Newsletter

JOINT INSTITUTE FOR FUSION THEORY

October 1987 **No. 10**

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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. J.M. Dawson - University of California at Los Angeles
Prof. Y.H. Ichikawa - Director of ICFT, Nagoya University
Prof. K. Nishikawa - Hiroshima University
Prof. M.N. Rosenbluth - University of California, San Diego
Dr. W. Sadowski - Chief, Fusion Theory and Computer Service, U.S. Dept. of Energy

JIFT activities are coordinated in the US 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 US Management Committee consists of W. Horton—Chairman, A. Aydemir, J-N. Leboeuf (ORNL), T. Tajima, P. Terry and J. Van Dam.

EXCHANGE SCIENTISTS for 1987 to 1988

From US to Japan

1. *Stellarator Equilibrium and Stability* — **IL 21**
   John Johnson, PPPL, Visiting Professor to IPP Nagoya and Kyoto University
   August 15, 1987 - February 1988

2. *Transport in Asymmetric Toroidal Magnetic Fields* — **IL 23**
   John Cary, Univ. of Colorado, Visiting Scientist to Kyoto and IPP Nagoya
   April 5 - May 26, 1987

From Japan to US

3. *Theoretical and Numerical Study on Current Drive in Toroidal Systems* — **JL 16**
   M. Okamoto, IPP Nagoya, Visiting Professor to IFS and PPPL
   November 15, 1987 - March 15, 1988

4. *Edge Plasma Physics* — **JL 17**
   M. Tanaka, HIFT-Hiroshima, Visiting Scientist to GAT, PPPL, and IFS
   June 26, 1987 - September 23, 1987

5. *Advanced Particle Simulation with Gyrokinetic Equations* — **JL 18**
   H. Naitou, IPP Nagoya, Visiting Scientist to UCLA

WORKSHOPS for 1987 to 1988

To be held in Japan

1. *Stability and Current Drive in Toroidal Systems* - Kyoto — **I 20**
   K. Itoh and P. Rutherford
   November 16 - 19, 1987

2. *Large Gyroradius Equilibrium and Stability Theory* - Niigata — **I 21**
   H. Momota and H. Berk
   September 28 - October 2, 1987

3. *Steering Committee Meeting* - Nagoya — **I 22**

To be held in US

4. *Plasma and Fluid Turbulence* - Austin — **J 19**
   W. Horton, H. Swinney, and Y. Ichikawa
   December 7-11, 1987

5. *Plasma Modeling with MHD and Particle Simulations* - San Francisco — **J 18**
   C. Birdsall and T. Kamimura
   September 25-26, 1987

JOINT COMPUTATIONAL PROJECTS for 1987 to 1988

1. *Long Time Scale and Large Space Scale Implicit Methods for Particle Simulation Code* — L 16
   T. Kamimura and Y. Abe (IPP, Nagoya)
   J.N. Leboeuf (ORNL), T. Tajima, A. Aydemir (IFS),
   and D.C. Barnes (SAIC)
2. *3D MHD Studies by BETA Code* — L 17
   M. Wakatani (Kyoto) and F. Bauer (New York-Courant)
3. *3D Tokamak Simulation with Gyrokinetic Equations* — L 18
   T. Kamimura and H. Naitou (IPP Nagoya)
   J. Dawson, V. Decyk (UCLA), and W. Lee (PPPL)
4. *Plasma Vortices, Rotation, and Anomalous Transport* — L 19
   A. Aydemir, W. Horton, J. Meiss, T. Tajima, and N. Bekki (IFS)
   K. Nozaki and T. Taniuti (Nagoya)
5. *MHD Stability and Control of a High Beta Tokamak* — L 20
   T. Takeda, T. Tsunematsu, and S. Tokuda (JAERI)
   J. Manickam (PPPL)

EXCHANGE SCIENTISTS
Reports from 1986 to 1987

Ronald E. Waltz
Visiting Professor to
IPP Nagoya
July 21 - November 21, 1986

Dr. Waltz, from GA Technologies, Inc., visited IPP Nagoya for four months. There he continued his research work on the numerical simulation of turbulence in tokamaks. In particular, he developed a global three-dimensional code for studying toroidal ion temperature gradient mode turbulence and for investigating convective or non-local effects in electron drift mode turbulence. The Nagoya-MFE computer link proved to be very useful. The motivation for the work was to address some key problems with conventional drift wave confinement models: viz., the apparent lack of strong dependence on safety factor for the bulk modes, such as the ion temperature gradient mode, and the apparent lack of a strong edge transport mechanism.

