TO: Executive Secretaries of the US-Japan Fusion Research Collaboration

FROM: Steering Committee, US-Japan Joint Institute for Fusion Theory (JIFT)

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SUBJECT: JIFT Annual Report of Activities for 2024-2025

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Annual Report of JIFT Activities

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Annual Report of Activities

US-Japan Joint Institute for Fusion Theory

April 1, 2024–March 31, 2025

JIFT Steering Committee

Co-Chairmen: H. Sugama and Jacobo Varela Rodriguez

Co-Executive Secretaries: Y. Todo and A. Arefiev

March 15, 2025

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1. INTRODUCTION

The Joint Institute for Fusion Theory (JIFT) is one of the four programs through which the US-Japan Fusion Research Collaboration is organized. The other three programs are the Fusion Physics Planning Committee (FPPC), the Fusion Technology Planning Committee (FTPC), and the US-Japan Joint Project (FRONTIER).

The distinctive objectives of the JIFT program are (1) to advance the theoretical understanding of plasmas, with special emphasis on stability, equilibrium, heating, and transport in magnetic fusion systems; and (2) to develop fundamental theoretical and computational tools and concepts for understanding nonlinear plasma phenomena. Both objectives are pursued through collaborations between U.S. and Japanese scientists by means of two types of exchange program activities—namely, workshops and exchange visitors.

Each year the JIFT program usually consists of four topical workshops (two in each country), six exchange scientists (three from each country). So far, during its 44 years of successful operation, JIFT has sponsored 254 long-term visits by exchange scientists and 143 topical workshops.

- The workshops typically have an attendance of 15–30 participants, of whom usually three to seven scientists (depending on the particular workshop) travel to the workshop from the non-host country. Scientists from countries other than the U.S. and Japan are also often invited to participate in JIFT workshops, either as observers or multi-laterals.
- Of the approximately three exchange visitors in each direction every year, one (called the “JIFT Visiting Professor”) is supported by the host country, while the others (called “Exchange Scientists”) are supported by the sending country. The visits of the Exchange Scientists usually last from one to several weeks in duration, whereas the Visiting Professors normally stay for one month.

The topics and also the participating scientists for the JIFT exchange visits, and workshops are selected so as to have a balanced representation of critical issues in magnetic fusion research, including both fundamental problems as well as questions of near-term significance, and also to take into account the specific capabilities and interests of both countries. The Japanese and US members of the JIFT Steering Committee agree together on the appropriateness of proposed topics before recommending them.

2. SUMMARY OF COMPLETED ACTIVITIES (2024-2025 PROGRAM)

Most of the activities in the two categories—workshops and personal exchanges—that had been scheduled for the 2024-2025 JIFT program were carried out during the past year. One workshop was successfully held. In the category of personal exchanges, one Visiting Professor and three Visiting Scientists made exchange visits. The JIFT Steering Committee meeting was held by email for discussing schedules for the 2024-2025 and 2025-2026 JIFT programs.

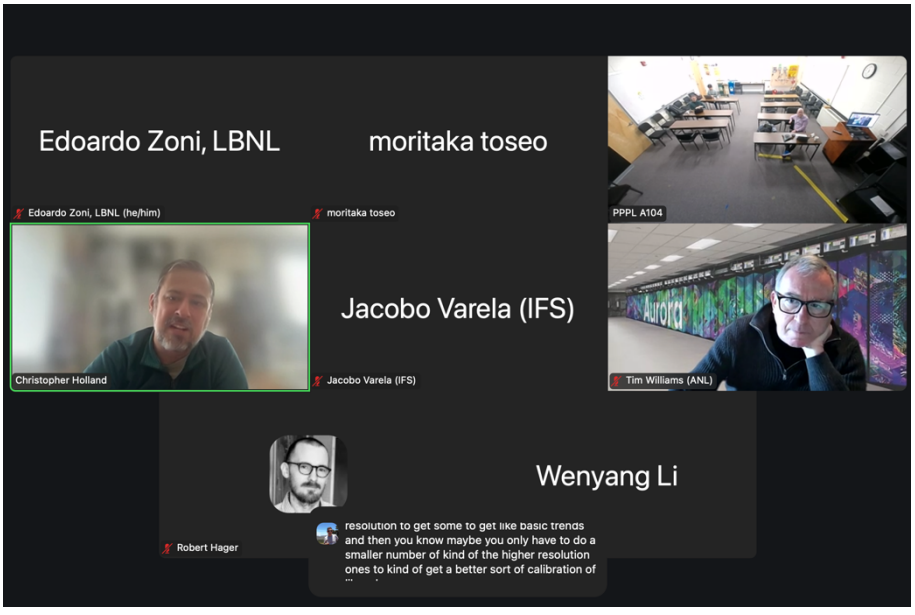
Summary reports about JIFT activities for 2024-2025 are given below.

