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Magnetic Field Generation and Energy Confinement with $T_e > 500$ eV in the SSPX Spheromak[1]

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The understanding of confinement and energy transport in spheromaks is key the understanding the physics of spheromak formation and self-organization as well as addressing the feasibility of the concept as a reactor scenario. In the Sustained Spheromak Physics eXperiment (SSPX), increased understanding of the physics in building and sustaining self-organized magnetic equilibria has resulted in record electron temperatures $T_e > 500$ eV and plasma currents of ~ 1 MA on the magnetic axis. We find that the highest edge magnetic field magnitudes (and correspondingly high T_e) is achieved when $\lambda = \frac{\mu_0 I_{gun}}{\Psi_{gun}}$ is near (but slightly below) the Kruskal-Shafranov instability limit $\lambda_{KS} \cong \frac{2\pi}{L} \cong 12.6\, m^{-1}$ where L is the length of the flux-conserver (0.5 m). Building on previously reported results, power-balance analysis has shown levels of electron thermal transport $\chi_e < 1$ m^2/s, indicating good confinement and closed flux surfaces. With the addition of a modular capacitor bank we are able to highly tailor the gun current to take advantage of the sensitive dependence of spheromak performance on the plasma λ. When in this optimum operating range we also find that the efficiency of field build-up (defined as the ratio of edge poloidal magnetic field to gun current) is increased 20% over prior results, to $\sim$1.0 T/MA. Additionally this brings the efficiency of spheromak formation into numerical agreement with results from the NIMROD 3-D MHD code. Plasma energy evolution has been studied by taking time-resolved measurements of T_e(r) and n_e(r) indicating a distinct and robust feature of spheromak formation; a hollow-to-peaked temperature transition with an inverse relationship to the electron density. This feature, as well as sub-microsecond transport, is being studied with the upgrade of the Thomson scattering diagnostic to double-pulse operation. We also present recent results of the impact of charge-exchange losses on overall power balance and estimates of the plasma ion temperature as measured with a neutral particle analyzer.

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