ASDEX Upgrade Letter

No. 4/May 2003

Foreword

One of the main issues of the present experimental campaign is the implementation of coordinated joint experiments at all major divertor tokamaks as proposed by the ITPA topical groups based on the High Priority Research Aims. In a coordination meeting last November at Boston (USA) the project leaders of major tokamaks evaluated and approved this joint research in the framework of the IEA Implementing Agreements. Besides exchanging scientists for the different joint experiments at each device the use of video conferencing is essential in the present budget situation. The integration of our external collaborators in the operation of ASDEX Upgrade and the scientific discussion has been considerably improved by making the participation in the Monday operation meeting possible via high quality and reliable video conferencing.

A couple of hardware changes and improvements have been finalised at the end of last year and are exploited in the current experimental campaign. The inner heat shield, the bottom divertor entrance baffle at the high field side and parts of the low field side structure are covered with tungsten tiles. Plasma operation is not hampered by this increase of the tungsten covered surface. The tungsten coverage programme will continue.

The upper divertor is now strengthened to withstand disruptions with VDEs in the upper direction up to 1.2 MA plasma current. Discharges in double-null and with an upper X-point are now routine scenarios. Extreme shaping of the plasma is possible with triangularities up to 0.55 to further optimise performance. A new active damping system of torsional oscillations dangerous for the mechanical stability of the flywheel generators permits longer plasma current flat-tops, and a more reliable operation in combination with an enhanced safety for the power supplies.

These operational improvements and the joined activities will certainly contribute to discover new exciting scientific results.

O. Gruber

Highlights

from recent ASDEX Upgrade experiments

Suppression of 2/1 NTMs with ECCD (collaboration with IPF, Stuttgart University)

For successful operation of a future burning plasma experiment like ITER in a high β regime with high confinement the control of NTMs will be a crucial element. Within its 'MHD stability and active control' programme ASDEX Upgrade is exploring the possibilities and requirements for suppression of NTMs with localised ECCD and ECRH.

The existing ECRH system at ASDEX Upgrade, with a flexible deposition of the RF power of up to 1.9 MW in the plasma is well equipped to demonstrate key physics experiments and techniques for MHD control.

Recent experiments showed the successful suppression of NTMs with poloidal mode number m=2 and toroidal mode number n=1 at ASDEX Upgrade with ECCD. In contrast to previously conducted experiments with the m=3, n=2 NTM, these instabilities are located at the q=2 surface which is closer to the vacuum vessel where the plasma temperature is reduced. Thus these modes have the tendency to stop rotation and lock to the wall. Since the current drive efficiency strongly depends on electron temperature a considerably higher ECCD power is needed for stabilisation.

In Fig. 1 time traces show the n=1 perturbation of the magnetic field, the heating power and the normalised pressure β_N for two similar discharges. Usually the 2/1 mode is excited at high β_N and locks after a short time. Note that during this time (marked in the figure by a shaded box), the magnetic diagnostic is not able to detect the mode. ECCD is injected at a later time where β_N is reduced to a level for which the width of the island is decreased and has the tendency to unlock and to rotate again.

The discharge #16999 shows a successful suppression of the instability by ECCD. In discharge #17000 the same parameters have been chosen, but the average NBI power and thus β_N were increased by a small amount. In that case, the available ECCD power is not sufficient to completely suppress the instability. Thus, with such experiments one is able to explore the β_N dependence of the ECCD power needed for NTM suppression.

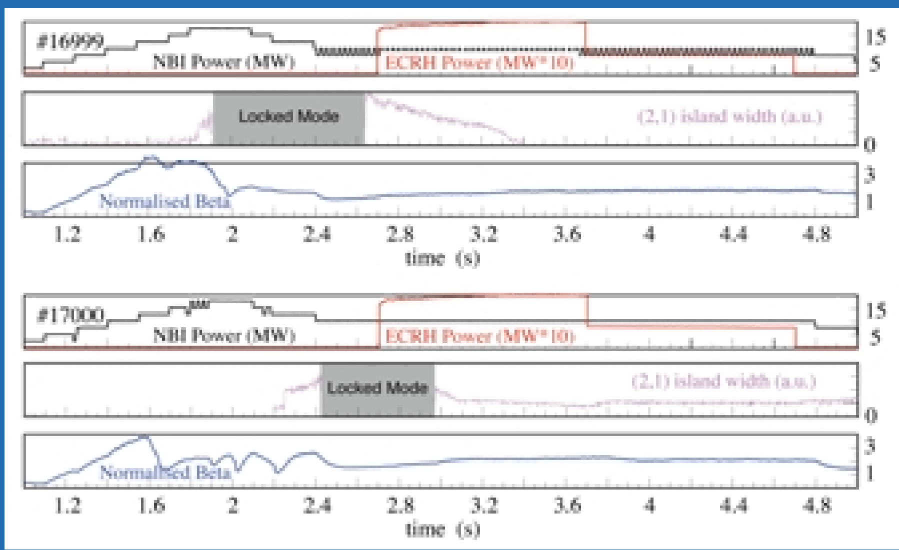


Fig. 1: Experiments on 2/1 NTM suppression by ECCD. At β_N = 1.9, the mode can be fully suppressed whereas at β_N = 2.1, this is no longer possible with the available ECCD power.

