A Potassium magnetometry based current source for the nEDM experiment at PSI

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Motivation

Our experiment requires a very stable $\vec{B}_0$-field during a measurement cycle (180s). Ideally, the $\vec{B}_0$-field should stay stable on the scale of the $\vec{E}$-field reversal time (an hour). At the moment we have several ways to control the field stability:

- Shielding the setup with a Mu-metal shield (shielding factor $\approx 10^4$).
- We use a surrounding field compensation system to diminish external field perturbations.
- We monitor the field in our setup with Mercury and Cesium magnetometers.
- We have a very stable current source for the main field ($\vec{B}_0$) of our experiment.

The stability of our present current source is 10^{-7} on 17 mA. We would like to improve on that by exploiting the sensitivities of atomic magnetometers (easily 10^{-8}) and convert them to a current stability.

Idea

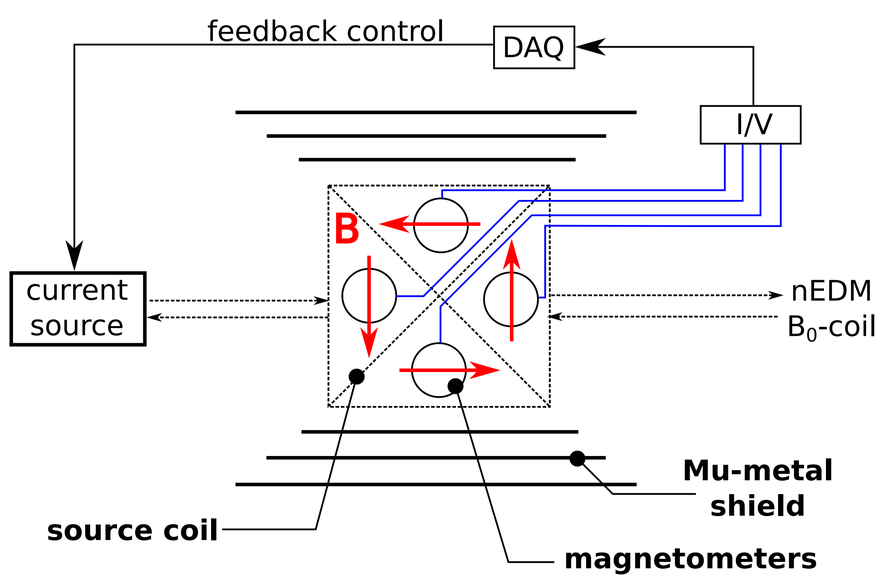

Figure 1: A commercial low noise current source provides the base current. Changes in this current are registered as changes in the magnetic field in a dedicated coil (source coil) which is connected in series to the nEDM B_0-coil. A magnetometer array in the source coil is able to detect these changes. A dedicated data acquisition system (DAQ) generates an appropriate feedback response for the detected drift.

Field containing coil

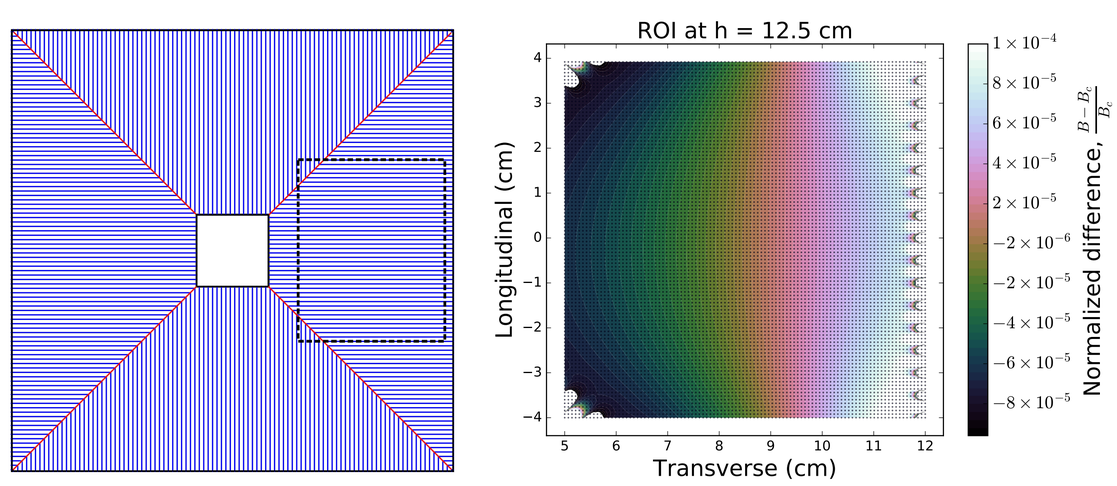

Figure 2: The design method is based on the magnetic scalar potential Φ [1]. The blue lines on the left are isopotentials of Φ but may be seen as the top view of a current loop. The righthand graph shows a typical region of interest (ROI) field map. The values are normalized to the value at the center of the ROI, B_c.

