The fusion fuel is an extremely low-density and electrically charged hydrogen gas – a "plasma". To ignite the fusion reaction, it must be heated to temperatures of more than a hundred million degrees Celsius. In terms of the principle of magnetic confinement, fusion research concentrates primarily on two types of facilities: the tokamak and the stellarator. Both confine the hot plasma in magnetic fields and thus keep it away from material vessel walls. Complex superconducting magnetic coils generate the magnetic field cage of the Wendelstein 7-X stellarator.

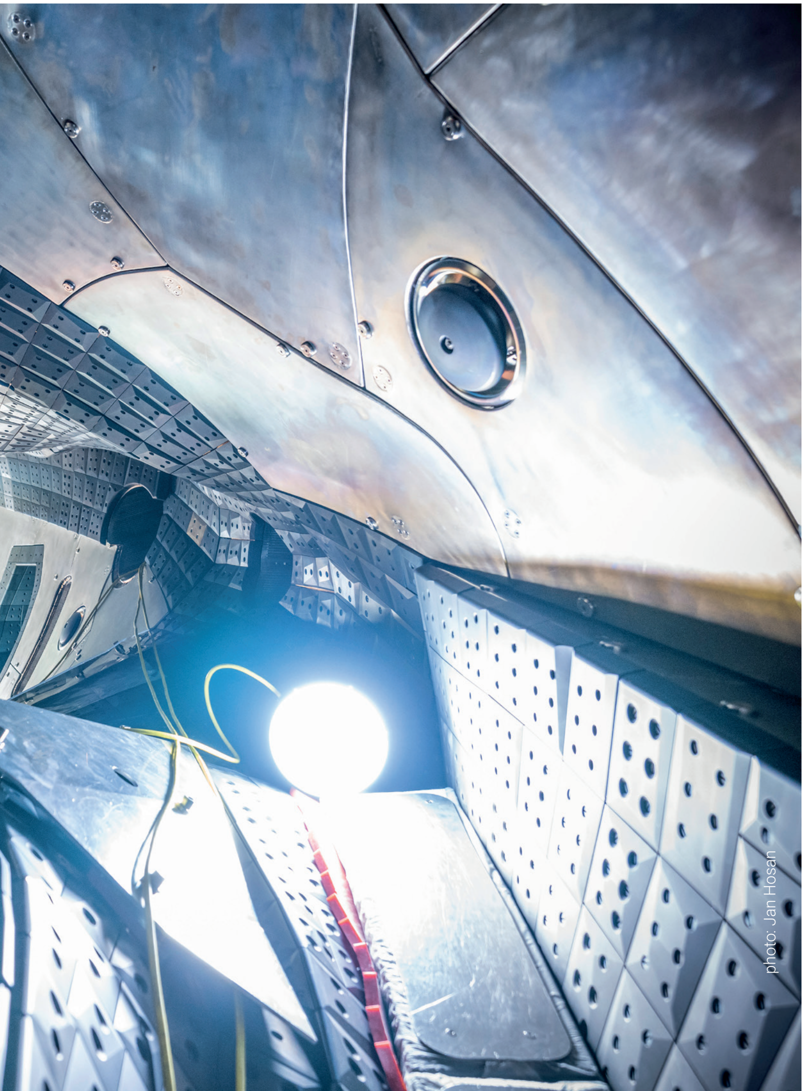


photo: Jan Hosan

Objectives of Wendelstein 7-X

Investigating the core issues of fusion under power plant-like conditions during long-term or quasi-stationary operation:

- particle confinement of the optimized magnetic field
- particle and impurity transport
- efficiency of non-ohmic heating
- plasma-wall interaction
- divertor studies
- verification of numerical models


photo: Ben Peters

You want to learn more about Wendelstein 7-X and the state of research? Visit us: www.ipp.mpg.de/visitors

Max-Planck-Institut
für Plasmaphysik (IPP)
Teilinstitut Greifswald
Wendelsteinstraße 1
17491 Greifswald

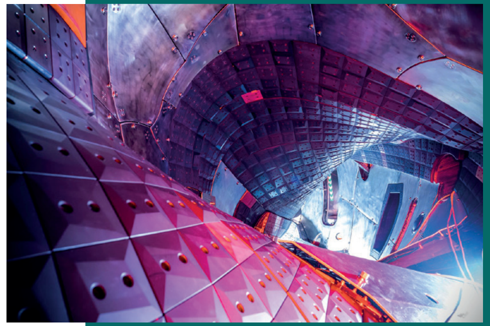
Phone: +49 (0) 3834 88-1000

E-Mail: info@ipp.mpg.de
www.ipp.mpg.de

Interactive tour to
Wendelstein 7X
www.sternenmaschine.eu

cover picture: view into the plasma vessel
photo: Jan Hosan

MAX PLANCK INSTITUTE
FOR PLASMA PHYSICS



WENDEL-STEIN 7-X FUSION DEVICE

Wendelstein 7-X, the world's largest and most modern stellarator-type fusion research facility, went into operation at the Greifswald Branch of the Max Planck Institute for Plasma Physics at the end of 2015. The objective of theoretical and experimental research is to develop a power plant that – similar to the process in the sun – generates energy by fusing hydrogen nuclei to form helium. If this process can be harnessed on Earth, a climate-friendly and almost inexhaustible source of energy will be available.

