LCLS-TN-06-03

A Degaussing Procedure for the QG01 Quadrupole Magnet of the LCLS Injector Beamline *

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January 18, 2006

Abstract

This note describes a degaussing procedure for the QG01 Quadrupole Magnet of the LCLS Injector Beamline and some relevant observations made during the development and testing of this procedure. An important observation is that care must be taken not to cause a current spike when the power supply to the magnet is switched off.

1 Introduction

The 'QG01' quadrupole magnet in the photoinjector beamline is required only for special studies, and should have a remaining integrated field strength or integrated gradient of 5 Gauss or less during normal operation. Hence a degaussing procedure was developed to achieve this low remnant field using this magnet, a quadrupole painted in green and labeled GTF. The procedure should also not require more than a few minutes of time.

The recommended procedure is a series of ramps with decreasing maximal currents alternating in sign, and is described in Section 2.

An important finding is that turning off the 'KEPCO' power supply used in these studies produces a current spike of 2.5 A; this spike re-magnetizes the magnet to produce a remnant field of about 39 Gauss or more. Therefore it is important to let the power supply stay on after degaussing. This effect may not occur in the MCOR power supplies used in operation, as is explained in Section 3.

*Work supported in part by the DOE Contract DE-AC02-76SF00515. This work was performed in support of the LCLS project at SLAC.

2 Degaussing Procedure

2.1 Development of Degaussing Procedure

The degaussing procedure uses a series of fast ramps with currents of alternate signs and magnitude decreasing by a factor from the preceding ramp. The maximum current for this magnet is 10 A (at 10.154 A, the integrated field is 0.416 T, and the remaining integrated field after a simple ramp to 0 from there is 0.0165 T). So, assuming that this is the highest previous magnetization, we start the degaussing procedure with a ramp to +10A. The complete procedure is then to cycle the magnet many times, with the current reduced by a factor f from the preceding cycle, starting with 10 A (that is, ramp, in sequence, to $+10A, -f*10A$[cycle 1], $+f^2*10A, -f^3*10A$ [cycle 2], $+f^4*10A, -f^5*10A$ [cycle 3], ...) and then to ramp to zero current.

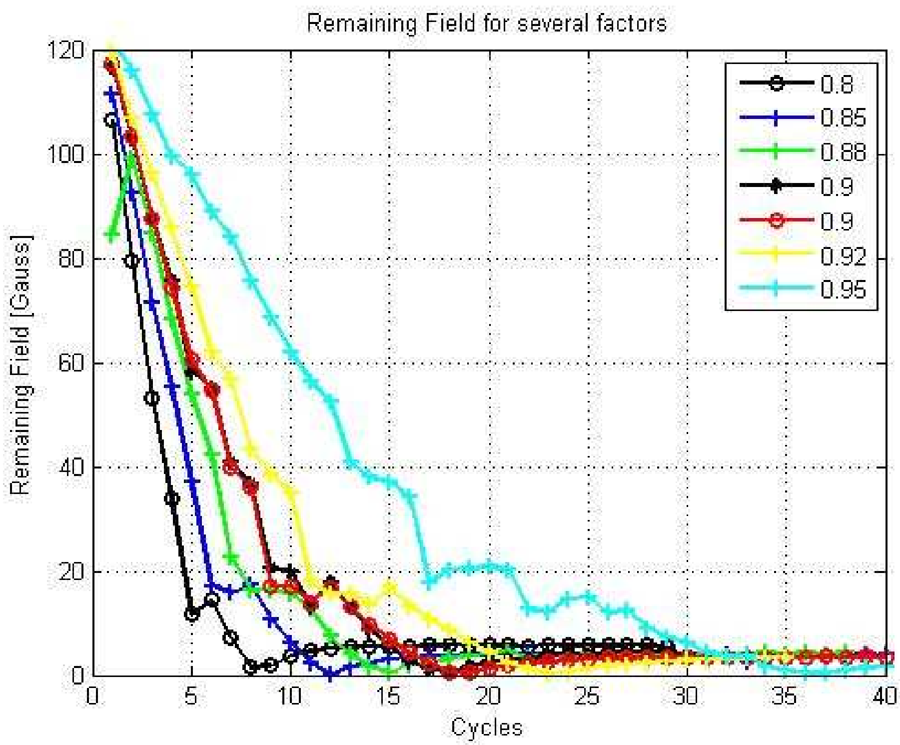

Figure 1: Remaining integrated field after cycles of degaussing.

