Enabling High-Temperature Superconducting Magnets on Small Satellites Using a Miniaturized Cryocooler

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High-temperature superconducting (HTS) tapes can carry very large electrical currents through very thin wires with no electrical resistance. This means HTS tape can be wound into lightweight, high field electromagnets that do not generate heat. HTS electromagnets therefore have the potential to be very useful in the space domain, which has extreme size and weight restrictions, and where it can be difficult to radiatively dissipate the amount of heat generated by conventional copper electromagnets. HTS is therefore posited as a miniaturisation technology, capable of generating high magnetic fields onboard small satellites for applications such as electric propulsion, radiation shielding, attitude control and inductive energy storage.

HTS devices require to be operated below some critical temperature, typically ~75 K. Maintaining these cryogenic temperatures in space can be achieved using an electrical cryocooler. The nature of the cryocooler and how it is integrated with the HTS electromagnet has a significant impact on the SWaP (size, weight and power) requirements.

This paper presents modelling and preliminary physical testing of an HTS electromagnet design, to be integrated into a 12U CubeSat. With satellite dimensions of 200 × 200 × 300 mm, this work investigated whether a single miniaturised cryocooler can cool an HTS electromagnet to below its critical temperature, using both a numerical modelling and experimental approach. Using a Sunpower CryoTel MT cryocooler, weighing only 2.1 kg and with a length and diameter of just 243 mm and 73 mm, respectively, a magnet temperature of less than 75 K was obtained, using only 40 W of input power and a 40°C hot end temperature. This demonstrates that HTS electromagnets can be operated on board small satellites using miniaturised, single stage cryocoolers.