ASDEX Upgrade LETTER

Max-Planck-Institut für Plasmaphysik

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IN GARCHING FOR EUROPE – FUSION RESEARCH WITH GERMANY'S LARGEST TOKAMAK DEVICE

CAD DRAWING: T. LUNT

Prof. Dr. Ulrich Stroth, Head of IPP's new »Plasma Edge and Wall« division, see page 3.

PHOTO: UNIVERSITY OF STUTTGART

EDITORIAL

After the successful start of the experimental campaign in March it is our pleasure to inform you with this issue of the ASDEX Upgrade Letter about the experimental plans and the modifications and improvements which have been carried out during the shutdown in 2011. ELM mitigation without a loss of confinement quality was an important achievement in the previous campaign obtained using two rows of four magnetic field perturbation coils. With the extension of the configuration to 2×8 coils and higher possible mode numbers, the parameter space for ELM suppression and the effect of the perturbations on the plasma edge and transport will be explored in a wider parameter range. With a newly installed core Doppler reflectometer, an ultra-fast sweeping reflectometer and correlation reflectometers contributed by collaboration partners, the capabilities to study turbulent transport from the SOL to the core will be substantially enhanced. The path-breaking development of a solution for the wall materials of future devices is consistently pursued by the installation of steel coated tiles as a first test of a new material for the first wall. Studies on impurity transport from the divertor and the wall to the plasma core will be strengthened by new CXRS systems and an ITER prototype spectrometer. In order to concentrate the investigations of the physical processes in action between the plasma edge and the material walls, the new department Plasma Edge and Wall (E2M) has been formed. As the department head of E2M and jointly with the ASDEX team I am looking forward to exploit together with our international partners the ASDEX Upgrade facility and the numerous diagnostics upgrades in order to advance our understanding of fusion plasmas and to further prepare the future devices ITER and beyond.

ULRICH STROTH

Highlight from a recent ASDEX Upgrade experiment

ELM mitigation bears fruit

Studies for future fusion power plants based on the tokamak principle show that at high central pressure, the temperature in the core plasma would reach values in excess of the optimum for deuterium-tritium fusion, if operation below the empirical Greenwald density limit is assumed. When gas puff fuelling is used in present-day tokamaks, density profiles become flat and are restricted to values below this limit. The latter is considered to be a limit of the plasma edge density and should not impose a restriction on the core density. Pellets made from frozen solid fuel, injected deep into the plasma in present devices, are the prime candidate for improving core fuelling. However, in reactor-relevant H-mode scenarios, pellet injection showed low fuelling efficiency as a result of ELM triggering.

Only recently, this obstacle was overcome at ASDEX Upgrade by external magnetic perturbations suppressing strong type-I ELMs. Such magnetic perturbations with n=2 have been found in ASDEX Upgrade to result in reproducible and robust ELM mitigation in a wide heating power and safety factor range. ELM mitigation is established for densities above a critical threshold; so far it has not been possible to distinguish whether this requirement corresponds to an edge collisionality threshold or a critical fraction of the Greenwald density limit. Once the mitigation regime is properly established, type-I ELMs completely disappear and are replaced by small ELM-like events. ELM mitigation persists in a high-density, high-collisionality regime even with the strongest perturbations applied, such as pellets.

When the latter are injected into ELM-mitigated plasmas, they do not trigger ELM events, unlike when injected into unmitigated type-I ELMy reference plasmas. The absence of ELMs results in improved fuelling efficiency leading to persistent density build-up. Strong pellet fuelling can be applied to access high-density scenarios beyond the limit encountered with pure gas puffing. No deleterious impact is found on MHD activity, plasma rotation or impurity transport. Notably, the pedestal parameters such as density (see graphic), temperature, pressure and rotation profiles remain virtually unchanged. Reliable and reproducible operation at line-averaged densities from 0.75 up to 1.5 times n_{GW} (core densities of up to 1.6 times n_{GW}) has been demonstrated when using pellets at ASDEX Upgrade.

