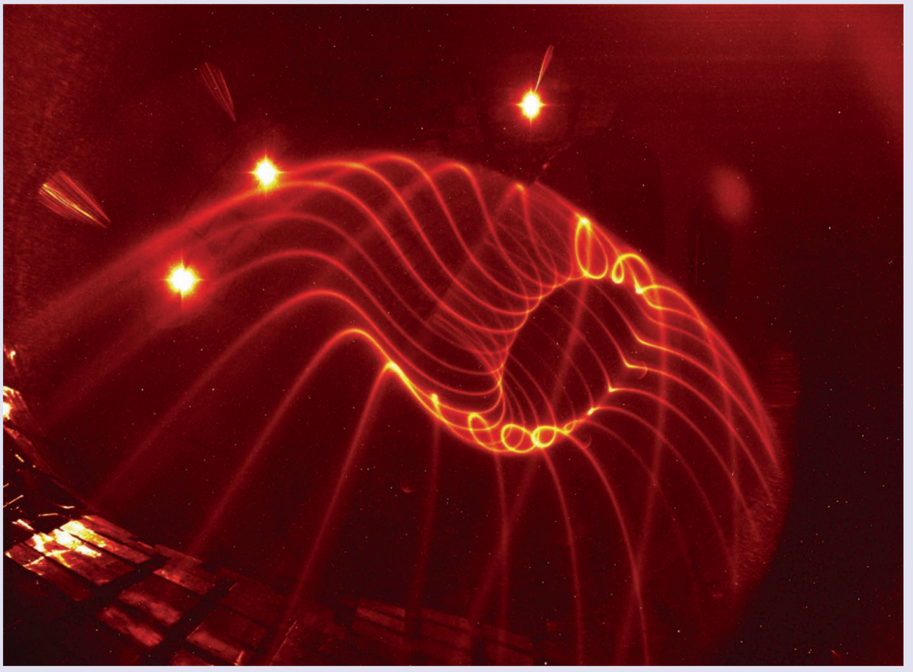
NUCLEAR FUSION

Stellar fieldwork

Harnessing the energy released in nuclear fusion reactions is a neat idea, but it's extremely difficult to realize — even a prototype fusion reactor producing net energy is still a long way off. Yet, the completion of Wendelstein 7-X (W7-X), a state-of-the-art experimental fusion device in the north of Germany, and recent tests of its magnetic-field topology reported by Thomas Pedersen and colleagues (*Nat. Commun.* **7,** 13493; 2016) are important steps towards producing energy from fusion.

W7-X is a stellarator, one of two standard types of machine capable of sustaining a hot plasma, for which temperatures of around 10^8 K are needed to spark fusion reactions. Just as in a tokamak, the more common type of fusion reactor, the charged particles of the plasma are confined by means of a magnetic field. In a stellarator, this field is solely generated by external current coils, whereas a tokamak additionally relies on the field created by the moving plasma particles. In principle, stellarators are more stable and offer steady-state operation, but these advantages come at a high engineering price: optimizing the highly complicated layout of the coils, building them and checking the produced magnetic fields are extremely challenging. Hence, tokamaks have afforded better progress in magnetically confining plasmas — less stable, but easier to build.

Originally signed off in 1994, W7-X was designed to be a machine with specifications close to that of an eventual fusion power plant — its vessel's major radius is 5.5 metres. Optimizing the geometry of the superconducting coils required years of ever-advancing computer resources. Its construction relied on state-of-the-art positioning technology and metrology. W7-X saw its first plasma one year ago.



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To check that all pieces of the W7-X puzzle were put together correctly, Pedersen *et al.* inspected the configuration of the magnetic field inside the machine in the absence of any plasma. They injected an electron beam into the stellarator vessel filled with a dilute mixture of water vapour and nitrogen gas. Collisions between the electrons and the background-gas particles resulted in excitations that mapped out the magnetic field lines (pictured).

More quantitatively useful images can be obtained by letting the electrons collide with a rod covered with a fluorescent substance. Moving the rod while continuing camera exposure gives a cross-sectional plot of a magnetic surface — the surface traced out by a single magnetic field line. These so-called Poincaré plots can feature 'island chains', structures that are extremely sensitive to small changes in the magnetic field, which can be used to look for deviations from the intended magnetic field. The authors found that the deviations were less than one part in 100,000, and that the errors came from slight imperfections in the placement and the shapes of the coils.

Achieving such a high magnetic-field precision for so complicated a construction is a grand feat. Tokamaks versus stellarators: the race is on again.

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