MINI-BETA SECTIONS IN THE STORAGE RING BESSY II

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Abstract

At BESSY II photon energies above 2keV can be produced only with a permanent magnet wiggler, with superconducting wavelength shifters and with a superconducting wiggler. The wiggler brilliance suffers from the depth of field effect and the wavelength shifters produce the X-rays only from a single pole. For the generation of brilliant radiation above 2keV a small period cryogenic undulator has to be used. This paper discusses the machine requirements for the operation of small gap cryogenic devices at BESSY II. A scheme with two adjacent vertical low-beta sections inside of one of the long straight sections is suggested. The straight is divided into two parts by a quadrupole triplet in the center. An optic with an increased vertical beta tune by 0.5 is presently studied. The optics outside of the low-beta section and the horizontal tune are kept unchanged.

INTRODUCTION

The development of highly efficient thin film solar cells is an important topic of research at the Helmholtz-Zentrum Berlin (HZB). **A** **S**ilicon **In**-**Si**tu Lab at the **Sy**nchrotron Beamline, called SISSY, is planned at BESSY II. This facility will permit an in-situ monitoring of the growth process of thin solar cells, the in-situ diagnostic of individual layers and the characterization of the interfaces. Various techniques will be available such as photoemission spectroscopy and PEEM of surface layers or X-ray absorption and diffraction for the study of deeper interfaces. With a photon energy range from 50eV-8keV the depth of observation can be tuned in the range from a few nm up to a few μm. Another field of research at BESSY II is the **HI**gh **K**inetic **E**nergy photoemission spectroscopy (HIKE). A wide energy tuning range is essential also for these experiments. Both classes of experiments are based on a high resolution secondary spectrometer which requires a spot size at the sample of 100μm.

So far, these experiments have to be done either at a dipole, a permanent magnet wiggler, a superconducting wavelength shifter (SC-WLS) or a SC-wiggler. These devices have a low brilliance and a short period undulator provides a better performance. Therefore, two canted undulators with a canting angle of 3-4mrad are planned. An elliptically polarizing device will cover the soft X-ray regime and a cryogenic planar device will deliver hard X-rays up to 8keV. A grating and a crystal monochromator are foreseen to transmit both photon beams simultaneously to one of up to three end stations.

It is worth noting that for energies above 8keV the photon beam of a BESSY II dipole or WLS, may be focused to a 100μm spot with a comparable flux density as a cryogenic undulator. However, this can never be accomplished for three independent end stations.

In this paper possible modifications of the storage ring optic are discussed which minimize the impact of the small period small gap undulator on the ring.

CRYOGENIC UNDULATOR

The cryogenic undulator has a hybrid design with PrFeB-magnets [1] and CoFe-poles. The device has a period length of 16.25mm, a minimum gap of 5mm and a magnetic length of 1.2m. The period length has been chosen such that the 3rd harmonic goes down to 2keV and the 3rd and 5th harmonic overlap. The device is supposed to be operated up to the 9th harmonic.

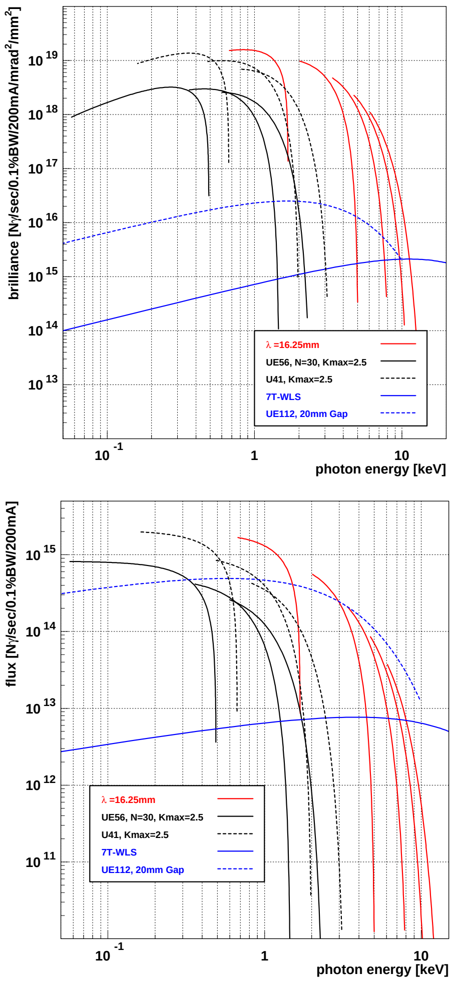

Figure 1 & 2: Brilliance (top) and flux (bottom) of existing insertion devices at BESSY II and of a cryogenic undulator with a period length of 16.25mm. The fluxes of the SC-WLS and the UE112 in the wiggler mode are given for a horizontal angle of 1mrad (vertically integrated).

