JOINT INSTITUTE FOR FUSION THEORY

NEWSLETTER

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Joint Institute For Fusion Theory

The Institute for Fusion Studies (IFS) at the University of Texas at Austin and the International Center for Fusion Theory (ICFT) in Nagoya work together to form the Joint Institute for Fusion Theory (JIFT). The primary purpose of JIFT is to foster the progress of scientific research by providing a planned set of exchange visits, workshops, and computational projects that involve United States and Japanese theoretical plasma physicists working on problems associated with the development of fusion systems.

The JIFT Steering Committee members are:

Prof. Y. Ichikawa - Director of ICFT, Nagoya

Prof. K. Nishikawa - Hiroshima University

Dr. D. B. Nelson - Director of Applied Plasma Physics, U. S. Department of Energy

Prof. M. N. Rosenbluth - Director of IFS, University of Texas at Austin

Prof. J. M. Dawson - University of California at Los Angeles

JIFT activities are coordinated in the U. S. and Japan by two committees. The Japanese Management Committee consists of T. Kamimura (IPP), Chairman, T. Sato (HIFT), T. Takeda (JAERI), and M. Wakatani (Kyoto). The U. S. Management Committee is at the IFS and consists of W. Horton, Chairman, J.-N. Leboeuf, T. Tajima, and J. W. Van Dam.

Published by the JIFT Management Committee of the Institute for Fusion Studies, University of Texas at Austin, Austin, TX 78712. Newsletter correspondence should be directed to J. Van Dam (editor): Tel. (512)471-6129 or FTS 770-5270.

Exchange Scientists for 1985 to 1986

Dr. Janardhan Manickam, PPPL, Visiting Scientist to JAERI
May 30–September 16, 1985
"Ideal and Resistive MHD Instabilities"

Prof. Russell M. Kulsrud, PPPL, Visiting Professor to IPP Nagoya and Kyoto University
September 1–December 31, 1985
"Stellerator Stability and Transport, Magnetic Reconnection"

Dr. Robert Huff, UCLA, Visiting Scientist to IPP Nagoya
September 22, 1985–February 28, 1986
"New Methods in 3D Simulations for RF Heating and Antenna Coupling Problems"

Prof. Hiromu Momota, IPP Nagoya, Visiting Professor to IFS and MIT
November 15, 1985–March 15, 1986
"Theoretical Studies on Reversed Magnetic Field Configurations"

Dr. Hitoshi Hojo, Hiroshima Univ., Visiting Scientist to LLNL, Wisconsin, MIT, and IFS
September 30, 1985–March 29, 1986
"RF Control of Plasma Stability"

Workshops for 1985 to 1986

Japan to US:

(1) RF Heating and Current Drive
Organizers: N. Fisch, C. Karney, H. Abe, and S. Tanaka
Location: PPPL
Date: August 6–7, 1985

(2) 3D MHD Simulation
Organizers: B. Carreras and T. Sato
Location: ORNL
Date: March 3–7, 1986

US to Japan:

(1) Advanced Plasma Modeling
Organizers: T. Kamimura and J. Dawson
Location: IPP Nagoya
Date: September 24–27, 1985

(2) Advanced Concepts for Stability in Axisymmetric Systems
Organizers: T. Watanabe and J. Van Dam
Location: IPP Nagoya
Date: September 9–13, 1985

(3) Statistical Plasma Physics
Organizers: T. Hatori and R. Littlejohn
Location: IPP Nagoya
Date: February 17–21, 1986

Joint Computational Projects for 1985 to 1986

JIFT Joint Computational Projects involve collaboration by the participants through the MFENET-IPPNET computer link, as well as a visit of approximately one month's duration by one U. S. scientist to Japan and vice versa.