In addition to some informal seminars, he gave a series of lectures entitled *Turbulent Transport in Tokamaks*, which covered theory, simulations, and phenomenology. These will soon be published as an IPP report. The introductory lecture, *Drift Wave Models for Tokamak Confinement*, discussed the successes and failures of drift wave models and was also presented during visits to Kyoto and Hiroshima Universities.

John Cary
Visiting Scientist to
IPP Nagoya
April 5 - May 26, 1987

Prof. Cary, from the University of Colorado, spent approximately seven weeks in Japan at IPP Nagoya and Kyoto University. During this time he collaborated with T. Kamimura and M. Wakatani on a Monte Carlo transport code capable of handling transitions of trapping/detrapping orbits. Without assuming small ripple, they derived the averaged equations of motion and the transition probabilities for a generalized model field. These results are being implemented numerically, using random jumps to model collisions.

Prof. Cary plans to visit Japan next year to follow up on this visit.

Tadatsugu Hatori
Visiting Scientist to
Dartmouth College and IFS
September 10, 1986 - January 6, 1987

Dr. Hatori, from IPP Nagoya, spent his first three months at Dartmouth College where he collaborated with Prof. D. Montgomery in a study of the kinetic theory and transport coefficients for two-dimensional MHD cellular automata. Results of this work were presented at the workshop on *Modern Approaches to Large Nonlinear Physical Systems* at Santa Fe, New Mexico, in October 1986. Subsequent to his stay in Dartmouth, Dr. Hatori spent a month at IFS where he worked with W. Horton and T. Tajima on stationary vortices and transport in non-axisymmetric toroidal plasmas. On his way back to Japan he visited UC-Berkeley.

Gregory Rewoldt
Visiting Scientist to
Kyoto University and IPP Nagoya
September 7, 1986 - January 11, 1987

Dr. Rewoldt, from Princeton Plasma Physics Laboratory, spent four months in Japan, three at Kyoto University and the remainder at IPP Nagoya. At Kyoto, he collaborated with M. Wakatani, performing stellarator expansion MHD equilibrium and stability calculations applicable to Heliotron-E. He surveyed a number of pressure profiles of varying widths, analyzing for low-n and high-n ideal MHD stability. It was found that critical $<\beta>$ values for marginal stability were nonmonotonic in the parameters that measure pressure profile width and pressure profile peaking. This was attributed to the folding together of the variation of low-order rational surface location with respect to local plasma current and the variation of the maximum pressure gradient location with respect to pressure profile width. In general, the critical $<\beta>$ for marginal stability was around 2% for toroidal mode numbers $n = 1, 2, 3$, and 4, consistent with experiment. It was determined that the critical $<\beta>$ was not strongly affected when the free boundary stability calculations were made into fixed boundary calculations by moving the conducting shell in from infinity to the plasma surface. At IPP Nagoya, Dr. Rewoldt worked with J. Todoroki, making comparisons of results from respective stellarator expansion MHD equilibrium and stability codes, again for Heliotron-E cases. When differences in the definitions of β and ι were accounted for, they found that the two free-boundary equilibrium codes gave reasonable agreement (1-3%) on the results.

Note: JIFT Exchange Visitors

We would like to remind those participating in JIFT exchanges regarding arrangements for leaving their countries. Some of the administrative problems encountered over the years can be traced to having too many exchanges in the February-March time frame. We suggest therefore, that you schedule your exchange visit as early in the fusion year as possible (the fusion year starts in April).

