MULTIPOLE KICKERS FOR THE ALS *

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Abstract

For quadrupole, sextupole or octupole magnets, the field at the center is zero and will not disturb the stored beam, while the field away from the center increases in magnitude, giving a larger kick to the particles off axis. By pulsing such multipole magnets it is possible to improve the injection efficiency of the Advanced Light Source (ALS) in top off mode. The requirements for a multipole kicker injection scheme for ALS are to kick a 1.9 GeV beam by an angle of 10 mrad with a magnet of 1 meter length. In the proposed scheme, the stored beam will be centered in the aperture while the injected beam is off center by 10 mm [1], [2]. Both quadrupole, sextupole and octupole magnets have been studied, as well as a dipole magnet with non-constant field magnitude across the center of the aperture. This paper describes the design and gives a comparison of each type of magnet as well as the modulators needed to drive them.

KICKER REQUIREMENTS

The requirements for using any multipole kicker for injection into the ALS are given in Table 1. The beam aperture size was selected to make use of the existing ALS injection kicker's beam chamber. Using a smaller aperture greatly reduces the demands from the power supply however, and this option is being studied.

Table 1.Requirements of a multipole kicker for ALS.

Beam Energy	1.9 Gev
Bend Angle	10 mrad
Magnetic Length	1 m
Position of Injected Beam	10 mm
Aperture HxW	15x50 mm
Vertical B-Field	633 G
Rise/Fall Time	100 ns
PRF	10 Hz

DIPOLE & QUADRUPOLE MAGNETS

Dipole magnets offer the advantage of simplicity, lower cost and because of the high magnetic gain are easier to drive than higher pole magnets. The major disadvantage in using them in this application is that it is difficult to design a magnet with zero field on axis. For this reason, using a dipole magnet would require a second magnet located 180° downstream, so they were not studied in great detail. A dipole magnet with non-uniform magnetic field across the aperture and its flux are shown in Fig. 1. This magnet has a gain of 0.15 G/A at 10 mm off axis, and would require a 48 kV, 1170 A drive. Figure 1 shows a coated beam chamber used for an image current return path. The chamber's effects on the magnetic field are negligible and the chamber was not considered in the following calculations.

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For all of the magnets with higher numbers of poles, there is a choice of driving the coils in series which minimizes the current required from the modulator, or in parallel which minimizes the inductance and thus the voltage. In the following discussions, it will be assumed that the coils are driven in parallel. It is also assumed that the cores are constructed from laminated steel. All plots of the B field shown below are in Tesla per Ampere per bus.

Quadrupole magnets were also considered because they also offer high gains, but were rejected because of focusing and the effects on beam dynamics. Two types of quadrupole magnets are shown in Fig. 3 with a rectangular core (Quad1) and Fig. 4 with a more conventional round core (Quad2) and pole tips. A plot of the y component of the B field in Quad2 is shown in Fig. 5. Quad2 would need a modulator producing 13.6 kV and 1660 A to drive it.

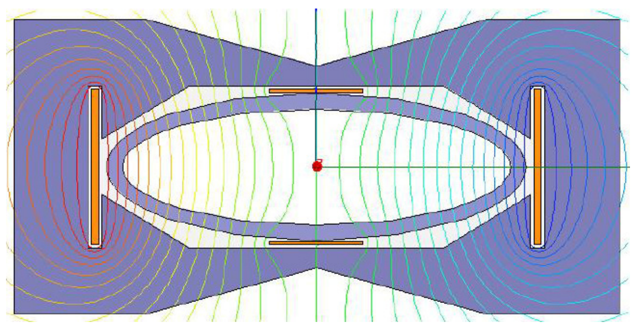

Figure 1: Dipole magnet flux line.

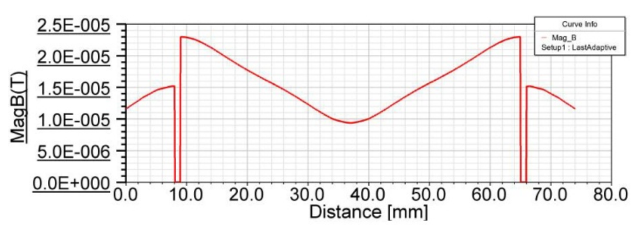

Figure 2: Magnitude B across center of aperture.

