JOINT INSTITUTE FOR FUSION THEORY

NEWSLETTER

DECEMBER 1984 No. 6

Joint Institute For Fusion Theory

The Institute for Fusion Studies (IFS) in 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 and workshops 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:

Mr. I. Kawano - Director of Physical Research
Japan Ministry of Education

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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

Exchange Scientists for 1984 to 1985

Prof. Jiro Todoroki, IPP Nagoya, Visiting Scientist to IFS
November 1, 1984 – February 28, 1985
"Transport and Stability in 3D Systems"

Dr. Hiroshi Naito, IPP Nagoya, Visiting Scientist to UCLA and IFS
September 1 – December 16, 1984 (UCLA)
December 17, 1984 – March 15, 1985 (IFS)
"MHD Equilibrium and Stability"

Dr. Russell Kulsrud, PPPL, Visiting Professor to IPP Nagoya

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Dr. J. Manickam, PPPL, Visiting Scientist to JAERI
"Ideal and Resistive MHD Instabilities"

Dr. William Grossman, NYU, Visiting Scientist to Nagoya
"Field Reversed Pinch Dynamics"

Dr. H. Hojo, Hiroshima, Visiting Scientist to LLNL, MIT, Wisconsin, and IFS
"RF Control and Plasma Stability"

Workshops for 1984-1985

Japan to US:

(1) Magnetic Field Reconnection in Fusion Systems

Organizers: P. Diamond and T. Sato
Location: University of Texas at Austin
Date: December 10-13, 1984

(2) Stochasticity and Turbulence in Plasmas

Organizers: Wendell Horton, Linda Reichl, Yoshi Ichikawa, and John Krommes
Location: University of California, Santa Barbara
Date: March 26-29, 1985

US to Japan:

(1) Anomalous Transport Processes in Confined Plasmas

Organizers: M. Wakatani and R. Waltz
Location: Kyoto University
Date: February 2-8, 1985

(2) Advanced Plasma Modeling

Organizers: T. Kamimura and J. Dawson
Location: Nagoya University
Date: June 1985

Reports from 1984 Workshops

Transport in Open-Ended Systems

Organizers: R. Cohen and T. Kamimura
Location: Nagoya University
Date: July 30-August 3, 1984

The US fusion program includes ongoing analytic and computational efforts in the theory of transport in tandem mirrors as well as in other nonaxisymmetric devices (such as stellarator and bumpy torus). At the time this workshop was being organized, it was apparent that similar problems were being addressed by the groups working on these various machines. Transport phenomena associated with nonaxisymmetry were being observed on several experiments (TMX, TMX Upgrade, EBT). In addition, some results from TMX-U and Phaedrus suggested a deleterious effect of RF on confinement.

In Japan, the theoretical effort in transport is at present much smaller. There have been studies of particle orbits, some analytic modeling of RF effects, and Monte Carlo studies of transport coefficients. There has been no work on a transport code for tandem mirrors, but a code by D. Hastings has been implemented at Nagoya to study

transport in the Nagoya Bumpy Torus (NBT). Experimentally, many interesting results have recently become available on asymmetries induced by ICRH and ECRH (in RFC-XX and GAMMA-10), on potential profiles in NBT, and on the effect of potential control plates in GAMMA-10.

This workshop was motivated by the availability of increasing amounts of data on transport in both countries, by the growing interest in understanding this data among Japanese theorists, by the appearance of closely related phenomena in the transport theory of different nonaxisymmetric devices, and by an increased recognition of the possibilities for and benefits of increased communication and collaboration between Japanese and Americans working on these problems. Because of the third point, it was decided to broaden the scope of the workshop to include stellarators and bumpy tori as well as tandem mirrors. As the oral talks during the workshop pointed out, electrostatic potential and RF effects are common and crucial to all of these devices. Increased collaboration seems especially likely now as computer links between our two national programs are being established. (In fact, essentially all of the international arrangements for this workshop were made via the US MFE Computer Center link to Nagoya.) It was decided to have a "working workshop" since a number of unanswered questions had arisen concerning the role of azimuthal electric fields, the determination of the radial electric field, and the mechanisms by which RF affects transport. Two topics — azimuthal electric fields and RF effects — were agreed upon in advance (April 1984), and participants were asked to explore these topics before the workshop. The workshop itself consisted of a limited period of oral talks, followed by an extended period of small group discussions in order to address some of these questions.

The workshop had five US participants and eighteen Japanese participants. Also, several experimentalists participated part time, including two American scientists from the General Atomic team at RFC-XX.