P. LANG

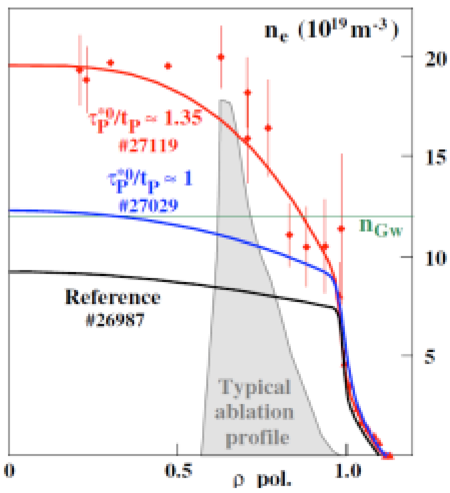


FIGURE: P. LANG

Radial density profiles in a phase with strong ELM suppression by magnetic perturbation for gas puff fuelling (black) and for pellet fuelling at frequencies of 35 Hz (blue) and 47 Hz (red). The region of particle deposition by an ablating pellet is shown as well.

EUROPE PARTICIPATES

A call for participation in the 2012 ASDEX Upgrade campaign was launched in the second half of 2011. This call was answered by a total of 101 (48) scientists submitting 215 (62) experimental proposals and requesting 2081 (693) discharges. The numbers in brackets correspond to the contributions by non-IPP scientists. Particularly impressive is that the number of external authors (48) from 14 EU Associates who submitted proposals is almost as high as that for IPP (53). In addition, we received proposals from IPP Greifswald, University of Stuttgart, ITER-IO, JAEA and US labs.

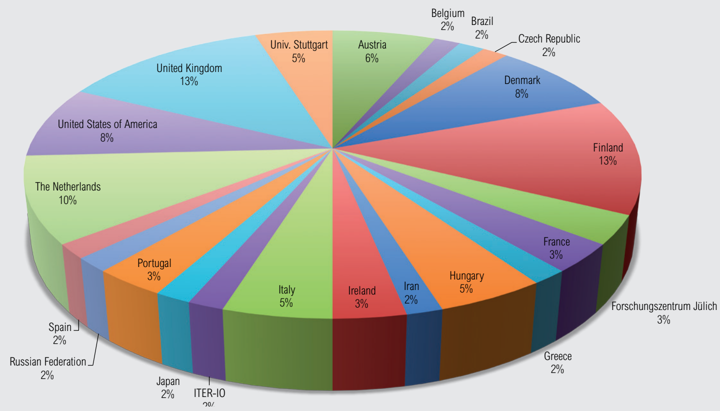


FIGURE: J. SCHWEINZER

Shutdown and hardware installations in 2011

ASDEX Upgrade is improving

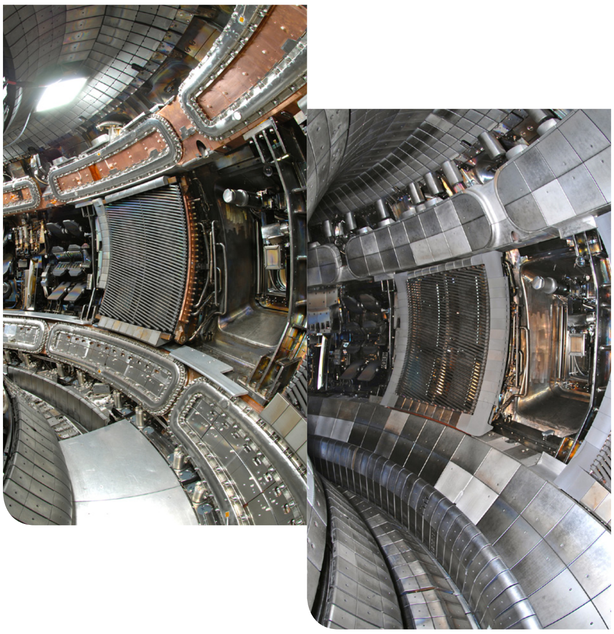
The in-vessel inspection immediately after the vessel's re-opening in August 2011 showed the machine to have a very good status. Local surface modifications and melting were observed only at leading edges of B-coil and inner-column protective components and on two out of 128 tiles of the outer divertor. A main concern, however, is the significantly increased number of high-power arc tracks in the vicinity of the passive stabilizing loop (PSL).

