Institute for Magnetic Fusion Research

# WEST

Newsletter N°19 - December 2017

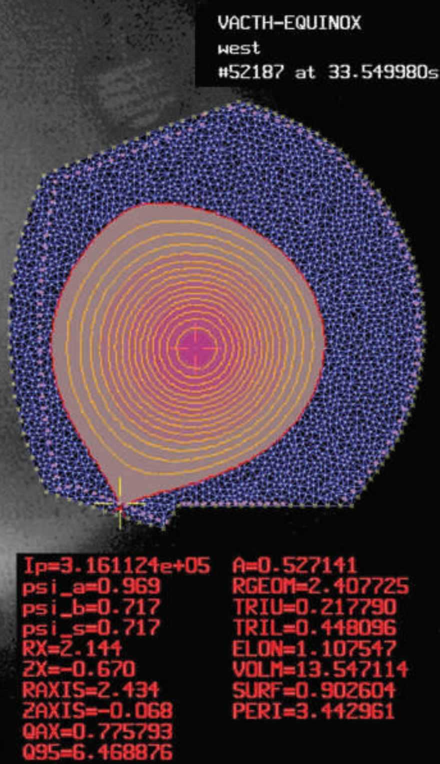

## WEST joins the family of Divertor Tokamaks!

**On the 18th of December current was raised in the divertor coils and the very first X-point plasma was obtained in the WEST tokamak.**

After the summer shutdown, plasma operations were resumed on the 24th of October. The modifications of the passive stabilizing structures were fruitful and the plasma current could be ramped above 50 kA promptly indicating a stable magnetic configuration. However at that stage most of the current was carried by runaway electrons. After an extensive vessel conditioning by deuterium glow discharge cleaning, a narrow window in neutral pressure was found and on the 8th of December the current could be raised in limiter configuration up to 500 kA and controlled during a couple of seconds. Afterwards, divertor coils entered into action and an X-point configuration was reached.

The experiments will continue until February 2018 when the machine will be stopped notably for the insertion of the ITER-like plasma facing unit provided by F4E.

This major milestone and collective result nicely conclude the 2017 activity of IRFM and the WEST members!




## Six European Plasma Facing Unit ready to be installed

**The ITER-like Plasma Facing Unit (PFU) prototypes for WEST divertor procured by F4E and manufactured by ATMOSTAT-ALCEN (France), CNIM (France) and Research Instruments (Germany) have successfully passed the reception tests.**

Six European PFU prototypes (two PFU by manufacturer) were delivered at IRFM in March 2017 and immediately took over for an adaptation for their integration into WEST divertor. The adaptation consisted first of equipping them with tube-to-tube multi-material (CuCrZr / Inconel / Stainless steel) transitions on both sides (including the insertion and the fixing of twisted tape inside the cooling tube). It will allow them to be connected to the hydraulic cooling system. Then four attachments in stainless steel (ANSI 316) have been inserted in the rear side of the monoblocks by mechanical machining of the "U-shaped" fixing geometry. Then they could be installed onto the dedicated steel supporting structure.

Afterwards, an extensive pre-characterization program (i.e. reception tests before plasma exposure) including High Heat Flux testing at IPP-Garching (GLADIS facility) has been successfully carried out.

The behavior and particularly the power handling capabilities of these F4E-PFU will be assessed under realistic tokamak conditions in WEST from experimental campaign C3 (2018).

***Stainless steel attachment.***

***Tube-to-tube multi material (CuCrZr/Inconel/stainless steel) heterogeneous transitions.***

# WEST Science — Plasma Startup recipe

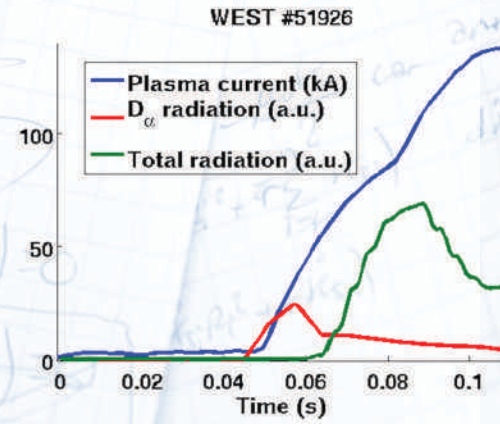
**Once routine operation is established in a tokamak, little attention is usually payed to plasma startup. The start of WEST reminds us of the complex physics involved and the fine tuning necessary.**

