MAGNETS FOR THE 3 GEV BOOSTER SYNCHROTRON FOR THE DIAMOND LIGHT SOURCE

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Abstract

The Diamond Booster is a full energy injector for the Diamond Storage Ring, designed to accelerate an electron beam from 100 MeV to 3 GeV with a 5 Hz repetition rate. This paper describes the main features of the magnetic designs and the magnetic measurements results for the booster magnets which have now been delivered and installed at Diamond.

INTRODUCTION

The Diamond booster magnet lattice is a missing dipole FODO lattice consisting of 22 unit cells, containing 36 dipole magnets, 44 quadrupole magnets, 28 sextupole magnets and 44 corrector magnets distributed over a circumference of 158.4 m. The magnetic field in the dipoles will be ramped from B = 0.026 T at injection to B=0.809 T at the top of the ramp. The quadrupoles will have a maximum operating gradient of 15 T/m. The initial design of pole tip profiles of the magnets was carried at Diamond. The magnets were manufactured at Danfysik as a part of preassembled girder units (44 in total) complete with vacuum vessels. High quality magnets were required to meet the accelerator physics requirements of alignment and positioning accuracies and field tolerances over the required good field apertures. Material selection, the ramp rates and field ranges have been selected to obtain almost linear response during ramping of the magnets.

DIPOLE MAGNETS

Table 1 lists the principle requirements for the dipole magnets.

Table1: Dipole Magnet Specifications

Magnetic Length	2.16 m
Gap Height	21 mm
Peak Dipole Field	0.809 T
Injection Dipole Field	0.027 T
Horizontal GFR	± 23 mm
Vertical Good Field Region	± 8 mm

The magnets were manufactured to meet the specifications of Table 1 along with other specifications related with machining and assembly tolerances. Figure 1 shows the dipole magnets. The field measurement setup is shown in Figure 2. A full length coil was used to measure the bending strength of the magnet at different radial positions. Figure 3 shows the distribution of integrated field strength in the radial direction.

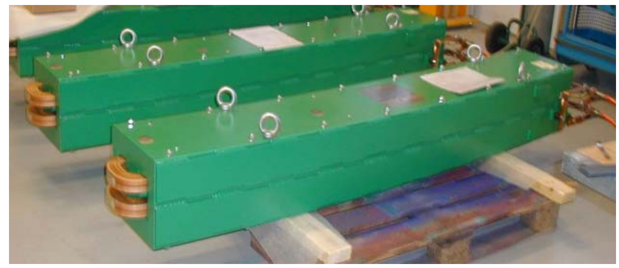

Figure 1: Dipole magnets

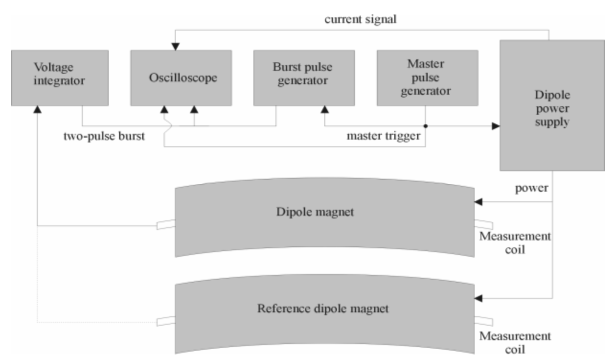

Figure 2: Integrated field measurement setup

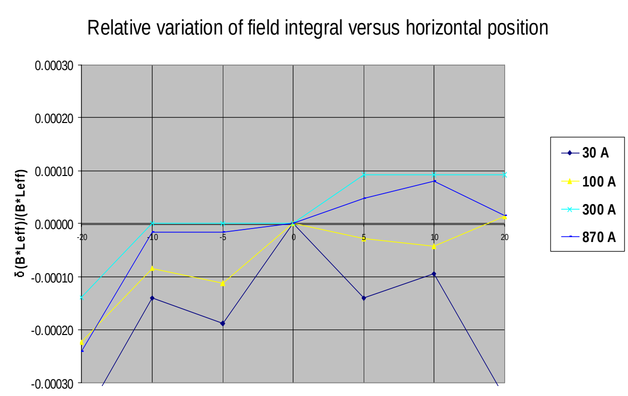

Figure 3: Integrated field distribution

The variation of the integrated field within the good field region at all the excitation levels is excellent, within a few parts in 10^4. Magnet to magnet variation of field strength is within 1 part in 10^3. This is the result of careful selection and mixing of yoke material and maintenance of specified machining and assembly tolerances. Figure 4 shows the excitation curve for the dipole magnets which is almost linear. This is very useful for smooth acceleration of electron beam in the booster synchrotron. Magnets were sorted for their bending strengths for their placement in the ring to minimise the closed orbit distortion. This also helped in minimizing the commissioning time.

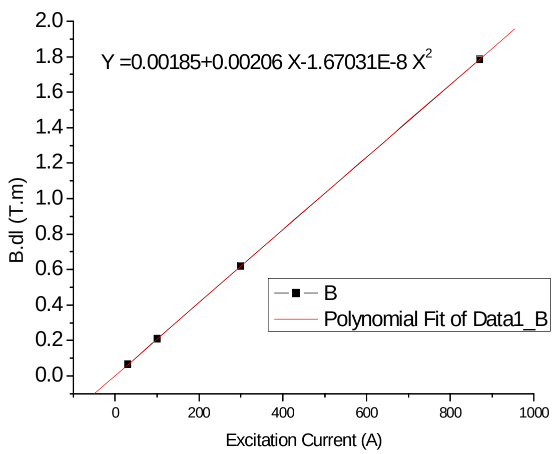

Figure 4: Dipole Magnet Excitation Curve

QUADRUPOLE MAGNETS

Table 2 lists the principle requirements for the quadrupole magnets.

