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The EMIL project at BESSY II: beamline design and performance

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Abstract. The Energy Materials In-Situ Laboratory Berlin (EMIL) at BESSY-II is currently under construction. Two canted undulators for soft- and hard X-rays will be installed into the BESSY II storage ring in one straight section, complex beamlines with more than twenty optical elements will be set up and a new laboratory building attached to BESSY II will host three endstations and a large UHV-transfer system connecting various HV- and UHV-deposition systems. The undulators, UE48 and U17, provide a broad energy spectrum of 80 - 10000 eV, of which the harder radiation (>700 eV) is provided by a cryogenic in-vacuum device. Three monochromators (two plane grating monochromators (PGM) and one LN_2-cooled double crystal monochromator (DCM)) disperse the radiation into separate pathways of 65 m length, while downstream of the monochromators split-mirror chambers distribute the photon beam to one (or simultaneously to two) of five upcoming endstations. Three of these endstations are designed for the full energy range with spatial overlap of the soft and hard foci, whereas one endstation (PEEM) uses only the soft and another one (PINK) only the hard branch, respectively.

INTRODUCTION

The Energy Material In-Situ Laboratory Berlin (EMIL) at BESSY-II combines the research activities of the Helmholtz-Zentrum Berlin (HZB) and the Max-Planck-Gesellschaft (MPG) with the focus on processes and devices for sustainable renewable energy supply. A new infrastructure is created consisting of novel undulator sources, a complex beamline layout and several endstations [1]. In a new laboratory attached to the BESSY-II facility several of these endstations are connected to deposition facilities integrated in one ultra-high vacuum system. Thereby an in-system, in-situ and in-operando X-ray spectroscopy approach meets challenges like investigating the growth of materials, formation of functional interfaces as well as the evolution of their properties [2].

At EMIL the most complex beamlines at BESSY-II so far will be installed. Two canted undulators provide the energy ranges of 80 - 2200 eV (UE48) and 700 - 10000 eV (U17): The hard X-ray beamline houses a double crystal monochromator (DCM) for the energy range above 2 keV and alternatively a plane grating monochromator (PGM) for the first harmonic of the cryogenic undulator from 700 - 1650 eV. The radiation of the soft X-ray beamline (80 - 2200 eV) is dispersed by another plane grating monochromator. Both PGM's are operating in collimated light. Over a distance of 65 m both branches are focused onto one joined spot. Similar optical layouts with two canted undulators are successfully in operation at Diamond Light Source [3] and planned at the NSLS II (Brookhaven National Laboratory) [4].

More than 20 optical elements and several switching mirror units serve five endstations. Three of them have to be supplied with the full energy range of 80 – 10000 eV. These stations are (a) Solar Energy Material In-situ

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Spectroscopy at the Synchrotron (SISSY I), (b) in-situ deposition/analysis chamber and/or Hard X-ray photo emission electron microscopy (SISSY II) and (c) Catalysis Research for sustainable Energy Supply (CAT). A pointing stability of 20 µm for the joined focus of both beamlines has to be realized. Furthermore an additional station will be supplied with the soft radiation (Photoemission Electron Microscopy – PEEM) and another station with hard radiation (PINK) for (non-)resonant X-ray Fluorescence.

UNDULATORS

The two undulators are designated to deliver photons in the energy range from 80 to 10000 eV. An APPLE II undulator UE48 will provide photons from 80 to 2200 eV. An in-house developed planar cryogenic in-vacuum undulator U17 will cover the energy range from 700 to 10000 eV. The insertion devices are canted by 2 mrad to separate both beam cones. The vertical electron beam waist in the straight section is shifted to the center of the cryogenic undulator to realize a minimum gap of 5.5 mm. The minimum of the horizontal beta-function is located at the center of the straight section [5]. The expected brilliance and photon flux curves are shown in Figure 1 while undulator parameters are listed in Table 1.

