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Development of non-planar, HTS, tabletop-sized-stellarator coils

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Stellarators are a leading concept for magnetic confinement of plasmas – usually with the goal of enabling terrestrial fusion power plants. At small scales, they are also attractive for fundamental science, such as studies of non-neutral plasmas or matter-antimatter plasmas; this is the goal of EPOS (Electrons and Positrons in an Optimized Stellartor), part of the APEX Collaboration, which aims to study low-temperature (eV-scale) e+e- plasmas confined in compact (~10-liter), ultra-high vacuum (UHV) traps using modest magnetic fields (up to 1-3 T). Stellarator magnetic configurations are typically achieved with coil shapes that are significantly non-planar, in addition to requiring sophisticated numerical optimization methods. The non-planarity presents challenges for the design and development of HTS stellarator coils, due to HTS tapes' anisotropic bending properties and critical current dependence. To help tackle these challenges, our group and others have developed numerical tools for incorporating winding angle optimization into stellarator coil design – i.e., adjusting winding pack orientation along the coil path to stay within HTS strain limits [1]. The coil shapes themselves can also be adjusted to be more HTS-compatible, while still together generating a confining magnetic field with the desired properties [2]. Having used these tools to calculate that small (10-cm-scale) HTS coils based on 3-mm ReBCO tape are indeed feasible for EPOS, we then designed winding frames for test coils, which we conductively cool in UHV down to 20 K and energize [3]. This contribution will present results from the test coil campaign, design choices for the EPOS experiment, and plans for higher-field test coils that can further inform HTS stellarator coil development.

[1] "A Non-planar ReBCO Test Coil with 3D-printed Aluminum Support Structure for the EPOS Stellarator." P. Huslage, et al. arXiv:2505.08488

[2] "Strain Optimization for ReBCO High-Temperature Superconducting Stellarator Coils in SIMSOPT."P. Huslage, et al. Journal of Plasma Physics. 2025;91(2):E71. doi:10.1017/S0022377825000224

[3] "Winding angle optimization and testing of small-scale, non-planar, high-temperature superconducting stellarator coils."P Huslage et a, Supercond. Sci. Technol. 37 085010 (2024). DOI 10.1088/1361-6668/ad5382

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