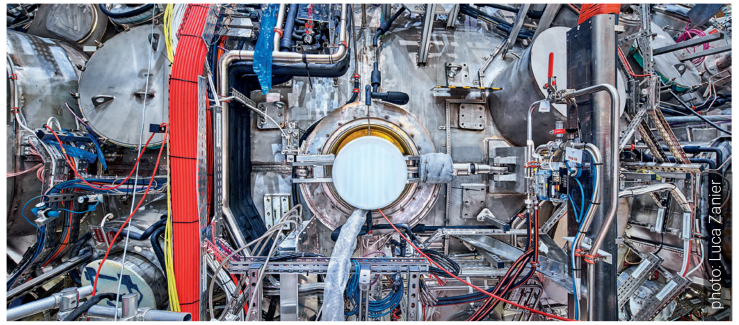

View into the plasma vessel

Research objectives

Wendelstein 7-X will demonstrate the power plant suitability of the stellarator principle and its main advantage: continuous operation. For this purpose, discharges of up to 30 minutes are planned with plasma conditions relevant to a power plant. However, Wendelstein 7-X will not generate an energy-supplying plasma. This is the task of the international experimental reactor ITER.

Design of the fusion facility

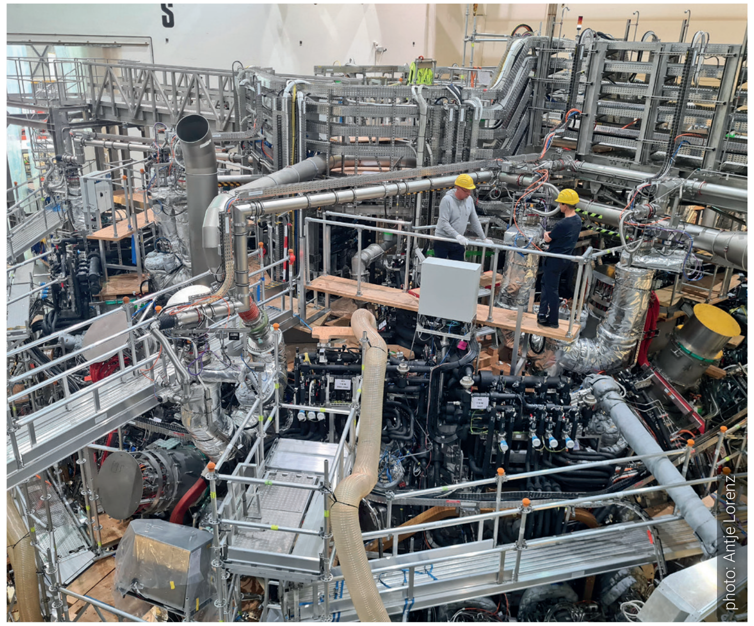
The coil system consisting of 50 non-planar and 20 planar superconducting magnetic coils is the core of Wendelstein 7-X. Cooled to minus 270 degrees Celsius, which is close to absolute zero, they operate almost without any electrical losses – important for the envisioned continuous operation. The coils are threaded onto a ring-shaped plasma vessel and enclosed in a cryostat for thermal insulation.The plasma is observed, supplied, and heated through 254 steel pipes, so-called ports, leading from the outside into the plasma vessel. To protect the inner wall of the vessel from thermal loads of the plasma and, conversely, to protect the plasma from impurities out of the wall, the magnetic fields direct the plasma boundary layer to specially equipped areas of this wall: the water-cooled plates of the so-called divertor. It is thus possible to remove both the heat and the impurities.