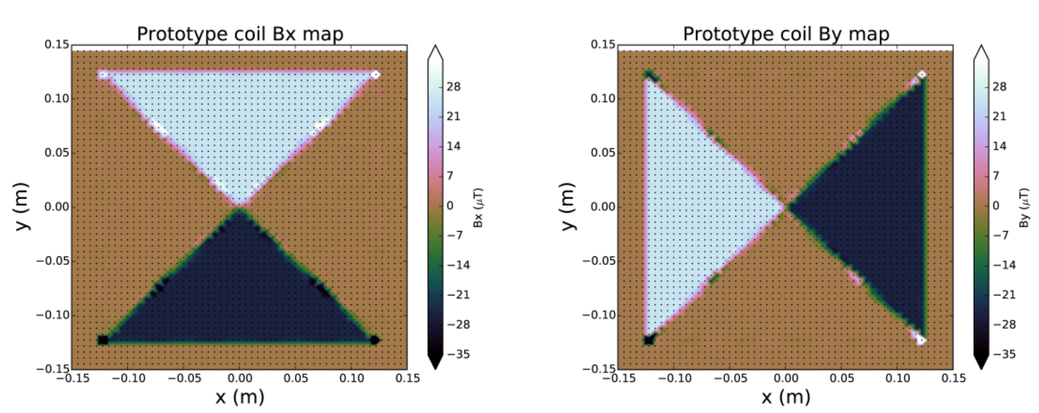

Figure 3: Field maps resulting from the simulation of the magnetic field in the coil when applying a current of 100mA. Each quadrant of the coil has a very uniform field. This field points into another direction in each quadrant.

Prototype

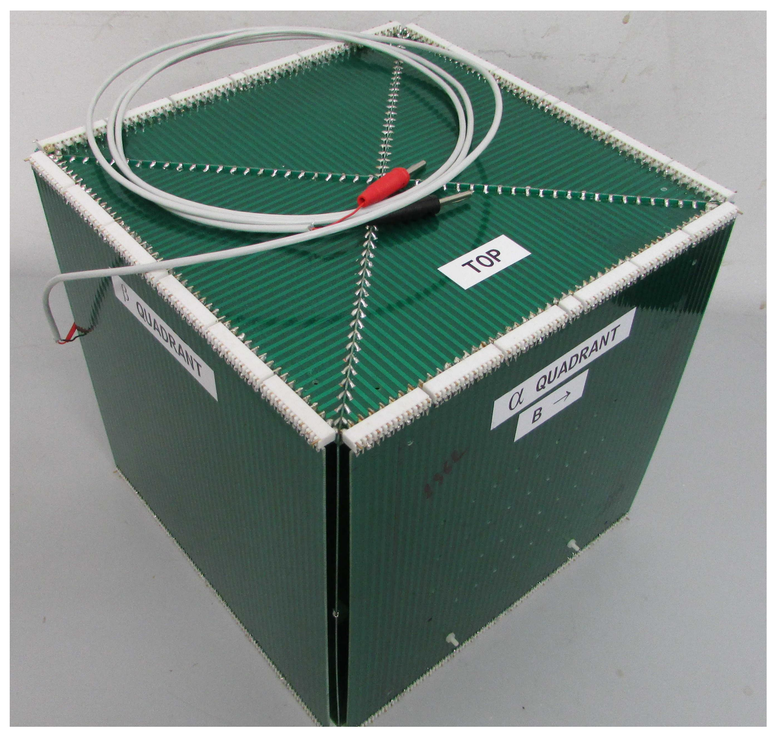

Figure 4: Prototype made out of printed circuit boards. This coil has a resistivity of 50Ω and produces a field of $B = 0.25\frac{\mu T}{mA}$. The resistivity can easily be reduced with thicker Copper layers. The current to field conversion can also be increased with more current loops per quadrant (now 50 per quadrant).

