Progress Toward Fully Noninductive, High Beta Discharges in DIII–D*

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Advanced Tokamak (AT) research in DIII-D focuses on developing a scientific basis for steady-state, high performance operating scenarios. For optimal performance, these experiments routinely operate with β in excess of the n=1 no-wall limit, enabled by active feedback control to limit the effect of error fields on plasma rotation. The ideal wall β limit is increased through a combination of plasma shape, current and pressure profile modifications. The required consistency with steady-state, fully noninductive sustainment provides additional constraints. To minimize the expense of external current drive, the self-generated bootstrap current fraction f_{BS} must be maximized. Present DIII–D AT experiments operate with $f_{BS} \approx$ 50-60%, with a long-term goal of 90%. Additional current can be provided by neutral beam (NBCD), fast wave (FWCD) and electron cyclotron (ECCD) current drive, the latter being localized well away from the magnetic axis. Guided by integrated modeling, recent experiments have produced discharges with $\beta \approx 3\%$, $\beta_N \approx 3$, $f_{BS} \approx 55\%$ and noninductive fraction $f_{NI} \approx 90\%$ using central NBCD and ECCD at $\rho \approx 0.4$, sustained for the duration of the ECCD. Additional control is anticipated using FWCD to control the central current density. A broad pressure profile is beneficial for maximizing the β limit and generating useful bootstrap current (a large, peaked bootstrap current is detrimental to sustainment). Density (and pressure) profile broadening via electron cyclotron heating (ECH) was recently demonstrated in Quiescent Double Barrier (QDB) plasmas. Further experiments will explore the potential of broadening the pressure profile through the use of other tools. Flexibility of the DIII-D plasma control system for integration of these tools has been demonstrated by real-time control of the electron temperature profile both with neutral beams and ECH.

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