Non-solenoidal startup using point-source helicity injection in the PEGASUS Toroidal Experiment[1]

Aaron J. Redd, David J. Schlossberg, Jayson Barr, Devon J. Battaglia, Mike W. Bongard, Raymond J. Fonck, Edward T. Hinson, Benjamin A. Kujak-Ford, Benjamin T. Lewicki, Kathreen E. Thome, Greg R. Winz, Nathan R. Woodruff

Department of Engineering Physics

University of Wisconsin – Madison, Madison, WI USA

Relatively small plasma guns are used to inject both ionized gas and toroidal current for forming non-solenoidal tokamak plasmas in the PEGASUS Toroidal Experiment. Discharges driven by this point-source DC helicity injection method have achieved peak plasma current $I_p > 170$ kA, using less than 4 kA of injected gun current. These plasmas form near the guns at the outboard midplane, transition to a turbulent tokamak-like equilibrium, and continue to grow inward as the plasma current increases due to helicity injection and outer-PF induction. The maximum I_p is determined by helicity balance (helicity and power injection rate *vs* resistive dissipation) and a Taylor relaxation limit, in which the maximum I_p is proportional to the square root of $I_{TF}I_{inj}/w$ (where I_{TF} is the total TF coil current, I_{inj} is the total "injected" current drawn from the guns, and w is the radial thickness of the gun-driven plasma edge). Preliminary experiments tentatively confirm that the relaxation limit scales as expected with I_{TF}, I_{inj}, and w, increasing confidence in this simple relaxation model. Adding solenoidal inductive drive during helicity injection can push I_p up to, but not beyond, the predicted relaxation limit, demonstrating that this can be a hard performance limit. Ohmic current drive couples easily after helicity injection, demonstrating the viability of this concept as a non-solenoidal startup technique in other devices.

This group has previously reported gun-driven plasma currents up to 110 kA[2]. Since those experiments, there have been significant improvements to the construction of the plasma guns, the placement of the gun array, and the gun gas control system. These changes have allowed a higher injection voltage (that is, a higher helicity injection rate), a reduced w, and more reliable operations with better shot-to-shot repeatability. Recent experiments have systematically explored the effects of edge field geometry and gun bias current programming with respect to both the relaxation and helicity limits. Near-term experimental studies will: further test the scalings of the simple relaxation model; explore coupling to solenoidal induction after the helicity injection has terminated; and, further optimize the gun system performance through additional modifications. Near-term analysis tasks include MHD equilibrium reconstructions of various gun-driven discharges, both during and after the helicity injection shutoff, and detailed study of the bursty n=1 activity that is observed to correlate with rapid increases in I_p. Longer-term planned studies include the use of electrodes as helicity injection sources, and further modifications to both the plasma guns and the corresponding anode structure.

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[2] D.J.Battaglia *et al*., Phys. Rev. Lett. **102**, 225003 (2009).