4. International Collaboraiton

Many research activities in NIFS are strongly linked with international collaborations with institutes and universities around the world. These collaborations are carried out in various frameworks, as follows,

1) Multinational coordination in Fusion Power Coordinating Committee (FPCC) under International Energy Agency (IEA),
   - Stellarator-Heliotron Technology Cooperation Program (TCP)
   - Plasma-Wall Interactions TCP
   - Spherical Tori TCP

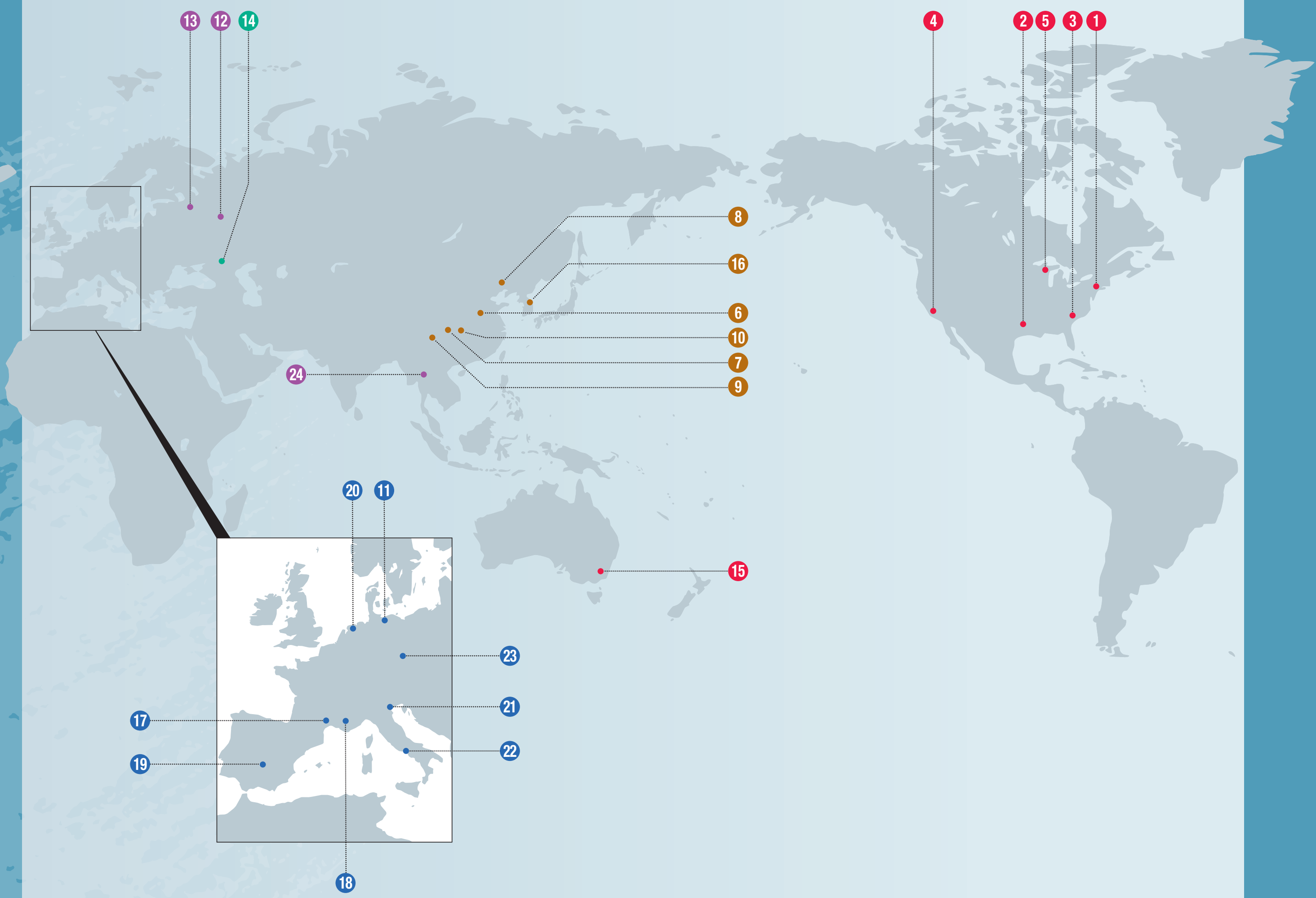
2) Binational coordination,
   - Japan-United States Collaborative Program
   - Japan-Korea Fusion Collaboration Programs
   - Japan-China Collaborative Program
   - Japan-EU Cooperation

3) Coordination with other institutions
   - 30 international academic exchange agreement

The geographical distribution of international collaborations and summary of each activity are shown in following pages.

