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Stray Light Control Suspension, Magnetic Field Measurements of the Eddy Current Damper

Virgínio Sannibale

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California Institute of Technology
LIGO Project - MS 18-34
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project - MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

URL:http//www.ligo.caltech.edu/

1 Introduction

This document briefly reports the measurement of the magnetic field generated by the eddy current damper of the SLC suspension prototype and the estimation of the expected coupling force with the core optics suspension magnets .

All the measurements were performed using an FW Bell Gauss-meter 9200 with FW BELL 1X HTB92-0608 Hall sensor probe. The nominal resolution of the magnetometer with the particular Hall probe used was $\delta B = 0.01$ Gauss.

The magnets used are nickel-plated neodymium cylindrical permanent magnets, (1"Ø, 0.5" H) from Bunting Magnetics , part # N35P1000500 .

Compared to the previous version, this document contains the correct analysis of the magnetic field using a power law fit according to the magnetic induction approximation formula analogous to the electric dipole approximation. Good agreement of the experimental data to a power law function was evident after adding an offset in the measured distance from the magnets. This offset was unfortunately forgotten in the first analysis.

2 DC Magnetic Field Measurement, Power Law Fit

This sections reports the measurements done on the magnets pair and the magnet double pair used in the SLC suspension eddy current damper. The orientation on the four magnets differs from a magnet quadrupole because the north-south poles axis orientation is axial and not radial. Moreover, the magnet are placed on a ferromagnetic steel plate that should provide some shielding to the magnetic field.

All measurements were done from the side of the steel plate face, which was not in contact with the magnets.

The average magnetic field measured in the modal lab located in the third floor of Downs is $B_{env} = (0.30 \pm 0.05)$ G, which is a typical value inside Caltech buildings.

The maximum of the magnetic field component was found orienting the probe tip nearby the permanent magnets. Once the maximum was found, the probe orientation was kept constant and the magnetic field B was measured as a function of the distance from a magnets holder plate. The collected data points were finally fitted with:

$$B(x) = \beta x^{\alpha} + B_0$$

The magnetic induction $\underline{B}$ at a distance given by the vector $\underline{x}$ is

$$\underline{B}(\underline{x}) = \frac{\mu_0}{4\pi} \frac{3\hat{x}\,(\hat{\underline{x}} \cdot \underline{m}) - \underline{m}}{|\underline{x}|^3}\,, \qquad |x| \gg \{\text{ magnets dimensions}\}\,,$$

where μ_0 is the permeability in vacuum, $\underline{m}$ is the permanent magnet magnetic moment, and $\underline{x}$ the vector from the magnet to the point where $\underline{B}$ is calculated.

In our case, the vector $\underline{m}$ can be considered the effective magnetic moment generated by the chosen distribution of magnets, and therefore it can be experimentally measured.

Considering the fit parameters and the case of $\underline{x}$ parallel to the magnetic moment $\underline{m}$, we will have

$$\begin{aligned} |\underline{m}| &= \frac{2\pi}{\mu_0}\beta\,, \text{ (effective magnetic moment,)} \\ \alpha &= -3\,, \\ B_0 &= B_{env}\,. \end{aligned}$$

