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Fast MHD Analysis on FTU

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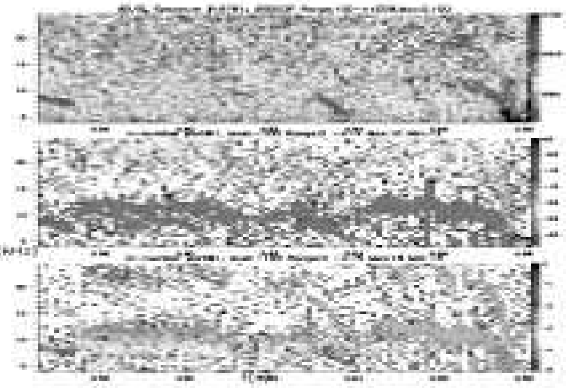
Introduction

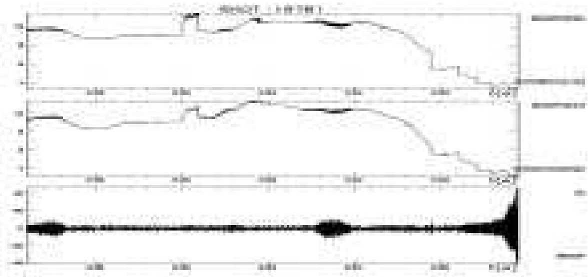
MHD analysis is required to determine mode activity and turbulence level. These have implications to establish the tokamak operation space and its transport or confinement properties. Below follow examples of various phenomena observed in FTU

LH Fishbones

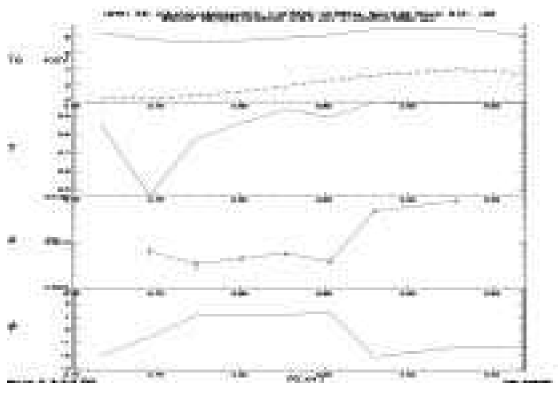
Lower Hybrid heated 2.5 MW discharge 19781 6T, 0.5 MA
Fourier spectrum of Mirnov coil with n and m number of modes analysed (top figure) as function of time
Note the presence of bursts of (1,1) on top of the (2,1) modes. These are fishbone like structures located at the q=1 and are present only during high power LH. It is believed that these are related to the fast electrons



These fishbones can also be seen on the ECE diagnostic.
The middle figure shows the time traces of 2 ECE channels near the plasma centre together with a Mirnov coil signal. Two fishbones appear followed by a precursor to a disruption.

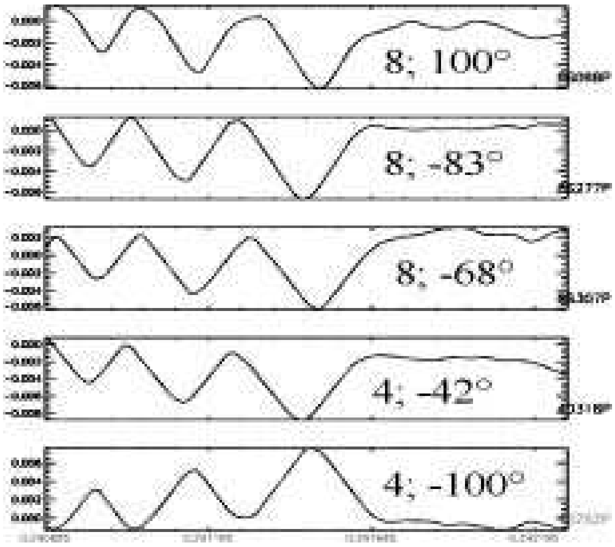


The lower figure shows the T_e (broken line: Thomson Scattering), the coherence γ, the displacements γ due to the perturbation and the phase γ as function of R. The plasma centre is around R=0.95 m. Typical size of the displacements is one cm (roughly in agreement with δB). The q=1 position is estimated to be R<0.9 m from the sawtooth inversion. A phase jump occurs there suggesting the presence of an island.



Mode Lock.

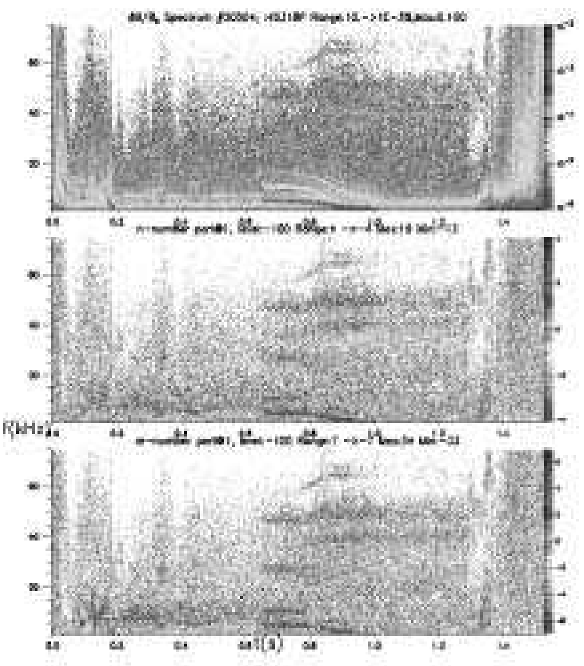
Mode lock of (2,1) and (3,1) modes can occur at the location of strong interaction with mechanical structures (the Mirnov coil diagnostic system) in the vacuum vessel. This position changed with the change in position of these mechanical structures, suggesting that not necessarily error fields alone are determining the lock position.
Time integrated Mirnov coil signals yield the X and O-point position of the (2,1) island (X-points at B maxima and O-points at B minima).