(1) Long-Time-Scale/Large-Space-Scale Implicit Methods for Particle Simulations
Organizers: T. Kamimura, T. Tajima, and J.-N. Leboeuf
Location: IPP Nagoya and IFS Texas

(2) RF Heating and Current Drive
Organizers: V. Decyk and H. Abe
Location: Kyoto University and UCLA

Reports from 1985 to 1986 Workshops

RF Heating and Current Drive

Organizers: N. Fisch, C. Karney, H. Abe, and S. Tanaka
Location: PPPL
Date: August 6–7, 1985

Approximately thirty-five U. S. scientists from several locations, though largely from Princeton, attended this workshop along with the Japanese delegation, which consisted of H. Abe (Kyoto University), the organizer, A. Fukuyama (Okayama University), M. Okamoto (IPP Nagoya), and S. Tanaka (Kyoto University). The delegation spent from August 5 to August 10 at Princeton, conferring informally with PPPL scientists both before and after the workshop.

The aim of the workshop was to review recent theoretical and experimental developments in lower-hybrid heating and current drive, and, in particular, to explore suggestions for rf experiments on large devices. In part, the idea here was to couple the considerable U. S. expertise and emphasis on heating and current-drive theory with the more ambitious outlook in Japan for rf experiments on large devices.

Titles of items on the agenda for the workshop included: RF current-drive experiments on WT2, heating and current drive on JT-60, PLT and next generation experiments, MIT research and suggestions for new experiments, current-drive efficiency near LHR density and EM simulations, 2D analysis of ICRF and Alfvén waves, new theoretical ideas, and reaction relevance.

The format of this workshop, designed to encourage the free flow of ideas, was somewhat novel. There were three modes of presentation: hour-long talks given by the Japanese visitors; discussion periods in which all participants were asked merely to summarize ideas quickly or to ask questions; and posters for more detailed information. There were no formal poster sessions, but long coffee breaks were scheduled in the area where the posters were posted. The format was found to be quite useful, and it might work even better when participants get used to it.

Advanced Concepts for Stability in Axisymmetric Systems

Organizers: T. Watanabe and J. W. Van Dam
Location: IPP Nagoya
Date: September 9–13, 1985

This workshop was attended by eighteen Japanese scientists and five U. S. scientists. In addition, several observers from Japan, U. S., Egypt, and China also participated in the meeting.

The participants were officially welcomed by Prof. Y. H. Ichikawa, who summarized JIFT activities for the past five years and noted that the subject of the present workshop has been one of the recurrent themes of past workshops. Professor Y. Terashima noted the significance of the topic of this workshop to current efforts by IPP Nagoya to plan for a large, advanced concept experiment.

The aim of this workshop was to bring together plasma physicists working on a variety of confinement systems—tokamaks, mirrors, compact tori, and bumpy tori—in order to discuss a number of novel stabilization methods. The methods were usually discussed in a specific context, but with generic interest and broad applicability to many experimental plasmas. This format was conducive to wide-ranging, free discussions that took advantage of the broad experience of the participants and their familiarity with both MHD and kinetic theory.

(1) Axisymmetric Torus

Theory for high-mode-number ballooning modes in tokamaks predicts access to high-beta second stability by the introduction of highly energetic particles (Van Dam). However, resonant interaction at the magnetic curvature drift frequency of these particles severely reduces the stable regime. The use of a "sloshing" distribution, where the hot particle turning points are situated on the small-major-radius side with favorable average drifts, is a possible way to avoid resonant destabilization. Computational work is now under way to obtain the nonresonant ballooning critical beta values with energetic particles for realistic self-consistent anisotropic equilibria that have finite aspect ratio (Naitou). The numerical results so far indicate that the maximum stable beta can increase by a factor of two. This problem will be pursued with optimized pressure profiles in circular or D-shaped cross sections. Experimental observations of the "fishbone" instability seem to be explained by $m = 1$ ideal internal kink modes resonantly excited by neutral beam-injected energetic ions (Chen). Theory for internal resistive kink and ballooning modes with hot particles indicates that fishbones should be absent for JET parameters. Also, resistive interchange may be a candidate for the high-n fishbone precursor oscillation. Currently, non-resonant hot particle effects on the internal kink are being studied, with the idea that they will reduce the ideal growth rate to that of a slow tearing mode, so that feedback stabilization can be effective.

In general, the theory of tokamak stability with energetic particles seems to be sufficiently advanced that it is now desirable to consider various options for possible experiments—e.g., experiments on second stability or on suppression of MHD modes with ECRH/ICRH, beams, sloshing particles, alphas, etc. Determining the experimental option of interest should generate further theoretical issues for study.

