ASDEX Upgrade Letter

No. 11/April 2010

Foreword

With this issue of the ASDEX Upgrade letter, we are pleased to give an overview of our present shutdown activities as well as our plans for the coming campaign, which is scheduled to begin in autumn 2010. During this shutdown period significant upgrades are being made to the ASDEX Upgrade tokamak. For example, the first set of in-vessel coils is presently being installed and the ECRH system is being expanded. These upgrades will, to a large extent, drive the scientific programme of the next campaign, which will be organized by our new Task Force Leaders. Additionally, one of the ICRF antennas is being modified in an attempt to reduce the high-Z impurity influx from active antennae limiters. In the next campaign we will be able to asses the success of this modification and thus the proposed strategy to cure this problem.

Another major asset for the coming campaign will be the availability of the EZ4 generator, which has been back in operation since autumn 2009. This additional power will help us to further enlarge the operational space of the all-W ASDEX Upgrade. On this front we are optimistic since at the end of the 2009 campaign we already achieved new, record values of P/R; a topic which will be expounded upon in this letter.

While ASDEX Upgrade will continue to characterize the compatibility of ITER relevant scenarios with a metal wall, we also look forward to the start of JET operation with the ITER-like wall in 2011, where our operational expertise is being used to prepare this important step on the European stepladder. Together, these two machines should be able to provide a solid basis for the first wall material strategy in ITER and, looking to the future, also for DEMO.

Hartmut Zohm

Highlight
from a recent ASDEX Upgrade experiment

Record P / R values reached in the all-W AUG

Dissipation of the plasma heating power P is a formidable problem for fusion reactors. The power to be handled in future machines like ITER and DEMO will reach values of P / R between 20 and 50 MW/m, which is significantly higher than in most present day machines. Here, R is the major radius of the device and the ratio P / R is believed to be the relevant quantity for the characterisation of the power exhaust problem. The radiation of a substantial power fraction in the plasma edge and in the divertor by impurity radiation is the main concept being considered to reduce the power flux on the divertor tiles down to technically feasible values. With increasing heating power more and more power has to be radiated in the volume at the plasma edge and in the divertor. Unfortunately, this volume has the tendency to become smaller with higher edge temperatures. Therefore, the demonstration of discharges with high levels of edge and divertor radiation at high input power is of the utmost importance for the preparation of ITER and DEMO operation. At the end of the 2009 AUG campaign a total heating power of close to 20 MW (P/R = 12) was applied to a standard H-mode discharge (see fig. 1). This is a record value for AUG after the installation of its all-tungsten wall. In order to protect the divertor from excessive heat loads deuterium and nitrogen were puffed. The puff-rate of the latter was feedback-controlled by the signal T_{div}, which is closely related to the divertor temperature and thus to the target power load. When the heating power is ramped-up, more nitrogen is needed to keep the divertor temperature, T_{div}, at its preset value (see fig. 1). The normalized energy confinement stays close to H-Mode confinement, the concentration of tungsten does not exceed $2 \cdot 10^{-5}$ even in the phase with the highest power, and Z_{eff} remains throughout the discharge, below 2. Discharges of this type will be the target of much more detailed investigations during future campaigns, in which ITER relevant P/R values of close to 20 will become possible once the current ECRH upgrade is finished and ICRH is back to full performance with antennas that are compatible with the all-W AUG wall.

