Overview of recent results in Heating and Current Drive at JET

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** See appendix of M.L.Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu) IAEA (2006).*

During the 2006-2007 campaign, methods were developed in the JET Heating Task Force to optimise coupling of LH and ICRF waves in view of ITER, and specific studies undertaken for plasma heating, current drive and rotation in plasmas with low momentum input.

Using deuterium (D_2) gas injection from a specially designed gas pipe close to the LH launcher, high levels of LH power (~3.2MW) have been coupled for several seconds in an H-Mode plasma with a distance of 14cm between plasma separatrix and LH launcher. D_2 gas injection near the launcher is now routinely used in order to couple the LH waves to optimised shear or hybrid scenarios for which a control of the q-profile is crucial. Gas puffing is also an essential tool to counteract the deterioration of LH coupling when using the ICRF antenna that is magnetically connected to the launcher. During LH operation hot spots are sometimes observed on components that are magnetically connected to the launcher and quantitative measurements of the temperature have been made.

The evolution of the SOL density profile during LH and gas puffing has been measured with Langmuir probes. We measure a higher ne,SOL if LH is applied, indicating that the LH power plays a role in the ionization of the gas. The work to model the density in the SOL with the fluid code EDGE-2D had started, and confirms that in order to explain the observed profiles we need to include ionization of the gas by LH in the modeling.

Gas puffing in the SOL also allowed for the first time to couple high levels of ICRF power at ITER relevant distances between the antenna strap and the separatrix. A study of the variation of the ICRF antenna loading in ELMy H–mode at ITER relevant distances between the antenna and the separatrix shows that the loading perturbations caused by the ELMs decrease significantly but that the loading between ELMs deteriorates to rather low values. This can be compensated by D_2 injection in the divertor and in the midplane. For distances between the antenna strap and the separatrix of 19 cm, up to 8 MW of ICRF of power was coupled in H-mode plasmas in this way. The use of hybrid couplers installed between two of the four JET A2 ICRF antenna pairs also improved the ELM tolerance of the ICRF system. However, it shows the necessity of developing suitable arc detection techniques, to avoid damage of low voltage arcs occurring simultaneously with ELMs.

Experiments with fundamental ICRH demonstrated ion and electron heating together with increased neutron reactivity. Absorption of the RF waves on impurities (Be, Ar) showed to be negligible compared to the direct absorption on pre-heated D. Although in JET the efficiency of the fundamental majority heating is low, due to poor coupling at the low frequencies needed for the experiment, reasonable heating can be achieved when preheating the plasma with NBI, in agreement with calculations.

Combined central ICRF and NBI heating was used to create conditions where neo-classical modes (NTMs) could be triggered by fast ion induced long sawteeth. Ion Cyclotron Current Drive, applied near the sawtooth inversion radius, resulted in shortening of the sawteeth period and absence of destructive n=2 NTMs. As the optimal distance between the H cyclotron resonance layer and the q=1 surface was found to be sensitive to the plasma evolution, feedback control of the resonance position is necessary. A possible solution is feedback control of the ICRF frequency using the sawtooth period as an actuator. Toroidal rotation has been studied in plasmas with ICRF heating and LHCD. The observed plasma toroidal rotation was generally found to be in the co-current direction in the outer part of the plasma and in some cases hollow rotation profiles were observed.