13. 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, such as 1) coordination with foreign institutes, 2) bilateral coordination with intergovernmental agreements, and 3) multilateral coordination under the International Energy Agency (IEA).

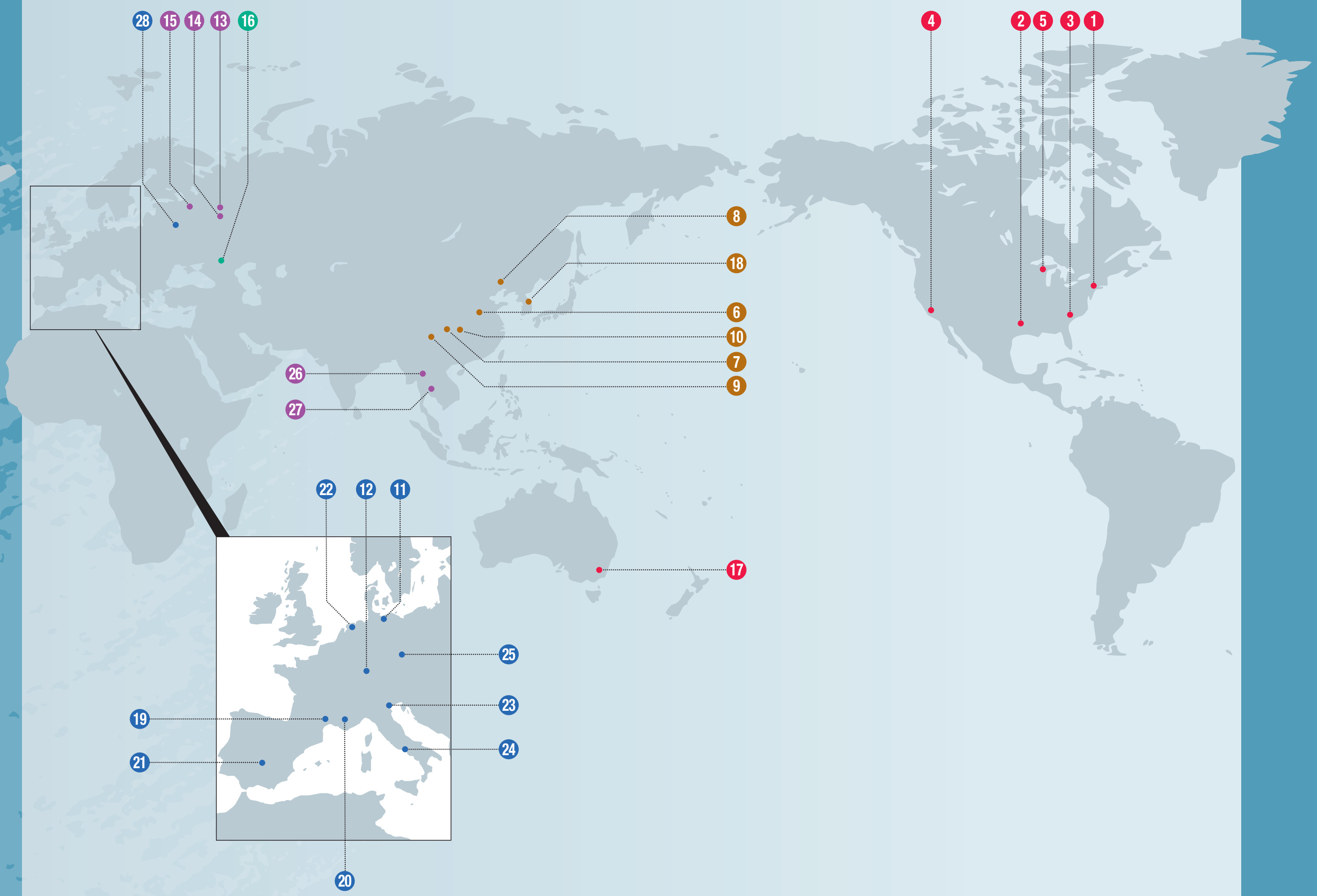
The coordination with foreign institutes is important as a basis of collaborative research. From 1991, NIFS concluded 30 coordinations through FY2018. In FY2019, a new coordination was concluded between NIFS and Belgrade University (Serbia). In this collaboration, progress in research of plasma transport simulation and plasma-wall interactions are expected.

