Magnet Design for the Synchrotron Light Source ANKA

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Abstract

ANKA, a 2nd to 3rd generation 2.5 GeV light source will be built at the Research Center Karlsruhe, Germany. This source will be dedicated to the fabrication of microstructure and X-ray analysis. The magnet system exist of 16 bending magnets, 40 quadrupoles, 24 sextupoles and 40 steerers. The nominal bending flux of the bendings is 1.5 T and the gap height is 40 mm. The dimensions of the lamination have been optimized to reach the required homogenity ($\Delta B/B < 5 \bullet 10^{-4}$ for $\Delta X < \pm 25$ mm) and to minimize the material costs. For the design of the quadrupoles with an aperture of 70 mm it was chosen to take cone width poleshoses in order to get a large gradient (20 T/m) with a small amount of saturation (8 %). The sextupole design (l=0.1m) with a differential gradient of $g´=750$ T/m^2 is based upon the BESSY II type and the steerer design is according to the APS one.

1 INTRODUCTION

The synchrotron light source ANKA [1] will be built at the Forschungszentrum Karlsruhe within the next three years. It is a 2nd to 3rd generation light source with an energy of 2.5 GeV, a circumference of 103.2m and an emittance around 50 nmrad. The magnetic system of ANKA [2] exist of 16 bending magnets (without a gradient), 40 quadrupoles, 24 sextupoles and up to 40 steerers. In order to get a compact machine, it was chosen to have a nominal field of 1.5 T in the bendings, to reach a gradient in the quads of 20 T/m and have a differential gradient in the sextupoles of 750 T/m^2. According to the DBA-structure, the horizontal betatron functions run within the bending through a minimum of 6 mm. Including closed orbit deviations of ± 10 mm, the beam uses a region of ± 20 mm. Within this range the homogenity of the field should be better as $5 \bullet 10^{-4}$. For the quads, the beam stay clear area is ± 25 mm. Within this range the homogenity of the gradient should also be better as $5 \bullet 10^{-4}$.

2 BENDING MAGNETS

There exist a lot of designs of bending magnets with a nominal field of 1.5 T: BESSY I [3], ELETTRA-transfer-line[4] and MAX II [5]. In order to minimize the production-, the running costs, and the space for the coil at the end of the magnets, however we had to make a new design. For minimising the running costs it was decided to havn't any bake out system and the gap was fixed to 40mm. To keep the saturation up to 1.5 T below 10 % the thickness of the return yoke has to be at least 160 mm. Our design is based on the ELETTRA-Magnet [4]. The cross section of the magnet is given in fig.1, the optimized pole profile in fig.2, the homogenity of the field is presented in fig.3, and the excitation curve in fig.4. The main parameters are summarized in table 1.

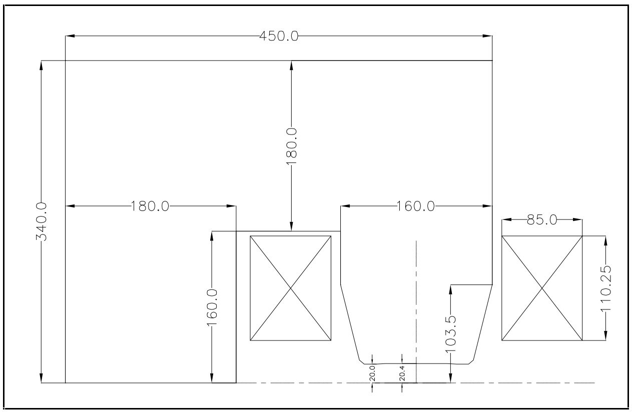
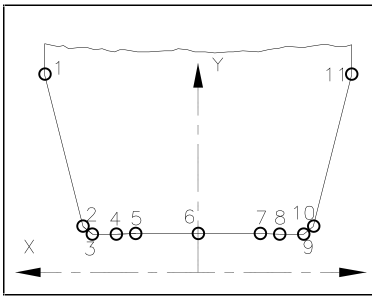


Fig.1: Cross section of the ANKA bending magnet.