(T. Morisaki)

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. Letters & Science and College of Engineering, University of Wisconsin–Madison College (UWM)

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)

Russia
12. A. M. Prokhorov General Physics Institute, Russian Academy of Sciences (GPI)
13. Peter the Great St. Petersburg Polytechnic University

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

Australia
15. Australian National University (ANU)

South Korea
16. National Fusion Research Institute (NFRI)

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

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

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

Italy
21. CONSORZIO RFX
22. Institute of Lonized Gas (IGI)

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

Tailand
24. Chiang Mai University

The ITER International Fusion Energy Organization (ITER)

US – Japan (Universities) Fusion Cooperation Program

US-Japan joint activity has continued from 1977. The 43rd CCFE (Coordinating Committee for Fusion Energy) meeting was held on April 24, 2024 via a video conference system. Representatives from the MEXT, the DOE, universities and research institutes from both Japan and the US participated. At the meeting, the current research status of both countries was reported, together with bilateral technical highlights of the collaborations. Fiscal year 2023 cooperative activities were reviewed, and FY 2024 proposals were approved.

(1) Fusion Technology Planning Committee (FTPC)

In the category of the FTPC, four personnel exchanges were performed in fiscal year 2023, including three Japan to US and one US to Japan. Three of the exchanges were in the research field of "in-vessel/high heat flux materials and components". The linear plasma-surface interactions research facility PISCES at UCLA was used to expose tungsten samples in hydrogen and deuterium plasmas. For the US to Japan collaboration, the samples were sent to NIFS to investigate surface modification using facilities such as FIB-TEM (Fig. 1). In the category of "superconducting magnets", current distribution in a High-Temperature Superconducting (HTS) large-current conductor fabricated at MIT was clearly evaluated from the measured magnetic field.

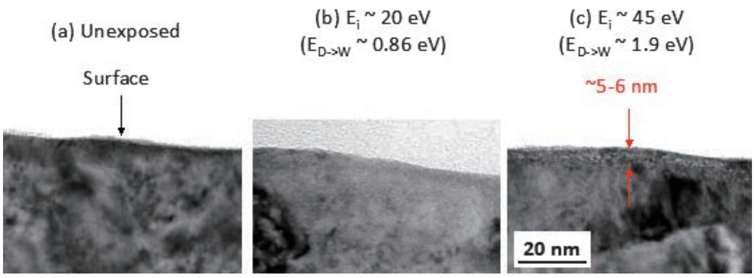


Fig. 1 TEM images of the Deuterium Supersaturated Surface Layer (DSSL). [D. Nishijima *et al.*, Nucl. Fusion **63**, 126003] (2023).

(2) Fusion Physics Planning Committee (FPPC)

In the field of fusion physics, collaborative research has been conducted in the following five categories: a steady-state operation, MHD and high Beta, confinement, diagnostics, and high energy density science. In FY 2023, one committee meeting was held, and four workshops and seven personnel exchanges were implemented from Japan to the U.S. Also, two workshops and four personnel exchanges from the U.S. to Japan were completed.

In the U.S., there was an experiment on MHD stability in an inverted triangular configuration and an optimization study on isotope ratio measurements in DIII-D. There were also experiments on the interaction between zonal flows and the phase-space vortex and on phase-space turbulence measurements in the linear plasma device LAPD at UCLA (Fig. 2). There was too an experiment on two-fluid relaxation in the reversed-field pinch device, MST, at the University of Wisconsin. Experiments on magnetic reconnection using high magnetic fields generated by lasers were done at the Princeton Plasma Physics Laboratory and the University of Rochester; and an experiment on laser-ion sources for heavy-ion inertial fusion at Brookhaven National Laboratory were conducted.

In Japan, an experiment on a non-inductive current start-up in the spherical tokamak device QUEST at Kyushu University was conducted. Discussions on plasma measurement were held at the Kyoto Institute of Technology and NIFS. At QST, plasma measurement in JT-60SA was discussed.

Fig. 2 LAPD (https://commons.wikimedia.org/wiki/File:Lapd_exterior.jpg#filelinks).

Fig. 3 Participants of the workshop on RF heating and current drive physics at UCSD.

Workshops were held on the following topics: RF heating and current drive (Fig. 3), MHD measurement and control, and inertial fusion in the U.S.; liquid metal plasma-facing walls, magnetic reconnection in Japan; and innovative and alternative confinement concepts online.