Figure 1 shows the remaining integrated field after each cycle of ramping, for factors f between 0.8 and 0.95. One sees that after 8-25 cycles the remaining integrated field reaches a minimum, after a sharp drop, and then increases slightly to an asymptotic value below the 5 Gauss requirement. Figure 2 enlarges the portion of Figure 1 below 20 Gauss.

One may be tempted to use the minimum to determine the number of cycles to be used, however I believe that this is not reliable; before the minumum, the remaining field drops by a large amount; so being just one cycle short could leave a rather large remaining field. However, past the minumum, the remaining integrated field rises only slowly, and does not exceed an asysmptotic value (of about 4 Gauss for factors of 0.85 and above).

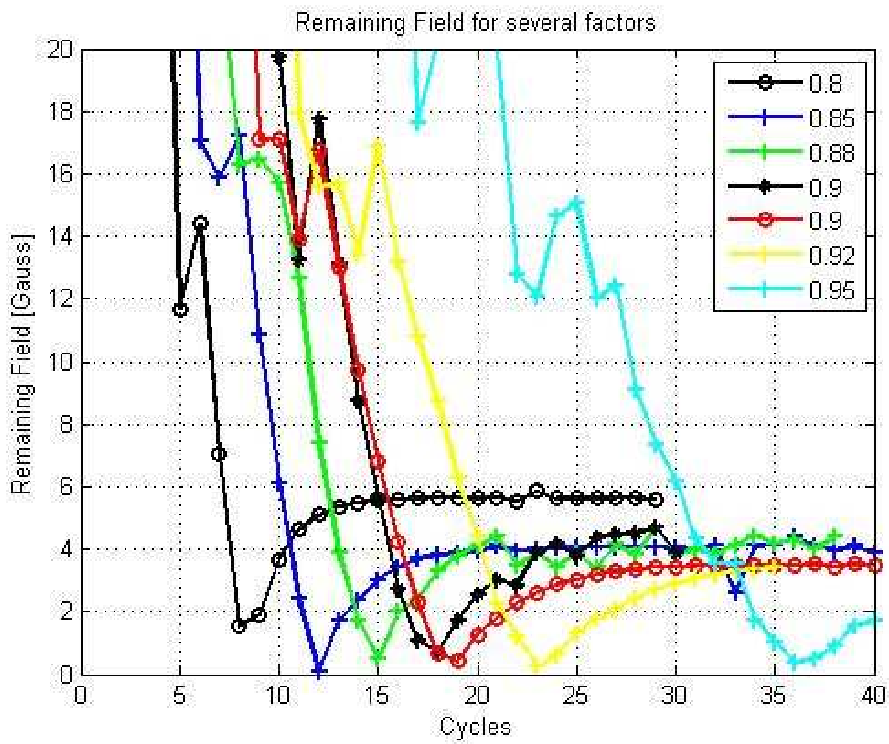

Figure 2: Remaining integrated field after cycles of degaussing.

A fast ramp at 10A/s, with a 2 s wait after each ramp was always used. Slower ramp rates, 1A/s and (1/10 of desired current)/s, had also been considered, but did not change the results.

2.2 Recommended Procedure

From the figures, I conclude that the most desirable degaussing procedure is one using a factor of 0.9, and 25 cycles, that is 50 ramps, to +10A, -9A, +8.1A, -7.29A, +6.561A,

-5.905A..... ...-57 mA, followed by a ramp to 0. We used here a fast ramp at 10A/s, with a 2 s wait after each ramp. The total procedure takes about 3 1/2 minutes.

From Figure 2, one sees that the remaining integrated field is then less than 4 Gauss.

