INSERTION DEVICES PRODUCED AT DANFYSIK A/S

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Abstract

Four insertion devices have been designed and manufactured at DANFYSIK A/S, three undulators with 55, 50 and 100 mm period and a wiggler with 175 mm period. The undulators have been multipole- and spectrum shimmed [1], and are characterised by small phase angle errors (1°-3°), small integrated multipoles and a small variation of the field integrals with the undulator gap without the need for correction coils. The wiggler is designed with a "flat top" magnetic field to drive several high energy beam lines simultaneously. The integrated multipoles are small and well within specifications, the variation of the first integrals with the wiggler gap is maximum 2 Gauss-meters and there is no need to use correction coils at the 16 mm minimum gap. All insertion devices designed and manufactured meet the customer specifications with good margins.

1 INTRODUCTION

Danfysik A/S has produced insertion devices for synchrotron light sources based on electromagnet and permanent magnet technology since 1993. A total of 15 devices have been built, and four of the them are presented here with special emphasis on the 100 mm period hybrid undulator and the 175 mm period hybrid wiggler. The specifications and the as-built performance for each device are listed in Tables 1 and 2.

2 THE 55 MM HYBRID UNDULATOR

A 50 mm period hybrid undulator has been constructed for the 600 MeV ASTRID storage ring in Aarhus, Denmark. It was designed using B3D[2], the end sections are of traditional form with half thickness pole and magnet block. The undulator shows very small variations in the integrated multipoles and the second integrals when changing the undulator gap without using the correction coils.

3 THE 50 MM HYBRID UNDULATOR

A 50 mm hybrid undulator, 3.9 m long, has been delivered to the SRRC synchrotron light source in Taiwan. The specification calls for a high magnetic field, low higher order Fourier components in the magnetic field and very small transverse roll off. The central section of the undulator was designed using OPERA-3d[3] and the end sections using B3D[2].The end section design was modified to eliminate the horizontal offset of the electron orbit in the undulator, this eliminates the large values of the vertical second integral for asymmetric configurations. The modified end section is shorter than the traditional one, the variations of the integrated multipoles and second integrals are within the specified range without using the correction coils for all gap sizes.

4 THE 100 MM HYBRID UNDULATOR

A 100 mm period hybrid undulator has been designed and built for the SU8 beam line at the 800 MeV Super-ACO storage ring at LURE in Orsay, France. The modified end section design was used, the orbit for a 800 MeV electron in the undulator at minimum gap is shown in Fig.1, there is no horizontal offset of the orbit. The RMS phase error is shown in Fig. 2, it is less than 1° if the two first and last poles are excluded. The RMS phase error increases to 4° at 70 mm gap, if the horizontal correction coil is used to correct the first integrals the phase error can be reduced to about 2°.

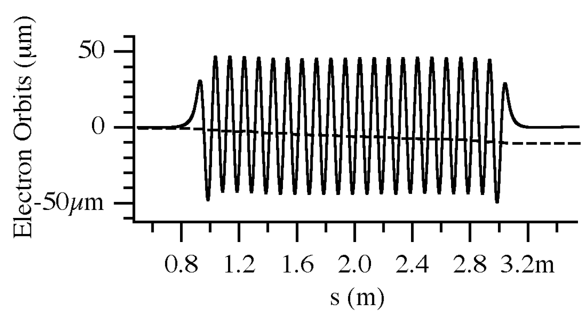

Fig. 1. Horizontal (solid) and vertical (dashed) orbits for a 800 MeV electron.

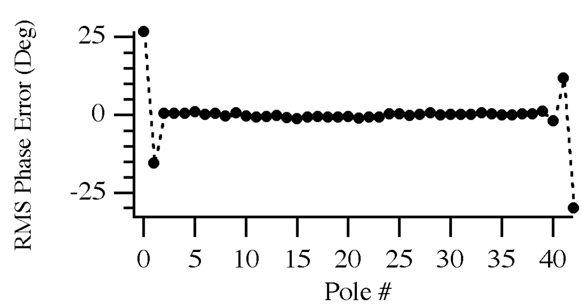

Fig. 2. RMS Phase angle error at minimum gap.

