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Mitigation of non-uniform current distribution in bulk high-temperature superconducting rings for the generation of NMR-grade magnetic fields

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The cost of high-field NMR systems has led to the development of low-cost 'benchtop'instruments for use by academic and commercial institutions. Whilst these devices have made NMR-spectroscopy more accessible, their use of permanent magnets limits the available resolution. Bulk high temperature superconducting (HTS) materials offer a route to bridge the performance gap to high-field devices.

Stacks of bulk HTS rings, magnetized in a NMR-grade field, have been demonstrated for use in NMR/MRI [1]. However, for practical applications, a low-cost, portable magnetization technique such as pulsed field magnetization (PFM) will be required. PFM has been shown to successfully magnetize disk-shaped HTS bulks, but is prone to inducing thermomagnetic instabilities (flux jumps) in rings, which can severely affect the trapped magnetic field [2]. Even if flux jumps can be avoided, the growth process of single-grain HTS bulks introduces local non-uniformity in the critical current density distribution. This impacts the flow of the supercurrent within the ring when magnetized and can introduce higher-order spherical harmonics to the field trapped in the bore of the ring.

Here we use finite-element models to investigate the impact of the size of circumferential inhomogeneity of the critical current density within the ring on the trapped field properties for both quasi-static magnetization and PFM. Following this, the models are extended to analyze techniques to mitigate the effects of the current inhomogeneity. Finally, we will compare the obtained results with the requirements for benchtop NMR, and discuss the implications of this for such benchtop devices.

[1] T. Nakamura et al., "Development of a superconducting bulk magnet for NMR and MRI,"J. Magn. Reson., vol. 259, pp. 68–75, 2015.
[2] D. Zhou et al., "Flux jumps in ring-shaped and assembled bulk superconductors during pulsed field magnetization,"Supercond. Sci. Technol., vol. 33, no. 3, p. 034001, 2020.

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