Press release

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Plasma fingers point to the taming of the ELM

New images from the MAST device at Culham Centre for Fusion Energy could find a solution to one of the biggest plasma physics problems standing in the way of the development of fusion power.

MAST (the Mega Amp Spherical Tokamak) is the first experiment to observe finger-like lobe structures emanating from the bottom of the hot plasma inside the tokamak's magnetic chamber. The information is being used to tackle a harmful plasma instability known as the 'edge localised mode', which has the potential to damage components in future fusion machines, including the key next-step ITER device.

Edge localised modes (ELMs) expel bursts of energy and particles from the plasma. Akin to solar flares on the edge of the Sun, ELMs happen during high-performance mode of operation ('H-mode'), in which energy is retained more effectively, but pressure builds up at the plasma's edge. When the pressure rises, an ELM occurs – ejecting a jet of hot material. As the energy released by these events strike material surfaces, they cause erosion which could have a serious impact on the lifetime of plasma-facing materials.

One way of tackling the problem is 'ELM mitigation' – controlling the instabilities at a manageable level to limit the amount of harm they can do. MAST is using a mitigation technique called resonant magnetic perturbation; applying small magnetic fields around the tokamak to punch holes in the plasma edge and release the pressure in a measured way. This technique has been successful in curbing ELMs on several tokamaks.

The lobe structures that have recently been observed in MAST are caused by the resonant magnetic perturbation, which shakes the plasma and throws particles off course as they move around the magnetic field lines in the plasma, changing their route and destination. Some particles end up outside the field lines, forming finger-like offshoots near the base of the plasma. Changing the shape of a small area of the plasma in this way lowers the pressure threshold at which ELMs are triggered. This should therefore allow researchers to produce a stream of smaller, less powerful ELMs that will not damage the tokamak.

First predicted by US researcher Todd Evans in 2004, the lobes – known as homoclinic tangles – were seen for the first time during experiments at MAST in December 2011, thanks to the UK tokamak's excellent high-speed cameras. CCFE scientist Dr Andrew Kirk, who leads ELM studies on MAST, said:

"This could be an important discovery for tackling the ELM problem, which is one of the biggest concerns for physicists at ITER. The aim for ITER is to remove ELMs completely, but it is useful to have back-up strategies which mitigate them instead. The lobes we have identified at MAST point towards a promising way of doing this."

The lobes are significant for another reason; they are a good indicator of how well the resonant magnetic perturbation is working: "The length of the lobes is determined by the amount of magnetic perturbation the plasma is seeing," explains Dr Kirk. "So the longer the 'fingers', the deeper the penetration. If the fingers are too long, we can see that it has gone too far in and will start to disturb the core, which is what we want to avoid."

The next phase of the research will involve developing codes to map how particles will be deposited and how the lobes will be formed around the plasma.

"We already have codes that can determine the location of the fingers but we cannot predict their length due to uncertainties in how the plasma reacts to the applied perturbations. Our measurements will allow us to validate which models correctly take this plasma response into account," said Dr Kirk. "New codes will mean we can produce accurate predictions for ITER and help them tame the ELM."

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For more information please contact Nick Holloway, Media Manager at Culham Centre for Fusion Energy, on 01235 466232 or at nick.holloway@ccfe.ac.uk.

Notes to Editors:

Published research

- The MAST results relating to the lobe structures are published in Physical Review Letters, 20 June 2012. See: http://prl.aps.org/abstract/PRL/v108/i25/e255003

Culham Centre for Fusion Energy

- Culham Centre for Fusion Energy is home to the UK's fusion research programme, most notably the MAST (Mega Amp Spherical Tokamak) experiment. It also hosts the world's largest fusion facility, JET (Joint European Torus), which is operated for CCFE's European partners under the European Fusion Development Agreement. Further information is available at www.ccfe.ac.uk and www.jet.efda.org.
- Fusion research at Culham is funded by the Engineering and Physical Sciences Research Council (EPSRC – www.epsrc.ac.uk) and by the European Union under the EURATOM treaty.