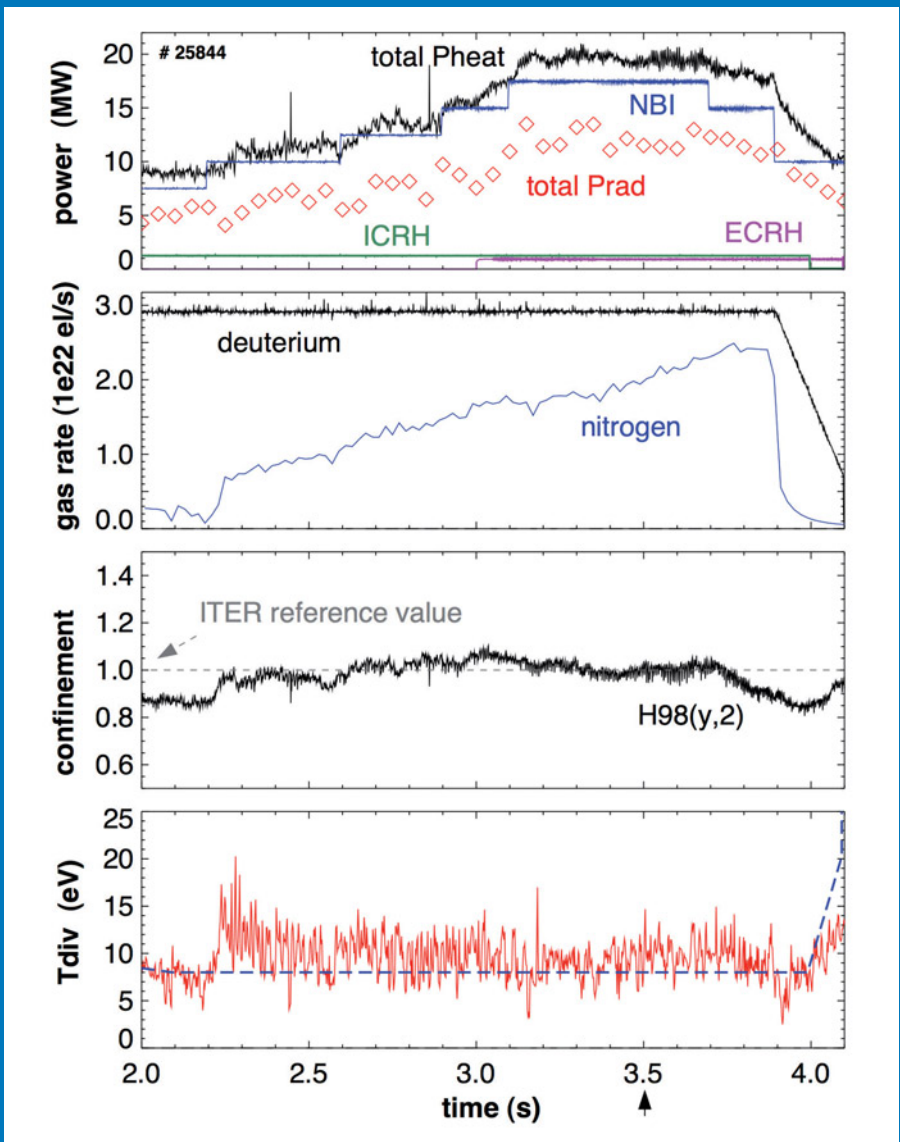

Fig. 1: Time-traces of AUG discharge #25844 (1.2 MA/2.5 T, low triangularity shape) for heating power, gas puff rate, H-factor and temperature T_{div} in the outer divertor.

Shutdown Activities & Outlook to the 2010 Campaign

Currently, AUG is in a shutdown phase that is devoted to two major alterations:

(i) In AUG a highly flexible, active set of 3x8 in-vessel saddle coils will be installed in a stepwise manner. These coils will be capable of producing non-axisymmetric error fields with toroidal mode numbers up to n=4. Such a system is foreseen for ITER with a coil geometry very similar to that chosen for AUG. In the first step, which is currently being implemented, 4 coils above and 4 coils below the midplane will be installed, allowing a field structure up to n=2 with odd or even poloidal parity. These coils will have DC power supplies and can be used to produce error fields for ELM control, disruption mitigation and other experimental applications.

(ii) The ECRH-II system is currently undergoing an upgrade to a total available power of 4 MW (in 2011) operating at 2 frequencies (105 and 140 GHz). This system allows for strong electron heating and, together with the installed fast steerable antennae, the study of the avoidance of impurity accumulation by central heating, feedback control of performance limiting NTMs, disruption avoidance and also support for the CTS diagnostic. In addition, q-profile shaping via the application of ECCD will become possible for the development of Hybrid and AT scenarios. From the very start of the 2010 campaign, three 1 MW/10s gyrotrons are expected to be available.

The start of the 2010 campaign is foreseen for September 2010. Most likely it will continue into 2011 and presumably, operation will stop at the end of February 2011 to allow the installation of the next 8 internal coils. The process of preparing the 2010 AUG scientific programme began in the end of March 2010 with an open call for participation.

