COHERENT FLUCTUATIONS IN THE INITIAL TFTR D-T EXPERIMENTS

by

E. FREDRICKSON, Z.Y. CHANG, R.V. BUDNY, ET AL.

Published in the Proceedings of the 21st European Physical Society's Division of Plasma Physics Meeting (June 27-July 1, 1994, Montpellier, France), published by EPS 1994.

Work supported by U.S. Department of Energy Contract DE-AC02-76-CH0-3073.

Princeton University
Plasma Physics Laboratory

DISCLAIMER

DISCLAIMER

Coherent fluctuations in the initial TFTR D-T experiments*

E Fredrickson, Z Y Chang[a], R V Budny, C Z Chang, J L Dunlap[b], G Y Fu, A Janos, E Mazzucato, K M McGuire, R Nazikian, K L Wong, S Zweben

Princeton University, Plasma Physics Laboratory, Princeton, NJ 08543, USA

The initial operation of TFTR with approximately equal power in the Tritium and Deuterium neutral beam injectors has resulted in the production of fusion power in excess of 9MW and central $\beta_\alpha > 0.25\%$. This β_α is within a factor of 2-3 of the β_α in projections of ITER performance. Effects of this α population on TAE modes, sawteeth and fishbone activity are being searched for. The D-T plasmas are also being studied for evidence of changes in MHD activity which might be attributed to the fast α population. This paper reports on the activity in the Alfvén range of frequencies in the D-T plasmas and on detailed measurements of the MHD activity preceding major disruptions in D-D and D-T.

Activity in the Alfvén Range of Frequencies

A relatively broad ($\delta f/f \approx 15\%$) peak in the Mirnov spectrum in the Alfvén range of frequencies is commonly observed in NBI heated plasmas. This feature also often appears following pellet injection into Ohmic plasmas. The integrated power in the mode is small, comparable to the weakest ICRF driven TAE modes. The frequency follows the previously derived scaling for ICRF driven TAE modes and NBI driven TAE modes at low (1T) toroidal field. There is no theoretical model as yet describing this instability, but the mode may either be driven by the beam ions at $V_A/V_{beam} \geq 3$ or they may represent some thermal level of excitation. The present analysis of the Mirnov data from a toroidal array of coils shows that these modes are axi-symmetric, i.e., the toroidal mode number n = 0. The axi-symetric character may result from the non-linear coupling in a spectrum of TAE modes generating an n=0 component[1].

The presence of this thermal or NBI driven mode complicates the search for α driven modes in the Alfvén range of frequency. A comparison of spectra from a D-only plasma, the previous record fusion power shot (73268) and a shot with 7.5MW of fusion power (76770) is shown in Figure 1. The amplitude of the mode is significantly higher in shot 76770, however, many plasma parameters as well as the β_α profile were different. It is not clear whether the change in the mode amplitude reflects additional drive from the fusion α population or whether the change is due to differences in the plasma equilibrium parameters such as the pressure, density or temperature profiles.

The energetic tail ions from ICRF H-minority heating have been used to simulate α-driven TAE modes[2]. These studies provide an empirical basis for extrapolation to D-T operation on TFTR and to help benchmark the theoretical models. In the recent ICRF driven TAE mode studies, the toroidal mode numbers, n, can now be measured with a new array of Mirnov coils. A wide variety of toroidal mode numbers have been identified in these experiments. Typically, at the higher ICRF powers, one or more clusters of modes are seen. Analysis of the mode numbers find that the toroidal mode numbers of the individual peaks range from about 5 to 9 at higher plasma currents (1.8MA, $q(a)\approx6$) and 1 to 3 for lower plasma currents (1.4MA, $q(a)\approx8$). In many cases two peaks at different frequencies will have the same toroidal mode number. The models suggest that the dominant damping mechanism for the TAE modes in TFTR DT plasmas is not ion Landau damping. The models presently predict that the damping on the slowing down distribution of the beam ions, and the profile of q, which affects the radial location of the mode and its interaction with the β_α profile, seem to be the most important parameters to vary in future experiments.

MHD activity in DT plasmas

Low wavenumber (m=3-4) MHD and major and minor disruptions were expected to play a significant role in the TFTR D-T experiments. At the higher plasma currents (1.8 -2.0 MA) used for most of the D-T operation, the MHD activity is restricted to (m,n) = (4,3) or (5,4) modes or an internal (1,1) fishbone-like mode. These modes have only a modest affect on confinement and plasma performance in contrast to the (3,2) and (2,1) MHD modes observed at lower plasma currents. The MHD activity in D-T plasmas was unchanged from that observed in D-D plasmas, with the exception of the fishbone-like modes. The fishbones tended to have a larger amplitude in D-T plasmas than in comparable D-D plasmas. This might reflect the somewhat different pressure profiles or ion temperatures in the D-T plasmas or the presence of the fusion α population. The fishbone modes seen in TFTR are probably not driven by the trapped fast ion population (which is rather small with the tangential beam injection) but are more like the 'parallel fishbones' first observed on PBX[3]. The present theoretical models predict that the TFTR fusion α population is about a factor of five below the threshold necessary to drive α-fishbones.

