Wendelstein 7-X

NEWSLETTER

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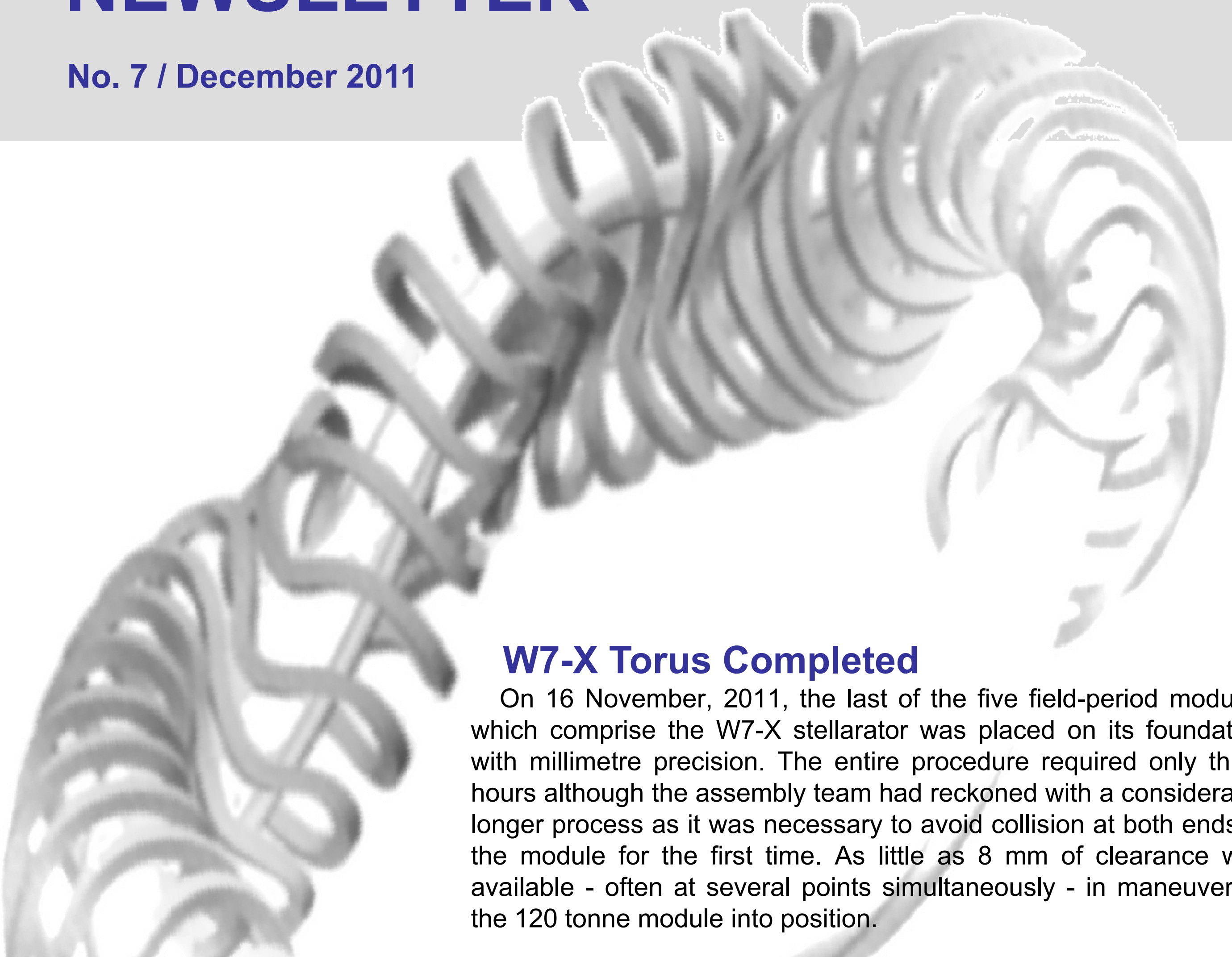

W7-X Torus Completed

On 16 November, 2011, the last of the five field-period modules which comprise the W7-X stellarator was placed on its foundation with millimetre precision. The entire procedure required only three hours although the assembly team had reckoned with a considerably longer process as it was necessary to avoid collision at both ends of the module for the first time. As little as 8 mm of clearance was available - often at several points simultaneously - in maneuvering the 120 tonne module into position.