You should determine the validity and limits of the health, disability, and life insurances issued through your employer. Your medical doctor can advise you on the need for any immunizations and the type of records recommended. You are reminded to take an adequate supply of any prescribed medications, an extra pair of eyeglasses, immunization records for each member of the family, and other health-related items. Excellent doctors are available in either the US or Japan, and they can better attend to your needs if you are prepared to give them your medical history. Additional information and suggestions may be found in a booklet published by the World Health Organization, entitled *Be a Healthy Traveler*. Another helpful booklet, entitled *Informal Handbook for Long-Term Exchangees in US-Japan Cooperation Program in Fusion Research* is printed in the US by the National Technical Information Service. Exchange visitors may request copies from the Institute for Fusion Studies.

WORKSHOPS
Reports from 1987

MHD Stability of Strongly Shaped Tokamaks and Paths to High Beta

Organizers: D. Sigmar and T. Amano
Location: GA Technologies, San Diego
Date: January 19-23, 1987

Ten talks were presented by Japanese scientists and twenty-two by US scientists at this workshop. A large Japanese delegation attended the workshop consisting of S. Tokuda (JAERI), N. Suzuki (JAERI), K. Yamazaki (IPP), H. Naitou (IPP), Y. Hamada (IPP), T. Amano (IPP), Y. Mizuno (IPP), T. Sato (Hiroshima University), Y. Nakayama (Hiroshima University), A. Mohri (IPP), and M. Nagami (JAERI). The US participants included scientists from Applied Microwave Plasma Concepts, Columbia University, USDOE, Grumman Corporation, Livermore, MIT, Oak Ridge, Princeton, SAIC, University of Illinois, The University of Texas at Austin, and GA Technologies. The purpose of this conference was for theorists and experimentalists working on achievement of high beta in tokamaks through shaping, aspect ratio, and other advanced methods to report on what is known from experiments, transport studies, modeling studies, and theory. In addition to the scheduled talks and accompanying discussion sessions, an effort was made to assemble some guidelines for CIT-like ignition devices. These guidelines and the conclusions reached in discussion sessions were incorporated into the final report.

The workshop addressed four main areas:

1. *Experimental and Theoretical Studies of High Beta in Conventional Tokamaks*—This included reports on beta studies in ISX-B, TFTR, numerical MHD modeling for high beta on the basis of low shear equilibria with q on axis greater than one, and analytical and numerical investigation of ballooning and interchange stability of plasmas with equilibrium flows.

2. *Theory of MHD Instabilities*—Talks in this area presented results from theoretical studies of kink and ballooning modes in shaped plasmas and studies of resistive and ideal instabilities.

3. *Paths to High Beta Through Shaping and Aspect Ratio*—This area featured the largest number of talks, including reports of experimental studies on JFT-2M, DIII-D, and PBX; computational MHD stability studies for CIT and TCV; and MHD stability studies for shaped plasmas. The plasma shaping considerations featured crescent and bean shapes, elongated and elliptical cross-sections, and the ellipsoidal shell tokamak.

4. *Advanced Methods Towards High Beta*—This included talks on neutral beam injection current drive, RF stabilization, and energetic particle stabilization in shaped and finite aspect ratio tokamaks.

A report was prepared by the meeting's organizers which summarized discussions concerning theoretical understanding of observed MHD behavior, methods of achieving high beta, and guidelines for CIT-like ignition devices. Highlights of the discussions are given below.

The following topics were discussed:

I. Theoretical Understanding of Observed MHD Behavior

A. *Fast Ideal Crash vs. Slow Resistive Crash Sawtooth Oscillations*—The observation of both slow and fast crashes in ISX-B, JET, JT-60, and TFTR tokamak discharges was reviewed. It was stated that the ideal driving mechanism for $n = 1, m = 1$ modes for κ (elongation) > 1 and q flat and near one in the core region could give fast crashes even if resistive dynamics plays a role.