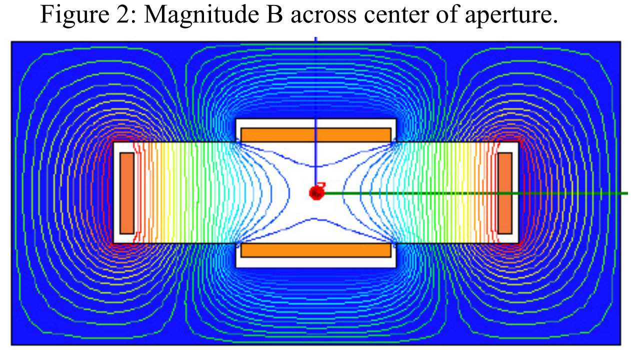

Figure 3: Quadrupole flux with a rectangular core.

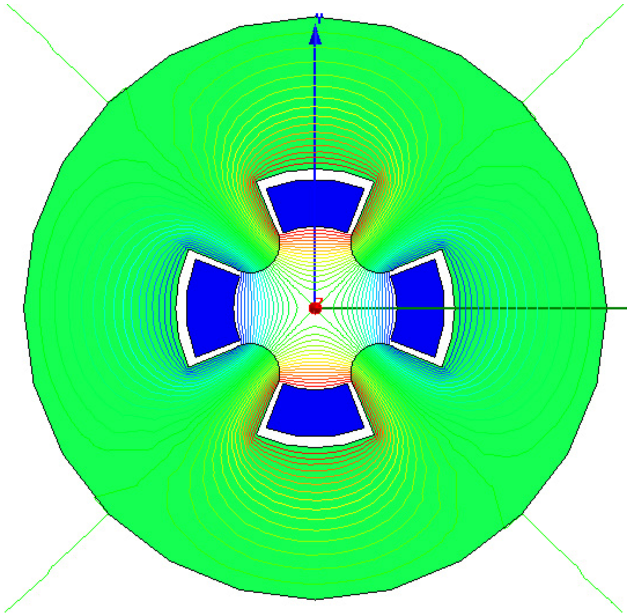

Figure 4: Quadrupole flux with circular core and pole tips.

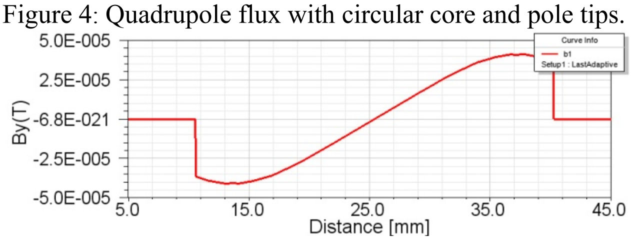

Figure 5: Y component of B for magnet in Fig. 4.

SEXTUPOLE MAGNETS

Sextupole magnets appear to be the most promising, and several designs have been considered. The major disadvantage of them is the low magnetic gain at 10 mm off axis. Figure 6 shows the flux of one sextupole magnet (Sext1) while the y component of the B field is shown in Fig. 7. Note that this magnet has a gain of only 0.035 G/A at 10 mm. Reducing the aperture by 20 % yields about a factor of two improvement in the gain for this

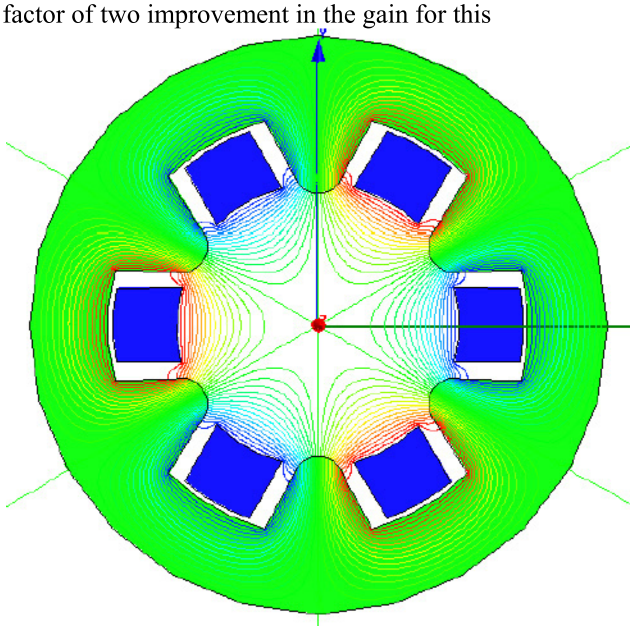

Figure 6: Flux line in a sextupole magnet.

