MULTIPOLE DESIGN FOR CAMD STORAGE RING

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Abstract

The CAMD storage ring has been in operation more than 12 years with only sextupole elements in the lattice for correction of nonlinear beam dynamics. To compensate for coupling arising from the integrated effect of skewed elements around the ring, and to improve beam lifetime, a multipole element is required which can be operated in active mode. The design of a magnetic multipole is presented as well as power and control systems designs. The strength and effect and of this element are calculated.

INTRODUCTION

The CAMD storage ring has a Chasman-Green lattice with two families of sextupoles [1]. Recent beam dynamics and size measurements show coupling effects in the beam that could be fixed by installing skew quadrupoles in the lattice. To compensate the nonlinearities and improve beam lifetime it was decided to install a multipole magnet that could include skew quadrupole, sextupole and higher order harmonics. This magnet could replace one or more sextupoles without impacting on the space in the storage ring lattice. The experience of using this kind of magnet at the storage ring in Daresbury Lab was taken in account [2].

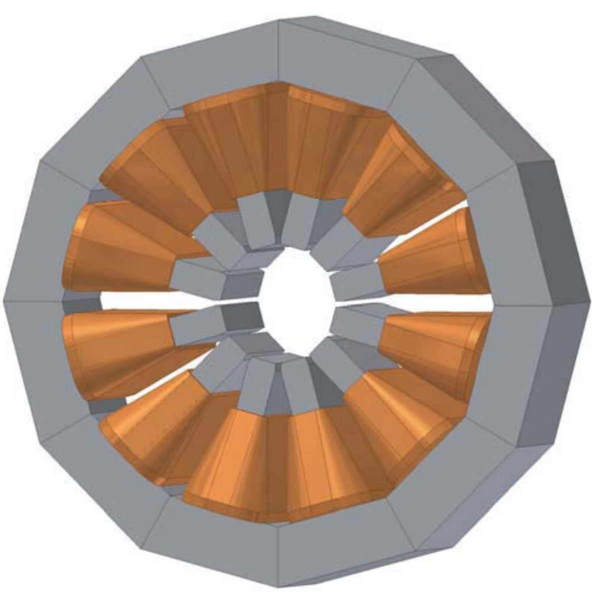

Figure 1. Multipole magnet

Coil #	Dipole	Skew quadrupole	Focus Sextupole	Defocus Sextupole	Octupole	Decapole	Dodecapole
1	1	1	1	-1	0	1	1
2	0.5	0	-1	1	1	-0.732	-1
3	0	-1	-1	1	1	0.268	1
4	0	-1	1	-1	0	-0.268	-1
5	-0.5	0	1	-1	-1	0.732	1
6	-1	1	-1	1	-1	-1	-1
7	-1	1	-1	1	0	1	1
8	-0.5	0	1	-1	1	-0.732	-1
9	0	-1	1	-1	1	0.268	1
10	0	-1	-1	1	0	-0.268	-1
11	0.5	0	-1	1	-1	0.732	1
12	1	1	1	-1	-1	-1	-1

Table 1: Normalized configuration of currents in coils to induce different field harmonics

MULTIPOLE MAGNET DESIGN

The best choice to fit skew quadrupole together with sextupole is a 12 pole magnet. Two poles of the multipole magnet will substitute one pole of the sextupole. A general view of the magnet is shown in Figure 1.

The pole width of the existing sextupole is 35 mm and the coil is rated for 1160 Ampere-turns. In the new multipole the polewidth is 20 mm and the coil is rated for 2000 Ampere-turns to give greater flexibility for different combinations of skew quadrupole together with high order field components. The configuration of currents in the coils for different magnetic components is presented in the Table 1. The multipole pole gap is 78 mm, and length is 100 mm.

Limited space has forced a compact design of the multipole magnets. Design parameters included step wound coils for fitting in triangular spaces, and pole pieces made to assemble and bolt together after coil placement. Accommodating these requirements, the core will be composed of iron having the lowest available carbon content (0.03%C) in 1 mm sheets. Laminations will be laser cut and assembled to form twelve pole

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pieces, 100 mm thick. The poles will be bolted together after the coils are wound onto the poles.

Each coil will be composed of 400 turns of AWG15 copper magnet wire over 15 layers having a nominal resistance of 1.3 Ω.

POWER SUPLIES FOR MULTIPOLE

Each magnet requires individual control of the twelve coil currents, thereby calling for twelve individual current regulating power supplies for each magnet. Future plans of replacing all sextupole magnets with multipole magnets will mandate a bank of 192 power supplies. Thus a high density, modular design is proposed and described herein.

