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Non-Inductively Driven Tokamak Plasmas at Near-Unity Toroidal Beta in the Pegasus Toroidal Experiment[1]

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A major goal of the spherical tokamak research program is accessing a state of low internal inductance l_i, high elongation κ, high toroidal and normalized beta (β_t and β_N), and low collisionality without solenoidal current drive. A new local helicity injection (LHI) system in the lower divertor region of the ultra-low aspect ratio Pegasus ST provides non-solenoidally driven plasmas that exhibit most of these characteristics. LHI utilizes compact, edge-localized current sources ($A_{inj} \sim 4$ cm^2, $I_{inj} \sim$ 8 kA, $V_{inj} \sim 1.5$ kV) for plasma startup and sustainment, and can sustain more than 200 kA of plasma current. Plasma growth via LHI is enhanced by a transition from a regime of high kink-like MHD activity to one of reduced MHD activity at higher frequencies and presumably shorter wavelengths. The strong edge current drive provided by LHI results in a hollow current density profile with low l_i. The low aspect ratio ($R_0/a \sim 1.2$) of Pegasus allows ready access to high κ and MHD stable operation at very high normalized plasma currents ($I_N = I_p/aB_T > 15$). Thomson scattering measurements indicate $T_e \sim 100$ eV and $n_e \sim 1{\times}19$ m^{-3}. The impurity T_i evolution is correlated in time with high frequency magnetic fluctuations, implying substantial reconnection ion heating is driven by the applied helicity injection. Doppler spectroscopy indicates $T_i \geq T_e$ and that the anomalous ion heating scales consistently with two fluid reconnection theory. Taken together, these features provide access to very high β_t plasmas. Equilibrium analyses indicate β_t up to $\sim$100% and $\beta_N \sim 6.5$ is achieved. At increasingly low B_T, the discharge disrupts at the no-wall ideal stability limit. In these high β_t discharges, a minimum $|B|$ well forms over $\sim$50% of the plasma volume. This unique magnetic configuration may be of interest for testing predictions of stabilizing drift wave turbulence and/or improving energetic particle confinement.

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