High-Performance ECRH at W7-X: Experience and Perspectives

H.P.LAQUA, J. BALDZUHN, H. BRAUNE, S. BOZHENKOV, K. BRUNNER, M. HIRSCH, U. HOEFEL, J. KNAUER, A. LANGENBERG, S.MARSEN, D. MOSEEV, E. PASCH, T.STANGE, R. WOLF AND WENDELSTEIN 7-X TEAM
Max-Planck-Institute for Plasma Physics,Greifswald, Germany, laqua@ipp.mpg.de
N. PABLANT
Princeton Plasma Physics Laboratory 08543 Princeton, USA

ABSTRACT

The **second operation phase of W7-X (OP1.2)** showed the potential of exclusively ECRH-sustained plasma operations in stellarators, employing a multi-pass ECRH scenario in the second harmonic O-mode (O2-ECRH). **Three high performance scenarios** are reported here.

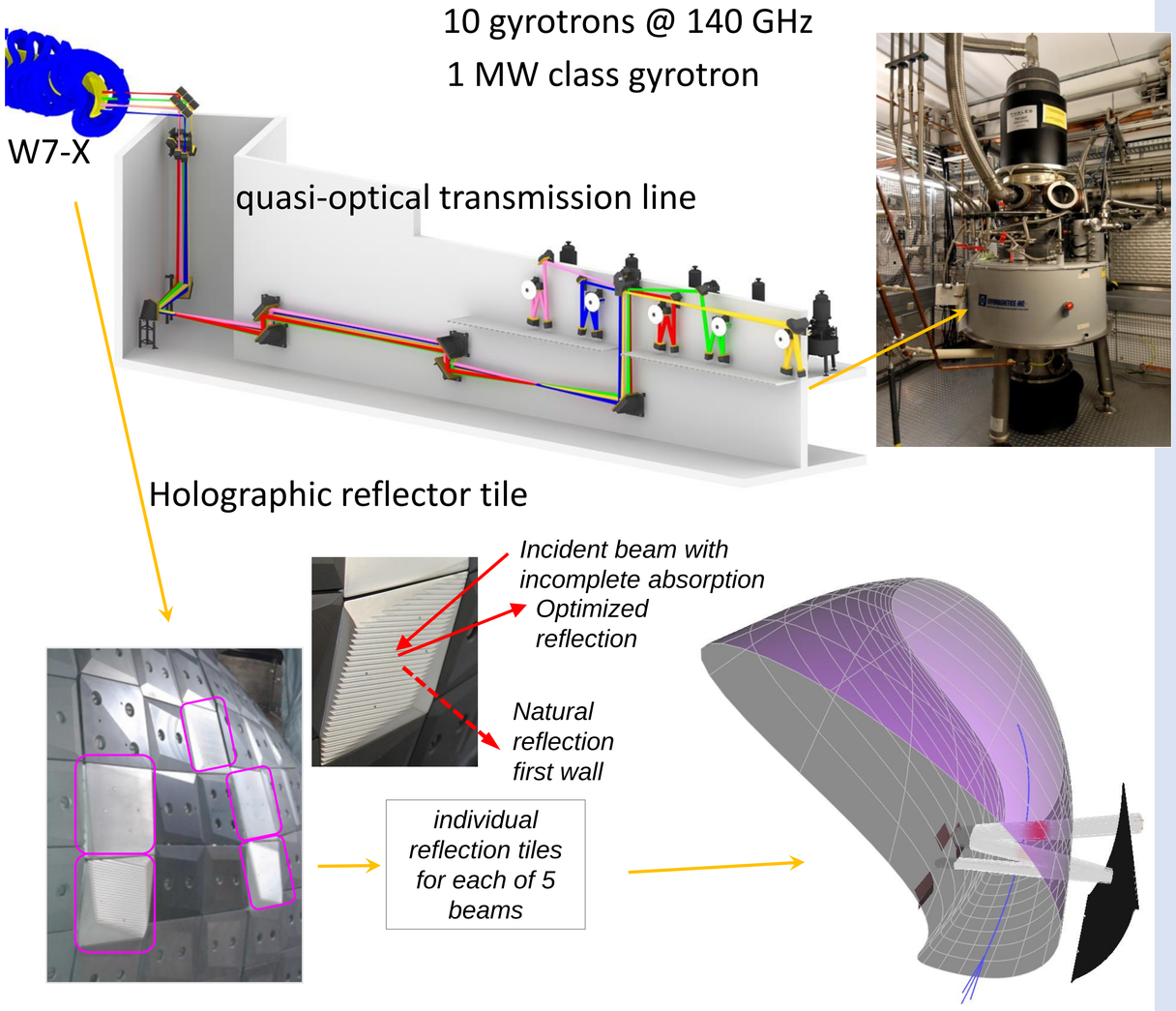
- In the first scenario, a stationary plasma at a density of 1.4 10^{20} m^{-3} with only 6 MW O2-ECRH was achieved. The electron and ion temperatures almost equalized each other.
- In the second scenario, the density was built up with the help of pellet injection, which lead to a temporarily peaked density profile with a strongly improved ion confinement.
- In the third scenario the so-called detachment was demonstrated, in which the power flux to the divertor is strongly reduced.

