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Improving Magnetic Field Unformities for Quantum Sensing with Advanced PCB Design

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Strict magnetic field control is an integral part of quantum sensors such as optically pumped magnetometers (OPMs). OPMs are used in pioneering research including biomagnetic measurement, which utilises hybrid shielding to provide the low and stable field environment required for precise measurements. Further applications where controlled field environments are required include atom interferometry for inertial navigation, graviometry, or other fundamental physics measurements. Controlled fields are also needed for the design, development and testing of OPMs themselves.

In hybrid systems, electromagnetic coils must be optimised to produce a desired field within the system geometry and accounting for the response of high permeability alloys, such as mu metal. Due to the complexity, each use case will require a different coil design for peak performance. The current standard for cylindrical geometries incorporates one Flexible Printed Circuit Board (or Flex-PCB) for each desired field, with the coil traces printed onto the PCB. This approach, which reliably sees uniform fields produced with <0.5% deviation in the fields along the target region, is effective, but alternative coil design methodologies can also be explored. Here, we present coil design methodology and manufacturing advancements including multi-face coils. This involves simultaneously optimising multiple coils together to produce a single, more uniform, field. The field fidelity can also be further improved through multi-surface coil design that builds on the standard cylindrical or planar coil by including endcaps further enclosing the geometry. We also present multi-layer coils, that take advantage of advanced PCB manufacturing techniques to combine standard coil designs into a single, multilayer, Flex-PC. This approach mitigates alignment errors found with multiple single-layer Flex-PCBs, thereby improving field fidelity.

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