Point	X[mm]	Y[mm]
1	−80.0	103.5
2	−60.0	24.0
3	−55.0	20.0
4	−42.5	20.0
5	−32.5	20.4
6	0.0	20.4
7	32.5	20.4
8	42.5	20.0
9	55.0	20.0
10	60.0	24.0
11	80.0	103.5

Fig.2: The pole profile of the bending magnet.

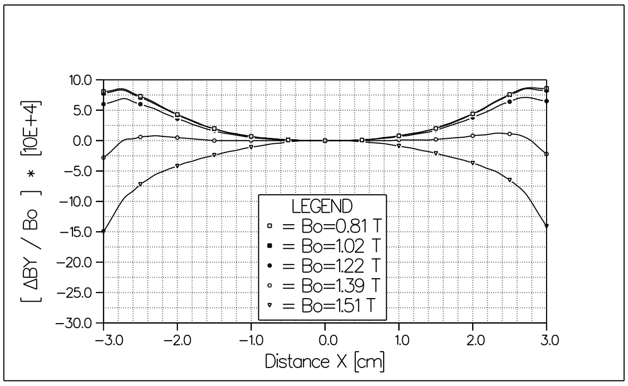


Fig. 3: The homogenity of the magnetic field

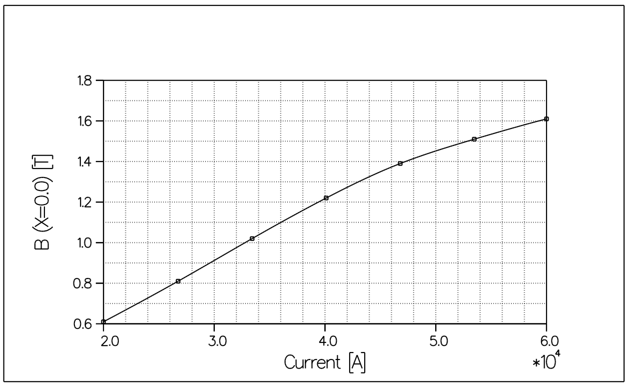


Fig. 4: The excitation curve of the ANKA bending magnet.

Table 1:Main parameters for the ANKA bending magnet

Parameter	Unit	Value
Number of magnets		16
Bend angle	Degree	22.5
Energy	GeV	2.5
Magnetic flux densitiy	T	1.5
Bending radius	m	5.559
Magnetic length	m	2.183
Iron length	m	2.130
Total lenght	m	2.310
Gap height	mm	40.0
Pole width	mm	160.0
Fieldindex		0.0
Ampereturns	A	54000
Number of turns		60
Nominal current	A	900.0
Number of pancakes		6
Conductor dimensions	mm	15*15,∅=7.5
Total resistance	mΩ	29.0
Total inductance	mH	72
Power	kW	23.5

For the ELETTRA-Magnet [4] the agreement between the theoretical [7] and experimental results were excellent. Hence according to fig. 3 we can assume a homogenity better then $5\bullet10^{-4}$ within the region $\Delta X \le 20$ mm. The saturation in fig. 4 is at the nominal field (B_0 =1.5 T) roughly 10 %. The homogenity and also the saturation are within the requirements.

3 QUADRUPOLE

The ANKA storage ring requires 40 normal quadrupole magnets, consisting of 7 families with two different lenghtes (l_1=420mm and l_2=350mm). All quads have the same 2D- geometry and have a bore radius of 35 mm. For the reduction of production cost and getting a simple assembling the quads have a closed flux return yoke. Because of the required gradient of 20 T/m the quad must have a cone pole shoe. The pole profile is roughly the same one as the BESSY II [6] type. The lamination and the pole profile are presented in fig. 5, the homogenity of the gradient along the x-axis is given in fig. 6 and the excutation curve in fig. 7. The main parameters are summarized in Table 2.