A 2024-2025 Workshops

Japan to US:

JF-1 US-Japan Joint Institute Fusion Theory (JIFT) Collaboration Meeting on Exascale Computing
Organizers: Robert Hager (PPPL) and Toseo Moritaka (NIFS)
Location: Princeton Plasma Physics Laboratory (PPPL), Princeton, NJ, USA
Dates: February 27-28, 2025
Summary:

The purpose of this meeting was to promote theoretical fusion plasma research utilizing large-scale simulation, data science, and machine learning on cutting-edge high-performance computers. This was the 8th in the series of JIFT meetings on exascale computing. The venue has alternated between the US and Japan. This time, the meeting was held at the Princeton Plasma Physics Laboratory in the US. There were 15 oral presentations, with 6 from Japan and 9 from the US. The presentation topics covered: (1) Simulation code developments and applications, including those of GT5D, MEGA, XGC, GYRO, GENE-X, FAR3d, and WarpX, (2) Data science softwares for extreme-scale computing, (3) US SciDAC projects for high-fidelity integrated simulations, and (4) The latest status of flagship high-performance computers in Japan (Fugaku and Fugaku NEXT) and the US (Frontier, Aurora and El Capitan). There were also discussion sessions on incorporating artificial intelligence/machine learning methods in HPC simulations. We attach a conference photo.



B. 2024-2025 Exchange Visits

Japan to US:

JF-2 Kinetic turbulence simulation of helical confinement plasmas using graphics processors
Visiting Scientist: Tomoya Tatsuno (Univ. Electro-Communications)
Location: IREAP, University of Maryland, College Park, Maryland
Dates: September 15-29, 2024 (15 days); paid by Japan
Summary:

In general, helical devices are computationally more difficult to analyze than tokamaks due to their complicated geometry. Thus, turbulence calculations, which require a large amount of computational resources, are not as advanced as those in tokamaks. In particular, in Heleotron J, turbulence analysis using gyrokinetic theory has been rarely performed except by Ishizawa et al. [1]. However, even in helical systems, anomalous transport due to turbulence is considered to be larger than neoclassical transport due to inter-particle collisions [2], so more analyses are expected.

Since the use of graphics processors is now widely spread due to the effort of NVIDIA, the group at Univ. Maryland (UMD) started developing gyrokinetic simulation code GX around 2015 in the hope that it can be used for turbulence simulations of helical systems. In addition, the UMD and the Princeton Plasma Physics Laboratory have jointly developed a transport analysis code T3D that runs multiple GX processes and connects them to perform multiscale simulations of the whole device.

In 2024, Dr. Tatsuno learned and started to run GX for Heliotron J to perform turbulence simulations. So far, he has performed linear and nonlinear calculations of Ion-Temperature-Gradient (ITG) instability in the plasma equilibrium of Heliotron J using the supercomputer Perlmutter of the U.S. Department of Energy Scientific Computing Center (NERSC), and confirmed that turbulence actually develops. In addition, he has confirmed that T3D can be used to simulate turbulence transport by giving the profile of particles and heating sources taken from the experiment.

In the future, we plan to conduct turbulence analysis in collaboration with the Heliotron Group in order to compare the experiments in Heliotron J.

[1] A. Ishizawa,Y. Kishimoto, T.-H. Watanabe et al., Nucl. Fusion 57, 066010 (2017).
[2] S. Nagasaki, T. Mizuuchi, H. Okada et al., J. Plasma Fusion Res. 96, 475 (2020) [in Japanese].