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 coordinations under the IEA (Plasma Wall Interactions (PWI), Stellarator-Heliotron concept, Spherical Tori, and Steady State Operation). For the three bilateral coordinations, and the multilateral coordination PWI Technology Collaboration Program (TCP), NIFS coordinates the collaborative research not only for NIFS researchers, but also for researchers in universities. The activities of the bilateral and the multilateral coordination activities are reported in the following subsections, respectively.

In 2019, the 28th International Toki Conference on Plasma and Fusion Research was held on 5 – 8 November in Toki, Japan, and NIFS hosted the meeting. More than 200 researchers from 11 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 been continued from 1977. The 40th CCFE (Coordinating Committee for Fusion Energy) meeting was held on March 6, 2020 via televideo conference system. The 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 were reported together with bilateral technical highlights of the collaborations. The FY 2019 cooperative activities were reviewed, and the FY 2020 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.

Fusion Physics Planning Committee (FPPC)

In the area of fusion physics, 4 workshops (1 from JA to US, 3 from US to JA) and 24 personnal exchanges (15 from JA to US, 9 from US to JA) were carried out. Compared to the initial plan, 2 workshops and 1 personnel exchange from the U.S. to JA were not executed due to the COVID-19 effect, and 2 more personnel exchanges from the U.S. to JA were not executed due to lack of funding or time scheduling.

The exchanges continue to be productive and beneficial to both sides. Among them, the research categories “MHD and High Beta”, and “Diagnostics” were rather active in 2019.

In the category of diagnostics, a new collaboration with Princeton Plasma Physics Laboratory has started in LHD. An impurity particle dropper (IPD) to inject impurity powders, e.g., Li, B, C, BN, etc., was installed in an upper port of LHD. The first experiment of boron (B) and boron- nitride (BN) powder dropping was performed on Dec. 3, 2019. After the B powder injection, substantial reduction of the oxygen emission was observed, together with the reduction of the electron density, which suggests the low wall recycling.

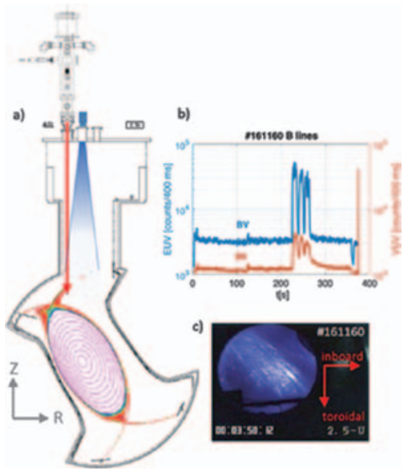


Fig. 1 (a) Experimental set-up, (b) BII and BV line intensities during long-pulse discharge, and (c) video image during B injection.

Joint Institute for Fusion Theory (JIFT)

Most of the activities in the two categories, workshops and personal exchanges, that had been scheduled for the 2019–2020 JIFT program were carried out. Three workshops were successfully held in addition to the JIFT Steering Committee meeting. In the workshops, “US-Japan collaborations on co-designs of fusion simulations for extreme scale computing,” “Theory and simulation on the high field and high energy density physics,” and “Progress on advanced optimization concept and modeling in stellarator-heliotrons” were discussed as main topics (Figure 2). In the category of personal exchanges, one Visiting Professor and nine Visiting Scientists made exchange visits for the purpose of collaborations on theoretical modeling and simulation of magnetic and inertial confinement fusion plasmas. One personal exchange

Fig. 2 Workshop on “US-Japan collaborations on co-designs of fusion simulations for extreme scale computing” which was held in Kobe during October 28–29, 2019.

program for a Visiting Professor was postponed to 2020–2021 due to the influence of COVID-19. At the JIFT Steering Committee meeting that was held using Zoom on December 6, 2019, the status of JIFT activities for 2019–2020 was reviewed and the recommendation plans for 2020–2021 were discussed. The JIFT discussion meeting was held at Toki on September 20, 2019, in the Plasma Simulator Symposium.

