Wendelstein 7-X: Second round of experimentation started

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A view inside the Wendelstein 7-X plasma vessel with graphite tile cladding. Credit: IPP, Jan Michael Hosan

The plasma experiments in the Wendelstein 7-X fusion device at Max Planck Institute for Plasma Physics (IPP) in Greifswald, Germany, have been resumed after a 15-month conversion break. The extension has made the device fit for higher heating power and longer pulses. This now allows the optimised concept of Wendelstein 7-X to be tested. Wendelstein 7-X, the world's largest fusion device of the stellarator type, is to investigate its suitability for a power plant.

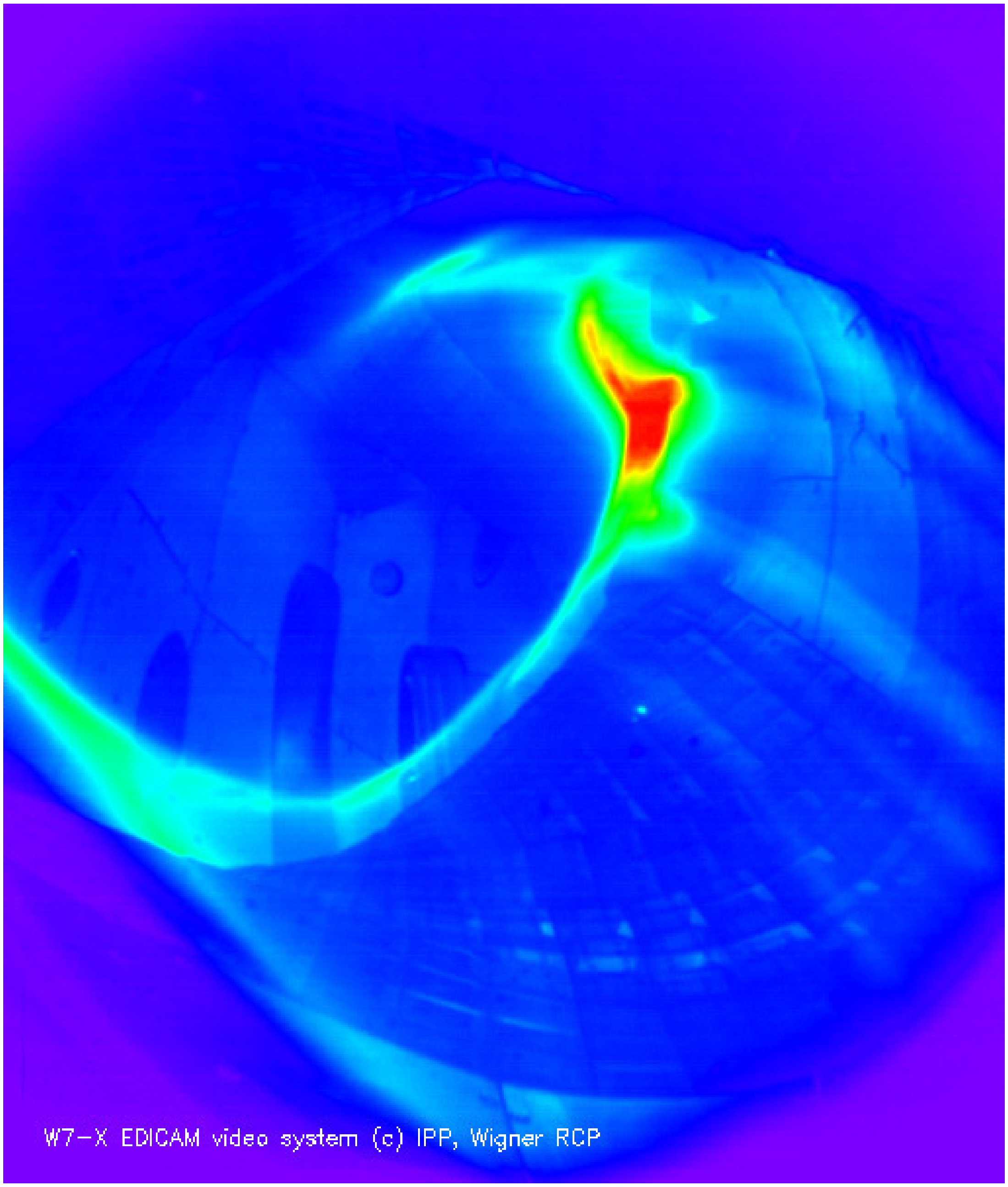
Besides new heating and measuring facilities, over 8,000 graphite wall tiles and ten divertor modules have been installed in the plasma vessel since March last year, i.e. the scheduled end of the first experimentation phase. This cladding is to protect the vessel walls and allow higher temperatures and plasma discharges lasting 10 seconds in forthcoming experiments.

