DRAGON Power Supply Calibration

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1 Introduction

Proper tuning of the DRAGON optics requires precise knowledge of the magnetic fields of the magnets located in the electromagnetic separator. These fields, in turn, are dependant on the electric current provided to them by the power supplies. Following the installation of the new dipole power supplies in February 2003, it was necessary to revise the relationship between the magnetic field and the electric current to account for the change in hardware.

Magnetic field data was taken for MD1, MD2, Q9, and Q10 over a range of setpoint currents. The data was then fit to a quadratic curve, and relationships were found for the field as a function of setpoint current, and current as a function of magnetic field. The error between the measured values and the fits were on the order of a hundredth of a percent, giving confidence in the derived relationships.

2 Results

2.1 MD1 and MD2

Using the EPICS control system, NMR readings for MD1 and MD2 were taken at evenly space intervals of current over the range 250A to 450A. The range of DAC values for which the NMR would lock onto the field was also determined. This data is presented in Tables 1 and 2. (The NMR DAC value given is the average of its range.)

Data was taken both in the direction of increasing current and in the direction of decreasing current to determine the extent of hysteresis in the dipoles. Though small, hysteresis was noticeable, with ΔB as high as 12G for MD1 and 15G for MD2 (see Figures 1 and 2).

Quadratic fits were calculated for sets of data taken in both the direction of increasing current, and the direction of decreasing current. The fit for the data taken in the direction of increasing current was favoured because it was found to deviate less from the data. The average absolute error for this set of data was 0.005% for MD1 and 0.006% for MD2, as compared to 0.03% and 0.02% for the data taken in the direction of decreasing current (see Figures 3 and 4).

The data was fit in two separate ways - first, the magnetic field was fit as a function of the setpoint current, and then, the current was fit as a function of the field. These fits are given below:

$$B_{MD1} = 13.5 + 12.1I - 0.000433I^2 \tag{1}$$

$$I_{MD1} = -1.01 + 0.0825B - 2.64 \times 10^{-7}B^2 \tag{2}$$

$$B_{MD2} = -0.983 + 16.8I - 0.000521I^2 \tag{3}$$

$$I_{MD2} = 0.140 + 0.0595B + 1.18 \times 10^{-7}B^2 \tag{4}$$

The percentage error given in Figures 3 and 4 was calculated according to Eq. 5. Absolute error was calculated by taking the absolute value of the difference between the measured and fitted values.

$$\%\ \text{Error} = \frac{\text{(Measured Value - Fitted Value)}}{\text{Measured Value}} \tag{5}$$

2.2 Q9 and Q10

Using the EPICS control system, magnetic field readings for Q9 and Q10 were taken at evenly spaced intervals of current over the range 10A to 40A. This data is presented in Tables 3 and 4.

Data was taken both in the direction of increasing current and the direction of decreasing current to determine the extent of hysteresis in the

Current I (A)	Field B (Gauss)	NMR DAC	% Error in Fit
250	3012.7	3.161	-0.001
275	3309.9	3.452	0.007
300	3606.1	3.720	0.001
325	3901.5	3.974	-0.011
350	4197.0	4.258	-0.006
375	4492.1	4.575	0.002
400	4786.6	4.894	0.007
425	5080.3	5.394	0.007
450	5372.7	6.116	-0.007
425	5087.3	5.407	-0.029
400	4794.2	4.916	0.038
375	4504.1	4.584	-0.013
350	4208.9	4.268	0.005
325	3912.3	3.997	-0.021
300	3614.6	3.717	-0.036
275	3316.4	3.458	-0.018
250	3017.7	3.171	0.042

Table 1: MD1 magnetic field as a function of setpoint current.

Current I (A)	Field B (Gauss)	NMR DAC	% Error in Fit
250	4164.4	1.713	0.015
275	4576.1	2.262	-0.013
300	4988.6	2.713	-0.006
325	5400.3	3.065	-0.004
350	5811.6	3.336	0.003
375	6222.1	3.555	0.006
400	6631.5	3.752	0.002
425	7040.6	3.993	0.004
450	7448.3	4.100	-0.005
425	7048.4	3.929	0.017
400	6644.0	3.759	0.025
375	6236.5	3.568	0.015
350	5826.6	3.342	-0.006
325	5415.3	3.078	-0.022
300	5002.8	2.742	-0.026
275	4589.4	2.284	-0.011
250	4175.2	1.726	0.034

Table 2: MD2 magnetic field as a function of setpoint current.

