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 32 coordination through FY2019.

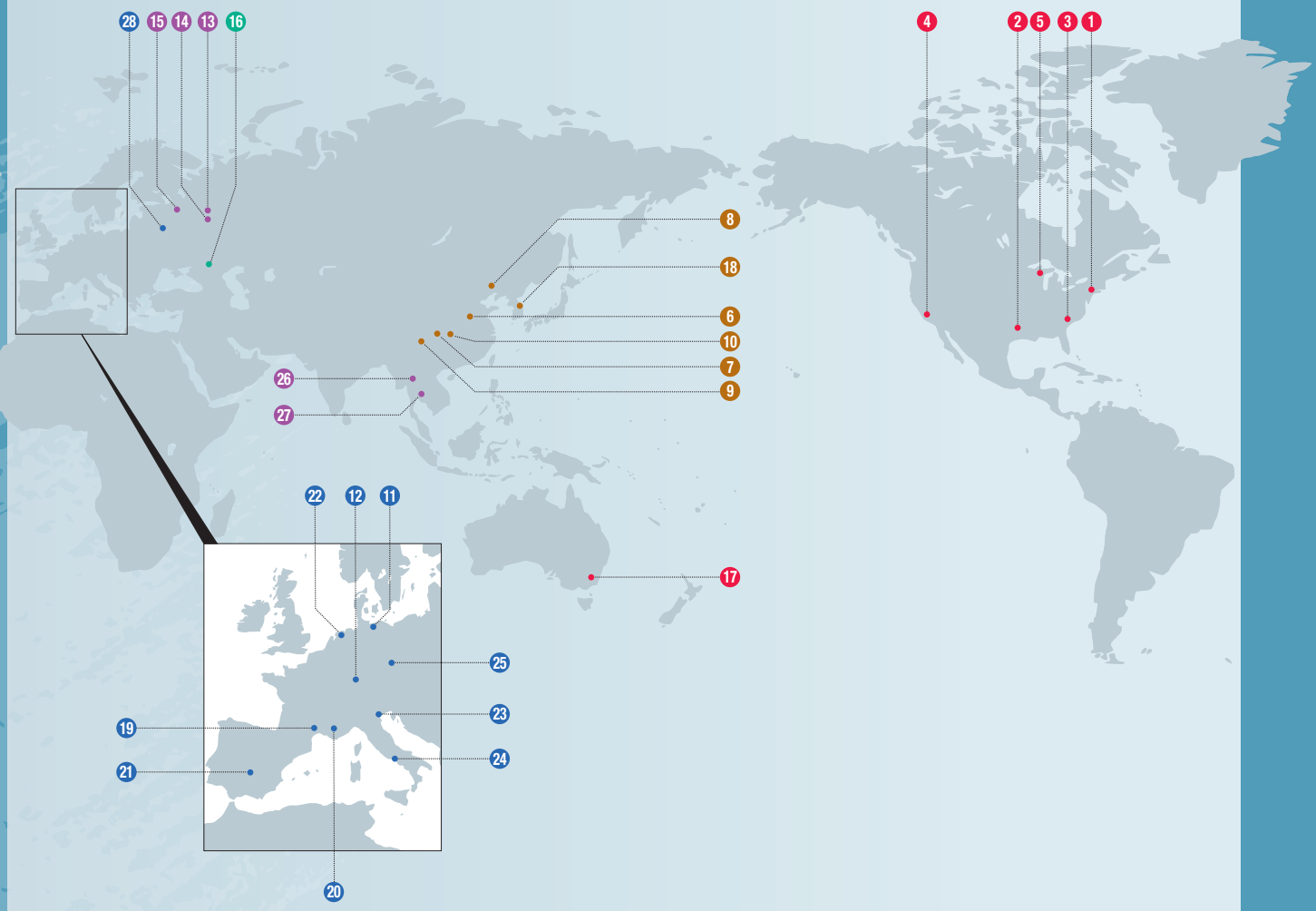
NIFS is the representative institute for the three bilateral coordination with intergovernmental agreements (J-US, J-Korea, and J-China), and for the four multilateral coordination under the IEA (Plasma Wall Interactions (PWI), Stellarator-Heliotron concept, Spherical Tori, and Steady State Operation). For the three bilateral coordination, 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.

Since the beginning of 2020, for the COVID-19 pandemic, social activities have been strongly limited to prevent the outbreak of COVID-19 all over the world. Many of international activities with personal exchanges could not be conducted, and many of international conferences were postponed or held online. For example, IAEA FEC planned to be held in October 2020 was postponed to May 2021. Online communications drastically increased, and people became very familiar with such communications though the time difference is a serious problem to hold an international online conference.

Under such situation, the 29th International Toki Conference on Plasma and Fusion Research was held in Toki, Japan on 27–30 October 2020, and NIFS hosted the meeting. More than 220 researchers from 11 countries participated. For reducing the risk of the expansion of COVID-19, the conference was held under online connection for video conferencing.