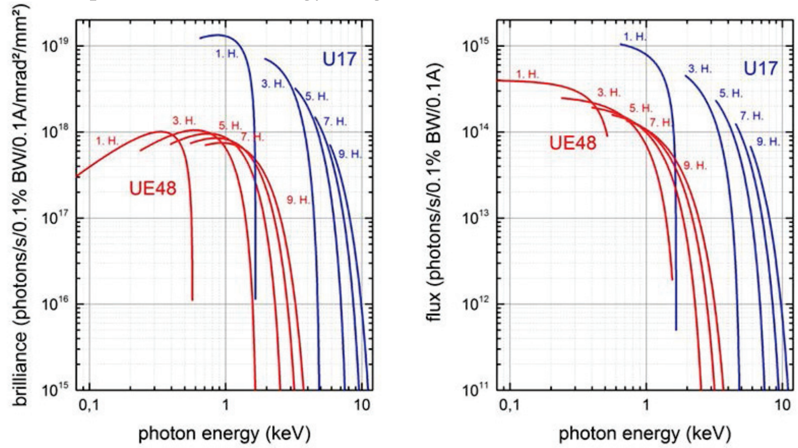

FIGURE 1. Brilliance and photon flux of both undulators – the odd harmonics 1,3,5,7 and 9 are shown

TABLE 1. Parameters and energy ranges of the soft and hard undulators UE48 and U17

Undulator		**UE48**	**U17**
Period length	[mm]	48	17
Periods		29	88
Total length	[mm]	1392	1496
K_{max}		3.55	1.78
B_{max}	[T]	0.79	1.12
gap_{min}	[mm]	15	5.5
Total power (300mA ring current)	[W]	479	1031
Max. power density @ 10 m (300 mA)	[W/mm^2]	6.9	25
Max. central cone $\sigma_{u_{x',y'}}$ @ lowest energy	[µrad²] h × v	108 x 72	87 x 27

HARD X-RAY BEAMLINE

Two monochromators for different energy ranges are integrated in the hard X-ray beamline to exploit the full energy range of the U17 above 700 eV (compare Fig. 2). After passing the Pt (35 nm) / Rh (6 nm) coated toroidal mirror M1, which focuses horizontally on the exit slit unit of the CAT beamline, the vertically collimated beam will be either diffracted by the double-crystal monochromator or passed to a plane grating monochromator with blazed gratings (400 and 800 l/mm). The double-crystal monochromator is equipped with three crystal pairs: Si 111 (2 – 10 keV), Si 311 (3.8 – 10 keV) and Si 422 (5.7 – 10 keV). Both PGM and DCM create a vertical beam shift of 20 mm. A switching mirror unit M3 distributes the radiation to the endstations SISSY I and II or CAT. The cylindrical mirrors M3 focuses vertically on the corresponding exit slit that determines the bandwidth in PGM operation mode. An ellipsoidal mirror M4 refocuses the radiation to the CAT-experiment. A further switching mirror unit M4 in the SISSY branch allows operation of two experimental stations SISSY I and SISSY II behind each other.

