New Results from Non-solenoidal Startup via Local Helicity Injection on PEGASUS and Projections for NSTX-U

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Non-solenoidal plasma startup via local helicity injection (LHI) at the PEGASUS Toroidal Experiment now provides routine operation at $I_p \approx$ 0.17 MA with $I_{inj} \approx$ 5 kA and $V_{inj} \approx$ 1 kV from four active arc injectors. Studies in the past year have advanced the understanding of the governing physics of LHI and its supporting technology. Experiments have yielded new insight into the injector impedance, which scales as $V_{inj}^{1/2}$ at useful LHI voltages and is governed by two effects: a quasineutrality constraint related to the tokamak edge density, and double-layer sheath expansion related to the injector arc density. Experiments varying the shape, $I_p(t)$, and helicity input test a predictive 0D power-balance model for LHI startup. These tests increase confidence in the underlying analytic low-A plasma inductance models used to predict the $I_p(t)$ evolution in PEGASUS plasmas and projections for NSTX-U. More sophisticated predictive modeling, however, requires accurate knowledge of the confinement properties during LHI and its scaling with B_T. Initial measurements of the electron temperature profile in LHI have been made with multi-point Thomson scattering to address this need. They indicate a surprisingly high $T_e > 300$ eV in the plasma core. This may indicate the dominance of high-energy electron fueling from the injector current streams and better-than-expected confinement in the core region, as the electron beam is confined long enough to thermalize. If verified, these measurements will impact the conceptual design for LHI on NSTX-U. Finally, the design of new divertor injectors for PEGASUS that increase available helicity injection to attain higher I_p and enable electron confinement studies in plasmas with strong helicity drive (like those projected for NSTX-U) will be discussed. Proposed upgrades to the PEGASUS facility will extend these LHI studies to higher B_T and I_p, enabling experiments at NSTX-U relevant parameters. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, under Award Numbers DE-FG02-96ER54375 and DE-SC0006928.