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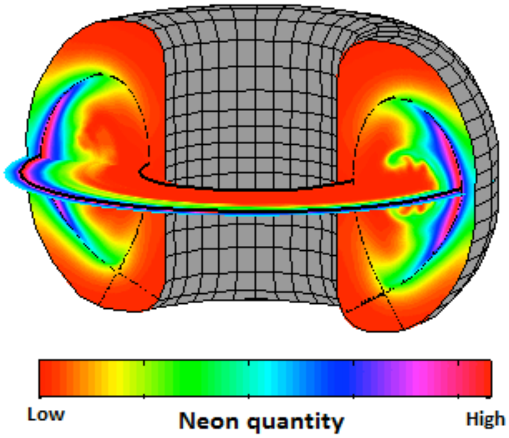
Cooling Fusion in a Flash

For a brief instant, hot fusion plasma becomes a giant fluorescent lamp, converting heat into light.

PROVIDENCE—Scientists at the Massachusetts Institute of Technology (MIT) and the University of California, San Diego (UCSD), are learning how to quickly cool a 200 million degree fusion plasma—in roughly 1/100 of a second—by injecting a noble gas like helium, neon or argon, which converts the energy stored in the plasma to light in much the same way that a neon sign (or fluorescent tube) works. Experiments performed by graduate student Geoff Olynyk, Prof. Dennis Whyte, and Dr. Bob Granetz at the MIT Plasma Science and Fusion Center, as well as computer modeling done by Dr. Valerie Izzo at the UCSD, have studied how best to achieve uniformity in the light emitted during this flash, since the gas cannot be injected evenly everywhere—it must come in via a limited number of gas injectors. Both the experiments and the simulations have found that this unevenness in the injected gas can interact with unevenness in the plasma itself in a way that can alter the uniformity of the emitted light—in sometimes unexpected ways.

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 move too close to one section of the vacuum vessel wall, producing localized heating, and it becomes necessary to stop the fusion reactions quickly to avoid damage to internal components of the tokamak. As larger tokamaks are built, such as the upcoming ITER project in France, it becomes more crucial to have this procedure in place to avoid unnecessary downtime for machine repairs. When the plasma must be cooled quickly, it's better to turn the whole tokamak into one very large, dim light bulb than to create a very small, very bright bulb in one spot, which can also result in localized wall heating.



A computer simulation (with the NIMROD code) of neon injected uniformly around the plasma. Flows associated with internal distortions in the plasma redistribute the neon in a non-uniform way.

"The basic assumption was, as long as we can get the gas injection to be even enough, the flash of light will be too, but that turns out to be an oversimplification," said Dr. Izzo. "The plasma itself is off-center at this point—in fact that's why we want to cool it quickly—and that also needs to be accounted for."

Even if the gas could be injected from all sides at once, the simulations (done with a computer code called NIMROD) show the light can still be brighter in some spots than others. The MIT experiments on the Alcator C-Mod tokamak also show that having more gas injectors does not always lead to a more uniform flash. On the other hand, if the non-uniformities internal to the plasma can be partially controlled, the symmetry of the flash of light could be significantly improved, even for a small number of gas injectors. For instance, the "bright spot" on one side of the torus could be made to rotate, creating a sort of lighthouse effect inside the reactor. The bright light would not shine on any one part of the wall long enough to heat it past its melting temperature.

Both the MIT experiments and the computer simulations illuminate promising new avenues of investigation to help keep the ITER experiment operating as much as possible, and maximize the potential for scientific advancements that will lead to a prototype fusion reactor.

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Abstracts:

PI2.00003	**Impurity Mixing, Radiation Asymmetry, and Runaway Electron Confinement in MGI Simulations of DIII-D and ITER (V.A. Izzo)**
PI2.00002	**Disruption mitigation experiments with multiple gas jets on Alcator C-Mod (G.M. Olynyk)**
Session	**PI2: Plasma Wall Interactions, Disruptions, and Plasma Technology** Ballroom DE, Wednesday, October 31, 2012, 2:00PM–5:00PM