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Detailergebnisse / Details

TEC Main Topic 4 — MagnetoHydroDynamics

The work of this topic group concentrated on sawtooth stabilization experiments with respect to the triggering of neoclassical tearing modes (NTM), the direct stabilization of NTMs by ion-cyclotron current drive (ICCD), and the analysis of MHD modes in conjunction with edge localized modes (ELM) at the JET tokamak. The work performed on TEXTOR comprised sawtooth and mode stabilization experiments with electron cyclotron heating (ECRH) and current drive (ECCD), and first investigations of the influence of error fields induced by the dynamic ergodic divertor (DED) on the MHD characteristics of the plasma.

The control of sawteeth is an important issue for a next step fusion experiment like ITER. It is well known that a large fraction of high energetic particles leads to the stabilization of the central sawtooth instability. The time between sawteeth collapses becomes longer and the sawteeth get much larger amplitudes. This large sawteeth trigger NTMs more easily and at much lower beta values. Once the NTM is excited it causes a considerable reduction of confinement or even leads to a disruption of the plasma current. It is therefore desirable to have means to control the sawtooth period and thus its amplitude in the presence of a high fraction of fast particles. TEC scientists participated in JET experiments where central ion cyclotron heating (ICH) was applied in order to create longer sawtooth periods due to the enhancement of the fast particle population. A second ICH system was then successfully utilised for ICCD at the $q = 1$ surface and to destabilize the sawteeth again.

The reverse B campaign on JET allowed to study the influence of counter neutral beam injection (NBI) on the sawtooth period. The main effect of counter injection is a change of the plasma rotation. A detailed scan of the injected power was made in L-mode plasmas. Compared to the pure ohmic and co-injection cases a clear reduction of the sawtooth minimum was observed at around 4 MW of counter NBI. A candidate mechanism to explain the experimental findings is the dependence of the internal kink stability on the sheared rotation profile. Previous experiments made at TEXTOR have shown a minimum in the sawtooth period at low values of co-NBI. Work to model the JET results and a comparison with the TEXTOR results is underway.

Once the NTM is excited in the plasma, various means to stabilize this mode again have to be explored. An experiment at JET aimed on the stabilization of a NTM by ICCD at the mode rational surface, i.e. at $q = 3/2$. A series of discharges where the ion cyclotron resonance was moved across the q = 3/2 radius by varying the toroidal magnetic field was performed. Only a marginal effect on the mode amplitude was observed.

The new powerful 140 GHz gyrotron at TEXTOR will be used in the future to stabilize modes induced by the DED under well controlled conditions and to study the physics of mode stabilization by heating and current drive in detail. Preparatory experiments on TEXTOR aimed on a modulated operation of the gyrotron in a well defined phase with the DED current which creates the mode. The milestone of modulated ECRH at 2 kHz controlled by the external DED current signal was successfully achieved.

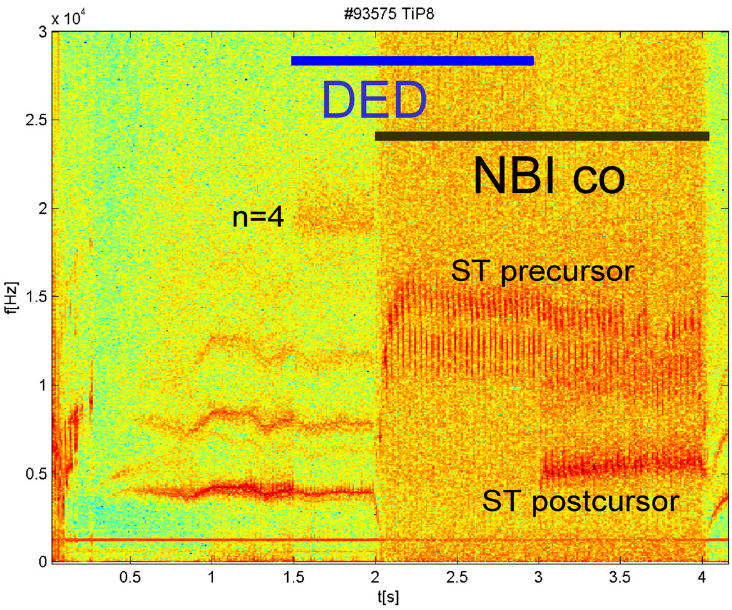

Fig. 1: *Spectrogram calculated from the signal of a magnetic pick-up coil.*

Another plasma instability of concern for future fusion reactors are ELMs. The related modes lead to periodic collapse events which release a considerable part of the plasma stored energy as well as particles to the plasma facing components and the divertor target plates, leading to unacceptable high heat loads. Work performed at JET aimed on a better understanding of various types of MHD modes at the plasma edge which may be connected to energy and particle losses or the ELM crash itself. Especially so-called type-II ELMs, where the energy losses are driven by much more benign instabilities between the ELM crashes are currently of great interest. Observations made on ASDEX Upgrade have shown that high confinement plasmas with acceptable divertor heat loads have been achieved. A similar scenario has not been obtained at JET up to date, but mixed type-I/II phases where the ELM frequency dropped were observed. In these plasmas, part of the energy is transported via an additional loss mechanism which is still not definitely explained. In-between the ELMs a characteristic change of the turbulence due to so-called washboard modes, rotating in the electron diamagnetic direction, was observed. These modes show a rather complex interplay with the ELM precursor modes observed recently, and could be a good candidate to explain the additional losses. The analysis showed that the electron temperature at the edge pedestal could be kept constant when these modes occurred at high amplitudes, but the electron density was still rising, leading finally to the triggering of an ELM crash. The experimental observations of ELM precursor and washboard modes suggest that the standard peeling-ballooning ELM model has to be revisited.

TEXTOR resumed operation after a long shutdown for the integration of the Dynamic Ergodic Divertor (DED). The 16 coils were linked up to produce an m = 12, n = 4 mode structure which does not show deep penetration into the plasma, but merely influences the plasma edge. During the shutdown many diagnostic systems were upgraded as well. Figure 1 shows a spectrogram (windowed Fourier analysis) of a signal from one of the new Mirnov coils. The n = 4 mode induced by the DED is clearly visible. A more striking feature is that during operation of the DED the sawtooth postcursor mode, situated deep in the plasma core at the q = 1 surface, is not visible. This behaviour is presently not understood and the analysis is ongoing. The new pick-up coil design yields a large bandwidth and allows to measure the whole range of frequencies which are expected to be important. More interesting measurements of MHD features in DED plasmas were made with the correlation reflectometry system. There is a strong influence of the DED perturbation on the rotation frequency of modes located at the plasma edge. This has been observed for both directions of rotation (co and counter) of the external ac DED field.

After the 2003 campaign the DED coils a re-linked to the m = 3, n = 1 mode configuration. This mode of operation is much more favoured for MHD investigations. Experiments on error field amplification and ECRH/ECCD mode stabilization are planned for 2004.