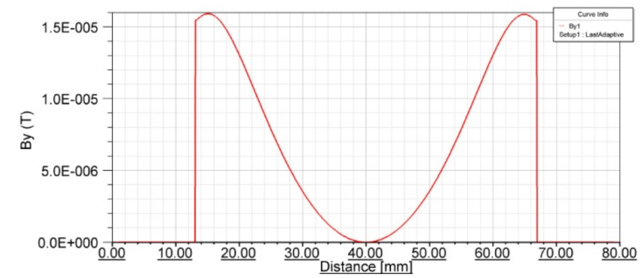

Figure 7: Y component of B for the magnet in Fig. 6.

magnet, but would require a new coated beam chamber.

One option to improve the gain is to build a nonconventional sextupole like the one shown in Fig. 8 (Sext2). Here the busses have symmetry in that they are centered at multipoles of 60 degree, but the size of the conductors differ and the pole tip positions are symmetrical in pairs with 120 degree spacing. The B field for this magnet is shown in Fig. 9. Again, reducing the size of the aperture would improve the gain significantly. Sext 2 needs 95 kV at 12.7 kA from the modulator when driving the coils in parallel.

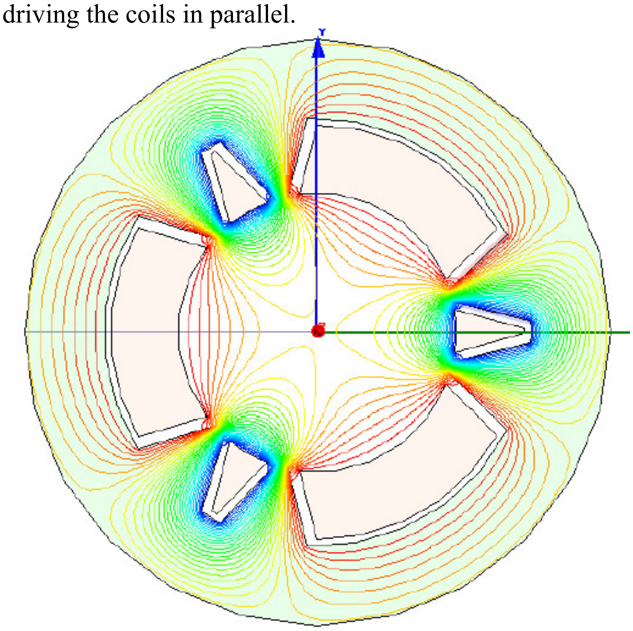

Figure 8: A nonconventional sextupole magnet.

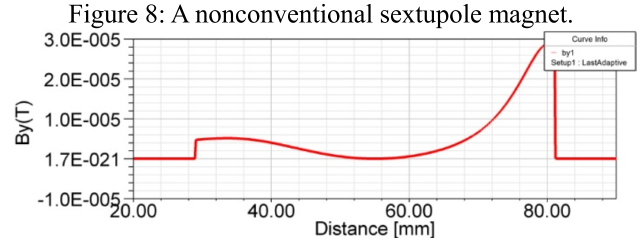

Figure 9: Y component of B for the magnet is Fig. 8.

In an effort to further increase the gain of the magnet at 10 mm off axis, a magnet with tri-symmetry shown in Fig. 10 was simulated (Sext3). The y component of the B field across the center of the aperture is shown in Fig. 11. Here the field rises steeply away from the axis, however the amplitude is low and the gain at 10 mm is only 8.7 mG/A.

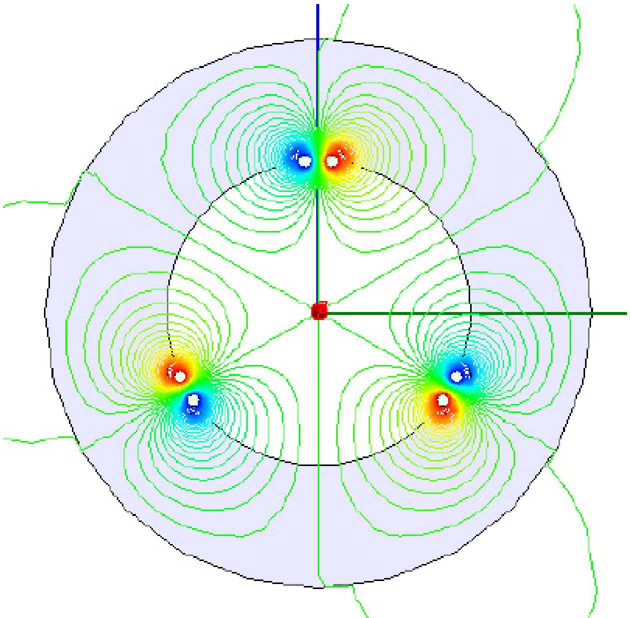

Figure 10: Magnet with tri-symmetry and flux.