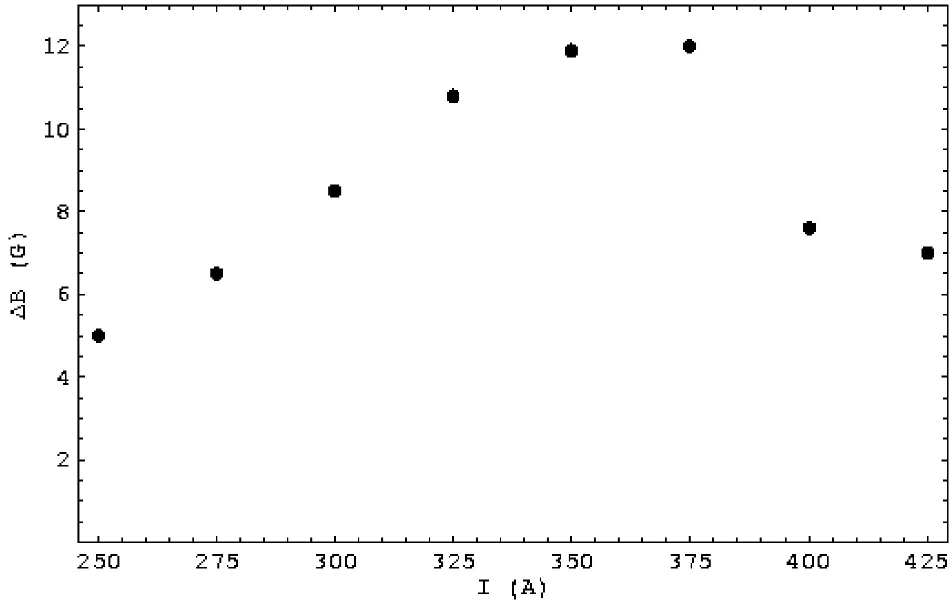

Figure 1: Extent of hysteresis in MD1.

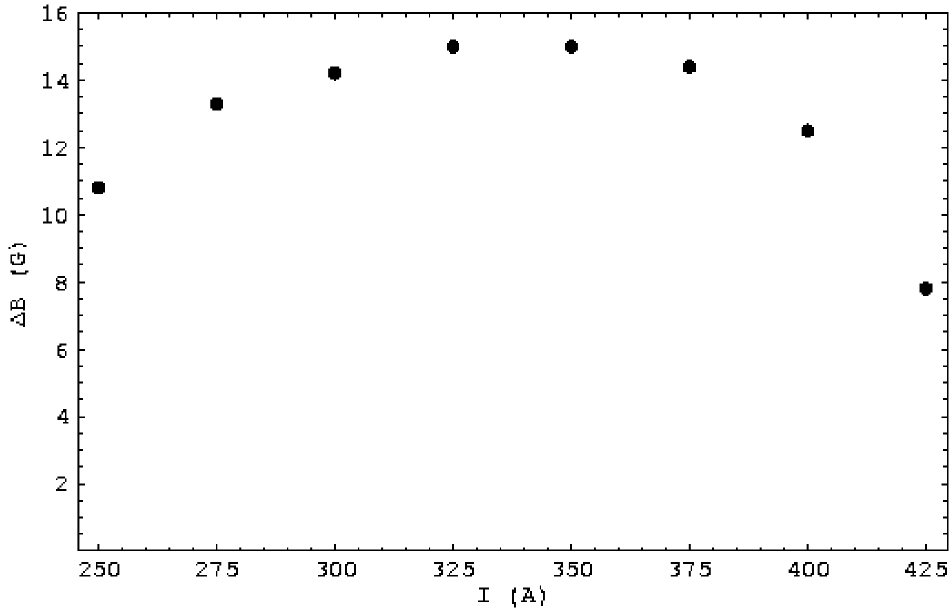

Figure 2: Extent of hysteresis in MD2.