A special function is exercised here by the ten sections of the divertor: As broad strips on the wall of the plasma vessel, the divertor tiles conform exactly to the twisting contour of the plasma edge. They thus protect especially those wall areas to which particles escaping from the edge of the plasma ring are specifically directed. Along with unwanted impurities the impinging particles are neutralised and pumped off. The divertor is thus an important tool for regulating the purity and density of the plasma.

The smaller predecessor, the Wendelstein 7-AS stellarator at IPP in Garching, had already yielded encouraging results in divertor tests. But not till the much larger successor, Wendelstein 7-X at Greifswald, did the geometry conditions come up to power plant size, particularly the ratio of the divertor area to the plasma volume. "We are therefore very excited that we are now able for the first time to investigate whether the divertor concept of an optimised stellarator can really work properly", says Project Head Professor Thomas Klinger. These tests will play a major role: Many detailed investigations will carefully check how to guide the plasma and what magnetic field structures and heating and replenishing methods are most successful.

Newly enlisted measuring instruments will also allow observation of turbulence in the plasma for the first time: The small eddies entailed influence how successful magnetic confinement and thermal insulation of the hot plasma are, these being important parameters for a future power plant, because they determine the size of the plant and hence its economical merit. "We shall be able for the first time to check whether the promising predictions of theory for a completely optimised stellarator are correct. In comparison with previous devices, Wendelstein 7-X is expected to yield quite new, possibly even better, conditions", says Thomas Klinger.

As all ten microwave transmitters for the microwave heating of the plasma are meanwhile ready for use, this will allow a higher energy throughput and plasmas of higher density. It will now be possible to raise the energy to 80 megajoules once all versions of the microwave heating have been tackled and tested, as compared with 4 megajoules in 2016. The rather low plasma density hitherto can now be more than doubled to attain values meeting power plant requirements.



A plasma discharge in the upgraded vessel. Credit: IPP/Wigner RCP

This has significant consequences: First the density of the plasma has to be sufficient to allow electrons and ions to exchange energy effectively. Previously, the microwave heating had only been able to heat essentially just the electrons. Instead of hot electrons with 100 million degrees and cold ions with 10 million degrees as hitherto the electrons and ions in the new plasma will have almost equal temperatures of up to 70 million degrees. This should also enhance the thermal insulation of the plasma. Whereas it was hitherto just upper average in relation to the size of the device, the effect of optimising Wendelstein 7-X should now become visible: "It's getting very exciting", states Thomas Klinger.

Background

The objective of fusion research is to develop a power plant favourable to the climate and environment. Like the sun, it is to derive energy from fusion of atomic nuclei. As the fusion fire does not ignite till temperatures exceeding 100 million degrees are attained, the fuel, viz. a low-density hydrogen plasma, ought not to come into contact with cold vessel walls. Confined by magnetic fields, it levitates inside a vacuum chamber with hardly any contact.

The magnetic cage of Wendelstein 7-X is formed by a ring of 50 superconducting magnet coils about 3.5 metres high. Their special shapes are the result of sophisticated optimisation calculations. Although Wendelstein 7-X is not meant to produce energy, the device should prove that stellarators are suitable for power plants. For the first time the quality of the plasma confinement in a stellarator is to attain the level of competing devices of the tokamak type.

For this purpose, further stages of modification are being planned. For example, the graphite tiles of the divertor are to be replaced in a few years by carbon-fibre-reinforced carbon elements that are additionally water-cooled. This will allow discharges lasting up to 30 minutes in which it can be tested whether Wendelstein 7-X will achieve its optimisation targets in the long run: In this way the device is to demonstrate the essential advantage of stellarators, viz. their capability for continuous operation.