Superconducting DC Magnetic Shielding For Quantum Computing

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Abstract

Quantum computers are extremely sensitive to external disturbances which cause them to lose their quantum states. Reliable operation of quantum computers therefore requires effective magnetic shielding to protect qubits from external magnetic fields.

Quantum computers typically operate at cryogenic temperatures well-below 1 K. Traditional shielding materials such as Mu-metal lose effectiveness under these conditions. Therefore, specialized materials and superconducting shielding are employed for these applications.

At DEMCON Multiphysics, we support the system engineering department through computer simulations that guide the design and optimization of such shielding solutions. In this work, the performance of a proposed shielding solution is determined through FEM analysis in COMSOL.

As a case study, we developed a magnetic shield with dimensions of 30 cm in height and 20 cm in diameter. The shield consists of four 1-mm thick layers alternating between Cryoperm and aluminium spaced 10 mm apart. The shield features a removable top lid, allowing for ease of qubit replacement. To facilitate connectivity with external electronics, openings are incorporated on both the top and sides of the shield.

Cryoperm exhibits high magnetic permeability at cryogenic temperatures and therefore acts as a conventional magnetic shielding material. At cryogenic temperatures, the aluminium is superconducting. Due to the Meissner effect, magnetic flux lines are expelled from the aluminium meaning it acts as a perfect diamagnet. This behavior is ideal for shielding purposes, as the material thus acts as a perfect magnetic insulator.

In COMSOL, the problem is modelled by positioning the shieldings inside a sphere with an external magnetic field imposed on its boundaries. The magnetic shielding feature is used for describing the Cryoperm layers, while the magnetic insulation feature is used for the superconducting shields.

A 1T axial magnetic field is applied to the system. This design with openings achieves a magnetic flux density reduction at the qubit location by a factor >10.000. This will result in a significant reduction in noise at the quantum chip, thereby improving the reliability of the quantum computer.

Figures used in the abstract

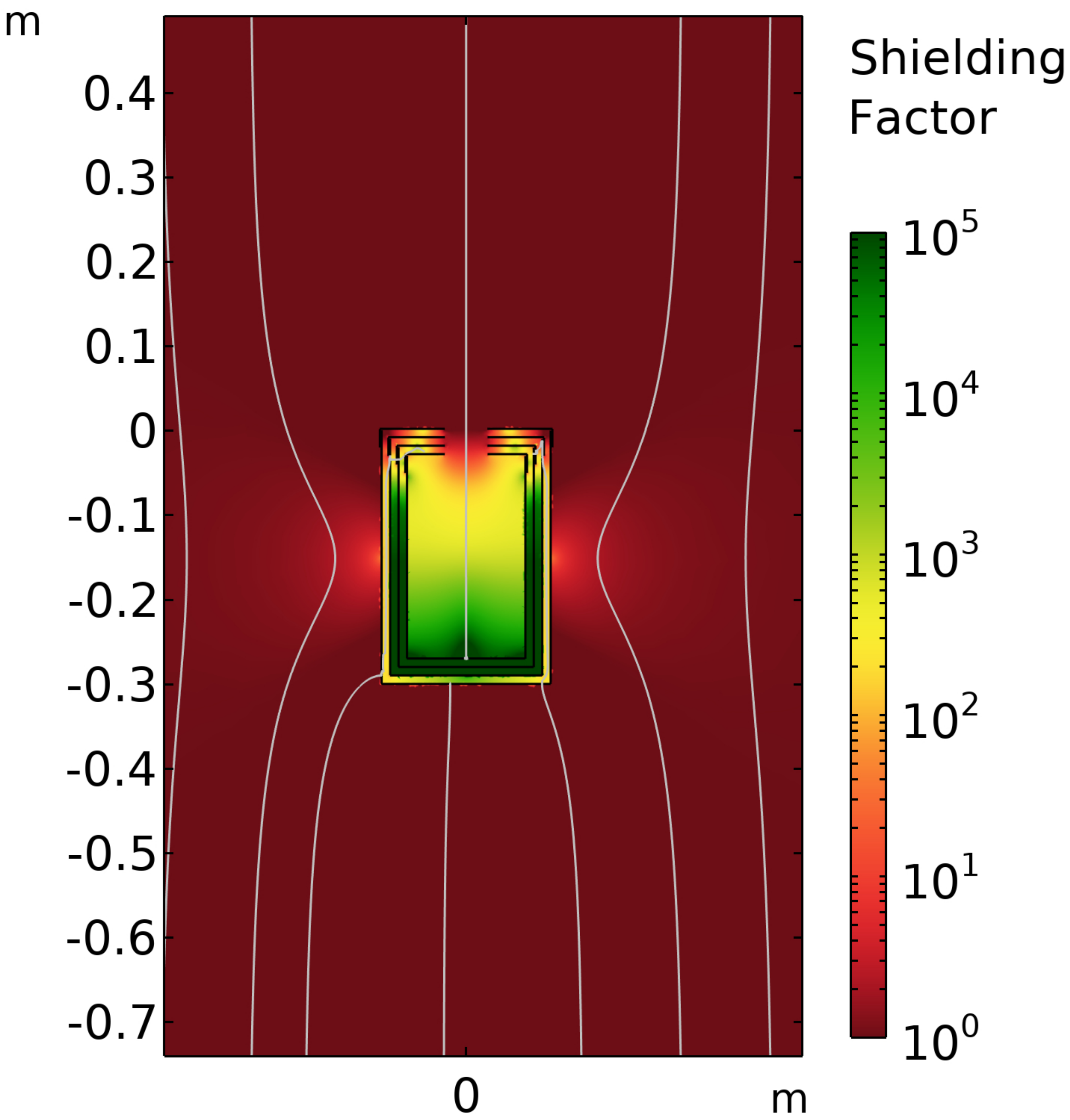

Figure 1 : Cross-sectional plot of the shielding factor (Bext/B).

