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A CANTED DOUBLE UNDULATOR SYSTEM WITH A WIDE ENERGY RANGE FOR EMIL

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Abstract

At BESSY II a canted double undulator system for the Energy Materials In-situ Laboratory EMIL is under construction. The energy regime is covered with two undulators, an APPLE II undulator for the soft and a cryogenic permanent magnet undulator CPMU-17 for the hard photons. The layout and the performance of the undulators are presented in detail. The minimum of the vertical betatron function is shifted to the center of the CPMU-17. The neighboring quadrupoles and an additional quadrupole between the undulators control the vertical betatron function. Prior to the undulator installation a testing chamber with four movable vertical scrapers has been implemented at the CPMU-17 location. Utilizing the scrapers the new asymmetric lattice optics will be tested and optimized.

INTRODUCTION

EMIL, the Energy Material in-situ Laboratory at BESSY II, is under construction. The facility offers the tools for in-situ and in-system X-ray analysis of materials and devices for photovoltaic applications and for (photo-) catalytic processes. Spectroscopic methods such as PES, PEEM, HAXPES, XES, XAS, XRF, XRD are well suited for the investigation of sample structures with arbitrary depth information between a few nanometer and the micrometer regime. The EMIL laboratory is described in detail in [1]. Two canted undulators deliver photons over a wide energy regime: An APPLE II undulator for soft X-rays (80 eV- 2.2 keV) and a planar CPMU for hard X-rays up to 8 keV. Two beamlines including a double crystal monochromator (hard photons) and a collimated plane grating monochromator with variable deflection angle (soft photons) distribute the light to various end stations. The short period small-gap undulator CPMU-17 will be operated in a mini-beta section to mitigate deleterious effects to the storage ring performance and to avoid beam scraping with the magnets.

MINI-BETA-SECTION

The implementation of short-period small-gap undulators into low energy storage rings requires specific lattice modifications to maintain the beam lifetime at the reduced vertical aperture. Small-gap undulators installed in dedicated mini-beta section are in operation at the NSLS X-ray ring for many years [2]. At BESSY II it was decided to shift the waist of the vertical betatron function to the center of the cryogenic undulator. Asymmetric detuning of the neighbouring quads and an additional quad between the undulators permit a minimum aperture of 5 mm. The lattice modification and the asymmetric re-wiring of the adjacent multipoles are described in detail in [3] [4]. The modified optics without the central quad was already tested with beam. Meanwhile, the central quad and a testing chamber at the location of the CPMU-17 are installed. The chamber is equipped with four vertical scrapers for the detection of the vertical aperture at two locations which gives information about the size and the gradient of the vertical betatron function. The undulators are canted by an angle of 2 mrad which is accomplished with an electromagnetic coil integrated into the central quad. Space for a replacement with permanent magnet 1-mrad-steerers at a later time is foreseen. The 1-mrad kicks are generated from the steerer coils integrated in the neighbouring sextupoles.

UE-48 APPLE II UNDULATOR

The UE-48 is an APPLE II undulator with full polarization control (see Fig. 3). The low photon energy device is designed to cover the range between 80 eV (including the Si L II/III-edge at 99eV) and 2.2 keV (including the Si-K- edge at 1839eV) with the harmonics 1-7. The parameters are listed in Table 1.

Table 1: Parameters of the UE-48

Period length	48 mm
Number of periods	29, symmetric endpoles
Minimum magnetic gap	15 mm nominal
Gap between mag. rows	0.8 mm
Operational modes	Elliptical, inclined, universal
Magnets	$Nd_2Fe_{14}B$, transversally pressed in a dye
A-magnet (long. magn.)	1.28 T / 1670 kA/m
B-magnet (vert. magn.)	1.33 T / 1275 kA/m
B_{eff} (hor. lin. / hel. / vert. lin. / inclined 45°)	0.791 T / 0.626 T / 0.535 T / 0.443 T

The magnets were sorted with respect to systematic production errors, glued to pairs (one A- and one B-magnet) and finally machined before magnetization. The pairs were magnetized in a 45° oriented magnetic field where the easy orientations of the individual magnets determined the individual block magnetization orientation. This procedure will be described in detail in a separate publication.