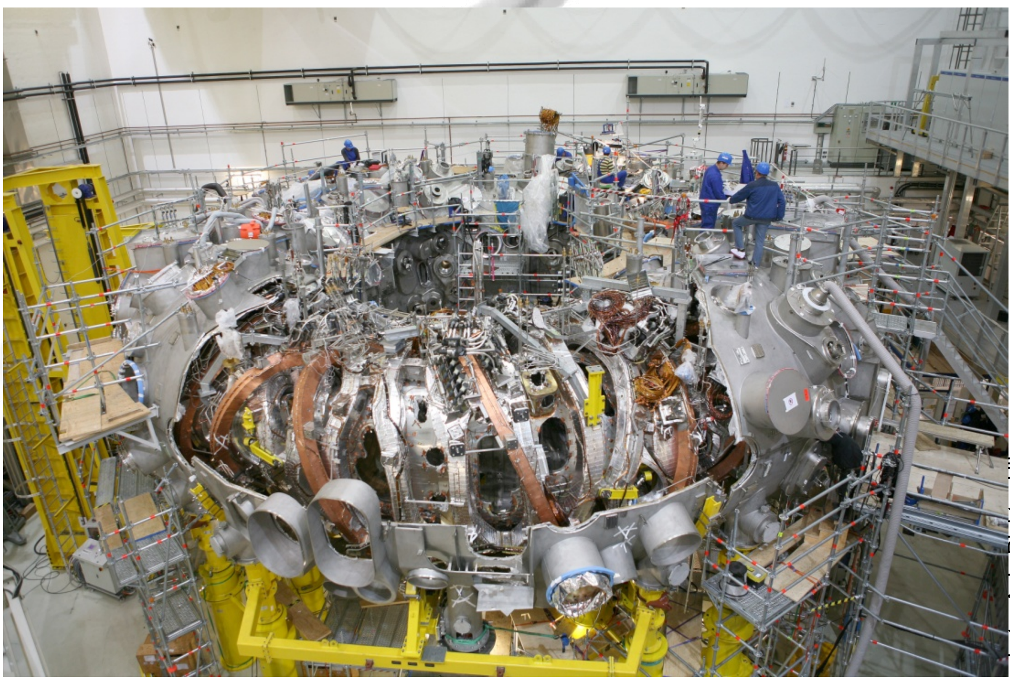

photo: Anja Richter Ullmann

Figure 1: Wendelstein 7-X on November 16th 2011

In the coming months, each module will be connected to its two neighbours. The separate cryo-piping, instrumentation and bus systems of the individual modules will then be joined with the aid of superconducting joints. The sections of the central support ring will be bolted together, the thermal insulation joined at the seams and the plasma and external vessels will be sealed by welding.

At the beginning of 2012, assembly of the in-vessel components will commence by cladding the plasma vessel with stainless steel cooling panels. Regions which will be subjected to high thermal loads must be protected with carbon tiles.

Ports Provide Access to the Plasma

Before assembly of the numerous in-vessel components can begin, however, it is necessary to install the ports which will provide the links between the external and plasma vessels.