The programme is organized into five Task Forces (TF):

- Improvement of H-mode and integrated scenarios
- Pedestal physics including tolerable ELMs
- SOL & Divertor physics and first wall materials
- MHD instabilities and their active control
- Transport

The TF IV ‘MHD instabilities and their active control’ will be lead by a scientist from FZ-Jülich. The management of AUG Task Forces by non-IPP scientists for periods of two years has been a tradition since 2004 and demonstrates the successful integration of external collaborators, in particular from European Associations, into the AUG programme.

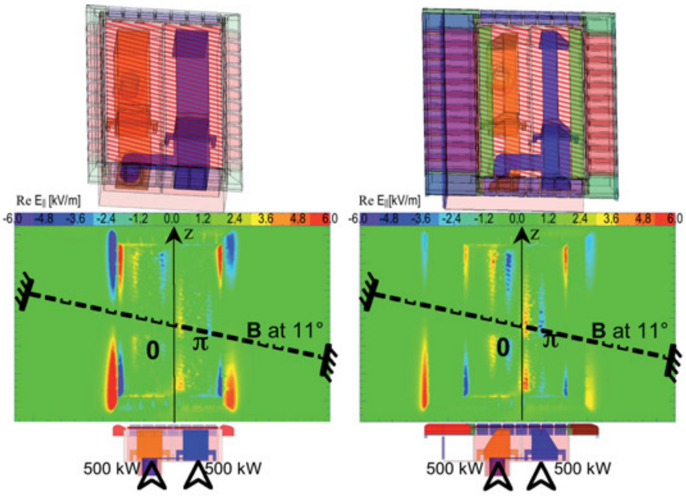

Fig. 2: Contour plots of Re ($E_{||}$) for the current AUG 2-strap antenna (left); and for an modified design of a 2-strap antenna with broad limiters and reduced $E_{||}$ fields (right).

A modified antenna to test the design approach for improved ICRF operation in the all-W AUG

The performance of the ICRH in the all-W AUG is considerably poorer than it was when AUG was a low-Z walled machine. Although ICRH was very useful during AUG’s transition phase from a carbon to a W machine as a central heating method to avoid density peaking and impurity accumulation, the use of ICRF heating is now hampered by ICRF-related impurity sources produced at the W-coated plasma facing components close to the antennas. Since the installation of W-coated antenna limiters, ICRF heating is accompanied by a strong W release, which obliterates the beneficial effect of the central heating. This impurity release is thought to be produced by the acceleration of light impurity ions along magnetic field lines in the rectified electric antenna near-fields ($E_{||}$). Although this W source can be reduced by increasing the antenna to plasma distance or by a higher gas puff rate, the ICRF antenna itself needs to be optimized in order to demonstrate the compatibility of ICRF with a high-Z wall in a tokamak. The optimization involves reducing the parallel electric fields ($E_{||}$) near the antenna, which can be calculated with a commercial code (HFSS, **H**igh **F**requency **S**tructure **S**imulator). To test this approach a cost effective antenna modification, with only modest hardware changes, will be installed in one of the four ICRF antennas (antenna 4, sector 12) during the present shutdown. The design with lower $E_{||}$ values is shown in figure 2 (r.h.s.) together with the current AUG ICRF antenna (l.h.s.) for reference. The modifications concern mainly the limiters (considerably broader), and the antenna straps (narrower). The calculated reduction of $E_{\parallel}$ is roughly a factor 2 (see fig. 3). Experiments in the coming 2010 AUG campaign will characterize the performance of this modified antenna. Experiments which show a reduction of the W source during ICRF heating would validate the applied modelling approach. The same approach could then be used for designing advanced antennas with more significant reductions of $E_{\parallel}$.

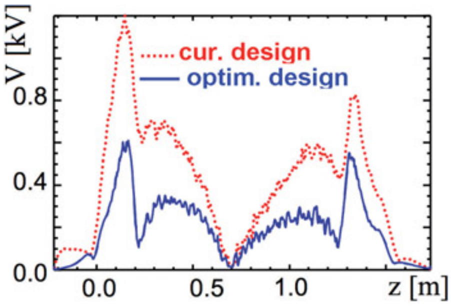

Fig 3: Voltage obtained by integrating the electric field along the field lines passing in front of the antenna as a function of the ordinate z of the field line at the middle of the antenna.

