Wendelstein 7-X

NEWSLETTER

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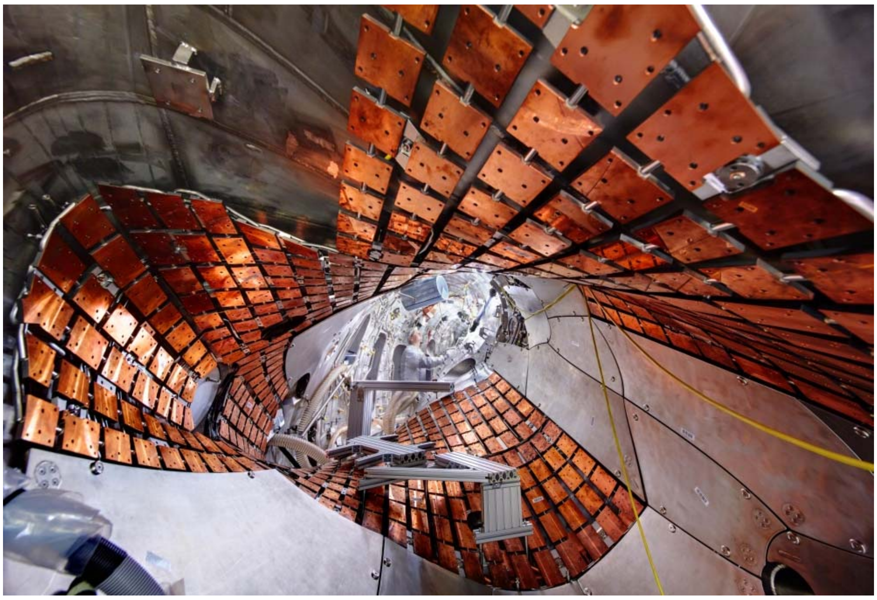
Graphite Covering for Wendelstein 7-X

photo: IPP, Torsten Bräuer

The aim for the first operation phase (OP 1.1) at Wendelstein 7-X (from 10 December 2015 to 10 March 2016) was to conduct integrated testing of the most important systems as quickly as possible and to gain first experience with the physics of the machine. Therefore, the divertor and most of the graphite tiles of the baffles and wall protection elements had not been installed for this first phase. Instead, five symmetrically placed limiter structures were installed in the plasma vessel. During a discharge the plasma could deposit the majority of its energy on these limiters whereas all the other plasma vessel components were in the “shadow” of the limiters and hence were protected against thermal overload. However, using inertially cooled limiters restricted the energy which could be coupled into the plasma to four mega joules thus limiting the discharge time.

The longest discharges possible during this phase lasted for six seconds with a heating power of 0.6 MW provided by microwaves. Shorter discharge pulses were produced with a heating power of up to 4.3 MW. The limiters as well as the magnetic field of the stellarator worked excellently: The plasma vessel structures showed no evidence of damage.



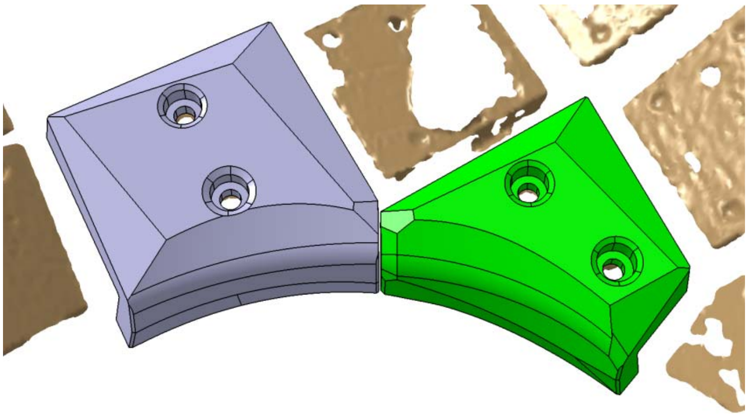
View into the plasma vessel before the first operation phase. In the mean time, precisely fitting graphite tiles have been mounted over these wall protection elements made of copper-chromium-zircon.

photo: IPP, Bernhard Ludewig

In preparation for the next operation phase (OP 1.2a), which is scheduled to start in late summer of this year, the limiter structures have been replaced by a test divertor and all graphite tiles on the baffles and wall protection elements have been installed. This will allow the use of more heating power and access to the required magnetic field configurations. In Wendelstein 7-X, the divertor utilizes the specific topology of the magnetic field at the plasma edge to direct the heat from the plasma to large prepared surfaces.