MINI-BETA SECTIONS

BESSY II has a double bend achromat lattice with 16 straight sections. Eight straights are equipped with additional quadrupoles which produce small horizontal beta functions. Thus, the lattice consists of alternating high- and low- beta sections with slightly different available length. Due to the geometric constraints the two canted undulators can be installed only in a high-beta section. The optic has to be modified such that the vertical beta function is reduced to a value which allows for a minimum gap of 5mm without sacrificing dynamic aperture. This has to be guaranteed for Top-Up operation as well as for special modes like single bunch or low-alpha optics.

It is well known that the on-momentum single particle dynamic does not change if a phase advance of multiples of 2π is introduced to either the horizontal or the vertical plane in a part of a storage ring leaving the rest of the ring unchanged. Regarding only magnets with midplane symmetry (no skew magnets) the on momentum particle dynamic is unchanged also if the phase in the vertical plane is enhanced by multiples of π while keeping the horizontal phase constant [2]. This concept was already used at BESSY I to prepare the ring for a 6T-WLS. Two mini-beta straights, each employing a phase advances of π, were realized. Other facilities have implemented the concept as well [3-5]. The following studies are based on a symmetric solution with two mini beta sections as produced with a quadrupole triplet in the center of the straight. Non-symmetric solutions such as a quadrupole doublet [5] or a non-symmetric triplet (shifted with respect to the center of the straight) are not considered here.

The new mini-beta optics provides a minimum vertical beta-function of 0.67m (figure 3). For the nominal vertical physical aperture of 11mm (assuming an ideal alignment of all existing ID-chambers and negligible fabrication errors) a cryogenic undulator with a length of 1.2m would not reduce the vertical aperture. Nevertheless, apertures have to be provided to avoid scraping the halo of the electron with the undulator.

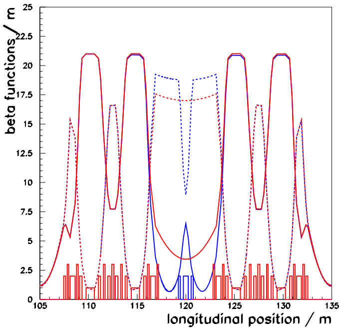

Figure 3: Old optic (red) and new optic (blue). Solid lines: vertical betatron function, dashed lines: horizontal betatron function. The existing magnets are plotted in red. The additional quadrupole triplet is plotted in blue.

TRACKING SIMULATIONS

The tracking simulations are based on analytic generating functions [6]. The complete 3D-undulator fields are represented by scalable analytic expressions which are directly implemented into the generating functions [7]. A numerical FEM code is required to evaluate the transverse field profile at one pole which is decomposed into Forurier components for the field parametrization. With a pole width of 21.67mm (including cut outs for camping of 3.56 x 1.78 mm^2) the transverse field distribution has been expanded within a region of 100 mm into 20 Fourier components. This data set provides an excellent field representation for the tracking simulations (figure 4).

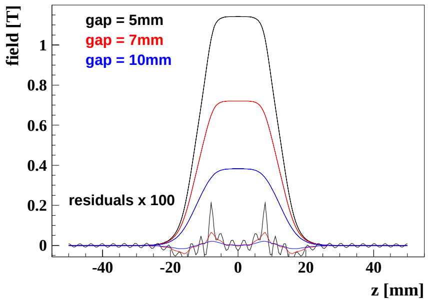

Figure 4: Transverse field profiles at various gaps of the cryogenic undulator with a pole width of 21.67mm (including cut outs). The deviations of the model and the exact fields are plotted as well.

So far tracking simulations have been performed only for on momentum particles. The dynamic aperture is reduced with the new quadrupole triplet. It can partly be recovered by detuning the harmonic sextupoles close to the modified straight section (figure 5, figure 6, top). Overall, BESSY II has 4 harmonic sextupole families, two independent families in either of the low-beta and high-beta straights.

