Nuclear Fusion and the Control of Magnetohydrodynamic "Tearing" Instabilities

Francesco Volpe
General Atomics, San Diego

The plasma parameters –thus, ultimately, the nuclear fusion yield- achievable in toroidal magnetic confinement devices are limited by various magnetohydrodynamic instabilities. Among the most important are the Neoclassical Tearing Modes (NTMs). In these instabilities, helically perturbed pressure-gradient-driven "bootstrap" currents alter the topology of the confining magnetic field by "tearing" and reconnecting the field lines in the form of magnetic islands. NTMs permit heat transfer and particle transport across them, thus lowering the plasma pressure. Islands typically rotate, but they can also 'lock' to the wall and lead to a loss of confinement or even to a catastrophic loss of thermal energy and plasma current known as disruption. For all these reasons, NTMs can undermine the production of reactor-relevant fusion power (500MW) in the ITER device, the fruit of an international collaboration currently under construction in southern France and are object of active study in present experiments.

The main stabilization technique exploits the resonant absorption of microwaves at an electron cyclotron harmonic. Due to an asymmetry in the absorption in the velocity space, a net current is driven as a result, which compensates for the bootstrap current deficit. This approach, however, fails if the island locks to a position not accessible by the microwave launchers, a situation which occurs already in present machines and will be even more likely in ITER, due to slower rotation.

Part of the colloquium will therefore concentrate on a new method, developed at the DIII-D national facility in San Diego, which makes use of magnetic perturbations to "steer" the island and either sustain its rotation or reposition it in a location accessible by the microwave beams. Mitigation by a factor of 2 was observed with this method and full suppression is expected in new experiments where the double amount of power will be deployed.

The final part is concerned with the reduced stabilization efficiency expected in ITER in case of rotation: due to broader microwave deposition, currents would be driven both inside and outside the island, with stabilizing and destabilizing consequences, respectively, which would tend to cancel out. Improvements to the standard method have been addressed at DIII-D. The idea is to modulate the microwave injection in synch and in phase with the island rotation. The latter is tracked by means of microwaves emitted, by reciprocity, at the same frequency of resonant absorption. The emission diagnostic adds the benefit of a test of radial alignment of the injected microwaves to the island.