Fusion Technology Planning Committee (FTPC)

In this category of the US-Japan Collaboration, personal 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). One of the highlights in FY2019 was the joint research between Shimane University and University of California San Diego (UCSD) on the microstructural changes and deuterium retention properties of beryllides (intermetallic compounds of beryllium (Be) with other metals). Samples exposed to fusion relevant deuterium-helium mixture plasmas in the PISCES-B linear device at UCSD were analyzed at Shimane University. The beryllide samples exposed to deuterium (D) and helium mixture plasmas showed lower total retention of D than that of Be.

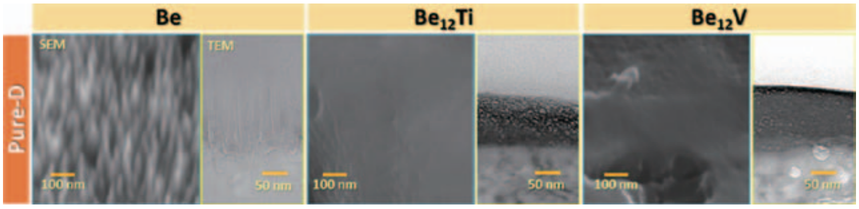


Fig. 3 Surface analysis of beryllide samples after exposure to mixed plasmas in PISCES-B. Formation of cone structures observed in beryllium was suppressed in beryllides.

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.

The objectives of the task of Irradiation Effects on Reaction Dynamics at Plasma-Facing Material/Structural Material Interfaces (Task 1) are to understand neutron-induced microstructure modification and the consequent change in mechanical and heat transfer properties of the interfaces. Layered and joined materials were prepared, which will be irradiated with neutrons.

Task 2 (Tritium Transport through Interface and Reaction Dynamics in Accidental Conditions) examines the effects of neutron and helium irradiation on retention and permeation of hydrogen isotopes, and the oxidation of neutron-irradiated W materials. Oxidation of W-Re alloys was shown to be more moderate than that of pure W.

The objective of Task 3 (Corrosion Dynamics on Liquid-Solid Interface under Neutron Irradiation for Liquid Divertor Concepts) is to study the corrosion characteristics of liquid Sn for a divertor coolant with and without neutron irradiation. Screening tests showed that Al-rich steels have excellent compatibility with liquid Sn.

Task 4 (Engineering Modeling) aims to consolidate the results of each task.

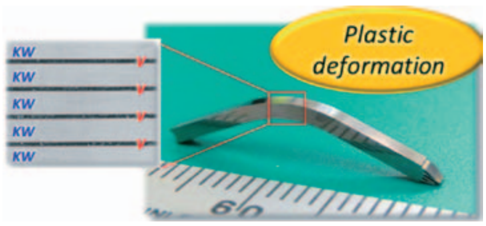


Fig. 4 Layered material of K-doped W (KW) and V-4Cr-4Ti alloy (V) developed by Tohoku U. and NIFS. In contrast to single phase W being brittle at room temperature, this material shows ductility. Effects of neutron irradiation will be examined in Task 1.

(T. Muroga, T. Morisaki, H. Sugama, N, Yanagi 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” (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 effects of plasma exposure on ferritic steels, impacts of helium plasma exposure on tungsten erosion, mechanical examination of tungsten alloys, and plasma diagnostics were conducted. All the collaborations are listed in Table I. Highlight of each activity is described in this report.

Microstructure and Hydrogen Retention Property in Reduced-Activation Ferritic Steels Irradiated with High Density Plasma

Hydrogen retention behavior and the microstructure evolution for F82H samples irradiated with high density deuterium / helium (10%) mixture plasmas in the linear plasma device, PISCES-A in UCSD, were examined. Results of the examination show that bubbles and peculiar cone structures was formed at the near surface of samples exposed to the mixture plasma. Deuterium retention on the sample exposed to the mixture plasma was reduced to one-third of that on a sample exposed to a pure deuterium plasma exposure was observed.

