Non-solenoidal Tokamak Startup and Near-Unity Toroidal Beta Using High-Field-Side Local Helicity Injection on the Pegasus ST

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Local Helicity Injection (LHI) is a non-solenoidal startup technique utilizing small injectors at the plasma edge to source current along helical magnetic field lines. Unstable injected current streams relax to a tokamak-like configuration with high current multiplication: I_p up to 200 kA is achieved with 8 kA of injected current. Recent experiments on the Pegasus spherical tokamak explore the efficacy of high-field-side (HFS) injection using a set of two increased-area (4 cm^2) injectors in the lower divertor region, providing increased helicity injection while reducing the influence of inductive effects from plasma geometry evolution, which were significant in past experiments using low-field-side (LFS) injection at the outboard midplane. Experiments with HFS injection explore tradeoffs inherent in the choice of injector location, including: HI dominated current drive; injector geometry required to mitigate plasma-material interactions; and substantially different MHD characteristics. During LFS injection, large-amplitude MHD activity is present throughout the discharge and was thought responsible for current drive. During HFS injection, large-amplitude MHD is present initially, but can abruptly decrease by over an order of magnitude without loss of drive, resulting in improved particle confinement and pointing to additional physics behind the current drive mechanism. Access to this reduced MHD state is sensitive to edge field pitch, injector power, and neutral fueling. The high normalized current ($I_N \sim I_p / aB_{T,0}$) attainable with LHI and the favorable stability of the ultra-low aspect ratio, low-ℓ_i LHI-driven plasmas allow access to high β_t. Kinetically-constrained equilibrium reconstructions indicate $\beta_t \sim 100\%$ was obtained in 100 kA LHI discharges, with reconnection-driven ion heating providing a significant part of the stored energy. These high-β_t plasmas feature a minimum $|B|$ well spanning ~50% of the plasma volume.

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