The variation of the first integrals with the undulator gap without using the correction coils is shown in Fig. 3, the integrals are well within the specified range of ±40 G-cm for all gap sizes.

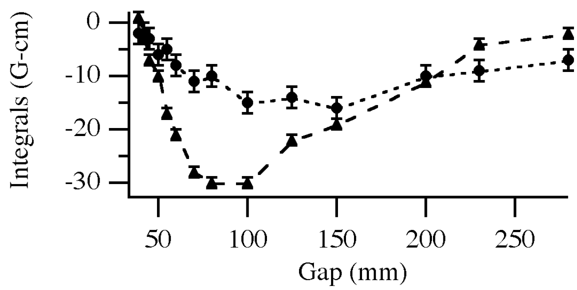

Fig. 3. Normal (triangles) and skew (circles) first integrals as function of the undulator gap. The correction coils were not used in the measurement.

5 THE 175 MM HYBRID WIGGLER

A high field wiggler with 175 mm period has been designed and built for SPEAR Beamline 11 at SSRL, Stanford University. The wiggler shall drive two high energy beam lines, one on the wiggler axis and the other at a 3 mrad angle for 3 GeV electron energy. This requires a vertical field configuration with wide maxima and unusually long poles.

The central part of the wiggler has been designed using OPERA-3d[3] and the end sections using B3D[2]. The wiggler is asymmetric, and the end sections have been designed to minimise the second integrals and eliminate the need to use the correction coils at minimum gap. Special care has also been taken to reduce the demagnetising fields in the permanent magnet blocks.

Table 1. Parameters for the hybrid undulators.

Parameter:	**Insertion Device:**					
	55 mm Hybrid		50 mm Hybrid		100 mm Hybrid	
	Specification	As Built	Specification	As Built	Specification	As Built
Period Length (mm)	55	55.07±0.12	50	49.92±0.12	100	99.97±0.13
Minimum Gap (mm))	22	22	14	14	39	39
Maximum Gap (mm)	230	230	230	230	230	280
Length of Magnetic Assemblies (mm)	< 2000	1980	< 3900	< 3900	< 2200	2155
Average Vertical Field at Minimum Gap (T)	> 0.505	0.558	> 0.641 (18 mm Gap)	0.678 (18 mm Gap)	> 0.45	0.479
Number of Full Strength Poles	69	69	152	152	41	41
Total Number of Poles	71	71	154	154	43	43
Transverse Roll-Off at x=±10 mm for Minimum Gap (%)	< 6	3.6	< 0.1	< 0.1	2	1.3
Limits on Integrated Normal and Skew Multipoles for All Gaps:						
Dipole (G-cm)	40	≤ 10	50	≤30	40	≤ 30
Quadrupole (G)	30	≤ 8	50	≤ 36	30	≤ 10
Sextupole (G/cm)	15	≤ 8	100	≤ 37	15	≤ 5
Octupole (G/cm^2)	8	≤ 2	300	≤ 21	8	≤ 2
Limits on Normal and Skew Second Integrals for all Gaps (G-cm^2)	–	≤ 7600	50000	≤ 8000	15000	≤ 12000
Spectrum Quality at All Gaps (%):						
Harmonics # 1	–		≥ 80	~ 100	–	
Harmonics # 3	–		≥ 80	≥ 94.5	–	
Harmonics # 5	> 90	≥ 81			> 90	≥ 84
Harmonics # 9	> 75	≥ 67			> 75	≥ 73
Harmonics # 15	> 50	≥ 55			> 50	≥ 69

Remarks: The correction coils were not used when measuring the integrated multipoles and the second integrals.

The spectrum quality for a given harmonics is defined as the ratio between the intensity of the real undulator and the intensity of an undulator with a perfect sinusoidal field, the same number of poles and the same effective peak field.