Twenty-one oral talks were presented. The theoretical talks divided into three general areas: transport due to nonaxisymmetric confinement fields with particular emphasis on the role of the electrostatic potential (8 papers); effects of RF on symmetry and transport (6 papers); and four papers not directly related to radial transport but which may lead to future transport work. In addition, three experimental papers were presented in order to familiarize workshop participants with relevant results from GAMMA-10, RFC-XX, and NBT. The experimental reviews were found to be extremely useful.

Since the oral talks indicated a division of interest into transport associated with asymmetric confining fields and with RF effects, it was decided to form two working groups. Each group listed outstanding questions and then settled on two issues for detailed discussion.

This workshop has had and will have a beneficial effect on the development of transport theory in both countries. By focusing on specific topics for several months in advance, a number of new ideas on potential and RF effects had emerged by the time the workshop began. There was a substantial and perhaps unprecedented degree of interaction among the participants from each country during the pre-workshop period. The working sessions during the workshop clarified outstanding issues on how the radial potential profile should be determined in nonaxisymmetric devices and furthered the understanding of how RF affects transport. The latter subject is still in its infancy; the workshop should hasten its maturation. The workshop will assist future modeling of transport processes in both the US and Japan and should provide needed background for building transport codes for stellarators and tandem mirrors in Japan.

At the conclusion of this workshop, it was recommended that: (a) Another workshop on transport in nonaxisymmetric systems be scheduled in two years; (b) Individual contacts between US and Japanese researchers be maintained and developed; and

(c) Researchers from both countries make every effort to cross-check transport theory with detailed experimental results.

Reports from 1984 Exchange Scientists

Atlee Jackson
IPP Nagoya
August 1984 - January 1985

For the past three months Prof. Atlee Jackson, from the University of Illinois, has been working as the JIFT visiting professor at IPP Nagoya on problems of nonlinear dynamics in collaboration with Prof. Tetsuo Kamimura and Prof. Yoshi Ichikawa. They have been interested in attempting to introduce collective effects into area-preserving plasma dynamics. The role of nonlinear Landau damping and its possible relationship with the structure of strange attractors in plasmas is also being investigated.

Prof. Jackson will give a series of lectures on a variety of viewpoints that can be used to analyse nonlinear dynamics, with the aim of increasing communication between the research scientists working on practical problems involving plasma dynamics and those doing university-type studies with simplified nonlinear models.

Prof. Jackson reports that his visit is proving to be most rewarding both professionally and personally. During August, he participated in the Seventh Kyoto Summer Institute on the topic of Dynamical Problems in Soliton Systems. In addition, he has visited the Research Institute of Kyushu University to give a lecture on his recent topological results in the pre-turbulent state of the Lorentz equations and to learn first hand about their research on the interactions of "solitons" in two dimensions. He also planned to attend a three-day mathematically oriented conference on the Development of Soliton Theory, held at the end of November at Kyoto University.

Akio Ishida
Cornell University
September - November 1983
and
IFS, University of Texas at Austin
December 1983 - February 1984

Prof. Ishida, from Niigata University, worked with Prof. Ravi Sudan and Prof. Marshall Rosenbluth on the kink stability of a fat field-reversed cylindrical ion layer immersed in a background plasma. The model for this calculation is based on a fluid description of the ring-plasma system developed by himself. The present theory reveals the relationship between the theories derived from the particle and kinetic descriptions in the thin ion layer limit and also shows that the field-reversed fat ion layer has a kink stability window.

He also worked with Prof. Wendell Horton on low frequency modes in a rotating plasma of finite axial length along the magnetic field. It was recently found that the centrifugal force on ions due to E×B rotation, temperature anisotropy, and finite axial length drives a new type of flute mode unstable. The frequency of this $\ell=1$ flute mode is equal to the frequency of the E×B rotation, and its real frequency and growth rate are insensitive to the position of the conducting wall. These properties are in contrast to those of the conventional $\ell=1$ flute mode.

Prof. Ishida reports that he had an exciting and fruitful time at Cornell University and at the University of Texas at Austin. His family enjoyed daily life in Ithaca and Austin, and his two daughters especially enjoyed attending school. They had a good opportunity to understand directly the similarities and differences between American and Japanese daily life.

