# CEA Contribution to Steady-State Ion Cyclotron Resonance Heating Systems

Julien Hillairet[1], Patrick Mollard[1], Jean-Michel Bernard[1], Arnaud Argouarch[1], Rob Bamber[2], Bertrand Beaumont[3], Gilles Berger-By[1], Nicolas Charabot[1], Zhaoxi Chen[5], Laurent Colas[1], Jean-Marc Delaplanche[1], Pierre Dumortier[6], Frédéric Durodié[6], Philippe Lamalle[3], Annika Ekedahl[1], Fabien Ferlay[1], Marc Goniche[1], Walid Helou[1], Jonathan Jacquot[1], Emmanuel Joffrin[1], Xavier Litaudon[1], Gilles Lombard[1], Riccardo Maggiora[2], Roland Magne[1], Daniele Milanesio[2], Jean-Claude Patterlini[1], Marc Prou[1], Mark Shannon[2], Robert Volpe[1], Karl Vulliez[8], Konstantin Winkler[7]

1. *CEA, IRFM, F-13108 Saint Paul-lez-Durance, France.*
2. *CCFE, Culham Science Centre, Abingdon, OX14 3DB, UK*
3. *ITER Organization, Route de Vinon-sur-Verdon, 13067 St. Paul Lez Durance Cedex, France*
4. *Department of Electronics, Politecnico di Torino, Torino, Italy*
5. *Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China*
6. *Laboratoire de physique des plasmas de l'ERM, Laboratorium voor plasmafysica van de KMS – (LPP-ERM/KMS) - Ecole royale militaire-Koninklijke militaire school - BE-1000 Brussels-Belgium*
7. *Max-Planck Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany*
8. *Laboratoire d'étanchéité, DEN/DTEC/SDTC, CEA, 2 rue James Watt 26700 Pierrelatte, France*

In order to mitigate the risks associated with the fabrication of the ITER divertor, relevant tungsten plasma facing components will be tested under realistic ITER load case conditions on WEST (Tungsten-W Environment in Steady-state Tokamak), with heat fluxes of 10 MW/m² for up to thousand seconds. The workhorse scenario allowing to reaching such heat fluxes relies on three Continuous Wave (CW) Ion Cyclotron Resonance Heating (ICRH) antennas, designed to operate up to 3 MW each for 20 s and 1 MW each for 1000 s. The design of the WEST ICRH antennas is based on a previously tested load-resilient prototype equipped internal vacuum matching capacitors. The design was optimized to improve the coupling performance while adding CW operation capability by introducing water cooling in the entire antenna. This unique combination allows the WEST ICRH antennas to bridge the technological and operational gap towards the ITER ICRH system, both in terms of high power / high electric field operation, but also in terms of RF sheaths physics, real-time matching algorithms and antenna heat flux monitoring.

The ITER ICRH system is designed to couple 20 MW (10 MW each from two antennas) of RF power in the 40-55 MHz frequency range, during 1000 s, under various plasma conditions with Edge Localized Modes (ELMs). As the ITER ICRH components must assure a very high reliability, their qualification requires extensive long duration tests. To that end, CEA has developed a coaxial CW RF resonator under vacuum, operating in the 60 MHz range, connected to a 250°C / 44 bars water cooling system, in order to test ICRH components in ITER relevant conditions of RF currents / voltages and baking temperatures.

This paper reviews the steady-state ICRH system for WEST, currently under fabrication in collaboration with CAS/ASIPP, as well as the results of the first ITER ICRH RF contacts that have been tested on the RF resonator at CEA/IRFM. Implications linked to high power handling in CW operation conditions are discussed, as well as some solutions proposed to deal with them.