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Magneto-hydrodynamically stable axisymmetric mirrors

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The achievement of high beta (60%) plasma with near classical confinement in a linear axisymmetric magnetic configuration has sparked interest in the Gas Dynamic Trap concept. The significance of these results is that they can be projected directly to a neutron source for materials testing. The possibility of axisymmetric mirrors (AM) being magneto-hydrodynamically (MHD) stable is also of interest from a general physics standpoint (as it seemingly contradicts to well-established criteria of curvature-driven instabilities). The axial symmetry allows for much simpler and more reliable designs of mirror-based fusion facilities than the well-known quadrupole mirror configurations. In this tutorial, after a brief summary of classical results (in particular of the Rosenbluth-Longmire theory and of the energy principle as applied to AM) several approaches towards achieving MHD stabilization of the AM will be considered: 1) Employing the favorable field-line curvature in the end tanks; 2) Using the line-tying effect; 3) Setting the plasma in a slow or fast differential rotation; 4) Imposing a divertor configuration on the solenoidal magnetic field; 5) Controlling the plasma dynamics by the ponderomotive force; 6) Other techniques. Several of these approaches go beyond pure MHD and require accounting for finite Larmor radius effects and trapped particle modes. Some illuminative theoretical approaches for understanding axisymmetric mirror stability will be described. Wherever possible comparison of theoretical and experimental results on AM will be provided. The applicability of the various stabilization techniques to axisymmetric mirrors as neutron sources, hybrids, and pure-fusion reactors will be discussed and the constraints on the plasma parameters will be formulated. Prepared by LLNL under Contract DE-AC52-07NA27344.