(3) Joint Institute for Fusion Theory (JIFT)

One workshop on “theory and simulation of high-field and high-energy density physics” was held at Yokohama in April 2023, and one workshop on “the progress of fusion research with extreme-scale computing and data science” was held at NIFS in November 2023. In the category of personal exchanges, one US to Japan exchange visit and one Japan to US exchange visit were successfully carried out for “collaboration on Tokamak boundary plasma turbulence simulations for divertor heat flux width,” which resulted in a publication in Physics of Plasmas (Fig. 4). A JIFT discussion meeting was held at Toki in September 2023 at the Plasma Simulator Symposium. The status of JIFT activities for 2023–2024 was reviewed, and recommendation plans for 2024–2025 were discussed at Nagoya among members of the JIFT Steering Committee in November 2023.

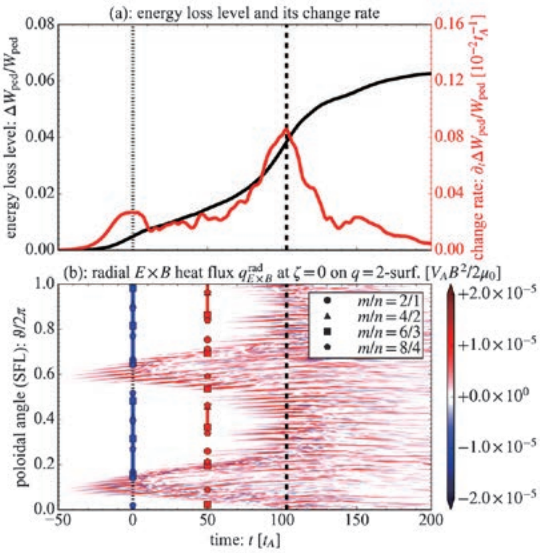


Fig. 4 Simulation results of (a) ELM energy loss level and its change rate, and (b) the spatio-temporal structure of radial heat flux at $\zeta=0$ on $q=2$ surface, where the dotted and dashed lines are the first ($t=0t_A$) and second crash ($t=103t_A$) respectively. In Fig (b), the colored solid lines represent the regions with magnetic islands (MIs), and the circle, triangle, square, and pentagon symbols are the location of X-points of $m/n=2/1$, 4/2, 6/3, 8/4 MIs [H. Seto *et al.*, Phys. Plasmas **31**, 032513 (2024)].

(4) US-Japan Joint Project: FRONTIER

The FRONTIER collaboration started in April 2019 to provide the scientific foundations for reaction dynamics in interfaces of plasma facing components for DEMO reactors. This project consists of four tasks: Irradiation Effects on Reaction Dynamics at Plasma-Facing Material/Structural Material Interfaces (Task 1), Tritium Transport through Interface and Reaction Dynamics in Accidental Conditions (Task 2), Corrosion Dynamics on Liquid-Solid Interface under Neutron Irradiation for Liquid Divertor Concepts (Task 3) and Engineering Modelling (Task 4). Regarding Task 3, liquid metal-structural material compatibility under neutron irradiation was examined. Sn capsules containing pre-oxidized FeCrAl tensile specimens (Fig. 5a) were exposed in 2022 to 0.8 Fe dpa neutrons in the High Flux Isotope Reactor at Oak Ridge National Laboratory (ORNL) for ten days at around 460 °C. The irradiated capsules were opened in 2023, and pre-oxidized Fe-Cr-Al alloy samples were successfully retrieved. Optical analyses of the specimens showed no serious corrosion (Fig. 5b). Tensile and microstructural characterization will follow. In the Safety and Tritium Applied Research (STAR) Facility at Idaho National Laboratory (INL), oxidation tests of W and W-Re alloy were successfully performed at 873–1173 K to simulate the loss of vacuum-accident conditions. Clear effects of Re on oxidation rate were observed at 1073 K and at lower temperatures (Fig. 6).

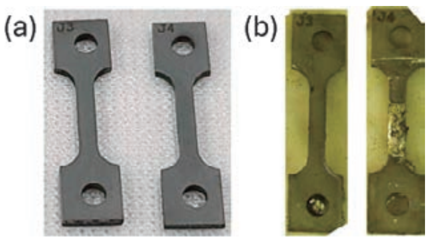


Fig. 5 Optical images of pre-oxidized FeCrAl oxide dispersion strengthened steel (ODS) samples (a) before and (b) after ten days HFIR neutron irradiation (0.8 Fe dpa) in liquid Sn environment at around 460 °C.