Tsuguhiro Watanabe
IFS, University of Texas at Austin
November 1983 – February 1984

Prof. Watanabe, from the Institute for Fusion Theory at Hiroshima University, worked mostly in collaboration with Prof. Herb Berk on two problems. One was the general problem of developing analytic continuation techniques for obtaining the complex spectra and eigensolutions for Alfvén modes. The other was the specific problem of the stability of hot electron rings in an axisymmetric mirror, with account taken of the interaction of Alfvén and precessional modes below drift reversal.

During his stay, he was able to attend the APS Plasma Physics Meeting in Los Angeles, as well as the US-Japan Workshop on Heating and Stability of Energetic Electron Plasmas in Mirrors and Bumpy Tori and the US-Japan Workshop on RF Heating. He also briefly visited the plasma theory groups at UCLA and LLNL.

Viktor Decyk
Kyoto University
April 15 – June 20, 1984
and
IPP, Nagoya University
June 20 – July 15, 1984

During his two-month stay at the Department of Electronics at Kyoto University, Dr. Decyk collaborated with Dr. Hirotada Abe and other members of Prof. R. Itatani's group on a particle simulation of lower hybrid current drive. In order to explain the mystery of why current drive experiments are successful even though the waves are launched with phase velocities which are too fast to interact appreciably with electrons, they tested the hypothesis that the high-k, low energy secondary peaks in the launched spectrum (which are due to the finite size of the waveguide aperture) are important in this process. Although current could easily be driven with the full spectrum, eventually they were able to show that when the high-k modes were filtered out of the spectrum the current drive practically ceased, despite the fact that only a few percent of the energy was in these modes. The conclusion then is that there is no mystery if the full spectrum is taken into account.

On April 27-28, he attended a symposium at Hiroshima Institute for Fusion Theory and was given a tour of the computer facilities.

In Nagoya, he collaborated with Prof. Tetsuo Kamimura and other members of the simulation group on the development of a bounded 3D particle simulation model. The only thing accomplished in the short time he was there was a 3D cylindrical Poisson solver. However, this collaboration will be continued at UCLA, since it is possible to send programs and messages to IPP Nagoya via the MFE computer network.

Dr. Decyk comments as follows: "Kyoto is a delightful place to visit. Kyoto University has an International House for foreign scholars, where my wife, our four-year old daughter, and I had a modern two-bedroom apartment. I was surprised that as far as the material aspects of life, Kyoto was not much different than a US city. In other words, most anything we were used to in the US could be found, and the cost of most things was comparable. In personal relations, however, it was quite different. The Japanese treat visitors like we treat guests. My four-year-old daughter was a big hit with teenagers and grandmothers alike, although she found that other four-year-olds were not willing to play with strangers, and she was lonely for kids her age. My wife and I both studied Japanese for six months before we went to Japan. This is not enough to say much, but it was enough to help us travel freely around on our own, go shopping, meet people in the park, etc., and therefore was worth the effort. Of course, knowing Japanese was not necessary around the university. Overall the visit was both scientifically and personally very rewarding."

Jean-Noel LeBoeuf
IPP, Nagoya University
May 31 - July 14, 1984

Dr. LeBoeuf, from IFS Austin, worked in collaboration with Prof. Kamimura and Mr. Ohara to build and test a multiplicity of electromagnetic implicit particle codes. These codes involve either a fully implicit treatment of electron and ion dynamics or an implicit treatment of electron dynamics only, while the ions are treated explicitly. The latter version has the advantage of retaining the finite Lamor radius effects for the ions. All versions share a correct treatment of the low frequency dynamics of the electrons. The high frequency waves such as light waves and plasma waves, as well as electron cyclotron motion, are suppressed by the implicit treatment of the equations of motion and Maxwell's equations. A gain of several orders of magnitude in the time step and running time is thus achieved.

This work was carried out in close collaboration with Dr. Dan Barnes (now at SAI-Austin) in Texas through the data link facility between IPP-Nagoya and MFECC at Livermore, California. Dr. LeBoeuf emphasized that the work could not have progressed as rapidly without the data link.

Dr. LeBoeuf offers the following comparisons between the CRAY-1 computer at MFECC and the new vector computer, FACOM VP-100, at Nagoya: "It appears that the VP-100 does a better job at vectorizing crucial parts of particle codes such as the particle pusher and the interpolation of microscopic particle quantities to the grid to define such macroscopic quantities as density and current. This is also true of the grid force assignment to the particles. One problem which was actually encountered by Dr. Viktor Decyk from UCLA, whose visit to IPP concurred with my own, is that the VP-100 needs a lot more memory than even the non-vector machine FACOM M-200 or the CRAY-1 to run the same code. This is due to the extra arrays internally created at compilation for efficient computation in the vector mode. The problem is being solved by the addition of more memory."

