FIRE, A Test Bed for ARIES-RS/AT Advanced Physics and Plasma Technology

Dale Meade

Princeton Plasma Physics Laboratory, Princeton, N. J., dmeade@pppl.gov

The overall vision for FIRE is to develop and test the fusion plasma physics and plasma technologies needed to realize capabilities of the ARIES-RS/AT power plant designs. The mission of FIRE is to attain, explore, understand and optimize a fusion dominated plasma which would be satisfied by producing DT fusion plasmas with nominal fusion gains ~10, self-driven currents of ≈ 80%, fusion power ~ 150 - 300 MW and pulse lengths up to 40 s. Achieving this goal will require the deployment of several key fusion technologies under conditions approaching those of ARIES-RS/AT.

The FIRE plasma configuration with strong plasma shaping, a double null pumped divertor and all metal plasma facing components is a 40% scale model of the ARIES-RS/AT plasma configuration. "Steady-state" advanced tokamak modes in FIRE with high β ($\beta_N \approx 4$), high bootstrap fraction ($f_{bs} \approx 80\%$) and 100% non-inductive current drive are suitable for testing the physics of the ARIES-RS/AT operating modes. The FIRE AT mode utilizes Fast Wave Current Drive (FWCD) for on-axis current drive and Lower Hybrid Current Drive (LHCD) for off-axis current drive with no external momentum input, similar to the systems envisioned for ARIES. Although inductive and non-inductive current drive are used to ramp the plasma current, the flattop plasma has a "steady-state" 100% non-inductive current provided by the combination of bootstrap, lower hybrid, and fast wave current, and the current profile is held constant for 3.2 τ_{CR}. Both FIRE and ARIES-RS/AT would rely on passive stabilization from close fitting conducting structures and Resistive Wall Mode (RWM) stabilization from coils mounted just behind the first wall structure. The development of closely coupled RWM coils for an environment with neutron fluxes similar to ARIES-RS/AT will be an important contribution of the FIRE program.

The removal of plasma exhaust power is a major challenge for a magnetic fusion power plant, and the development of techniques to handle power plant relevant exhaust power is a major objective for a burning plasma experiment. The FIRE-AT $\beta \approx 4\%$ would result in fusion power densities in FIRE from 3 - 10 MWm^{-3} and neutron wall loading from 2 - 4 $\mathrm{MW\ m}^{-2}$ which are at the levels expected from the ARIES–RS /AT design studies. The divertor and first wall thermal loads would also be in the range expected for ARIES. The FIRE tungsten divertor has the capability of handling steady-state thermal loads approaching those of ARIES while maintaining low tritium inventory. The first wall design of FIRE features Be tiles that are capable of absorbing 1 MWm^{-2} for ~40s, and would provide a good test of whether Be would be suitable as a first wall material in ARIES-RS/AT. The effective tritium retention in the plasma facing components (PFC) of ARIES must be < 0.04% to allow operating periods of ≈ one year before an intervention to remove tritium. This is much less than the typical 10-30% tritium retention observed in the DT experiments on TFTR and JET, which had carbon PFCs. FIRE would be able to provide a good test of the feasibility of a W/Be divertor first wall design for ARIES-RS/AT. FIRE utilizing articulated boom remote manipulators would provide remote handling experience of internal plasma facing components.

Work supported by DOE Contract # DE-AC02-76CHO3073.