Quiescent H-mode in ASDEX Upgrade

A stationary H-mode is usually accompanied by Edge Localised Modes (ELMs), a burst-like instability that helps to remove particles and impurities from the main plasma, but also poses the risk of excessively large peak heat loads to the divertor of a fusion reactor. ELM-free H-mode plasmas typically lead to a linear rise of density and radiation losses, resulting in a thermal collapse or a very big ELM which terminates the regime.

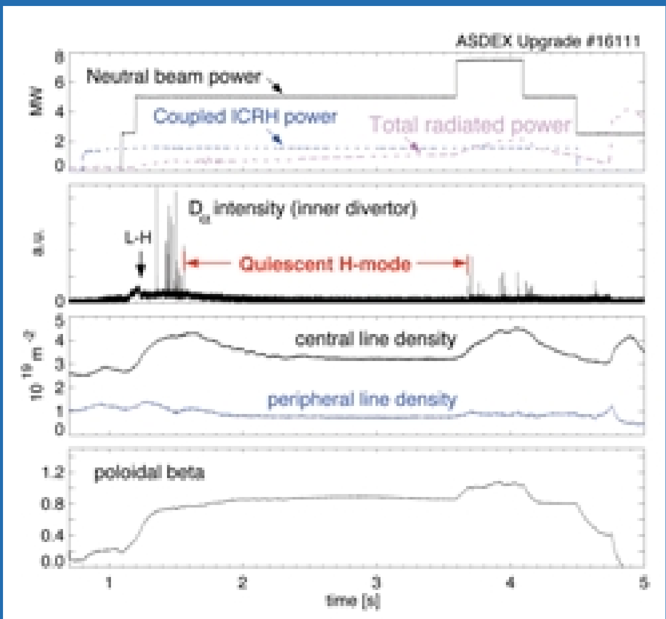
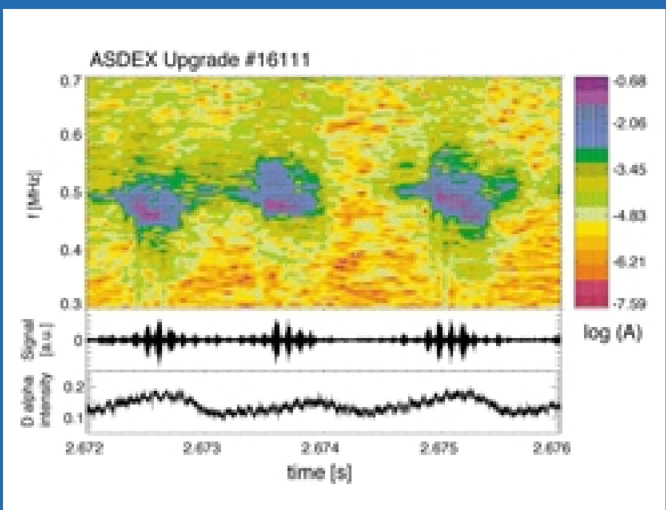


Fig. 2: Time traces of a stationary ELM-free H-mode discharge in ASDEX Upgrade

During the experimental campaign in 2002, a type of stationary ELM-free H-mode with high performance has been produced in ASDEX Upgrade. These plasmas resemble in all their main properties the 'Quiescent H-mode' (QH-mode) regime previously observed in the DIII-D tokamak.

Fig. 3: Spectrogram of the, high frequency oscillation' showing bursts, correlated with oscillations of the divertor D_α signal.



The QH-mode is only obtained with neutral beam injection in a direction opposite to the plasma current ('counter'-injection), achieved by reversal of the plasma current, and in a configuration with sufficiently large gap between the plasma boundary and limiting surfaces in the plasma chamber (≥ 7.5 cm at outer midplane). The time traces in Fig. 2 demonstrate the overall discharge behaviour.

After ICRH and NBI heating power is applied and H-mode is reached, a brief ELMy phase occurs. As soon as a configuration with high wall clearance is reached, the ELMs disappear and QH-mode is obtained. The central and peripheral line densities drop to stationary values below those in a ELMy phase. Only a moderate increase of the radiated power is observed. The poloidal beta (β_p = 0.89), normalized beta (β_N = 1.8)}, and H-factor ($H_{97P,y}$ = 1.1) are all above the respective values in ELMy H-mode.