B. *Troyon* β *Limit*—β_p driven ballooning modes vs. pressure driven external kink modes—It was agreed that the Troyon formula successfully describes the tokamak operating limits provided $\kappa \leq 1.8$, δ (triangularity) ≤ 0.6, and A (aspect-ratio) ~ 3. Dependence of the Troyon coefficient on q and lack of dependence on indentation was noted. It was stated that passive wall stabilization was viable as long as the mode rotates. For ballooning modes it was observed that β_{crit} is extended (by increasing the Troyon coefficient) when indenta-

tion and triangularity are increased. Increased elongation helps only if triangularity is increased. Consideration of external kinks leads to a similar result. At high values of the elongation, without increasing the triangularity, the Troyon coefficient is lowered. Assuming external kinks, Freidberg's sharp boundary model investigation of the shape dependence of β_{crit} provides guidance for the maximum current.

C. *Disruptions Driven by q vs. β Driven Disruptions*—Observations from DIII-D, PBX, and ISX-B were reviewed. A purely growing 2/1 mode that causes a drop in β on DIII-D was alleged to be a tearing mode for $q(a) > 2$ and an external kink for $q(a) < 2$. It was stated that in PBX, the behavior of major disruptions following an internal sawtooth is affected by the size of beta. Precursor-free disruptions in ISX-B were discussed, and it was noted that such disruptions have yet to be modeled successfully by theory.

D. *Profile Effects*—Including fast ion contributions in the pressure profile makes the interior plasma region unstable to low-n pressure driven modes and is suspected of causing fast ion losses (PBX). The need to perform theoretical studies which simultaneously optimize both the pressure profile and the current profile for stability in order to provide guidance to current drive experiments at finite beta was noted.

II. Paths to High Beta

A. *Profile Shaping*—The need for pressure and current profile shaping was underscored by a discussion of second stability access via low shear, high pressure gradient conditions, and infernal mode instability occurring under the same conditions. It was observed that a difficulty in MHD-code stability analysis is the large number of profile parameters which must be varied without a simple unifying guiding principle towards optimal configuration.

B. Safety Factor Value on Axis Relative to Unity—The use of lower hybrid current drive to suppress or eliminate sawteeth by offsetting the ohmic tendency for current peaking was reviewed with examples from JT-60, Alcator-C, and PLT. It was cautioned that raising q on axis for a fixed plasma current implies a possible destabilizing decrease in shear. Since high beta is also required for destabilization of these pressure driven modes, this issue is not critical at present but could become so later.

C. *Low and High Aspect Ratios*—Both resistive mode stability and higher β_{crit} are favored by low aspect ratio configurations. For high aspect ratio configurations, second stability must be reached. This, in turn, requires ponderomotive stabilization, energetic particle beams, raising q on axis in order to lower shear, or a combination of these methods.

III. CIT Related Discussions

The following suggestions were formulated on the basis of experimental evidence:

1. $q_\psi(a) > 3.5$, at $\kappa \geq 2$ to avoid disruptions.

2. $\beta_{crit} \leq$ { 2.5 I/aB for $q_\psi(a) > 3.5$; 2 I/aB for $q_\psi(a) < 3.5$; $a = 0.96\, a_{sep}$

3. Optimized profiles and/or close fitting walls produce a significant gain in β_{crit} (2 × Troyon).

4. Optimum elongation is around $\kappa \sim 2$ at $\delta = 0.5$. Higher triangularity is needed for $\kappa > 2$.

5. The alpha particle precession resonance appears to have a substantial destabilizing effect on the kinetic ballooning mode boundaries.

Anomalous Transport in Toroidal Fusion Devices

Organizers: R. Waltz and M. Wakatani
Location: GAT, San Diego
Date: February 23-27, 1987

Approximately twenty-five scientific participants attended this workshop. The Japanese delegation consisted of S.I. Itoh (HIFT), M. Wakatani (Kyoto), T. Tuda (JAERI), H. Shirai (JAERI) and K. Itoh (Kyoto). US Scientists from GA, Princeton, Maryland, Texas, Bell Labs, and Oak Ridge

participated. The goal of the workshop, the fourth in a series, was to identify and describe the most important mechanisms underlying turbulent transport in high temperature toroidal confinement devices by comparing recent results from experiment, theory, and simulation.

