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Institute for Magnetic Fusion Research

WEST

Newsletter N°30 - December 2023

Best wishes !

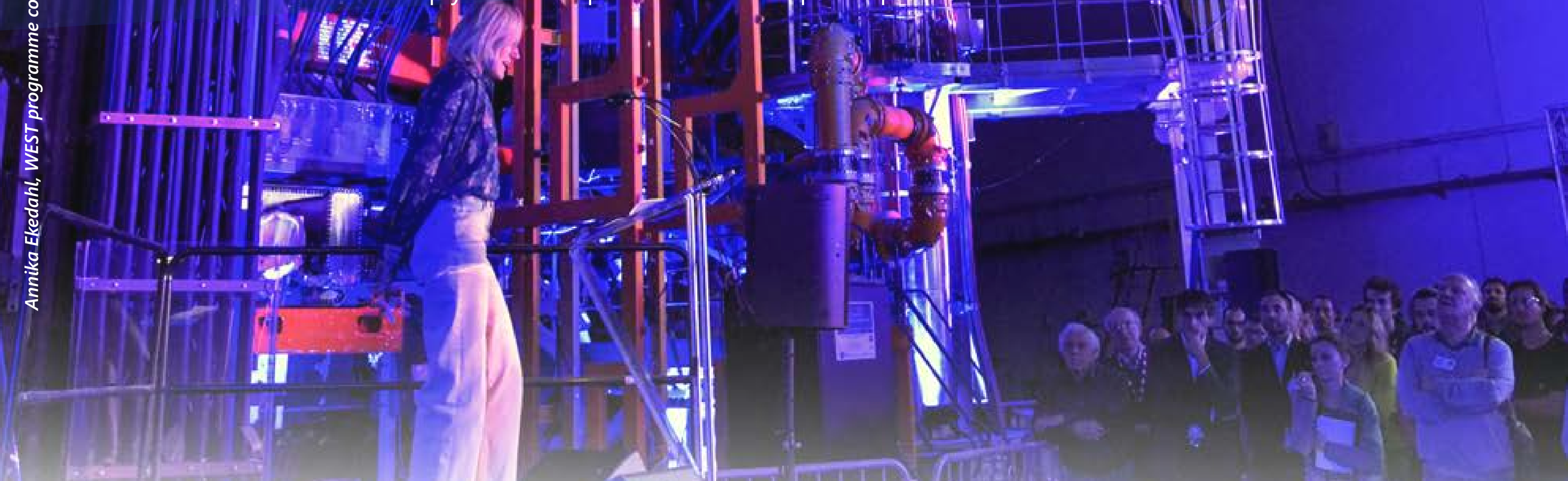
The complete ITER-grade divertor enters the scene

On 6 June, IRFM employees, retirees, colleagues from CEA and Iter Organization, representatives of the state and the region, industrial partners, journalists, all gathered to celebrate the first experimental campaign of the WEST tokamak, with its complete divertor of ITER technology. This experimental campaign marked the start of a new phase in the life of the WEST tokamak, full of promises of unprecedented results for ITER and future fusion power plants.

The production and the installation of the fully actively cooled ITER-grade Plasma-Facing Units (PFUs) for the WEST lower divertor (i.e. 456 PFUs in total) was successfully completed in 2021. The collaboration between IRFM and ASIPP under the SIFFER partnership was decisive for their production in China, whose manufacturing process involves several critical steps. The European agency Fusion for Energy (F4E) also supplied several components.

The new divertor has been aligned with extreme precision. The bearing surface of the support structure was machined to a tolerance of 0.05 mm and the vertical alignment was checked by 3D metrology (and corrected if necessary) using a robotic laser arm before and after welding the water manifolds. The PFUs therefore comply with the specification: 0.3 to 1.0 mm gap between PFUs, with a maximum relative vertical misalignment of 0.3 mm. Numerous diagnostics have been integrated into the ITER-grade PFUs, such as innovative temperature sensors, which will enable comprehensive testing for ITER application.

Between December and April, the new divertor was exposed to plasma heat and particle loads and performed perfectly. This initial campaign sets the stage for upcoming long pulse operation campaigns at higher power and different divertor plasma regimes. These endeavours will allow us to test the actively cooled plasma-facing components for ITER and to carry out studies on the plasma-wall interaction, bringing us closer to the constraints associated with long pulses in fusion power plants.



Annika Ekedahl, WEST programme coordinator, during the ceremony

The role of WEST in the EUROfusion WPTE programme

WEST holds a distinctive role in the EUROfusion Work Package Tokamak Exploitation (WPTE) programme, standing alongside JET, ASDEX Upgrade, TCV and MAST-U as one of the five European tokamaks in operation.

WPTE is coordinating the experiments on five large and medium-sized tokamaks: JET (until the end of 2023), ASDEX Upgrade, MAST-U, TCV, and WEST. WEST has a unique role to play in this programme, as it is the only tokamak capable of long, quasi steady-state discharges in an all-tungsten environment, with divertor plasma facing components manufactured using ITER technology.

