OPTIMIZATION OF LOWER HYBRID WAVE COUPLING FOR THE WEST LHCD LAUNCHERS

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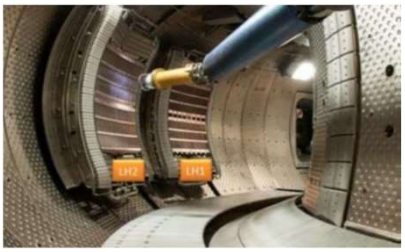
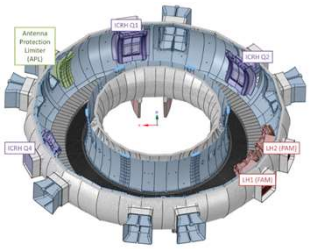
WEST LHCD launchers

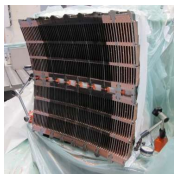




Full Active Multijunction launcher (LH1)
- $N_{//0}$ = 2 ± 0.3
- **Target : 4MW / 1000s**

Passive Active Multijunction launcher (LH2)
- $N_{//0}$ = 1.7 ± 0.3
- **Target : 3MW / 1000s**

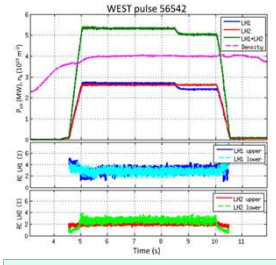
- Protections limiters: W-coating on CFC
- All antennas and APL can be moved radially between shots

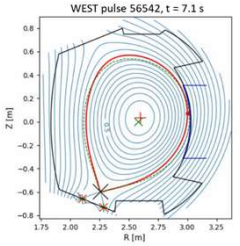


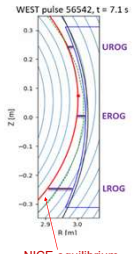
- LH1 launcher has been reshaped toroidally to match curvature of WEST plasmas, since WEST plasmas have smaller volume and launchers need to be moved inwards by ~ 15-20 cm
- 6 mm removed from the edge modules on LH1
- Reshaping not yet done on LH2

DELPECH, L., et al., Fusion Eng. Des. ***96-97*** *(2015) 452.*

Coupling in WEST plasma configuration







NICE equilibrium reconstruction

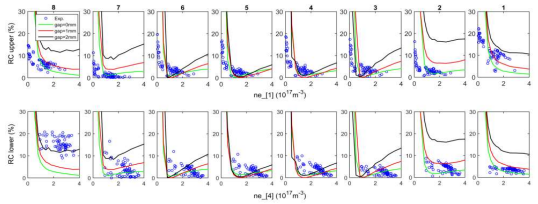
Main results in WEST:
- Max P_{LHCD} : 5.3 MW
- Max LHCD pulse duration : 51 s
- Max P_{add} : 8 MW (LHCD+ICRH)
- H-mode obtained with P_{Add} ~ 5 MW and fresh boronization ($f_{Prad,bulk}$ ~ 30%)

GONICHE, M., et al., this conference.
HILLAIRET, J., et al., this conference.

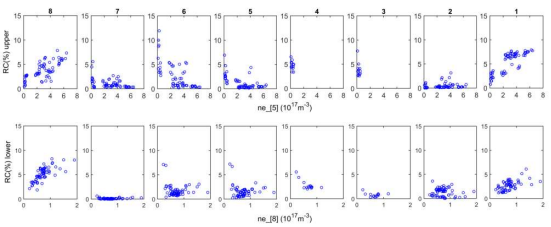
Plasma shape control :
- Feedback control of EROG (Equatorial Radial Outer Gap)
- Feedfoward control of **UROG** (Upper ROG) and **LROG** (Lower ROG) by tuning currents in the low field side coils from shot to shot

NOUAILLETAS, R., et al., Fusion Eng. Des. ***146*** *(2019) 999.*
FAUGERAS, B., et al., Fusion Sci. Technol. 69 (2016) 495-504.

Effect of toroidal shaping on LH coupling

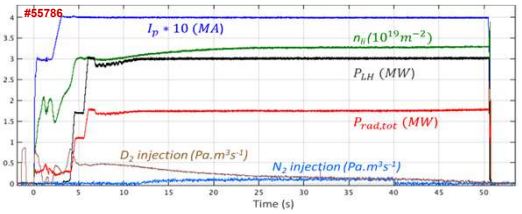


- Homogeneous behaviour of coupling on all modules on LH1: RC decrease on all modules for increasing density at grill.
- ➔ Density is homogeneous toroidally along the grill, i.e. toroidal reshaping has been efficient on LH1.
- ALOHA modelling using two density gradients (λ_1 = 1 mm; λ_2 = 15 mm) and different vacuum gaps (0 mm, 1 mm, 2 mm) shows reasonable agreement.



