THE STORAGE RING MAGNETS OF THE AUSTRALIAN SYNCHROTRON

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Abstract

A 3 GeV Synchrotron Radiation Source is being built in Melbourne, Australia. Commissioning is foreseen in 2006. The Storage ring has a circumference of 216 m and has a 14 fold DBA structure. For the storage ring the following magnets will be installed: 28 dipoles with a field of 1.3 T, and a gradient of 3.35 T/m; 56 quadrupoles with a gradient of 18 T/m and 28 with a gradient of 10 T/m; 56 sextupoles with a strength of B'' = 350 T/m and 42 with 150 T/m. The sextupoles are equipped with additional coils for horizontal and vertical steering and for a skew quadrupole. The pole profile was determined by scaling the pole profile of the SPEAR magnets [1] to the aperture of the ASP magnets. The magnets are to be supplied by Buckley Systems Ltd in Auckland, New Zealand.

BASIC DESIGN

The lattice of the ASP storage ring has a 14 fold DBA structure with gradient magnets [2]. Compared to the standard DBA (without gradient in the magnet) there is only a pair of weak defocusing quadrupoles between the dipoles. Sextupoles are installed both in the dispersive and non dispersive section. Fig 1. shows the lay out of the lattice.

Each quadrupole and sextupole will have its individual power supply while the dipoles are connected in series.

Each dipole will be installed independently on its own supports. The quadrupole and two sextupoles at the entrance of the achromat will be installed together on a girder, the same for the magnets at the exit of the achromat. The four quadrupoles and three sextupoles in the centre of the achromat will be installed together on a girder. Each girder will be positioned via a kinetically constrained, six degree of freedom alignment system. The magnets will be aligned on the girder by precision machined rails and keys connecting magnets and girder without the provision for shimming.

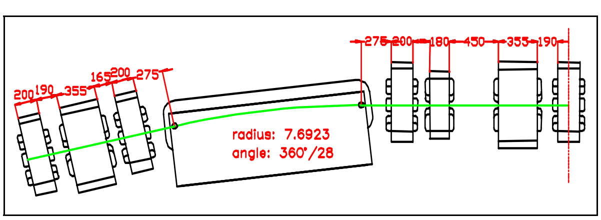

Figure 1: Half DBA cell of the ASP storage ring.

DIPOLES

The ASP storage ring will be equipped with 28 dipole magnets, having a field of 1.3 T and a gradient of 3.35 T/m. The 3 GeV beam energy corresponds to a magnetic rigidity of 10 Tm. The dipoles are C magnets with a straight core rather than curved. Although straight magnets need a larger good field region requiring more iron, production is simplified and tolerances are easier achievable. The Sagitta is 47.5 mm and the region afforded for the beam is +/-15 mm. Thus, the good field region of the dipole has to be +/-39 mm. The main parameters of the dipole magnet are listed in Table 1. The upper half of the dipole is shown in Fig.2.

Table 1: Main Parameters of the ASP storage ring dipoles

Field	1.3	T
Gradient	3.35	T/m
Iron length	1.7	m
Gap	42	mm
Turns per pole	36	
Conductor (outer size, bore)	12.7 / 6.35	mm
Water circuits	6	
Nominal current	695	A
Nominal Voltage	32	V

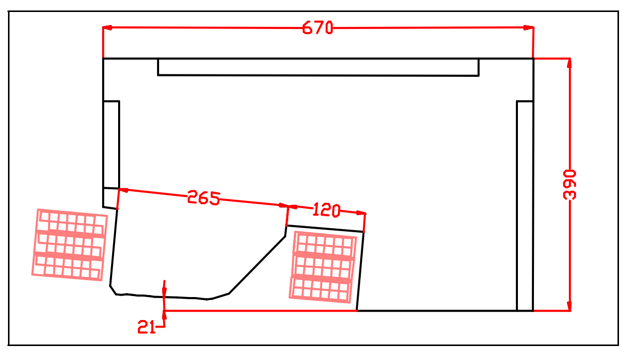

Figure 2: Cross section of the dipole.