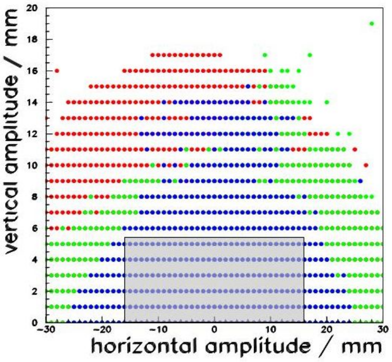

Figure 5: Amplitudes of particles which survived 1000 turns. Red: old optic; blue: mini-beta optic with old sextupole settings; green: mini-beta optic with new sextupole settings. The physical aperture is indicated as a grey rectangular area.

Introducing the undulator with a field roll-off as depicted in figure 4 the dynamic aperture breaks down (figure 6, middle). Scaling the transverse field distribution by a factor of two the dynamic aperture recovers (figure 6, bottom).

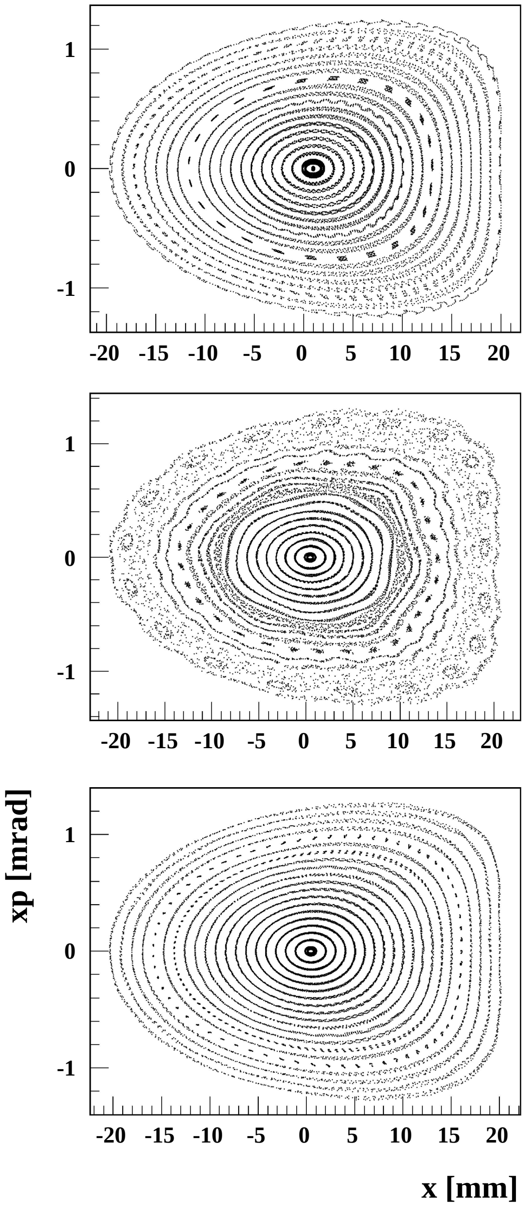

Figure 6: Horizontal phase space from tracking simulations. Mini-beta optic without undulator and y=5mm (top), with undulator with pole width of 21.67mm and y=3.5mm (middle) and with undulator with pole width of 2 x 21.67mm and y=3.5mm.

This artificial widening of the good field region can be accomplished in several ways:

- Using wider poles
- Shaping the poles
- Applying magic fingers at the undulator ends

Wide poles imply more magnetic material and stronger forces which influence the mechanic design. Furthermore, the working point of the magnetic material is closer to the 3rd quadrant. Shaped pole pieces are expensive to fabricate and they may interfere with the thin Ni-foil for RF-shielding. Probably, magic fingers at either end of the undulator are well suited to compensate the dynamic multipoles which would permit a smaller pole width. This concept has to be verified with tracking simulations.

CONCLUSION AND FUTURE PLANS

Preliminary on momentum particle tracking studies show that a mini-beta section for the installation of a narrow gap undulator into BESSY II seems to be feasible if the phase advance is π vertically and zero horizontally (π -trick). The transverse field roll-off of the undulator has to be controlled either by wide poles or by appropriate magic fingers. Off momentum particle tracking including other insertion devices as well has to be done in the future. Based on detailed tracking simulations it is planned to install a quadrupole triplet in the near future to verify and optimize the proposed mini-beta optic. Non-symmetric optic modifications which could provide more space for the insertion devices will be studied in the future as well.

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