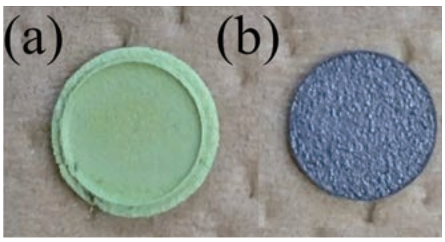


Fig. 6 Optical images of W (a) and W-10%Re alloy (b) after oxidation in Ar-20%O_2 mixture gas at 1073 K.

(T. Morisaki, S. Masuzaki, N. Yanagi, H. Sugama and Y. Hatano)

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” (PWI TCP) which involves Japan, Europe, the United States, Australia, and the United Kingdom. The objective of this program is to advance the physics and technologies of 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 a fusion reactor’s first wall materials and components, shown in the figure below.

NIFS collects proposals for international collaborative studies based on the PWI TCP, from domestic universities every year. The proposals are reviewed by the PWI technical committee whose members are domestic senior researchers in universities, QST, and NIFS, and some of the proposals are approved. Proponents of the approved collaborative research go to foreign institutes with support from NIFS and conduct the studies.

In the fiscal year of 2023, a collaboration on PWI experimentation was conducted.

Evaluation of D and He retention behavior in W-Re alloys and K-doped W in D+He mixed plasma irradiation

Evaluation of hydrogen-isotope retention in plasma-facing walls of fusion reactors is an important issue for the safety assessment of fusion reactors. Recently, W-Re alloys and K-doped W have been proposed as advanced plasma-facing materials, and it has been reported that irradiation-defect formation under neutron irradiation is reduced. Considering their use in plasma-facing materials, it is necessary to evaluate the hydrogen-isotope retention of these advanced plasma-facing materials to clarify He-mixing effects on the retention and to examine the applicability of the advanced plasma-facing materials from various perspectives.

In this study, deuterium plasma irradiation and mixed deuterium and He plasma irradiation of non-irradiated W-5%Ta, W-5.2%Mo, and K-doped W (40 ppm) samples were performed using a linear plasma irradiation system (DPE: Deuterium Plasma Experiment) in Sandia National Laboratories, and deuterium retention was evaluated.

As a result, it was found that the deuterium retention in W-5.2%Mo and W-5%Ta was about 1/5 of that in W, and that in W-K it was reduced by about one order of magnitude. It was shown that additive elements can significantly reduce hydrogen trapping sites. Future experiments using advanced plasma-facing materials with irradiation damage will be conducted to systematically summarize the effects of additive elements on hydrogen trapping and to study the mechanism of hydrogen trapping.

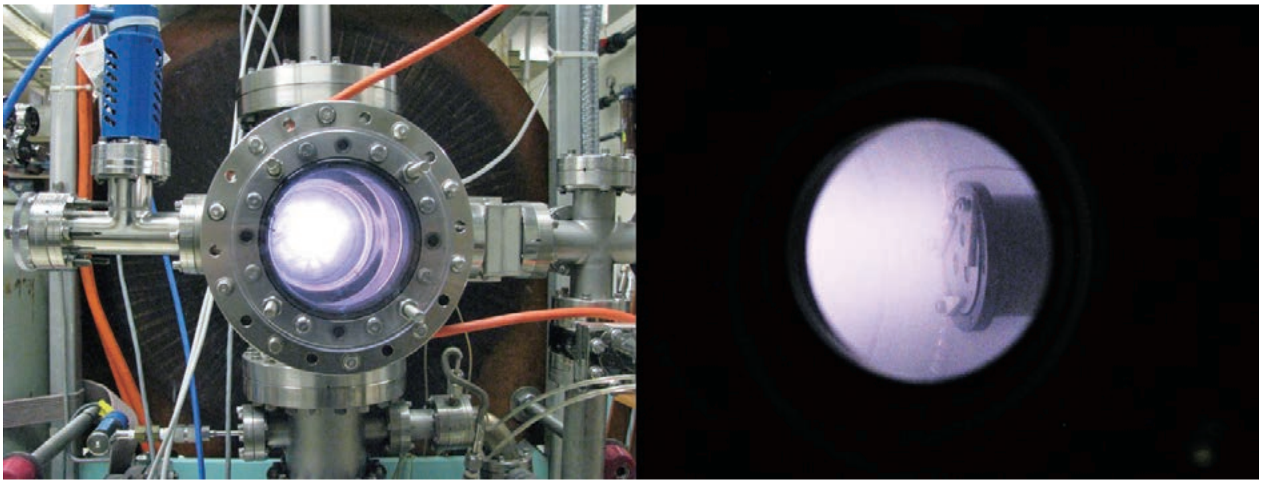


Fig. D+He mixture plasma in DPE and the material samples under the irradiation.

