboration of plasma diagnostic study on Magnum-PSI

The detached plasma conditions are successfully produced in some linear devices and the tandem mirror GAMMA 10/PDX with optimization of background gas pressures and plasma source parameters. In the detachment plasma condition, the strong density fluctuations are observed in the linear plasma devices. We concentrated to study fluctuation in the detachment plasma. A 3-channel frequency multiplied microwave interferometer (MIF) system, which was constructed in GAMMA 10/PDX, was installed to the Magnum-PSI device to measure the electron line densities and their fluctuation.

(M. Yoshikawa, University of Tsukuba)

Evaluation of Damage Formation Mechanism of Doped Tungsten Alloys Under Thermal Shock Loading

To clarify the thermo-mechanical properties of radiation-tolerant W alloys (pure W, K-doped W, W-3%Re, and K-doped W-3%Re), which have been developed by Tohoku university, Japan, thermal shock tests using the JUDITH 1 were carried out at Forschungszentrum Juelich GmbH in 2017 and the evaluation of cracks and defects produced by the thermal shock tests was performed in 2018.

(S. Nogami, Tohoku University)

Tritium Distribution Analysis of Be Limiter Tiles from JET-ITER Like Wall Campaigns using Imaging Plate Technique

In this study, tritium (T) distributions on plasma-facing surfaces and side surfaces of selected Be tiles were examined using imaging plate (IP) technique. Samples were inner-wall guard limiter (IWGL), outer poloidal limiter (OPL) and dump plate (DP) retrieved after ILW-3. The highest T concentration was observed at the central part of plasma-facing surface of the OPL. The T concentrations at the plasma-facing surfaces of IWGL and DP were significantly lower than those on the OPL.

(Y. Hatano, University of Toyama)

Table I. List of collaborations

Subject	Participants	Term	Key persons
Condition of generation of supersonic plasma flows and its effect on impurity transports and radiation losses in advanced divertors	Satoshi Togo (Univ. Tsukuba)	9 – 28 July 2018	Dirk Reiser, Petra Börner, Detlev Reiter (FZJ)
Impact of impurity on tungsten erosion expose to helium plasma	Ryuichi Sakamoto (NIFS)	16 – 23 Sep. 2018	A. Kreter (FZJ)
Collaboration of plasma diagnostic study on Magnum-PSI	Masayuki Yoshikawa (Univ. Tsukuba)	29 Sep. – 7 Oct. 2018	H. V. Meiden (DIFFER)
Evaluation of Damage Formation Mechanism of Doped Tungsten Alloys Under Thermal Shock Loading	Shuhei Nogami (Tohoku Univ.)	18 – 31 Oct. 2018	Jens Reiser (KIT), Gerald Pintsuk (FZJ)
Tritium Distribution Analysis of Be Limiter Tiles from JET-ITER Like Wall Campaigns using Imaging Plate Technique	Yuji Hatano (Univ. Toyama)	26 Jan. – 2 Feb. 2019	J. Likonen (VTT)

(S. Masuzaki)

IEA (International Energy Agency) Technology Collaboration Programme for Cooperation in Development of the Stellarator-Heliotron (SH) Concept (“IEA SH-TCP”)

Highlight

Programmatic collaborations have been extending centering on two-flagship experiments, Large Helical Device and Wendelstein 7-X

The SH-TCP’s objective is to improve the physics base of the Stellarator-Heliotron concept and to enhance the effectiveness and the productivity of research by strengthening cooperation among member countries. All collaborative activities among worldwide stellarator and heliotron research are combined under the umbrella of this programme, which promotes the exchange of information among the partners, the assignment of specialists to facilities and research groups of the contracting parties, joint planning and coordination of experimental programmes in selected areas, joint experiments, workshops, seminars and symposia, joint theoretical and design and system studies, and the exchange of computer codes. The bi-annual “International Stellarator-Heliotron Workshop” (ISHW) has served as an important forum for scientific exchange within the scientific community. The joint programming and research activities have been organized mainly through the “Coordinated Working Group Meetings” (CWGM).
The second Deuterium experimental campaign of the LHD and the third operation phase (OP 1.2b) of Wendelstein 7-X (W7-X) mark the highlights of 2018.