Impact of plasma exposure on surface damage structure development and erosion in tungsten

Impact of the helium plasma exposure on the W surface damage structure development and erosion has been investigated by comparing impact of the hydrogen plasma exposure. The hydrogen and hydrogen / helium mixture plasma exposure experiments have been carried out in the linear device, PSI-2 in FJZ, with the typical flux and fluence of 0.6×10^{22} /m^2/s and 1×10^{26} /m^2, respectively. In the series of experiments over the past five years, the undulating surface structure which shows crystal orientation dependence is typically observed in the pure helium plasma exposure. However, it became clear that the undulating surface structure is not peculiar effect of the helium plasma exposure but common effect of the plasma exposure, because similar undulating surface structures are developed in pure hydrogen plasma and hydrogen/helium mixture plasma exposures.

Evaluation of High Temperature Impact Properties of Dispersion-strengthened Tungsten-Rhenium Alloys

To clarify the effects of grain refining, K-doping, dispersion strengthening by La_2O_3 particles, and alloying by Re on the ductile-brittle transition temperature (DBTT) of tungsten materials, high temperature Charpy impact tests were carried out at Karlsruhe Institute of Technology (KIT). K-doping and Re-addition could produce lower DBTT. Recrystallization was suppressed by K-doping, dispersion of La_2O_3 particles, and Re-addition. Based on these indexes, K-doped W-3%Re (H) plate could be a better solution. Although W-3%Re-1%La_2O_3 (L) and W-3%Re (L) could not show lower DBTT, this would be attributed to relatively lower deformation ratio in fabrication. Thus, the effect of dispersion of La_2O_3 particles on DBTT is not clear at present

Collaboration of plasma diagnostic study on Magnum-PSI

In the detachment plasma condition, which is a necessary condition for ITER and future fusion reactors, the strong density fluctuations are observed in the linear plasma devices. In this study, a 70 GHz frequency multiplied microwave interferometer (MIF) system which was constructed in GAMMA 10/PDX, was used as a reflectometer system for measuring the electron density fluctuations in the Magnum-PSI device in DIFFER. A low frequency fluctuation on the electron density was successfully observed. The fluctuation intensity changed according to the distance from the target plate. It is thought that the position of maximum fluctuation intensity shows the recombination front region in the detached plasma condition.

(S. Masuzaki)

Table I. List of collaborations

Subject	Participants	Term	Key persons
Microstructure and Hydrogen Retention Property in Reduced-Activation Ferritic Steels Irradiated with High Density Plasma	Yutaka Sugimoto (Shimane Univ.)	18 Aug. – 8 Sep. 2019	D. Nishijima (UCSD)
Impact of plasma exposure on surface damage structure development and erosion in tungsten	Ryuichi Sakamoto (NIFS)	1 – 9 Sep. 2019	A. Kreter (FZJ)
Evaluation of High Temperature Impact Properties of Dispersion-strengthened Tungsten-Rhenium Alloys	Shuhei Nogami (Tohoku Univ.)	8 – 20 Sep. 2019	M. Rieth (KIT)
Collaboration of plasma diagnostic study on Magnum-PSI	Masayuki Yoshikawa (Univ. Tsukuba)	21 – 29 Sep. 2019	H. V. Meiden (DIFFER)

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

Highlight

IEA SH-TCP
Programmatic collaborations have been further extended in the next step of SH research

The SH TCP’s objective is to improve the physics base of the Stellarator concept and to enhance the effectiveness and productivity of research by strengthening co-operation among member countries. All collaborative activities of the 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 joint-programming and research activities are organized via the Coordinated Working Group Meetings (CWGM), an interactive workshop to facilitate agreements on joint research actions, experiments, and publications under the auspices of the SH-TCP. The bi-annual “International Stellarator-Heliotron Workshop” (ISHW) serves as a forum for scientific exchange.

Fig. 1 The group photo at 22nd International Stellarator-Heliotron Workshop, Memorial Union, Madison, Wisconsin, September 2019, Courtesy of University of Wisconsin-Madison

Major achievements in 2019

In 2019, major achievements were the deuterium plasma campaign in the Large Helical Device (LHD) and the start of the first Island Divertor campaign of the Wendelstein 7-X (W7-X). Main highlights were reported in many presentations at the International Stellarator-Heliotron Workshop (ISHW) in Madison, WI. From LHD, the effects of isotope ratios (H vs. D) were investigated in detail, including diagnostic innovations to quantify the effects of isotope mixtures. Results from a variety of international conceptual design studies for next step stellarators were shown and advances in numerical methods to optimize these new experimental devices were discussed. W7-X demonstrated high performance plasmas with up to 1 MJ confined energy at 8 keV electron temperature and 3 keV ion temperature during pellet-fuelled high density plasmas. Also, full detachment of the island divertor for up to 30 s has been demonstrated.