Jon Mondt
Kyoto University
February 13 - April 30, 1984

Dr. Mondt, from Los Alamos Scientific Laboratory, visited the Plasma Physics Laboratory at Kyoto University in order to become acquainted in detail with the experimental data obtained on the Heliotron-E Stellarator experiment under currentless operation. The acquisition of first-hand knowledge about the Kyoto experiment would benefit the Los Alamos program, which includes a small theoretical effort to investigate higher beta advanced stellarator concepts. During his stay, he attended two workshops, one on Heliotron-E organized at the Plasma Physics Laboratory at Kyoto University, the other on Statistical Physics organized at the Institute of Plasma Physics at Nagoya University.

At the invitation of Dr. M. Wakatani, he gave two talks during his stay at Kyoto University, namely, "Some Aspects of Edge Physics in the Reversed-Field Pinch ZT-40M," and "Vacuum Scaling and Plasma Effects on Heliac Configurations."

At the beginning of his stay, Heliotron-E was down for the purpose of improving the heating facilities, specifically, to increase the neutral beam power from 2.6 to 4 MW; to bring the number of 200 kW gyrotrons from two to five, and to improve the ohmic heating system from constant voltage to constant current. Furthermore, an ICRH experiment of increased power is planned for the fall of 1984 (3 MW instead of the present 550 kW). These improvements are even more impressive in view of the results of various experiments performed so far:

(a) High-Beta Experiment: Peak betas of 3.6% (average beta $\simeq$ 2%) were achieved under currentless operation by producing a target plasma by electron cyclotron heating, after which it is sustained by neutral beam injection. Fluctuations detected by soft X-ray, bolometer, and far-infra-red interferometry were observed to commence close to 2% average beta, consistent with theoretical predictions on the basis of the nonlinear evolution of the m=n=1 interchange instability (Wakatani). The fluctuations only appear in the discharge when the gas puffing is stopped after a density maximum has been reached, whilst their absence requires a high degree of purity. Because in the theory nearly concentric, circular flux-surfaces were assumed, it is not entirely certain whether the MHD threshold has been reached in the experiments performed so far. A more complete incorporation of geometry effects into the theory would perhaps substantially raise the predicted beta limit. On the other hand, neutral beam injection in Heliotron-E must be considered as a powerful external m=1 disturbance. It is believed to have led to 'Fishbone' activity in PDX, and it may well contribute to the m=1 signals that were observed. Conclusively, a more complete theory that takes into account the elliptic shape (ellipticity=2) of the flux-surfaces and the influence of trapped energetic particles on stability ultimately will be required for a correct interpretation of the present and future results on beta limitations.

(b) High-Temperature and Confinement Experiments: Impurity radiation losses constitute the most severe problem to confinement, causing the ratio of the net divided by gross confinement time to reach about three in the high-temperature experiment (two for the high-beta experiment). Apart from direct influx from the wall, possible impurity sources include the oxygen contained in the neutral beam system and shine-through due to perpendicular neutral beam injection; also, the perpendicular neutral beam injection may cause high-energy ion orbit losses and consequent radial electric fields that contain the impurities. The next most important loss mechanism is electron edge heat loss. Unlike the core transport the edge transport in Heliotron-E cannot be explained by neoclassical and ripple effects, and moreover, is of more immediate concern as it provides a direct loss channel. In this respect an elaborate theoretical analysis of plasma-wall interactions in Heliotron-E would be valuable. Dr. Mondt commented that such an analysis is not possible because a representation of the field configuration near the separatrix that is both accurate and amenable to be used as input for further analysis is lacking at the present time.

As a first step in starting either a stability analysis that takes into account the ellipticity of the flux-surfaces in Heliotron-E or an analysis of edge transport near the separatrix, Dr. Mondt collaborated with Dr. M. Nakasuga in establishing a representation of the vacuum magnetic field in terms of an integral over a function with only slowly varying ingredients by means of the Bogolyubov-Mitropolskii method. At the present time this result is being tested numerically.

Dr. Mondt personally recommends that visitors to Kyoto University arrange for their housing at least six months in advance or, if that is impossible, be especially aware of the tight hotel accommodations during spring in Kyoto.

Have you heard that...

The JIFT Joint Steering Committee held its annual discussion and planning meeting on November 12, 1984, at Nagoya University. A report on this meeting will be presented in the next JIFT Newsletter.