FOR ABSTRACT SUBMISSION

Paper Title

Advancing Local Helicity Injection for Non-Solenoidal Tokamak Startup

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Abstract Text: Enter the abstract in one continuous paragraph (maximum 2400 characters including spaces); text exceeding the space limit will be truncated. Do not use mathematical characters or expressions, Greek or other symbols, and superscripts or subscripts. The size of the text box cannot be exceeded.

Robust non-solenoidal startup methods may simplify the cost and complexity of next-step burning plasma devices, and especially STs, by removing the need for a solenoid. Experiments on the $A\sim1$ Pegasus ST are advancing the physics and technology basis of Local Helicity Injection (LHI). LHI creates high-I_p tokamak plasmas without a solenoid by injecting helicity with small current sources in the plasma edge. Its hardware can be withdrawn before a fusion plasma enters a nuclear burn phase. Flexible injector placement offers tradeoffs between physics and engineering goals. They are tested with LHI systems on the low-field-side (LFS) and the high-field-side (HFS) of Pegasus, producing plasmas predominantly driven by non-solenoidal induction and DC helicity drive ($V_{LHI}\sim B_{inj}A_{inj}V_{inj}$), respectively. Record LHI plasmas with $I_p = 0.2$ MA, $T_e > 100$ eV, $n_e\sim10^{19}$ m⁻³, and $Z_{eff} < 2.5$ are attained. A predictive 0D power-balance model describes experimental $I_p(t)$ and partitions the active current drive sources. It uses improved inductance models that have been extended to $A\sim1$. The analysis confirms the dominance of induction in LFS LHI and DC helicity drive in HFS LHI. Model projections for NSTX-U suggest MA-class LHI startup may be feasible with a modest LFS system. An advanced port-mounted LHI system is being deployed on Pegasus to test this path. Studies of HFS scenarios find favourable, positive scalings of I_p with V_{LHI} and T_e with B_T. If they hold at higher B_T, LHI may directly offer useful targets for RF and NBI current drive. High-frequency MHD activity plays a strong role in LHI current drive, in addition to $n=1$ modes previously found in NIMROD simulation and experiment. A new regime of reduced MHD activity was discovered where the $n=1$ activity is suppressed. In this regime, high-frequency activity increases, LHI CD efficiency improves, and long-pulse plasmas are sustained with $V_{IND}\sim0$. LHI facilitates access to the favourable low-A ST regime with non-solenoidal sustainment, high κ, low ℓ_i, and high β_t. Low B_T LHI operation has led to record $\beta_t=100$%, high β_N, and a minimum-$|B|$ well that may positively affect turbulence, transport, and fast particle confinement. Discharges at highest β_t disrupt at the ideal no-wall MHD limit.