SESSION EX1

Tuesday, 20 October 1998, at 11.20 a.m.

Chairman: A. IIYOSHI (Japan)

PERFORMANCE, IMPROVED MODES, ALPHAS

Paper IAEA-CN-69/EX1/1 (presented by P.R. Thomas)

DISCUSSION

Ya.I. KOLESNICHENKO: Can you explain why the frequency spectrum of the ion cyclotron emission that you showed differs essentially from those in deuterium discharges and in the preliminary tritium experiment (spectral lines are not split into doublet, and they do not merge into continuum in the high-frequency part of the spectrum)?

P.R. THOMAS: The spectra I showed are simple because they arise from excitation by fast ions in a plasma with a short slowing down time. The inversion of the fast ion population at the edge is not very strong and so only the fundamental is excited. The ICRH heated plasmas that I referred to have much higher electron temperatures and so produce ICE spectra very similar to those in the preliminary tritium experiment.

R.D. STAMBAUGH: Congratulations on these excellent measurements of α-heating, one of our principal objectives in fusion research. Do you anticipate new α-effects in the optimized shear regime?

P.R. THOMAS: Thank you for your kind remark. Optimized shear plasmas, with their increased central safety factor, are more unstable to TAEs than those with q on axis near to unity. However, intense ICRH is used in the optimized shear scenarios, which provides strong TAE drive. Alpha driven TAEs could undoubtedly be observed if ICRH were not used. This might require more NBI than is presently available.

Paper IAEA-CN-69/EX1/2 (presented by T. Fujita)

DISCUSSION

K. LACKNER: Did you observe neoclassical modes in the reversed shear scenarios with H-mode edge and relatively low q_{min}?

T. FUJITA: The β limit in H-mode edge reversed shear discharges was mostly determined by a collapse with ideal modes, as was the case in L-mode edge discharges. Continuous modes were observed in some H-mode edge discharges but their properties have not yet been analysed.

V.V. PARAIL: Your example of ITB plasma with H-mode edge shows a weak internal barrier. Do you have any examples of the ITB plasma in ELMy H-mode with better performance?

T. FUJITA: We have some discharges with clearer ITB with an ELMy H-mode edge, though their duration was shorter (less than 2 seconds). An example is shown in Refs [9] and [10 - this conference, paper IAEA-CN-69/EX5/4] (Fig. 1(c)).

M.E. MAUEL: Have you identified the MHD instability responsible for the β collapse limiting your high-performance reversed shear discharges?

T. FUJITA: The MHD instability responsible for β collapse is considered to be a low-n kink-ballooning mode based on observations of the fast growth time of fluctuations.

M.E. MAUEL: Do you have a theoretical explanation for the improvement in stability seen with the H-mode edge?

T. FUJITA: Improvement of the β limit with the H-mode edge is shown by ideal stability analysis in paper IAEA-CN-69/THP2/31.

R.J. HAWRYLUK: Previously on TFTR and JET, it was reported that the threshold power for ITB formation was a strong function of B_t. What is the scaling on JT-60U? For the JT-60U reversed shear discharge presented, what was B_t?

T. FUJITA: No systematic study of the B_t dependence of threshold power has yet been carried out on JT-60U, though it appears that ITBs can be formed easily in a low field. The toroidal field of the discharges in this paper is 3.5-4.3 T.

Paper IAEA-CN-69/EX1/3 (presented by R.R. Weynants)

DISCUSSION

K. LACKNER: Your confinement law has no explicit dependence on magnetic field or current, which is of course counter-intuitive. Do you have a dimensionless form of this scaling law?

R.R. WEYNANTS: We have studied the dependence on <n> ⌋, P and B and have indeed found that the B-dependence is very weak in both the linear ohmic confinement and the radiation improved mode (RI-M) regime. As we are not in a position to study the size dependence, I would hesitate to advance a dimensionless scaling as yet.

E.S. MARMAR: In many enhanced confinement modes related to peaked density profiles, the fuelling must be dominated by core sources (beams or pellets). For the RI-M discharges, what fraction of the fuelling is due to beam particles?

R.R. WEYNANTS: As only 20-25% of the total power input has to come from beam injection, in order to maintain the RI-M at high density, the beam fuelling accounts for only about 10%. It should be noted that the observed profile peaking (n(0)/<n>) in our RI-M stays below a value of 2, whereas in such regimes as the TFTR supershot regime much higher values can be achieved.

B. COPPI: What is the typical value of the parameter $\eta_i = \mathrm{dln}T_i/\mathrm{dln}n$ of your peaked density profiles?