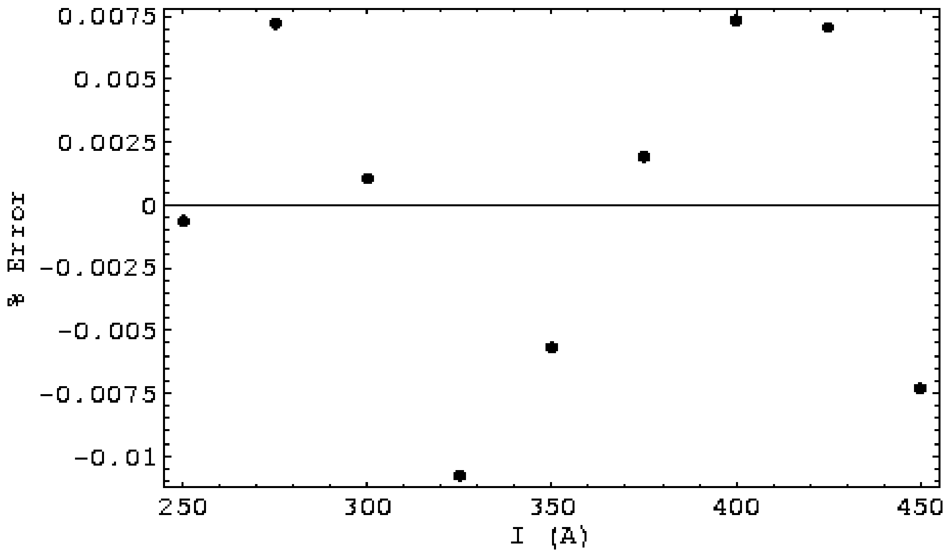

Figure 3: Percentage error in fit for data from MD1 taken in the direction of increasing current.

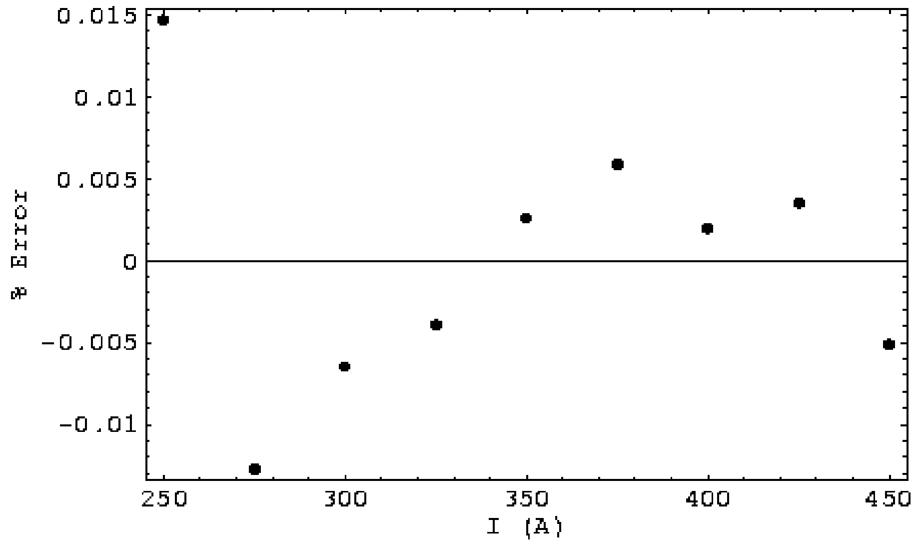

Figure 4: Percentage error in fit for data from MD2 taken in the direction of increasing current.

quadrupoles. Q9 had no obvious hysteresis, so only readings taken in the direction of increasing current were included in the analysis. Q10 showed slightly more hysteresis than Q9, but not enough to warrant the analysis of two separate sets of data. Thus, only readings taken in the direction of increasing current were analyzed for Q10.

As with MD1 and MD2, data was fit in two separate ways - with the magnetic field as a function of the setpoint current, and current as a function of the field. These fits are given below:

$$B_{Q9} = 4.01 + 21.6I + 0.00329I^2 \tag{6}$$

$$I_{Q9} = -0.185 + 0.0462B - 3.17 \times 10^{-7}B^2 \tag{7}$$

$$B_{Q10} = 8.53 + 21.5I + 0.00310I^2 \tag{8}$$

$$I_{Q10} = -0.396 + 0.0465B - 3.04 \times 10^{-7}B^2 \tag{9}$$

The percentage error in the fits is given in Figures 5 and 6. It was calculated using the same method as that for MD1 and MD2.

In the course of data collection, a curious observation was made relating to the Hall probes located in Q9 and Q10. Initially, readings were made with the Hall probe set at the 2kG level. After all the data had been collected, the level was switched to 20kG. Upon return to the 2kG level, the magnetic field readings were found to be different than those taken before the brief change to 20kG. This disagreement between field readings occurred in both Q9 and Q10. The "new" data was less stable than the original readings (the magnetic field readings varied more at a set current), but it deviated less from a quadratic fit (the difference between measured and fitted values were on the order of a hundredth of a percent rather than on the order of a percent, as it was for the "old" data). For this reason, this "new" data was favoured over the "old" data. The cause of this inconsistency in field readings is currently unknown.