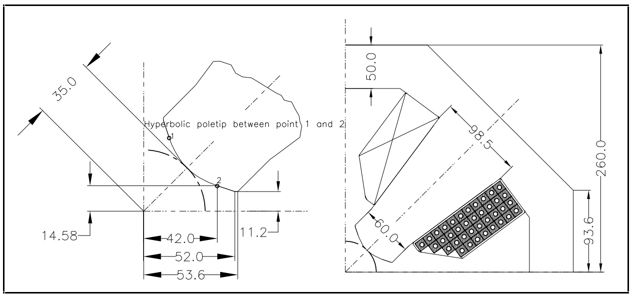


Fig. 5: Lamination and pole profile for the ANKA quadrupole.

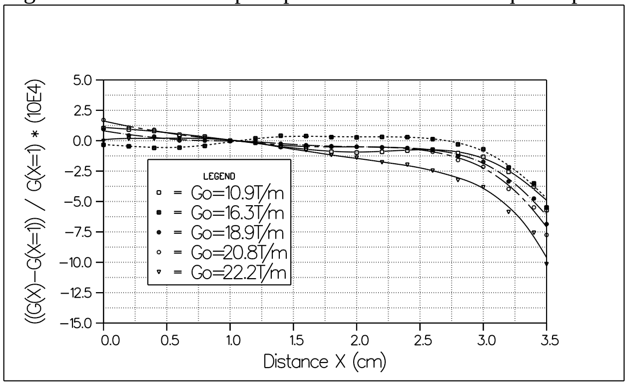


Fig. 6: The homogenity of the gradient within the quadrupole

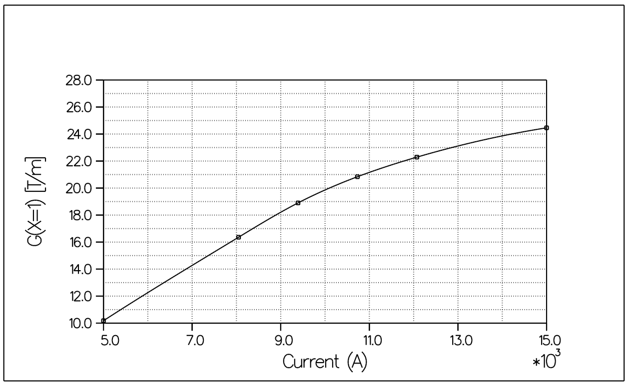


Fig. 7: Excitation curve for the ANKA-quadrupole.

Table. 2: Main parameters of the ANKA quadrupole.

Parameter	Unit	TYPE 420	TYPE 350
Number of magnets		8	32
Energy	GeV	2.5	2.5
Gradient	T/m	17.5	16.7
Magnetic length	m	0.42	0.35
Iron length	m	0.39	0.32
Total lenght	m	0.53	0.46
Aperture radius	mm	35.0	35.0
Pole width (max)	mm	90.0	90.0
Ampereturns per pole	A	8800	8300
Windings per pole		38	38
Nominal current	A	231.6	218.4
Conductor dimensions	mm	10*10,∅=5.0	10*10, ∅=5.0
Total resistance	mΩ	39.0	34.2
Total inductance	mH	19.0	16.0
Power	kW	2.1	1.63

Most important for the description of the magnetic fields within the quads are the amount of the higher harmonics.

The ratio of n=6/n=2 and n=10/n=2 are summarized in table 3 for different exitations at a radius of 27.5 mm .