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The standard BESSY end-pole configuration was adopted (Figure 1). The evaluated phase dependent field integral variations are small (Figure 2). Magic fingers [5] for the compensation of residual field integral errors are implemented at each and of a girder.

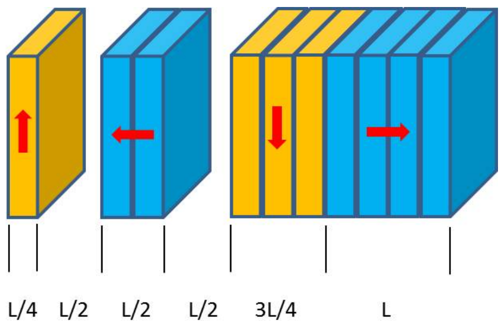

Figure 1: End-pole configuration.

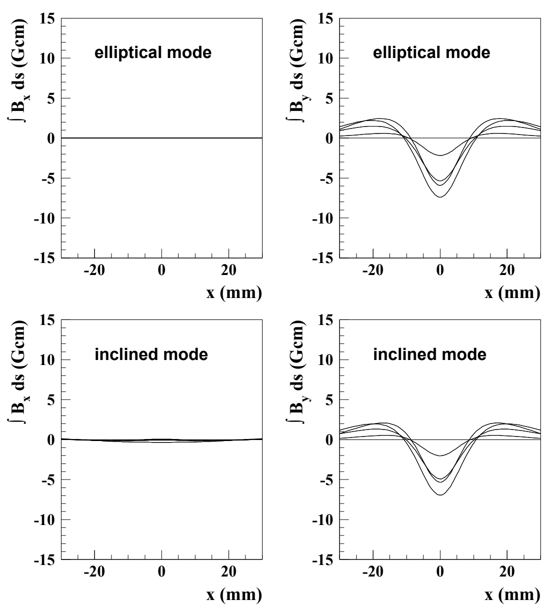

Figure 2: Evaluated field integral variations with phase at 15 mm gap (magnet size 40 x 40 mm^2).

The gap position and the gap size are controlled with four servo motors. Two motors drive the lower magnet girder. The related encoders are mounted to the support structure below the lower girder. The accuracy is ±20µm which is sufficiently accurate for the gap center position. The gap size is controlled independently with the other two motors. These motors use the standard C-shaped BESSY gap measurement system which connects upper and lower girders [6]. All four magnet rows can be moved independently, enabling all operational modes including the universal mode [7]. The girders are preloaded with springs to prevent them from jumping during the shift motion (reversal of vertical force direction). The specific engineering challenge of this device is the short length, particularly, for the implementation of the for longitudinal drive systems.

The vaccum chamber of the UE-48 is made from extruded Aluminum with an elliptical inner cross section. The inner surface is coated with non-evaporable getter (NEG).

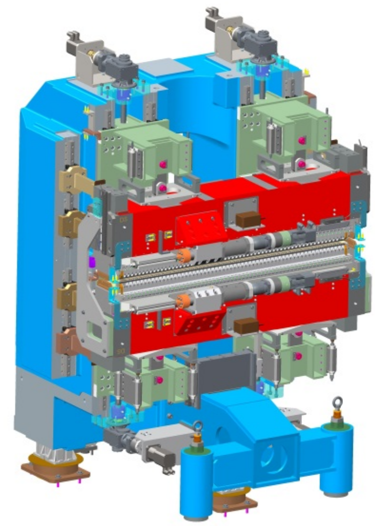

Figure 3: UE-48 APPLE II undulator.

CPMU-17 UNDULATOR

The CPMU-17 extends the energy range of the EMIL facility up to 8 keV (9th harmonic). The 3rd harmonic has an overlap with the UE-48. The 1st harmonic is used as well with a different monochromator (grating monochromator). The CPMU-17 (Figure 4) is a result of the CPMU-R & D at HZB over the last years [8]. The undulator is based on cryogenically cooled (Pr,Nd)2Fe14B magnets from Vacuumschmelze. The TiN-coated magnets are treated with a grain boundary diffusion process for an enhanced stability. The parameters of the undulator are summarized in Table 2.

