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Physics Design of NCSX, a Compact Quasi-axisymmetric Stellarator

M.C. Zarnstorff[1], L.A. Berry[2], A. Boozer[3], A. Brooks[1], W.A. Cooper[4], E. Fredrickson[1], G.-Y. Fu[1], R. Goldston[1], R. Hatcher[1], S. Hirshman[2], S. Hudson[1], M. Isaev[5], C. Kessel[1], L.-P. Ku[1], E. Lazarus[2], J. Lewandowski[1], J. Lyon[2], R. Majeski[1], P. Merkel[6], M. Mikhailov[5], D. Mikkelsen[1], D. Monticello[1], H. Mynick[1], G.H. Neilson[1], B.E. Nelson[2], C. Nuehrenberg[6], N. Pomphrey[1], M. Redi[1], W. Reiersen[1], A. Reiman[1], P. Rutherford[1], R. Sanchez[7], J. Schmidt[1], D. Spong[2], D. Strickler[2], A. Subbotin[5], and R. B. White[1].

[1]*Princeton Plasma Physics Laboratory, Princeton, NJ 08543 USA*
[2]*Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA*
[3]*Columbia University, New York, NY 10027 USA*
[4]*Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland*
[5]*Kurchatov Institute, Moscow, Russia*
[6]*Max Planck Institute for Plasma Physics, Greifswald, Germany*
[7]*Universidad Carlos III de Madried, Spain*

Compact quasi-axisymmetric stellarators offer novel solutions for confining high-beta plasmas and developing magnetic confinement fusion. The 3D plasma shape can be designed to enhance the MHD stability without feedback or nearby conducting structures and provide drift-orbit confinement similar to tokamaks. These configurations offer the possibility of combining the steady-state low-recirculating power, external control, and disruption resilience of previous stellarators with the low-aspect ratio, high beta-limit, and good confinement of advanced tokamaks. Quasi-axisymmetric equilibria have been developed for the proposed National Compact Stellarator Experiment (NCSX) with aspect ratio 4.1 - 4.4 and average elongation ~1.8. Even with bootstrap-current consistent profiles, they are passively stable to the ballooning, kink, vertical, Mercier, and neoclassical-tearing modes for $\beta > 4\%$, without the need for external feedback or conducting walls. The bootstrap current generates only 1/4 of the magnetic transform at $\beta = 4\%$ (the rest is from the coils), thus the equilibrium is much less sensitive to the plasma profiles and is more controllable than for similar advanced tokamaks. Transport simulations show good fast-ion confinement, thermal neoclassical transport similar to equivalent tokamaks, and reduced damping of toroidal rotation. The low toroidal rotation damping should allow efficient manipulation of the turbulent transport using driven flows and allow persistent zonal flows, as in tokamaks. A flexible coil design allows variation of the plasma shape to separately vary the rotational transform, magnetic shear, and residual ripple, for study of physics properties.

Topics: 10, 9
Poster preferred: no.