Major and minor disruptions in the DT campaign

To reach the highest fusion powers and fusion-α densities it is necessary to operatre TFTR at the highest plasma current, toroidal field, beam power and with the best confinement. Even with Ip = 2.5MA and B_T

= 5T, this will result in being near the β limit. Considerable experience in operation of TFTR near the β limit led to a very successful effort to avoid major disruptions while still providing many high performance plasmas in the D-T campaign. While several of the D-D setup shots suffered major or minor β-limit disruptions, there were no minor disruptions (X-events) in the TFTR D-T plasmas. However, two D-T shots did suffer major disruptions, including the highest performance (P_{fusion} >9 MW) TFTR D-T plasma with 6.5MJ of stored energy.

In the disruption of the highest performance shot and the four other major disruptions made since the start of the D-T campaign, moderate n ballooning mode was observed prior to the disruption. The fast T_e profile measurements from two toroidal locations separated by 126º has confirmed that the ballooning mode is toroidally localized. In Figure 2 the flux surface displacements are visible in the contours of electron temperature across the midplane vs. time. Approximately one period of a low frequency (1,1) mode can be seen. At the times when the m=1 mode pushes the flux surfaces outward in major radius, a higher frequency (n≈9) mode is seen. The mode appears in this figure as a toroidally localized burst moving toroidally (from one GPC to the other) and growing in amplitude. The distortions to the plasma caused by a large ideal mode are assumed to locally push the plasma over the ballooning mode stability boundary. The (m,n)=(1,1), plus the ballooning mode may cause or trigger the disruption.

[a]University of Wisconsin, Madison Wisconsin
[b]Oak Ridge National Laboratory, Oak Ridge TN
*Supported by DoE contract No. DE-AC02-76-CHO-3073

[1]D A Spong, B A Carreras, and C L Hedrick, Phys. Plasmas **1** (1994) 1503.
[2]K L Wong, J R Wilson et al., Plasma Phys. Cont. Fusion **36** (1994) 879.
[3]R Kaita, R B White, A W Morris, et al., Phys. Fluids B **2**, (1990) 1584.
[4]Y Nagayama, M. Yamada, et al., Phys. Fluids B **5** (1993) 2571.

Figure Captions

Fig. 1 Mirnov coil spectra for D-T shots with 6.2MW and 7.5MW of fusion power and a comparison D only shot.

Fig. 2 Data from two ECE grating polychromators showing the toroidally localized ballooning mode β-limit disruption precursor.