BACKGROUND

- W7-X is an optimized stellarator in which the otherwise highly neoclassical transport is reduced.
- It was exclusively heated ECRH for the experiments reported here.
- The scenario is similar to a fusion reactor with strong alpha particle heating, where only the electrons are heated. The Ions were heated indirectly by electron ion collisions.
- The superconducting coil system of W7-X generates a magnetic field strength of 2.5 T and determines the ECRH frequency to 140 GHz.
- Only a multi-pass heating with the incompletely absorbed O2-Mode gave access to the high density operation above 1.0 10^{20} m^{-3}.
- Benefit from positive confinement scaling and the increasing coupling between the electrons and ions with density.

EXPERIEMENTAL SET-UP

The W7-X ECRH System



Multi-pass O2 high density heating

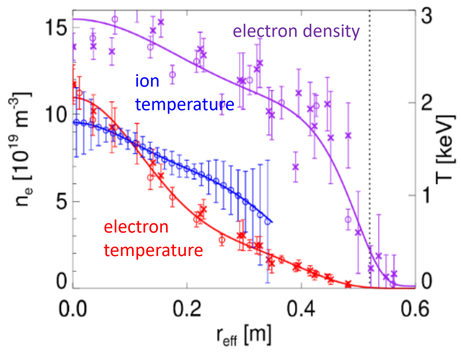
Second harmonic O-mode has an incomplete (<70%) single pass absorption at W7-X. Here individual ECRH beam have more than 3 transits through the plasma center at a total absorption of around 90%.

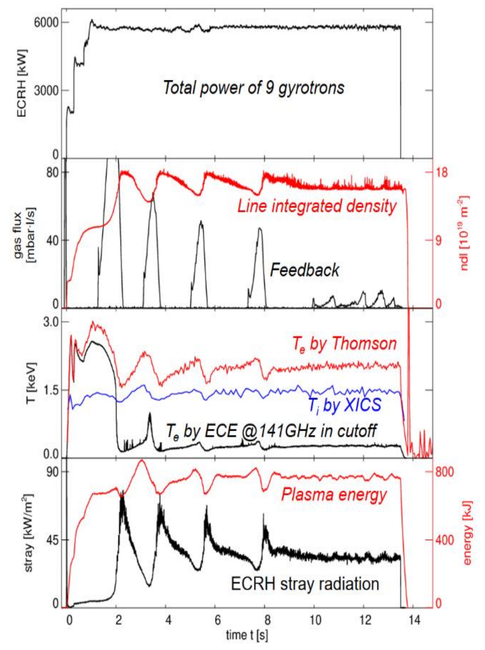
In the next OP the polarization will be taken into account and 95% total absorption will be possible.

