Institute for Magnetic Fusion Research

WEST

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Waiting for C4

After an exciting C3 experimental campaign that ended last December, WEST is in shutdown to prepare the next scientific experiments.

During the C3 campaign, two major milestones were achieved: 5 MW of additional power in view of H-mode operation and 30 s of plasma duration.

As expected, the boronisation procedure (deposition of a ~100 nm boron layer on the plasma facing components surface) performed at the beginning of the campaign opened the operational window by reducing the light impurity radiation, in particular the oxygen which is gettered by the boron. Up to 5.5 MW of RF additional power were coupled to the plasma but did not, however, permit to reach the H-mode threshold yet.

For the first time, ICRH was injected with the new actively cooled antennas, with up to 1 MW coupled from a single antenna. The first EUROfusion experiments, focused on plasma edge physics, were successfully performed. In total, about 20 scientists from the international partners (EU, China, Japan, USA) were involved in the C3 campaign.

For the C4 campaign, the third ICRH antenna is being installed, completing the plasma heating system. The C4 objective is to reach 10 MW of RF coupled power. The divertor test sector has been equipped with 2 additional ITER grade Plasma Facing Units.

On the diagnostic side, the infrared monitoring system coverage is extended to the new ICRH antenna and further lower divertor sectors (66% coverage). In total, 12 infrared cameras will be operated in C4, including the very high resolution (100 μm) divertor view. ECE imaging diagnostic in-vessel mirrors were also installed.

Plasma restart is scheduled by the end of May.

ECE diagnostic in-vessel mirrors alignment with cross-line laser.

ECE imaging for the next campaigns

The installation of the ECE diagnostic developed with Korean laboratories reaches completion. This new diagnostic will provide images of electron temperature fluctuations to study MHD instabilities.

The ECE diagnostic collects the electron cyclotron emission coming from the plasma. On the Korean tokamak KSTAR, it provides precise observations of MHD modes (sawteeth, neoclassical tearing modes, Alfvén modes, fishbones, ELMs...) and plasma turbulence.

The KSTAR design was adapted to cope with WEST long duration plasma constraints: two in-vessel mirrors make the diagnostics first optics instead of an out-vessel composite lens on KSTAR. A compact optical enclosure was also built to house the beam forming lenses and the detector array. The enclosure fits in the 1 m space between the tokamak flange and the maintenance access lobby. It must therefore be lifted by crane at each maintenance period.

The in-vessel mirrors and the optical enclosure were installed on March 2019. A cross-line laser was used to align the in-vessel mirrors first and then the optical cubicle. Final assembly and testing of the complete diagnostic is scheduled in April-May 2019. The diagnostic will thus be in operation for the C4 campaign.

WEST Science

Tungsten signature

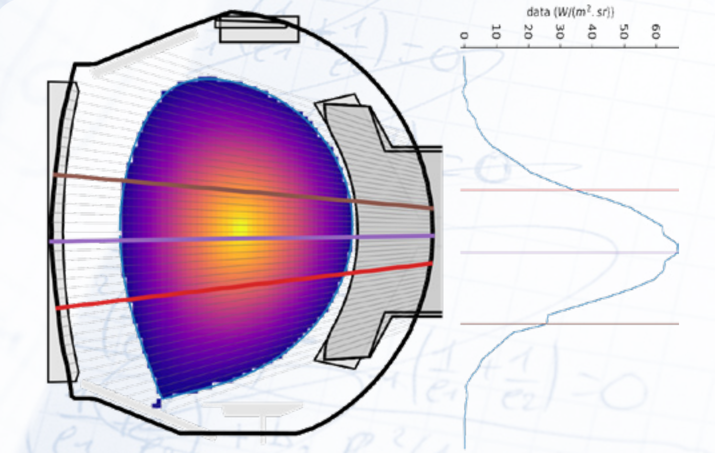
A fusion plasma, due to its high temperature, emits low-energy X-rays called Soft X-Rays (SXR).

This X-ray radiation comes from three different sources: mainly the Bremsstrahlung radiation, the radiative recombinations and the spectral lines, which have respectively a continuous, semi-continuous and the discrete spectrum. These components exist for each ionic species present in the plasma, and especially for the tungsten.

The SXR radiation thus conveys a wealth of information, as its local intensity depends on the local electron temperature and density, and on the density of each ion. These various dependencies make the SXR diagnostics «une pièce de choix» as the French say for studying MHD modes and impurity transport alike. But it comes at the cost of complex interpretation and sometimes uneasy disentangling of the role played by each component.

Measuring SXR is achieved by putting many semiconductor diodes around a poloidal cross-section and restraining their field of view to thin cones, approximated as lines of sight (LOS), using pinholes. The signal on each diode is proportional to the total SXR intensity, integrated along the LOS. From these spatially integrated measurements, one can then try to reconstruct the 2D SXR intensity field in the cross-section using inversion algorithms similar to the tomography techniques use in medical imaging.

The main scientific challenge is then to properly interpret this complex data. In WEST, SXR diagnostics will be extensively used to understand tungsten transport inside the confined plasma.



Tomographic reconstruction of SXR intensity in a WEST poloidal cross section (left) with a synthetic field peaked on the magnetic axis and all three highlighted LOS of the SXR diagnostics (right) corresponding to LOS-integrated signal.

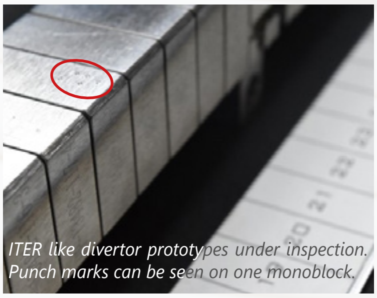
The 2 last ITER like PFU prototypes embarked on the test sector

These additional Plasma Facing Units (PFU) bring the number of PFU prototypes to 14 on the divertor test sector. All the potential suppliers of ITER divertor vertical target PFU are now represented for the last campaign of short pulse exposure.

The two additional ITER like Plasma Facing Units (PFU) have been provided by F4E, the European Domestic Agency in charge of procuring the ITER inner divertor target. The test sector is now fully equipped with 2 PFU from the Japanese Domestic Agency (2 suppliers), 4 from the ASIPP laboratory in China (1 supplier), and 8 from F4E (4 suppliers).

The test sector configuration has been optimized for the C4 campaign: PFU re-aligned, pre-damaged PFU shifted in position, groove machined in a monoblock for a melting experiment, punch marks for easier identification of monoblocks with the very high resolution IR camera.

In parallel, the ITER like PFU exposed during the C3 campaign were thoroughly inspected. Local melting/cracking has been observed on PFU leading edges due to misalignments. Optical hot spots have also been evidenced at the position where they are predicted to occur, showing that plasma flows within the 0.5 mm toroidal gaps between monoblocks. The evolution of the damages will be evaluated after the C4 campaign, with a particular focus on the impact of helium operation on tungsten components, planned at the end of the campaign.



ITER like divertor prototypes under inspection. Punch marks can be seen on one monoblock.

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