(2) Compact Torus

A new method for determining the $n = 1$ tilt stability of arbitrary-aspect-ratio axis-encircling ion or electron rings shows that the rings are tilt stable if they are axially elongated with axial length greater than the diameter (Lovelace). A method was described for determining the fast particle current needed to stabilize the tilt instability of a spheromak plasma in the absence of conducting walls. An example of a tilt-stable spheromak with a fast particle toroidal current equal to one-half of the plasma toroidal current was shown. An experimental demonstration of the fast particle stabilization of the tilting is needed: electron rings would appear to be useful for this purpose, although ion rings loaded with plasma could also provide a test.

The kink ($n \geq 2$) stability of long cylindrical ion layers was analyzed by a method based on two-fluid magnetohydrodynamics (Ishida). The motivation for the work came from detailed computer simulations of ion layer stability that showed some discrepancies with previous theoretical predictions. The theory shows excellent agreement with the simulation results.

Another analysis of the problem of stabilizing a spheromak-type plasma against tilting by the presence of an energetic axis-encircling particle ring was also presented (Nomura). The application of a large-orbit energetic particle beam was proposed (Momota) to stabilize the $l = 2$ modes observed in the Osaka FRC pinch experiment. Stability occurs when the Doppler-shifted frequency of the beam matches its cyclotron frequency.

(3) Bumpy Torus

Recent experimental observations on the NBT bumpy torus experiment were presented (Iguchi). A large amount of ICRH on top of the main ECRH heating increases the density and leads to $\oint dl/B$ density profiles. Higher density, but with a hollow profile, is also obtained with fundamental resonance heating only. The H_α diagnostic shows 60 kHz density fluctuations inside the ring, with $m = 2$ and $E \times B$ rotation, as well as 5 kHz fluctuations localized outside the ring with no poloidal rotation.

Various high-frequency instabilities can be theoretically found in a bumpy torus, where a hot electron population drifts in bad curvature regions with enough pressure to improve the stability of the curvature-driven low-frequency modes (El Nadi).

(4) Mirror

The macroscopic stability of RFC-XX-M, an axisymmetric mirror experiment heated by ICRH with double spindle cusp end cells, was discussed (Okamura). With strong central cell heating, there is abundant evidence of an $m = 1$ interchange instability with frequency approximately equal to 30 kHz. This instability is stabilized by additional gas puffing into the cusp.

A number of U. S. theoretical studies of low-frequency MHD stability of axisymmetric tandem mirrors were reviewed (B. Cohen). A paraxial formulation of low-frequency ballooning, rotation, and interchange stability with FLR, hot electron diamagnetic well stabilization effects, and wall stabilization effects has been developed. The multi-dimensional initial value code FLORA has been used to show that hot electron and FLR stabilization can provide a start-up path to achieve high-beta wall stabilization. Wall stabilization with diffuse profiles and field ripple admits a lower critical $\beta_{\perp}$ for stabilization. However, a parameter study of the compatibility of Alfvén-ion-cyclotron stability, high-beta wall-stabilized MHD, and adiabaticity indicates only a very small region of parameter space in which all constraints can be satisfied. Calculations of interchange stability by RF ponderomotive force and parametric coupling effects were also discussed.

Two-dimensional particle and hybrid simulations in Japan and the U. S. appear to differ on whether ion-cyclotron waves influence interchange stability. Particle simulation results were presented showing that ion-cyclotron waves can stabilize or destabilize interchange modes and that favorable or unfavorable ponderomotive potential profiles do not have any substantial influence on interchange stability (Sakai).

The coupling of the $E \times B$ drift (relative to the center cell) of the plug cell plasma in a tandem mirror, to the shear Alfvén wave in the center cell, can lead to instability (Tsang). Also a comprehensive analysis of the stability of the hot electron stabilized symmetric tandem mirror was presented. It was also pointed out that parallel compressibility of the hot electrons may be changed due to their finite bounce frequency; this effect may potentially defeat the wall stabilization of the hot electron precessional mode.

Experimental results were presented for strong potential-driven oscillations excited by a small disk electrode biased to a positive voltage (Hatakeyama). Feedback stabilization and drift-pumping schemes that bias the end cell plate in a tandem mirror may have to contend with this effect. Also, a high-beta ballooning mode was observed in a low-temperature axisymmetric mirror.