The field homogeneity is shown in Fig 3 and is better than $5x10^{-4}$ for the specified good field region. The excitation curve is given in Fig.4 together with the efficiency curve. For the nominal field of 1.3 T the saturation effects are approximately 3 %.

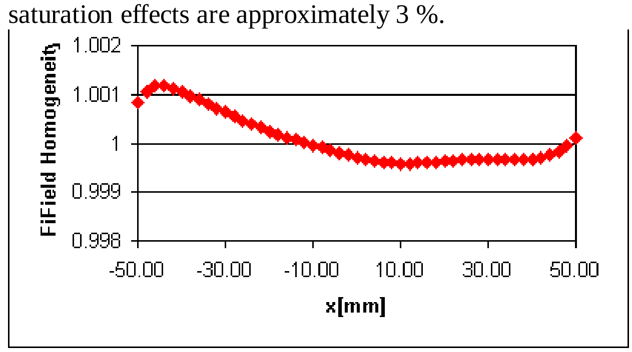

Figure 3: Field homogeneity of the dipole magnet.

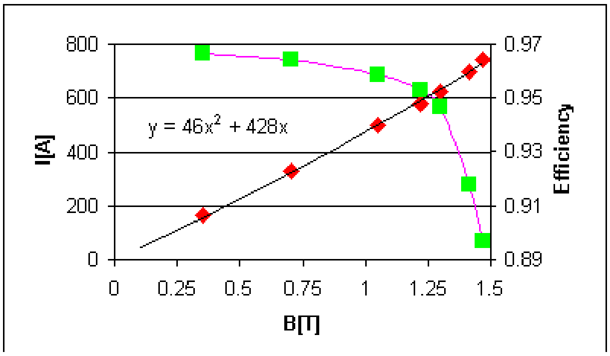

Figure 4: Excitation and efficiency of the dipole magnet.

QUADRUPOLES

42 horizontal focusing and 28 vertical focusing quadrupoles will be installed in the storage ring. The horizontal focusing quadrupoles are 335 mm long and have a gradient of 18 T/m. The vertical focusing quadrupoles are 180 mm long and have a gradient of 10 T/m. The quadrupole magnets are closed and the core is made from two pieces rather than four to enhance its rigidity and simplify assembling. The yokes of the focusing quadrupoles are extended at the sides to give internal clearance for beam line ports while the defocusing quadrupoles have slim yokes for external beam line port clearance. The main parameters of the quadrupole magnets are listed in Table 2. Fig. 5 shows one half of the horizontal focusing quadrupole magnet. The proper pole contour of both magnets is the same. The field homogeneity in horizontal direction is shown in Fig. 6. and is better than 10^{-3} within the 35 mm aperture of the vacuum chamber. The excitation curve together with the efficiency is given in Fig. 7. The saturation effect at a gradient of 18 T/m is approximately 1%.

Table 2: Main parameters of the storage ring quadrupoles

	Focusing	**Defocusing**	**T**
Gradient	18	10	T/m
Iron length	0.355	0.18	m
Pole radius	38	38	mm
Turns per pole	72	72	
Conductor (outer size, bore)	5.6 x 5.6 3.6	5.6 x 5.6 3.6	mm
Water circuits	4 x 2	4	
Nominal current	153	83	A
Nominal voltage	45	20	V