3 Current Spikes

In these measurements, a bipolar KEPCO Power Supply/Amplifier had been used. When measuring the remaining field at the end of a degaussing cycle, the power supply was normally left turned on, at 0 output; the remaining current was typically less than 1 mA as indicated by the transducer.

As concern had been expressed about this remaining current[2], another measurement of the remaining integrated field strength was also taken with the power supply turned off. Surprisingly, the new measurement gave an integrated field of about 37 Gauss This effect could be reproduced. Looking at the transducer output with an oscilloscope, it was found, that turning off the power supply created a current spike of 2.5 A amplitude shown in Figure 3, which apparently re-magnetized the magnet. Indeed a ramp to +2.5A, then -2.5 A then

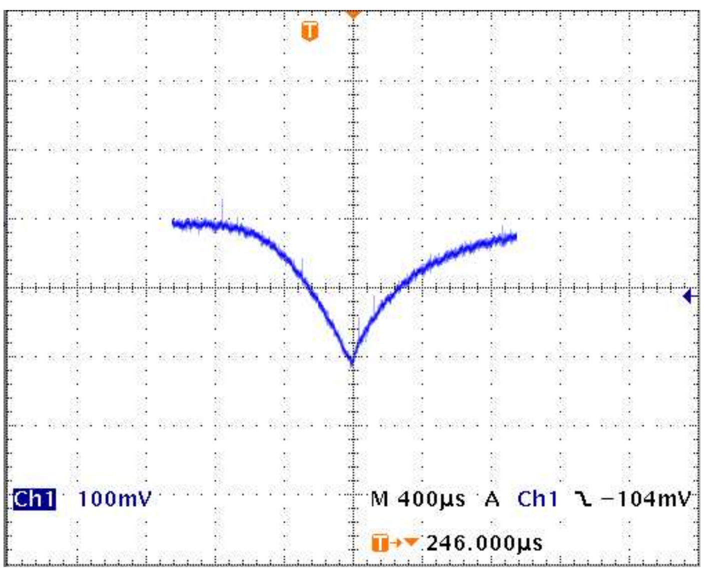

Figure 3: - 2.5A current spike when turning off Kepco power supply (100mV $\sim$ 1.25A).

0, also produces a remaining integrated field of the same magnitude (39 Gauss, if starting from a small remaining field [< 10 Gauss]).

This magnet will be normally powered by a MCOR 12 Corrector Magnet Driver,[3] so there is a concern that turning off this supply might also give rise to a current spike.

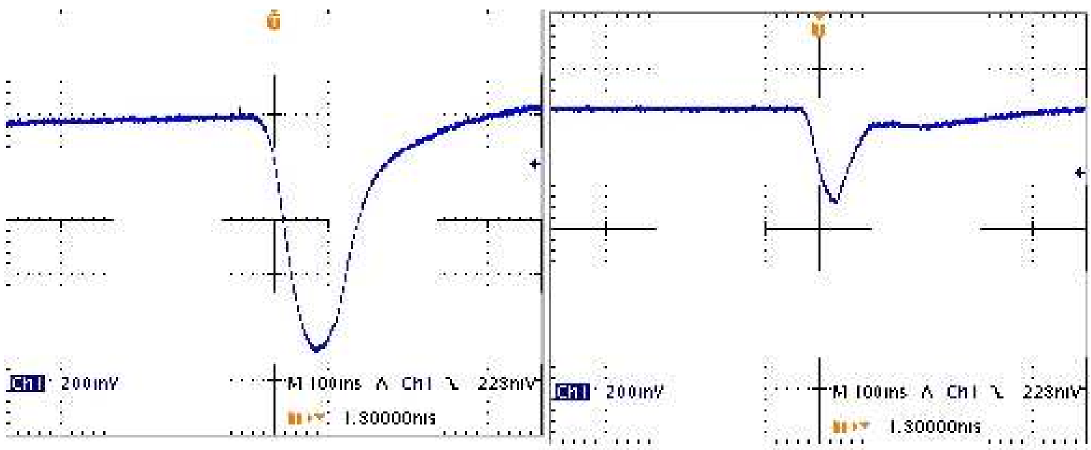

Figure 4: Current Spikes when turning off Power Supply of MCOR Calibration Stand;
left: peak current -11A, right: peak current -3.75A