R.R. WEYNANTS: I cannot quote the η_i values, but will check with our modellers.

B. COPPI: Given that it is difficult to ignite for $Z_{eff} > 1.6$, how do you envisage attaining ignition regimes?

R.R. WEYNANTS: At the present time I can only note that the ITER FDR (Final Design Report) studies have shown that radiation levels as high as 75% can be achieved using Ar or Xe injection without jeopardizing the chances of ignition. These radiation levels should be enough to set up RI-confinement.

R.W. CONN: As one goes to more powerful machines, the power flow to the edge increases and neon will burn out at the edge. Do you think switching to Ar, or even Xe, will work in a reactor such as ITER, and what are the associated values of Z_{eff}?

R.R. WEYNANTS: The ITER FDR studies show that Ar or Xe impurity seeding can bring the total power radiated from inside the LCFS (last closed flux surface) to levels (± 75%) that would allow the RI-mode to develop at central Z_{eff} values that are compatible with the central alpha heating power. However, these calculations were performed with an impurity transport model that is not necessarily describing the transport in RI-mode.

M. PORKOLAB: In the past you needed at least ~ 25% of the heating power to be in the form of neutral beams (in addition to ICRF power) to get RI-M. If the beam fuelling contribution is indeed only 10%, what is the role of NBI and, in particular, have you been able to obtain the RI-M with only ICRF heating?

R.R. WEYNANTS: With ICRH we can also restore some density dependence, but with a slope that is lower than the RI-M scaling. Analysis shows that ICRH (not counter injection) can provoke the peaking of the density profile that can be achieved with co-injection.

Paper IAEA-CN-69/EX1/4 (presented by M.J. Greenwald)

DISCUSSION

Y. KAMADA: You indicate the regions related to non-dimensional parameters such as q_{95}, β_N and δ for the onset condition of enhanced D-alpha (EDA). Have you also observed the onset condition related to absolute values, such as edge temperature or density?

M.J. GREENWALD: The edge temperatures for EDA discharges are only slightly lower than for ELM-free. On C-Mod, the global confinement and core temperature gradients are proportional to the edge temperature, so the small difference in confinement between the two regimes is reflected by the edge temperature. We do see a dependence on target density, that is the density in the ohmic phase, just before the RF is applied. EDA predominates for target densities greater than about 1.5×10^{20} m^{-3}, which is about ¼ the density limit. No dependence on density in the H-mode is observed.

F. PERKINS: Could the EDA be the result of direct interaction between the edge plasma and an energized antenna?

M.J. GREENWALD: We have no evidence that the EDA is a direct consequence of RF vs NBI heating. Our feeling is that the regime may be seen on C-Mod rather than other machines because of its particular shape or closed divertor configuration.

F. PERKINS: ASDEX-U sees ordinary Type I ELMS with ICRF. Which phenomenology is appropriate for extrapolation to ITER?

M.J. GREENWALD: The absence of EDA in RF heated ASDEX-U discharges might be seen as evidence that RF alone is not responsible. It is worth noting that, so far, ASDEX-U has run at triangularities below the threshold at which we observe EDA.

M.C. ZARNSTORFF: Your plot showing sensitivity of the EDA onset to neutral pressure (Fig. 3c) appears to show EDA points across the full range of neutral pressure. What parameter distinguishes the EDA from non-EDA plasmas at low neutral pressure?

M.J. GREENWALD: While we have identified global variables which begin to separate the EDA and ELM-free regimes, there are - as you noted - regions of substantial overlap. This suggests that we have not identified all the relevant variables. It is possible that consideration of local variables and gradients will allow clearer separation.

M.C. ZARNSTORFF: How does the ICRF driven rotation at fixed (~ large r/a) location vary with resonance location?

M.J. GREENWALD: We have carried out field scans, which moved the ICRF resonance off axis to perhaps $r/a = \pm 0.3$. No difference in rotation (or heating efficiency) was observed. We plan to extend the range of these scans in future experiments.

K. IDA: In most measurements toroidal rotation is in the counter direction when there is no toroidal momentum input, and this can be explained by the off diagonal term of the transport matrix. Toroidal rotation in the co-direction is, therefore, a unique feature. Is there any evidence to suggest that the co-rotation observed is directly driven by ICRF wave? How sensitive is the toroidal rotation profile to the position of ICRF resonance?

M.J. GREENWALD: Without ICRF we do indeed see the counter rotation which is predicted by neoclassical theory. This rotation is much smaller than the co-rotation seen with RF. In our next campaign, we will be carrying out a series of experiments to test the theory of RF flow drive.