(Y. Oya, Shizuoka University)

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

Highlight

The LHD experiment has restarted under a new budget framework.

The objective of the Stellarator-Heliotron Technology Collaboration Programme (SH-TCP) is to improve the physical basis of the Stellarator-Heliotron concept and to increase the effectiveness and productivity of research and development efforts related to that concept by strengthening cooperation among IEA Member Countries. The cooperation program will consist of the following activities: exchange of information; dispatch of experts to facilities or research groups of the Parties; joint planning and coordination of experimental programmes in specific fields; workshops, seminars, and symposia; joint theoretical design and systems studies; exchange of computer codes; joint experiments.

The LHD project ended in FY2022, supported by the Large-Scale Science Frontier Promotion Project, a budget framework for promoting large-scale projects in Japanese academic research. However, due to the high recognition of its significance and importance, a new LHD project has been launched for three years until the end of 2026, with support from another budget framework, the Academic Research Foundation Project, which also promotes large-scale projects in Japanese academic research. This new LHD project will utilize LHD as an interdisciplinary research platform to promote international joint research that seeks to elucidate the basic principles of various complex phenomena that exist not only in nuclear fusion but also in space and astronomical plasma. This three-year extension of the LHD project is expected to further invigorate the activities of the SH-TCP.

Significant achievements in 2023–2024

Significant events in the IEA SH-TCP from 2023 to 2024 are as follows: (1) As mentioned in the highlights above, the operation of LHD has been extended for three years with support from the Academic Research Foundation Project. It is now possible to conduct two more experimental campaigns (the first of which began in March 2024), and (2) the 23rd Coordinated Working Group Meeting (CWGM) was held in Kyoto, Japan, from June 5 to 8th, 2023.

As mentioned in the highlights above, the operation of LHD was extended for three years from FY2023. This extension has given us more time to consolidate the results of the comparative study of large-scale stellarator-heliotron devices. From the perspective of revitalizing SH-TCP activities, extending the LHD operation is a critical decision.

Next, the CWGM held in Kyoto, Japan, was the first multi-day CWGM since travel restrictions due to COVID-19 were eased. As explained in more detail later, from the 23rd CWGM, the strategic task force system was reorganized to realize a stellarator-heliotron-type fusion reactor, and more specific work activities were carried out. To prepare for this renewal, the CWGM Organizing Committee held many remote meetings, using

Zoom, to redefine the activities carried out by the CWGM.

In addition, the IAEA Fusion Energy Conference, the most prominent international conference on nuclear fusion, was held face-to-face in London, UK, from October 16 to 21st, 2023. At this conference, the latest research results from each stellarator-heliotron device, such as LHD, W7-X, TJ-II, and Heliotron J, were presented and attracted the attention of researchers worldwide. Moreover, the researchers gathered for the conference frequently engaged in lively discussions during the meeting about the future of international collaboration on their respective research topics. Therefore, like the International Stellarator-Heliotron Workshop (ISHW), this conference, held once every two years, significantly contributes to the revitalization of SH-TCP activities.

Summary of 52nd S-H TCP Executive Committee meeting

During the IAEA Fusion Energy Conference, the 52nd Executive Committee (ExCo) meeting of the IEA S-H TCP was held in London, UK, on October 18, 2023. At this meeting, the chair reported on preparations for an IAEA-led Workshop on Physics and Technology aspects of stellarator-based fusion power plants and the status of CICLOP, as well as confirming TCP membership, particularly about the participation of private companies. There were also reports on the preparations for the 24th ISHW and the activities of the CWGM, and the representatives from the stellarator community participating in each ITPA topical group were confirmed. The next, 53rd, meeting will be held during the 24th ISHW, which will be held in Hiroshima, Japan, in September 2024.

23rd Coordinated Working Group Meeting (CWGM)

The 23rd Coordinated Working Group Meeting (CWGM) was held in Kyoto, Japan, from June 5th to 8th, 2023, with support from the Japan Society for the Promotion of Science (JSPS) Core-to-Core Program “Advanced Core-to-Core Network for High-Temperature Plasma Dynamics and Structure Formation Based on Magnetic Field Diversity (PLADyS).” It was held in a hybrid format with in-person and remote participation. This meeting rearranged the organization into a strategic task force structure to realize a stellarator-heliotron-type fusion reactor. Specifically, the CWGM topical groups were reorganized into