High precision regulation makes analog electronics circuits sensitive to effects such as noise, OP Amp input & output offsets, and temperature drift. The regulation circuit will be built around a high precision OP Amp (National LMP2011) that utilizes patented techniques to measure and continually correct the input offset error voltage. Input offset voltages are significant compared to the millivolt current feedback signal.

It is configured as a summing amplifier taking an inverted 0-10V reference which is divided down and summied with the millivolt current feedback signal from a water cooled resistive current measuring shunt, as shown in figure 2.

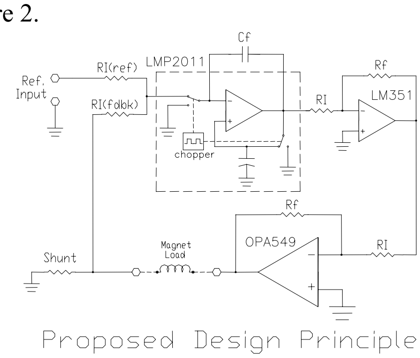

Figure 2: Proposed power supply design

The 5A nominal output of the power supply is supplied by a bi-polar high power OP Amp (TI OPA549) in the inverting configuration. It has on-board programmable current limiting and an over current alarm output. Its pins solder to the PCB while its body is heat-sinked to a common water cooled cold plate.

The output current is measured, for regulation feedback, by a low value resistive shunt mounted on the PCB. To minimize thermal effects, an isolated shunt (Isotek BVR) is heat sinked to the cold plate.

Each power supply will be built as a slide-in card into a card rack. Control lines pass through connectors on the back plane, while power cables bolt directly to terminal blocks in the rear compartment. The power OP Amp and shunt reside on the rear of the card and are bolted to the water cooled cold plate in the back plane.

Each card supplies ±5A DC (nominal) seeing up to 7.5V across its load coil. The cards are grouped 48 per quadrant. Each of the four banks of cards is supplied from ±10VDC dual output power supply rated at 150A per channel.

Control of the multipole magnets will be accomplished by means of a customized operator interface allowing individual control of each of the 16 magnets. Each field component can be weighted individually on each magnet. Alarms can be set up to warn of power supply saturation.

MULTIPOLE CONTROL

Ramping of the CAMD storage ring is accomplished using a VME system running EPICS on RTEMS. Ramp tables are generated by the control/operator PCs, and are downloaded to VME for execution. All software, including ramping and power supply control/diagnostics have been written generically, only taking lists of magnets and setpoint tables as inputs. Dipoles and quadrupoles are ramped at 250Hz, whereas the correctors and RF system are ramped at 25Hz. It is anticipated that the multipole magnets will not need to be ramped faster than about 10Hz, and that slight variations in ramp timing will be acceptable. This leaves open the option for non-VME based ramping of these magnets.

The remainder of the CAMD control system is Linux based, running a combination of legacy code and Linux IOCs. I/O is performed using CAMAC and PLCs. The PLC platform is ethernet based and, using the same I/O modules, can be configured either with traditional processors for hard real-time devices such as the Linac, or remote I/O processors to provide inexpensive ethernet based I/O.

The design for the multipole control calls for the use of inexpensive ethernet based PLC I/O. A Linux IOC will be responsible for ramping, power supply control, and timing coordination with the main VME ramp. The existing ramping, control, and diagnostic software will be extended to handle the additional power supplies.

FIELD CALCULATIONS

Preliminary calculations of the magnetic fields produced by the multipole magnet were done by modeling in ANSYS code. The coils were energized by the same current value (560 Ampere-turns) in different configurations (Table 1). This value of current corresponds to the strength of sextupole magnet used in operation at the CAMD storage ring. The result of modeling the magnetic fields can be seen in figures 3-7. In figures 3-7 the blue curve is the result of modeling and the red curve represents the theoretical shape obtained from the equation:-

$$By + i\cdot Bx := \sum_{n=1}^{6} \left(b_n + i\cdot a_n\right)\cdot\left(\frac{x + i\cdot y}{r_0}\right)^{n-1}$$

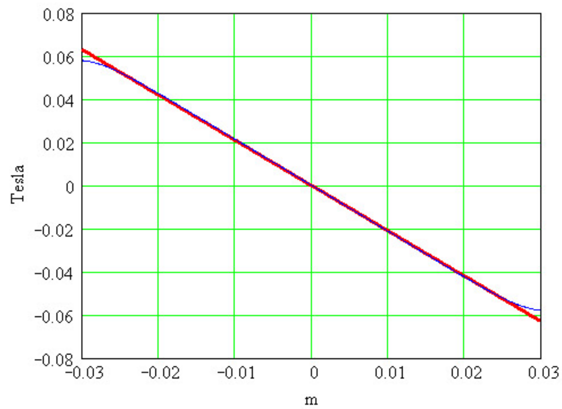

Figure 3: Quadrupole configuration $\frac{\partial B}{\partial x} = -2.1 \cdot \frac{Tesla}{m}$

