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 2016-2017

CONTENTS:

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Annual Report of Activities

US-Japan Joint Institute for Fusion Theory

April 1, 2016–March 31, 2017

JIFT Steering Committee

Co-Chairmen: R. Horiuchi and F. L. Waelbroeck

Co-Executive Secretaries: H. Sugama and A. Arefiev

February 7, 2017

TABLE OF CONTENTS

1. *INTRODUCTION*

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

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 36 years of successful operation, JIFT has sponsored 226 long-term visits by exchange scientists and 131 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 several weeks to two or three months 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 (2016-2017 PROGRAM)*

Most of the activities in the two categories—workshops and personal exchanges—that had been scheduled for the 2016-2017 JIFT program were carried out during the past year. Four workshops were successfully held, in addition to the JIFT Steering Committee meeting. In the category of personal exchanges, two Visiting Professor and four Visiting Scientists made exchange visits.

Summary reports about JIFT activities for 2016-2017 are given below.

A 2016-2017 Workshops

US to Japan:

JF-8: Theory and simulation of 3D physics in toroidal plasmas - comparison to experiments
Organizers: Yasuhiro Suzuki (NIFS) and Ted Strait (GA)
Location: Kyoto University, Kyoto
Dates: October 24-25, 2016
Summary:

> The purpose of this workshop was to promote the activities on the 3D physics in toroidal plasmas, which are stellrators, tokamaks, and other configurations. This was 2nd in the series of JIFT workshop on 3D physics. There were 19 oral presentations (6 from US and 13 from Japan), which covered a wide range subjects relalted to 3D physics in theoretical and experimental studies.

JF-9: Extended MHD and MHD simulations for magnetized plasmas

Organizers: Hideaki Miura (NIFS), and Linda Sugiyama (MIT)
Location: Kyoto University, Kyoto
Dates: October 24-25, 2016.
Summary:

The purpose of this workshop was to promote the activities on extended MHD and MHD simulations of magnetized plasmas, focusing on non-ideal (two-fluid and finite Larmor-radius) effects as well as to three-dimensional simulations in fusion torus plasmas. This was the fourth in the series of JIT workshops on extended MHD simulations. This workshop was jointed with another workshop "Theory and simulation of 3D physics in toroidal plasmas – comparison to experiments" and with the ITPA MHD task group meeting partially. There were 19 oral presentations (6 from the US, 13 from Japan), which covered subjects of nonlinear simulations of 3D extended MHD and MHD models, reduced two-fluid MHD model, linear instability analysis, equilibrium computation, gyro-kinetic turbulence simulations, and so on.

Japan to US:

JF-1: Innovations and co-designs of fusion simulations towards extreme scale computing
Organizers: T.-H. Watanabe (Nagoya) & C. Chang (PPPL)
Location: Oak Ridge,
Dates: August 17-19, 2016
Summary:

The purpose of the workshop was to continue the promotion of the US-Japan collaboration on co-design of fusion application codes towards extreme and exa scale computing, including core and edge nonlinear plasma physics and plasma-material interaction. The workshop was held at Oak Ridge National Laboratory on August 17 - 19, 2016. The first day was used for individual and group discussions. This was the second JIFT workshop on the co-design and extreme scale computing related to fusion theory and modeling. The first workshop was at Nagoya University, Japan on August 20-21, 2015. Twenty-two (22) official presentations were made from a variety of fields, such as computer science, applied mathematics, computational center, ECP project, fusion plasma physics, and material science. There were fourteen (14) US participants, including leading edge scientists from PPPL, ORNL, UCLA, University Tennessee, and Courant Institute of Mathematical Sciences. Major topics presented at the workshop include prospects of high performance computing on the extreme-scale supercomputers towards exascale, and recent progress in fusion plasma and material simulations capabilities.

JF-2: Theory and Simulation on the high energy density physics related to the inertial confinement fusion plasmas
Organizers: J. Sunahara (ILT) & Dr. Alexey Arefiec
Location: San Jose,
Dates: November 7-8, 2016
Summary:

This workshop followed the 58th Annual Meeting of the APS Division of Plasma Physics. The main objective of the workshop was to provide a platform for the researchers from the US and Japan working on high intensity laser-plasma interactions and high energy-density physics (HEDP) to exchange new ideas, promote research in the field, and discuss the future direction of research. The workshop was devoted to an in-depth discussion of laser-plasma interactions at relativistic laser intensities and relevant high energy-density physics. While the workshop was tilted towards simulations and theory, the experimental results were also discussed to provide the context. The general topics that the workshop will cover include: Fast electron generation;Hot electron transport in plasmas; Proton and ion production and transport; Hard x-ray and gamma-ray emission in strong laser and plasma fields; Magnetized HEDP plasmas; Electron and ion based fast ignition physics and innovative ignition concepts. The overall interest in our workshop exceeded our expectations. We scheduled 29 talks and even then we were unable to accommodate everybody who wanted to

participate. A large number of people attended the workshop (particularly on the first day) to listen and participate in discussions. There were 14 speakers from Japan, 14 speakers from the US, and a guest speaker from Chalmers University in Sweden. There were in total 10 talks given by graduate students and postdocs, which underscores the important role that our workshop plays in development of the next generation of researchers in our field.