Figure 1

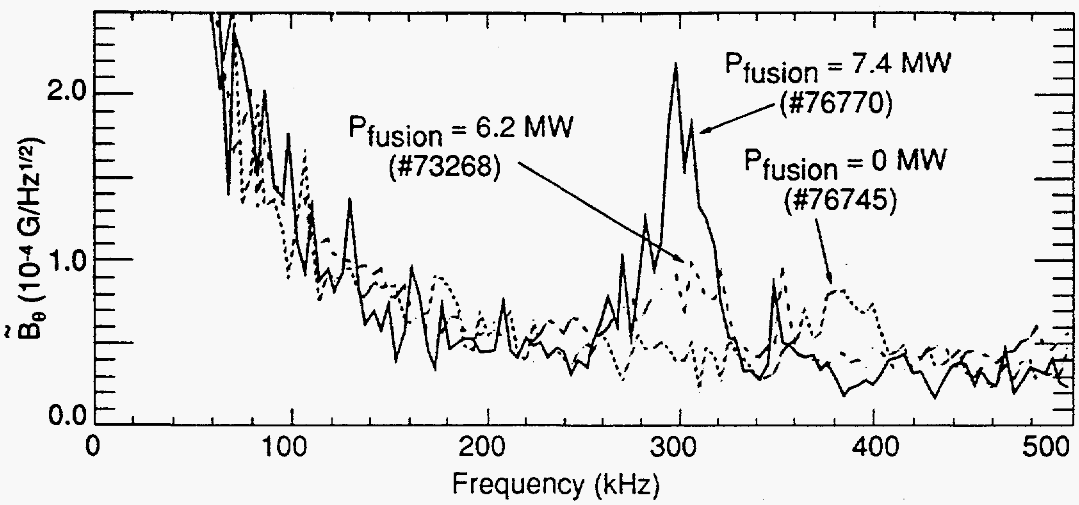
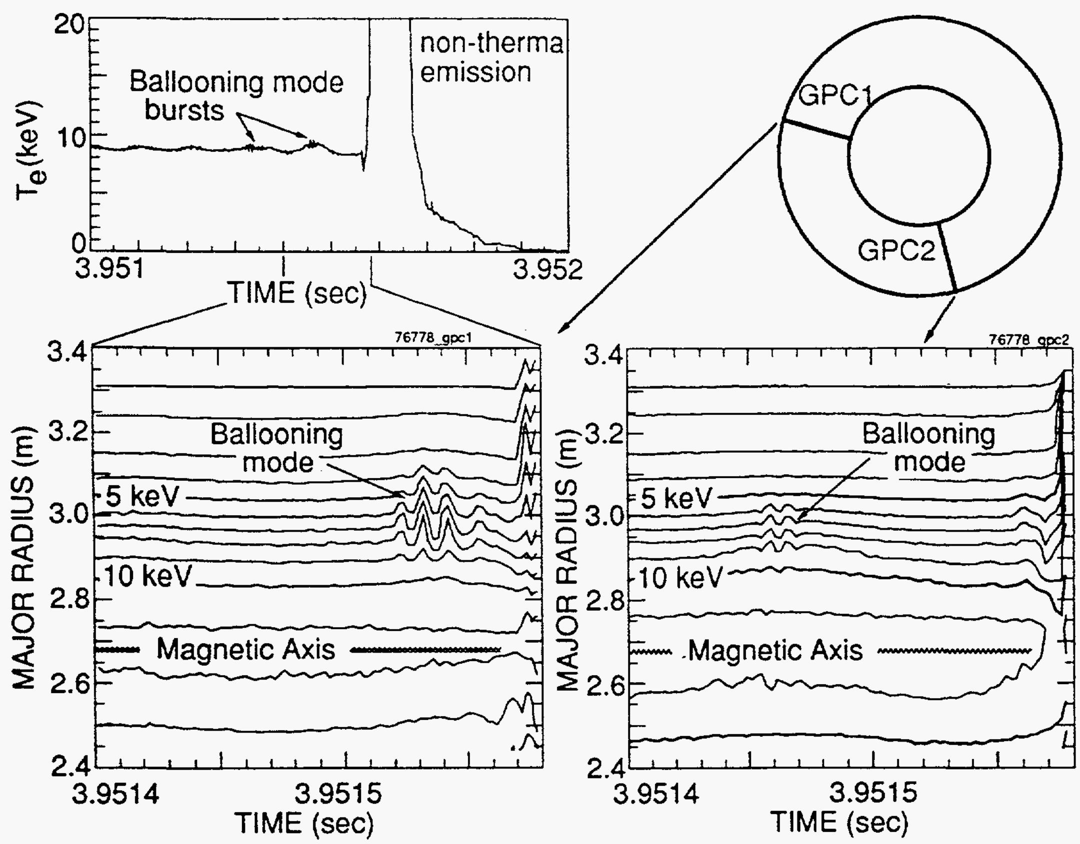