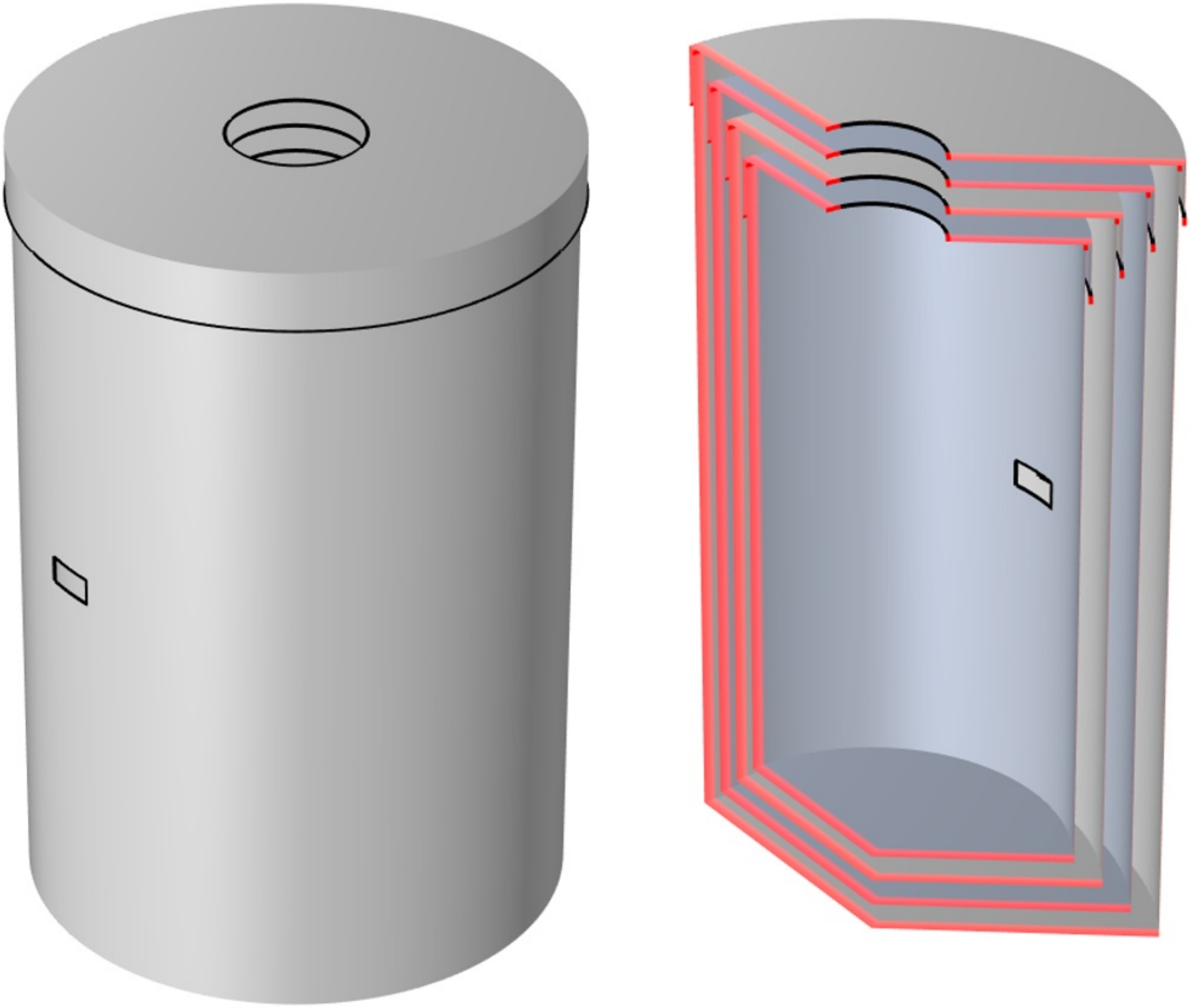

Figure 2 : Illustration of the 4-layer magnetic shielding. The light-grey surfaces indicate Cryoperm shields while dark-grey surfaces indicate aluminium.

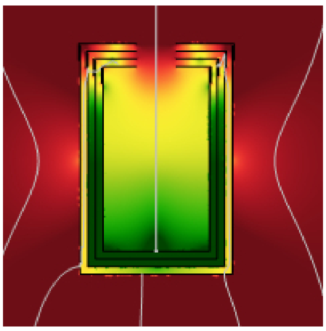

Figure 3 : Shielding factor calculation for superconducting DC magnetic shielding.