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Fri-Mo-Or3-05: 40 Tesla All-HTS Miniature Magnets

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The generation of ultra-high magnetic fields is critical for advancing a wide range of scientific and technological research areas, including condensed matter physics, materials science, and biomedical imaging. Conventionally, achieving magnetic fields exceeding 40 T requires the combined use of superconducting and resistive magnet technologies, which are characterized by their substantial size, weight, and power consumption often reaching the megawatt range. In this study, we present the development and characterization of two compact all high-temperature superconducting (HTS) magnets. These magnets, small enough to be held in one hand, are capable of continuously generating magnetic fields of 38 T and 42 T, respectively, while operating at currents exceeding 1000 A. In particular, they achieve this high field strength with an ultra-low power consumption of less than a few hundred watts, significantly lower than the conventional systems.

The high magnetic fields reached by these HTS magnets is facilitated by the application of the no-insulation (NI) winding technique and a soldered coil structure, both of which contribute to enhanced mechanical strength and operational stability under strong forces and magnetic fields. To validate the field strength and reliability of these coils, nuclear magnetic resonance (NMR) measurements were conducted within the narrow 3 mm bore of the magnet. These NMR experiments also served as a precise calibration method for Hall effect sensors.

The compact size, high field strength, and energy efficiency of these HTS magnets hold significant promise for a broad spectrum of scientific and industrial applications, such as high-field NMR spectroscopy, enabling more widespread use in chemical analysis, structural biology, and materials research. Beyond NMR, these magnets could also support advancements in fundamental physics experiments, fusion research, and medical diagnostics, offering a transformative step toward more versatile and energy-efficient high-field magnetic systems.

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