November 1, Wednesday, 11:00 a.m., Grand Salon ABF, Philadelphia Marriott Downtown, Paper NI1.00004 – "Achievement of Low Recycling and High Power Density Handling in CDX-U with Lithium Plasma-Facing Components" by R. Kaita (Princeton Plasma Physics Laboratory)

Keeping Tokamaks Toasty: Small Fusion Machine Achieves Big Breakthrough in Energy Confinement

For the first time, experiments on the Current Drive Experiment-Upgrade tokamak at the Princeton Plasma Physics Laboratory have demonstrated that using liquid lithium as a wall material can dramatically increase the energy confinement in a fusion device.

Fusion holds the promise of providing a virtually inexhaustible, safe, and environmentally attractive means of generating electricity and hydrogen for the long-term. Three conditions must be satisfied for fusion reactions to occur. Fusion occurs in a hot, ionized gas called plasma. The ions in the plasma all have the same charge, and thus repel each other. This means that the temperature of the plasma has to be high enough, so that the ions have enough energy to overcome this repulsion and fuse together. Furthermore, the plasma must have a high enough density, so that the ions collide often enough for fusion to occur. Finally, the energy in the plasma has to be confined for a sufficiently long time, so that high temperature required for fusion can be maintained.

One way to contain the hot fusion plasma is in a magnetic "bottle," inside a doughnut shaped machine called a tokamak. When the plasma hits the solid wall of a conventional tokamak, some of its particles become neutral again. These cool particles reenter the plasma where they are re-ionized. The process is called "recycling," and it cools the plasma edge. It means that to maintain a hot plasma core, you must keep it away from the cool edge. Up until now, this has meant that fusion reactors had to be very large.

Recently, researchers at the US Department of Energy's Princeton Plasma Physics Laboratory[1] challenged this idea in small tokamak called the Current Drive Experiment-Upgrade (CDX-U). Inside CDX-U, they put a tray that completely encircled the bottom of the machine, and filled it with liquid lithium (Figure 1). Lithium chemically reacts very readily with hydrogen, which is the primary constituent of fusion plasmas. Because of this, the lithium "soaked up" the particles in the edge of the CDX-U plasma. This lowered the recycling, so the particles that made it to the edge did not reenter and cool the plasma.

Figure 2 shows the energy confinement times measured in CDX-U compared to predictions based on previous tokamak experiments. Before lithium was introduced into the CDX-U tray, the energy confinement times were low (blue circles).[2] When the tray was filled with lithium, however, energy confinement times up to six milliseconds were measured (red squares). This indicated an enhancement in energy confinement time that was far greater than anything ever achieved in a small machine like CDX-U.

These results have exciting implications for the practicality of fusion energy. If the walls of fusion reactors can be made of a low-recycling material like liquid lithium, they can be made more compact. Bigger machines mean more cost, so any scheme that would reduce their size will help make fusion commercially feasible.

[1]USDOE Contract DE-AC02-76CH-03073

[2]"Transient Transport Experiments in the Current-Drive Experiment Upgrade

Spherical Torus" by T. Munsat *et al.,* Physics of Plasmas, Vol. 9, pp. 480 – 487 (2002)

Contacts:

Bob Kaita, PPPL, 609-243-3275, rkaita@pppl.gov

Dick Majeski, PPPL, 609-243-3112, rmajeski@pppl.gov

Further Information:

"Enhanced Energy Confinement and Performance in a Low-Recycling Tokamak" by R. Majeski *et al.*, Physical Review Letters, Vol. 97, pp. 075002-1 – 075002-4 (2006)