Figure 2



EXTERNAL DISTRIBUTION IN ADDITION TO UC-420

Dr. F. Paoloni, Univ. of Wollongong, AUSTRALIA
Prof. R.C. Cross, Univ. of Sydney, AUSTRALIA
Plasma Research Lab., Australian Nat. Univ., AUSTRALIA
Prof. I.R. Jones, Flinders Univ, AUSTRALIA
Prof. F. Cap, Inst. for Theoretical Physics, AUSTRIA
Prof. M. Heindler, Institut für Theoretische Physik, AUSTRIA
Prof. M. Goossens, Astronomisch Instituut, BELGIUM
Ecole Royale Militaire, Lab. de Phy. Plasmas, BELGIUM
Commission-European, DG. XII-Fusion Prog., BELGIUM
Prof. R. Boucique, Rijksuniversiteit Gent, BELGIUM
Dr. P.H. Sakanaka, Instituto Fisica, BRAZIL
Prof. Dr. I.C. Nascimento, Instituto Fisica, Sao Paulo, BRAZIL
Instituto Nacional De Pesquisas Espaciais-INPE, BRAZIL
Documents Office, Atomic Energy of Canada Ltd., CANADA
Ms. M. Morin, CCFM/Tokamak de Varennes, CANADA
Dr. M.P. Bachynski, MPB Technologies, Inc., CANADA
Dr. H.M. Skarsgard, Univ. of Saskatchewan, CANADA
Prof. J. Teichmann, Univ. of Montreal, CANADA
Prof. S.R. Sreenivasan, Univ. of Calgary, CANADA
Prof. T.W. Johnston, INRS-Energie, CANADA
Dr. R. Bolton, Centre canadien de fusion magnétique, CANADA
Dr. C.R. James,, Univ. of Alberta, CANADA
Dr. P. Lukác, Komenského Universzita, CZECHO-SLOVAKIA
The Librarian, Culham Laboratory, ENGLAND
Library, R61, Rutherford Appleton Laboratory, ENGLAND
Mrs. S.A. Hutchinson, JET Library, ENGLAND
Dr. S.C. Sharma, Univ. of South Pacific, FIJI ISLANDS
P. Mähönen, Univ. of Helsinki, FINLAND
Prof. M.N. Bussac, Ecole Polytechnique,, FRANCE
C. Mouttet, Lab. de Physique des Milieux Ionisés, FRANCE
J. Radet, CEN/CADARACHE - Bat 506, FRANCE
Prof. E. Economou, Univ. of Crete, GREECE
Ms. C. Rinni, Univ. of Ioannina, GREECE
Preprint Library, Hungarian Academy of Sci., HUNGARY
Dr. B. DasGupta, Saha Inst. of Nuclear Physics, INDIA
Dr. P. Kaw, Inst. for Plasma Research, INDIA
Dr. P. Rosenau, Israel Inst. of Technology, ISRAEL
Librarian, International Center for Theo Physics, ITALY
Miss C. De Palo, Associazione EURATOM-ENEA, ITALY
Dr. G. Grosso, Istituto di Fisica del Plasma, ITALY
Prof. G. Rostangni, Istituto Gas Ionizzati Del Cnr, ITALY

Dr. H. Yamato, Toshiba Res & Devel Center, JAPAN
Prof. I. Kawakami, Hiroshima Univ., JAPAN
Prof. K. Nishikawa, Hiroshima Univ., JAPAN
Librarian, Naka Fusion Research Establishment, JAERI, JAPAN
Director, Japan Atomic Energy Research Inst., JAPAN
Prof. S. Itoh, Kyushu Univ., JAPAN
Research Info. Ctr., National Instit. for Fusion Science, JAPAN
Prof. S. Tanaka, Kyoto Univ., JAPAN
Library, Kyoto Univ., JAPAN
Prof. N. Inoue, Univ. of Tokyo, JAPAN
Secretary, Plasma Section, Electrotechnical Lab., JAPAN
Dr. O. Mitarai, Kumamoto Inst. of Technology, JAPAN
Dr. G.S. Lee, Korea Basic Sci. Ctr., KOREA
J. Hyeon-Sook, Korea Atomic Energy Research Inst., KOREA
D.I. Choi, The Korea Adv. Inst. of Sci. & Tech., KOREA
Prof. B.S. Liley, Univ. of Waikato, NEW ZEALAND
Inst of Physics, Chinese Acad Sci PEOPLE'S REP. OF CHINA
Library, Inst. of Plasma Physics, PEOPLE'S REP. OF CHINA
Tsinghua Univ. Library, PEOPLE'S REPUBLIC OF CHINA
Z. Li, S.W. Inst Physics, PEOPLE'S REPUBLIC OF CHINA
Prof. J.A.C. Cabral, Instituto Superior Tecnico, PORTUGAL
Prof. M.A. Hellberg, Univ. of Natal, S. AFRICA
Prof. D.E. Kim, Pohang Inst. of Sci. & Tech., SO. KOREA
Prof. C.I.E.M.A.T, Fusion Division Library, SPAIN
Dr. L. Stenflo, Univ. of UMEA, SWEDEN
Library, Royal Inst. of Technology, SWEDEN
Prof. H. Wilhelmson, Chalmers Univ. of Tech., SWEDEN
Centre Phys. Des Plasmas, Ecole Polytech, SWITZERLAND
Bibliotheek, Inst. Voor Plasma-Fysica, THE NETHERLANDS
Asst. Prof. Dr. S. Cakir, Middle East Tech. Univ., TURKEY
Dr. V.A. Glukhikh,Sci. Res. Inst. Electrophys.I Apparatus, USSR
Dr. D.D. Ryutov, Siberian Branch of Academy of Sci., USSR
Dr. G.A. Eliseev, I.V. Kurchatov Inst., USSR
Librarian, The Ukr.SSR Academy of Sciences, USSR
Dr. L.M. Kovrizhnykh, Inst. of General Physics, USSR
Kernforschungsanlage GmbH, Zentralbibliothek, W. GERMANY
Bibliothek, Inst. Für Plasmaforschung, W. GERMANY
Prof. K. Schindler, Ruhr-Universität Bochum, W. GERMANY
Dr. F. Wagner, (ASDEX), Max-Planck-Institut, W. GERMANY
Librarian, Max-Planck-Institut, W. GERMANY