Title
LASER OPTOACOUSTIC SPECTROMETER PROJECT. PRODUCING A VARIABLE UNIFORM FIELD IN A CONFINED VOLUME

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Publication Date
1982-03-01
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INTRODUCTION

Nabil Amer (Energy and Environment Division) in collaboration with Shu-Hsia Chen (University of Taiwan) asked Magnetic Measurements Engineering to design a magnet which will produce field strengths up to 500 Gauss, uniform over a 5 mm cube (125 mm³) to ±0.1% of the central field. In addition, they want the capability of superimposing a horizontal component of magnetic induction of unspecified magnitude and variation (over the volume of interest). The design constraints are size limitations imposed by the microscope required for observing the effects that will be produced by magnetic fields.

Because of the urgency of moving the project forward (Dr. Chen wants to complete this work before returning to Taiwan this summer) and because of uncertainty in the actual requirements for field strength and uniformity, it was decided that a "Phase I" magnet will be designed and built with more modest requirements in order to gain experience before specifying additional requirements.

This report describes the (Phase I) magnet I designed and outlines the tasks I want to complete in preparation for subsequent design work.

PHASE I DESIGN REQUIREMENTS (as I understand them)

1. Single component only
2. Magnitude (a few hundred Gausses)
3. Uniformity - "Don't worry about uniformity" (for Phase I)
4. Completion of Phase I magnet by March 19th.

UNIFORMITY APPROXIMATION

The physical constraints imposed by the microscope objective lens and platform, and the need to insert specimens, suggested designing an approximate Helmholtz coil pair to optimize uniformity with a minimum of variables.
I made the rough determination\(^1\) that for an ideal Helmholtz coil with a radial dimension of 12 mm (\(\sqrt{3}-1/3\) times the radius of a circle circumscribed about a sample 5 mm on an edge) the field uniformity over the sample would be better than 0.4%. The approximate "Helmholtz pair" will have different properties which may be evaluated by computer aided calculations that I hope to complete by March 31, 1982.

**PHASE I COILS**

In collaboration with S. Buresh (mechanical technicians) and D. Van Dyke (electronics fabrication), I designed the coil-form shown in Figure 1.

Assuming the (0.36 x 0.47 in.) crosssection is filled with conductors, the mean radius of the resultant coil will be 16 mm. The uniformity will be improved (compared to a 12 mm radius).

**ESTIMATE OF ATTAINABLE FIELD STRENGTH**

For the geometry shown in Figure 1, a pair of coils mounted bottom-to-bottom will form a Helmholtz pair of radius \(a = 0.016\) m. The center of each coil will be \(\pm a/2\) \(|a|\) from the location of the specimen center. Equation 12 gives field strength on the axis of a single coil of radius \(a\).

\[
H_z(r = 0, z) = \frac{I_0 a^2}{2(a^2 + z^2)^{3/2}} \text{ (A/m)}
\]

\(I_0\) - current in a single turn loop of radius, \(a\) (A)
\(a\) = radius of current loop (m)
\(z\) = axial distance from plane of coil (m)

Using equation 1 for a coil pair, each having \(n\)-turns, located at \(z' = \pm a/2\), I compute the following field strengths at \(z' = 0\):
Field strength is directly proportional to current density, and the maximum attainable current density increases as you progress from uncooled (actually convection cooled) to conventionally cooled and then to superconducting coils.

For Phase I, I chose an uncooled coil design. To the "first-order", the attainable maximum for uncooled coils is independent of conductor size. (The choice of conductor size is more dependent on power supply characteristics.) I "arbitrarily" chose AWG No. 24 heavy formvar coated copper conductor which can carry up to 1-1/2 Amperes in a confined volume. I estimate that with reasonable care in winding that we may wind ~350 turns per coil. This may result in a maximum field strength of

$$350 \times 1.53 \times 0.56 = \approx 300 \text{ Gauss}.$$
The uniformity due to the coil is easier to predict than to measure. For the small volume of interest, the prediction is also probably as accurate as a measurement. I plan to use the most up-to-date version of the FORTRAN program COILS to predict the uniformity of the "approximate Helmholtz pair". This exercise will prepare me to use COILS as an aid in subsequent design work.

ADDITIONAL TASKS

1. Provide hardware for energizing Phase I coil pair.
2. Calibrate system - $B_z(0, 0)$ vs $I$.
3. Predict field uniformity with the aid of COILS.
4. Examine the effect of magnetic material, the earth's magnetic field and fields produced when the Bevatron is pulsing on the resultant field.
5. Develop a computer program to predict fields produced by REC (Rare Earth Cobalt) magnets.

Tasks 1, 2 and 3 are part of completing Phase I. Tasks 1 and 2 were completed by March 15th. Task 3 is delayed until I locate a suitable computer program, e.g., COILS. Tasks 4 and 5 will not be started without more direction from Dr. Amer and Dr. Chen.

SCHEDULE

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Start Date</th>
<th>Estimate of Effort</th>
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<tbody>
<tr>
<td>Coil Form Fabrication</td>
<td>March 8th</td>
<td>8 Hours</td>
</tr>
<tr>
<td>Wind Coils</td>
<td>March 10th</td>
<td>4 Hours</td>
</tr>
<tr>
<td>Deliver Coils</td>
<td>March 10th</td>
<td>2 Hours</td>
</tr>
<tr>
<td>Provide Hardware (Task 1)</td>
<td>March 10th</td>
<td>2 Hours</td>
</tr>
<tr>
<td>Calibrate (Task 2)</td>
<td>March 15th</td>
<td>4 Hours</td>
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REFERENCES


DISTRIBUTION

N. Amer
S.H. Chen
C.G. Dols
M.I. Green
E.C. Hartwig/L.J. Wagner/W.H. Deuser
J. Katz

This work was supported by the U.S. Dept. of Energy under Contract No. DE-AC03-76SF00098.
This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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