From Wendelstein 7-X to a Stellarator Reactor

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Abstract: The design of the optimized stellarator Wendelstein 7-X which is presently under construction in Greifswald, Germany, is based on a quasi-isodynamic magnetic field configuration minimizing internal plasma currents to achieve an equilibrium which is basically determined by external magnetic field coils without a strong influence of the plasma pressure. Additional important properties are low neoclassical transport in the long mean free path regime and good fast ion confinement. The magnetic field configuration of Wendelstein 7-X has five field periods and low magnetic shear necessary for the realization of a magnetic island divertor. The magnetic field is provided by 50 modular non-planar coils (10 per field period) and 20 planar coils for higher experimental flexibility. The whole device is designed for a discharge duration of 30 minutes which includes superconducting coils, an actively cooled divertor and an electron cyclotron resonance heating system which can deliver 10 MW over such a time period.

Various studies of a HElical Advanced Stellarator (HELIAS) reactor have been conducted already (see e.g. [1] or [2]). The HELIAS reactor is basically an extrapolation from the Wendelstein 7-X design, which in itself is based on results from the Wendelstein 7-AS stellarator, the first advanced stellarator experiment. A summary of these studies will be given, where possible, referring to the experience from the construction of Wendelstein 7-X. Also the possibility to include more of the technical boundary conditions in the optimization procedure will be discussed.

Plasma operation of Wendelstein 7-X will start in 2015. Technically limited to pulse lengths of about 5 to 10 s at 10 MW of heating power, the first two years of operation will serve to prepare the high-power steady state operation of the device. This comprises (i) the exact characterization of the magnetic field topology including the distribution of the first wall and divertor heat loads for various magnetic field configurations, (ii) the control of the plasma configuration using electron cyclotron current drive (ECCD) within the L/R time, (iii) a first assessment of the particle balance including impurities and (iv) the investigation of heating schemes, ranging from X2 electron cyclotron resonance heating (ECRH) below the respective cut-off of $1.2\times10^{20}\mathrm{m}^{-3}$ to O2 ECRH for higher plasma densities and neutral beam injection. After these two years the actively cooled divertor will be installed in a shut-down of about 1½ years. The subsequent operation of Wendelstein 7-X will be devoted to achieving an integrated reactor relevant steady state plasma scenario with high densities ($> 10^{20}\mathrm{m}^{-3}$) and high temperatures, without impurity accumulation and with stationary heat fluxes to the plasma facing components. The status of the preparation of the plasma operation will be discussed and prospects for an extrapolation of the envisaged plasma scenarios to a stellarator reactor will be given.

[1] H. Wobig, Plasma Phys. Control. Fusion **41** (1999) A159
[2] C.D. Beidler et al., Nucl. Fusion **41** (2001) 1759