In September the remaining 2×4 B-coils were installed and the conditioning of the PEEK insulation separating the vessel potential of the current feed-through from the PSL potential of the coil casing was done by applying a routine baking procedure in November 2011.

The shutdown was also used to improve existing and install new diagnostics. A few diagnostic modifications were also necessitated by conflicts with the B-coils. The re-wiring for the reflectometry antennas and the installation of a new re-entrance port for the vessel viewing system required major effort. A total of three valves for disruption mitigation were installed – one at the low-field side, two at the high-field side behind the protection of the central column, toroidally separated by about 160°. A set of seven magnetic pick-up coils and four saddle coils for locked-mode detections were installed at the high-field side.

The investigation of ion temperatures in front of the ICRH antennas is supported by a new permanent retarding-field analyzer mounted on a magnetic drive near the mid-plane connected along the magnetic field to the broad antenna limiter. The CXRS diagnostics were completed by two new systems on the high-field side. In addition, a new Li-beam observation for fluctuation measurements and a test system for multiple-pass Thomson scattering were installed. Other newly installed diagnostic systems are an upgraded Doppler reflectometer with steerable k-value, a poloidal FIDA system, an ITER prototype CXRS spectrometer, new bolometer lines of sight, and a FADIS switch for in-line ECE. In-vessel work was finished with the closing of the entrance port on Friday, 20 January 2012.

J. SCHWEINZER



The interior of ASDEX Upgrade during the 2011 shutdown; left: during the installation of upper and lower B-coils, right: same view in the final stage of the shutdown. B-coils are now protected with tungsten-coated carbon tiles.

PHOTO: V. ROHDE

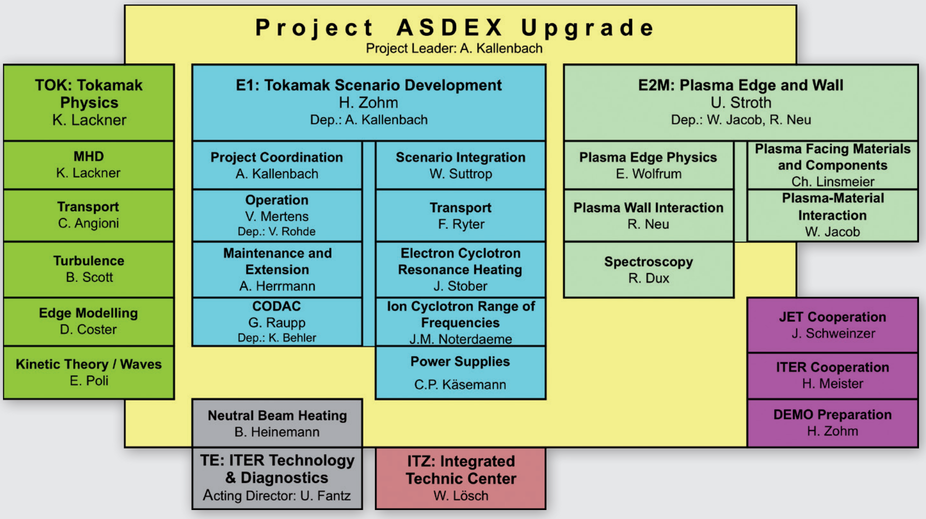
ASDEX Upgrade project structure

E2M – a new division established

Since the last ASDEX Upgrade Letter, there have been important changes in the ASDEX Upgrade project structure. In 2011 a new division, »Plasma Edge and Wall« (E2M), was formed by merging the two former divisions, Tokamak Edge and Divertor Physics (E2) and Materials Research (MF). The new division is headed by Prof. Dr. Ulrich Stroth, who left the Institut für Plasmaforschung of the University of Stuttgart to become a member of the Max Planck Society. Professor Stroth was born in 1957 in Erbach im Odenwald. After studying physics at the Technical University of Darmstadt and taking his PhD at the Laue Langevin Institute in Grenoble, from 1987 he was with IPP Garching for twelve years. His new »Plasma Edge and Wall« division explores dynamics and transport processes in fusion plasmas as well as processes in first-wall materials. In this way, the E2M division conducts interdisciplinary research in these fields and Prof. Stroth has started his second career at IPP with the goal of bridging the gap between fusion-oriented plasma physics and materials research.

