PHYS ORG

Fusion reactor wall manages unexpected shielding against extreme heat loads

March 24 2014

Hydrogen plasma in DIFFER's linear plasma generator Pilot-PSI. Credit: Fundamental Research on Matter (FOM)

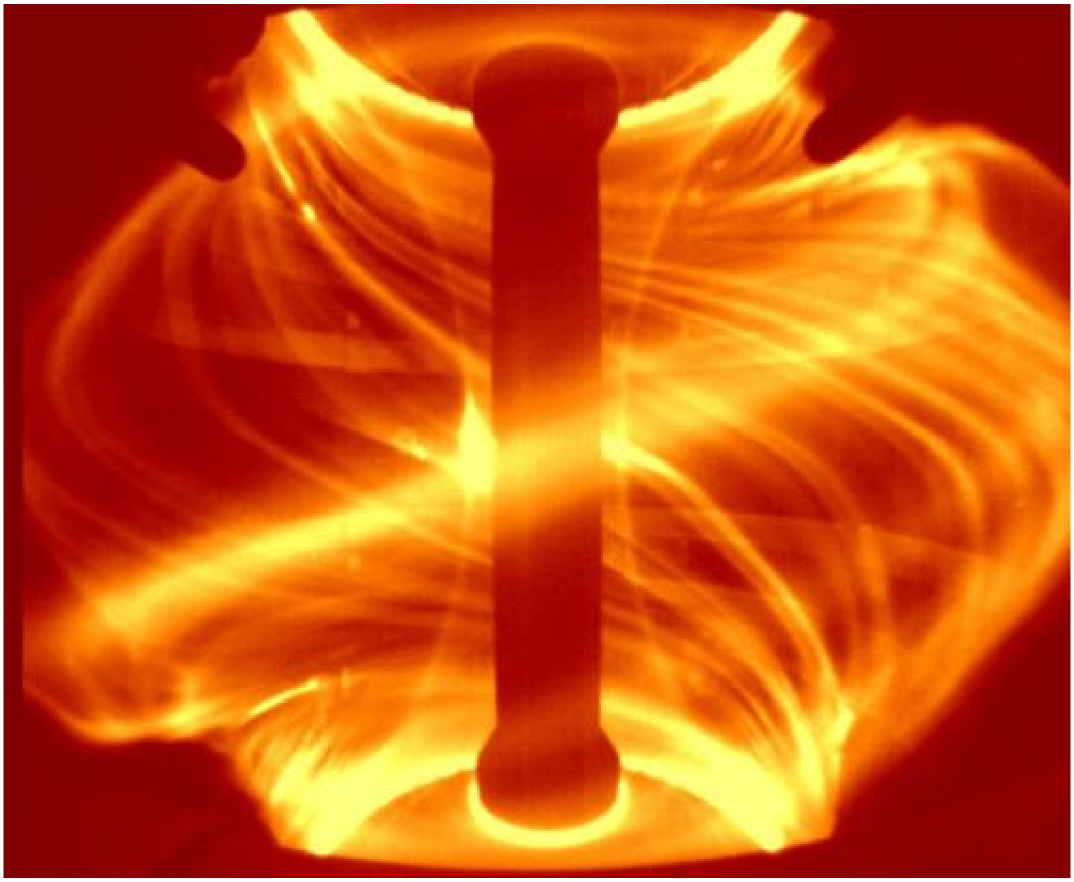
Researchers of the FOM Institute DIFFER[have discovered that the wall material of a fusion reactor can shield itself from high energy plasma bursts. The wall material tungsten seems to expel a cloud of cooling hydrogen particles that serves as a protective layer. The research team publishes their results on 24 March 2014 in the journal *Applied Physics Letters*.

Currently, an international collaboration building the fusion reactor ITER, designed to be the first in the world to produce net power from fusion. The heart of a fusion reactor like ITER contains an extremely hot plasma, from which short, intense energy bursts rain down on the reactor wall. In ITER, the tungsten wall will face powerful discharges of several gigawatts per square meter, several times per second. However, researchers at FOM Institute DIFFER discovered that under some conditions less than half of that incoming energy actually hits the surface.

Pilot-PSI

The physicists used their linear plasma experiment Pilot-PSI to show that the tungsten surface shields itself from the blast by expelling a cloud of cooling hydrogen particles. This is the first time that fusion researchers see the energy pulses and the wall react to each other at this level of detail.

Physicist Dr. Greg De Temmerman heads the plasma surface interactions-research at DIFFER. Using the laboratory setup Pilot-PSI, his team of physicists from DIFFER and Eindhoven University of Technology were the first in the world to mimic the extreme energy bursts (ELMs - Edge Localized Modes) that the wall materials of future fusion power plants will have to endure. "Of course such ELM eruptions already happen in existing fusion reactors", says De Temmerman, "but their energy is much smaller than that expected in ITER. Our laboratory setups offer conditions very similar to those in ITER, with much better diagnostics access and controllability of the system."



