INSERTION DEVICES FOR THE MAX IV 3 GeV RING

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Abstract

The MAX IV light source, presently under construction at MAX-lab in Lund, Sweden, will consist of two separate storage rings and a linac-driven short-pulse facility. The two storage rings are operated at different energies, 3 GeV and 1.5 GeV, to provide synchrotron radiation of high brightness over a broad spectral range. The 3 GeV linac serves as a full-energy injector for the storage rings as well as the driver of the short-pulse facility delivering intense x-ray pulses. The paper describes a selection of possible insertion devices to be installed at the MAX IV 3 GeV ring and the expected heat loads produced by the insertion devices.

INTRODUCTION

The MAX IV light source, consisting of two separate storage rings with 3 GeV and 1.5 GeV energies of the stored beams and a short-pulse facility driven by the 3 GeV linac injector, is described elsewhere [1].

No decisions have yet been made on what beamlines should be built or what insertion devices (IDs) should be used on the MAX IV facility. The choice of beamlines and IDs is, as of today May 2010, under intense discussion and a number of possible insertion devices have been modelled as a basis for the discussion. This note describes examples of IDs which could be built and installed at the MAX IV 3 GeV ring.

The lengths of the IDs in this note are in most cases the maximum lengths possible. It is possible to make the IDs shorter in order to decrease the heat load on the vacuum system, the front ends, and the optical components of the beamlines but not longer. It is also perfectly possible to increase the magnetic field strength of the superconducting wiggler but the higher magnetic field will lead to a higher flux of gamma-rays, which may give rise to radiation safety problems.

The final choice of IDs for the MAX IV 3 GeV ring, the MAX IV 1.5 GeV ring, and the linac driven short pulse facility will be included in the DDR of the MAX IV Facility [1, 2].

PHYSICAL LIMITS FOR THE INSERTION DEVICES AT THE MAX IV 3 GEV RING

The straight section length available for insertion devices at the 3 GeV MAX IV storage ring is 4.8 m and the minimum vertical beam stay clear aperture in the middle of the straight sections is 4 mm.

Table 1: Beam parameters in the middle of the straight sections of the MAX IV 3 GeV Ring [3]

Beam Energy	3.0	GeV
Beam Current	500	mA
Energy Spread (rms)	0.0010	
Horizontal Beta Function	9.00	m
Horizontal Emittance	0.263	nmrad
Vertical Beta Function	4.80	m
Vertical Emittance	0.008	nmrad
σ_h rms horizontal beam size	48.65	μm
$\sigma_{h'}$ rms horizontal beam divergence	5.406	μrad
σ_v rms vertical beam size	6.197	μm
$\sigma_{v'}$ rms vertical beam divergence	1.291	μrad

In-vacuum undulators are assumed to have a minimum magnetic gap of 4.2 mm and the magnetic length can be up to 3.8 m since approximately 500 mm are needed at the entrance and exit for valves, absorbers, flanges and tapers.

Elliptically polarising undulators and out of vacuum undulators are assumed to have a minimum magnetic gap of 9 mm and a maximum length of 4 m. The thickness of the NEG coated Al vacuum chamber is assumed to be 7 mm. Current strips to compensate for dynamic multipoles will occupy 1.2 mm of aperture and an additional 0.8 mm is needed for clearance.

Wigglers are assumed to have a minimum magnetic gap of 9 mm and a maximum length of 4 m. The gap may be decreased to 7.8 mm if the same vacuum chamber as for the elliptically polarising undulators is used.

The beam parameters in the middle of the straight sections of the MAX-IV3 GeV storage ring are given in Table 1 [3].

UNDULATORS

The undulators for high energy photons will by necessity be in-vacuum insertion devices since a small magnetic gap is needed in order to obtain a high undulator peak field in combination with a short period length. The first set of beam lines will use todays state of the art technology with in-vacuum undulators of hybrid type. Cryogenically cooled in-vacuum undulators may also be considered for installation at some of the initial beam lines at the MAX IV 3 GeV ring. The promising but not yet mature technique with superconducting undulators is however not considered for the initial set of beam lines since the fundamental problems with large phase error and field integrals as well as the heat load problems not yet have been solved for this technique. The 3 GeV MAX IV ring is however well suited for the installation of superconducting undulators since the soft end bending magnets flanking the straight sections and the long bunch length in the stored beam will give a moderate heat load to the cold mass of the superconducting undulator.