Current I (A)	Field B (Gauss)	% Error in Fit
10	220.9	0.029
15	329.4	-0.028
20	438.3	-0.003
25	547.3	0.000
30	656.5	0.008
35	765.8	0.005
40	875.2	-0.005

Table 3: Q9 magnetic field as a function of setpoint current.

Current I (A)	Field B (Gauss)	% Error in Fit
10	224.1	0.033
15	331.9	-0.032
20	440.1	-0.010
25	548.5	0.012
30	656.9	0.003
35	765.5	0.003
40	874.2	-0.004

Table 4: Q10 magnetic field as a function of setpoint current.

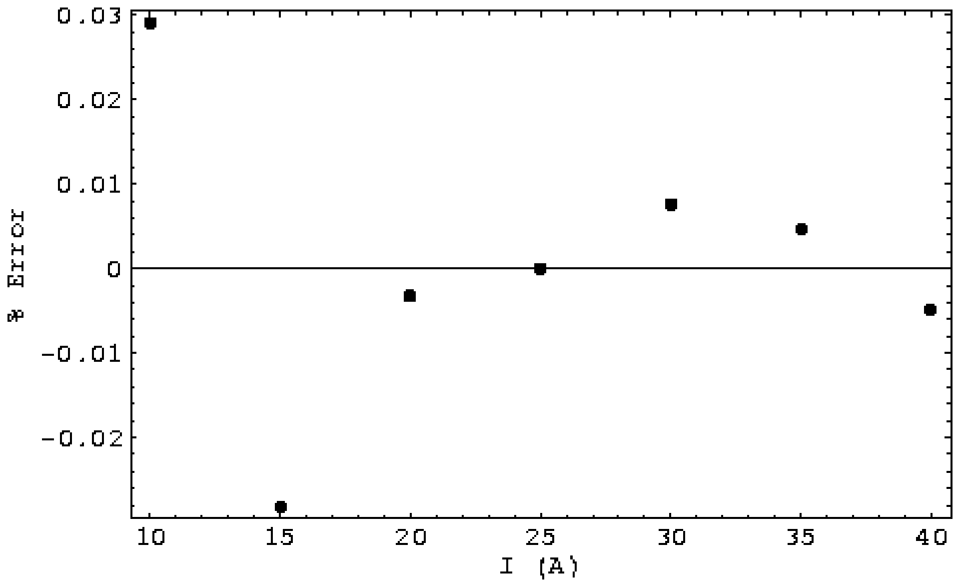

Figure 5: Percentage error in fit for data taken from Q9.

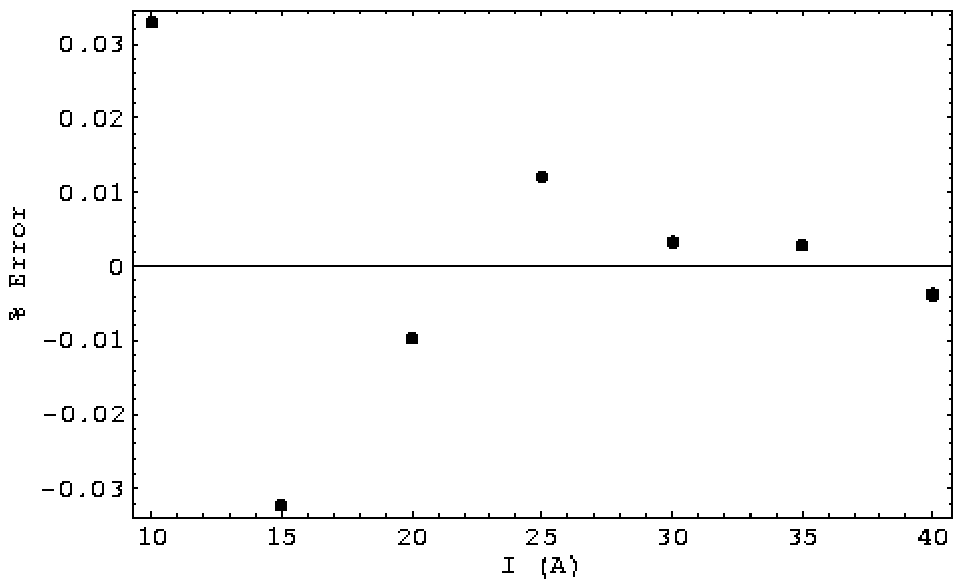

Figure 6: Percentage error in fit for data taken from Q10.