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 2015-2016

CONTENTS:

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Annual Report of Activities

US-Japan Joint Institute for Fusion Theory

April 1, 2015–March 31, 2016

JIFT Steering Committee

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

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

February 18, 2016

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 35 years of successful operation, JIFT has sponsored 220 long-term visits by exchange scientists and 127 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 (2015-2016 PROGRAM)*

Most of the activities in the two categories—workshops and personal exchanges—that had been scheduled for the 2015-2016 JIFT program were carried out during the past year. Three workshops were successfully held, in addition to the JIFT Steering Committee meeting. In the category of personal exchanges, two Visiting Professor and nine Visiting Scientists made exchange visits.

Summary reports about JIFT activities for 2015-2016 are given below.

A 2015-2016 Workshops

US to Japan:

JF-8 ***Innovations and co-designs of fusion simulations towards extreme scale computing***
Organizers: Tomo-Hiko Watanabe (Nagoya Univ.) and C. S. Chang (PPPL)
Location: Nagoya University, Nagoya
Dates: August 20-21, 2015
Summary:

Purpose of the workshop is to promote US-Japan collaborations on co-design of fusion applications towards extreme scale computing, and on high performance computing in fusion simulations of core and edge plasmas and plasma-material interactions. This was the first JIFT workshop on the co-design and high performance computing related to fusion theory and modeling. Twenty-five (25) participants attended to the workshop from a variety of research fields, such as computer science, fusion plasma theory, and the material science. There were eleven (11) US participants, including leading edge scientists from PPPL, ORNL, and UCLA. Major topics presented at the workshop include prospects of high

performance computing on the extreme-scale supercomputers, and recent progresses in fusion plasma simulations and material simulations.

Related publications:

The agenda and presentations are available on the web site: http://p.phys.nagoya-u.ac.jp/JIFT2015HPC/

JF-9 ***Theory and Simulation on the high energy density physics related to the inertial confinement fusion***

Organizers: Atsushi Sunahara (ILT, Osaka) and Alex Arefiev (U. Texas, Austin)
Location: Bansyokaku, FUKUI
Dates: March 24-25, 2016

Summary:

The purpose of this workshop is to provide a platform for the researchers from Japan and US working on high intensity laser-plasma interactions and high energy density physics (HEDP) to exchange new ideas, promote the research activities in the field, and discuss the future direction of research. This workshop will be the 3rd in the series of JIFT workshops on this topic. Over 20 participants will be expected (6 from the US, 15 from Japan), which will be devoted to an in-depth discussion of laser-plasma interactions at relativistic laser intensities and relevant high energy density physics. The general topics that the workshop will cover fast electron generation, hot electron transport in plasmas, proton and ion production and transport, and magnetized HEDP plasmas.

Japan to US:

JF-1 ***Theory and Simulation of 3D Physics In Toroidal Plasmas - Comparison to Experiments***

Organizer: Nate Ferraro and Ted Strait (General Atomics), Y. Suzuki (NIFS)
Location: San Diego, General Atomics
Dates: July 21-26, 2015

Summary:

The prevalence of 3-D physics is a theme common to both the stellarator/heliotron and tokamak confinement configurations. The US-Japan JIFT Workshop provided a forum for theory and computational researchers to compare and contrast how different topical areas of magnetic confinement physics are treated in these two communities. Additionally, opportunities for improving theory and modeling effort were identified. This is the third workshop on this topic. Topical areas discussed at this meeting included 3-D MHD equilibrium, magnetic island physics, extended MHD modeling, interaction between ECCD and Alfven eigenmodes, impacts of 3D geometry on pedestal formation in DIII-D, neoclassical toroidal viscosity in JT-60U (NIFS-JAEA collaboration), electromagnetic gyrokinetic simulation for finite-beta LHD plasmas, energetic ion confinement, transport modeling, impurity transport and divertor modeling. The workshop gathered experimentalists and theorists from Japan and the US to review recent progress in 3-D physics and highlight challenges. There were 21 oral presentations including 5 from Japanese scientists and 16 from the US community.