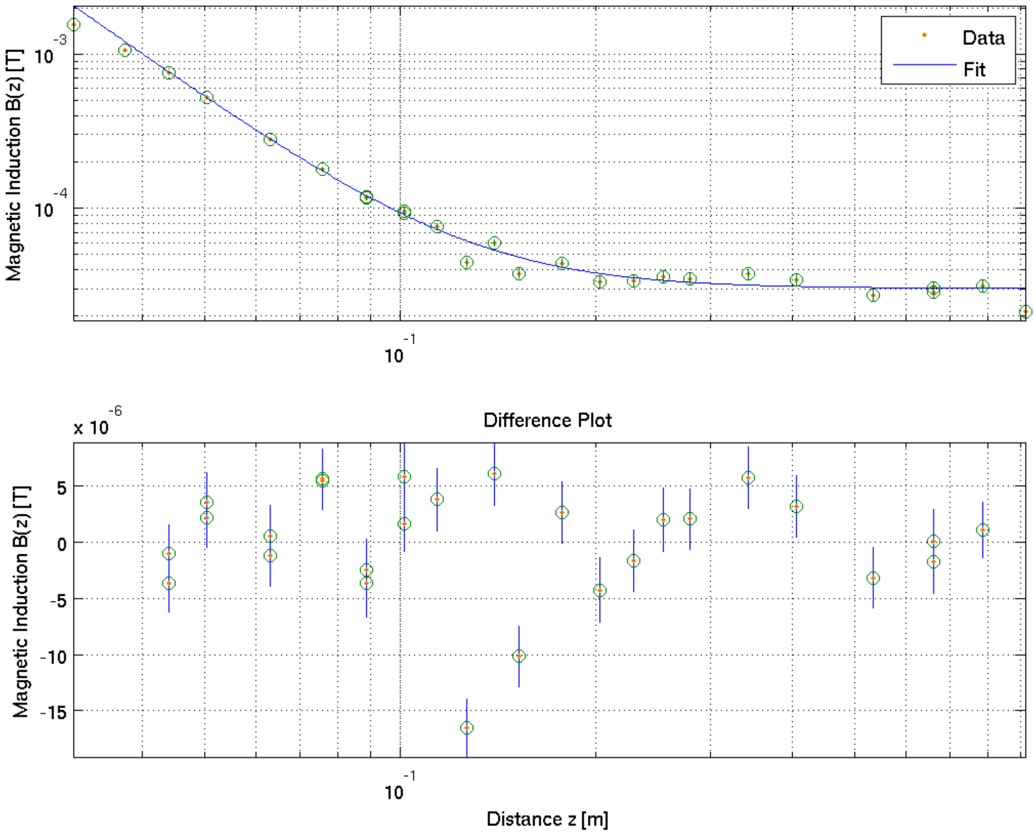

Figure 1: Fit of the magnetic field component versus distance orthogonal to the cylindrical magnets bases produced by a magnet pair using a power law $B(x) = \beta x^{\alpha} + B_0$. First two data-points were not included in the fit because of the dipole approximation.

Next subsection contains the results for a magnet pairs and a magnet double pair.

2.1 Magnets Pair

Results of the fit for a magnet pair is shown in Figure 1 and below:

- $\beta = (6.274 \pm 0.0286) \cdot 10^{-8}\ \mathrm{T\ m}^3$,
- $\alpha = -3$, (kept constant),
- $B_0 = (3.019 \pm 0.121) \cdot 10^{-5}\ \mathrm{T}$,
- $\chi^2_{n-v} = 3.8$, $n - v = 25$.

First two data-points were neglected vis-à-vis the dipole approximation. Considering the residuals and the reduced χ^2, the agreement with experimental and theoretical data-points is quite good.

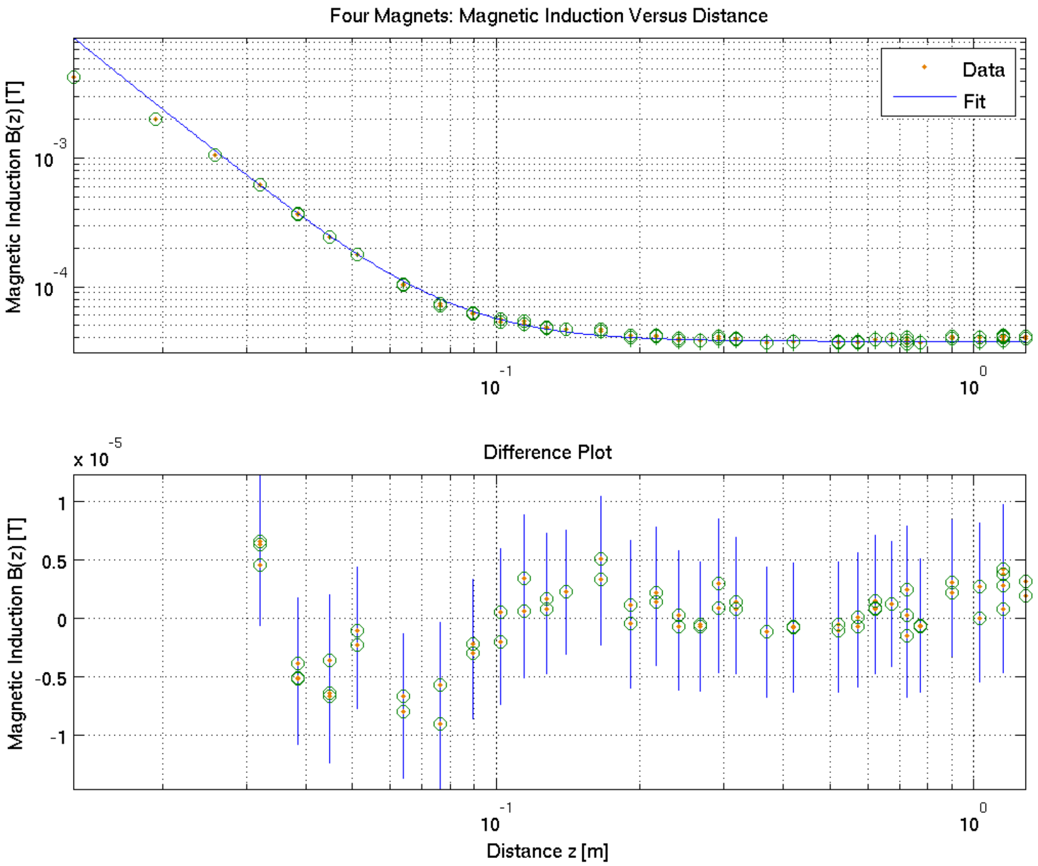

Figure 2: Fit of the magnetic field component versus distance orthogonal to the cylindrical magnets bases produced by a magnet double pair using a power law $B(x) = \beta x^{\alpha} + B_0$. First two data-points were not included in the fit because of the dipole approximation.

