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Integrated Studies of Solenoid Free Tokamak Startup

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The Pegasus Toroidal Experiment has focused on exploring the unique features of extremely low aspect ratio operation to study plasma stability at A ~ 1 and near-unity beta, including access to ohmic H-mode with associated ELM behavior and plasmas with an absolute minimum-B topology. For such studies, the Local Helicity Injection (LHI) technique was developed to initiate and drive toroidal current without use of a central solenoid. LHI utilizes compact, edge-localized current sources (Ainj ≤ 8 cm2, Iinj ≤ 8 kA, Vinj ≤ 1.5 kV), and has initiated > 0.2 MA of plasma current at low-field (BT ~ 0.15 T) and near-unity aspect ratio (A). Recent studies have addressed comparisons of LHI injector locations, MHD characteristics, confinement properties, and the transition to ohmic sustainment. The Pegasus program is now terminating and being replaced with an upgraded facility called Pegasus-III (for Pegasus-Phase III). This new program is focused on developing an understanding and comparative studies of several leading candidates for non-solenoidal startup techniques. These include: DC helicity injection, including LHI and sustained and transient coaxial helicity injection (S-CHI and T-CHI); electron Bernstein wave (EBW) radiofrequency electron heating and current drive; and poloidal field induction. Future capabilities may include electron cyclotron heating and current drive and/or neutral beam current drive. Upgrades include: a new solenoid-free centerstack assembly to provide a 4x increase in BTF to 0.6 T; a new high-stress TF coil system; increased pulse length to study confinement and current evolution; expanded power systems; enhanced diagnostics; and an expanded lab facility. Plasma startup will be enabled by: advanced LHI injectors with shaped electrodes and active helicity injection control; a refractory metal electrode system supporting S-CHI and T-CHI without vacuum electrical breaks or current flow through the vacuum vessel; and an expanded poloidal field coil set. An 8 GHz, ~400 kW EBW system will be added. A goal of the new experiment is to demonstrate non-solenoidal startup to □p = 0.3 MA and provide guidance for MA-class startup applicable to NSTX-U and ultimately a nuclear facility. This program includes collaborations from the University of Wisconsin, University of Washington, ORNL, and PPPL.

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