Table 2: Quadrupole Magnet Specifications

Magnetic Length	340 mm
Bore Radius	21 mm
Number of Turns per Pole	15
Peak Field Gradient	15 T/m
Current at Peak Gradient	180 A
Transverse Good Field Region	± 25 mm

The magnets were manufactured to meet the specifications of Table 2 along with other specifications related with machining and assembly tolerances. Figure 5 shows one of the quadrupole magnets. The harmonic bench setup used for the magnetic measurements is shown in Figure 6. The measured harmonic content of these magnets is shown in Table 3. The excellent field quality is due to careful selection and mixing of magnetic material and maintenance of machining and assembly tolerances. Magnet to magnet variation of focussing strength is within 1 part in 10^3. The excitation curve for the quadrupole magnets is shown in Figure 7 showing very good linearity.

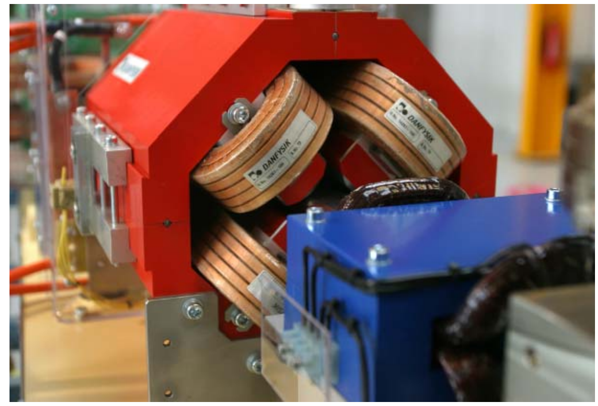

Figure 5: Quadrupole magnet

Figure 6: Harmonic bench setup

Table 3: Relative Integrated Harmonic Field Content of the Quadrupole Magnets at r=20mm; A_n=skew, B_n=normal components; n=3 sextupole, n=4 octupole etc.; all other components < 0.01 %.

n	dB/B (A_n)	dB/B (B_n)
3	-0.05%	0.02%
4	0.02%	0.03%
5	-0.01%	-0.01%
6	0.03%	0.00%
10	0.00%	0.01%
14	-0.02%	0.00%
Total n=3-18	-0.03%	0.08%

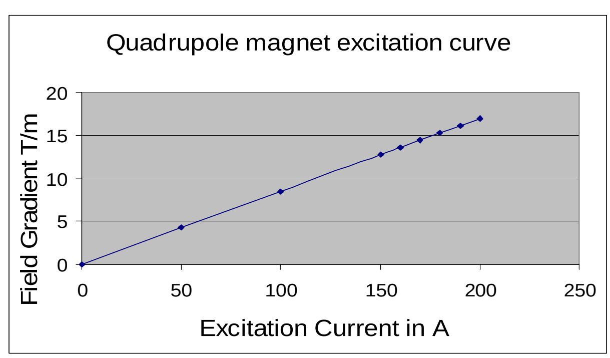

Figure 7: Excitation Curve for Quadrupole Magnets

SEXTUPOLE MAGNETS

Table 4 lists the principle requirements for the sextupole magnets. The magnets were manufactured to meet the specifications of Table 4 along with other specifications related with machining and assembly tolerances. The prototype sextupole magnet is shown in Figure 8. Figure 9 shows the dipole, sextupole and quadrupole magnets assembled on the girder. The coils are air-cooled as the required current density is low. The field measurements were carried on the harmonic bench setup shown in Figure 6. The strength of systematic multipoles of order 9 and 15 is below 1 %. The strengths of the random higher order multi-poles are significantly smaller. The field quality of these magnets is adequate with the requirements for the smooth functioning of the Booster Synchrotron.

Table 4: Sextupole Magnet Specifications

Magnetic length	160 mm
Bore Radius	24 mm
Number of Turns per Pole	15
Peak Sextupole Coefficient (half second differential)	70 T/m^2
Peak Current	19 A
Transverse Good Field Region	± 23 mm

Figure 8: Prototype Sextupole Magnet

Figure 9: Girder Assembled with Dipole, Sextupole and Quadrupole magnets.

CORRECTOR MAGNETS

Table 5 lists the principle requirements for the Horizontal and Vertical Corrector magnets. These are air cooled magnets. The integrated field strength of these magnets varies by ~1% over the specified aperture which is adequate for the field quality requirements of the Booster.

Table 5: Corrector Magnet Specifications

Type	Vertical	Horizontal
Magnetic length	0.16 m	0.16 m
Magnet Gap	56 mm	28 mm
Peak Dipole Field	0.02 T	0.02 T
Good Field Region	± 23 mm X ± 10 mm Y	± 23 mmX ± 10 mm Y

CONCLUSIONS

The Diamond Booster is now operating at the full design energy of 3 GeV and cycling at 5 Hz [1]. All of the magnets are performing as expected.

REFERENCES

[1] V.C.Kempson et al., "Commissioning of the Booster Synchrotron for the Diamond Light Source.", these proceedings.