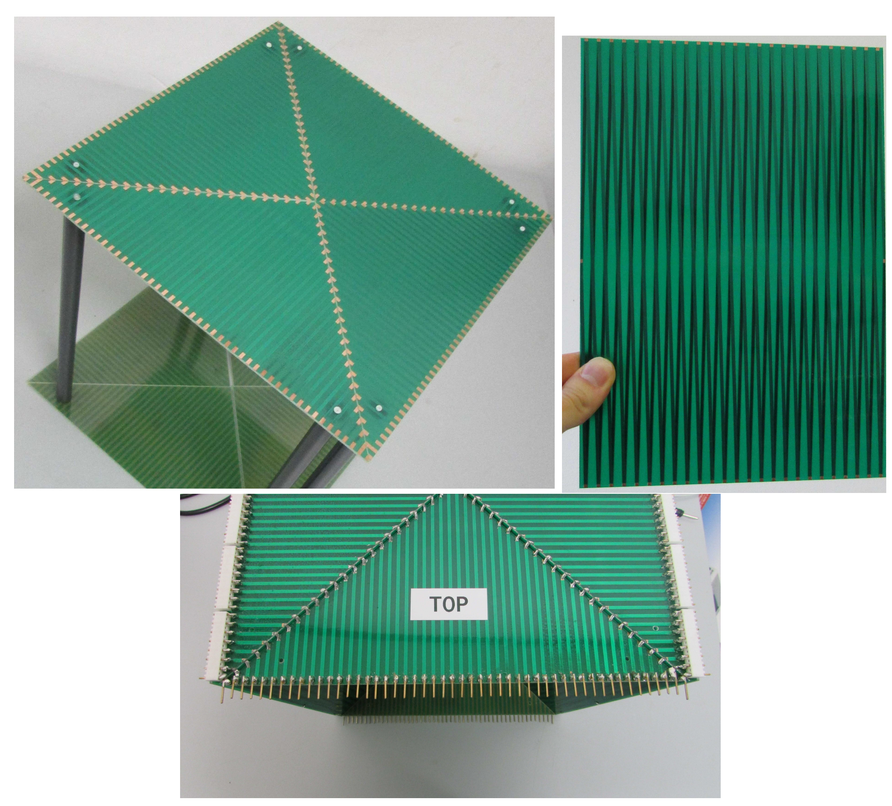

Figure 5: Triangular "top panels" make up the top and bottom planes of the coil. The "center panels" on the right implement connections between adjacent current loops. The "front panels" are connected to the rest of the coil via PCB headers. Brass rods were used as non-magnetic male pins.

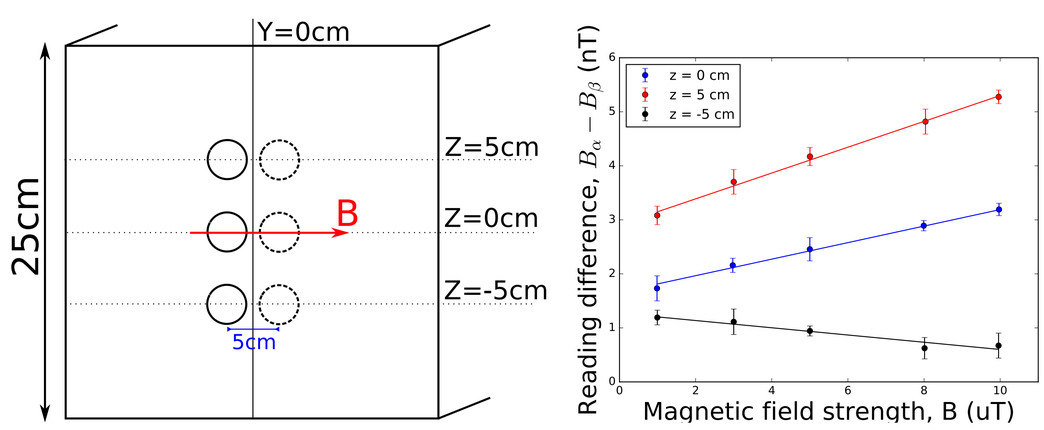

Figure 6: We have used Cesium magnetometers to measure the field uniformity in one quadrant. A Cesium magnetometer is more robust to misalignments of the sensor since in measures the modulus of the field ($B = |\vec{B}|$). The measurements are shown on the right as a difference in reading between two sensors.

References

[1] C. Crawford, M. Higginson-Rollins: Design of Precision Magnetic Fields for Fundamental Neutron Symmetries