RECENT INSERTION DEVICES PRODUCED AT DANFYSIK A/S

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Abstract

Four new insertion devices have recently been designed and manufactured at Danfysik A/S [1]. One device is a 68.3 mm period undulator for SRC in Wisconsin, one is a wiggler with a period of 60.7 mm for the Swiss Light Source (SLS) and then two similar wigglers with a 230 mm period for SSRL, Stanford. The high performance SRC undulator is designed to cover an energy range from 7.8 to 440 eV using the 1st to 9th harmonic. The SLS wiggler is a high-field small gap device designed for operation with a minimum gap of 7.5 mm together with a special small aperture vacuum chamber. The two SSRL wigglers are designed with a "flat top" magnetic field to drive several high-energy beamlines simultaneously.

1 INTRODUCTION

Danfysik A/S has over the last decade produced a total of 19 insertion devices for synchrotrons light sources. Four of these devices have previously been presented [2] and here we present four new devices built at Danfysik. All four devices have been designed using RADIA [3] for both the central part and the end section while OPERA-3d [4] has been used to verify the design of the central part and to calculate the demagnetisation fields. The specifications and as-built parameters for each of the devices are given in Table 1 and 2.

2 THE SRC PPM UNDULATOR

A 68.3 mm period pure permanent magnet undulator has been designed and built for the 0.8 GeV Aladdin synchrotron light source at SRC in Wisconsin, USA. The specifications called for minimum 90% of the ideal flux up to the 9th harmonic at all gaps. To obtain this, a RMS photon phase angle error below 2.1° is needed. For the delivered undulator the phase angle error variation at 24 mm gap is shown in Fig. 1. The RMS value of the phase angle varies between 1.15° at 24 mm gap and 1.76° at 71 mm gap.

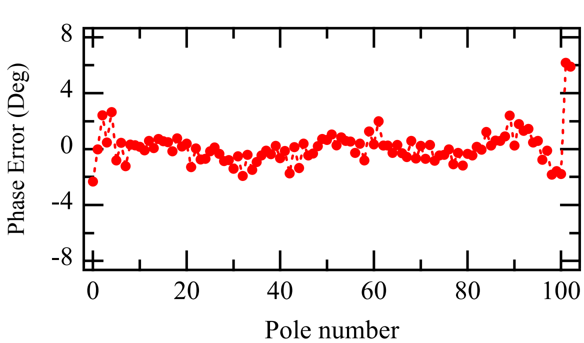

Figure 1: RMS phase angle error at minimum gap for the SRC undulator.

The variation of the first field integrals as a function of the horizontal position is shown in Fig. 2. The undulator has been installed at the ring where it performs according to specifications in good agreement with our test results [5,6].

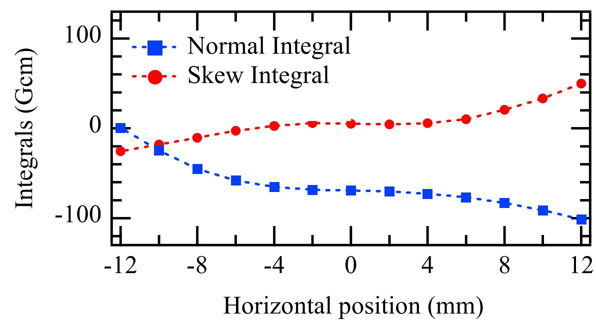

Figure 2: First integrals as a function of the horizontal position at 24 mm gap for the SRC undulator.

Table 1. Parameters for the SRC undulator

		Spec.	As-built
Wiggler period	(mm)	≤ 69	68.3
Gap range	(mm)	24-200	24-200
Wiggler length	(mm)	≤ 3520	3520
Number of full size poles		≥ 100	101
Total number of poles			103
Peak field at min. gap	(T)		0.711
Effective field at min. gap	(T)		0.716
Min. E_{photon} at 0.8 GeV	(eV)	≤ 7.8	7.83
Field roll-off for x=±3mm:			
min. gap	(%)		0.05
K = 0.5	(%)	≤ 0.15	0.14
Integrated multipoles at all gaps:			
Dipole	(Tm)	$< 100 \cdot 10^{-6}$	$\leq 92 \cdot 10^{-6}$
Quadrupole, normal	(T)	$< 6.7 \cdot 10^{-3}$	$\leq 2.7 \cdot 10^{-3}$
Quadrupole, skew	(T)	$< 1.0 \cdot 10^{-3}$	$\leq 0.97 \cdot 10^{-3}$
Sextupole	(T/m)	< 2.5	≤ 0.18
Octupole	(T/m^2)	< 250	≤ 150
Second integral, all gap	(Tm^2)	$< 250 \cdot 10^{-6}$	$\leq 77 \cdot 10^{-6}$