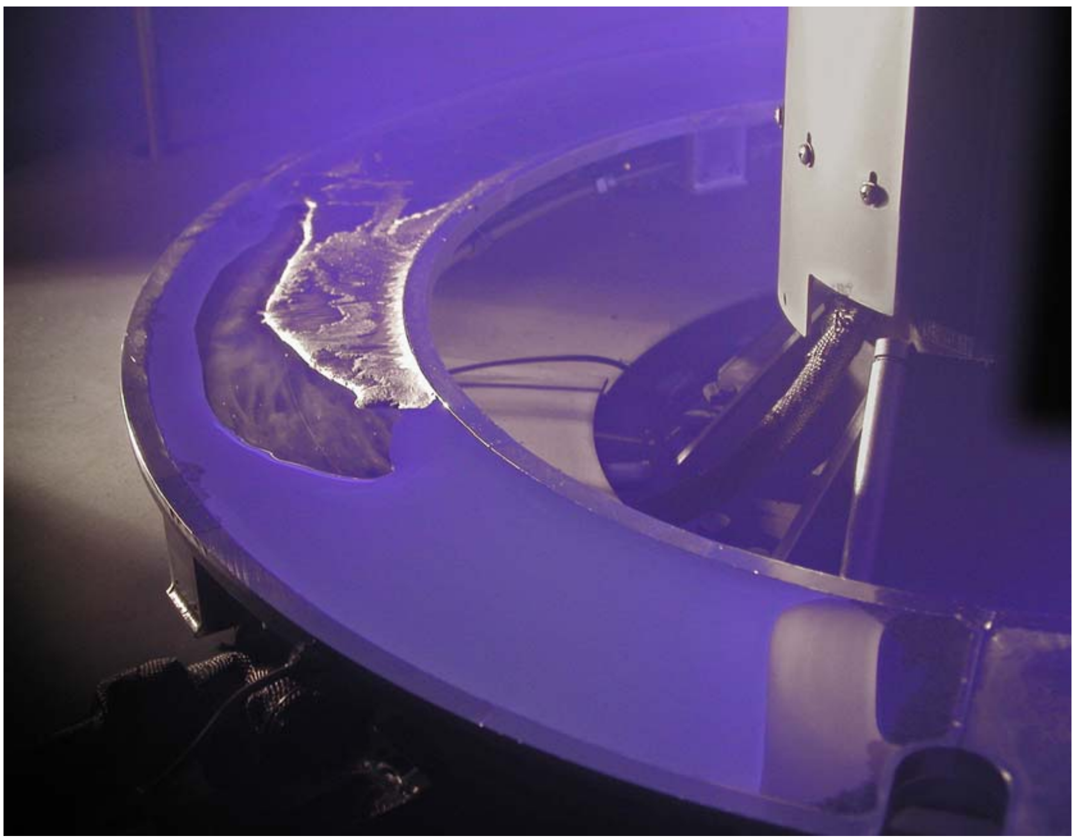

Fig. 1 – Photograph of plasma in CDX-U, resting above liquid lithium in a tray on the bottom of the machine. The lithium pool is about 4 inches (10 centimeters) wide and a tenth of an inch (3 millimeters) deep.

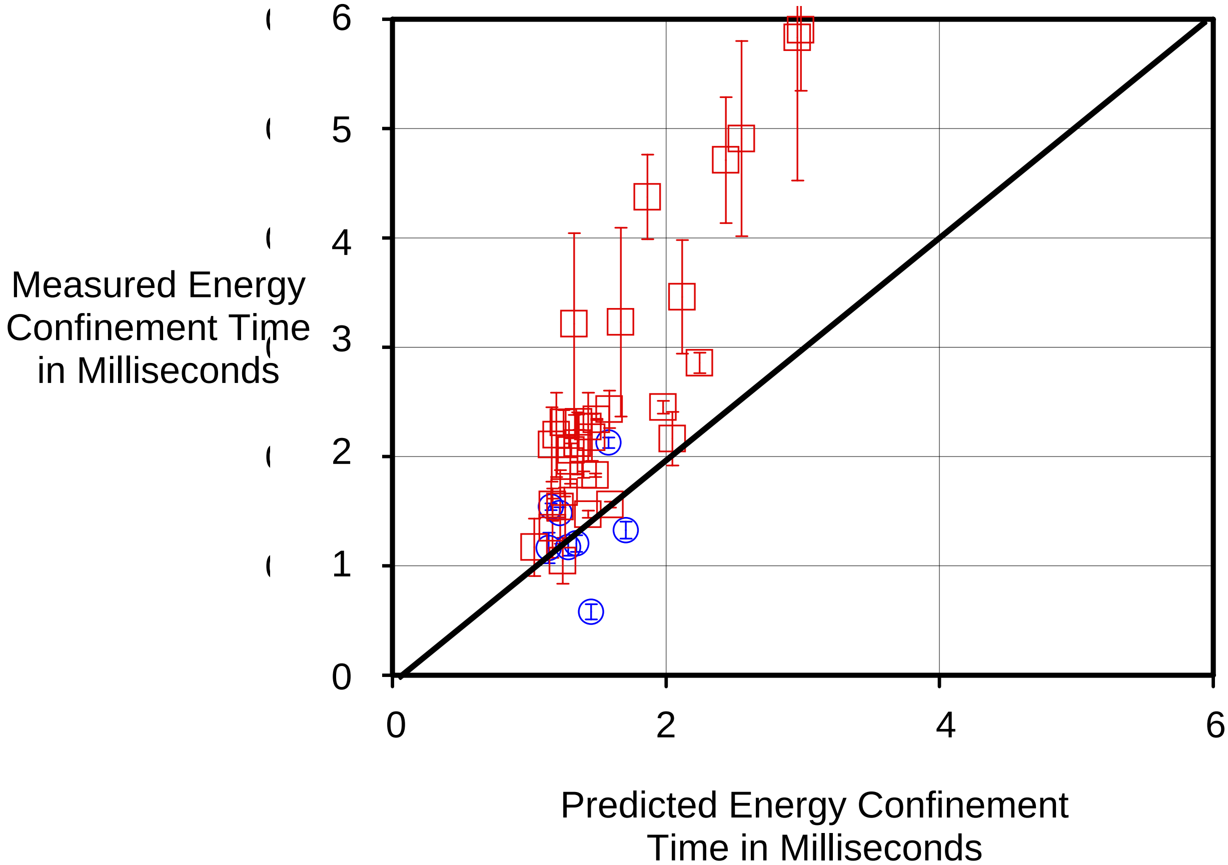

Fig. 2 – Plot comparing the predicted and achieved energy confinement times for CDX-U plasmas. If the liquid lithium wall values (red squares) were the same as the solid wall values (blue circles), they would be on the diagonal line. Instead, nearly all of the red squares are above it, so the energy stayed in the plasma much longer in the presence of a liquid lithium wall.