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Diagnostics for Advanced Tokamak Research*

K.H. Burrell, *General Atomics, San Diego, California*

Advanced tokamak research seeks to find the ultimate potential of the tokamak as a magnetic confinement system. Achieving this potential involves optimizing the current density and pressure profiles for stability to MHD modes while simultaneously controlling the current density, pressure and radial electric field profiles to minimize the cross field transport of plasma energy. In its ultimate, steady-state incarnation, the advanced tokamak also requires pressure profiles that have been adjusted to achieve the maximum possible bootstrap current, subject to the constraints of MHD stability. This simultaneous, nonlinear optimization of current, pressure and electric field profiles to meet multiple goals is a grand challenge to plasma physics.

Diagnostic measurements play a crucial role in advanced tokamak research. One outstanding example of this is the way motional Stark effect (MSE) measurements of the internal magnetic field revolutionized work on current profile shaping. Improved diagnostic measurements are essential in testing theories which must be validated in order to apply advanced tokamak results to next step devices.

In order to optimize MHD stability, the key issues to be confronted include 1) stability of the edge localized modes (ELM) in the H–mode, 2) stability to neoclassical tearing modes and 3) stability to resistive wall modes. Although existing diagnostics are being used to confront these issues, improvements are needed for definitive experiments. For example, to properly attack ELM stability, improved internal magnetic field measurements in the edge regions are needed to quantitatively assess the role of edge current profile in the stability of edge localized modes. Better measurements of 3D internal structure of MHD modes are also needed.

In order to optimize the pressure profile, control of heat and particle transport is needed. While significant progress has been made in the past five years in creating regions of the reduced transport in the plasma core, much remains to be done to understand transport, especially in the electron channel. One key issue here is the role of $E \times B$ shear in controlling turbulence and transport; this involves both the equilibrium electric field and the fluctuating field associated with the poloidally and toroidally symmetric zonal flows. While existing diagnostics have allowed us to investigate the role of the equilibrium electric field, zonal flow measurements are still in their infancy.

This talk will review the key MHD and transport issues in advanced tokamak research, will briefly summarize how existing diagnostics are being used and will present the opportunities for diagnostic innovation in the advanced tokamak area.

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