JF-3 Collaboration on Tokamak boundary plasma turbulence simulations for divertor heat flux width
Visiting Scientist: Haruki SETO (QST)
Location: Lawrence Livermore National Laboratory, Livermore, CA, USA
Dates: Jul. 28- Aug. 18, 2024
Summary:

The purpose of this collaboration is to improve the numerical treatment of BOUT++ code [1] used for study on the extrapolation of the experimental scale law of the divertor heat flux width [2,3] to the ITER-class device [4], which has been conducted at LLNL, by introducing a numerical scheme developed at QST to treat the interaction between zonal flows[5], low-n MHD[6,7] and turbulence. A reliable prediction of divertor heat loads in ITER-class devices is important for the design and lifetime

prediction of divertors in ITER and Japanese DEMO. Both parties will benefit from this collaboration, since QST can get the six-field reduced Braginskii module [8] developed at LLNL and LLNL can also get the extension to handle the interaction between zonal flows, low-n MHD and turbulence developed at QST. In this visit to LLNL, we discussed on improvement of the physics model of the BOUT++ code. A benchmark of linear growth rate of the ideal MHD instability was performed with the QST's 2D field solver for long wavelength components [6] working on CPU supercomputers and a LLNL's 3D field solver working on GPU supercomputers for verification of the implementation of both field solvers. H.S. attended "2024 BOUT++ and ABOUND joint meeting" organized by LLNL to report the results of the past JIFT collaboration and to research US numerical simulation activities on boundary layer tokamak plasmas related to the SiDAC adopted ABOUND project, as well as the development of a GPU-based numerical library. We also discussed about the improvement of BOUT++ grid generator which is necessary for the full-torus nonlinear simulation of ELMs in diverted geometries and is beneficial for both QST and LLNL.

[1] B.D. Dudson et al., Comput Phys. Commun. 180 (2009) 1467
[2] T. Eich et al., Nucl. Fusion 53 (2013) 093031
[3] T. Eich et al., Nucl. Fusion 60 (2020) 056016
[4] X.Q. Xu et al., Nucl. Fusion 59 (2019) 126039
[5] H. Seto et al., Phys. Plasmas 26 (2019) 052507
[6] H. Seto et al., Comput. Phys. Commun. 283, 108568(2023)
[7] H. Seto et al., Phys. Plasmas 31, 032513 (2024)
[8] B. Zhu et al., Comput. Phys. Commun. 267 (2021) 108079

US to Japan:

JF-4 Collaboration on Tokamak boundary plasma turbulence simulations for divertor heat flux width
Visiting Scientist: Ben Zhu (LLNL)
Location: National Institutes for Quantum Science and Technology (QST), Rokkasho, Japan
Dates: Sep. 2-6, 2024

This exchange visit was canceled.

JF-5 Reduced modeling of turbulent transport in the pedestal (Multi-scale turbulence interactions and transport modeling)
Visiting Scientist: Cole Stephens (IFS, USA)
Location: National Institutes for Fusion Science (NIFS), Toki, Japan
Dates: July 16 – 26, 2024
Summary:

This collaboration aimed to improve the reduced modeling of turbulent transport in the tokamak pedestal. Recent experimental evidence and gyrokinetic analysis have indicated that the microtearing mode (MTM) is responsible for substantial heat transport through the electron channel. Nonlinear gyrokinetic pedestal simulations are particularly challenging and computationally expensive, so reduced modeling is

necessary to describe turbulent transport in the pedestal. In this collaboration was one exchange, where Dr. Stephens visited NIFS for 2 weeks, being hosted by Dr. Shinya Maeyama. Dr. Stephens presented a seminar on his recent work regarding MTM modeling in the tokamak pedestal. Dr. Maeyama introduced various state-of-the-art modeling techniques, particularly multi-fidelity modeling via Gaussian process regression (GPR). We also discussed related problems, such as modeling transport in the tokamak core and how to properly include E-cross-B shear in gyrokinetic simulations via a rotating flux-tube model. Discussions with other fusion scientists, such as with Professor Hideo Sugama and Professor Alain Brizard (another visitor), also proved helpful. We are currently planning another visit via JIFT, in which Dr. Shinya Maeyama will visit the Institute for Fusion Studies (IFS) at the University of Texas at Austin for 1 month in August 2025.