3 THE SLS SMALL GAP WIGGLER

A 60.7 mm period small gap wiggler has been designed and built for the Materials Science beamline at SLS, Villigen, Switzerland. The device is designed to produce a high flux of hard x-ray (5-40 keV). The device has been installed at SLS with a vacuum chamber that initially allows a wiggler gap down to about 12 mm, which is later to be reduced to about 7.5 mm. Thus a relative small gap can be achieved without going to more expensive in-vacuum devices. The magnetic shimming of the wiggler was very challenging due to strong magnetic interactions, caused by internal magnetic defects of the permanent magnets, resulting in large gap dependent field integral variations. This effect was particularly pronounced as a result of the small minimum gap and could not be removed by the usual shimming measures. The problem was instead eliminated by magnet block exchange based on the known multipole contribution from each block. Fig. 3 shows the resulting variation of the first field integrals with gap which are well below the required limit of ±100 Gcm. The orbits for a 2.4 GeV electron at minimum gap are shown in Fig. 4.

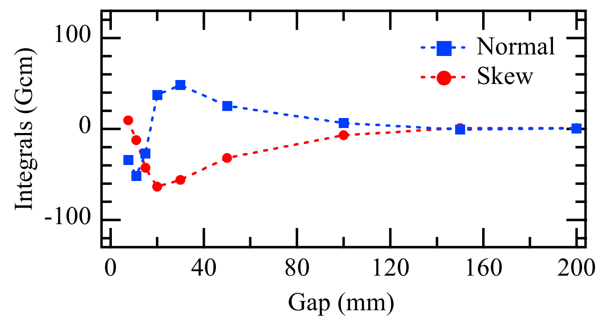

Figure 3: Gap dependence of the first integrals measured without use of correction coils for the SLS wiggler

Table 2. Parameters for the hybrid wigglers.

		SLS Hybrid Wiggler		SSRL Hybrid Wiggler		
		Spec.	As-built	Spec.	1. As-built	2. As-built
Wiggler period	(mm)		60.7	230	230.1	230.1
Gap range	(mm)	7.5-200	7.5-200	16-170	16-170	16-170
Wiggler length	(mm)	< 2000	1983	< 2335	2315	2315
Number of full size poles		-	62	18	18	18
Total number of poles		-	64	20	20	20
Parameters at minimum gap:						
Average peak field	(T)	> 1.90	1.92	≥ 1.7	2.020	2.018
Effective field	(T)	> 1.63	1.65	-	-	-
Peak field for end poles	(T)	-	1.05	> 0.8	1.2	1.2
Peak field fall-off at ±6mrad	(%)	-	-	< 10	≤ 8	≤ 8
Field roll-off , x=±5mm	(%)	≤ 0.1	< 0.09	-	-	-
Field roll-off, full gap range, |x| ≤ 25mm						
$\partial B/\partial x$	(T/m)	-	-	≤ (1 + 1.5|x|)	≤ 76% of spec	≤ 82% of spec
$\partial^2 B/\partial x^2$	(T/m^2)	-	-	≤ (1.22+2|x|)	≤ 82% of spec	≤ 92% of spec
Integrated multipoles in full gap range:						
Quadrupole, normal	(T)	$< 5\cdot10^{-3}$	$\leq 4.4\cdot10^{-3}$	$< 5\cdot10^{-3}$	$\leq 4.2\cdot10^{-3}$	$\leq 1.4\cdot10^{-3}$
Quadrupole, skew	(T)	$< 5\cdot10^{-3}$	$\leq 4.9\cdot10^{-3}$	$< 5\cdot10^{-3}$	$\leq 6.6\cdot10^{-3}$	$\leq 4.5\cdot10^{-3}$
Sextupole, normal	(T/m)	< 0.6	≤ 0.51	< 1.0	< 0.33	< 0.31
Sextupole, skew	(T/m)	< 0.6	≤ 0.78	< 1.0	< 0.10	< 0.29
Octupole, normal and skew	(T/m^2)	< 100	≤ 72	-	-	-
Field integrals in full gap range, |x| ≤ 25 mm:						
1. Integrals	(Tm)	-	-	$\leq (1+1.5\|x\|)\cdot10^{-4}$	≤ 55% of spec	≤ 50% of spec
2. Integrals	(Tm^2)	-	-	$\leq (1+1.5\|x\|)\cdot10^{-3}$	≤ 40% of spec	≤ 40% of spec
Derivative of 1.Integral	(T)	-	-	$\leq (2+3\|x\|)\cdot10^{-2}$	≤ 35% of spec	≤ 25% of spec
Field integrals at 7.5, 11, 15, 20 and 200 mm gap:						
1. Field integrals: |x| ≤ 4 mm	(Tm)	$\leq 0.3\cdot10^{-4}$	$\leq 0.3\cdot10^{-4}$			
4 < |x| ≤ 10 mm	(Tm)	$\leq 1.0\cdot10^{-4}$	$\leq 0.8\cdot10^{-4}$	-	-	-
10 < |x| ≤ 20 mm	(Tm)	$\leq 2.0\cdot10^{-4}$	$\leq 1.8\cdot10^{-4}$			
2. Field Integrals: |x| ≤ 4 mm	(Tm^2)	$\leq 0.2\cdot10^{-4}$	$\leq 0.4\cdot10^{-4}$			
4 < |x| ≤ 10 mm	(Tm^2)	$\leq 1.0\cdot10^{-4}$	$\leq 1.5\cdot10^{-4}$	-	-	-
10 < |x| ≤ 20 mm	(Tm^2)	$\leq 2.0\cdot10^{-4}$	$\leq 3.0\cdot10^{-4}$			