Major achievements in 2018

The second deuterium campaign (20th campaign) of LHD started on October 23, 2018 and continued until February 21, 2019. The four topical groups (TGs) examined: high-performance plasma, transport and confinement, edge/divertor/atomic and molecular processes, and high-beta/MHD/energetic particles, with the participation of international and domestic collaborators. The 3rd International Program Committee meeting was held on September 19, 2018, to share and discuss the main goals of the 20th campaign such as maximizing and integrating performance, isotope effects, increasing understanding of edge and divertor plasmas to be extrapolated to reactor-relevant regime, extension of high-beta plasmas in low-collisional and high field regime, and further extending the energetic particles physics study.

The NIFS-SWJTU (Southwest Jiaotong University, China) has proceeded with programmatic physics and engineering study on the joint project, CFQS (Chinese First Quasi-axisymmetric Stellarator), of which results were presented on many occasions (EPS, International Toki Conference, etc.). The first plasma is foreseen in 2021.

The third experimental campaign of W7-X (OP 1.2b) took place from July to October 2018. The experiments used electron cyclotron resonance heating (ECRH) with a maximum power of ~7 MW, which is the highest ECRH power ever employed in a fusion experiment. Later in the campaign, neutral beam injection (NBI) with up to 3.6 MW was tested for the first time on W7-X. This included first studies of fast ion confinement and the loss of fast ions. The scientific program focused on the demonstration of stationary, high performance discharges and the characterization of the inertially cooled test divertor in preparation for operation of the actively cooled high heat-flux divertor in the later campaigns.

Increasing the density in hydrogen plasmas was achieved reliably by improving the wall conditioning using boronization. It was demonstrated that high plasma densities can be reached with a transition of the micro-wave heating power from X2-polarization to full power O2-polarization which is necessary to exceed the X2 cut-off density. At 5 MW heating power discharge lengths could be considerably improved from a few seconds in the previous campaign to a maximum of 25 seconds with stationary conditions. Sustaining a plasma over such a long time without any active divertor cooling was only possible because of the so-called detachment.

Group photo taken at 18th Coordinated Working Group Meeting, Princeton, Courtesy of Dr. David Gates (Princeton Plasma Physics Laboratory.)

47th Executive Committee (ExCo) Meeting

The 47th Executive Committee took place on October 24, 2018 in Ahmedabad, India. The ExCo nominated Alvaro Cappa to replace Axel Könies in the ITPA Energetic Particle Physics Topical Group, confirmed the International Programme Committee for the ISHW 2019 in Madison, discussed and decided on a structure for future CWGM reporting milestones, and received progress reports from the CWGM and the SSOCG. The ExCo also received briefings about the member’s domestic stellarator activities. I. Vargas supplied an update on the progress of the accession of Costa Rica and Y. Xu gave a presentation on the Chinese stellarator activities.

18th Coordinated Working Group Meetings (CWGM)

The 18th CWGM was held in Princeton Plasma Physics Laboratory, in April 10–12, 2018. There was a total of 59 presentations from 45 from onsite participants, and 14 from offsite participants. Representatives from 14 institutions and 9 countries gave presentations.

Talks covered a wide range of topics:

- Divertor physics; W7-X scraper elements (section leader: Oliver Schmitz),
- 3D Turbulence; isotope effect (section leader: Motoki Nakata),
- Database Progress and ITPA Links (section leader: Jose Luis Velasco),
- Impurity Transport (section leader: Novimir Pablant),
- Core Electron Root Confinement (section leader: Felix Warmer),
- Plasma Terminating Events by Excess Fuelling and Impurities (section leader: Andreas Dinklage),
- Wall Conditioning (section leader: Paco Tabares), and
- Fuelling and Pellet Injection (section leader: Naoki Tamura).

Numerous joint activities and relevant responsible individuals were identified. The presentations are available at the meeting website located at: https://sites.google.com/a/pppl.gov/cwgm18/.