JF-6 The application of the metriplectic formalism to guiding-center transport theory
Visiting Scientist: Alain J. Brizard (Saint Michael's College, USA)
Location: National Institutes for Fusion Science (NIFS), Toki, Japan
Dates: Jun. 3 – Jul. 3, 2024
Summary:

The purpose of this collaboration is to derive the metriplectic structure for the guiding-center Vlahos-Maxwell-Landau equations to facilitate the numerical simulation of magnetically confined plasmas in realistic magnetic geometries. The metriplectic formalism was initially developed for the Vlasov-Maxwell-Landau equations [1], in which the collisionless and collisional plasma dynamics involving charged particles (Vlasov-Landau) and electromagnetic fields (Maxwell) are represented in terms of Hamiltonian and dissipative (Landau collision) bracket structures that preserve energy-momentum and angular momentum. This metriplectic formulation of the Vlasov-Maxwell-Landau equations has led to efficient numerical algorithms [2-4] used to study nonlinear plasma dynamics while preserving important conservation laws. Work on the derivation of the metriplectic structure for the guiding-center Vlasov-Maxwell-Landau equations relied on the collaboration between Dr. Brizard, an expert on the Hamiltonian structure of the guiding-center Vlasov-Maxwell equations, and Dr. Sugama (NIFS), an expert on guiding-center Vlasov-Maxwell theory as well as neoclassical transport theory. As a result of this collaboration, a guiding-center Landau dissipative bracket was successfully derived with a proper representation of standard neoclassical effects, without the constraint of linearizing the guiding-center Vlasov distributions about equilibrium distributions [5-6]. A publication is being prepared [7]. The development of advanced Hamiltonian and dissipative structure-preserving algorithms associated with reduced plasma models will thus provide plasma physicists with a set of powerful theoretical and computational tools for the investigation of a wider range of research problems associated with the nonlinear turbulent evolution of laboratory, space, and astrophysical magnetized plasmas. As part of Dr. Brizard's visit to NIFS, research seminars were also given at NIFS on July 23, 2024 (Metriplectic structures for reduced Vlasov-Maxwell equations), and Kyoto University on July 25, 2024 (The Lagrangian formulation of gauge-free electromagnetic gyrokinetic equations) and on July 26, 2024 (The Hamiltonian formulation of gauge-free electromagnetic gyrokinetic equations).
[1] P.J. Morrison, Phys. Plasmas 24 (2017) 055502.

[2] M. Kraus and E. Hirvijoki, Phys. Plasmas 24 (2017) 102311.
[3] J. Xiao, H. Qin, and J. Liu, Plasma Sci. Technol. 20 (2018) 110501.
[4] J. Xiao and H. Qin, Plasma Sci. Technol. 23 (2021) 055102.
[5] H. Sugama and S. Nishimura, Phys. Plasmas 9 (2002) 4637.
[6] H. Sugama, T.-H. Watanabe, and M. Nunami, Phys. Plasmas 16 (2009) 112503.
[7] A.J. Brizard and H. Sugama, (in preparation, 2025).

3. PROGRAM ADMINISTRATION

JIFT has a Steering Committee consisting of eight members, four from each country. Two of these members are the Japanese and US co-chairmen. Two other members of the Steering Committee, the US and Japanese co-executive secretaries, are responsible for the ongoing daily oversight of the progress of JIFT activities. The co-chairman and co-executive secretary on the US side are, respectively, the Research Scientist of the Institute for Fusion Studies (IFS) of The University of Texas at Austin and the Professor of the University of California San Diego. The Japanese co-chairman is the Professor of the Complex Global Simulation Unit at the National Institute for Fusion Science, and the Japanese co-executive secretary is the Deputy Director General of the National Institute for Fusion Science. Furthermore, on the Japanese side there is an Advisory Committee comprised of three members representing a spectrum of Japanese universities and the National Institutes for Quantum and Radiological Science and Technology; and on the US side there is an Advisory Committee comprised of four members representing a spectrum of US universities and national laboratories. The names of the persons on the Steering Committee and the names of the Advisors are listed below.