Related publications:

The agenda and presentations are available on the web site: https://fusion.gat.com/conferences/usjapan2015

JF-2 ***Extended MHD and MHD simulations for magnetized plasmas***

Organizers: H. Miura (NIFS) and L. E. Sugiyama (MIT)
Location: Golden, Colorado
Dates: August 10-11, 2015

Summary:

The purpose of this workshop was to bring together the leading researchers in the field of computational plasma physics to discuss advanced models, methods and algorithms to solve higher dimensional, complex nonlinear problems. This was the third workshop in the series of JIFT workshops on this subject. Sixteen participants attended the workshop, including three Japanese researchers. There were 30 oral presentations, covering various topics such as linear and nonlinear growth of ballooning modes, diamagnetic (or two-fluid) effects on the ballooning/ interchange/g- modes, energetic-particle effects on instabilities, heat transport, magnetic islands, analysis of ELMs, and so on. Among the topics, many of the presenters

mentioned diamagnetic effects, reflecting a focus of interest in three-dimensional numerical simulations of instability.

Related publications:

The agenda and presentations are available on the web site: http://www.icnsp.org

B. 2015-2016 Exchange Visits

Japan to US:

JF-3 ***Collaborations between TASK3D-a (for LHD plasmas) and TRANSP (for tokamak plasmas)***

Visiting Scientist: Masayuki YOKOYAMA (NIFS)
Location: Princeton Plasma Physics Laboratory, New Jersey, USA
Dates: 26 October–5 November, 2015 (11 days); paid by Japan

Summary:

This visit was primarily aimed to establish links among researchers on the development and applications of the integrated transport suite, TASK3D-a (NIFS) and TRANSP (PPPL). The host was Prof. Amitava Bhattacharjee. During my stay at PPPL, seminar on the development and application of TASK3D-a for LHD experiment (by M.Yokoyama), group meeting joined by the TRANSP developers and users organized by Prof. Steve Jardin, and individual discussion with TRANSP developers were successively held. This mutual information exchange has successfully provided human links on the integrated transport suite activities, and will be the basis for further collaboration such as on NBI modeling under multi-ion species, behavior of energetic particles, neutron production rate calculations and others.

JF-4 ***Simulation study of energetic particles in the quasi-helical symmetric configuration***

Visiting Scientist: Sadayoshi Murakami (Kyoto Univ.)
Location: HSX Plasma Experiment Laboratory, University of Wisconsin, Madison, Wisconsin
Dates: March 1-11, 2016 (11 days); paid by Japan

Summary:

Dr. S. Murakami has collaborated for a number of years with Dr. K.Likin and Dr. J. Talmadge at HSX Plasma Experiment Laboratory, University of Wisconsin on the kinetic behavior of the energetic particles generated by the plasma heating in the quasi-helical symmetric configuration. In this visit, they studied the ICRF minority heating and NBI heating in the HSX configuration and the confinement of energetic ions and plasma heating efficiency. First, they studied the ICRF minority heating using the improved GNET code, which can treat the multi-ion plasma effect on the Coulomb collisions accurately. They found that the heating efficiency of the ICRF minority heating strongly depends on the magnetic configurations and the neutral density in HSX. Next, they studied the NBI heating using the FIT3D and GNET code. Due to the complex plasma configurations, the NBI heating efficiency strongly depends on the injection geometry of the NBI heating. They also studied the confinement of the NBI beam ions changing the magnetic configuration in HSX

JF-6 ***Development and Applications of innovative scheme of numerical simulation for relativistic laser-plasma interactions in fast ignition laser fusion***

Visiting Scientist: Tomoyuki Johzaki (Hiroshima University)
Location: University of Nevada, RENO, Reno, Nevada
Dates: March 02–March 09, 2015 (8 days); paid by Japan

Summary:

Dr. Johzaki has been collaborating for a number of years with Prof. Y. Sentoku at University of Nevada, Reno (UNR) on the simulation study for the relativistic laser plasma interaction related to the laser fusion. Dr. Johzaki has developed the Fokker-Planck codes for fast electron transport and fast ions, and then analyses and optimizes the processes of those fast particles generation and energy transport to the imploded core for the fast ignition laser fusion. Prof. Sentoku has developed PIC code including particle

collision, ionization and radiation damping processes. In the past collaboration, they have developed the simulation model for the collision and ionization, and then have revealed the effects of collisional processes on the fast electron transport in the high Z Au cone, also demonstrated the potential probability for C^{6+} beam driven fast ignition laser fusion. In this fiscal year (2015), to make further development of their PIC code including collisional processes, ionization and radiation transport for the research on laser fusion and related relativistic laser plasma physics, they will discuss about numerical modeling of

(1) Scattering of photons (Thomson scattering and Compton scattering) in radiation transport
(2) Transport of fast particles generated by nuclear reactions (e.g., pair creation, nuclear fusion)
(3) Particle merging scheme for suppressing the increase in the number of super-particle due to the particle generation by various reaction processes

Among three subjects, we will focus on the first one and introduce in to the current PIC code. Installing these physical phenomena and numerical scheme into PIC code will expand and deepen the numerical experiments, which will contribute to the numerical research on the laser-plasma physics including nuclear fusion research.