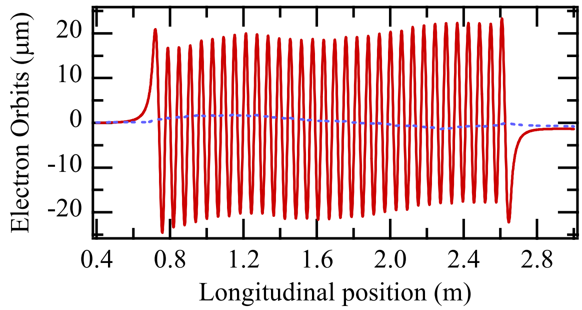

Figure 4: Horizontal (solid) and vertical (dashed) electron orbits for the SLS wiggler at 7.5 mm gap.

4 TWO SSRL HIGH-FIELD WIGGLER

Two nearly identical 230 mm period high-field wigglers have been designed and built for the SPEAR beamlines 4 and 7 at SSRL, Stanford University, USA. Both wigglers shall produce a nearly constant critical energy over an angular fan width of ± 6 mrad at 3 GeV electron energy in order to drive two beamlines simultaneously. This requires a design with wide magnetic field maxima and unusually long poles. The layout of the wigglers are asymmetric and the extremities have been designed to minimise the second field integral and eliminate the need to use correction coils at the minimum gap. Special care has also been taken to reduce the demagnetising fields in the permanent magnet blocks.

Fig. 5, 6 and 7 show results obtained for one of the devices at minimum gap. In Fig. 5 is shown part of the measured magnetic field variation with the characteristic "flat top" shape required to drive several beamlines simultaneously. The relative field variation with photon angle, obtained from this field shape, is in good agreement with theoretical calculations, as see in Fig. 6. The electron orbit calculated from the field variation is shown in Fig. 7.

The devices are required to fulfil a tight specification of the transverse field roll-off and field integral variations in order to avoid a previously observed dynamic field problem [7]. This is fulfilled with a good margin as shown in Table 2.

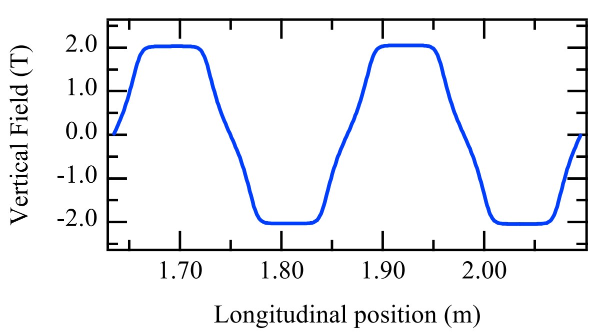

Figure 5: The vertical magnetic field at minimum gap for the SSRL wigglers.

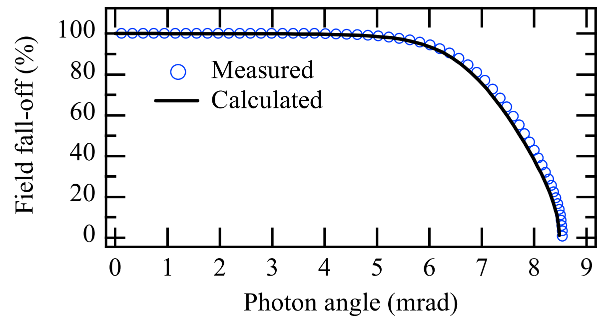

Figure 6: The calculated relative field variation with photon angle for the SSRL wigglers compared with the measured variation for a typical pole.

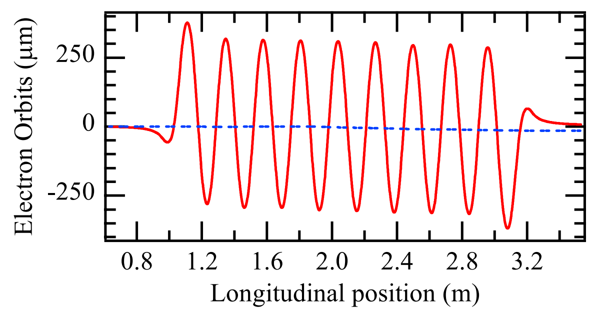

Figure 7: Horizontal (solid) and vertical (dashed) electron orbits for the SSRL wigglers at 3.0 GeV.

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