(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 41th CCFE (Coordinating Committee for Fusion Energy) meeting was held on March 11, 2021 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 was reported together with bilateral technical highlights of the collaborations. The FY 2020 cooperative activities were reviewed, and the FY 2021 proposals were approved. It should be noted that because of COVID-19 pandemic, most of the personnel exchange and workshops were cancelled. However, some collaborative activities were maintained by remote participation and web meetings.

Fusion Technology Planning Committee (FTPC)

In this category of the US-Japan collaboration, there are six research fields, namely, the superconducting magnets, low-activation structural materials, plasma heating related technology, blanket engineering, in-vessel/high heat flux materials and components, and power plant studies and related technologies. In usual years, personal exchanges are conducted and workshops are held in these research fields. However, in the fiscal year FY2020, due to the spreading of the COVID-19 pandemic, all the programs were either differed or canceled, including four J-to-US personal exchanges (differed), one J-to-US personal exchange (canceled), three US-to-J personal exchanges (differed), one J-to-US workshop (differed), and one US-to-J workshop (differed). For all these activities, information exchanges were done among responsible members and participants via e-mails and/or video conferences to make agreement about resumption of each program in the coming fiscal year FY2021.

Fusion Physics Planning Committee (FPPC)

In the area of fusion physics, 2 committee meetings and 11 personnel exchanges were performed remotely, amid the COVID-19 pandemic. However, due to travel restrictions, 3 Workshops and 13 personnel exchanges

Fig. 1 (a) "Virtual" LHD Control Room (b) "Vacant" DIII-D Control Room during operation.

from the JA to U.S. were deferred to next FuY. In spite of the unusual situation in this year, scientists from both sides have endeavored to continue their collaborative research activities. Some experiments were carried out with remote participation enabled by new tele-communication tools and data transport systems.

Joint Institute for Fusion Theory (JIFT)

Most plans of workshops and personal exchanges that had been scheduled for the 2020–2021 JIFT programs were changed due to the influence of COVID-19. Three 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 decided to be postponed to 2021–2022 based on online discussions among corresponding organizers. In the category of personnel exchanges, ten programs were also decided to be postponed to 2021–2022 by online discussions between corresponding researchers. A personnel exchange program for a Visiting Professor on "Electromagnetic turbulence in fusion plasmas" was carried out as a remote program in which online discussions were made for presenting collaborative research results in the APS DPP Annual Meeting and the journal Nuclear Fusion. Another personnel exchange program on "Kinetic-MHD hybrid simulations of energetic-particle driven instabilities" was also carried out as a remote program in which discussions on a simulation code benchmark study for kink and fishbone instabilities in a tokamak plasma were made by email. At the JIFT Steering Committee meeting that was held using Zoom on November 19, 2020, the status of JIFT activities for 2020–2021 was reviewed and the recommendation plans for 2021-2022 were discussed. The JIFT discussion meeting was held at Toki on September 17, 2020, in the Plasma Simulator Symposium.

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 3 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) and Corrosion Dynamics on Liquid-Solid Interface under Neutron Irradiation for Liquid Divertor Concepts (Task 3). All tasks perform neutron irradiation in High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) and examine neutron-induced modifications in microstructure, mechanical strength, tritium transport, corrosion behavior, etc. Many hundreds of joined and composite materials samples were prepared in Japan and shipped to ORNL to be accommodated in irradiation capsules. The conceptual design was completed for the first-of-the-kind irradiation capsule for *in-situ* compatibility tests between structural material and liquid Sn as shown in Fig. 4.

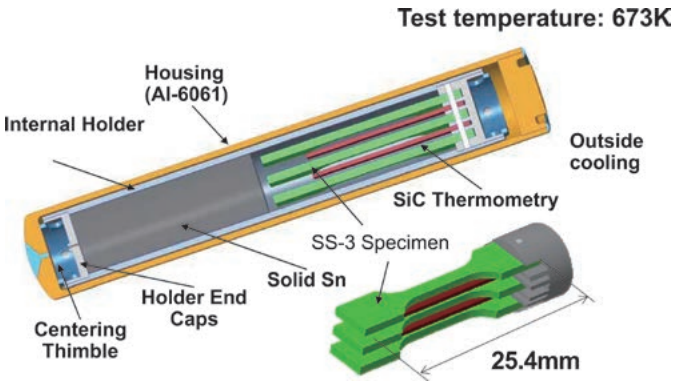


Fig. 4 Schematic diagram of liquid Sn rabbit capsule for compatibility study under neutron irradiation in High Flux Isotope Reactor (M. Kondo *et al.*, Plasma Fusion Res. **16** (2021) 2405040).

