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H-mode and Non-Solenoidal Startup in the Pegasus Ultralow-A Tokamak

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Studies at near-unity aspect ratio offer unique insights into the high confinement (H-mode) regime and support development of novel startup scenarios. Ohmic H-mode operation has been attained at $A < 1.3$. Edge plasma parameters permit probe measurements of the edge pedestal, including the local current density profile, with high spatial and temporal resolution. H-mode plasmas have standard L-H transition phenomena: a drop in D_α radiation; the formation of pressure and current pedestals; field-aligned filament ejection during ELMs; and a doubling of energy confinement time from $H_{98} \sim 0.5$ to ~ 1 . The L-H power threshold P_{LH} increases monotonically with n_e , consistent with the ITPA08 empirical scaling used for ITER and the theoretical FM3 model. Unlike at high A, P_{LH} is comparable in limited and single-null diverted topologies at $A \sim 1.2$, consistent with FM3 predictions. The magnitude of P_{LH} exceeds ITPA scalings by an order of magnitude, with P_{LH}/P_{ITPA08} increasing as A approaches 1. Multiple n modes are observed during two classes of ELMs, consistent with excitation of multiple peeling-ballooning modes. Small, Type III-like ELMs occur at $P_{OH} \sim P_{LH}$ with $n \leq 4$. Large, Type-I-like ELMs occur with $P_{OH} > P_{LH}$ and intermediate $5 < n < 15$. Helical edge current injection appears to suppress Type III ELM activity. $J_{edge}(R,t)$ measurements across single ELMs show the nonlinear generation and expulsion of current-carrying filaments during the ELM crash. Local Helicity Injection (LHI) offers a nonsolenoidal tokamak startup technique. Helicity is injected via current sources at the plasma edge. A circuit model that treats the plasma as a resistive element with time-varying inductance reasonably predicts $I_p(t)$. The electron confinement governs the power balance. Initial measurements show peaked T_e and pressure profiles, which are comparable to Ohmic-like transport or moderately stochastic confinement. Extrapolation suggests $I_p \sim 1$ MA may be achievable in NSTX-U. Resistive MHD simulations suggest I_p is built from current rings injected during reconnection between unstable helical current streams. Several experimental observations support this model: imaging of the merging current streams; $n=1$ MHD activity and discrete current stream localized in the plasma edge; and anomalously high impurity ion heating in the edge region.

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Primary author: Prof. FONCK, Raymond (University of Wisconsin-Madison)

Co-authors: Prof. SOVINEC, Carl (University of Wisconsin-Madison); Mr KRIETE, David (University of Wisconsin-Madison); Mr SCHLOSSBERG, David (University of Wisconsin-Madison); Mr BODNER, Grant (University of Wisconsin-Madison); Mr BARR, Jayson (University of Wisconsin-Madison); Dr REUSCH, Joshua (University of Wisconsin-Madison)

Wisconsin-Madison); Mr PERRY, Justin (University of Wisconsin-Madison); Dr THOME, Kathreen (University of Wisconsin-Madison); Mr BURKE, Marcus (University of Wisconsin-Madison); Dr BONGARD, Michael (University of Wisconsin-Madison)

Presenter: Prof. FONCK, Raymond (University of Wisconsin-Madison)

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