T2.01-9960 - Superconducting Coils for Small Nuclear Fusion Rocket Engines

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NON-PROPRIETARY DATA

IDENTIFICATION AND SIGNIFICANCE OF INNOVATION

Small fusion reactors for space propulsion and power, such as the Direct Fusion Drive, will require superconducting coils. Due to detailed interactions with the superconductor community, our magnet strategy for the DFD/PFRC has evolved into a hybrid approach: a combination of "dry" conduction-cooled low-temperature (LTS) superconductor magnets and high-temperature (HTS) magnets also operated at low temperature. "Dry" LTS magnets are becoming state-of-the-art for MRI machines and eliminate the large volumes of cryogenic fluids traditionally needed for cooling; these will be suitable for the PFRC's array of 3-6 T magnets surrounding the fusion core. The PFRC's mirror magnets present a larger engineering challenge, requiring 20-25 T with a bore exceeding 10 cm. For these, HTS operated at 5-20 K provide the lowest mass with sufficient margin in critical current. Our proposed Phase II experiment will provide proof-of-concept studies for operating the LTS magnets for many FRC conditions; for example, during FRC start-up or equipment failure, the magnetic field at the coil case may double.

TECHNICAL OBJECTIVES AND WORK PLAN

The main objectives are to procure an LTS split-pair magnet of capable of 0.5 T, build a copper pulsed coil insert to perform proof-of-concept studies of superconducting magnets response to FRC plasma start-up and termination modes, and perform those experiments. We will also continue design studies of the HTS 25 T mirror coils.

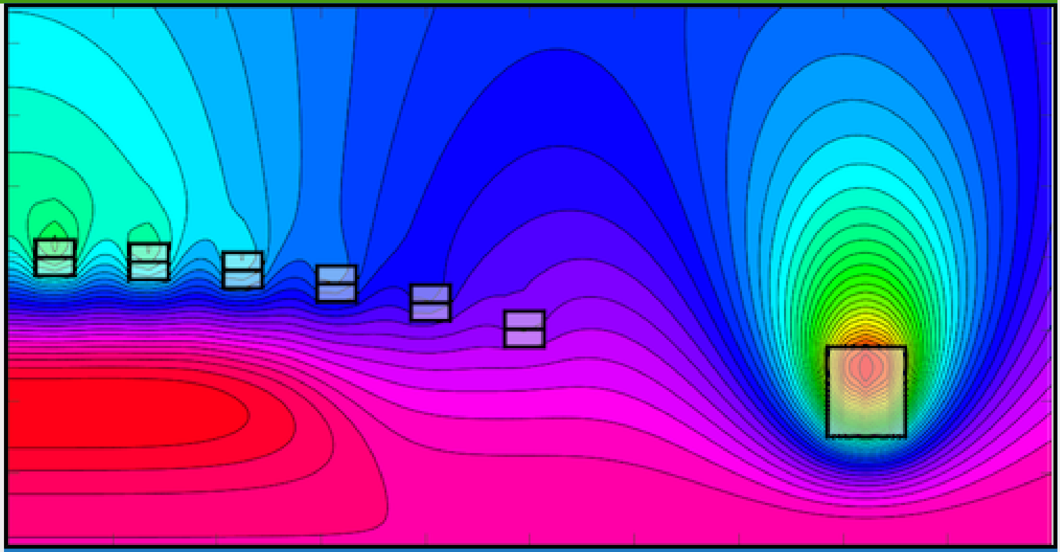
PPPL will provide lab space and technicians to house the Phase II magnet experiment and build and operate the pulsed driver coil. PSS will manage the vendor contract for the outer LTS magnet and provide analysis. In addition, a small subcontract to our LTS vendor, Superconducting Systems Inc, will support HTS magnet design. SSI has experience building both type of magnets and sells LTS magnets commercially.

The Phase II will begin with a design review of the experiment, followed by procurement and construction, installation and test of the magnets, and finally experiment operation. The magnet systems will be large and cumbersome and we do not anticipate delivering them to NASA, so the deliverable will be the final report with the experimental data and results.

TRL

Estimated

Scale 1–9: 2 to 5 highlighted



NASA APPLICATIONS

A small fusion engine such as Direct Fusion Drive would be useful for many deep- and inner-space missions, such as Lagrange points, manned Mars and lunar missions, a Pluto orbiter and lander, and the 550 AU solar gravitational lens. The novel superconducting coils have applications to additional advanced propulsion concepts and scientific payloads. One example is the AMS-02 experiment for which a low-temperature superconducting coil option was built and tested but later swapped out for a traditional magnet with a longer lifetime. Other advanced propulsion techniques require superconducting coils including the VASIMR electric thruster and the PuFF fission-fusion thruster. There has been considerable research on using superconducting coils for radiation shielding; these coils may also be useful for space materials processing and precision formation flying.

NON-NASA APPLICATIONS

There are many military and civil applications of the fusion engine and the coils. Military space applications include high-power Earth satellites with radar, laser, or communications payloads. There are wider applications including generators for wind turbines, high efficiency motors, particle accelerators, energy storage, and terrestrial fusion reactors. Small terrestrial fusion reactors of the PFRC type have unique application to remote and mobile applications, such as military forward power and disaster relief, as well as high-intensity energy applications like desalination. This project would contribute greatly to this wider body of work.

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