Non-solenoidal Plasma Startup using Outboard Washer Gun Current Injection on the Pegasus Toroidal Experiment

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The Pegasus Toroidal Experiment is an ultra-low aspect ratio (A $<$ 1.2) spherical tokamak (ST) capable of operating in the high I_N regime ($I_N >$ 12). Access to this regime requires a small center-post cross-section that consequently reduces the available inductive current drive from the central ohmic (OH) solenoid. Non-solenoidal plasma startup allows for more efficient use of the OH current drive and may possibly eliminate the need for a solenoid in future STs. Recent experiments on Pegasus use a single washer gun current source located near the outboard mid-plane to establish and sustain a tokamak-like plasma via DC helicity injection. A new gun head design permits high current (2 kA) injection with minimal impurity production and improved neutral fueling control. The washer gun and a biased anode are mounted at the same toroidal location, 20 cm below and above the mid-plane. The vacuum toroidal and vertical fields are chosen so the initial injected current follows a helical field line that connects the gun aperture to the anode. For a sufficiently large current density and small vertical field strength, the plasma relaxes into a tokamak-like configuration. With less than 2 kA of injected current, tokamak-like discharges with $I_P \approx$ 20 kA are produced. Line-averaged densities near the Greenwald density limit of 1.0 x 10^{19} m^{-3} indicate improved particle confinement. The formation of a current channel within the vacuum region separate from the gun injection region is verified using magnetic field measurements. Substantially longer current decay times (2 - 3 ms) indicate the buildup of stored energy. The length of the decay time is suitable for coupling to other current drive techniques. Discharges of 80 kA were obtained by applying $<$ 10 mWb of OH flux to a 20 kA seed plasma. These results are compared to discharges initiated with two 1 kA washer guns mounted in the lower divertor region. Future experiments with multiple injectors are also described.