JIFT Steering Committee

UD Members	*Japanese Members*
J. Varela (IFS)—Co-Chairman	H. Sugama (NIFS)—Co-Chairman
A. Arefiev (UCSD)—Co-Exec. Secretary	Y. Todo (NIFS)—Co-Exec. Secretary
D. Spong (ORNL)	S. Murakami (Kyoto)
F. Parra (PPPL)	Y. Sentoku (Osaka)

JIFT Advisors

Japanese Advisory Committee: Y. Kishimoto (Kyoto), T.-H. Watanabe (Nagoya), M. Yagi (QST)

US Advisory Committee: J. Palastro (LLE/Univ. of Rochester), F. Graziani (LLNL), A. Wright (Univ. *Wisconsin–Madison*), and P. Terry (UWM)

The JIFT Steering Committee attempts to schedule workshops in such a way as to dovetail with other meetings. It also encourages participation at workshops by interested experimentalists and invites relevant available scientists from other countries to attend workshops.

As the principal program for fundamental theoretical exchanges in the US-Japan Fusion Research Collaboration, JIFT operates alongside the Fusion Physics Planning Committee (FPPC), the Fusion Technology Planning Committee (FTPC), and the US-Japan Joint Project (FRONTIER). In particular, the JIFT activities are coordinated with the four FPPC areas of activity, viz., core plasma phenomena, edge behavior and control, heating and current drive, and new approaches and diagnostics.

4. PLANS FOR FUTURE ACTIVITIES (PROPOSED 2025-2026 PROGRAM)

The topics and themes of the exchange activities that have been proposed for the next year (April 1, 2025–March 31, 2026) are consistent with the traditional emphasis of JIFT on fundamental theoretical plasma physics issues. At the same time the proposed activities have direct relevance to the fusion science programmatic interests of both countries. The schedule of proposed activities for the coming year (2025-2026) is listed below.

A. 2025-2026 Proposed Workshops

Japan to US:

JWU1 Understanding non-diffusive phenomena in fusion plasmas
Organizers: Patrick H. Diamond (UCSD) and Yusuke Kosuga (Kyushu)
Proposed Place/Time: UCSD Aug. 25-26, 2025

US to Japan:

JWJ1 Self-organized structure formation and functional emergence driven by intense lasers
Organizers: Yasuhiko Sentoku (Osaka) and Alexey Arefiev (UCSD)
Proposed Place/Time: Yokohama Apr. 21-22, 2025

B. 2025-2026 Proposed Exchange Visits

Japan to US:

JPU1 Hamiltonian theory of collision operators in noncanonical phase space
Visiting Scientist: Naoki Sato (NIFS)
Location: The University of Texas at Austin
Dates: May 18-June 14, 2025

JPU2 Multi-scale turbulence interactions and transport modeling
Visiting Scientist: Shinya Maeyama (NIFS)
Location: The University of Texas at Austin
Dates: July 27-Aug. 23, 2025

JPU3 Collaboration on Tokamak boundary plasma turbulence simulations for divertor heat flux width
Visiting Scientist: Haruki Seto (QST)
Location: LLNL
Dates: Apr. 14-18, 2025

JPU4 Kinetic turbulence simulation of helical confinement plasmas using graphics processors
Visiting Scientist: Tomoya Tatsuno (UEC)
Location: The University of Maryland
Dates: Aug. 24-Sep. 7, 2025

US to Japan:

JPJ1 Validation study on avalanche transport in fusion plasmas
Visiting Scientist: Patrick H. Diamond (UCSD)
Location: Kyoto University
Dates: Sep. 15-19, 2025

JPJ2 Collaboration on Tokamak boundary plasma turbulence simulations for divertor heat flux width
Visiting Scientist: Ben Zhu (LLNL)
Location: QST
Dates: Sep. 29-Oct. 13, 2025

JPJ3 Effect of EP on Pressure driven MHD instabilities in the helical plasmas
Visiting Scientist: Jacobo Varela-Rodrigues (The University of Texas at Austin)
Location: NIFS
Dates: Apr. 15-May 15 and Sep. 16-Nov. 13, 2025