Recent advances in fast-ion generation and heating multi-ion plasmas with ion cyclotron waves

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**See X. Litaudon et al., "Overview of the JET results in support to ITER", Nucl. Fusion 57,102001 (2017)*

Plasma heating with waves in the ion cyclotron range of frequencies (ICRF) is a powerful method to increase temperatures in magnetic fusion devices. A new technique of resonant wave absorption in multi-ion plasmas was recently theoretically predicted [1] and later successfully confirmed in dedicated experiments on Alcator C-Mod and JET tokamaks [2]. One of the unique features of the so-called 'three-ion' minority ICRF scenarios is the possibility to reduce the concentration of resonant ions, which absorb RF power, to the level of a few per mille (‰), if needed. As a result, the absorbed RF power per resonant ion is increased and an effective acceleration of minority ions to high energies is possible. In this work, we discuss the physics behind three-ion ICRF scenarios and explain how the plasma composition has to be chosen to observe this phenomenon. Theoretical and modelling results will be supported with illustrations of the experimental observations.

We also outline the application of three-ion scenarios for the experimental programmes of W7-X and ITER. W7-X requires a source of energetic ions to validate the predicted improvement of fast-ion confinement at high β. Energetic ^{3}He ions can be generated in high-density H plasmas of W7-X, which also naturally include ^{12}C and ^{16}O impurities. Three-ion scenarios are also relevant for the non-activated and activated phases of ITER operation. As an example, intrinsic ^{9}Be impurities were computed to absorb efficiently RF power in D-T plasmas. This method was proposed for heating bulk D and T ions in ITER [3].

Finally, we discuss the synergetic ICRH+NBI heating scenario, which was recently developed and successfully tested on JET as a part of isotope mixture studies in summer 2016 [4]. This method was shown to be very effective in heating H plasmas, including a small amount of D ions. The role of D-NBI system is to provide a seed of fast ions, which can absorb RF power in the vicinity of the mode conversion layer in H-D plasmas through the Doppler-shifted cyclotron resonance $\omega = \omega_{cD} + k_{\|}v_{\|}$. In agreement with theoretical predictions, acceleration of D-beam ions to high energies $E_D > 0.5$MeV was confirmed by neutron spectroscopy and gamma-ray measurements.

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References

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