During the Spring 2023 campaign, WPTE focused primarily on studying the behaviour of ITER-grade tungsten Plasma-Facing Units (PFUs). In particular, a dedicated divertor PFU sector with a pre-damaged component was installed to monitor its evolution throughout a high power campaign. This 14-week campaign not only enabled the CEA to meet its commitments to EUROfusion, but also to host a large number of collaborators, achieve a major milestone with a 100-second long plasma and successfully conclude the first high fluence campaign by exposing the new ITER-grade divertor to a cumulative flux of particles equivalent to an ITER discharge.

Looking ahead, WEST will continue to explore plasma-wall interaction issues at high particle fluence in an all-W environment in preparation for the operation of ITER, a quest that WEST can achieve over a reasonable operating period thanks to its long pulse capability, which is unique among WPTE devices.

WEST Science — Energetic particles physics

WEST contributes to energetic particle research in preparation for burning plasmas experiments.

Energetic particles (EPs) are extensively studied in current fusion experiments. Several reasons motivate these efforts. Runaway electrons, which are sometimes generated during disruptions, get a lot of attention because of the potential threat they pose to the integrity of the vacuum vessel (see WEST newsletter #27). EP losses contribute to heat fluxes on the plasma facing components (PFCs). In devices with metallic walls, fast ions and electrons impinging the PFCs can contribute to material sputtering, and therefore to plasma impurity contamination. In the core of the discharge, EPs can trigger instabilities: fishbones, various Alfvén eigenmodes, cetc. While instabilities are often associated with deleterious effects, it has been established that the presence of energetic ions can result in an improvement of the global confinement, possibly mediated by the EP instabilities themselves. In preparation for burning plasma experiments, including ITER, it is therefore necessary to characterize EPs and their effects as extensively as possible.

WEST plasmas contain significant populations of energetic particles originating from its radiofrequency (RF) systems. Fast ions are massively generated by the ICRF (Ion Cyclotron Resonance Frequency) heating system while a substantial population of energetic electrons is driven by the LHCD (Lower Hybrid Current Drive) system, and will be further reinforced by synergy with the EC (Electron Cyclotron) waves since a new EC system should be available from 2024. In Tore Supra, EP effects have been studied in the past: particle losses caused by the magnetic ripple, fishbones destabilized by energetic electrons, ion-driven Alfvén eigenmodes, etc. In WEST, the upgraded capabilities of several diagnostics systems have already made it possible to observe EP-driven instabilities (see figure 1). In upcoming campaigns, EP physics will be investigated in WEST as an essential part of its scientific programme in relation to plasma heating and confinement, as well as with material resilience issues. As such, WEST is one of the active tokamaks contributing to this field of study, which will be crucial to the successful operation of JT-60SA, ITER and other future fusion devices.

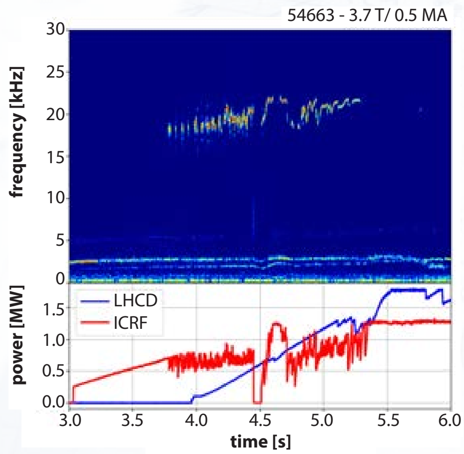


Figure 1 : Instability measured by the MHD Mirnov coils during ICRF operation in WEST pulse 54663 (top : spectrogram, bottom : RF power). This mode, with a frequency around 20kHz, is identified as a BAE (Beta-induced Alfvén eigenmode).

A new 3 MW steady-state ECRH system for WEST

The new ECRH system is expected to deliver a power of 3MW/1000s at a frequency of 105 GHz, and should start operating with the first gyrotron in autumn 2024.

The main objectives of WEST's new ECRH system are to increase the margin to reach the H-Mode and to control W-impurities in the plasma. The previous Tore Supra ECRH transmitter was equipped with two 118 GHz gyrotrons. With the modifications from Tore Supra to WEST, simulations at a magnetic field of B0~3.7T and a central density of ne0~6.1019 m-3 show that the optimum frequency for a central absorption is now 105GHz.

For this purpose, a 105GHz 1MW gyrotron (TH1511) has been designed at KIT (Karlsruhe Institute of Technology, Institute for Pulsed Power and Microwave Technology) in 2021, based on the technological design of the 140 GHz 1.5 MW gyrotron for W7X (TH1507U). The gyrotrons are being manufactured by THALES and the first is currently being test at KIT's FULGOR test stand in order to validate the RF design. In parallel, the integration of the auxiliaries (cryo-magnets, RF components, etc.) and the design of the control of all the components are under way. The previous Tore Supra Antenna has been modified to meet the new requirements and is now installed in WEST, awaiting connection to the gyrotrons.

ECRH antenna installed in WEST

cea irfm

Institute for Magnetic Fusion Research
DRF/IRFM
CEA Cadarache 13108 Saint Paul lez Durance Cedex France

+ info
http://west.cea.fr
Contact : Sylvie Gibert
sylvie.gibert@cea.fr