22nd International Stellarator and Heliotron Workshop (ISHW)

The 22nd International Stellarator and Heliotron Workshop ISHW2019 was held at the University of Wisconsin - Madison, Wisconsin, USA from September 23–27, 2019. It was attended by 156 participants from ten countries. The workshop covered key stellarator topics from confinement and equilibrium, to plasma edge and divertor physics, reactor concepts, energetic particle confinement, and new numerical and computational methods for stellarator optimization.

48th S-H TCP executive committee meeting

The 48th Executive Committee meeting of the S-H TCP took place on September 24, 2019 during the 22nd International Stellarator and Heliotron Workshop. The meeting was attended by representatives from all six contracting parties and observers from Costa Rica (I. Vargas) and China (Y. Xu).

19th Coordinated Working Group Meeting (CWGM)

The 19th CWGM was held in Berlin, Germany from March 12–14, 2018. On-site and remotely, fifty participants provided reports on collaborations grouped into seven topics. In an informal workshop format, the participants discussed proposals for joint actions and experiments, taking advantage of comparative studies in different devices. The CWGM effectively tracked the progress in the most active research fields and initiated a series of new Coordinated Working Group Actions (CWGA) for joint activities. A session on the program planning of the main contributors served to enable the exchange of information, and the community was invited to provide feed-back to programmatic considerations. China's rapidly developing stellarator program has a sound balance of sustainable build-up of know-how and scientifically interesting new concepts. In particular, the outline of a quasi-axially symmetric device attracted great interest.

(Y. Takeiri, T. Morisaki and Y. Suzuki)

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

I. Post-CUP collaboration

The post-Core University Program (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 2019

2019 Post-CUP Workshop & JSPS-CAS Bilateral Joint Research Projects Workshop was held at Nagoya International Center, Japan from 24th to 26th, July, 2019, to continue and enhance close collaborations in fusion research between Japan and China, as shown in Fig. 1. Over 30 researchers and Ph.D. students from both parties attended this workshop. Key physics issues specific to high-performance plasmas through joint experiments on advanced fully superconducting fusion devices, i.e., LHD in Japan and EAST in China, and other magnetic confinement devices were discussed to carry out multi-faceted and complementary physics researches [1].

In the category ①, the 2nd steering committee meeting for the NIFS-SWJTU joint project for CFQS quasi-axisymmetric stellarator, was held on May 29, 2019 at SWJTU in Chengdu, China, as shown in Fig. 2. Progress of engineering design and status of the construction of modular coil mockup were reviewed [2]. Also, construction site of CFQS building was discussed.

Fig. 1 2019 Post-CUP Workshop & JSPS-CAS Bilateral Joint Research Projects Workshop at Nagoya International Center, Japan.

In the research of energetic particles, NIFS and ASIPP discussed to conduct collaborative research for understanding triton confinement characteristics in EAST deuterium plasmas and comparison with results from LHD deuterium plasmas. To predict 1 MeV triton confinement/loss and investigate the possible scenario for triton burnup experiment in EAST, 1 MeV triton orbit analysis was performed using Lorentz orbit codes for EAST plasmas with various plasma current conditions [3]. We found that relatively high plasma current is required to perform triton burnup experiment in EAST plasmas.

In the research of the edge and divertor plasmas, JSPS-CAS Bilateral Joint Research Projects, "Control of wall recycling on metallic plasma facing materials in fusion reactor" (FY2019–FY2021) was started. Figure 3 is a group photo of the kickoff meeting of the project which was held in May 2019 in ASIPP. For understandings of spatial profiles of deuterium atoms, deuterium Balmer series was measured around divertor targets in EAST, which was operated under our own experimental time by our proposal [4]. A collaborative study on the extreme-ultraviolet spectroscopy had also continued progress, especially in a quantitative evaluation on the tungsten impurity concentration in LHD, EAST, and HL-2A [5].

