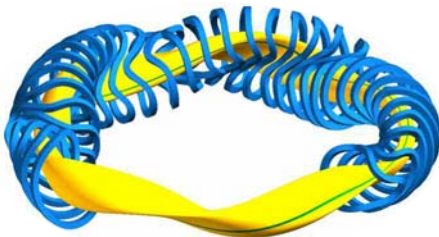
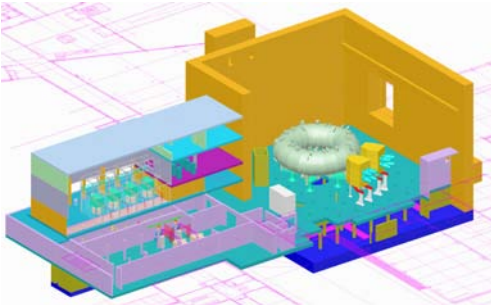


Wendelstein 7-X fusion experiment

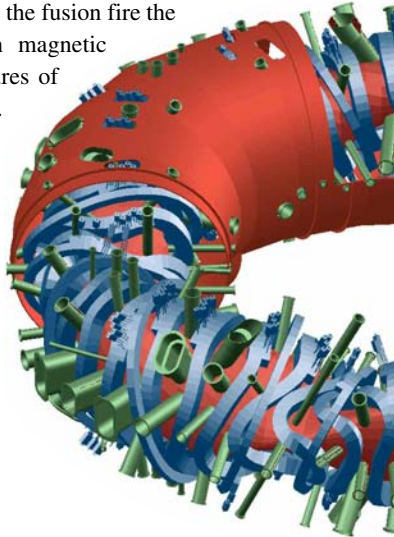


Max-Planck-Institut
für Plasmaphysik

Garching · Greifswald

The Wendelstein 7-X fusion experiment is now under construction at the Greifswald Branch of the Max-Planck-Institut für Plasmaphysik. It will be the world's largest stellarator-type fusion device. The objective is to show that stellarators are fundamentally suitable for operation as power plants.

The goal of fusion research is to develop a power plant that will produce energy from fusion of atomic nuclei – as takes place in the sun. The fuel is an ionised low-density hydrogen gas – a “plasma“. To ignite the fusion fire the plasma must be confined in magnetic fields and heated to temperatures of more than 100 million degrees.



**Cryostat,
magnet coils and
plasma vessel**

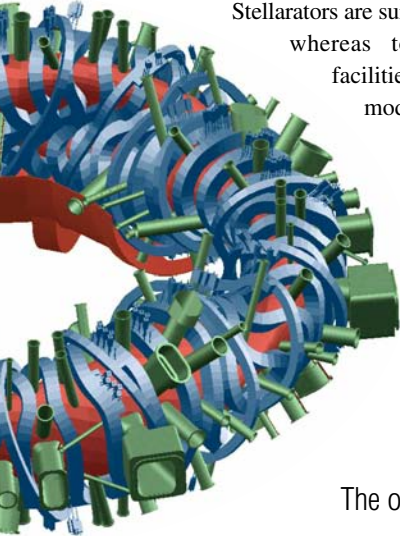
Essential data of Wendelstein 7-X

Size of the device	diameter 16 metres, height 5 metres
Mass	725 tons
Major plasma radius	5.5 metres (mean value)
Minor plasma radius	0.53 metre (mean value)
Magnetic field	3 tesla
Discharge time	continuous operation for 30 minutes with microwave heating
Plasma composition	hydrogen, deuterium
volume	30 cubic metres
quantity	0.005 up to 0.03 gram
Plasma heating	15 megawatts
Plasma temperature	up to 100 million degrees
Plasma density	up to $3 \cdot 10^{20}$ particles/m ³
Energy confinement time	0.15 second

Types of devices

Fusion research is focused at present on two types of devices – the tokamak and the stellarator. Both of them are being investigated at IPP. Most of the world's devices today are of the tokamak type. They produce part of the confining magnetic field by means of a strong electric current flowing in the plasma. Stellarators, on the other hand, form the magnetic field cage solely by means of external coils. They thus have strengths where tokamaks show weaknesses.

Stellarators are suitable for continuous operation, whereas tokamaks without auxiliary facilities can only work in pulsed mode.



The optimised stellarator

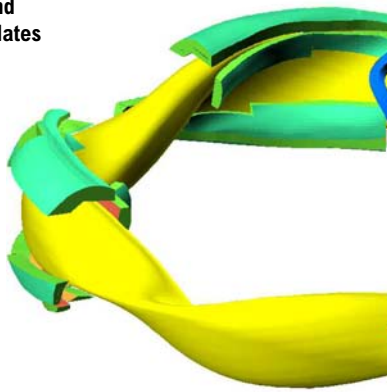
In this respect Wendelstein 7-X is a key device. It is intended to demonstrate that stellarators are suitable for operation as power plants. For this purpose Wendelstein 7-X will test an optimised magnetic field which will overcome the difficulties encountered by previous concepts: the quality of plasma equilibrium and confinement will be comparable to that of the tokamak.

The improved magnetic field cage will confine a hot hydrogen plasma that will demonstrate the suitability of the stellarator properties for a future power plant. Since Wendelstein 7-X is an experimental device and is not supposed to produce energy, it will be run without radioactive tritium as fuel component. The behaviour of a burning plasma will be investigated by means of the ITER international experimental reactor, which is being prepared in worldwide cooperation.