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

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 2020

The 3rd steering committee meeting for the NIFS-SWJTU joint project for CFQS quasi-axisymmetric stellarator, was held on Nov. 12, 2020 online as shown in Fig. 1. Progress of engineering design, results of various tests for the mockup of modular coil (MC) which is the most complicated in shape, current status of the construction of actual MCs, and vacuum vessel (VV) were reviewed [1]. Renovation plan of experiment building in the Jiuli campus in SWJTU was also discussed. As for the MC mockup, heat-run test was performed, by which the temperature increase of the mockup coil and the cooling capability by water were checked, and the expected performance was confirmed. For the first actual MC, winding mould construction was completed. For VV, the mould for press work was manufactured. Construction of MCs and VV is steadily in progress.

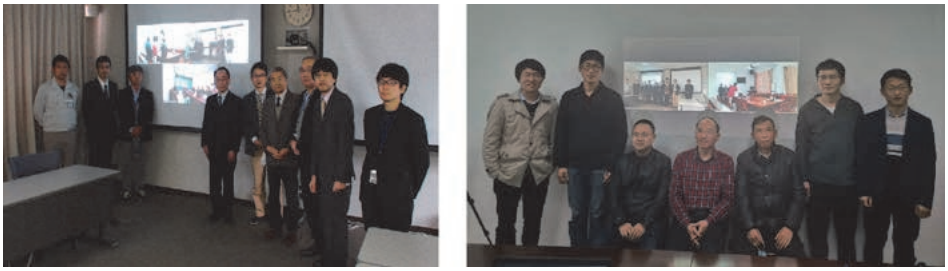


Fig. 1 The 3rd steering committee meeting of NIFS-SWJTU joint project for CFQS held on Nov. 12, 2020 online. The left and right pictures show participants from NIFS and SWJTU, respectively.

In the research of energetic particles, NIFS and ASIPP have been discussing about execution of collaborative research to measure a velocity distribution function of neutral beam (NB)-injected energetic ions in EAST and LHD through deuterium-deuterium (DD) fusion born neutron spectroscopy. Based on this discussion, we installed

a new 7Li-enriched Cs_2LiYCl_6: Ce (CLYC-7) fast-neutron scintillation detector having a tangential sightline onto LHD. The significant shift of DD neutron energy according to the direction of tangential NB injection was clearly observed as expected in the FY2020 campaign of LHD [2]. Comparison of neutron energy spectra measured in LHD with the neutron energy spectra predicted by numerical simulation was initiated. As for the DD fusion born 1 MeV triton confinement research, NIFS and SWIP discussed performing collaborative research for triton confinement in HL-2M deuterium plasmas in the future and comparison with the experimental results in LHD. The predictive analysis of triton burnup ratio, which is the index of triton confinement ability, in HL-2M deuterium plasmas was performed using NUBEAM code as well as FBURN and LORBIT codes developed by NIFS. A relatively high triton burnup ratio of ~1.3% in relatively low-density and high-plasma-current conditions was predicted for HL-2M as a result of joint work [3].

In the research of the edge and divertor plasmas, the 3rd Japan Society for the Promotion of Science (JSPS)-Chinese Academy of Science (CAS) Workshop on "*Control of Wall Recycling on Metallic Plasma-Facing Materials in Fusion Reactors*" was held on 23-24 September 2020, as the remote meeting. A group photo of this workshop is shown in Fig. 2. Based on research activities involving overseas travels in FY2019, researching results were presented [4]. Especially young researchers had a lot of discussions in English, in this workshop, and it was a good experience from the viewpoint of training young researchers. A collaborative study on the extreme-ultraviolet (EUV) spectroscopy had also continued progress. A new space-resolved EUV spectrometer was installed in HL-2A and data acquisition started for the spatial profiles of impurity emission lines [5], which provides us with an opportunity to compare the results in HL-2A with those obtained by EAST and LHD.

Fig. 2 The 3rd meeting of the JSPS-CAS Bilateral Joint Research Projects held on 23-24 September 2020. A total of 25 participants joined the remote meeting.

In the research of fusion engineering, tritium recovery characteristics from a Li_2TiO_3-Li_4SiO_4 mixed ceramic material developed in SWIP have been examined in Shizuoka University. The results and future plan were discussed in a remote seminar.

[1] CFQS TEAM, NIFS-PROC-119, 2021.
[2] S. Sangaroon *et al.*, European Conference on Plasma Diagnostics (ECPD) 2021, 7–11 June 2021, online, and submitted to Journal of Instrumentation.
[3] K. Ogawa *et al.*, Plasma Physics and Controlled Fusion **63** (2021) 045013.
[4] J. Huang *et al.*, Plasma Science and Technology **23** (2021) 084001.
[5] C.F. Dong *et al.*, Fusion Engineering and Design **159** (2020) 111785.

(M. Isobe)

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.

Every year, NIFS collects proposals of international collaborative studies based on the PWI TCP from domestic universities. The proposals are reviewed in the PWI technical committee in which members are domestic senior researchers in universities, QST and NIFS, and some of proposals are approved. Proponents of the approved collaborative researches are sent to the foreign institutes by NIFS, and conduct the studies.

Unfortunately, for the COVID-19 pandemic, collaborative activities based on the PWI TCP could not be conducted in FY2020 though three proposals were approved.