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Non-solenoidal Plasma Startup in the Pegasus Toroidal Experiment[1]

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Non-solenoidal (NS) startup will simplify the design of future tokamaks by eliminating need for a central solenoid and is required for an ST based CTF. In Pegasus, washer-stack current sources (plasma guns) are used to initiate NS discharges via point-source DC helicity injection. Current injected parallel to the helical vacuum field can relax into a tokamak-like configuration with toroidally-averaged closed flux and tokamak-like confinement. This requires no modification of the vacuum vessel and is scalable to fusion grade systems with proper geometry. Guns in the divertor region create discharges with I_p up to 50 kA, 3 times the vacuum windup. Nonlinear 3D simulation with NIMROD shows excitation of a line-tied kink, producing poloidal flux amplification. Evidence of flux amplification includes: reversal of edge poloidal magnetic flux; I_p increase over vacuum geometric windup; plasma position subject to radial force balance; and persistence of I_p after gun shut-off. Equilibria show high edge current ($l_i = 0.2$) and elevated q ($q_{min} > 6$), allowing access to high I_N ($I_N > 12$). Guns at the outboard midplane produce I_p up to 7 times the vacuum windup with large n=1 activity when edge q passes through rational surfaces. Line averaged density up to 2x10^{19} m^{-3} after relaxation shows an increase in particle confinement over non-relaxed cases. Maximum I_p is determined by helicity and radial force balance, tokamak stability, and Taylor relaxation. Coupling midplane gun discharges to other CD is straightforward due to I_p decay times >3 ms. Poloidal field induction has been used to create NS discharges up to 80 kA and gun plasmas with I_p of 60 kA have been ramped to over 100 kA by including OH drive. Present research is aimed at understanding the physics of this technique in order to form NS targets in excess of 200 kA and design NS startup systems for larger devices.

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