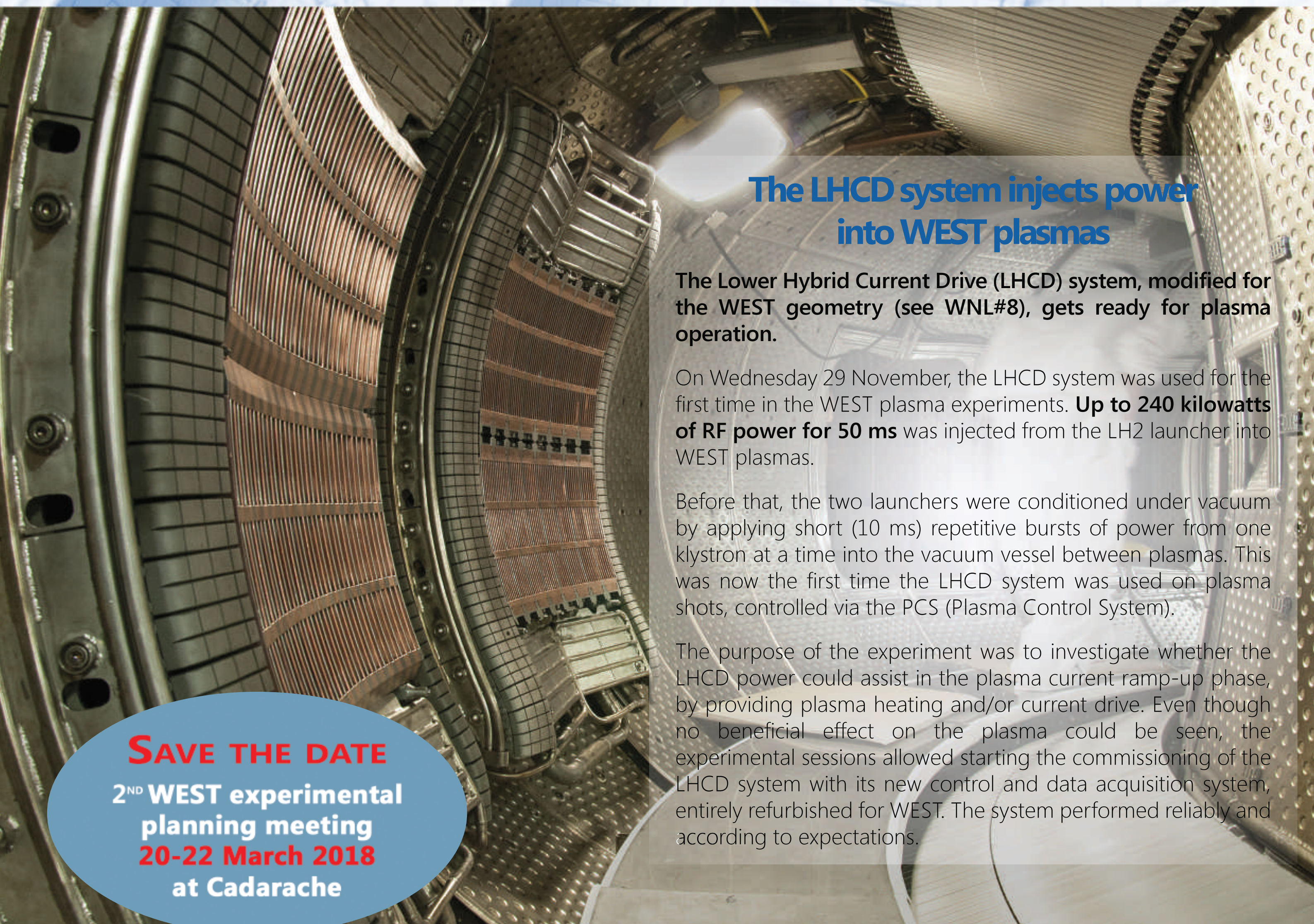
Broadly described, the recipe for plasma startup in a tokamak seems simple: first, inject a bit of gas in the vacuum vessel; then, apply a toroidal electric field by ramping fast the current in the central solenoid - this should turn the gas into a cold plasma by an ionization avalanche; finally, wait for the Joule effect to heat up the plasma, decreasing its electrical resistance, and... "Ting"! Your tokamak plasma is ready.

There are however some subtleties...
First, the ionization avalanche can occur only when the magnetic field is almost purely toroidal, otherwise electrons would be lost to the wall (by moving along field lines) too fast. Therefore, the poloidal magnetic field has to be minimized.
Second, as soon as the plasma starts to carry some current, force balance has to be guaranteed. In particular, the vertical magnetic field from the Poloidal Field (PF) coils has to be ramped up in proportion to the plasma current so as to balance the radial force that the plasma exerts on itself. The poloidal magnetic field should also guarantee plasma positional stability, both radial and vertical. All these requirements imply a fine tuning of the currents in the PF coils, all the more in the presence of in-vessel passive conducting components like in WEST.

But this is not the end of the story. Indeed, Joule heating may be annihilated by radiative cooling if the plasma contains too many impurities. A solution may be to decrease the amount of gas, which should reduce radiation, but then one runs the risk of creating runaway electrons, i.e. electrons accelerated up to the speed of light... All these obstacles have arisen in WEST, so it was a real relief when the first successful startup was obtained on November the 30th!

***The ionization of the deuterium gas is associated to a spike of Dα radiation (in red), alowing the plasma current (in blue) to start rising. Joule heating then increases the plasma temperature. An impurity radiation spike (in green) has to be passed for the startup to be successful.***



## The LHCD system injects power into WEST plasmas

**The Lower Hybrid Current Drive (LHCD) system, modified for the WEST geometry (see WNL#8), gets ready for plasma operation.**

On Wednesday 29 November, the LHCD system was used for the first time in the WEST plasma experiments. **Up to 240 kilowatts of RF power for 50 ms** was injected from the LH2 launcher into WEST plasmas.

Before that, the two launchers were conditioned under vacuum by applying short (10 ms) repetitive bursts of power from one klystron at a time into the vacuum vessel between plasmas. This was now the first time the LHCD system was used on plasma shots, controlled via the PCS (Plasma Control System).

The purpose of the experiment was to investigate whether the LHCD power could assist in the plasma current ramp-up phase, by providing plasma heating and/or current drive. Even though no beneficial effect on the plasma could be seen, the experimental sessions allowed starting the commissioning of the LHCD system with its new control and data acquisition system, entirely refurbished for WEST. The system performed reliably and according to expectations.

**SAVE THE DATE**
**2ND WEST experimental planning meeting**
**20-22 March 2018**
**at Cadarache**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