Divertor

Wendelstein 7-X is designed for steady-state operation. To protect the wall of the plasma vessel against hot particles from the plasma and, conversely, the plasma against impurities from the wall, the boundary layer of the plasma is diverted to specially equipped sections of the vessel wall, as in tokamaks. The geometry of this divertor conforms to the shape of the plasma ring.

**Plasma and
divertor plates**



Objectives of Wendelstein 7-X:

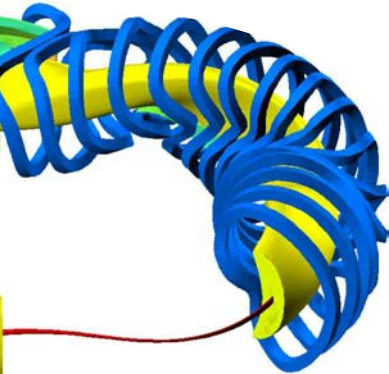
- producing plasmas allowing predictions on a stellarator power plant plasma
- continuous operation
- constructing a modular superconducting coil system
- developing a divertor for particle control

The set-up comprises:

- the stellarator device: magnet coils, cryostat, plasma vessel, divertor
- plasma heating systems
- supply facilities: electricity, water and helium cooling
- machine control system
- measuring facilities

Plasma diagnostics and heating

Approximately 60 measuring facilities will investigate the plasma of Wendelstein 7-X. The main plasma heating methods will be microwave, neutral particle and radio-frequency heating. The Forschungszentrum Karlsruhe is responsible for developing and supplying the microwave heating system.



**Magnet coils,
plasma and
magnet axis**



**Part of the
plasma vessel**

photograph: IPP, W. Filser

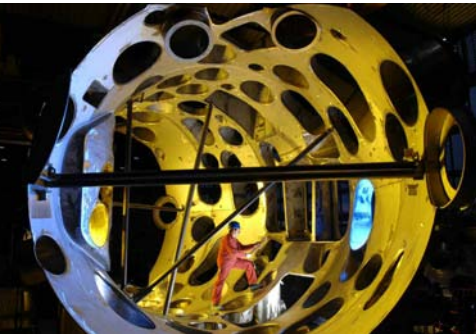
Coil system

The design of the magnetic cage enlists the concept of modular coils already successfully used by Wendelstein 7-AS, the predecessor device. Wendelstein 7-X will have a system of 50 non-planar coils, with 20 auxiliary planar coils being used for varying the magnetic field.

Unlike its predecessor, which uses normally conducting copper wires for the magnets, Wendelstein 7-X will be equipped with superconducting (i.e. zero loss) niobium-titanium wires. They will serve to demonstrate the essential stellarator property, steady-state operation. Liquid helium will be used to cool the coils to the temperature required for superconductivity, i.e. approx. 4 degrees Kelvin – close to absolute zero.

Cryostat and plasma vessel

Due to the low operating temperature the coils will be installed in a cryostat where they are thermally insulated by a vacuum. The plasma vessel inside the coils conforms to the winding shape of the plasma. The plasma can be investigated and heated through more than 250 ports.



photograph: IPP, W. Filser

Part of the cryostat

Plasma shape

The shape of the plasma results from the optimisation of the stellarator. Important features are the varying cross-section of the plasma (triangular to bean-shaped) and the spiral shape of the magnetic axis.

photograph: IPP, A. Künzelmann



Superconducting magnet coil during production

Stellarator experiments at IPP

The stellarator was proposed as one of the first concepts for magnetic plasma confinement by the American fusion physicist, Lyman Spitzer, in 1951. First experiments in Germany began in 1961 at the Max-Planck-Institut für Physik und Astrophysik in Munich. Since 1965 stellarators have been investigated at the Max-Planck-Institut für Plasmaphysik at Garching and have achieved internationally acknowledged success – latterly Wendelstein 7-A and Wendelstein 7-AS. In the ten years of planning Wendelstein 7-X as successor the theoretical concept of the optimised stellarator has been developed and experimentally substantiated with Wendelstein 7-AS.

The stellarator power plant

The big advantage of the stellarator power plant is that it can be operated in continuous mode. This greatly increases the life of critical components and the availability of the power plant. The modular coil system allows the use of relatively small single coils. The mass and magnetic field energy of the stellarator are comparable to those of a tokamak.

Project status

The Greifswald Branch of the Max-Planck-Institut für Plasmaphysik was founded in 1994. At present about 450 employees are working here. The Wendelstein 7-X project is supported by the European Union, the German Federal Government and the state of Mecklenburg-Vorpommern. The manufacturing of essential components – in particular the superconducting magnets and the plasma vessel – is finished. At present half-modules and modules are being mounted on the assembly rigs. Besides the basic machine, the devices for heating the plasma, the refrigeration plant for cooling the coils with liquid helium, the control system, the electric power supply and the measuring instruments have to be set up. The microwave heating is provided by Forschungszentrum Karlsruhe while Forschungszentrum Jülich is involved in the development of measuring facilities. Numerous other research establishments throughout Europe are contributing to the construction work. In 2014 the assembly of Wendelstein 7-X will be completed.

**Summer 2008:
The first module –
one fifth of the
inner core of
the device – is
assembled**



photograph: IPP, B. Kemnitz

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