Radial shear in the $E \times B$ drift velocity can stabilize the universal drift and the drift cyclotron modes (Hojo). However, for a well-type electrostatic potential, a new $E \times B$ shear-driven mode can be excited, which is eventually stabilized by strong $E \times B$ drift velocity shear.

Advanced Plasma Modeling

Organizers: T. Kamimura and J. M. Dawson
Location: IPP Nagoya
Date: September 24–27, 1985

There were four U. S. participants and twenty-three Japanese participants. The workshop featured lively discussion from both sides on details of modeling techniques, their advantages and disadvantages, how they might be improved, and what types of physics problems could be treated. It was clear that Japanese–U. S. collaboration has played a large role in developing many powerful new techniques for handling large-time-step/large-space-scale problems.

Several conclusions were drawn from this workshop:

1. Many powerful new techniques for handling large time steps and large space scales have been developed with kinetic effects still retained. These methods appear to be quite successful at handling many problems. Their full capabilities and limitations are not yet known and should be explored both computationally, theoretically, and by comparison with experiments.

2. The preceding techniques should be applied to many plasma physics problems important to fusion research. It would be desirable if such applications involved closer participation by plasma theorists, since the models are turning up results different from existing theory. They can provide a guide to the theorist for obtaining a more accurate description of plasma; in this role the effectiveness of both is increased.

3. The new techniques appear to be capable of treating three-dimensional problems. Efforts should be made to construct modules of realistic geometries. There is a definite possibility that realistic models of plasma transport will result.

4. Fluid models more sophisticated than simple MHD offer another method of attacking many fusion problems. Important advances have been made here which also promise to provide better fluid models of fusion plasma. These models should be applied to important fusion problems and their results should be compared with those of simple MHD models, with the kinetic models already mentioned, and with experimental results. Here, also, collaboration with theorists would be valuable and should be encouraged.

5. The combination of powerful new computational techniques and increasingly powerful computers promise to provide tools with which fusion physicists can solve many of the problems that have plagued fusion theory from the start; large advances can be made in the next few years. Therefore, strong support of these efforts will pay off in real results.

6. The U. S.–Japan computer link has just started. It is expected to play an important role in the future of simulation development.

Reports from 1985–1986 Exchange Scientists

Janardhan Manickam
Visiting Scientist to JAERI
May 30–September 16, 1985

During his visit to JAERI, Dr. Manickam primarily collaborated with Drs. T. Tsunematsu, S. Tokuda, and T. Takeda. He converted a version of the ideal-MHD PEST code to the FACOM computer system and conducted some corroboration test runs. A joint project of research to study the instability mechanism of the external kink mode was begun. He comments: "In particular we were both interested in understanding the role of the current profile in determining the external kink stability properties. At low β we expect that the kink mode has the classic structure dominated by a single high-m poloidal Fourier component; however, with appropriate choice of profile it is possible to couple the external high-m component to a low-m internal component. The variation between these two limits is quite interesting from an operational viewpoint and needs to be understood. The ERRATO code as implemented at JAERI is particularly well suited to this task. It has extensive diagnostic capabilities whereby we can identify and isolate the role of different terms in δW. To facilitate this, we wrote a computer code to interface between a PEST equilibrium and the JAERI-ERRATO stability code. With this interface we were able to check the basic principles outlined above, setting the stage for a more detailed study in the weeks ahead. In addition, we note that we verified the equilibrium and stability using PEST, generated a constant current equilibrium to test the interface, and studied a JT-60 simulation to test the dependence of the growth rate of the external kink mode as the q-edge was varied through integer values. Future activities are expected to include a detailed analysis of the external kink mode to understand the underlying physics." Dr. Manickam gave a series of seminars at JAERI, participated in a two-day MHD Experts Workshop there, and also briefly visited IPP Nagoya and Kyoto University. Based on his experience, he strongly recommends that efforts be made to establish a computer link between JAERI and the U. S. MFE network.