- Core transport and confinement in multi-ion plasmas
  TG coordinators: M. Nunami (NIFS), D. Carralero (CIEMAT)
- Energy, particle, and impurity transport in the SOL and divertor
  TG coordinators: A. Bader (UWM/Type One Energy), V. Winters (IPP)
- Energetic Particles, MHD, and High-Beta
  TG coordinators: A. Knieps (FZJ), A. Wright (PPPL)

In each of these three reconstituted topical groups, short-term goals were set to achieve long-term objectives, and specific research results were obtained through joint activities and joint experiments while also acquiring experimental data and tools to achieve the long-term objectives. The objectives and goals of each topical group were introduced at the meeting, and future activity policy was discussed. At the meeting, there was also a discussion about the relationship with the startup companies rapidly developing fusion reactors. It was announced that the next face-to-face CWGM would be held in Japan before or after the ISHW, and it was decided that until then, the follow-up to the discussions at this CWGM would be carried out remotely.

(N. Tamura, K. Nagaoka and K. Nagasaki (Kyoto Univ.))

Japan-China Collaboration for Fusion Research

Japan-China collaboration on fusion research is motivated by (1) a joint working group (JWG) for an implementing arrangement between MEXT of Japan and MOST of China, for cooperation in the area of magnetic fusion energy research and development and related fields. (2) Collaboration on fusion research with institutes and universities in China, including the Institute of Plasma Physics, the Chinese Academy of Science (ASIPP), the Southwestern Institute of Physics (SWIP), Peking University, Southwestern Jiaotong University (SWJTU), Huazhong University of Science and Technology (HUST) and other universities. The Japan-China collaboration is carried out both for studies on plasma physics and fusion engineering. Based on the following implementation system, the Japan-China collaboration for fusion research in FY 2023 was executed.

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

Category	① Plasma experiment				② Theory and simulation	③ Fusion engineering research
Subcategory	①-1	①-2	①-3	①-4	—	—
Operator	A. Shimizu	H. Takahashi	M. Isobe	M. Goto	G. Kawamura	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

Primary joint research activities in FY 2023

The sixth Steering Committee meeting for the NIFS-SWJTU joint project for the CFQS quasi-axisymmetric stellarator, was held on Dec. 11, 2023 at SWJTU Jiuli campus, as shown in Fig. 1. The progress of engineering design, the current status of the construction of modular coils (MCs), and vacuum vessels (VV) were reviewed [1]. At this time, for a total of 16 MCs, most of the manufacturing processes have been finished. Coil cases/ clamps, legs and other support structures were under construction. For the vacuum vessel, the manufacture of the first and second quarter toroidal sections were finished. Vacuum leak tests were perfomed on these sections, and no leaks were found. Manufacturing of the third and fourth toroidal sections on the vacuum vessel were in

Fig. 1 The sixth Steering Committee meeting of NIFS-SWJTU joint project for the CFQS held on Dec. 11, 2023 at SWJTU Jiuli campus.

progress. The first plasma will be produced in 2024 in a condition of 0.1 T operation. In additon to CFQS physics, basic research on the ion source for NBI were done joinlty with SWJTU [2,3].

Research of energetic particles, characterizations of compact neutron energy spectrometers, developed in collaboration with NIFS and ASIPP, have been utilized to measure the distribution of energetic ions in LHD and have been published [4-6]. NIFS and ASIPP performed triton burnup experiments to study alpha particle confinement ability in EAST July 2023. Also, NIFS and ASIPP have been discussing the execution of collaborative research to measure lost energetic ions for EAST and BEST. Research on energetic-ion loss due to MHD instability and runaway electron generation on the HL-2A tokamak were published as a joint outcome between NIFS and SWIP [7,8]. NIFS and SWIP have been discussing the design of neutral particle analyzers and neutron diagnostics in HL-3.

In the research of edge and divertor plasmas, we investigated the electron temperature measurement method, using the intensity ratios of impurity emission lines in relation to a steady-state operation with divertor heat load control in EAST. The main focus was on investigating the electron temperature dependence of the intensity ratio of the two emission lines of carbon ions, C IV 31.242 nm and C IV 41.971 nm, using the ADAS database. We also considered the intensity ratio of the two emission lines of neon ions, Ne VIII 10.31 nm and Ne VIII 8.809 nm, for which the neon impurity supplied for radiative cooling purposes was assumed to be used. We confirmed that it is feasible to measure electron temperature using these emission lines.

Regarding fusion engineering research collaboration, a withstand voltage test on a STARS conductor developed at NIFS was carried out at ASIPP using a mock-up sample in liquid nitrogen (temperature 77 K). The result suggested that the insulation between the copper-stabilized casing (that houses REBCO tapes) and the outer stainless-steel jacket could withstand up to ten times the required voltage.

