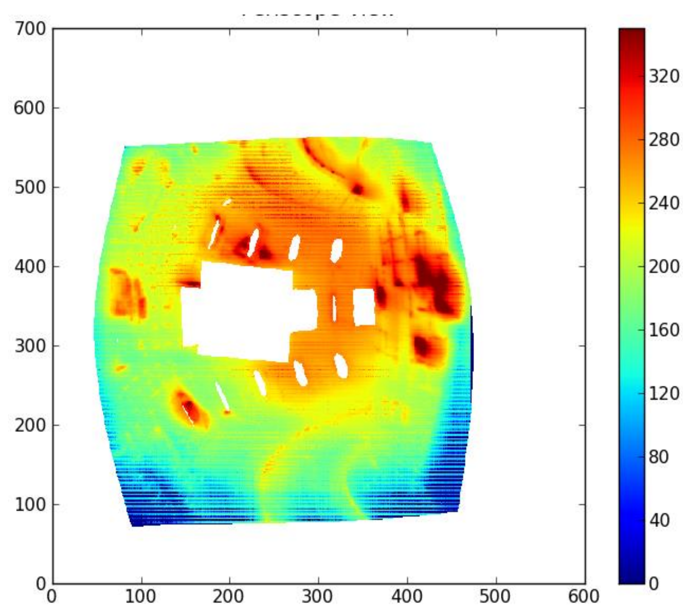
Radiating fusion power in all the right ways

Scientists working on the DIII-D tokamak in San Diego are exploring the best method to quickly cool a 200 million degree fusion plasma in roughly 1/100 of a second by injecting the noble gas neon. The research team, including scientists from General Atomics, Massachusetts Institute of Technology, Oak Ridge National Laboratory, Princeton Plasma Physics Laboratory, and the University of California, San Diego, are finding that, contrary to conventional wisdom, the asymmetry of the radiation flash is determined more by the internal perturbations within the plasma than the number or location of the impurity gas injectors.

Magnetic fusion relies on hot plasma (ionized gas) confined in a tokamak, which has a torus (or donut) shaped vacuum vessel, with the plasma held in the center by magnetic fields. Occasionally, the plasma can undergo a rapid instability (called a "disruption"), during which it can deposit all of its heat energy on a small portion of the vessel within a few thousandths of a second. This rapid flow of energy, which easily exceeds several billion watts of power (equivalent to several large power plants) for a short period of time, can damage the vessel wall. In future large fusion devices (such as ITER, now being built in France), such damage would require significant time expense to repair. In order spread out the plasma heat, neon gas can be injected into the plasma just before the disruption to convert the plasma energy to light, which (ideally) heats the entire vessel uniformly, avoiding damaging any single part (a process called "disruption mitigation"). This situation is akin to the difference between a 50W light bulb and a 50W laser: both produce the same amount of power, but only one will melt steel.



Infra-red image showing the temperature of the DIII-D vacuum vessel immediately after a disruption mitigated by neon gas injection.

Unfortunately, the radiated power after the gas injection is often not distributed evenly, so that some parts of the vessel receive a far more concentrated dose of radiated heat than others. Conventional wisdom held that this asymmetry was due to the number of gas injectors used, and that more injectors (evenly spaced around the device) should even out the radiated power distribution. However, previous experimental results (Olynyk, 2012 APS DPP) indicated that more valves did **not** help. Instead, computer models (Izzo, 2012 APS DPP) indicated that internal instabilities within the plasma should determine the radiation asymmetry more so than the distribution of gas injectors.

In results reported at the 2013 APS DPP conference in Denver, the DIII-D team has for the first time tested this theory that the internal plasma instabilities determine the radiation asymmetry. To test this, the team used 3D magnetic fields to "lock" the plasma instability in one direction or another. They found that by varying the direction in which the instability locked, they could repeatably change the amount of energy deposited at a given location within the vessel, as expected from the computer models. Moreover, no indication of the expected localized heating around the gas injector itself was found. Both of these results dispute the contention that radiation asymmetry during disruption mitigation can be alleviated by simply increasing the number of gas injectors used.

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