(Y. Takeiri, T. Morisaki and M. Yokoyama)

Japan-China Collaboration for Fusion Research (Post-CUP Collaboration)

I. Post-CUP collaboration

The post-CUP collaboration is motivated by collaboration on fusion research with institutes and universities in China including Institute of Plasma Physics Chinese Academy of Science (ASIPP), Southwestern Institute of Physics (SWIP), Peking University, Southwestern Jiaotong University (SWJTU), Huazhong University of Science and Technology (HUST) and other universities both in Japan and China. The Post-CUP collaboration is carried out for both studies on plasma physics and fusion engineering. Based on the following implementation system, the Post-CUP collaboration is executed.

Table 1. Implementation system of Japan-China collaboration for fusion research

Category	① Plasma experiment				② Theory and simulation	③ Fusion engineering research
Subcategory	①-1	①-2	①-3	①-4	—	—
Operator	A. Shimizu	S. Kubo	M. Isobe	T. Oishi	Y. Suzuki	T. Tanaka

①-1 : Configuration optimization, transport, and magnetohydrodynamics, ①-2 : Plasma heating, and steady state physics, ①-3 : Energetic particles, and plasma diagnostics, ①-4 : Edge plasma and divertor physics, and atomic process

II. Primary research activities of collaboration in FY 2018

As for the NIFS-SWJTU joint project for CFQS, the 1st steering committee meeting was held on May 30, 2018 at SWJTU in Chengdu, China, as shown in Fig. 1. Physics and engineering design, and the construction of mockup coil of CFQS quasi-axisymmetric stellarator were discussed. Physics design of CFQS was completed and fixed in this meeting [1-3]. The main parameters of CFQS were fixed as follows: the major radius is 1.0 m, the averaged minor radius is 0.25 m, the aspect ratio is 4.0, the toroidal periodic number is 2, and the maximum magnetic field strength is 1.0 T. The modular coil system for CFQS magnetic field configuration was designed by using the NESCOIL code. The main modular coil set consists of 4 different coil types with 4 identical coils, and the total number of modular coils are 16. Construction of mock up coil of the most complicated modular coil in shape was started. The casting blank mould of the mockup coil was made up to February 2019, and the mould fabrication will be continued by computerized numerical control machine until April, 2019. Supporting structure design of coil system and the finite element method analysis are now in progress.

Fig. 1 The 1st steering committee meeting of NIFS-SWJTU Joint project for CFQS.

Energy and pitch angle-resolved measurement of beam ion loss is conducted using scintillator-based fast ion loss detector installed under the Japan-China collaboration onto the EAST tokamak. Prompt loss of beam ions having energy of 45 keV and pitch angle of 55 degrees were clearly seen in NBI2L injection phase [4]. Study of global beam ion confinement is performed by time-dependent analysis of total neutron emission rate (S_n) using the one-dimensional neutron emission calculation code FBURN. Relative time evolution of S_n in plasma discharge with an injection of short pulse neutral beam was successfully reproduced in both LHD and EAST [5].

In the research of the edge and divertor plasmas, spectroscopic diagnostics for tungsten impurities has been progressed using extreme-ultraviolet (EUV) spectrometers developed in LHD. Tungsten density profiles of W^{43+} and W^{45+} were derived from the line emission profiles measured using the space-resolved EUV spectrometers in EAST [6]. A tungsten influx to the edge plasmas was evaluated using the EUV spectroscopy for W^{6+} line emission in HL-2A [7]. In addition, the subcategory ①-4 group had the 7th China-Japan-Korea joint seminar on atomic and molecular processes in plasma (AMPP2018) hosted by ASIPP in July, 2018 as shown in Fig. 2.

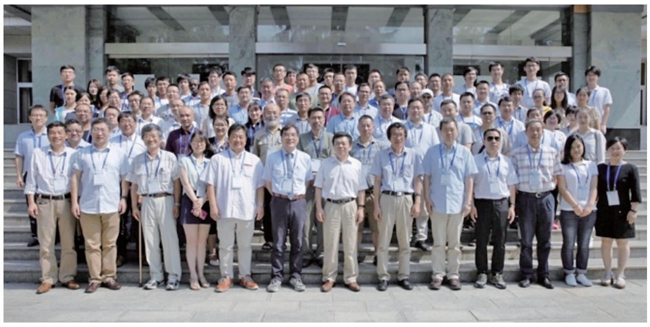


Fig. 2 AMPP2018 hosted by ASIPP, 24–26 July 2018.