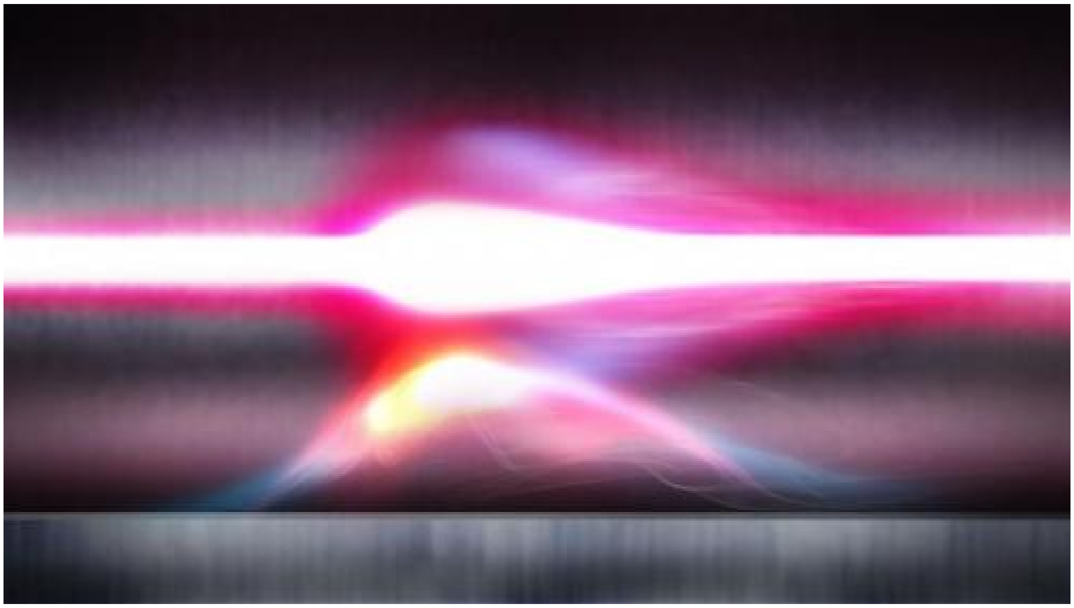
Edge Localized Mode-eruptions in the MAST tokamak, CCFE, UK. Credit: Fundamental Research on Matter (FOM)

Counterintuitive

"During the simulated ELM pulses, we saw a completely counterintuitive behaviour", says de Temmerman: "The more power we sent to the wall material, the less energy actually reached the surface. The temperature of the tungsten samples already peaked part-way through the energy pulse and then started to drop. At the same time, our fast camera saw Hα-light coming from near the surface." Hα-light is a spectral line that indicates that cool hydrogen gas has escaped from the tungsten wall surface. De Temmerman: "We already know that the metal tungsten can absorb limited amounts of hydrogen, like a sponge. It looks like the incoming energy pulse frees a cloud of this absorbed hydrogen from the tungsten. The gas blanket then sucks energy from the incoming power pulse and distributes it evenly, protecting the surface directly below it." Simulations of the hydrogen stored in the tungsten before and after a plasma pulse support this analysis.

Energy pulses in ITER

Fusion researchers try to recreate nuclear fusion, the power source at the heart of the sun, as a sustainable energy source on Earth in tokamak reactors like ITER. In a fusion reactor, hydrogen nuclei collide at hundreds of millions degrees Celsius, then fuse together to form helium and release prodigious amounts of energy. ITER has been designed to demonstrate the technical feasibility of fusion as an energy source, and will be online in the early 2020s. At peak performance, ITER will produce 500 megawatts of power, while the heating power will only be 50 megawatts. Much research is focused on dealing with the ELM energy bursts, which strike spots on the reactor wall with energies up to gigawatts per square meter - and could lead to uncontrolled melting of the wall. ITER is currently under construction in the south of France and will come online at the start of the next decade.



Artist's concept of tungsten shielding itself via outgassing of hydrogen (bottom) against the impact of a sudden energy burst from the plasma beam in Pilot-PSI (top). Image credits: ICMS. Credit: Fundamental Research on Matter (FOM)

The results in *Applied Physics Letters* might be good news for ITER: under certain conditions, its planned wall material tungsten appears to be able to shield itself from the worst of the ELM strikes. It is still not completely clear whether this effect will also occur in the more complex geometry of the ITER exhaust. Follow-up research needs to further investigate the mechanism behind the self-shielding process, so that researchers can design the optimal wall for future fusion power plants.

More information: Self-shielding of a plasma-exposed surface during extreme transient heat loads, *Applied Physics Letters*, 24 March 2014.

Fundamental Research on Matter (FOM)