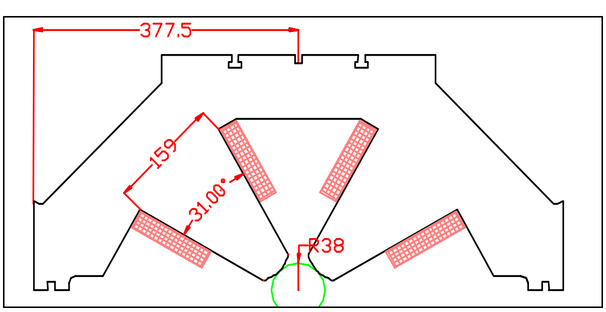

Figure 5: Cross section of half the focusing quadrupole

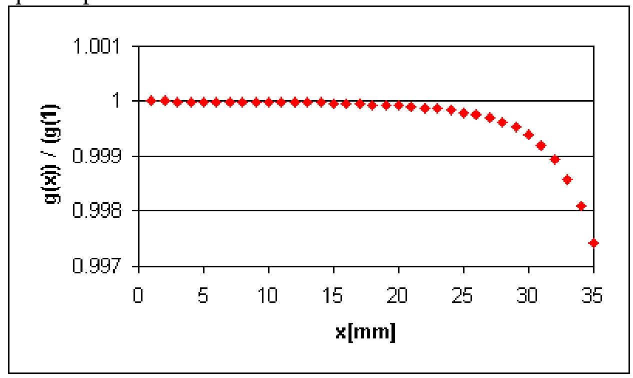

Figure 6: Field homogeneity of the quadrupole in the horizontal plane.

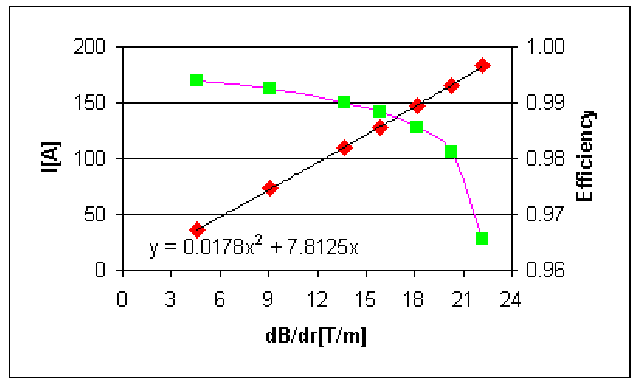

Figure 7: Excitation and efficiency of the quadrupole magnet.

SEXTUPOLES

Overall, 98 sextupoles will be installed in the storage ring, both in the dispersive (3 per achromat) and the non-dispersive sections (4). The sextupoles in the non-dispersive section require 320 T/m^2, in the dispersive section 140 T/m^2. The main parameters of the magnets are listed in Table 3. Like the quadrupoles, the magnets are closed. The magnet core is split into three pieces where in some cases the yokes are extended at one side to give clearance for the beam lines. At other locations a slim yoke design allows for external beam port clearance. Fig.8 shows one half of the sextupole (one third split). The field homogeneity in the horizontal plane is given in Fig.9. The excitation curve shows no deviation from linearity with I [A] = 0.304*B''[T/m^2]

Table 3: Main Parameters of the storage ring sextupoles

Strength (B'')	350	T/m^2
Iron length	0.2	m
Pole radius	40	mm
Turns per pole	26	
Conductor (outer size, bore)	5.6/3.6	mm
Water circuits	2	
Nominal current	127	A
Nominal Voltage	12	V

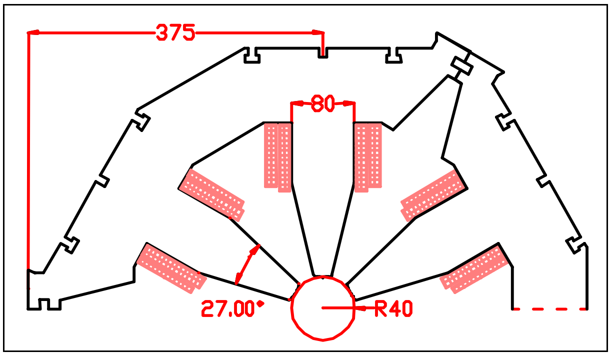

Figure 8:Cross section of the sextupole magnet.

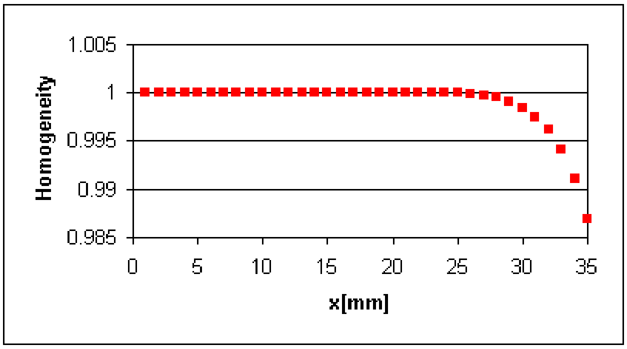

Figure 9: Homogeneity of the sextupole field in the horizontal plane.