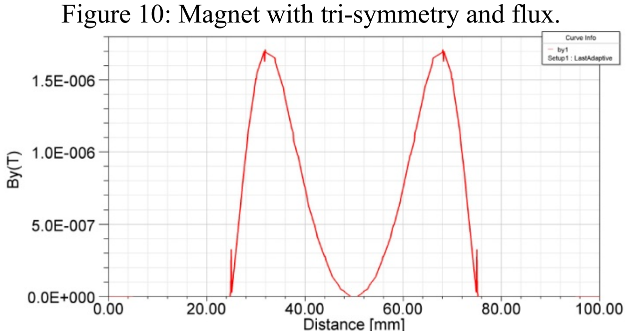

Figure 11: Y component of B for the magnet is Fig. 10.

OCTUPOLE MAGNETS

The last type of magnets considered were octupole that have the benefit of a relatively flat zero field area around the center of the aperture, with the field rising quickly further out. An octupole magnet with its flux is shown in Fig. 12, while the y component of the B field is shown in Fig. 13. This octupole magnet need 41.3 kV and 10.6 kA if the coils are driven in parallel.

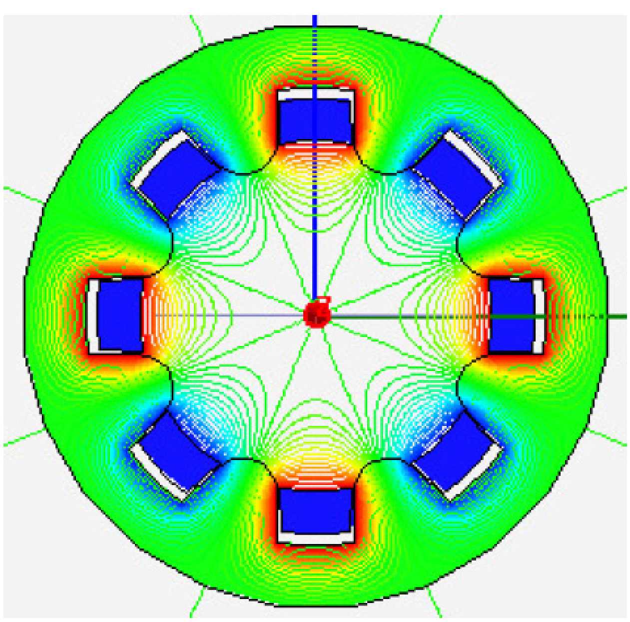

Figure 12: Octupole magnet and flux.

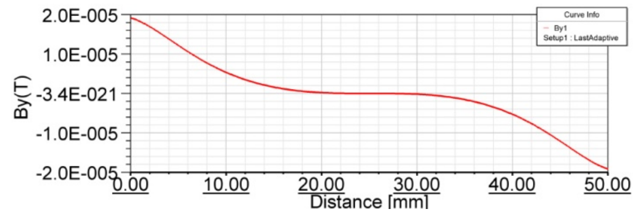

Figure 13: Y component of B for the magnet is Fig. 12.

CONCLUSIONS

Table 2 shows the power supply requirements to drive each of the magnets. Gain is given in Gauss per Ampere at a position of 10 mm off axis along the x axis, inductance in nH/m, current in kiloamperes, and voltage in kilovolts. The effects of each of the magnets on the beam is still being considered, after which a geometry will be selected for prototyping. The most promising magnet geometry at the present, from the point of view of the pulsed system, is Quad2, however this magnet presents problems from a beam dynamics point of view. Possible ways to improve the magnet designs in order to accommodate the modulator design would be to use a smaller aperture, and if the rise and fall time requirements can be relaxed, to drive the coils in series rather than in parallel. This should be possible as the 100 ns rise time requirement was somewhat arbitrary.

Table 2. Comparison of Magnet Types.

Magnet	Gain	Induct.	Current	Voltage
Dipole	.54	4112	1.17	48.1
Quad1	.24	792	2.6	20.9
Quad2	.38	813	1.66	13.6
Sext1	.035	393	18.1	71.1
Sext2	.05	748	12.7	95
Sect3	.0087	218	72.8	159
Octupole	.06	391	10.6	41.3

REFERENCES

[1] D. Robin. "Simulation of a Pulsed Multipole Injection Method for the Advanced Light Source," IPAC'10, Kyoto, May 2010.

[2] H. Kentaro, etal. Phys. Rev. Acc. and Beams 10, 123501 (2007). .