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A compact levitated dipole trap for the confinement of electron-positron pair plasma

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Over the past ~40 years, many theoretical papers have predicted the remarkable stability properties of magnetized pair plasmas –largely due to the mass symmetry of the opposite charge species. However, there is a nearly complete lack of experimental validation. The mission of the APEX (A Positron-Electron eXperiment) collaboration is to confine and study a low-temperature, long-lived, magnetically-confined electron-positron pair plasma, thereby opening a new frontier in laboratory physics [1]. To achieve quasineutral plasma conditions, positrons, provided by the reactor-based positron source NEPOMUC (NEutron induced POsitron source MUniCh), are collected in a series of linear traps, then transferred to one of two compact (~10 liter) magnetic traps: an optimized, quasi-axisymmetric stellarator (EPOS, currently under construction), or a levitated dipole (APEX-LD). Focusing on the latter device, the requirements for this application posed a number of challenges for experiment design and engineering (including, e.g., the need for the compact [R=7.5 cm] superconducting "floating coil" [F-coil] to repeatedly make and break thermal contact with cryogenically cooled components in a vacuum environment; excitation of the persistent current in the F-coil, followed by long-duration, feedback-stabilized levitation; and a demand for robustness to repeated quenches and possible mechanical shocks). A comparable number of experiment design and engineering solutions have been found and implemented, and APEX-LD has successfully started operation, enabling initial electron plasma experiments. This talk will outline the design of the APEX-LD systems, then present the highlights of the experiment commissioning (including, e.g., efficient persistent current induction to ~0.5 T on-axis, levitation times in excess of three hours with a stability of $_z = 18$ μm [2], and "gentle" quenching of the no-insulation [NI] rare-earth barium copper oxide [ReBCO] high-temperature superconducting [HTS] coil). Finally, it will describe results from first experiments (i.e., visualization of electron injection) and next steps for future injection of cold, dense pulses of positrons.

[1] Stoneking M.R., et al. (2020) A new frontier in laboratory physics: magnetized electron–positron plasmas. Journal of Plasma Physics, 86(6):155860601
[2] Card, A., et al (2024) FPGA-Stabilized Magnetic Levitation of the APEX-LD High-Temperature Superconducting Coil. IEEE Transactions on Applied Superconductivity, 34.9, pp. 1-9

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