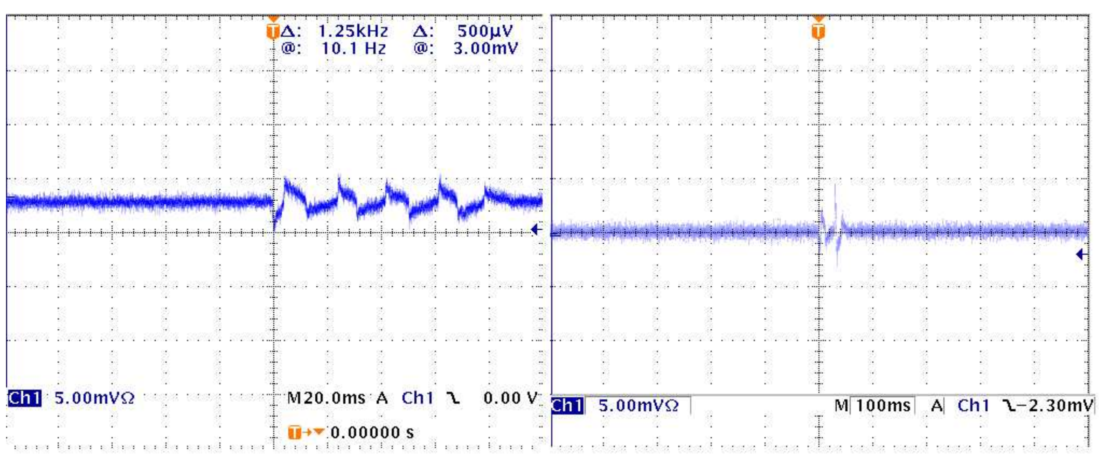

Figure 5: Current Spikes when turning off bulk power supply of MCOR 12;
left: ripple peak-to-peak ≈ 0.5A; right: a spike with peaks at ≈ -0.3, +0.5 A

A first test using a MCOR12 Calibration Test Stand (a box with a single MCOR Card) also showed similar and even bigger spikes, when the underlying bulk power supply was turned off. (11A, 3.75A in Fig. 4)

As used in the accelerator, an underlying bulk power supply provides power to many magnets through several MCOR 12 cards in a VME crate; turning a magnet off means just ramping it to 0 current, and the bulk power supply is never turned off.

We verified this in the Power Conversion Test Lab, using the MCOR Stability Test Stand there, with an ESS 30/165 (30V 165A) Power supply; there a ramp to 0 did not give a visible effect. However, turning off the bulk power supply did produce some ripples or a spike, as shown in Fig.5, where a 5mV vertical division corresponds to a 0.5 A current.

Hence it is most important to remember that the bulk power supply remain on at all times, and that whenever the bulk power supply is turned off, the magnet will be remagnetized, to possibly tens of Gauss.

Acknowledgements

The author wishes to thank Roger Carr and Cecile Limborg-Deprey for valuable discussions, and, of course, Zack Wolf and Scott Anderson for teaching me about magnetic measurements. For the spike investigation, Carl Blankenship kindly set up the MCOR Calibration Test Stand at the Magnetic Measurements Lab and the MCOR Stability Test Stand at the Power Conversion Test Lab.

Notes

1. The raw data for this study may be found at
`http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/LCLS/quad/OTF/`
(in files with extension .ru#, r##, or .### where #,##, or ### refers to a Run Number)

2. The concern about the remaining current was unfounded; measurements at low currents and fields indicate a slope of about 0.3 Gauss per mA. Thus a remaining field of +6 Gauss could be canceled by a small current of -20mA, but knowing this is not helpful for operation, as the exact remaining field is not known without a measurement.

3. Bira Systems, Albuquerque, NM,
`http://www.bira.com/products/mcor12/MCOR12_Technical_Manual.pdf`