Observations of Magnetic Turbulence During Local Helicity Injection on PEGASUS

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Local helicity injection (LHI) uses small localized current sources for DC helicity injection to provide high plasma current non-solenoidal tokamak startup, which is critically needed for the spherical tokamak. Helicity-conserving instabilities relax the injected electron streams to form a tokamak-like state with $I_p >> I_{inj}$. To better understand the relaxation and accompanying current drive processes, characterization of the magnetic activity present during LHI was conducted on the PEGASUS spherical tokamak. Frequency spectra of broadband turbulence during LHI follow power law behaviors ($\sim$ -5/3 at MHD scales and $\sim$ -8/3 at sub-ion scales) similar to those of Alfvén wave turbulence observed in astrophysical systems. Such turbulence transfers magnetic helicity from small to large scales, providing a candidate mechanism for magnetic relaxation. This activity is localized within the plasma edge where the injected current streams entrain to the tokamak-like core. The streams are both suprathermal and super-Alfvénic, and the turbulence shows a strong dependence on the inferred beam energy. Nonlinear spectral analyses indicate unstable modes in the intermediate, MHD frequency regime. Coarse estimates of current drive from dynamo EMFs are comparable with the current density from equilibrium reconstructions. These observations provide a working picture of a relaxation and current drive mechanism active during LHI. Beam-driven instabilities in the injected current streams drive MHD Alfvénic activity that nonlinearly couples to drive broadband turbulence. Small-scale dynamo activity from the associated cascades drives net plasma current. This paradigm imposes requirements on applications of LHI to fusion-scale, specifically that the injected streams must satisfy requirements for excitation of edge magnetic turbulence.

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