2.2 Magnets Double Pair

Results of the fit for a magnetic quadrupole is shown in Figure 2 and below:

- $\beta = (1.8985 \pm 0.0056) \cdot 10^{-8}$ T m^3 ,
- $\alpha = -3$, (kept constant),
- $B_0 = (3.767 \pm 0.045) \cdot 10^{-5}$ T ,
- $\chi^2_{n-v} = 0.365$, $n - v = 62$.

First three data-points were neglected due to the dipole approximation. Considering the residuals and the reduced χ^2, the agreement with experimental and theoretical data-points is quite good.

3 Magnetic Field Spectrum Measurement

The magnetic field spectrum generated by the magnets quadrupole was measured placing the Hall probe at a distance of about 0.05 m from the magnets plate, which was se-

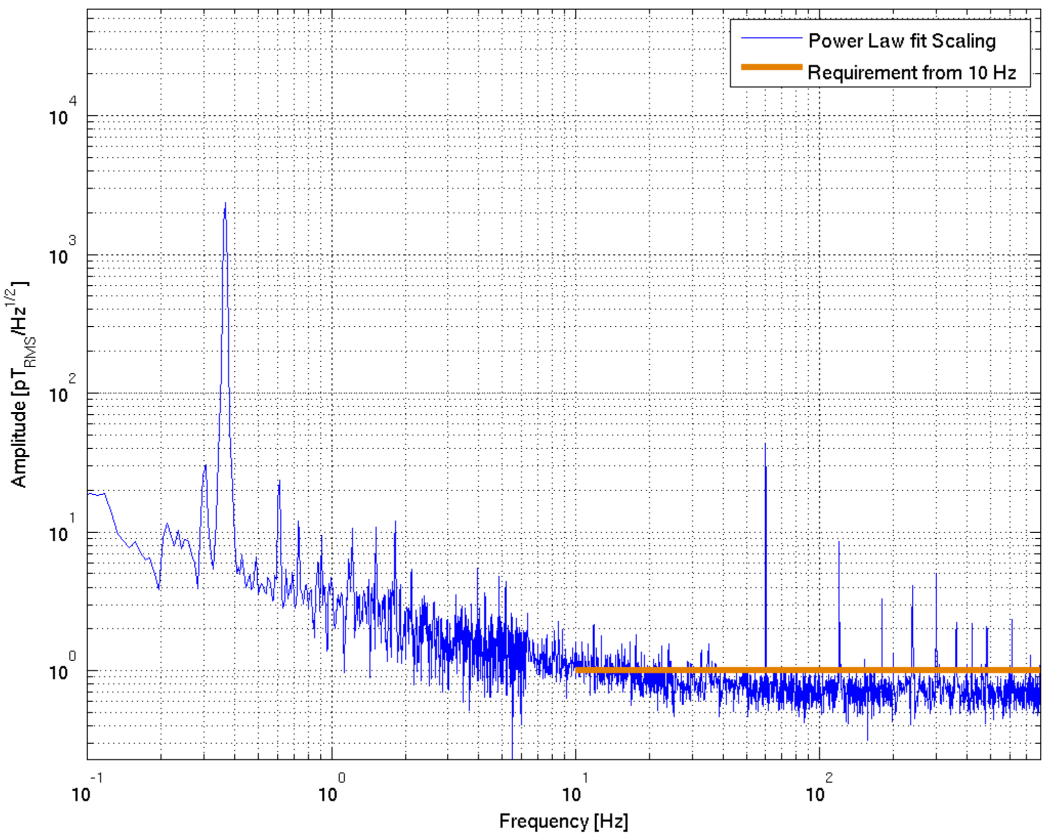

Figure 3: Magnetic spectrum measured close to the permanent magnet quadrupole and scaled down to 0.7 m far from the magnet using the fit of the DC value measurements.

cured to the SLC suspension. The suspension was excited with an amplitude of few millimeters to introduce a large and therefore easy to measure effect. The measured spectrum was then scaled down considering the DC magnetic field value measured at at 0.05 mm and the fit of the DC magnetic field at 0.7 m. The result is shown in Figure 3.

4 Conclusion

The results of those measurements and extrapolations from the fit show that the magnetic field spectrum at a distance of 0.7 m is estimated to be about 1 $\mathrm{pT_{rms}}/\sqrt{\mathrm{Hz}}$ above 10Hz, a value one order of magnitude lower than the natural magnetic field measured at Hanford.

Considering that the expected seismic noise on a Caltech's build third floor is presumably larger than the one at the sites, the spectrum noise is dominated by the instrument noise, and the number of permanent magnets used will be reduced by a factor two, the residual magnetic field spectrum estimation at a distance of 0.7 m is conservative.