Outer vessel with some of the 254 ports

Essential data of Wendelstein 7-X

Size of the device	diameter 16 metres, height 5 metres
Mass	725 tons
Plasma major radius	5.5 metres (mean value)
Plasma minor radius	0.52 metre (mean value)
Magnetic field strength	3 tesla
Discharge time	continuous operation for 30 minutes with microwave heating
Plasma	
• composition	hydrogen, deuterium
• volume	30 cubic meters
• mass	5 to 30 milligrams
Plasma heating	20 megawatts
Plasma temperature	up to 100 million degrees
Plasma density	up to $2 \cdot 10^{20}$ particles per m^3
Energy confinement time	up to 0.2 second



General view of the fusion device Wendelstein 7-X

The optimized stellarator

The concept of the stellarator was developed in 1951 by the American fusion researcher Lyman Spitzer. In contrast to a tokamak, which generates part of the magnetic cage by means of an electric current flowing in the plasma, a stellarator operates without plasma current using only external magnetic field coils. Since 1960, stellarators have been investigated at IPP in Garching. However, these "classic" stellarators could not confine the plasma as well as a tokamak. To improve the plasma confinement, IPP theorists, therefore, were looking systematically for an improved magnetic field. This further improvement of the Wendelstein stellarators to their present complex design was only possible using powerful supercomputers, which became available from the 1980s onwards. With their help, the theoretical concept for Wendelstein 7-X was developed within ten years. Parts of this optimization have been confirmed experimentally by the smaller predecessor Wendelstein 7-AS in Garching.

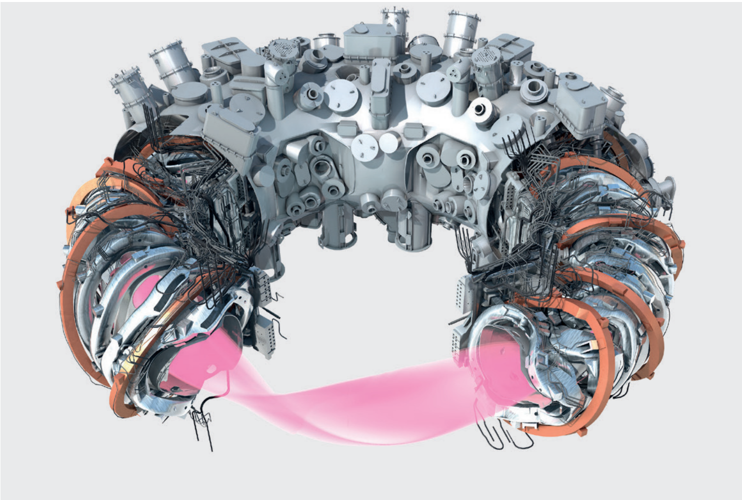
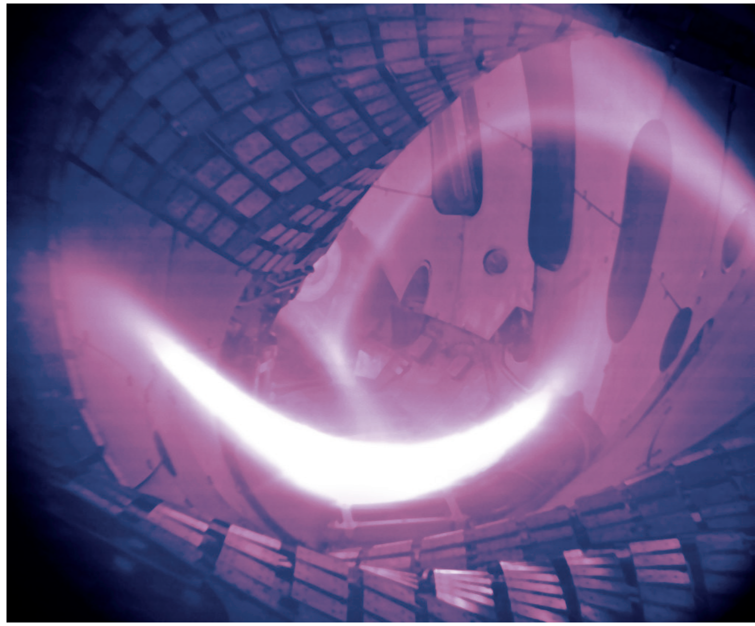


Illustration of the Wendelstein 7-X design

Operation of Wendelstein 7-X

Wendelstein 7-X fired up in 2015 using helium. In 2016, the generation of the first hydrogen plasma marked the start of scientific operation at Wendelstein 7-X. One year later, the facility achieved the stellarator world record for the fusion product. This product of plasma density, temperature, and quality of thermal insulation describes how close a fusion device is to the ignition of the fusion fire.
Intense experimentation phases at Wendelstein 7-X have alternated with sometimes complex upgrading and maintenance phases. In the meantime, all plasma vessel elements that come into thermal contact with the plasma, in particular the divertor, are being equipped with water-cooling. This should enable the divertor to withstand loads of up to ten megawatts per square meter. These are heat loads that are similar to those of the space shuttle during re-entry into Earth's atmosphere.



First hydrogen plasma in Wendelstein 7-X