[1] CFQS TEAM, “*NIFS-SWJTU JOINT PROJECT FOR CFQS – PHYSICS AND ENGINEERING DESIGN - VER. 6.0.*” December, 2023.

[2] Heng Li, Xin Zhang, Yuhong Xu, Guangjiu Lei, Sanqiu Liu, Katsuyoshi Tsumori, Haruhisa Nakano, Masaki Osakabe, Mitsutaka Isobe, Shoichi Okamura, Akihiro Shimizu, Kunihiro Ogawa, Hiromi Takahashi, Zilin Cui, Jun Hu, Yiqin Zhu, Xiaolong Li, Huaqing Zheng, Xiaoqiao Liu, Shaofei Geng, Xiaochang Chen, Haifeng Liu, Xianqu Wang, Hai Liu, Changjian Tang, CFQS team, “*Effect of H atoms and O impurities on the adsorption stability and work function of the cesiated Mo (001) surface: A study about negative hydrogen ion sources for neutral beam injection systems*”, Nuclear Materials and Energy **37**, 101550 (pp12) (2023).

[3] Heng Li, Xin Zhang, Yuhong Xu, Guangjiu Lei, Sanqiu Liu, Katsuyoshi Tsumori, Haruhisa Nakano, Masaki Osakabe, Mitsutaka Isobe, Shoichi Okamura, Akihiro Shimizu, Kunihiro Ogawa, Hiromi Takahashi, Zilin Cui, Jun Hu, Yiqin Zhu, Xiaolong Li, Huaqing Zheng, Xiaoqiao Liu, Shaofei Geng, Xiaochang Chen, Haifeng Liu, Xianqu Wang, Hai Liu, Changjian Tang, CFQS team, “*Effect of metal impurities on the adsorption energy of cesium and work function of the cesiated Mo (001) surface*”, Nuclear Materials and Energy **38**, 101619 (2024).

[4] S. Sangaroon, K. Ogawa, M. Isobe, L. Y. Liao, M. I. Kobayashi, G. Q. Zhong, S. Toyama, M. Miwa, S. Matsuyama, E. Takada, and M. Osakabe, “*Characterization of Liquid Scintillator-based Compact Neutron Emission Spectrometers for D-D Neutron Emission Spectroscopy in the Large Helical Device*”, IEEE Transactions on Instrumentation & Measurement **72**, 1010710 (2023).

[5] Siriyaporn Sangaroon, Kunihiro Ogawa, Mitsutaka Isobe, Longyong Liao, Makoto Kobayashi, Sho Toyama, Misako Miwa, Shigeo Matsuyama, H. Yamanishi, S. Tamaki, I. Murata, Eiji Takada, Guoqiang Zhong, Apiwat Wisitsorasak, and Nopporn Poolyarat, “*Characterization of CLYC7 Scintillation Detector in Wide Neutron Energy Range for Fusion Neutron Spectroscopy*”, IEEE Transactions on Instrumentation & Measurement **72**, 1011212 (2023).

[6] L.Y. Liao, K. Ogawa, M. Isobe, S. Sangaroon, Y. Kawamoto, G.Q. Zhong, T.S. Fan, “*The multi-sightline compact D-D neutron spectrometers based on CLYC7-scintillator for beam ion anisotropy study in LHD*”, Journal of Instrumentation (JINST) **19**, P03006 (2024).

[7] J. Zhang, Y. P. Zhang, W. Chen, S. K. Cheng, K. Ogawa, X. F. He, Y.Q. Wang, Y. Liu, M. Xu, M. Isobe, Y. X. Zhu, X. W. Zhan, J. H. Zhou, J. L. Zhang, L. Liu, X. X. He, D. Li, Y. G. Li, W. P. Guo, L. M. Yu, G. Z. Hao, B. Li, Z. B. Shi, X. Q. Ji, W. L. Zhong, and the HL-2A team, “*Investigation on energetic ion losses induced by long-lived saturated internal mode with energetic particle diagnostics in the HL-2A tokamak*”, Nuclear Fusion **63**, 086014 (2023).

[8] Y. P. Zhang, X. L. Zou, Y. B. Dong, X. Y. Bai, J. Zhang, K. Ogawa, J. M. Gao, S. K. Cheng, Y. X. Zhu, B. Li, X. Q. Ji, Y. Liu, Z. B. Shi, W. L. Zhong, M. Xu, “*Formation of the hot tail seeds for runaway electron generation during disruptions with lower hybrid waves in the HL-2A tokamak*”, Physics of Plasmas **30**, 072502 (2023).