Table 2. Parameters for the 175 mm hybrid wiggler.

Parameter	Specification	As Built
Wiggler Period (mm)	175	175.1
Minimum Gap (mm)	16	16
Maximum Gap (mm)	170	170
Total Length of Magnetic Assemblies (mm)	<2330	2310
Number of Full Size Poles	24	24
Total Number of Poles	26	26
Average Peak Field at Minimum Gap (T)	> 1.90	1.99 (poles 3-24) 1.91 (poles 2 and 25)
Peak Field for End Poles at Minimum Gap (T)	> 0.8	1.30
Peak Field Fall-Off at ±3 mrad Photon Angle (%)	< 11	9 (poles 3-24) 10 (poles 2 and 25)
Transverse Roll-Off at x=±10 mm and Minimum Gap (%)	< 2	1
Integrated Normal and Skew Multipoles at Minimum Gap:		
Dipole (G-cm)	< 100	23
Quadrupole (G)	< 50	4
Sextupole (G/cm)	< 100	40
Octupole (G/cm^2)	< 150	120
Normal Second Integral at Minimum Gap (G-cm^2)	100000	24000
Skew Second Integral at Minimum Gap (G-cm^2)	100000	51000

Remarks: The correction coils were <u>not</u> used when measuring the integrated multipoles and the second integrals.

The shape of the vertical field is shown in Fig. 4, the orbits for a 3 GeV electron through the wiggler in Fig. 5 and the first integrals over the interval $|x| \leq 3.6$ cm in Fig. 6. All figures are for minimum gap.

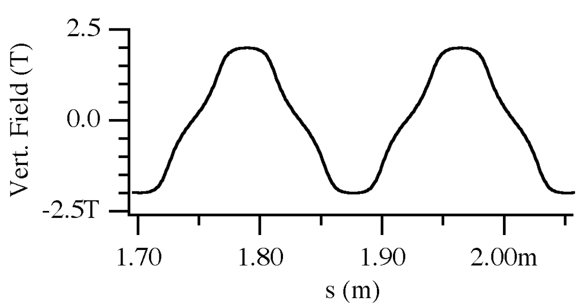

Fig 4. Vertical field shape at minimum gap.

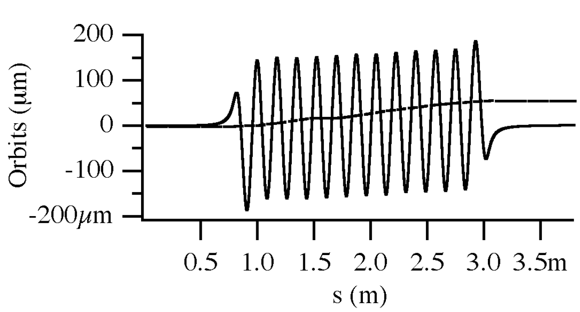

Fig. 5. Horizontal (solid) and vertical (dashed) orbits for a 3 GeV electron through the wiggler.

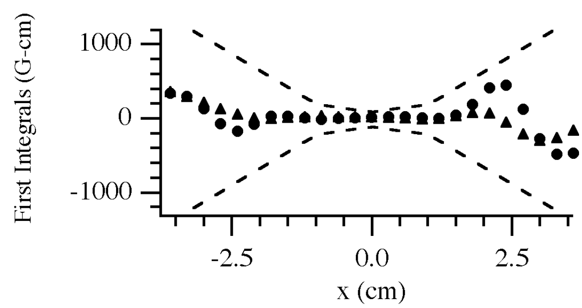

Fig. 6. Normal (triangles) and skew (circles) first integrals as function of x for 16 mm gap. The dashed lines show the specified limits.

REFERENCES

[1] J. Chavanne, P. Elleaume, Synchrotron Radiation News **8** (1995) 18.

[2] J. Chavanne, P. Elleaume, ESRF Internal Report ESRF-SR/ID-91-54.

[3] Vector Fields Ltd, Kidlington, Oxford, England.