B. 2016-2017 Exchange Visits

Japan to US:

JF-3: Numerical analysis of edge harmonic oscillation dynamics in DIII-D QU-mode plasmas
Visiting scientist: N. Aiba (JAEA)
Place: General Atomics (San Diego),
Dates: Sept. 4-18, 2016
This program was postponed to next year.

JF-4: Asymmetric Imploded Core Formation using Solid Targets
Visiting Scientist: Hitoshi Sakagami (NIFS)
Location: University of Nevada, Reno,
Dates: November 27 - December 10, 2016 (14 days); paid by Japan
Summary:

In recent fast ignition experiments at Institute of Laser Engineering, Osaka University, solid targets are introduced to stably compress the core, instead of conventional shell targets. The target is conventionally irradiated by 9 beams of Gekko XII for implosion, or only 6 beams are used in some cases to solve configuration problems. In any case, asymmetric implosion is essential and full three-dimensional fluid simulations are performed to investigate such asymmetric effects. Prof. Sawada, who is the host for this visit to University of Nevada, Reno, is a specialist in measurements of imploded core shapes by X-ray radiography [1] and has already taken X-ray images from experiments in this year. Simulation results of the core density are analyzed and core images are obtained by use of "SPECT3D", which is a multi-dimensional collisional-radiative spectral analysis code. We can directly compare both images and fruitfully discuss about issues. Estimated timing of the maximum compression and maximum density are found to be consistent between experiment and simulation. Compressed core shape, which is calculated by Abel inversion of experimental data, resembles that of three-dimensional simulation data rather than axisymmetric two-dimensional simulation, especially in 6 beam irradiation cases.

Related publications:

[1] H Sawada, et al., "Flash Kα radiography of laser-driven solid sphere compression for fast ignition", Applied Physics Letters **25**, 254101 (2016).

JF- 5: Optimization of stellarator and Heliotron using simple coil geometry
Visiting Scientist: Yasuhiro Suzuki (NIFS)
Location: PPPL, Princeton, NJ
Dates: March 20-26, 2017 (7 days); paid by Japan
Summary:

The purpose of this activity is the development of a new coil optimization code, COILOPT++. S. Hudson (PPPL) and C. Zhu (USTC), who is a Ph.D students of China-US joint Ph.D program, are developing the new coil optimization code, COILOPT++. Y. Suzuki (NIFS) applied that code to design an optimized heliotron configuration. Old version of COILOPT code used to a preconditioning sheme to improve the convergence of the optimization process. However, numerical implementation of the preconditioning leads to unphysical results. In our activity, a new preconditioning based on the physcis property is implemented. Using the new COILOPT++ code,

we could successfully design the coild system of an optimized heliotron reducing the neoclassical transport.

JF-6: Nonlinear two-fluid simulation of ballooning-type instability
Visiting Scientist: Hideaki Miura (NIFS)
Location: IFS, University of Texas at Austin, Texas
Dates: March 5-27, 2017; paid by US.
Summary:

The visiting scientist, Hideaki Miura, has been collaborated with Dr. Linjin Zheng and Professor Wendell Horton in IFS, University of Texas at Austin. HM and the two scientists published two papers in 2016, both of them being related with instabilities. This visit, JF-6 in March 2017, was proposed to enhance the collaborative works. Miura is going to carry out two-fluid or extended MHD simulations of Rayleigh-Taylor/interchange-type instability in the plasma edge region. We intend to clarify influences of two-fluid effects on the instability with steep pressure and density gradients at the edge region.

JF-7: Simulation Study of Magnetized Fast Ignition Fusion
Visiting scientist: T. Taguchi (Setsunan)
Place: University of Maryland,
Dates: Aug. 7-Sept. 4, 2016

This program was cancelled.