A total of 254 vacuum-tight ducts, some as long as 3 m, will provide these “windows” for plasma observation. Roughly half of the ports are devoted to diagnostic purposes, e.g. detection of signals in the microwave, visible and x-ray portions of the electromagnetic spectrum. One of the diagnostic goals is measurement of the plasma temperature which must reach approximately 100 million degrees Celsius to make a future fusion power plant a realistic possibility. The remainder of the ports provides access for plasma heating systems and for the vacuum pumps which are necessary for exhaust of the working gas as well as impurities. Also accommodated is the water-filled piping required for cooling of the plasma vessel.
The openings for the ports vary from circular with a diameter of 150 mm to approximately rectangular with dimensions of 1000 x 400 mm². The largest ports are reserved for the microwave and neutral beam heating systems and to provide physical access to the torus for maintenance.

photo: Beate Kemnitz

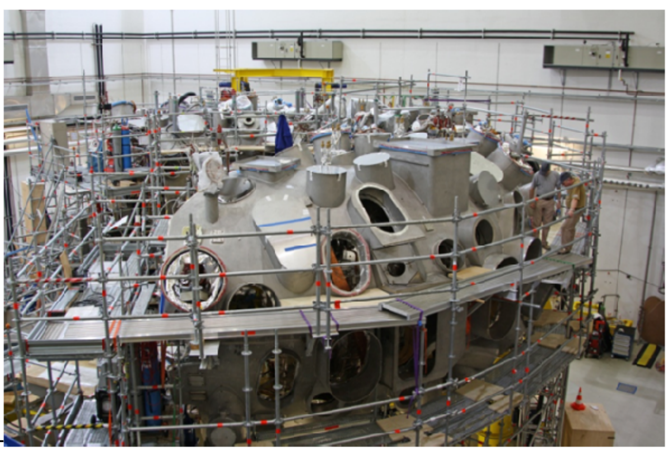

Figure 2: Real and virtual perspectives: the photo on the left shows a module without ports in the experimental hall. On the right is a CAD view of the same (with external vessel removed) with the ports highlighted in red.

Placement of the ports is done from the outside of the torus. This involves insertion through the opening in the external vessel and maneuvering through the cryo chamber to the target position on the plasma vessel, after which both ends are welded into place.
To accommodate movement of the plasma vessel during experimental operation of W7-X, connection of the ports to the external vessel makes use of bellows. As the ports must pass through the extreme cold of the cryo chamber it is mandatory that they be carefully insulated.
As foreseen in the project timetable, port assembly is completed for three of the five modules. This was achieved in spite of the technical challenges faced during the process. Indeed, ports weighing as much as a tonne have been maneuvered and welded into place with millimetre precision.

photo: Beate Kemnitz

Determination of correct lengths and the complicated curves along which the ports must be cut to shape was also technically demanding. The initial approach involving a provisional placement of each port and subsequent cutting to achieve a satisfactory fit has now been replaced with a 3-D construction technology which not only accounts for the plasma vessel shape and the port orientation but also distortion which can be expected during the welding process. Once the port has been cut to the correct shape it must be thermally insulated. To prevent subsequent collisions in the construction and in the operation of W7-X, it is necessary that the insulation be applied with millimetre accuracy.

Figure 3: For the accurate placement of the ports it was necessary to develop a carriage system encompassing five degrees of freedom at heights of up to 12 m above the floor of the experimental hall.

Zero Tolerance – Engineering Pushed to its Limits

A handful of ports pose special challenges as they require accuracy at the level of technical feasibility. Although in most cases tolerances of a few millimetres are allowed, these special ports have tolerances which are essentially zero. The reasons for this include maximization of the port cross sections and the necessity of avoiding collisions with other components.
An example is the port for neutral particle heating. Even a reduction of the port cross section by 1mm would significantly increase the number of fast particles which never reach the plasma and instead deposit their energy in the port. An increase of port dimensions is impossible in this case due to the surrounding components, including the magnetic field coils. To improve such situations an iterative design and test procedure is used in which the orientation and welding properties of prototype ports are investigated with current results incorporated into each subsequent design.
This approach requires teamwork of the highest level as it represents an interplay of scientific calculations, modern CAD modelling, accurate 3-D measurements, cutting-edge engineering and a fine human touch.

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