Advanced Tokamak Research at the DIII-D National Fusion Facility in Support of ITER*

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Developing a reliable energy system that is economically and environmentally sustainable is the long-term goal of Fusion Energy Sciences research. The leading candidate for magnetically confining fusion plasmas is the tokamak, a doughnut-shaped vessel in which a strong, helical magnetic field guides the charged particles around it. The DIII-D tokamak research program emphasizes development of integrated scenarios for burning plasma experiments and investigation of elements in those scenarios that are critical for the success of future devices such as ITER. One such element is advanced tokamak research that seeks to provide a scientific basis for steady-state high performance operation in future fusion devices. These regimes require high plasma pressure to maximize fusion output and to maximize the self-driven plasma current. Achieving these conditions requires integrated, simultaneous control of the plasma current and pressure profiles, and active control of large-scale (on the order of the machine) plasma stability, using a diverse set of control techniques. A sophisticated digital plasma control system allows integrated control of these elements during experimental operation. Steady-state operation requires replacing the inductively driven plasma current using other sources. In DIII–D, the approach primarily relies on self-driven bootstrap current and electron cyclotron current drive (ECCD). Active suppression of large-scale instabilities is accomplished using both nonaxisymmetric magnetic field coils and through plasma rotation. Using these and other techniques, fully noninductive plasmas have been obtained and sustained for time scales on the order of a current relaxation time. These experimental efforts are supported by a closely coupled effort in integrated simulation. These calculations are used both to plan and interpret experiments, with the results being used to further improve the physics based models themselves. In this way, our predictive capability is continually improving, with the goal being a set of models taking into account the complex nonlinear interactions in a fusion device that can be applied to future experiments in DIII–D, ITER and elsewhere. Experimental and simulation progress in AT research including the usage of FusionGrid, and its implications for ITER and other next-step devices, will be illustrated by results of recent experiment and simulation efforts. The anticipated future direction of this research, using simulation, experiment, and computational grids, will also be discussed.

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