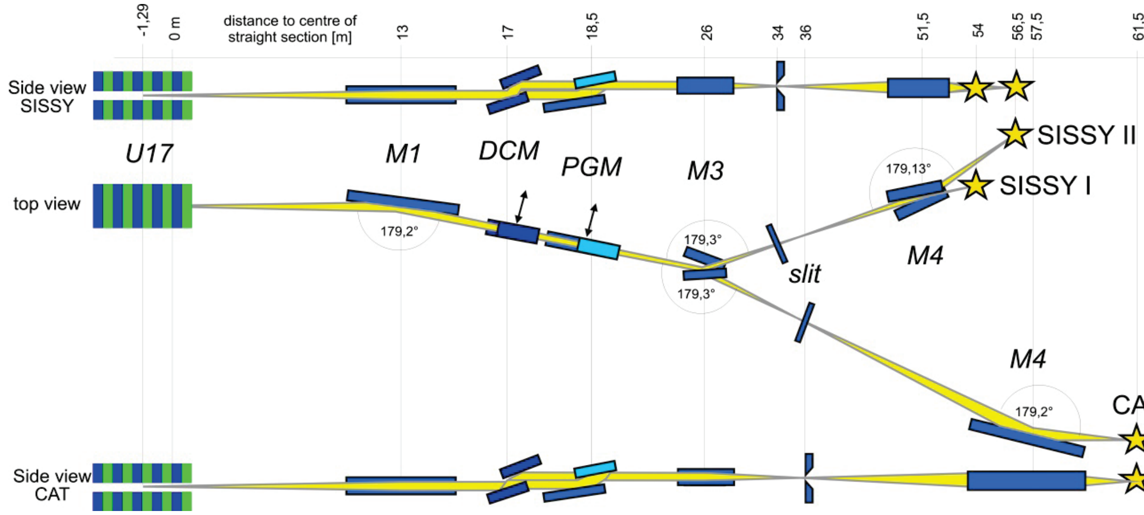

FIGURE 2. Layout of the hard X-ray beamline

SOFT X-RAY BEAMLINE

Figure 3 shows the optical layout of the PGM-beamline. A toroidal mirror M1 collimates (vertically) and focusses (horizontally) the UE48 beam onto the exit slit. The radiation is dispersed by a plane grating monochromator equipped with two blazed gratings (400 and 800 l/mm). A switching mirror unit M3 with two cylindrical mirrors deflects the beam to the endstations SISSY-I and SISSY-II or to another upcoming PEEM station

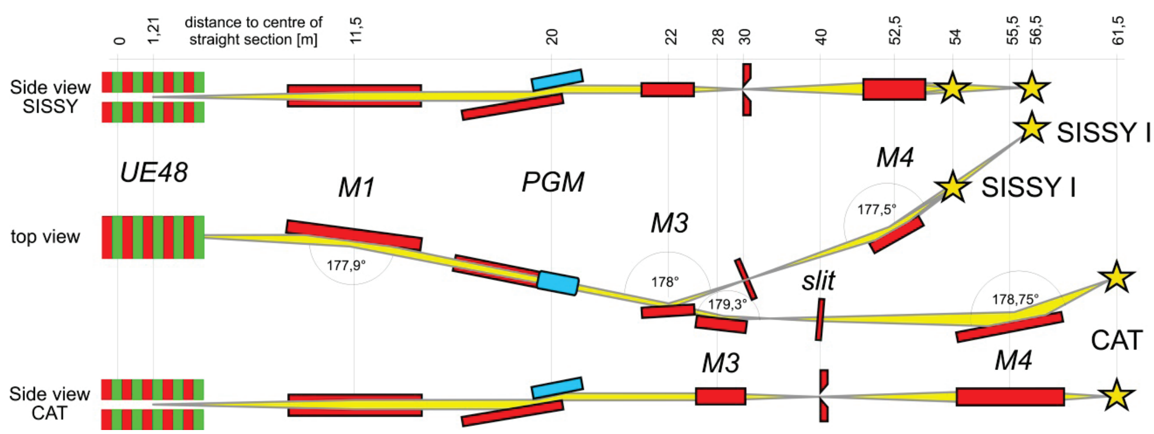

FIGURE 3. Layout of the soft X-ray beamline

(not shown in Figure 3). Alternatively the mirrors are retracted and an additional cylindrical mirror provides the radiation for the CAT experiment. Two ellipsoidal mirrors in the switching mirror unit M4 refocus the exit slit stigmatically to either the SISSY-I or SISSY-II endstation, and a toroidal mirror refocuses the beam to the CAT endstation.

PERFORMANCE

The optical performance of the EMIL beamline was intensively calculated with RAY [6]. We expect spot sizes of approximately 45 × 10 µm² and 120 x 10 µm² for soft and hard branch, respectively. The wide angular ranges of both plane grating monochromators (up to 15.3° for the mirror and 19.1° for the gratings) allow for a wide operating energy range without grating change. Figure 4 shows the estimated resolving power (left side) and photon flux at sample position (right side) for the soft X-ray beamline as a function of energy and c_{ff}-factor. At the standard c_{ff}-factor (2.25), for instance, the usable energy range is 70 – 2000 eV. In Figure 5 photon flux and resolving power for