Reports on 1985–1986 Joint Computational Projects

Toshiki Tajima

"Long-Time-Scale/Large-Space-Scale Implicit Methods for Particle Simulations"
IPP Nagoya
July 11–August 16, 1985

The main purpose of this trip was to work on the development of the implicit electromagnetic particle codes with Professor T. Kamimura and Mr. Y. Ohara and, in conjunction with this, to establish the computer link between Nagoya's computers (FACOM M-200 and FACOM VP-100) and the MFE Computer Center's CRAY machines. The implicit particle code development has been under way as a JIFT project for some time already. During Prof. Tajima's visit, the development of the one- and two-dimensional versions of the implicit EM codes was finished. The one-dimensional version of the code was thoroughly tested.

The latest version of the code is based on the algorithm that the electromagnetic Maxwell equations are solved implicitly (with iteration). By solving this way, high-frequency modes such as the plasma oscillations, light waves, cyclotron waves, etc., can be damped, so that it is possible to focus on low-frequency phenomena. Particles respond to these implicitly treated fields with characteristic frequency band only in low-frequency ranges. To handle (electron or ion) cyclotron motion, the decentered leapfrog equation of motion is employed so that $\Omega\Delta t \gg 1$ is possible, where Ω is the cyclotron frequency and Δt the time step. In this code it is possible to choose any number of particle-loop interactions to predict the necessary particle data in the future. In the conventional particle codes, the time step is restricted by the highest frequency mode such as plasma oscillations, light waves, and cyclotron waves, while the spatial grid is tied to the Debye length and collisionless skin depth. This code is not restricted to these constraints. It was demonstrated that this code can be operated both in the high-frequency domains and in the low-frequency domains, depending upon the choice of the time step Δt. This code reduces naturally to the conventional explicit particle code. By choosing $\Delta t \gg \omega_p^{-1}$, on the other hand, it damps high-frequency modes, with only low-frequency modes surviving. Depending upon the size of Δt, it is possible to look at intermediate modes such as lower hybrid waves, ion-cyclotron waves ($\omega \sim \Omega_i$), whistler waves, compressional Alfvén waves. By further increasing Δt, shear Alfvén waves, acoustic waves, etc., may be studied. As the time step is increased, it becomes possible to increase the spatial scale Δ/λ_D and $\Delta\omega_p/c$, where Δ is the grid length and λ_D and c/ω_p are the Debye length and collisionless skin depth. Thus, an algorithm and codes which universally describe plasmas have been achieved. As the time step Δt which determines the frequency response is varied, it is possible to focus on phenomena of any frequency (and wavelength) at will. The code is being applied to a few problems, including the gravitational instability, the tearing instability, and the shear flow instability. With the success of the present code, the prospect of building a three-dimensional implicit EM particle code was considered.

Other News ...

The Joint Steering Committee recently completed plans for the 1986–1987 JIFT program. The preliminary details are outlined below.

A. 1986–1987 Workshops

1. Anomalous Transport (in U. S.)
2. Advanced Plasma Modeling (in Japan)
3. MHD Stability of Strongly Shaped Cross Section Tokamaks (in U. S.)
4. MHD Relaxation Processes (in Japan)

B. 1986–1987 Exchange Visits

1. Radio Frequency Heating
   B. D. Fried (UCLA) → IPP Nagoya
2. Stellerator Expansion MHD Analysis of Equilibrium and Stability
   G. Rewoldt (PPPL) → Kyoto and IPP Nagoya
3. Bumpy Torus, Trapped Particle Modes, and Hot Electron Physics Stability
   H. L. Berk (IFS) → IPP Nagoya
4. Visiting Professor
   R. Waltz (GAT) → IPP Nagoya
5. Theory of Chaotic and Turbulent Phenomena in Plasmas
   T. Hatori (IPP Nagoya) → Dartmouth and IFS
6. Stabilization of FRC Plasma by Energetic Particle Beams
   Y. Nomura (IPP Nagoya) → IFS

C. 1986–1987 Joint Computational Projects

1. Long-Time-Scale and Large-Space-Scale Implicit Methods for Particle Simulation Codes
   T. Kamimura, J.-N. Leboeuf, and T. Tajima
2. RF Heating and Current Drive
   J. Dawson, V. Decyk, and H. Abe
3. 3-D MHD Studies by BETA Code
   M. Wakatani and F. Bauer