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Renaissance Fusion's Magnet Program for Simplified High-Field Stellarator Magnets Based on Laser Patterned Wide HTS Conductors

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***Abstract*–Stellarators have traditionally been constructed using complex 3D magnets to produce the helical-shaped magnetic field configuration needed to confine the plasma. The complexity of manufacturing stellarator magnets has prevented their large-scale development, despite their advantageous steady-state operations and current-free plasmas compared to other magnetic confinement devices such as tokamaks [1].**

Renaissance Fusion has been developing manufacturing processes, electromagnetic design optimization tools, high-temperature superconductors (HTS) and copper electromagnets to simplify the construction of stellarator magnets. Our aim is to deliver high-field simplified stellarator magnets based on laser-engraved, meter-wide, HTS sheets wound over cylindrical structures. The present work describes the company's program for fusion magnets and our recent experimental results, with a focus on three technological pillars; (1) a newly developed roll to roll HTS engraving laser machine with experimental tests showing the ability to engrave HTS tape and the processing of 500mm wide conductor sheets over hundreds of meters in length. (2) A 0.65m major radius toroidal device, based on piece-wise cylindrical coils made from laser engraved wide copper sheets optimized to replicate within field accuracy, a scaled-down Wendelstein 7X (W7X, stellarator fusion machine currently under operation in Germany) magnetic configuration with 0.1T on its axis. (3) A 6T peak Helmholtz-type, no-insulation, HTS magnet of 1.2m in diameter, cooled at 20K, developed to provide a background field 0.9T for a liquid metal experimental loop operating at temperatures up to 900°C.

The experimental results from these three demonstrators validate and de-risk our simplified stellarator magnet program. They provide a steppingstone towards integrating laser engraving coil technology with Renaissance Fusion's wide HTS sheets, delivering high-field, laser-engraved HTS magnets wound over cylindrical structures generating accurate stellarator magnetic configurations.

***Keywords (Index Terms)*–Fusion, HTS magnet, HTS coils, Magnet Design, Stellarator**

[1] Bosch, H. S., Wolf, R. C., Andreeva, T., Baldzuhn, J., Birus, D., Bluhm, T., ... & Jenzsch, H. (2013). Technical challenges in the construction of the steady-state stellarator Wendelstein 7-X. Nuclear Fusion, 53(12), 126001.