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IMPLICATIONS OF RECENT PHYSICS ADVANCES FOR THE DESIGN AND OPERATION OF BURNING PLASMA EXPERIMENTS SUCH AS ITER AND FIRE*

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Over the past five years significant advances have been made in obtaining tokamak operating modes with enhanced confinement, higher β and increased duration. These new operating modes span the range from improved H-modes, hybrid modes for long duration inductive operation and advanced tokamak modes aimed at high-β steady-state operation.

The International Tokamak Physics Activity (ITPA) has proven to be a very effective mechanism for stimulating new experiments in this area and for systematically documenting the results from a large number of tokamak experiments. Recent work by the Confinement and Data Base Modeling Working Group has developed an improved confinement scaling relation for H-Modes with reduced degradation at high β relative to the previous ITER98(y,2) scaling used to predict performance in ITER and FIRE. The new ITPA scaling projects to significantly higher fusion gains in FIRE ranging up to Q ~ 30.

The hybrid inductive mode developed on ASDEX-U and DIII-D leads to improved confinement (H98 ≈ 1.5) and moderate β ($\beta_N \approx 2.5$) that would be suitable for burning plasma studies (Q = 10 – 20) on ITER and FIRE, and increased duration for neutron production on ITER. The advanced tokamak (AT) mode with reversed magnetic shear is theoretically capable of producing the high β ($\beta_N = 5$) and high bootstrap current fraction ($f_{bs} \approx 90\%$) suitable for economically competitive fusion power plants. Recent experiments on DIII-D with $\beta_N \approx 4$ sustained for nearly 2 sec provide confidence that this regime can be attained. Using the Tokamak Simulation Code (TSC), FIRE has developed an AT scenario with β_N= 4, $f_{bs} \approx 80\%$ and Q = 5 – 10 that would provide DT fusion power densities of 5 MWm^{-3} and a neutron wall loading of ≈ 2 MWm^{-2} for durations of 3–5 plasma current redistribution times (35s). This high β regime is accessed with feedback stabilization of resistive wall modes using closely coupled coils mounted on the mid-plane port plug cassettes. This regime would allow the study of the physics and plasma technologies of the ARIES RS/AT. Studies are underway to develop similar AT modes for ITER. For both ITER and FIRE the exploitation of AT modes is limited by power handling capability of the present first wall designs.

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