Fig. 2 The 2nd steering committee meeting of NIFS-SWJTU joint project for CFQS.

In the category ②, An EMC3-EIRENE modeling work on effects of neon injection positions on the toroidally symmetric/asymmetric heat flux on the EAST divertor was presented at the 2019 Post-CUP workshop in Nagoya, and its paper was published [6]. As for J-TEXT, 3D MHD analyses using 3D equilibrium calculation code, HINT, is progressing. This result was presented as an oral contribution at the 12th Asia Plasma and Fusion Association Conference, Dec. 11–13, 2019 in Shenzhen, China. Also, the special campaign for the international collaboration was organized in J-TEXT. From Japan, there topics, which are the heat transport, the disruption, and the 3D helical core formation, were accepted and conducted experiments in that campaign.

In the category ③, tritium release kinetics for core-shell Li_2TiO_3-Li_4SiO_4 tritium breeders was studied by tritium-TDS method. There were two main release peaks for mixed biphasic pebbles, whose activation energies were obtained as 0.92 eV and 1.78 eV. While, only one release peak can be found for single phase breeder. The tritium migration of core-shell Li_2TiO_3-Li_4SiO_4 breeders was mainly controlled by the decomposition of O-T bonds or recovery of irradiation defects with higher activation energy. FLiNaBe is a promising tritium breeding material for a fusion blanket system. The solid-state sample of FLiNaBe was irradiated by thermal neutrons at Kyoto University Research Reactor, and tritium release behavior from the free surface of FLiNaBe by heating in Ar flow was observed in Kyushu University. The release ratio of each chemical form was approximately TF: HT: HTO = 30:64:6. Most of the tritium was released as HT (or T_2). This result indicates that corrosion of metals by TF occurred in tritium release process.

Fig. 3 Kickoff meeting of the JSPS-CAS Bilateral Joint Research Projects which was held in May 2019 in ASIPP.

[1] Corrected papers at the 2019 Post-CUP Workshop & JSPS-CAS Bilateral Joint Research Projects Workshop, 24th–26th July, 2019, Nagoya, Japan. NIFS-PROC-116, 2019.
[2] CFQS TEAM, "NIFS-SWJTU JOINT PROJECT FOR CFQS - PHYSICS AND ENGINEERING DESIGN VER. 2.1." NIFS-PROC-115, 2019.
[3] K. Ogawa, G. Zhong *et al.*, Plasma Fusion Res. **15** (2020) 2402022.
[4] K. Nojiri and N. Ashikawa, "Collaboration Works of JSPS Bilateral Joint Research Projects (Japan (NIFS)-China (ASIPP))", Journal of Plasma and Fusion Research **96** (2020) 149.
[5] S. Morita, C.F. Dong *et al.*, Journal of Physics: Conf. Series **1289** (2019) 012005.
[6] B. Liu, S.Y. Dai, G. Kawamura *et al.*, Plasma Physics and Controlled Fusion **62** (2020) 035003.

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

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
Both Parties had information exchanges on the upgrade of ion sources and the development of advanced neutral beam technology in the 6th China-Japan-Korea (CJK) workshop.

1.1 Radio Frequency Systems
Both Parties continued the collaboration and exchange of technical knowledge for development of radio frequency technologies in fusion plasmas.

2 Diagnostic Systems
2.1 Bolometer Systems[1)]
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. Discussions were continued regarding the reinstallation of the resistive bolometers on KSTAR as part of the KSTAR upgrade planned for 2021.

2.2 Edge Thomson Scattering System[2,3)]
Collaboration regarding high repetition rate sampling (5 GS/s) DAQ system has been carried out. For this collaboration, a Japanese expert from NIFS visited NFRI and a Korean expert from NFRI visited NIFS.

2.3 Electron Cyclotron Emission (ECE) and Imaging (ECEI) System
The KSTAR ECE diagnostic system with W-band and D-band heterodyne radiometers has been routinely operated for electron temperature profile measurements in both low and high field sides. However, because the W-band H-plane Tee was simply used as a beam splitting tool for both radiometers, the beam power into each radiometer was not controllable. In particular, it has led to poor measurements with a D-band radiometer. For solving this problem, the wire-grid beam splitter was adopted with a wire-grid polarizer and a linear polarization rotator. As a result of optimization by rotating the linear polarization, both radiometers successfully contributed to better ECE measurements.