In the category ②, EMC3-EIRENE transport modeling of neon-seeded EAST SOL/divertor plasma was performed to study non-axisymmetric impurity transport. This result will be compared with a result by SOLPS package. The simulation of energetic particle-driven instabilities is ongoing. MEGA code was applied to EAST plasma and it was found that the energetic particle-driven mode, which is toroidicity-inducted Alfvén eigenmode or energetic-particle mode, becomes unstable in an EAST plasma. In the J-TEXT tokamak, external resonant magnetic perturbation was used to control the tearing mode. To model the magnetic field, the HINT code is being applied. This result will be compared with NIMROD simulation result.

In the category ③, tritium release kinetics for biphasic Li2TiO3-xLi4SiO4 tritium breeders was studied by tritium-thermal desorption spectroscopy (TDS) method. The tritium release temperature and the shape of TDS spectra are dependent on the phase ratio of Li2TiO3 to Li4SiO4. In the case of Li2TiO3- 2 Li4SiO4, tritium release starts at 400 K, and the tritium migration is mainly controlled by the diffusion process. As increasing Li4SiO4 content, tritium release is influenced by the de-trapping process[8]. Also, the category ③ group had the 14th Japan-China symposium on materials for advanced energy systems and fission & fusion engineering (JCS-14) was held in September, 2018, in Sendai, Japan as seen in Fig. 3.

Fig. 3 JCS-14 hosted by Tohoku University, 25–27 September 2018, Sendai, Japan (100 participants).

[1] A. Shimizu *et al.*, Plasma Fusion Res. **13**, 3403123 (2018).
[2] H. Liu *et al.*, Plasma Fusion Res. **13**, 3405067 (2018).
[3] Y. Xu *et al.*, "*Physics and Engineering Designs for Chinese First Quasi-axisymmetric Stellarator (CFQS)*", 27th IAEA Fusion Energy Conference, Ahmedabad, India, 22–27 October 2018, EX/P5-23.
[4] C.R. Wu *et al.*, Rev. Sci. Instrum. **89**, 10I144 (2018).
[5] K. Ogawa *et al.*, Plasma Phys. Control. Fus. **60**, 095010 (2018).
[6] Ling Zhang *et al.*, Nucl. Instrum. Meth. **A 916**, 169–178 (2019).
[7] C.F. Dong *et al.*, Nucl. Fusion **59** (2019) 016020.
[8] Q. Zhou *et al.*, J. Nucl. Mater. **522**, 286–293 (2018).

(M. Isobe, T. Oishi, Y. Suzuki and T. Tanaka)

Collaboration under implement agreement between MEXT of Japan and the MOST of China for cooperation in the area of magnetic fusion energy research and development and related fields (JWG)

The People's Republic of China-Japan collaboration under the collaboration agreement between the MEXT of Japan and the MOST of the People's Republic of China has been performed following the results of the 11th JWG (Joint Working Group) held in Tianjin, China on July 26–27 2018.

In the meeting, in total collaborative programs (sixteen programs from NIFS and other institutes to the People's Republic of China and twenty-one programs from the People's Republic of China to NIFS and other institutes) are proposed and approved for the fiscal year 2018. The ollowing ten among sixteen approved programs from Japan to the People's Republic of China are performed.

