Recent advances in ICRF technology, theory and experiment in view of ITER and future fusion reactors

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Plasma heating with waves in the Ion Cyclotron Range of Frequencies (ICRF) is an important auxiliary heating system to heat the ions in ITER and future fusion reactors. The paper will present an overview of recent developments in view of applying ICRF on DEMO and future fusion reactors. Among the various topics that will be discussed, we summarize three of them below. Maximizing fusion performance requires to keep the plasma dilution low and to minimize edge impurity release from ICRF antennas. Optimization studies have been performed using the novel code ANTITER IV [1], providing an accurate description of both the fast and slow waves launched into the plasma. (Fig. 1). Understanding the physics of slow waves in regions of low plasma density is important as slow waves can lead to surface modes and edge power deposition far from the antenna [1]. The unwanted edge interaction and associated impurity production also depends on the detailed geometry and the phasing of the antenna [2], and are crucial for optimizing the design of ICRF antennas in future fusion devices. Coupling of ICRF power to the plasma core can be improved by minimizing slow wave excitation using appropriate gas puffing in front of the antenna [3].

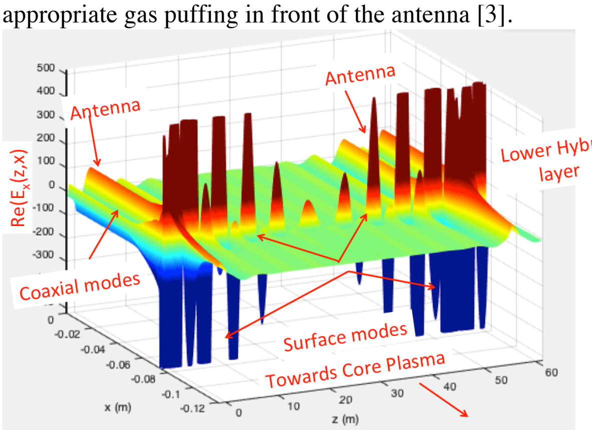

Figure 1. Surface waves and coaxial modes modes along the machine periphery as calculated by ANTITER IV. The antenna is located at x=0. Waves are propagating towards the plasma at x=-0.12m. At the location of the Lower Hybrid resonance layer (x=~-0.08m) a conversion takes place to surface waves and coaxial modes that can propagate to places far from the antenna location.

A distributed antenna, in the form of a Travelling Wave Antenna system, has been proposed for DEMO [4]. It consists of many individual straps all around the tokamak and embedded in the blanket of DEMO. The advantage is reduced power density and voltage per strap (enhancing reliability), absence of a complex matching system and the ability to couple over large antenna – LCMS distances. The talk will summarize recent theoretical and experimental developments for a TWA design.

Novel 3-ion ICRF heating scenarios have been developed for plasma heating and fast-ion generation in multi-ion species plasmas [5].

Recent experimental and modeling developments have expanded the use of these scenarios from dedicated ICRF studies to a flexible tool with a broad range of applications in fusion research (Fig. 2) [6]. The presentation will review main recent findings on JET and AUG in support of future ITER operations Furthermore, the scenario was also successfully applied in JET D-^{3}He plasmas to generate fusion-born alpha particles and study complex effects of fast ions on plasma confinement under ITER-relevant plasma heating conditions. Plasma heating and fast ion physics studies with these novel scenarios will be explored in the forthcoming D-T campaign at JET.

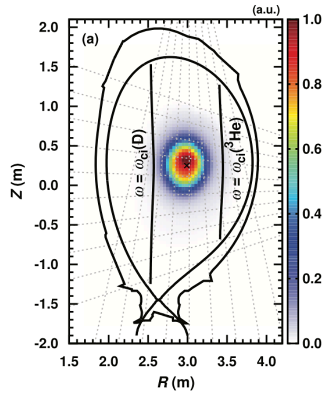

Figure 2. Example of the application of the three-ion ICRH scenario in D-^{3}He plasmas in JET. D-NBI ions with an initial energy of 100keV are accelerated to MeV range energies at the ion-ion hybrid resonance (located for these experiments in the plasma core) leading to a strongly localized production of neutrons originating from the D-D reaction.

References

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