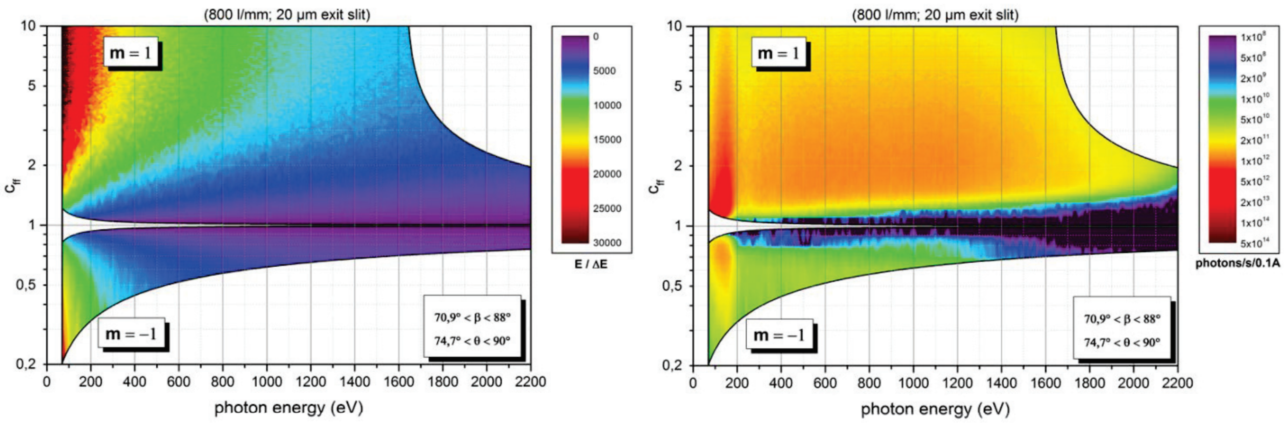

FIGURE 4. Resolving power (left) and flux on sample (right) for the soft X-ray beamline

soft and hard X-ray beamline are plotted (here shown for c_{ff} = 3 in PGM-operation). The performance for the endstations SISSY-I, SISSY-II and CAT will be similar.

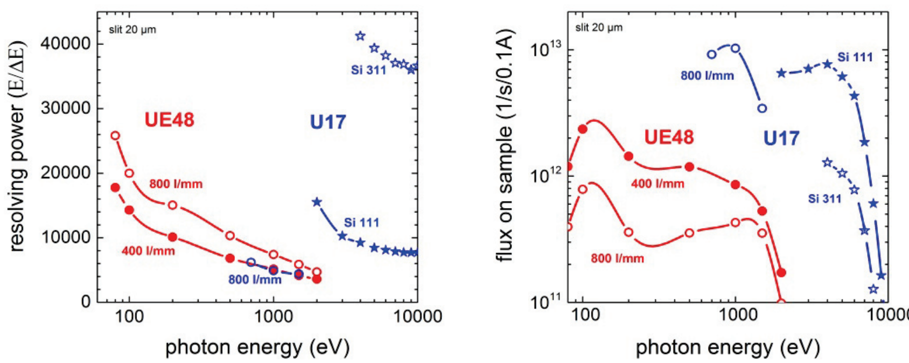

FIGURE 5. Resolving power and flux on sample for different settings of both beamlines

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REFERENCES

1. R. Follath, M. Hävecker, G. Reichardt, K. Lips, J. Bahrdt, F. Schäfers and P. Schmid, J. Phys.: Conf. Ser. 425 212003, pp. 1-4 (2013)
2. K. Lips, D. E. Starr, M. Bär, T. F. Schulze, F. Fenske, S. Christiansen, R. van de Krol, S. Raoux, G. Reichardt, F. Schäfers, S. Hendel, R. Follath, J. Bahrdt, M. Scheer, G. Wüstefeld, P. Kuske, M. Hävecker, A. Knop-Gericke, R. Schlögl and B. Rech, Photovoltaic Specialist Conference PVSC IEEE 40th pp. 698-700 (2014).
3. J. J. Mudd, T.-L. Lee, V. Munoz-Sanjose, J. Zuniga-Perez, D. Hesp, J. M. Kahk, D. J. Payne, R. G. Egdell and C. F. McConville, Phys. Rev. B 89, p. 035203 (2014).
4. R. Reininger, J. C. Woicik, S. l. Hulbert, D. A. Fischer, Nucl. Instr. and Meth. in Phys. Res., A, 649 , pp. 49-51 (2011)
5. P. Schmid, J. Bahrdt, T. Birke, R. Follath, P. Kuske, D. Simmering and G. Wüstefeld, Proceedings of IPAC, New Orleans, USA, pp. 1614-1616 (2012).
6. F. Schäfers, RAY - the BESSY raytrace program, (In: Springer Series in Modern Optical Sciences: Modern Developments in X-Ray and Neutron Optics, eds. A. Erko, M. Idir, Th. Krist, A.G. Michette), Springer Berlin/Heidelberg, Vol. 137, pp. 9-41 (2008).