Table 3: Harmonics of the quadrupole for R=27.5 mm

I [A•Wdg]	n=2 [T]	n=6/n=2	n=10/n=2	gradient [T/m]	saturation [%]
1072.6	0.0602	9.0E-6	-3.7E-5	2.19	0.0
2681.6	0.1505	6.0E-6	-3.4E-5	5.47	0.0
5363.1	0.3010	-4.7E-6	-2.7E-5	10.95	0.0
8044.7	0.4500	4.2E-6	-2.9E-5	16.36	0.0
9385.4	0.5198	-1.5E-6	-3.1E-5	18.90	1.3
10726.2	0.5732	-1.7E-5	-3.1E-5	20.84	5.0
12067.0	0.6128	-3.4E-5	-4.7E-5	22.28	10.5

With this quadrupole design it is possible to have up to a radius of 30 mm a homogenity better than $5 \bullet 10^{-4}$ with gradients up to 20 T/m. The saturation at 22 T/m is less than 10 % and the power (2.1 kW forl =420 mm) is quite small.

4 SEXTUPOLE

The sextupoles have only a lenght of 100 mm. For such a small devices the contribution of the end field are relatively high and they lead to a considerable amount of saturation. To keep this in limits we have to use an extreme cone pole shoe. The lamnitaion and pole profile is given in fig. 8 and the exitation curve in fig. 9. From this figure one concludes, that it is posible to run the sextupole with a gradient up to g´ = 800 T/m^2.

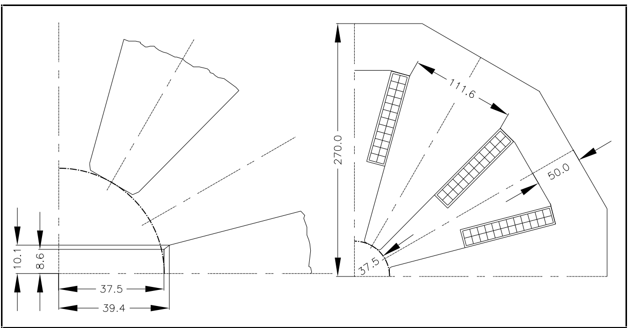


Fig. 8: Lamination and pole profile for the ANKA sextupole.

Table. 4: Main parameters of the ANKA sextupole.

Parameter	Unit	TYPE Sh	TYPE Sv
Number of magnets		8	16
Energy	GeV	2.5	2.5
Differ. Gradient (g“)	T/m^2	782	584
Magnetic length	mm	120	120
Iron length	mm	100	100
Total lenght	mm	147	147
Aperture radius	mm	37.5	37.5
Pole width (max)	mm	70.0	70.0
Ampereturns per pole	A	5500	4108
Windings per pole		24	24
Nominal current	A	229.0	171.0
Conductor dimensions	mm	7*7,∅=3.0	7*7, ∅=3.0
Total resistance	mΩ	27.9	27.9
Total inductance	mH	4.42	4.42
Power	kW	1.46	0.815

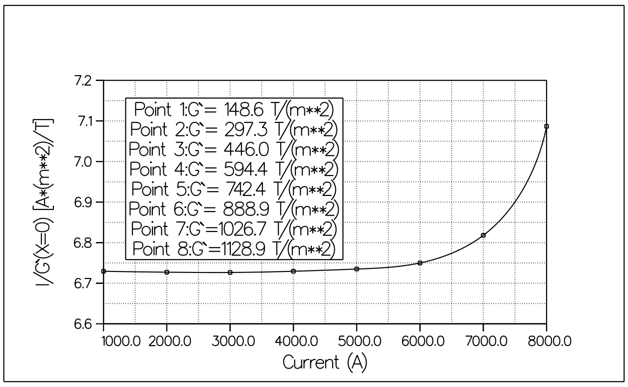


Fig 9: Excitation curve of the ANKA-sextupole.

The contributions of the endfield and also the saturation for a 0.1 m long sextupole are observable. According to the 2D-calculations [7], the integrated sextuplole strenght is for an excitation of 6000 A•Wdg equal to 90 T/m. A rougly estimation shows that a 3 D-calculation reduces this value according to the above mentioned effects to 85 T/m. Furthermore the 2 D calculations show, that a sextupole dominate field does only exist for as radius smaller than 24 mm.

6 REFERENCES

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