Plasma Startup via Local Helicity Injection and Stability Studies at Near-Unity Aspect Ratio in the Pegasus Experiment

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Magnetic helicity injection from localized current sources at the outboard plasma edge and poloidal field induction produced plasma currents I_p to 0.17 MA, using ~4 kA injected current in the Pegasus spherical tokamak. These results are consistent with a model invoking helicity balance and Taylor relaxation. Changes in the edge current density J_{edge} via source realignment produced a rise in the ultimate plasma current, as expected. A double-layer plasma sheath describes the impedance of the current injectors, which determines the helicity injection rate for a given injected current. This suggests the helicity input and discharge evolution can be manipulated by variations in the edge density. MHD activity during plasma growth correlates with rapid equilibrium shifts and current redistribution into the plasma interior. Impurity ion spectroscopy indicates that the ions are strongly heated during helicity drive. Successful handoff to another current drive approach requires a relatively slow plasma evolution to allow current profile relaxation. In contrast to Ohmically initiated plasmas, such handoff plasmas are MHD quiescent and remain so during subsequent current rampup using inductive drive. This provides a path to generating plasmas at high normalized current and high beta at near-unity aspect ratio. Proof-of-principle experiments demonstrate that plasmas can be smoothly driven through the growth stage using passive gas-fueled electrodes as the helicity sources, after initial tokamak formation with the active current sources. Such electrode structures hold promise for detailed control of the Taylor limit that determines the maximum I_p while optimizing the helicity input rate needed to attain it. Developing a fully predictive model of this startup technique will allow application to next-step fusion experiments. Spherical Tokamak plasmas provide an environment for detailed studies of instabilities leading to Edge Localized Mode (ELM) activity in fusion plasmas. In Pegasus, peeling modes are observed at the edge of limited plasmas. They generate edge localized, electromagnetic activity with low toroidal mode numbers $n \leq 3$ and amplitudes that scale strongly with measured J_{edge}/B instability drive, consistent with theory. ELM-like field-aligned, current-carrying filaments form from an initial current-hole J_{edge} perturbation that detach and propagate outward, in agreement with theoretical pictures of ELM evolution.