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MAGNET DESIGN CONSIDERATIONS FOR AN ULTRALOW EMITTANCE CANADIAN LIGHT SOURCE

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Abstract

The strong focusing requirements for ultralow emittance light sources result in high field magnets that are very close together. High fields are readily achieved by using small magnet gaps. This is possible due to the small beam sizes involved. Reduction in the physical aperture and the reduction in the good field region requirements results in magnets with compact transverse dimensions. The very strong focusing of the magnets results in very small drift spaces between the various magnetic elements. To keep these drift spaces clear magnets with recessed coils have been studied. In such magnets the coils do not stick out beyond the end of the magnet yoke in the longitudinal direction. By placing the coils on the outer yoke loss of efficiency can be avoided while maintaining good control of the higher order field harmonics. This is very well suited for quadrupole magnets where only two coils are required. Possible designs for gradient dipoles and sextupoles are also considered.

INTRODUCTION

The next generation of storage ring light sources are moving towards Multi-bend achromat (MBA) lattices [1,2,3]. MBA lattices will provide users with high brilliance photon beams, from an ultralow emittance electron beam, with relatively high transverse coherence. Several facilities have been built or are being upgraded to this end [4,5,6]. The CLS is now designing an upgrade to a MBA. A unit cell design is shown in Fig. 1 and discussed in more detail in these proceedings [7].

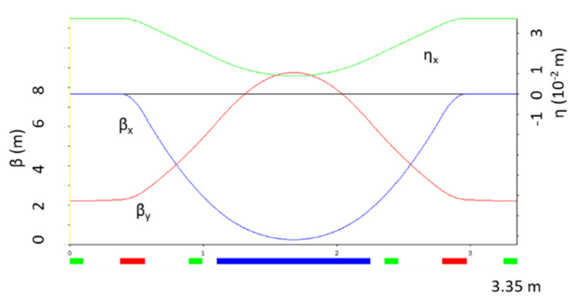

Figure 1: One cell of a multi-bend design for the CLS.

The design requires quadrupoles. This is in part achieved through a reduction in the magnet bore size. As well, the magnets are spaced very close together. In our present design consideration, the drift space between magnets can be as small as 11 cm. This drift space must be used to accommodate the longitudinal extent of the magnet windings as is the case for a conventional magnet. An example of such a magnet is in Fig. 2.

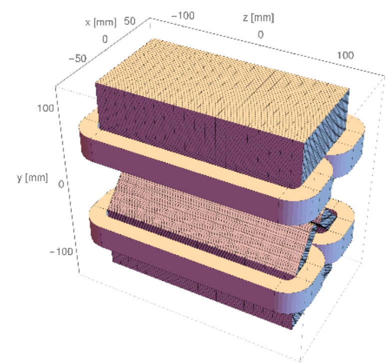

Figure 2: Conventional quadrupole. It shows the magnet coils mounted on the pole and protruding into the drift space.

Some MBA magnet designs consider coils that are recessed on the poles such as the quadrupole design in [8]. Details of our quadrupole investigation are given below. The details include quadrupoles with conventional coils mounted either on the poles or on the outer yoke and the same quadrupoles with the coils recessed.

QUADROPLE DESIGN

As a reference point we begin by showing the design of a conventional quadrupole using the 2D magnet program POISSON [9]. The following analysis does not attempt an optimization of the higher order multipoles. A plot of the 2D field distribution is shown in Fig. 3 with reflection symmetry applied to the vertical and horizontal planes. The steel used is the default 1010 steel built into POISSON. The magnet windings have a cross-section of 30 mm by 20 mm and a current of 4020 Ampere-turns flowing through them. The pole-tip radius is 12 mm. The resulting quadrupole term is 54.58 T/m.

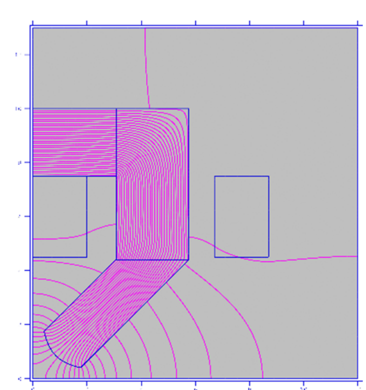

Figure 3: 2D POISSON field distribution of a conventional quadrupole (units [mm]).

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Figure 4 shows a quadrupole that uses the same yoke as used in Fig. 3. In this compact quadrupole model, we move the coils to the top of the magnet. The quadrupole gradient was found to be ~ 54 T/m as well. This indicates that there is virtually no loss of field with the new coil placement.

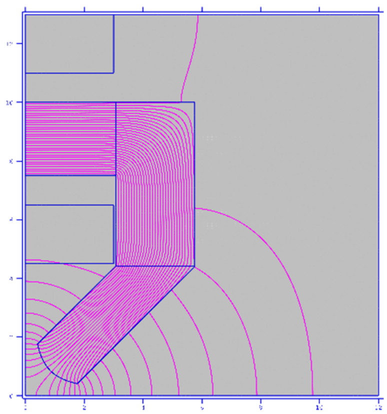

Figure 4: 2D quadrupole with top mounted coils (units [mm]).

Qualitatively the magnetic field distribution of the quadrupoles with side or top mounted coils is similar. The 2D multipole distribution, calculated from the POISSON simulation, shows negligible difference.