- JC152 KUBO Shin and YANAI Ryoma (NIFS) to SWIP/ASIPP, 24–28 Mar., 2019
  - *ECRH System Optimization and ECRH Experiment in HL-2A,EAST and HL-2M*
- JC153 TSUMORI Katsuyoshi (NIFS) to SWIP, Feb. 24 – Mar. 8, 2016
  - *Development of Cs-Seeded Negative Ion Source for NBI*
- JC155 ISOBE Mitsutaka and OGAWA Kunihiro to ASIPP, Mar. 27–30, 2019
  - *Energetic-particle confinement study in LHD and EAST*
- JC156 YAMADA Ichihiro to SWIP, Feb. 26 – Mar. 1, 2019
  - *Electron temperature profile measurement by the HL-2A/2M Thomson scattering system*
- JC159 OISHI Tetsutaro and KAWAMOTO Yasuko to ASIPP, Feb. 24 – Mar. 2, 2019
  - *Collaboration on EUV spectroscopy in EAST*
- JC160 MORITA Shigeru and KATO Daiji to ASIPP, Jul. 23–27, 2018
  - *The 7th China-Japan-Korea Joint Seminar on Atomic and Molecular Processes in Plasma (AMPP2018)*
- JC163 TODO Yasushi to ASIPP, Jan. 23–27, 2019
  - *Simulation of energetic particle driven instabilities*
- JC165 YANAGI Nagato and MIYAZAWA Junichi to ASIPP/SWIP, Nov. 6–11, 2018
  - *Simulation of energetic particle driven instabilities*
- JC166 SAKAMOTO Yoshiteru and HIWATARI Ryoji to /SWIP, Nov. 7–8, 2018
  - *Discussion of Fusion DEMO Design and R&D in SWIP*
- JC167 SAKAMOTO Yoshiteru and HIWATARI Ryoji to /SWIP, Nov. 9–10, 2018
  - *Discussion of Fusion DEMO Design and R&D in SWIP*

Each program has been performed as substantial collaborations in each field and have benefitted the research progress of both sides as well as making the mutual understanding stronger for the future collaborations.

The following eight (CJ190 divided into three and CJ196 into two) collaborations are executed, eight are postponed and five are cancelled out of the twenty-one approved programs from People's Republic of China to NIFS.

- CJ190A ZHANG Ling (ASIPP) with MORITA Shigeru (NIFS), Jan.6-19, 2019
  - *Impurity radiation and transport Line analysis of EUV spectra and tungsten control in LHD and EAST*

  MORITA Shigeru
- CJ190B DUAN Yanming (ASIPP) with PETERSON Byron (NIFS), June 25 – July 5, 2019
  - *Impurity radiation and transport The EAST Bolometer diagnostics and the LHD IRVB technique*

- CJ190C ZHANG Yang (ASIPP) with ISOBE Mitsutaka and SUZUKI Yasuhiro (NIFS), June 25 – July 2, 2019
    - *Impurity radiation and transport Modeling of FTD experiment with HINT2*
- CJ192 ZHENG Jinxing (ASIPP) with YANAGI Nagato (NIFS) and SAKAMOTO Yoshiteru (QST), July 11–18, 2019
    - *HTS superconducting samples HTS superconductor of CFETR and JA DEMO*
- CJ193 QIN Shijun (ASIPP) with YANAGI Nagato (NIFS) and SAKAMOTO Yoshiteru (QST), July 11–18, 2019
    - *Design, analysis and assessment on CFETR and JA DEMO divertor*
- CJ194 GUO Fei (ASIPP) with CHIKARAISHI Hirotaka (NIFS), Jan. 15–22, 2019
    - *High voltage power supply*
- CJ195 LI Jiang (ASIPP) with CHIKARAISHI Hirotaka (NIFS), Jan. 15–22, 2019
    - *Coil power supply system*
- CJ196A FU Jia (ASIPP) with IDA Katsumi (NIFS), June 9–15, 2019
    - *The motional Stark effect diagnostic on EAST and LHD*
- CJ196B CHANG Jiafeng (ASIPP) with IDA Katsumi (NIFS), June 9–15, 2019
    - *FILD diagnostic development on EAST and Large Helical Device*
- CJ199 JIANG Caichao and WEI Jianglong (ASIPP) with OSAKABE Masaki (NIFS), Nov. 6–12, 2018
    - *N-NBI system*
- CJ200 DONG Chunfeng (SWIP) with OHISHI Tetsutaro (NIFS), July. 15–20, 2019
    - *Comparative study of the edge impurity transport between HL-2A and LHD*
- CJ201 HUANG Mei and ZHANG Feng (SWIP) with KUBO Shin (NIFS), Dec. 5–9, 2018
    - *Comparative study of ECRH transmission line, antenna and system commissioning on HL-2A and LHD*
- CJ202 GENG Shaofei, LIU He, WEI Huilin, YU Peixuan and YANG Xianfu (SWIP) with TSUMORI Katsuyoshi (NIFS), Nov. 25 – Dec.1, 2018
    - *Discuss about the design and control on neutral beam line based on negative ion source*
- CJ204 XU Min, ZHENG Pengfei and CHE Tong (SWIP) with YANAGI Nagato (NIFS), May 12–18, 2019
    - *Testing of HTS conductors for magnets design*
- CJ206 CHEN Jiming and WEI Ran (SWIP) with NAGASAKA Takuya (NIFS) and TANIGAWA Hiroyasu (QST), May 12–18, 2019
    - *Discussion about neutron irradiation testing technology for structural materials*
- CJ207 LIU Yi and ZHANG Yipo (SWIP) with ISOBE Mitsutaka and OGAWA Kunihiro (NIFS), June 23–28, 2019
    - *Developments of neutron diagnostics for HL-2A/LHD and joint experimental studies of energetic particles Physics in LHD*