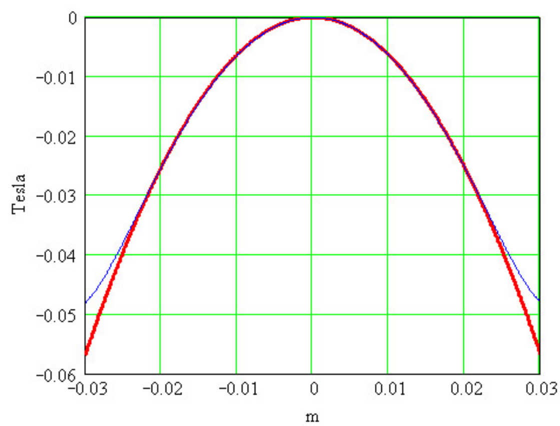

Figure 4: Sextupole configuration $\frac{\partial^2 B}{\partial x^2} = 126 \cdot \frac{Tesla}{m^2}$

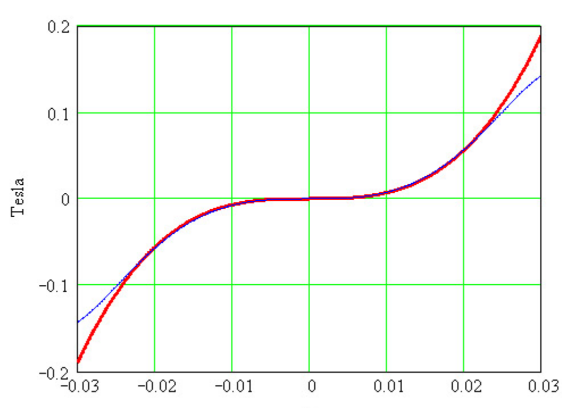

Figure 5: Octupole configuration $\frac{\partial^3 B}{\partial x^3} = 42000 \cdot \frac{Tesla}{m^3}$

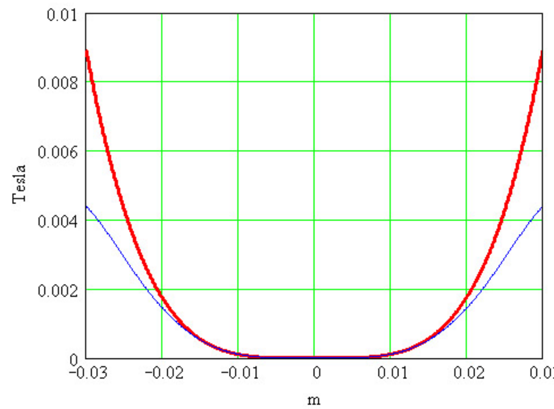

Figure 6: Decapole configuration $\frac{\partial^4 B}{\partial x^4} = 2.64 \cdot 10^5 \cdot \frac{Tesla}{m^4}$

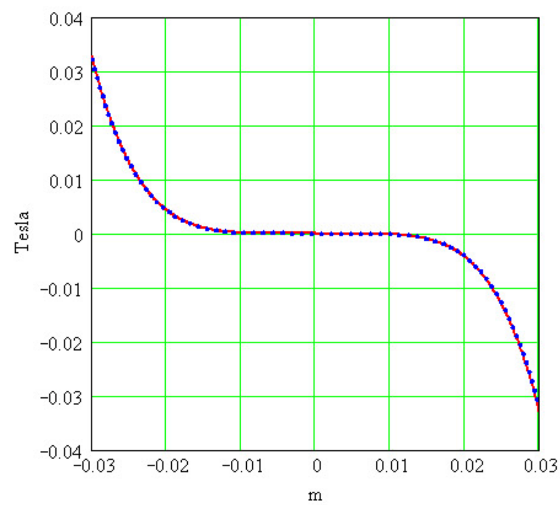

Figure 7: Dodecapole configuration $\frac{\partial^5 B}{\partial x^5} = 1.62 \cdot 10^8 \cdot \frac{Tesla}{m^5}$

CONCLUSION

The first new multipole magnet for CAMD is planned to be installed for test studies in the fall of this year. Only one sextupole will be replaced with a new magnet. On the basis of the test studies and any requirement to increase strength, another three sexutpoles will be replaced. If necessary all will be replaced.

REFERENCES

[1] V P Suller et al., Proceedings of EPAC'04, Lucerne, 2004, pp.2424-2426

[2] N Marks, Proceedings 6th International Conference on Magnet Technology, Bratislava 1977. pp528-534 (MT-6)

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