JF-7 ***Two-fluid simulation of magnetic islands***
Visiting Scientist: Masahiko Sato (NIFS)
Location: IFS, University of Texas at Austin, Austin, Texas
Dates: February 1-26, 2016 (26 days); paid by US
Summary:

The influence of the two-fluid effects of the magnetic islands generated by MHD instabilities such as tearing modes and resistive interchange modes is being investigated by simulation based on a two-fluid reduced MHD model. In the linear phase, the propagation velocity of the resistive interchange modes is smaller than the electron fluid velocity. However, the propagation velocity becomes close to the electron fluid velocity in the nonlinear phase due to generation of magnetic islands. The propagation velocity of the magnetic islands seems to depend on not only width of the magnetic island but also the mode's parity. The mechanism of the propagation velocity of the magnetic islands will be clarified by comparing between the resistive interchange modes and the tearing modes.

US to Japan:

JF-12 ***Hamiltonian, Topological, and Geometric Structure of Plasma Dynamics***
Visiting Scientist: Prof. Philip J. Morrison, University of Texas at Austin
Location: University of Tokyo, Kashiwa Campus
Dates: December 1-15, 2015
Summary:

The RT-1 experiment at the University of Tokyo Kashiwa Campus is a plasma dipole configuration that self-organizes to form equilibrium plasma states. Equilibria observed in this experiment can be understood as extrema of specific invariants of plasma dynamical equations, invariants that contain geometrical and topological information about the electromagnetic field and the plasma. Motivated by the experiment, we have been investigating topological constraints that play a key role in general plasma self-organizing processes. In particular, there is a key connection between the pertinent topological invariants and Hamiltonian formalisms for plasma dynamics, in which some topological constraints are represented by Casimir invariants (for example, the helicities of fluid or plasma physics) and the effective phase space is reduced to lower dimension, the so-called Casimir leaves. However, for the infinite-dimensional systems of plasma physics, partial differential equations such as extended MHD that includes Hall and electron inertia physics, the nature of the infinite-dimensional phase space leads to many open and subtle questions. For example, a general constraint is not necessarily integrable, which precludes the existence of an appropriate Casimir invariant -- the loop integral of Kelvin's circulation theorem of fluid mechanics is an example of such an invariant. In recent times we made significant progress in formulating a systematic method to embed plasma Hamiltonian systems into an extended phase space by introducing phantom fields, which can then be reduced to better understand the nature of possible plasma dynamics. During this visit, we brought to fruition earlier work by completing Ref. [1],

which has recently been published. This work describes how phantom fields open up that phase space to reveal constraints at singular points of the Hamiltonian structure. Also, a newer project [2] reveals how non-Hamiltonian effects arise at singular points in Hamiltonian systems. This remarkable discovery explains why there is Chirality in a toy Rattleback system, which could be a key to explaining such effects as dynamo reversal. We expect to submit our paper on this project on a time scale of one month.

Related publications:

[1] Z. Yoshida and P. J. Morrison, "Hierarchical structure of noncanonical Hamiltonian systems, "Physica Scripta 91, 024001 (7pp) (2016).

2] Z. Yoshida1, T. Tokieda, and P. J. Morrison, "Prototype Rattleback Systems as a Bianchi Type VILie-Poisson System with Chirality," under preparation (2016).

JF-13 ***Modeling of RMP penetration by 3D MHD codes***

Visiting Scientist: N. Ferraro (PPPL)
Location: NIFS
Dates: March 14-18, 2015 (pending)
Summary:
Dr, Ferraro will use his visit to apply the M3D-C1 code to the study the penetration of resonant magnetic perturbations in the edge of tokamaks. He will compare the results of M3D-C1 to simulations carried out by the host, Prof. Suzuki, using the HINT code.

