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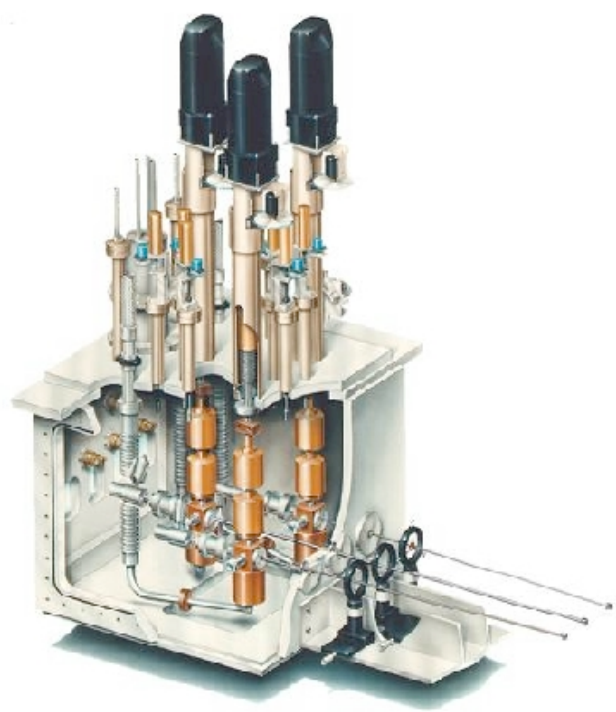
Frozen Bullets Tame Unruly Edge Plasmas in Fusion Experiment

Technique triggers more frequent, but less powerful, plasma eruptions to reduce a potential source of damage to reactor vessel walls.

PROVIDENCE—Using a frozen hydrogen machine gun installed on the DIII-D magnetic fusion plasma experiment in San Diego, researchers were able to fire millimeter-sized pellets of frozen hydrogen into the edge of a 20 million degree fusion plasma, dramatically reducing the size of periodic edge disturbances called ELMs, which are similar to solar flares at the surface of the sun.

“The rapid-fire frozen-pellet machine gun technology actually triggers many smaller disturbances, effectively short-circuiting the plasma’s natural tendency to have less frequent, but much larger outbursts,” said Dr. Larry Baylor of Oak Ridge National Laboratory, where the pellet gun was designed and built.



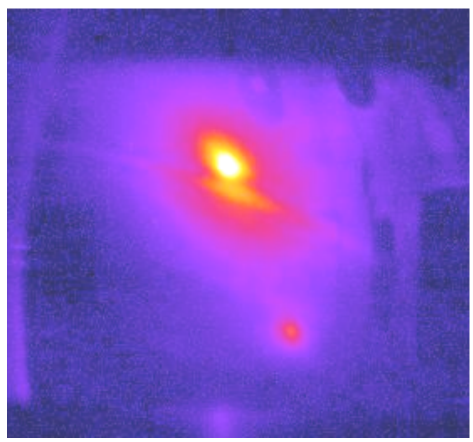
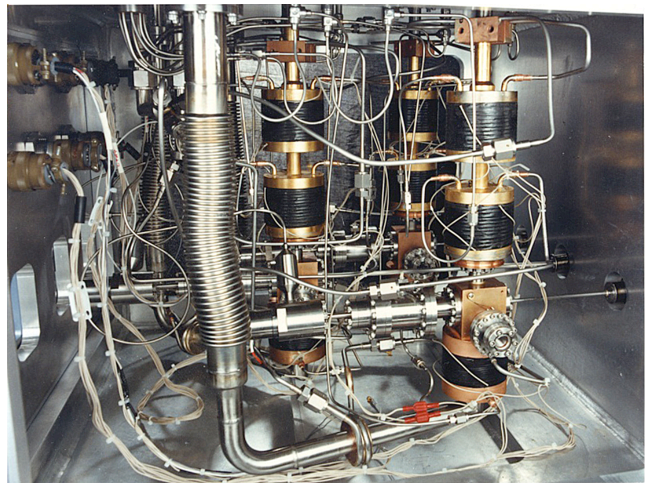


Image of the ORNL three barrel machine gun used on to tame the plasma edge (left), and image of a single frozen deuterium pellet entering the hot plasma (above). Graphic: ORNL

Fusion scientists want to reduce the size of the ELM outburst because the sudden energy pulse can lead to erosion of the walls of the vessel containing the fusion plasma.
This is the first time the technique has been demonstrated at a level nearing the requirements of ITER, an internationally supported experimental fusion reactor now under construction in France.



Internal image of the three barrel repeating pneumatic deuterium pellet injector used on DIII-D for pellet ELM pacing experiments. Photo: US ITER/ORNL

To make the experiment work, Baylor's team had to reduce the size of the pellets and increase the firing rate by a factor of five over previous models. The latest guns are able to fire 1.3 mm diameter hydrogen ice pellets at speeds of 300 feet per second through curved barrels into the edge of the plasma, at combined rates of 60 times per second. Dr. Baylor said that the biggest challenge was getting the gun to reliably fire the frozen pellets at slow speeds to survive the curved barrels. The pellets are frozen to within several degrees of absolute zero.

The researchers observed, that the more frequently the ELMs occur, the smaller they become and consequently the smaller the energy pulses that leave the plasma. Furthermore, it was found that such pellet injection actually made the plasma cleaner: The injected pellets stimulate the flow of particles on the outer boundary of the plasma downwards along the lines of the magnetic field and towards the divertor at the bottom of the plasma vessel, where the heat flux exits the tokamak. This acts as a screening mechanism to keep the metal atoms from migrating into the plasma.

In the future, the Oak Ridge Team and their colleagues at General Atomics in San Diego, who operate the DIII-D tokamak experiment, hope to increase the firing rate still further, while using high speed cameras and other instruments to observe the effectiveness of the pellets at taming hotter, higher power plasmas.

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Abstracts:

TI3.00001	**Reduction of ELM Intensity on DIII-D by On-demand Triggering With High Frequency Pellet Injection and Implications for ITER**
Session	**TI3: Pedestal ELMs and ELM Mitigation** Ballroom BC, Thursday, November 1, 2012, 9:30AM–12:30PM