2.4 Fast RF spectrometer system
Based on the systems developed on KSTAR and LHD, a new RF radiation measurement system in VEST spherical tokamak device in Korea. Consideration of the alignment of the measurement system at QUEST, LHD, and KSTAR is ongoing.

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

2.7 Soft X-ray CCD Camera (SXCCD)
A researcher from NIFS visited NFRI to accelerate the progress of the installation of the SXCCD camera system, using the same support structure shared with the VUV telescope system. Both parties agreed that one NFRI researcher will newly join this project. The shipment of the remaining necessary items (a cooling water chiller and an in-vacuum neutron shield) of the SXCCD camera system was completed by March.

2.8 VUV Telescope System
Japanese and Korean researchers cooperated together to develop the interface of the VUV telescope system

to the KSTAR device. A Japanese researcher from NIFS visited twice to NFRI to discuss the interface. Japanese and Korean experts are continuing the collaboration on the VUV telescope for edge MHD activities and RMP physics studies.

2.9 EMA Post Data Analysis System[8,9]

Japanese researchers visited NFRI, and updated the AutoAna (Automatic Analysis) system and myView2. These modifications were reflected to the AutoAna systems working for the LHD project in NIFS. Also, Japanese and Korean r researchers have developed analysis programs run by the AutoAna for the diagnostics devices for KSTAR projects.

2.10 The 10th Japan-Korea Seminar on Advanced Diagnostics

The 10th Korea-Japan Seminar on Advanced Diagnostics will be hosted in 2020 in Korea by Seoul National University. Detailed arrangements are currently being made.

2.11 SC Toroidal Device Experiments

Japanese researchers participated in the KSTAR experiment to study rotation transport dynamics under the non-axisymmetric magnetic perturbation field.

II. Human Resource Development

The total number of researchers that were exchanged between Japan and Korea in JFY 2019 were 29 from Japan to Korea and 53 from Korea to Japan. Eight Workshops in various fields were held in each country (4 in Japan and 4 in Korea).

- Workshop on Physics validation and control of turbulent transport and MHD in fusion plasmas, Busan, Korea, Apr. 21–24, 2019.
- Modeling and Simulation of Magnetic Fusion Plasmas, Kyushu U., Japan, Jun. 27–28, 2019.
- 15th JCM, Nagoya, Japan, Jul. 2–3, 2019.
- Physics of fine plasma particles, NFRI, Daejeon, Korea, Aug. 7–9, 2019.
- Evaluation of Tritium behavior for reactor design in fusion, Okinawa, Japan, Oct. 7–8, 2019.
- Workshop on ITER tritium system, Okinawa, Japan, Oct. 7–8, 2019.
- 13th Workshop on ITER Diagnostics, NFRI, Daejeon, Korea, Jan. 15–16, 2020.
- Korea-Japan Blanket Workshop, NFRI, Daejeon, Korea, Jan. 30, 2020.

1) Seungtae Oh, Juhyeok Jang, Byron J Peterson, “Radiation profile reconstruction of Infra-Red imaging Video Bolometer (IRVB) data using Machine Learning (ML) algorithm”, Plasma Phys. Control. Fusion 62 (2020) in press.
2) Ichihiro Yamada, Hisamichi Funaba, Jong-ha Lee, Yuan Huang, and Chunhua Liu, “Influence of neutron irradiation on LHD Thomson scattering system”, 28th International Toki Conference, Japan (2019).
3) H. Funaba *et al.*, “Fast-signal processing for Thomson scattering measurement and effects on evaluation of electron temperature on LHD”, LAPD2019, USA, 2019.
4) E. Takada, T. Amitani, A. Fujisaki, K. Ogawa, T. Nishitani, M. Isobe, J. Jo, S. Matsuyama, M. Miwa, and I. Murata, “Design Optimization of a Fast-Neutron Detector with Scintillating Fibers for Triton Burnup Experiments at Fusion Experimental Devices”, Review of Scientific Instruments 90 (2019) 043503.
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