The sextupoles are equipped with additional coils in order to provide horizontal and vertical correction. The sextupoles providing vertical correction adjacent to the dipole can also be used as skew quadrupoles. The conductor used for the correctors is the same as for the sextupoles. The turns per coil are 24 at the 0 and 6 o'clock position and 12 at the 2, 4, 8, 10 position.

RADIA CALCULATION

The pole profile of all magnets has been designed with the POISSON 2D FEM program [3]. Further calculations have been done with the 3D program RADIA developed at the ESRF [4] in order to determine the magnetic length dependence on the chamfer and for general comparison. For these calculations, the magnet is divided into segments for which the magnetization is calculated iteratively. For the present calculations the segments had been in the range of 2x3x4 mm at the pole tip to 10x10x25 mm at the yoke. The results agree well with the POISSON 2D calculations.

The magnetic length has been calculated with the RADIA program for various chamfer lengths. The chamfer design scaled from the SPEAR magnets has an angle of 58° and a depth of 20 mm for the quadrupoles; an angle of 56° and a depth of 10 mm for the sextupoles and an angle of 45 ° and a depth of 20 mm in the centre for the dipole. The chamfer cut of the dipole is inclined to the x-z plane by 7.8° to accommodate to the gradient in the profile. Concerning the multipole content the n=6 (first allowed) component in the quadrupole can be influenced by the chamfer size, but is negative for small chamfers and approaches 0 for 20 mm. For the sextupole the n = 9 component shows the same behaviour, changing sign at 5 mm.

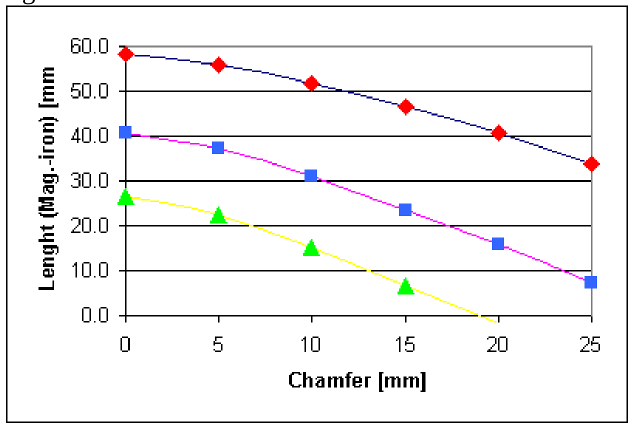

Figure 10: Dependence of the magnetic length as a function of the chamfer length for the storage ring dipole (diamond), quadrupole (square), sextupole (triangle).

PRODUCTION

All Magnets will be produced from 1mm thick lamination (STABOCOR 1200-100 from EBG). This is a low carbon (<0.003%) steel with medium silicon content (1.3%),, The B/H values are given in Table 4. The coarse profile of the laminations will be laser cut from sorted sheets, then the laminations will be stacked, flipped, compressed and baked to activate the epoxy. The yoke's pole profile, assembly reference surfaces and fiducialization features will be precision machined in a single CNC milling operation. Mechanical tolerances will be verified for each assembled magnet by coordinate measurement machine (CMM) as part of factory acceptance requirements. Magnetic measurements are performed on each magnet as required for quality assurance of functionality.

Table 4: B/H dependence of the selected steel

H [A/m]	100	200	300	500	1000	2000	5000
B [T]	.4	.9	1.2	1.35	1.5	1.6	1.7

REFERENCES

[1] N.Li, J.Tanabe, R.Boyce, D.Dell'Orco, D.Ernst, PAC03, Portland (2003)2174

[2] A.Jackson, H.Nishimura PAC03, Portland (2003)244

[3] uspas.fnal.gov/PCprog

[4]www.esrf.fr/machine/groups/insertion_devices/Codes/Radia/Radia