Re-integration of flywheel-generator EZ4 into the AUG power supply system

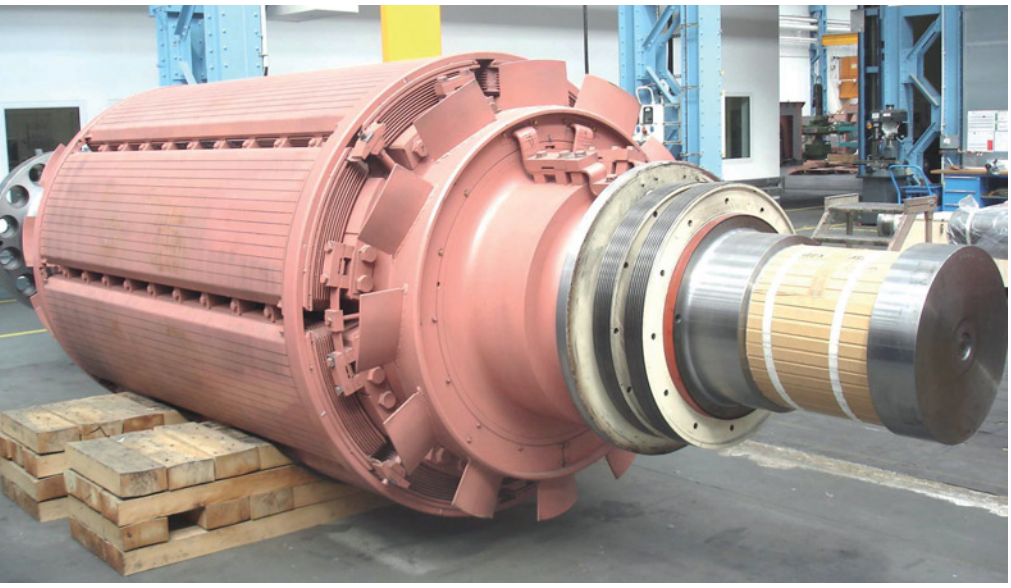

Fig. 4: Repaired rotor of flywheel generator EZ4 (220 MVA / 650 MJ, 160 tons).

In April 2006 an incident with the flywheel generator EZ4 led to serious damage of the device (AUG letter No. 9). EZ4 is one of three generators used on AUG to supply the ohmic transformer as well as the poloidal field coils and additional heating systems. This incident with EZ4 gave rise to the need of a safety review of all three generators. Based on recommendations from external experts many improvements in the control, instrumentation, protection, and the auxiliary systems of the flywheel-generators were made. These improvements were done in parallel to the repair of the EZ4 rotor and the reconstruction of the stator at SIEMENS Dynamowerk, Berlin. Additional electrical braking systems were implemented for the EZ2 and EZ3 generators. Furthermore, the electrical supply of the EZ4 oil lubrication pumps has been improved. It includes now one DC-pump with its own battery, which extends the emptying time of the top oil tank to 30 minutes. An additional future safety measure is the installation of a mechanical brake for EZ4, which will be commissioned in early 2011. It consists of a 7 MW hydraulic dynamometer and a 40 kNm disc-brake. The required water cooling system, including a 15 m^3 tank for storing 1800 MJ of energy and the 15 tonnes support structure for the braking unit, are being installed during the 2010 shutdown. Also, the technical basis for the control of all flywheel generators from a single room has been established. This data acquisition and visualisation centre will help to identify emerging faults earlier and to react faster and more efficiently in cases of operational problems.

Since October 2009 AUG has made use of its full generator capability, which extends the AUG operational space towards longer pulse lengths, more heating power (see highlight of this letter) and more highly shaped plasmas.

ASDEX Upgrade Letter
published by
Max-Planck-Institut für Plasmaphysik
Association Euratom-IPP
Boltzmannstraße 2
D-85748 Garching

Coordination Prof. Dr. Hartmut Zohm
Contact Dr. Josef Schweinzer
Phone +49/89/3299 22 05
Fax +49/89/3299 25 80
josef.schweinzer@ipp.mpg.de
www.ipp.mpg.de

PDF copy of letter available at:
http://www.ipp.mpg.de/ippcms/eng/for/publikationen/letters/download/aug_letter_4_10.pdf

IPP
MAX-PLANCK-GESELLSCHAFT
HELMHOLTZ GEMEINSCHAFT