Experimental results were presented which detailed H-mode observations in DIII-D and JFT-2M, magnetic fluctuation measurements and confinement in TFTR and DIII-D, the effect of limiter bias on particle transport in PBX and DIII-D, and the correlation in TEXT of fluctuations propagating in the ion direction with confinement saturation at high densities.

Theoretical work described in the meeting included transport studies based on drift wave models incorporating the dissipative trapped electron instability for low density ohmic discharges and the ion temperature gradient mode for higher densities and beam heated discharges. Anomalous transport in low collisionality regimes was addressed in a theory incorporating rf- or beam-driven fast trapped particles in the stability of resistive MHD modes and also in a study of voltage density scaling near the slide away regime. A related work stressed the importance of tail losses in rf heating. Destabilization of moderate-m tearing modes by bootstrap current effects was addressed in another paper. Two turbulence theories utilizing a collisionless skin depth and producing Ohkawa-like scaling were given, one based on η_e modes and the other on test particle transport computations. Stellarator transport in Heliotron-E determined by modeling turbulent edge losses and including neoclassical ripple loss was discussed in two papers. The calculation of upper bounds on anomalous transport and the idea that tokamak confinement may be described in terms of classical collisions and MHD stability were also advanced.

Simulation results presented at the workshop included those obtained from 3D electrostatic fluid and particle simulations of η_i turbulence, 3D fluid simulations of resistive curvature driven drift wave turbulence and electromagnetic turbulence in 2D representations near the critical beta.

The summary of the workshop, prepared by the meeting's organizers, noted that there has been some success with the drift wave models in describing L-mode confinement. It was conceded, however, that these models fail to produce the favorable scaling of confinement with respect to current which is observed experimentally. Further difficulties in describing the large edge transport with drift wave models were also acknowledged. It was noted that no satisfactory theoretical explanation yet exists for the H-mode results presented at the meeting. With regard to the skin depth theories, the report observed that while these theories possess only a weakly unfavorable temperature scaling ($t \sim T^{-1/2}$), in contrast to the strongly unfavorable scaling of the dissipative trapped electron mode ($\tau \sim T^{-7/2}$), they still require an additional mechanism to explain the scaling of beam heated discharges at high densities and powers. The report pointed to progress made in simulations over the five-year period beginning with the first workshop, contrasting the rather small grid electrostatic 2D mode coupling simulations initially carried out, with the multifield and electromagnetic simulations discussed in the workshop.

OTHER NEWS ...

JIFT Program Planning Activities:

Members of the JIFT steering committee and management committees had a chance to meet on November 22, 1986, following a celebration of the twenty-five year anniversary of the Institute for Plasma Physics in Nagoya, in order to discuss the current status of JIFT activities and to exchange views on future plans for the collaboration program.

Two five-year workshop progress reports, one on 3-D MHD Simulations and one on Statistical Plasma Physics, were completed and presented to the steering committee.

As for the 1987-1988 JIFT program, all of the proposed visits, workshops, and computational projects were decided upon at the meeting of the JIFT Steering Committee on February 4 in Austin and approved by the US-Japan Coordinating Committee on Fusion Energy which met on May

14-15, 1987, in Maryland. The level of JIFT exchange activity was reviewed, and it was concluded that the current number of workshops is still adequate. It was noted, however, that the number of workshop participants from the host country has increased substantially. In view of this increase, the JIFT steering committee recommended an increase in the number of scientists authorized to travel to the host country, from 5-6 persons to 7-8 persons. This proposal was accepted by the Coordinating Committee.

Based on the achievements and cumulative experience of the JIFT collaboration program, members of the JIFT steering committee recommended that scientists from countries with developing fusion programs (i.e., China, South Korea, and India) be invited as observers to future JIFT workshops.

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