Design of Active Magnetic Field Stabilization for Quantum Gas Experiments

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Bose-Einstein Condensates (BECs) are a novel state of matter that exhibit unique characteristics where atoms behave as waves. BECs are highly sensitive to magnetic fields, and precision experiments require highly stable levels of magnetic fields in order to successfully be conducted. At a certain research institution an apparatus that can mitigate magnetic fluctuations to the order of 100 microgauss in a 1mm cubed region of interest is necessary for further experiments on BECs and their peculiar behaviors. The study developed a 3D cage with independent Helmholtz Coils along each axis to cancel magnetic fields, considering environmental noise and size constraints. A simulation validated the design's effectiveness to maintain magnetic stability, followed by a model test. After this, the bias cage was constructed (64.36x48.86x70.18 inches) and the helmholtz coils were wound. After the completion of the cage, subsequent tests demonstrated its efficiency in modulating the magnetic field to stabilize environmental noise effectively. The observed discrepancy between the produced magnetic fields against the simulated values 8.3×10^(-3) Gauss per Ampere, underscoring the precision of the finished construction of the bias cage. An electronic system featuring a PID control and a power driver was then developed, although it has not been implemented yet. This successful construction sets the stage for advancing to an autonomous control system in the future. This control system will actively receive feedback from sensors and accordingly output a current to stabilize the magnetic field. This system aims to dynamically stabilize external magnetic fields, thereby establishing an optimal environment for manipulating BECs.