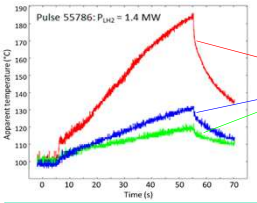
- Inhomogeneous behaviour of coupling on LH2: RC increases on edge modules, and decreases on central modules. This indicates that density is higher in front of edge modules.
- Consistent with the fact that LH2 launcher is not reshaped.

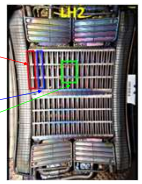
Heat load on launchers during long pulse operation

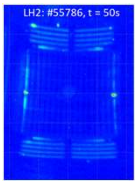


- Up to 55 s long discharges obtained
- Upper Single Null (USN) configuration
- 3 MW LHCD power: P_{LH1} = 1.6 MW & P_{LH2} = 1.4 MW
- V_{Loop} = 100 mV

LOARER, T., et al., Nucl. Fusion ***60*** *(2020) 126046.*





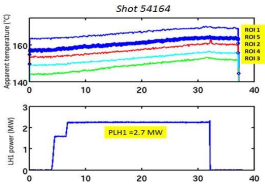


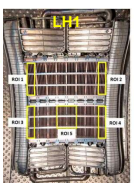
Apparent temperature (emissivity = 1.0) recorded by the IR system

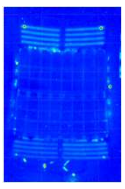
Emissivity ~ 0.2-0.4 for metallic surfaces ➔ real temperature is higher

COURTOIS, X., et al., Fusion Eng. Des. ***146*** *(2019) 2015.*

- Inhomogeneous temperature increase on LH2: Local heating on edge modules caused by electrons accelerated in front of the grill mouth. The electrons follow the field lines and end up on the edge of the launcher since toroidal shaping of grill is not matched to the plasma.
- ➔ Reshaping of LH2 will be carried out before next WEST campaign: ~ 2 mm will be removed from passive waveguides at the edge of the launcher, by in-situ operation.





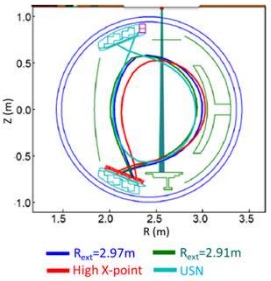


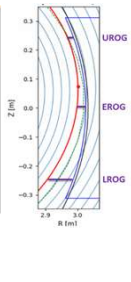
- Beneficial effect of reshaping of LH1 confirmed
- Homogeneous temperature increase on central and edge modules

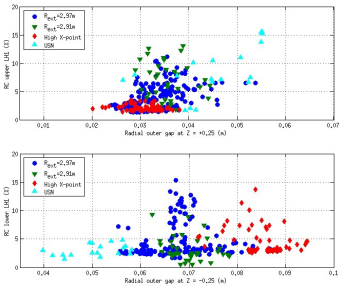
DELPECH, L., et al., AIP Conf. Proc. ***2254*** *(2020) 080004.*

Effect of plasma configuration on LH1 coupling

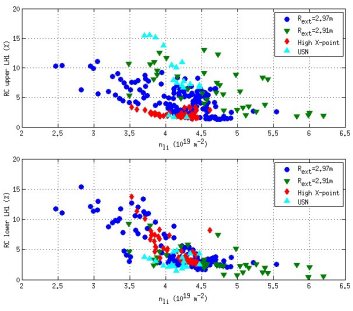
- Both Lower Single Null (LSN) and Upper Single Null (USN) configurations are used in WEST
- Positions of the LH launchers are adjusted to ~3-4 cm from R_{ext} (last closed flux surface at mid-plane)
- Four main configurations explored in 2019-2021 with different X-point height and location of R_{ext}

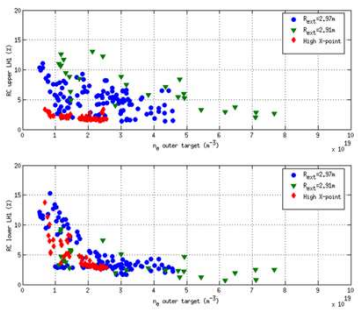






- Average reflection coefficient (RC) on upper and lower rows of LH1, plotted versus UROG and LROG, show that the coupling on upper and lower rows behave differently in different plasma configurations.





- Coupling on upper rows of LH1 is very sensitive to plasma configuration: best coupling is obtained for larger R_{ext} launcher position located at ~ 3.01 m.
- In contrast, coupling on lower rows of LH1 is less sensitive to plasma configuration. It seems to depend mostly on density, and less on plasma-launcher gap (as given by NICE equilibrium reconstruction).