The O-point locks on the position of the highest damage (strongest interaction) to the mechanical structure of the Mirnov coil arrays.

Inverted q-profiles in plasma core ?

Evidence is obtained from MHD analysis of high frequency modes that appear in a number of discharges at moderate field and current when there is a strong (2,1) present at 5 kHz or below. The structure of the high frequency mode suggests that perhaps q-profiles can occasionally become inverted in the plasma core.
(3,2) and (2,2) modes rotate in the electron diamagnetic direction ,but opposite to these, other(-3,-1) and (-3,-2) modes occur at similar frequencies. It is seen that the temperature profile becomes flat to slightly hollow in the very plasma centre (within the q=1 surface).

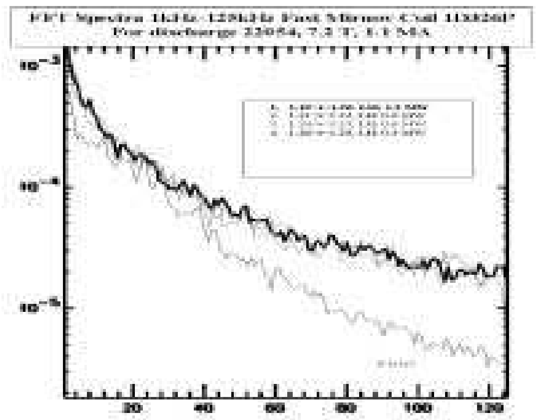


In some discharges again improved confinement is occasionally observed.

Turbulence during LH heating

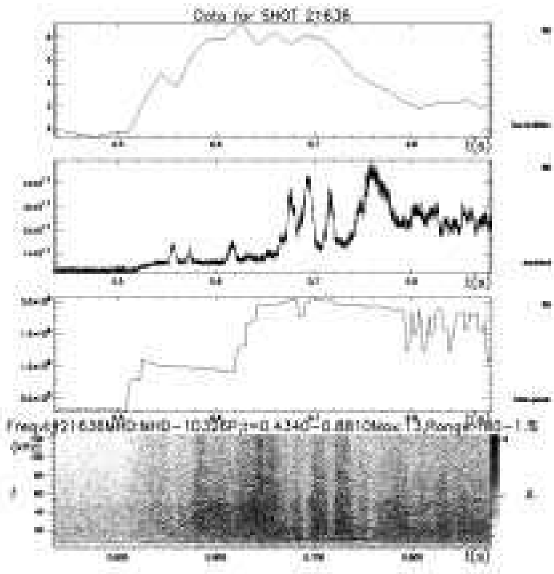
During LH heating generally high frequency turbulence is observed on the Mirnov coils. This is not a direct pick-up from the LH waves, since once a threshold seems to be overcome the turbulence level can be constant independent on the power level. At low power (< 0.3 MW) the level falls back to the Ohmic heating level, which is still more than a factor of 10 higher than the noise level.

Whether this turbulence is genuine plasma turbulence due to critical gradients or still related to the LH heating, like parametric decay of the LH spectrum in FT and Asdex [V.Pericoli, private communication] is not yet clear.



Turbulence and Confinement

In discharge 21636, 5.2T, 0.35MA, 1.8 MW LH, short periods of **improved confinement** were observed which coalesce with reduced turbulence levels at <ne> of 7 10^{19} m^{-3}. The figure shows $T_e(0)$, the neutron flux, the LH power and spectrum of a Mirnov coil as function of time.
Each decrease in the turbulence can be seen to be accompagnied by an increase in the neutron flux. Typically a reduction of factor of 2 in turbulence is related to an increase of a factor of 2 to 3 in the neutron rate.



Conclusions

With the old Mirnov coil diagnostic set-up (essentially nearly complete poloidal coverage at 2 toroidal positions) it has been possible to determine the mode lock position accurately. This showed that mode lock in FTU has not been related to error fields alone but more to position of interaction of plasma and the damaged protection plates of the same diagnostic. A complete poloidal coverage allows for determination of the q^* effect, which is a function of radius. Hence some information on the radial position of the MHD activity can in principle be obtained.
In certain discharges during m=2 mode activity around 5 kHz with the fast data acquisition system faster 40 to 60 kHz modes can be observed. The type of modes observed suggests

the presence of an inverted q-profile in the plasma core. Further measurements with other diagnostics are required to corroborate this interpretation.

In discharges with a large LH heating and current drive power fishbones are observed both on the magnetic, the central ECE and central SXR diagnostic. It is believed that in these high power LH discharge the fishbones are due to the fast electrons.It is further observed with the new Mirnov pick-up coils (poloidally +/- 16°, toroidally only 2° separation) that in general there exist a level of turbulence, which increases with heating power. In the Ohmic heating phase the level is an order of magnitude above the noise level of the coils. During LH heating this noise like turbulence (low m,n) generally increases, but since it has no relationship with the power level this increase is believed to be originating from the plasma (either plasma turbulence or parametric decay of the LH waves).
There also appears a direct relationship between decreasing turbulence and increasing neutron rate (increasing confinement).

On the other hand during the longer wavelength IBW direct pick-up on the Mirnov coils seem to occur (noise level increases/decreases with IBW power).

A new Mirnov coil diagnostic is being constructed and will be installed during the autumn shutdown, which will again have nearly full poloidal coverage and this time will allow for full toroidal analysis.