In-vacuum undulators (pmu)

The in-vacuum undulators used for the comparison are of hybrid type with Sm_2Co_{17} (B_r = 1.05 T) as the magnetic material and pure iron as pole material. The peak field is found by magnetic model calculations using the computer code Radia [4]. The transverse dimensions of the magnet material are 50×30 mm^2 and the pole material 32×24 mm^2. The longitudinal length, or thickness, of the iron pole disk is 13.6 % of the period length and the longitudinal length, or thickness, of the magnet material disk is 36.4 % of the period length. The vertical physical aperture is 4 mm and there is a 0.1 mm thick sheet covering the pole faces, which results in magnetic aperture of 4.2 mm. In-vacuum undulators with 3 different periods lengths, as described in Table 2, have been modelled. Figure 1 shows the magnetic model of the pmu18p5.

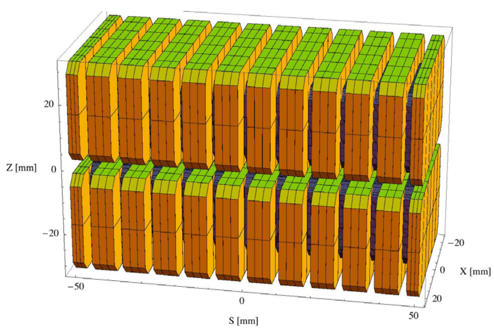

Figure 1: Magnetic model of the pmu18p5 ID. The magnet has been modelled with Radia [4].

Cryogenically cooled in-vacuum undulators (cpmu)

The peak field in the cryogenically cooled in-vacuum undulator operating at a temperature of 140 K in the comparison is found by carrying out an identical calculation as for the in-vacuum undulator except for that the magnetic material has been changed to NdFeB (B_r = 1.35 T at 140 K, B_r = 1.18 T at 293 K), the pole longitudinal length has been increased to 15 % of the period length, and the longitudinal length of the magnet material has been decreased to 35 % of the period length. Cryogenically cooled in-vacuum undulators with 3 different periods lengths, as described in Table 2, have been modelled. Figure 2 shows the cpmu16. The magnet has been modelled with Radia [4].

Elliptically polarizing undulators (epu)

The MAX IV 3 GeV storage ring will be an excellent storage ring for the installation of elliptically polarizing un-

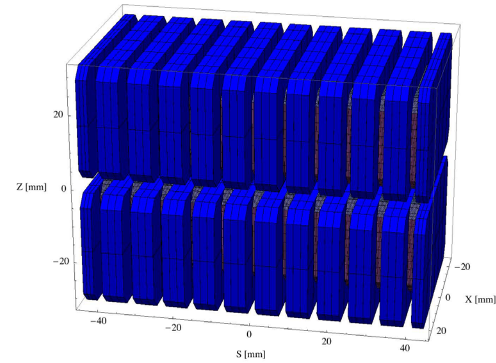

Figure 2: Magnetic model of the cpmu16 ID. The magnet has been modelled with Radia [4].

dulators since the magnetic gap can be as small as 9 mm. It will be possible to reach a photon energy of 2 keV with 100 % circularly polarized light using an elliptically polarizing undulator with 38 mm period length. Elliptically polarizing undulators with 5 different periods lengths, as described in Table 2, have been modelled.

The Radia [4] magnet model of the epu38 is shown in Figure 3. The magnetic material in the model is NdFeb with a remanence of 1.28 T. The block size is 30.x30.x9.5 mm^3 and there is a 5 mm cut-out in two of the corners of the blocks.

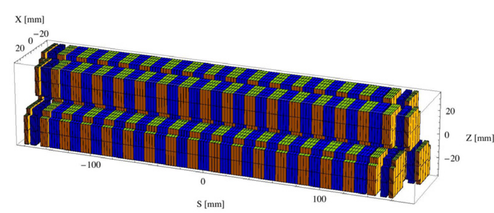

Figure 3: Magnetic model of the epu38Heli ID. The ID has been modelled with Radia [4]

WIGGLERS

The function of the wigglers at the 3 GeV storage ring is twofold, to act as damping wigglers to decrease the emittance of the stored beam and to be photon sources for experimental stations. The wigglers will also increase the energy spread of the stored beam. The wigglers may either be hybrid type wigglers using permanent magnet material in combination with soft magnetic materials in the pole centres or superconducting wigglers. The hybrid wiggler type have the advantages of e.g. lower running costs and lower technical risks compared to superconducting wigglers. On the other hand, the peak performance of superconducting wigglers is superior to hybrid type wigglers.

