Physics in the Magnetic Configuration Space 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 in a first experimental phase to gain experience. The choice of a robust initial divertor allows a safe preparation of the experiments with the fully-cooled high-heat-flux divertor to explore quasi-steady-state (discharge length \( \leq 1800 \text{s} \), 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-\( \beta \) and stability limits, low 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-\( \beta \) 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 the physics properties of the magnetic configuration space of W7-X and consequences for experimental scenarios. We investigate 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. We also explore configurations suitable for dedicated physics investigations of single optimization criteria. Even with these results, scenario development will face many experimental challenges, e.g. density and impurity control, to name only two.

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