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Magnetic Field Optimisation and Design Procedures for Quantum Sensing Applications

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High-precision control of magnetic fields is critical for the operation of a range of quantum technologies. For example, optically pumped magnetometers (OPMs) utilise electromagnetic conductor networks within sensor housings to generate zero-field environments and modulation or bias fields. Current-carrying systems are also used within magnetically shielded rooms for hybrid active-passive magnetic field shaping and system calibration for OPM-based magnetoencephalography systems.

For any conductor network, topological optimisation ensures that currents produce high-fidelity magnetic fields with specified shape and strength. We have developed several optimisation methodologies including discrete and distributed current approaches, which incorporate apriori the effects of high-permeability materials on the field profiles. We have also developed methods for converting optimised conductor network designs to functioning hardware, including Printed Circuit Board (PCB) track milling/printing, wire winding on 3D printed formers for low power dissipation, and a full PCB design pipeline. The latter encompasses connection between conducting tracks, locations of vias and connection pads, track width and depth, and testing to ensure that the finalised PCB generates the desired field accurately and within size, weight and power constraints. We have also developed methods for optimising the layout of permanent magnets in cases where the field is continually required.

Here, we will present the implementation of our PCB design pipeline and optimisation methods, highlighting the improvements that resulted from a range of different projects and magnetic field requirements, and through interactions with project partners and industry contractors. These projects include designing and miniaturising bias coil flex PCBs for an RF magnetometer, shimming and nulling coils for use within a shielded CubeSat, and advances on permanent magnet optimisation for applications such as quantum computing.

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