Hybrid type wigglers (wig)

The hybrid type wigglers are built from three basic building blocks, which are the main blocks of NdFeB with a remanence of 1.25 T, the side blocks of NdFeB with a remanence of 1.28 T , and the poles of Vanadium Permendur. Hybrid type wigglers with 3 different gaps, as described in Table 2, have been modelled. Figure 4 shows the wig 80 wiggler. The ID has been modelled with Radia [4].

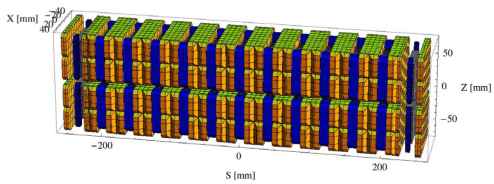

Figure 4: Magnetic model of the wig80 ID. The ID has been modelled with Radia [4].

Superonducting wigglers (scw)

The scw46 is a superconducting wiggler with NbTi coils operating at 4.2 K. The magnetic model of the scw46 is shown in Figure 5. The ID has been modelled with Radia [4]. The magnet model consists of the standing racetrack coils, with iron pole cores and iron return yokes. The current density in the coils is 750 A/mm^2. The period length is 46 mm and the magnetic gap is 12 mm, which should give enough room for a liner for the beam induced heat loads. The poles are 9.2 mm thick, 20 mm high, and 60 mm wide. The coils are 6.9 mm thick and have the same height as the poles. The return field yoke on top and bottom is 25 mm thick.

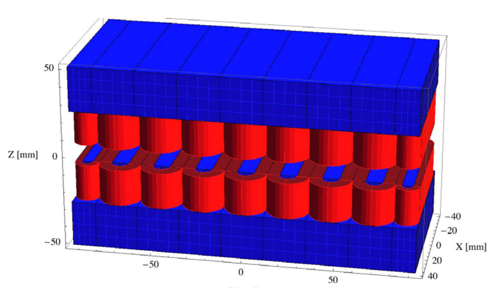

Figure 5: Magnetic model of the scw46 ID. The ID has been modelled with Radia [4].

SUMMARY

In total 15 different IDs for the MAX IV 3 GeV Ring have been modelled. The modelled IDs are listed in Table 2. The coice of IDs for the MAX IV Facilty is at present under discussion and the final choice of IDs for the MAX IV 3 GeV ring, the MAX IV 1.5 GeV ring, and the linac driven short pulse facility will be included in the DDR of the MAX IV Facility [2].

Table 2: The name, length, period length, magnetic peak field, *K*-value, total emitted power, and on-axis power density of the 15 modelled IDs

Name	Leng. [mm]	Per. [mm]	Field [T]	K	Power [kW]	P. Dens. $[\frac{kW}{mrad^2}]$
pmu18p5	3783	18.5	1.24	1.92	13.3	97.1
pmu20	3790	20	1.32	2.19	14.8	95.8
pmuC	3795	22	1.42	2.56	16.7	92.3
cpmuA	3799	15.6	1.23	1.67	14.3	119
cpmu16	3800	16	1.27	1.75	14.9	119
cpmuB	3800	16.4	1.29	1.83	15.5	119
epuI1011	2135	46.6	0.707	3.10	3.08	14.0
epu38	3931	38	0.974	3.50	10.9	43.9
epu43p6	3941	43.6	1.064	4.41	13.1	42.1
epu48	3906	48	1.12	5.12	14.5	40.0
epu53p6	3931	53.6	1.17	6.03	16.2	38.0
wigS	951	80	1.87	12.2	7.28	8.93
wigD	3991	80	2.22	14.1	40.4	47.7
wig80	3991	80	2.38	14.9	45.1	51.2
scw46	1969	46	3.69	15.6	74.3	67.2

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