Magnetic tweezers aid island suppression

Scientists at the DIII-D National Fusion Facility, operated by General Atomics in San Diego, CA, have developed innovative techniques to control undesired energy-leaking magnetic structures that can form in fusion plasmas. A special detector acts as a "gun sight" to aim a stabilizing beam of microwaves at its target, while magnetic "tweezers" can move the target into position. The techniques will be useful for the international ITER device, which is expected to demonstrate the feasibility of a fusion power plant.

Nuclear fusion is the process of fusing light nuclei to form heavier ones. The process is accompanied by the release of energy, which powers the stars and might represent an abundant, clean and safe source of energy on Earth. One of the most successful approaches to fusion is the tokamak device: a doughnut-shaped chamber is filled with an ionized gas called plasma, which is kept far from the wall by magnetic fields and brought to temperatures of up to 200 million degrees, at which fusion reactions occur. The ITER tokamak, now under construction in France, is the fruit of an international collaboration involving the US, with the goal of demonstrating the feasibility of a fusion power plant.

It is desirable to keep the tokamak's plasma at a high pressure, in order for the fusion reactions to be numerous. This high pressure, however, alters the magnetic configuration. The new, non-optimal configuration is characterized by "magnetic islands" which leak energy and make it difficult to achieve even higher pressures. Experiments in DIII-D and other tokamaks have successfully suppressed these undesired islands by injecting an intense beam of microwaves at the magnetic island location.

Normally, islands rotate at 10-50 thousand turns per second. Previous experiments in the German ASDEX Upgrade tokamak have shown that islands can be more efficiently suppressed if microwaves are injected *intermittently*, just at the time when the islands transit in front of the microwave generator. In the German experiment, islands were magnetically sensed.

In the DIII-D experiment, new detectors track the islands via the microwaves that they emit. The symmetry with the microwave *emission* permitted better timing and, for the first time, optimized aiming of the microwave *injection*. Ultimately, microwave suppression of islands is like the "Hit the duck, win a prize" game at the fairground, with a periodic target moving in front of a gun (Fig. 1). "Looking" at islands in the microwave range of frequencies is like viewing them in the gun sight. Based on that, an automatic system decides when and in which direction to "shoot" the microwaves. Islands were completely suppressed by this technique for the first time, and advantages over continuous injection were confirmed.

But what if the island stops rotating, or forms directly as a stationary, non-rotating structure? A particular challenge is the case when the island "locks" in a position not accessible from the microwave launcher – a "sitting duck" is an easy target only when it is in a place where the gun can be aimed. Researchers at DIII-D also tackled this situation, which is known as mode locking and which could occur in ITER.

It is well-known that a magnetic field exerts a force on an electric circuit. One property of magnetic islands is that they carry an electric current. This led the DIII-D scientists to the idea of utilizing a set of magnet coils (Fig. 2) to generate "magnetic tweezers" that "grab" the islands and bring them in view of the microwave launcher. The repositioning worked successfully, and microwaves significantly reduced the islands. Experiments at increased power, for complete suppression, are under preparation.

Work supported by the U.S. Department of Energy under DE-FC02-04ER54698.

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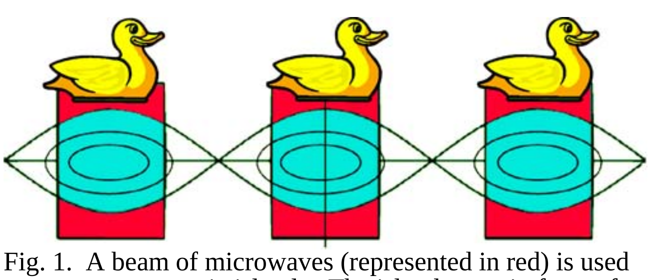

Fig. 1. A beam of microwaves (represented in red) is used to suppress magnetic islands. The islands pass in front of the microwave launcher in a never-ending parade, like ducks in a fairground shooting gallery.

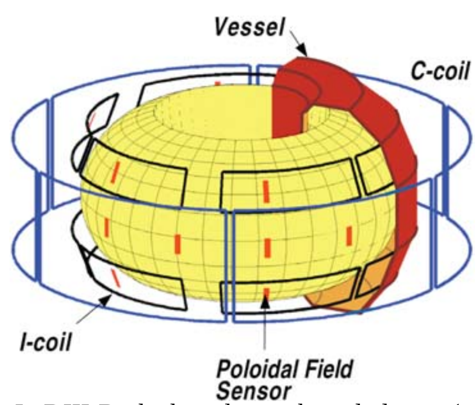

Fig. 2. In DIII-D, the hot, donut-shaped plasma (yellow) is surrounded by special coils (blue and black) that can be used as "magnetic tweezers" to position a magnetic island in front of the microwave beam.