Physics Properties of Magnetic Configurations of Wendelstein 7-X

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The assembly of the stellarator experiment W7-X in Greifswald will be completed in 2014 and will be followed by a one-year commissioning phase with flux-surface measurements and first plasma operation for testing diagnostics and data acquisition systems. An inertially cooled test divertor unit will then be installed and used during a first experimental phase. This choice of a robust initial divertor will allow safe preparation of subsequent experiments with the fully cooled high-heat-flux divertor for quasi-steady-state (discharge length $\leq$ 1800s), high-performance operation.

The 5-periodic magnetic configuration of W7-X resulted from a physics optimization and is realized with a system of 70 coils of seven different types (five of which are non-planar) arranged to conform with stellarator-symmetry. Each type has its own power supply, so that the space of magnetic configurations can be described by six coil current ratios and the overall field strength. The vision in the optimization of W7-X was to create a magnetic configuration suitable for a stellarator reactor. The result was a list of goals to be achieved simultaneously: high equilibrium-β and stability limits, small neoclassical transport at low collisionality, small bootstrap current and good fast-particle confinement. Simultaneous best-case results for all goals is not possible but the so-called “high-mirror” configuration is a fair compromise combining stability and sufficiently low neoclassical transport with a negligible bootstrap current (important for stable island divertor operation without an ohmic transformer for current control). In addition, fast-particle confinement should be good at high-β in the plasma core. The simultaneous achievement of these properties in one configuration is crucial for its reactor prospects.

This contribution provides an overview of these physics properties of the magnetic configuration space of W7-X and consequences for experimental scenarios. We investigate how the properties of the magnetic configurations change when coil currents are varied to deviate from the optimized “high-mirror” configuration in order to facilitate the development of physics scenarios. For example, we assess which configurations allow reactor-relevant scenarios (high-performance plasmas in long pulses using the island-divertor) and whether the rotational transform needs adjustment by the coils or current drive with ECRH, or which configurations are suitable for dedicated physics investigations of single optimization criteria. Beyond the existing theoretical understanding, however, there are experimentally important physics topics like particle and impurity transport or the role of turbulent transport, about which too little is known to make reliable predictions.

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