US to Japan:

JF-10: Non-local transport modeling in LHD plasmas
Visiting scientist: Diego Del Castillo (ORNL)
Place: NIFS,
Dates: July 4-15, 2016, Paid for by US.
Summary

In collaboration with his host, Prof. Naoki Tamura, Dr. Diego del-Castillo-Negrete used this visit to study perturbative experiments in LHD. The specific goal was to apply a non-local transport model developed by del-Castillo-Negrete and collaborators at the Oak Ridge National Laboratory (ORNL). Previous successful applications of this model include the description of perturbative experiments in JET. Like in the JET experiments, the cold pulses in LHD (produced by pellet injection) exhibit a time delay of the order of ~4 ms which is significantly faster than the diffusive time scale. However, a unique signature of the LHD experiments is that the cooling of the core happens in the absence of significant cooling of intermediate regions of the plasma. This non-monotonic cooling is accompanied by the existence of a long-range flux that extends throughout the whole plasma domain. Describing these phenomena using a diffusive model is problematic because the measured perturbed fluxes and temperature gradients show regions of up-hill transport and regions where the flux changes without a significant local change in the temperature gradient. In addition, the measurements indicate the lack of a single valued flux-gradient functional relation needed to justify a diffusive model with a physically meaningful diffusivity. Progress was made showing that this phenomenology can be consistently described using the ORNL non-local transport model in which the total flux, q, has a component, qnl, that depends non-locally on the temperature gradient throughout the whole plasma domain.

JF-11: Multi-scale simulations of electron kinetics in laser-plasma interactions and microwave heating of tokamak plasmas
Visiting scientist: Alexey Arefiev (IFS, Univ. Texas)
Place: ILE (Osaka),
Dates: Oct 10-22, 2016. Paid for by US.

Summary:

This visit was coupled with Dr. Arefiev's trip to the 2016 Fusion Energy Conference in Kyoto (Oct. 16-22) where he presented his recent work on kinetic simulations of X-B and O-X-B mode conversion. The results of Dr. Arefiev's research revealed that high levels of input power can have a deteriorating effect on the excitation of electron Bernstein waves. This finding is important for future experiments aimed at heating plasma using microwaves at high input power.

Before coming to Kyoto, Dr. Arefiev visited ILE as a JIFT visiting researcher on Oct. 12-14. On Oct. 12 Dr. Arefiev gave a colloquium talk to present his resent research results on enhanced multi-MeV photon emission by a laser-driven electron beam in a self-generated magnetic field. Dr. Arefiev had extensive discussions with ILE researchers (Prof. Sentoku, Prof. Mima, Prof. Murakami, Prof. Yogo, and Dr. Iwata) to exchange ideas, identify project for possible future collaborations, and to plan future JIFT US-Japan workshops. One of the discussion topics was the newly developed experimental capability of generating large-scale kT-level magnetic fields by kJ-level, ns-long laser pulses. Dr. Arefiev presented his recent computational work [New Journal of Physics 18, 105011 (2016)] where it was shown that the kT magnetic fields generated at the LFEX facility can have a profound effect on generation of laser-driven proton beams at relativistic intensities. The result of this discussion was a joint proposal to perform proof of principle experiments at the LFEX facility. The proposal has been submitted, with Dr. Arefiev serving as a PI. The collaborators for this project will include Prof. Fujioka, Prof. Yogo, and Prof. Sentoku of ILE. Another important outcome of Dr. Arefiev's visit was a new proposal to organize JIFT workshops over the next two years together with Prof. Sentoku. The workshops will specifically focus on multi-ps laser-plasma interactions at relativistic laser intensities. The scope of the workshop was motivated by newly available experimental capabilities at such facilities as LFEX and NIF ARC to access these previously unexplored regimes.

JF-12: Fusion plasma simulation with XGC code
Visiting scientist: CS Chang (PPPL)
Place: Nagoya University
Dates: Oct. 27-31, 2016. Paid for by US
This program was canceled.

JF-13: Nonlinear theory of Fast-particle driven instabilities
Visiting scientist: Herb Berk (IFS, Univ. Texas)
Place: NIFS,
Dates: Sept. 5-30, 2016, Paid for by US
This program was cancelled.

JF-14: Simulation of Alfven eigenmodes in toroidal plasmas
Visiting Professor: D. Spong (ORNL)
NIFS, Feb 20 – Mar 19, 2017, paid by Japan
Summary:

In collaboration with his host, Prof. Todo, Dr, Spong will apply the GTC global gyrokinetic code to observations of Alfven instabilities in the LHD stellarator and for code verification studies with the MEGA hybrid particle/MHD model developed by Prof. Todo. A recently developed global gyrofluid model (FAR3D) for stellarator energetic particle instabilities will also be used to model LHD discharges.