Next JWG meeting (JWG-12) will be held in Nagoya, Japan near the end of July 2019 to discuss fiscal year 2019 programs.

(S. Kubo)

Japan-Korea Fusion Collaboration Programs

Closer and deeper cooperation in the areas of plasma heating systems, diagnostic systems, and SC toroidal device experiments were essential for physics research. Another important aspect of this collaboration is human resource development for future fusion research.

I. KSTAR collaboration

1 Plasma Heating Systems

The Korea-Japan Workshop on the Physics and Technology of Heating and Current Drive was held in Seoul, Korea in March 2019.

1.1 Radio Frequency Systems

Both Parties continued the collaboration and exchange of personnel and technical knowledge for the development of radio frequency technologies in fusion plasmas.

2 Diagnostic Systems

2.1 Bolometer Systems

Discussions continued regarding the reinstallation of the resistive bolometers on KSTAR as part of the KSTAR upgrade planned for 2021[1,2]. Joint work was done by Japanese and Korean researchers from NIFS and NFRI on the design and the proposal of a future upgrade of the IRVB for disruption mitigation experiments in KSTAR[3].

2.2 Edge Thomson Scattering System

Collaboration regarding the high repetition rate sampling (5 GS/s) DAQ system has been continued. For this collaboration, Japanese researchers from NIFS visited NFRI. NIFS and NFRI continued the collaboration on the 10 Hz YAG Laser.

2.3 Electron Cyclotron Emission (ECE) and Imaging (ECEI) System

The ECE radiometer system was continuously used for the KSTAR experiment. There has been discussion about the information on the ECE imaging systems of KSTAR and LHD. Both parties will continue the discussion regarding how to understand the imaging data and other issues.

2.4 Fast RF Spectrometer System

Collaboration papers have been submitted/published including those by UK collaborators for comparison between nonlinear simulation and KSTAR/LHD data. Based on the experiences from KSTAR and LHD, the design of a new RF radiation measurement system on QUEST has been discussed through a collaboration with Japanese researchers from Kyushu University. This diagnostic is primarily intended to measure RF radiations from runaway electrons.

2.5 Charge Exchange Recombination Spectroscopy

Charge exchange spectroscopy is one of the active spectroscopy using neutral beam to measure ion temperature, plasma rotation velocity, and impurity density. Korean and Japanese researchers continued the collaboration on the three types of CES spectrometers for the advanced KSTAR physics research.

2.6 Neutron and Energetic-ion Diagnostics

Japanese and Korean researchers will cooperate together to enhance temporal resolution of the Fast ion Loss Detector (FILD) system utilizing the fast electronics[4,5,6,7]. In addition, collaborative works on the Lorentz-Orbit (LORBIT) and/or Orbit Following Monte Carlo (OFMC) simulation will be continued to understand beam-ion behaviors in KSTAR.