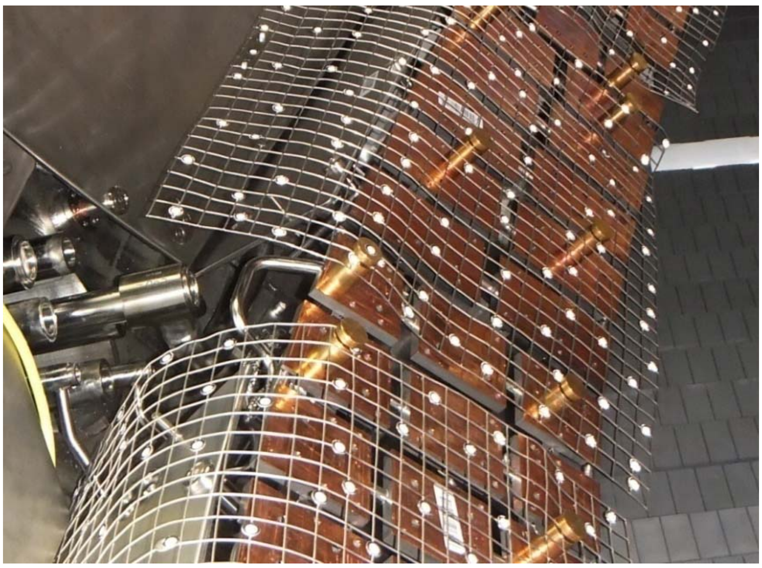
In addition to the components necessary for the first operation of W7-X, components for the upgrade of the machine had already been installed in the plasma vessel before the first operation phase such as piping for the cooling of in-vessel components, cooling shields for the plasma vessel wall (so called panels), the cooling structures of the baffle and wall protection elements, the support structures of the divertors and a series of plasma diagnostics.

The installation of the cooling structures for the baffles and wall protection elements was technologically complex as well as time-consuming and resource-intensive. Particular attention was paid to vacuum-tight assembly of the water connections and the position accuracy. If we had tried to install the cooling structures of the baffle and wall protection structures with the same or even higher accuracy as the graphite tiles to be mounted to them later on (with a lateral distance between the tiles of 3 mm and a tolerance of -0.5 mm and +4 mm as well as a step (leading edge) between the tiles of max. 3 mm) this would have led to in-acceptable costs in both time and resources. Therefore, we chose an assembly concept for the installation of the baffles and wall protection elements as well as for their covering with graphite tiles in which the cooling structures were installed with practice-oriented assembly tolerances (less than 1.5 mm) before the positions of the structures were measured precisely. Based on these measurement values the tiles were manufactured from pre-fabricated graphite tiles and then mounted. With this process, the tile dimensions were exactly adjusted to the actual position of the cooling structures.



Adjustment of the tile geometry to the actual position of the cooling structures. In the CAD representation of the cooling structures the models of the graphite tiles (blue and green) are positioned. Then gaps or penetrations are analyzed and the size of the tiles is adjusted to millimeter accuracy. The precisely fitting tiles are then manufactured from pre-fabricated tiles according to the modified CAD models.

During the current upgrading phase of the experiment the actual positions of these components were measured by means of a hand-held laser scanner which had the advantage that separate stands and orientation to the main W7-X coordinate system were not needed for the measuring system. It was only necessary to install a system of reference points which enclosed the components to be measured. The distances between the single measuring points had to be about 150 mm. This allowed within a very short time, the measurement of relative positions of the cooling structures with respect to each other at an accuracy of 1 mm x 1mm and a measurement uncertainty of less than 0.5 mm. Between May 2016 and January 2017 the cooling structures of 170 baffles and 160 wall protection elements have been scanned and the respective CAD representations for the adjustment of the graphite tiles generated.



Installation of the reference points (white dots) on the cooling structures of the baffles to be scanned. The actual position of the cooling structures is measured by means of a hand-held scanner to determine the dimensions of each graphite tile with better than millimeter accuracy.

photo: IPP, Torsten Bräuer

From the knowledge of the actual position of the cooling structures, especially the position of the edges of individual cooling structures relative to each other, it was possible to determine the exact dimensions of the graphite tiles to be mounted on the cooling structures in a reverse engineering process. IPP used the know-how and reverse-engineering experience of the company Winter 3D GmbH. In a weekly cycle, scan data were sent to this external design office. Within a week or two the CAD models for the graphite tiles to be modified were back at IPP.

Here the CAD data were checked again and then handed over to the internal workshop. Based on the new CAD data precisely fitting tiles were manufactured on a five axis milling machine from already pre-fabricated tiles. The accuracy during the mechanical machining of the graphite tiles is below 0.01 mm. Before the assembly in W7-X all machined tiles were heated in vacuum to 2000 °C to remove impurities and water.

Machining of a graphite tile on the five axis milling machine

photo: IPP, Beate Kemnitz

Assembly of the first graphite tile of the baffles and wall protection elements. Altogether about 8000 graphite tiles have been mounted in the plasma vessel of Wendelstein 7-X. About 4500 of these 8000 graphite tiles were adjusted to keep the gaps and leading edges between adjoining tiles as narrow and small as possible.

photo: IPP, Torsten Bräuer

Altogether about 4500 graphite tiles of the 8000 graphite tiles for the baffles and wall protection elements have been modified and brought into the precisely fitting form. All installed graphite tiles meet the required tolerances with respect to the lateral distance as well as the leading edges between the adjoining neighbors.

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