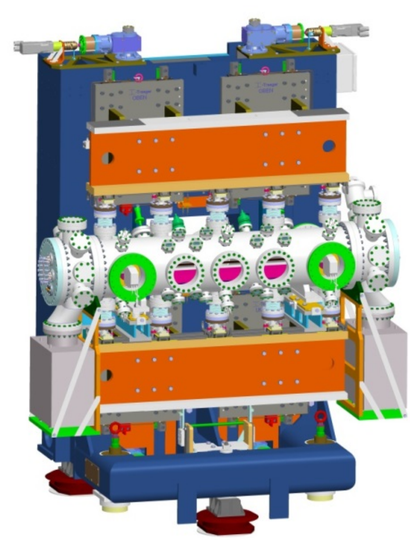

Figure 4: CPMU-17 undulator.

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Table 2: Parameters of the CPMU-17

Period length	17 mm
Number of full poles	175, symmetric endpoles
Minimum magnetic gap	5.5 mm
Minimum aperture	5.3 mm
Magnet material	(Nd,Pr)FeB grain boundary diffusion
Remanence (300 / 77K)	> 1.38 / 1.62 T
Coercivity (300 / 77 K)	> 1640 / 5340 kA/m
Maximum effective field	1.17 T
Coating	$3\mu m$ TiN
Pole material	CoFe
Cooling concept	direct cooling, liquid N_2

For a given aperture the minimum period length for K=2.5 is well defined (Figure 5). For the CPMU-17 the overlap of the 1st and 3rd harmonic is of minor importance, instead, the device is optimized for a high performance at the harmonics up to 9.

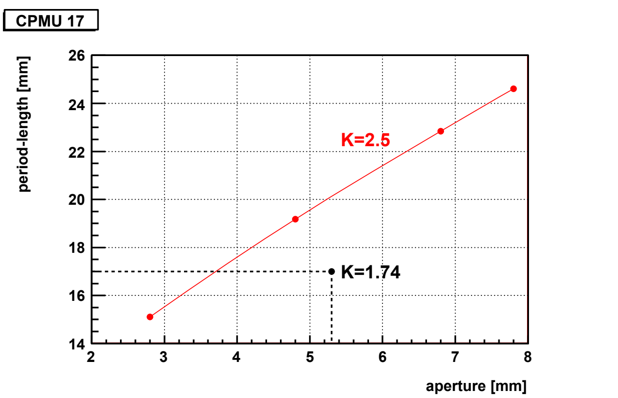

Figure 5: Red: Minimum period length which provides K=2.5 at a given aperture (magnetic gap - 0.2mm). By design the CPMU-17 value lies below this curve.

The endpole structure (Figure 6) consists of a magnet and a pole of reduced height (magnet: 2/3 of periodic magnet height). The other dimension (width, thickness) are equal to the values in the periodic part.

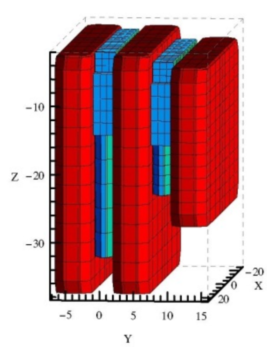

Figure 6: Endpole configuration of the CPMU-17 (RADIA coordinate system). The last magnet (red) and the last pole (blue) can be adjusted vertically.

The height of the endpole is optimized to minimize the field integral variations. The fine tuning of the device will be conducted with a height adjustment of either the end magnet or the endpole (Figure 7).

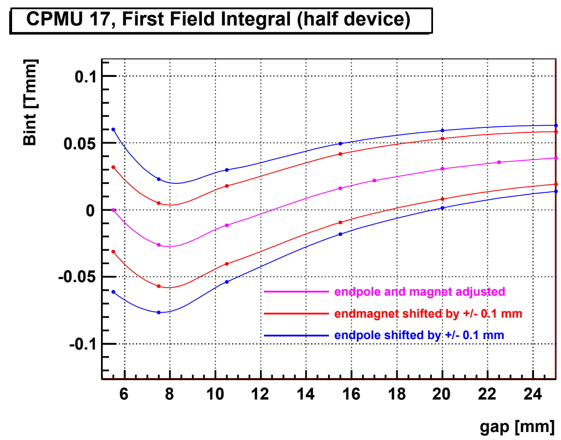

Figure 7: First field integral of the CPMU-17 endpole structure.

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