We now take the discussed 2D magnet cross-section and extend it to three dimensions using the 3D magnet code, RADIA [10, 11]. This is the conventional quadrupole shown in Fig. 2. There are four coils in total, each belonging to a pole of the quadrupole. The magnet is 240 mm long and uses the built-in steel definition *RadMatSteel37*. The cross-section of the coil is the same as the POISSON simulation and an excitation of 4020 Ampere-turns was used.

If a hard-edge model with 240 mm length is assumed for the POISSON simulation then the integrated field strength, at 10 mm is 0.1310 T-m. The conventional quadrupole achieved a quadrupole field of 51.02 T/m. Figure 5 shows the longitudinal distribution of the magnetic field and its deviation from a hard-edge model. Integration of the field along the longitudinal coordinate at 10 mm resulted in an integrated field of 0.1301 T-m which is in good agreement with the 2D POISSON model.

We next consider the case of recessed coils in Fig 6. We have evaluated this by maintaining the same geometry and excitation but cut into upstream and downstream sides of the pole by the extent of the coil thickness.

In this configuration the gradient is 44.80 T/m. The integrated field strength was reduced to 0.1080 T-m. This is a significant loss to increase the unobstructed drift space.

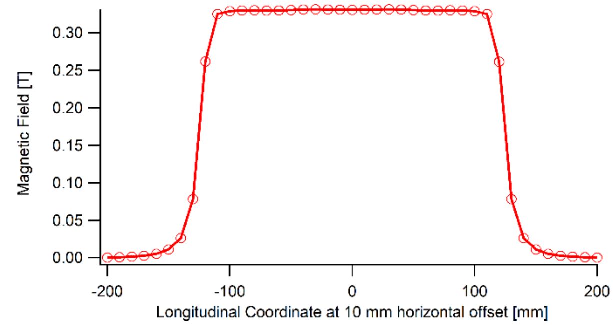

Figure 5: Magnetic field distribution along the longitudinal coordinate, at a transverse offset of 10 mm, of the compact quadrupole with pole-mounted non-recessed coils.

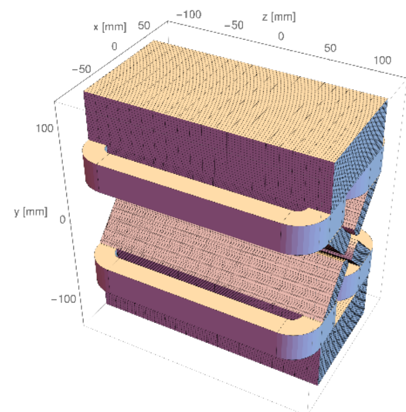

Figure 6: Compact quadrupole with pole mounted coils that are recessed.

The next step in our analysis is to shift the position of the coils to the top and bottom of the yoke as shown in Fig. 7. Each of the four coils from the previous simulation are now rotated by 90 degrees through their long axis and shifted to the top of the magnet. All parameters of the magnet were kept the same except the positioning on the coils. The quadrupole field achieved was 48.53 T/m. Integration of the longitudinal field profile, at an offset of 10 mm is 0.1224 T-m.

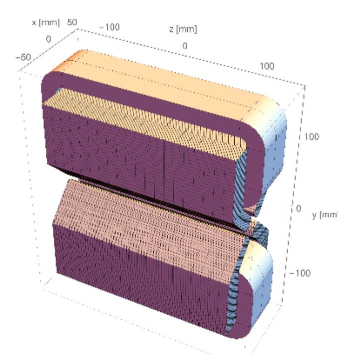

Figure 7: Compact quadrupole top mount coils with protruding end coils.

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Finally, we considered the case where the coils are mounted on the yoke of the magnet but recessed into the steel by an extent defined by their thickness. The resulting quadrupole field was 42.48 T-m and the integrated field was 0.1058 T-m. This was a significant loss of gradient and integrated strength. This can be recovered by increasing the thickness of the top and bottom of the magnet by 25 mm. The model with increase yoke thickness is shown in Fig. 8. The resulting quadrupole strength was 50.96 T/m and the integrated strength (offset at 10 mm) achieved was 0.1278 T-m. This is less than 3% loss of efficiency compared to the conventional quadrupole.

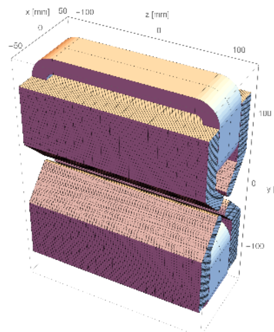

Figure 8: Quadrupole with top mounted and recessed coils.

OTHER MAGNETS

Last, we briefly show that dipole and sextupole designs are in progress for the future CLS upgrade. Such magnets with recessed coils are shown in Fig. 9.

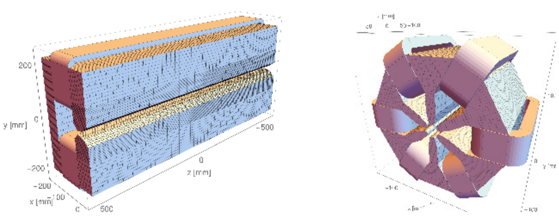

Figure 9: Dipole and quadrupole designs under progress.

CONCLUSION

The quadrupole magnet with recessed coils can achieve high gradients with virtually the same field quality (harmonics) as a conventional magnet. There is very little loss of integrated field strength if the coils are mounted on an outer yoke that has been widened to improve the flux through the shortened yoke. The advantage of this design is that there are only 2 coils required and most importantly the magnet coils do not stick out beyond the magnet yoke. Such magnets are ideal for lattices with very small drifts between magnets.

ACKNOWLEDGMENT

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