URANIA: A Dedicated Spherical Tokamak Experiment for Developing Non-Solenoidal Plasma Startup Techniques

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Developing attractive means of initiating current without using magnetic induction from a central solenoid is a critical scientific and technical challenge facing the spherical tokamak (ST). The PEGASUS program has focused on developing the physics basis and predictive models for non-solenoidal tokamak startup using local helicity injection (LHI) and has demonstrated startup to ~0.2 MA in a low-field, near-unity aspect ratio (A) ST. A major upgrade is underway to convert the PEGASUS facility into a solenoid-free ST with a programmatic focus on non-solenoidal startup. The upgraded device and research program will be called the Unified Reduced A Non-Inductive Assessment (URANIA) experiment. A major feature of URANIA will be an ST centerstack assembly that enables a four-fold increase of B_T to 0.6 T, a value relevant to larger experiments, while retaining a low $A \sim 1.4$ ST geometry with I_p up to 0.3 MA and pulse length up to 100 ms. The higher B_T of URANIA directly supports the new mission to expand the breadth of non-solenoidal startup research on the facility to include examination and comparison of several leading startup candidates in a single, well-diagnosed experiment. These techniques are: dc helicity injection, including LHI, sustained coaxial helicity injection (S-CHI), and transient coaxial helicity injection (T-CHI); electron Bernstein wave (EBW) radiofrequency electron heating and possibly current drive; poloidal field induction; and in the future neutral beam current drive (NBCD) as needed. After the conversion to and commissioning of the URANIA facility, research will begin on developing and characterizing higher-B_T LHI scenarios, including studies of current formation and growth, MHD activity, and confinement scaling properties as B_T is raised. New engineering and physics capabilities of URANIA will include: deployment of impurity and internal plasma kinetics diagnostics, enabled by a diagnostic neutral beam (DNB); advanced LHI injectors with shaped electrodes and active control of the helicity injection rate; a novel refractory metal electrode system supporting S-CHI and T-CHI without vacuum electrical breaks or requiring current flow through the vacuum vessel; and an expanded poloidal field coil set supporting poloidal field induction and improved shape control. A modest power (200 – 400 kW) EBW system will be added for heating helicity-driven target plasmas and evaluating EBW current drive. The overarching goal of the new experiment is to demonstrate routine non-inductive plasma startup to $I_p = 0.3$ MA in URANIA and thereby provide guidance for MA-class startup with an approach that promises scalability to NSTX-U and beyond.

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