OUTCOME

High density operation

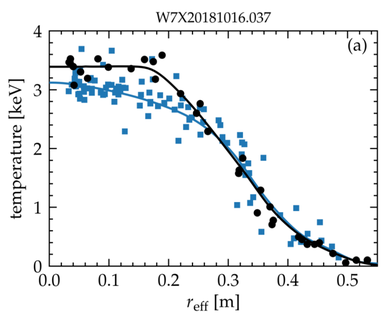
O2 ECRH operation with 6 MW sustained a density of 1.4 10^{20} m^{-3}, where strong electron ion coupling could be achieved.

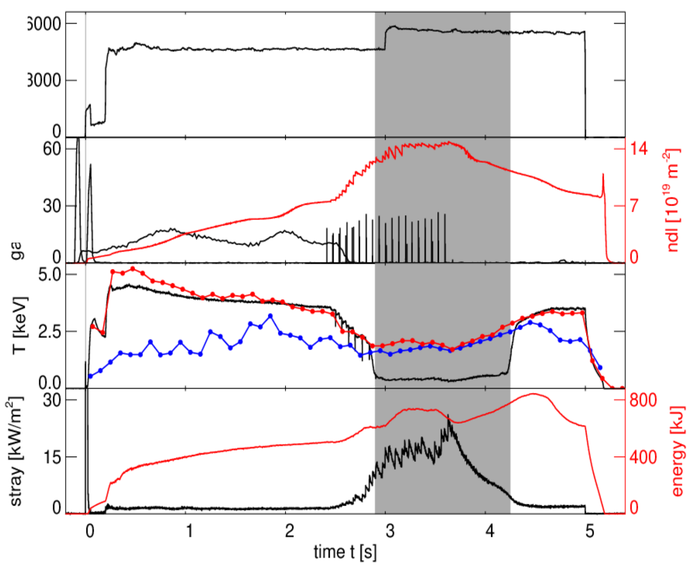




High performance with pellet injection

- Plasma start-up with X2
- Density peaking and ITG suppression by PI.
- Highest triple product.

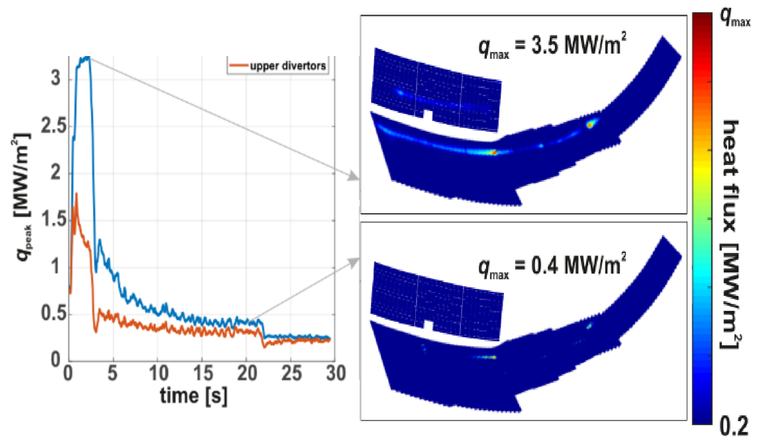




Detachment divertor operation

High density O2 operation give access to stabile stationary divertor detachment () up to 26 s) with a strongly reduced power load at the divertor.

More than 90% of the input power has been radiated and a sufficiently high neutral gas pressure for efficient pumping has been achieved.



OUTLOOK

- Increase of ECRH power by 2 additional positions and a unit power enhancement towards 1.5 MW (2 MW). The new 1.5 MW TE28.10 gyrotron is being developed now.
- Improvement of the O2 multi-pass reflectors taking into account the polarization. The absorbed power fraction will rise from 90 to 95%.
- Reduction of the humidity in the atmospheric transmission line will increase the reliability of power transmission. 0.9 MW reliably power transmission has been demonstrated at 20 % relative humidity.
- Density profile control is envisaged by a new steady state pellet injector (ITER prototype, US-contribution) for central fueling and a powerful cryo-pump for edge neutral density control.

ACKNOWLEDGEMENTS / REFERENCES

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training program 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.