The central and pedestal ion temperatures are very high, reaching about 9 keV and 1.2 keV, respectively. Often, strong toroidal core plasma rotation up to 300 km/s sets in during the quiescent phase. Neutral particle analyser measurements show that the density of fast particles in the plasma periphery of a stationary QH-mode is well above that of ELMy phases.

The quiescent H-mode regime is characterized by pronounced MHD behaviour: No sawteeth, instead strong m=1,n=1 fishbone activity and at the edge a continuous edge mode with harmonics up to n=11 is observed ('Edge Harmonic Oscillation', EHO) similar to that seen in DIII-D. A new finding is that the EHO is linked with a high-frequency magnetic oscillation (f > 350 kHz), dubbed the 'High Frequency Oscillation' (HFO, Fig. 3), which is amplitude modulated in phase with the EHO. Often the HFO occurs in bursts during which the HFO frequency drops by a few 10 kHz. The bursts are correlated with oscillations of the divertor D_α signal with 22 µs time delay, suggesting that these bursts are connected with fast particle losses to the divertor.

A drawback of the present Q-mode are the low density and high Z_{eff} values. In the reversed (B_t,I_p) campaign of 2003 further experiments are planned to extend the regime towards higher densities and reduced impurity content.

Discharges with extreme triangularity δ=0.55 commissioned

In previous campaigns the best combination of high confinement at densities close to the Greenwald density with stability against NTMs has been obtained at the maximum triangularity (δ=0.44) which were possible at a plasma current I_p of 1 MA. In addition this plasma shape is close to a double-null configuration which gives access to the favourable type II ELM regime where good confinement at high density is simultaneously reached with a tolerable ELM type.

In the present campaign the limits for a shaping coil (OH2s) was increased to allow higher currents by extending the thermal capability of a vacuum switch. With this hardware improvement operation at higher triangularity becomes possible. At I_p = 600 kA a new highly shaped equilibrium (see Fig. 4) has been obtained recently with triangularity δ=0.55 (δ_{upper}=0.45, δ_{lower}=0.65).

In a next step the plasma current will be increased to I_p = 800 kA where similar shaping seems to be possible. With these highly shaped plasmas, a new domain will be exploited, which permits to reach triangularities beyond the current ITER design value.

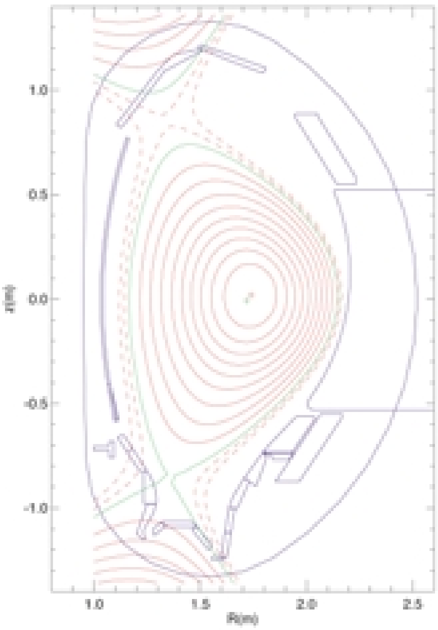


Fig. 4: Poloidal cross section of ASDEX Upgrade with magnetic equilibrium reconstruction of a highly shaped discharge (δ=0.55).

ASDEX Upgrade weekly operation meeting broadcasted routinely on Monday mornings

Fig. 5: Snapshots from a Monday morning meeting where the results of a recent series of discharges are presented remotely by Dr. Jacchia from IFP-CNR Milano to the ASDEX Upgrade team in the main seminar room.

Since the beginning of this year the weekly ASDEX Upgrade operation meeting (during campaigns every Monday 9:00) from the main seminar room is broadcasted in the internet in order to allow all external collaborators to follow the experimental work as close as possible. In this meeting, which is chaired by the ASDEX Upgrade project leader, the first analysis of experimental results from the previous week are presented by the respective scientific coordinators.

In the second part the programme for the coming experimental days is defined. Thus this meeting is well suited to gain an overview about the current scientific work. For scientific coordinators it is the forum to bring forward their experimental proposal which in the case of acceptance will be scheduled for the next operational days.

Participation in this weekly video conference is possible via the H.323 standard as well as via VRVS. Technical details for participation can be received via email by subscribing to the mailing list 'aug-remote' (see http://www.aug.ipp.mpg.de/wwwaug/ for subscription details).

ASDEX Upgrade Letter
published by
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