Plasma: The trouble with bubbles

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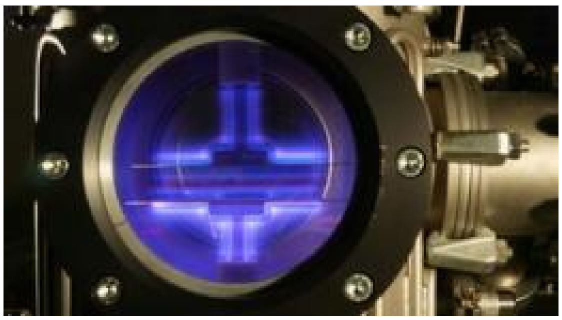

Plasma © Alain Herzog

Controlling a boiling plasma at several million degrees Celsius – that's the challenge of nuclear fusion, our great energy hope for the future. EPFL's Plasma Physics Research Center (CRPP) has just published two scientific articles that advance the state of knowledge in the domain.

If plasmas can be controlled, then it may one day be possible to use nuclear fusion as an energy source. As in stars, however, this ultra-hot material is constantly boiling, which makes it hard to control in a reactor. Instabilities in the plasma create bubble-like "blobs" that, upon bursting, can damage the internal walls of the reactor. Scientists are trying to find ways to stabilize plasmas from the inner core out to the surface. Two CRPP teams have recently made progress in this area by improving our understanding of these instabilities.

On the surface

Surface instabilities appear as filaments. Physicists have observed that these structures originate from waves propagating in the plasma. They worked out the wave dynamics, and then precisely measured the filaments' properties (electrical, in particular), using instruments capable of taking 250,000 images per second. These measurements represent a major accomplishment, because the filaments, only a few centimeters long, move at a speed of one to two kilometers a second, are at a temperature of nearly 50,000°C and hold the energy of a 10-ton truck going at 80 km/hour. The researchers nonetheless managed to observe that the filaments carried their own current. They thus confirmed the theory proposed by Christian Theiler as part of his PhD research at the CRPP.

Thanks to this discovery, it will be possible to apply voltage directly to the filaments. Ivo Furno, who led the experiment, explains: "It is very difficult to prevent them from forming, but it may be possible to control their speed and trajectory." Given the plasma's elevated temperature, it is necessary to act on it without direct contact to control the filaments, which makes this technique particularly promising. The discovery will have a very important impact on research, because filaments appear in all plasmas in "tokamaks", or nuclear fusion reactors. In fact, controlling the behavior of the filaments in the ITER tokamak is considered a gauge of the project's success.

In the core

Reactors like EPFL's TCV have a plasma core that is maintained at extremely high temperatures – up to a hundred million degrees – as long as possible, in order to generate fusion reactions. To do this, physicists confine the plasma using magnetic fields. Despite their efforts, hot blobs are still created in the core, and the danger is that several blobs could combine and eventually escape to the surface.

A group of scientists led by Timothy Goodman has - for the first time - managed to concentrate radiation equivalent to a thousand microwave ovens with a precision of just a few millimeters, using a set of mirrors that can be adjusted in real time. With this powerful beam they were able to prevent the blobs from aggregating, without disturbing the reactions taking place in the plasma core.

“Like surgeons, physicists must intervene in the plasma in the least invasive manner possible to guarantee its stability,” adds Ambroglio Fasoli, the EPFL Professor responsible for the two teams. This research marks a new step in the journey towards controlling nuclear fusion. And its arrival is timely; not only is conventional nuclear power (fission) under considerable scrutiny, but fusion is also being called upon to provide proof of its potential. “We can’t just sit back and watch. We also have to control the reactions,” concludes the physicist. And so physics takes another step forward.

More information:
Direct Two-Dimensional Measurements of the Field-Aligned Current Associated with Plasma Blobs, I. Furno, M. Spolaore, C. Theiler, N. Vianello, R. Cavazzana, and A. Fasoli, Physical Review Letters, vol. 106, 2011.
prl.aps.org/abstract/PRL/v106/i24/e245001

Sawtooth Pacing by Real-Time Auxiliary Power Control in a Tokamak Plasma, T. P. Goodman, F. Felici, O. Sauter, and J. P. Graves (the TCV Team), Physical Review Letters, vol. 106, 2011.
prl.aps.org/abstract/PRL/v106/i24/e245002

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