JF-14 ***Construction of chaotic coordinate system and its implementation to the HINT code***

Visiting Scientist: S. Hudson (PPPL)
Location: NIFS
Dates: June 1-August 31, 2015
Summary:
In collaboration with his host, Prof. Y. Suzuki, Prof. Hudson used his visit to study the magnetic field lines and heat transport in strongly stochastic fields. He applied the theory of quadratic-flux-minimizing (QFM) surfaces to improve the analysis of heat transport in robustly stochastic fields. Their work involved the implementation of computational techniques enabling the efficient construction of high-order QFM surfaces for experimentally relevant, chaotic magnetic fields. As a practical application, they examined the non-integrable edge of the Large Helical Device (LHD) as well as that of JT-60SA. Near the edge, there is a fractal mix of low-order islands, high-order islands, KAM surfaces, and cantori. They implemented precise technique for finding the outermost surface, and calculated the staircase of partial barriers associated with the near-critical cantori. They also constructed a coordinate system, called chaotic coordinates, based on a selection of QFM surfaces. This system simplifies the description of the magnetic field, so that flux surfaces become straight and islands become cartesian.

JF-15 ***Simulation of Alfven eigenmodes in toroidal plasmas***

Visiting Scientist: D. Spong
Location: National Institute for Fusion Science, Toki, Japan
Dates: March 14-18, 2015; paid by US (pending)
Summary:
In collaboration with his host, Prof. Todo, Dr, Spong will continue code benchmarking/verification studies between the gyrokinetic GTC model and the MEGA hybrid particle/MHD model that he initiated during his previous visit. Of particular interest are the observations of TAE instabilities in the LHD stellarator. Dr. Spong will also continue work with the PENTA/DKES stellarator neoclassical transport codes that he developed with Masayuki Yokoyama and co-workers.

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 2016-2017 PROGRAM)*

The topics and themes of the exchange activities that have been proposed for the next year (April 1, 2016–March 31, 2017) 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 (2016-2017) is listed below.

A. 2016-2017 Proposed Workshops

Japan to US:

Innovations and co-designs of fusion simulations towards extreme scale computing
Organizers: T.-H. Watanabe (Nagoya) & C. Chang (PPPL)
Proposed Place/Time: Oak Ridge, August 17-19, 2016

Theory and Simulation on the high energy density physics related to the inertial confinement fusion plasmas
Organizers: J. Sunahara (ILT) & Dr. Alexey Arefiec
Proposed Place/Time: San Jose, November 7-8, 2016

US to Japan:

Extended MHD and MHD simulations for magnetized plasmas
Organizers: H. Miura (NIFS) & L.E. Sugiyama (MIT)

Proposed Place/Time: Kyoto, Nov. 24-25, 2016

3D Physics - systematic comparison of theory and experiment
Organizers: Y. Suzuki (NIFS) & Ted Strait (GA)
Proposed Place/Time: Kyoto, Nov. 17-19, 2016

B. 2016-2017 Proposed Exchange Visits

Japan to US:

Simulation Study of Magnetized Fast Ignition Fusion
T. Taguchi (Setsunan)
University of Maryland, Aug. 7-Sept. 4, 2016➔ cancelled

Numerical analysis of edge harmonic oscillation dynamics in DIII-D QU-mode plasmas
N. Aiba (JAEA)
General Atomics (San Diego), Sept. 4-18, 2016➔ cancelled

Asymmetric Imploded Core Formation using Solid Targets
H. Sakagami (NIFS)
University of Nevada, Reno, Nov 20-Dec 3, 2016

Optimization of stellarator and Heliotron using simple coil geometry
Y. Suzuki (NIFS)
Princeton Plasma Physics Laboratory (PPPL), Jan. 29-Feb.10, 2017

Nonlinear two-fluid simulation of ballooning-type instability
H. Miura (NIFS)
Institute of Fusion Studies, University of Texas (Austin), Feb. 20-Mar 12, 2017

US to Japan:

Simulation of Alfven eigenmodes in toroidal plasmas
Visiting Professor
D. Spong (ORNL)
NIFS, Feb 20 – Mar 19, 2017

Nonlinear theory of Fast-particle driven instabilities
Herb Berk (IFS, Univ. Texas)
NIFS, Sept. 5-30, 2016, Paid for by US➔ cancelled

Non-local transport modeling in LHD plasmas
Diego Del Castillo (ORNL)
NIFS, July 4-15, 2016, Paid for by US.

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

Fusion plasma simulation with XGC code
CS Chang (PPPL)
T. Watanabe, Osaka Univ.
Oct. 27-31, 2016. Paid for by US➔ cancelled