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Physics of the Tokamak Pedestal, and Implications for Magnetic Fusion Energy[1]

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High performance in tokamaks is achieved via the spontaneous formation of a transport barrier in the outer few percent of the confined plasma. This narrow insulating layer, referred to as a "pedestal," typically results in a >30x increase in pressure across a 0.4-5cm layer. Predicted fusion power scales with the square of the pedestal top pressure (or "pedestal height"), hence a fusion reactor strongly benefits from a high pedestal, provided this can be attained without large Edge Localized Modes (ELMs), which may erode plasma facing materials. The overlap of drift orbit, turbulence, and equilibrium scales across this narrow layer leads to rich and complex physics, and challenges traditional analytic and computational approaches. We review studies employing gyrokinetic, neoclassical, MHD, and other methods, which have explored how a range of instabilities, influenced by complex geometry, and strong ExB flows and bootstrap current, drive transport across the pedestal and guide its structure and dynamics. Development of high resolution diagnostics, and coordinated experiments on several tokamaks, have validated understanding of important aspects of the physics, while highlighting open issues. A predictive model (EPED) has proven capable of predicting the pedestal height and width to ˜20-25% accuracy in large statistical studies. This model was used to predict a new, high pedestal "Super H-Mode" regime, which was subsequently discovered on DIII-D, and motivated experiments on Alcator C-Mod which achieved world record, reactor relevant pedestal pressure. We review open issues including improved formalism, particle and momentum transport, the role of neutrals and impurities, ELM control, and pedestal formation. Finally we discuss coupling pedestal and core predictive models to enable more comprehensive optimization of the tokamak fusion concept.

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