2.7 Soft X-ray CCD Camera (SXCCD) and VUV Telescope System

Japanese and Korean researchers continued the preparation of the SXCCD camera system to be installed at the B port in KSTAR. A new supporting structure shared with the VUV telescope system has been jointly designed and fabricated. The remaining necessary items (a cooling water chiller and an in-vacuum neutron shield) of the SXCCD camera system will be shipped from NIFS to NFRI in the next scal year.

2.8 EMA Post Data Analysis System

Korean researchers from NFRI and Japanese researchers from NIFS continued the collaboration on data analysis system, EMA, which consists of EG data server, Myview data viewer, and Autoana automatic analysis system. We use Git, a distributed version-control system, to establish remote collaborative development. Also, the latest AutoAna system was installed for the KSTAR project using VPN service.

2.9 The 9th Japan-Korea Seminar on Advanced Diagnostics

The 9th Japan-Korea Seminar on Advanced Diagnostics was held at the National Institute for Fusion Science and at the KKR Hotel in Nagoya from August 7–10, 2018 and was hosted by Prof. K. Ida of NIFS. The purpose of this seminar was as follows: (1) to give young researchers and students from both countries a comprehensive knowledge of diagnostics for steady-state fusion plasmas, (2) to give them the opportunity to present their scientic results and (3) to help them to develop international friendships and collaborations. The number of lectures given was 15 (8 from Japan and 7 from Korea) on a variety of topics related to plasma diagnostics. 34 young researchers attended the seminar (20 from Japan and 14 from Korea) and gave poster presentations of their research.

2.10 SC Toroidal Device Experiments

Korean researchers from NFRI visited NIFS to participate in LHD D-D experiments to study rotation dynamics by external heating beam direction. Japanese researchers participated in the KSTAR experiment to study rotation transport dynamics under the nonaxisymmetric magnetic perturbation field.

II. Human Resource Development

The total number of researchers that were exchanged between Japan and Korea in JFY 2018 were 47 from Japan to Korea and 54 from Korea to Japan. Thirteen Workshops in various fields were held in each country (6 in Japan and 6 in Korea).

- Workshop on Physics validation and control of turbulent transport and MHD in fusion plasmas, Kyoto U., Japan, May 24–26, 2018.
- 4th Japan-Korea Joint Workshop for Fusion Material Technology Integration and Engineering, Otsu, Japan, June 29–30, 2018.
- 14th JCM, Seoul, Korea, July 4–5, 2018.
- Recovery of tritium in fusion reactor and its safety technology (III), Seoul National University, Korea, July 10–13, 2018.
- Workshop on ITER tritium system, Seoul National University, Korea, July 11–12, 2018.
- Modeling and Simulation of Magnetic Fusion Plasmas, Busan, Korea, July 11–14, 2018.
- Physics of fine plasma particles, Kamakura, Japan, July 26, 2018.
- The 9th Korea-Japan Seminar on Advanced Diagnostics, NIFS, Nagoya, Japan, August 7–10, 2018.
- Japan-Korea Blanket Workshop, QST, Japan, November 19–20, 2018.
- 12th Workshop on ITER Diagnostics, QST, Japan, December 13–14, 2018.
- KSTAR Conference, Seoul Korea, February 19, 2019.
- Workshop on Physics and Technology of Heating and Current Drive, SNU, Korea, March 18–21, 2019.

1) Juhyeok Jang *et al.*, Rev. Sci. Instrum. **89**, 10E111 (2018).
2) B. J. Peterson *et al.*, Rev. Sci. Instrum. **89**, 10E115 (2018).
3) Seungtae Oh *et al.*, Rev. Sci. Instrum. **89**, 10E118 (2018).
4) M. Isobe *et al.*, IEEE Trans. Plasma Sci. **46**, 2050 (2018).
5) K. Ogawa *et al.*, Rev. Sci. Instrum. **89**, 10I101 (2018).
6) K. Ogawa *et al.*, Plasma Phys. Control. Fusion **60**, 095010 (2018).
7) Jungmin Jo, et al., Rev. Sci. Instrum. **89**, 10I118 (2018).

(K. Ida)