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 director and a research scientist at the Institute for Fusion Studies (IFS) of The University of Texas at Austin. The Japanese co-chairman is the Leader of the Numerical Simulation Research Project at the National Institute for Fusion Science, and the Japanese co-executive secretary is the director of the Fusion Theory and Simulation Research Division in the Department of Helical Plasma Research at the National Institute for Fusion Science. Furthermore, on the Japanese side there is an Advisory Committee comprised of several members representing a spectrum of Japanese universities and the Japan Atomic Energy Agency; and on the US side there is an Advisory Committee comprised of several 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

US Members	*Japanese Members*
F. Waelbroeck (IFS)—Co-Chairman	R. Horiuchi (NIFS) —Co-Chairman
A. Arefiev (IFS)—Co-Exec. Secretary	H. Sugama (NIFS)—Co-Exec. Secretary
D. Spong (ORNL)	A. Fukuyama (Kyoto)
J. Mandrekas (DOE)	H. Nagatomo (Osaka)

JIFT Advisors

Japanese Advisory Committee: N. Nakajima (NIFS), S. Ishiguro (NIFS), Y. Kishimoto (Kyoto), Z. Yoshida (Tokyo), H. Naito (Yamaguchi), M. Yagi (JAEA), T. Ozeki (JAEA)

*US Advisory Committee***:** P. Catto (MIT), V. Chan (GA), B. Cohen (LLNL), W. Horton (IFS), W. Tang (PPPL), 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) and the Fusion Technology Planning Committee (FTPC). 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 2017-2018 PROGRAM)*

The topics and themes of the exchange activities that have been proposed for the next year (April 1, 2017–March 31, 2018) 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 (2017-2018) is listed below.

A. 2017-2018 Proposed Workshops

Japan to US:

JF-1 Multiscale methods in plasma physics
Organizers: S.ISHIGURO (NIFS) & Scott Parker (Colorado)
Proposed Place/Time: Boulder, August 21-26, 2017

US to Japan:

JF-6 US-Japan collaborations on co-designs of fusion simulations for extreme scale computing
Organizers: T.WATANABE (Nagoya) & C. S. Chang (PPPL)

Proposed Place/Time: JAEA, AUG.7-9, 2017

JF-7 Progress on advanced optimization concept and modeling in stellarator-heliotrons
Organizers: S. MURAKAMI (Kyoto) & J. Talmadge (Wisconsin)
Proposed Place/Time: KYOTO U., OCT.8-10,2017

JF-8 Theory and simulation on the high field and high energy density physics
Organizers: Y. SENTOKU (Osaka) & Alexey Arefiev (Texas)
Proposed Place/Time: HIROSHIMA, JAN.25-26,2018

B. 2017-2018 Proposed Exchange Visits

Japan to US:

JF-2: Numerical analysis of edge harmonic oscillation dynamics in DIII-D QH-mode plasmas
Visiting Scientist: N.AIBA(QST)
Location: GA
Dates: SEP.10-24,2017

JF-3: Optimization of stellarator and Heliotron using simple coil geometry
Visiting Scientist: Y. SUZUKI(NIFS)
Location: PPPL
Dates: FEB.4-17,2018

JF-4: Numerical Analysis of Energetic Particle Phase Space Structure in Toroidal Plasmas
Visiting Scientist: Y.TODO (NIFS)
Location: IFS, Texas U.
Dates: SEP.1-SEP.30,2017

JF-5: Extension of gyro-kinetic simulation to the helical edge plasmas
Visiting Scientist: T.MORITAKA(NIFS)
Location: PPPL,IFS
Dates: Fe b .19-MAR.23.2018

US to Japan:

JF-9: Numerical analysis of Alfvén eigenmodes in LHD
Visiting Scientist: J. Varela (ORNL)
Location: NIFS
Dates: APR.4-13,2017

JF-10: Gyrokinetic turbulent transport simulation study in magnetized plasmas
Visiting Scientist: David Hatch (IFS)
Location: NIFS
Dates: AUG.28-SEP.8,2017

JF-11: Fast ion acceleration by intense short laser pulse under mega-gauss magnetic fields
Visiting Scientist: Alexey Arefiev (IFS)
Location: OSAKA U.
Dates: OCT.10-22,2017

JF-12: Polarization corrections to ray equations and their effects on the propagation of radiofrequency waves in magnetized plasmas
Visiting Scientist: Ilya Dodin (PPPL)
Location: NIFS
Dates: Apr.1-May.1,2017

JF-13: 3D MHD simulation of helical axis core
Visiting Scientist: Karsten McCollam (U. WISCONSIN)
Location: NIFS
Dates: SEP.3-OCT.14,2017