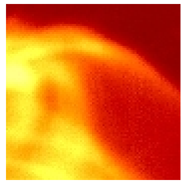
Fusion energy

- Fusion research is focused on copying the process which powers the Sun for a new large-scale source of clean energy here on Earth.
- When light atomic nuclei fuse together to form heavier ones, a large amount of energy is released. To utilise this, gaseous fuel is heated to extreme temperatures, hotter than the centre of the Sun, forming a plasma in which fusion reactions take place. A commercial power station will use the energy from neutrons produced by fusion reactions to generate electricity.
- Fusion has huge potential as an energy source that is safe, environmentally responsible, economically viable, with abundant and widespread fuel resources. In Europe, fusion research is organised in a co-ordinated programme, which brings together pan-European R&D resources in collaborations on major research topics.
- The fusion programme's objectives are to obtain and study conditions approaching those needed in a power plant, using the 'tokamak' machine concept – effectively a magnetic bottle which contains the hot plasma. The next step is ITER, an international tokamak experiment which should provide a full scientific demonstration of the feasibility of fusion in power plant-like conditions. ITER – a partnership between China, Europe, India, Japan, South Korea, Russia and the United States of America – is now being constructed at Cadarache in the south of France. ITER (www.iter.org) will be followed by a demonstration fusion power station, DEMO.

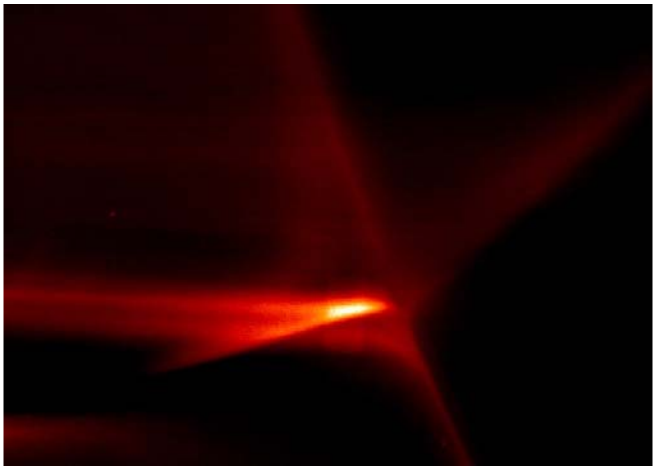
Mega Amp Spherical Tokamak (MAST)

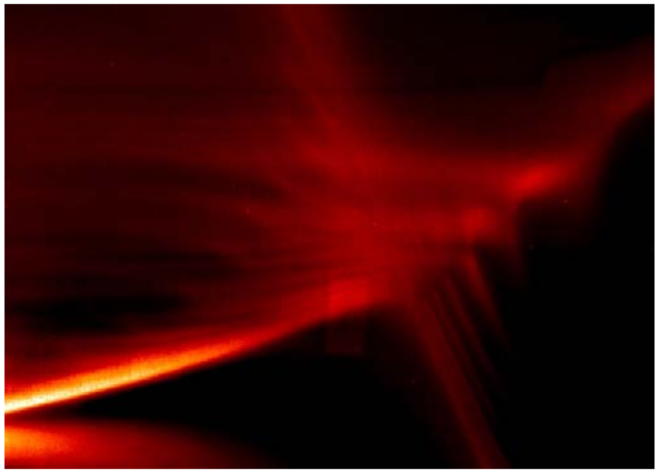
- MAST (Mega Amp Spherical Tokamak) is the UK's fusion energy experiment, based at Culham Centre for Fusion Energy. Along with NSTX – a complementary experiment at Princeton in the USA – MAST is one of the world's two leading spherical tokamaks (STs).
- Experiments on MAST are important because they test ITER physics in new regimes and they help determine the long-term potential of the ST, which may eventually be suitable as the basis for a power station. A design based on MAST may lead to a compact Component Test Facility, which would reduce risk and accelerate the development of commercial fusion power.
- Over 16,000 man-made 'stars' have now been created by experiments inside MAST. They have provided a wealth of data, enabling many advances in key research areas including plasma instabilities and start-up methods. This is assisted by MAST's impressive suite of diagnostics for analysing plasmas, which is among the best of any tokamak now operating.
- To take STs to the next level, more powerful and flexible machines will be needed. With this in mind, Culham Centre for Fusion Energy is implementing a major £30 million upgrade that will give MAST unique capabilities.

Related images (originals available on request):



High-speed video image of the MAST plasma obtained at the start of an ELM. The top right hand corner of the photograph has been expanded on the right to highlight the similarity of the ELM filament with a solar eruption.





False colour images of the ‘X-point’ region at the base of the MAST plasma captured by the high-speed camera during an H-mode.

Left: without resonant magnetic perturbation;

Right: with resonant magnetic perturbation, showing the finger-like lobe structures emerging from the edge of the plasma.