(M. Isobe, A. Shimizu, K. Ogawa and M. Goto)

Japan-Korea Fusion Collaboration Programs

I. KSTAR Collaboration in FY 2023

Workshop on Physics and Technology of heating and current drive

This workshop was held from 22nd to 23rd in February 2024, in Hanyang University in Seoul as a hybrid of face-to face and remote participation. There were 15 oral presentations (JA: 5, KO:10). Three people including two students traveled from Japan to Korea for on-site participation. There were 27 participants in total including eight students. The topics were electron cyclotron resonance heating/current drive, helicon wave heating/current drive, ion cyclotron range of frequency wave heating, neutral beam heating/current drive, and measurements of hard X-ray and electron cyclotron emissions related to the physics or technology of plasma heating.

KSTAR collaboration on plasma diagnostics

Thomson scattering diagnostics: Two people traveled to KFE from Japan to participate in the KSTAR experiment and a conference on diagnostics. Three people traveled to Japan to participate in the 20th International Symposium on Laser-Aided Plasma Diagnostics (LAPD20) held in Kyoto and visited NIFS. Information exchanges and discussions regarding polychromators were conducted.

Neutron and high energy ion diagnostics: Two people from NIFS and two students from SOKENDAI university traveled to KFE from Japan with a researcher from Thailand for an in-person meeting on neutron and high energy ion diagnostics.

SXCCD Camera: Work to install a soft X-ray CCD camera (SXCCD) which was previously installed in LHD and an imaging system using a beryllium filter into KSTAR was continued. One person traveled from NIFS (C. Suzuki) to KFE to conduct a status assessment. Considering that the expected results were not obtained in operational tests of the camera itself, discussions about future plans, including the possibility of replacing it with other detectors were conducted.

Japan-Korea KSTAR Diagnostics Collaboration Meeting: This meeting was held on February 6th, 2024 at KFE. Five people from NIFS traveled to Korea to participate in this meeting on-site and five people participated remotely from NIFS. Twenty-two people participated from Korea. The status of each diagnostics collaboration was reported and a discussion on JK diagnostic collaboration was conducted.

Fig. 1 Image from Japan-Korea KSTAR Diagnostics Collaboration Meeting

Collaboration of RF plasma heating in KSTAR

One person traveled to KFE from Japan (T. Seki) for discussions about improvement, and consideration of increased power capacity of the ion cyclotron range of frequency (ICRF) heating system in KSTAR. An issue with the new compact ICRF antenna (CIA) whose design was led by NIFS side arose during the experiment. The antenna strap was deformed. The investigation by KFE revealed that poor quality control during the assembly of the antenna might have led to some bolts not being properly tightened.

It is considered that the poor heating performance of the power injection system of 170 GHz GYCOM gyrotron is due to issues with beam alignment. Information about the mode content analysis was exchanged via e-mail. A preparation meeting for using a mode content analysis program that was developed in Japan was held remotely. IR images of the beam radiated from the waveguide that was connected to the matching optics unit (MOU) of the gyrotron were sent to Japanese side.

II. Human Resource Development in FY 2023

Studies on multi-scale and multi-species transport in fusion plasma

The "17th Japan-Korea Workshop on "Modeling and Simulation of Magnetic Fusion Plasmas" was held from 28th to 29th August 2023 at Seoul National University in Korea, as a hybrid of face-to face and remote participation. There were 14 participants from Japan and 16 from Korea in total. There were 11 presentations from Japan and ten from Korea. Three people traveled to Korea to participate in this workshop onsite. Transport phenomena at different space-time scales or related to impurity ions and energetic particles were focused on in this workshop. The workshop program was designed to address both aspects of anomalous transport due to waves and turbulence.

Evaluation of Tritium behavior for reactor design in fusion (V)

The "2023 Japan-Korea Tritium Workshop" was held from 30th November to 1st December 2023 at Youtree Hachinohe, in Japan, face-to face. There were six participants from Japan and six from Korea, including students. The status of the development of tritium handling technology was reported from Japan and Korea. A report was also presented on the status of the development of the Tritium Storage and Supply System (SDS) as part of ITER procurement-related technology development. Verification of fuel supply through modeling, and design activities of K-DEMO were reported from the Korean side. From the Japanese side, reports covering a wide range of research areas, such as the development of tritium recovery technology from solid tritium breeding materials, the latest status of procurement activities and BA activities for the ITER tritium removal facility at QST were presented.

Fig. 2 Image from 2023 Japan-Korea Tritium Workshop

(H. Igami, B. Peterson, T. Seki, T.H. Watanabe and Y. Oya)