Thus, since January 2011 the two divisions, Tokamak Scenario Development and Plasma Edge and Wall, are the main experimental units pursuing the ASDEX Upgrade project. The overview shows not only their substructure, but also all other departments contributing to the ASDEX Upgrade project with some of their activities.

For more than a year the ASDEX Upgrade project has been headed by Prof. Dr. Arne Kallenbach as successor to Dr. Otto Gruber, who had managed the ASDEX Upgrade project since 1996 with a high level of commitment and great skill, making ASDEX Upgrade one of the most successful tokamak experiments worldwide. The transition from Dr. Gruber to Prof. Kallenbach went smoothly and the scientific results of 2011 prove that the standing of ASDEX Upgrade in the international



The ASDEX Upgrade project with all IPP divisions involved and their substructure.

FIGURE: J. SCHWEINZER

fusion community has been maintained under the new leadership.

What has not been changed is the scientific structure of the five task forces which co-ordinate the programme and prepare the experimental campaigns in conjunction with the project leader. The ASDEX Upgrade team is grateful to Forschungszentrum Jülich for the fact that also in 2012 task force IV, MHD instabilities and their active control, will be headed by one of their leading scientists.

J. SCHWEINZER

Campaign and midterm planning

Outlook for 2012

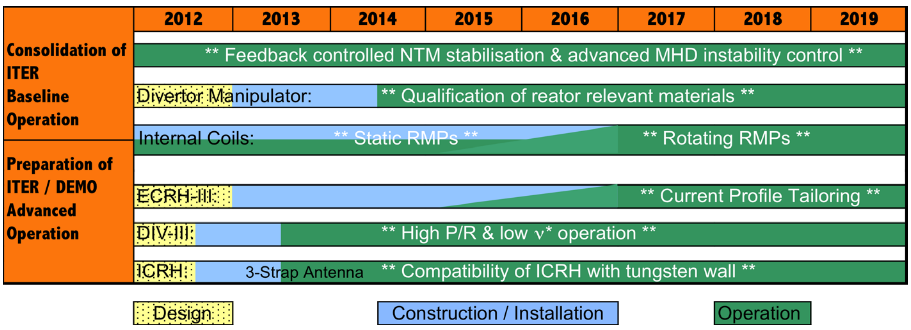
The major enhancement of the ASDEX Upgrade hardware available in 2012 is another set of eight magnetic perturbation coils, completing the B-coil set above and below the mid-plane to a total of 16 coils. These coils will allow studies with magnetic perturbations up to n=4. In addition, a second DC power supply has been installed to allow more flexible coil configurations. Two ICRF antennas have received boron-coated limiters to reduce tungsten sputtering during their operation. In addition to having ICRH back as a reliable heating method, further insight is expected into the role of near-antenna tungsten sources in comparison with remote tungsten sources from locations connected to the antenna by field lines.

After a call for participation in the 2012 ASDEX Upgrade campaign and its discussion and iteration with the ASDEX Upgrade team, a prioritized programme was compiled and finally endorsed by the ASDEX Upgrade Programme Committee at a meeting in Garching at the end of November 2011. Plasma operation started on 1st March 2012. Participation by external scientists will be encouraged from April onwards. The campaign is planned to last roughly till the end of 2012.

At the beginning of 2013 another vent is scheduled for installation of a solid-tungsten divertor (DIV-III) and possibly two new three-strap ICRF antennas.

Further mid-term upgrades planned are replacement of the old ECRH I system by two-frequency, long-pulse gyrotrons (ECRH III, completion planned for 2016) and eight mid-plane coils (A-coils) with AC capability up to three kHz for improved ELM mitigation, rotating field studies and potentially-resistive wall mode stabilization.

J. SCHWEINZER



Current planning of major hardware upgrades of ASDEX Upgrade.

FIGURE: J. SCHWEINZER

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