A Double Undulator for the Production of Circularly Polarized Light at BESSY II *

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1 INTRODUCTION

The low emittance synchrotron radiation light source BESSY II [1] is presently being constructed in Berlin Adlershof. The specifications of an elliptical undulator to provide elliptically polarized light were derived from the requirement to reach the rare earth $M_{IV/V}$ edges. For the BESSY II beam energy of 1.7 GeV a Sasaki type undulator [2] with a period length of 56 mm and a minimum vertical gap of $\pm$ 10 mm covers the range up to 1300 eV with the fifth harmonic.

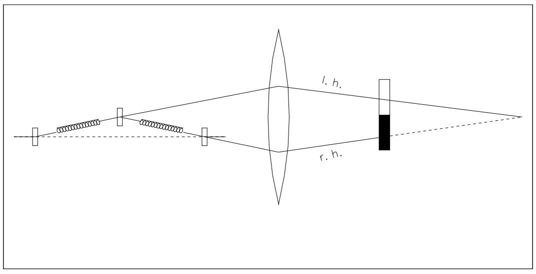

Figure 1: Setup of the double elliptical undulator and a chicane to separate the two beams, which are focussed to a probe.

A double undulator setup with a photon beam separating chicane (200 μrad deflection) and a chopper was adopted to provide a polarization switching rate of 100 Hz. The arrangement is illustrated schematically in the fig. 1.

2 CALCULATION OF MAGNETIC FIELD

The Sasaki design consists of two upper and two lower rows of permanent magnets. Between the upper and lower rows is a variable gap to change the on-axis field. In addition two e.g. the left upper and the right lower rows can be shifted simultaniously with respect to the other rows. This phase or row shifting results in a magnetic field of arbitrary ellipticity.

The magnetic field of the UE56 (2 times 30 periods) has been calculated with a current sheet method integrating the contributions of all magnets [3]. The remanent field of the permanent magnets was set to 1.1 Tesla in the calculations. The dimension of the NdFeB magnets are 40 mm $\times$ 40 mm $\times$ 14 mm with a magnetization along the 40 mm and the 14 mm side. The resulting on axis field amplitudes are shown in fig. 2.

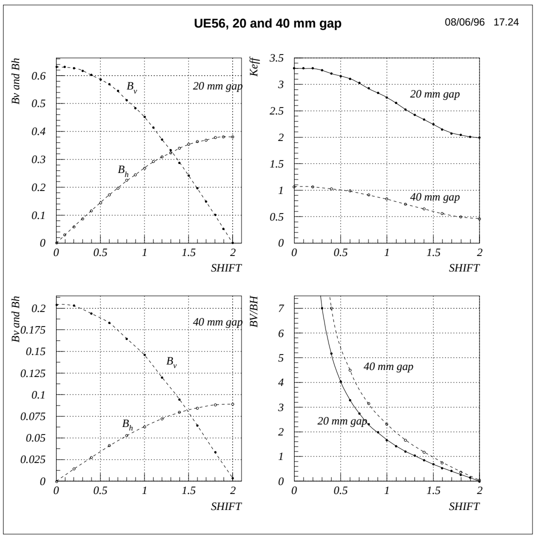

Figure 2: Dependence of horizontal and vertical field components B_h and B_v, respectively, and the resulting K-value for two different gaps on the shift parameter.

The figure shows that the maximum horizontal field is less than the maximum vertical field. This is a feature of all planar elliptical undulators. The shift for purely helical field depends weakly on the gap.

3 CALCULATIONS OF SPECTRA AND OPTIMIZATION OF THE SHIFT PARAMETER

To calculate the spectral features and optimize the magnetic design the program WAVE [4] has been used. The program makes use of the current sheet method mentioned above. The program tracks a single electron through the magnetic field of the undulator including the chicane. From the trajectory the electric field amplitude at the observation plane

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had been calculated by integrating the corresponding equations as given by Jackson [5]. The Stokes vectors were calculated from the field amplitudes. A typical distribution of the circularly polarized photon flux (S_3) is shown in fig. 3.

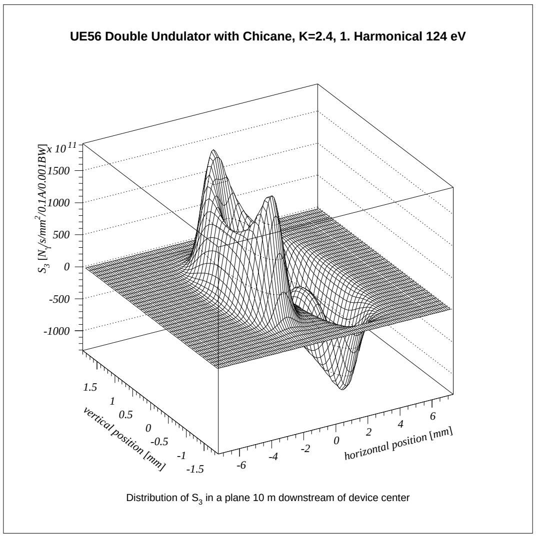

Figure 3: The figure shows the circularly polarized photon flux density S_3 in a 10 m distance from the center of the straight section. The spererated cones corresponds to the left and right handed light of the two elliptical undulators.

The program takes into account the beam energy spread and beam emittance effects by folding the single electron distributions with appropriate gaussians. By varying the phase shift of the magnet rows the optimum shift parameter with respect to the figure of merit $((S_3/S_0)^2 \times S_0)$ has been derived. For the first harmonic the figure of merit has a maximum at a shift parameter of 1.3 where the horizontal and vertical fields have the same strength (fig. 2). To produce higher harmonics the field must be elliptical, and the optimized shift parameter decreases with an increase of the harmonic number. It turned out that the optimum phase shift is same for the polarized flux and brilliance.

4 INTERACTION WITH THE STORAGE RING

The magnetic field of the elliptical undulator forces the electrons on a rather complex orbit. The closed orbit of the beam is screwed around the devices axis with one turn per period. Off axis particles will oscillate around this orbit with a much longer period. The focal length of the device is of the order of some few 10 meters, which indicates a rather weak disturbance to the optics. Of more concern are the coupling terms between the horizontal and vertical plane.

Linear 4×4 transfer matrices of the double undulator as a function of the phase shift are shown in fig. 4. Each plot corresponds to one matrix element. The matrices were derived from tracking particles within a phase space of $0.1\ mm$ and $0.1\ mrad$ around the central axis of the device. The figures show that coupling terms occur for non zero phase shifts.

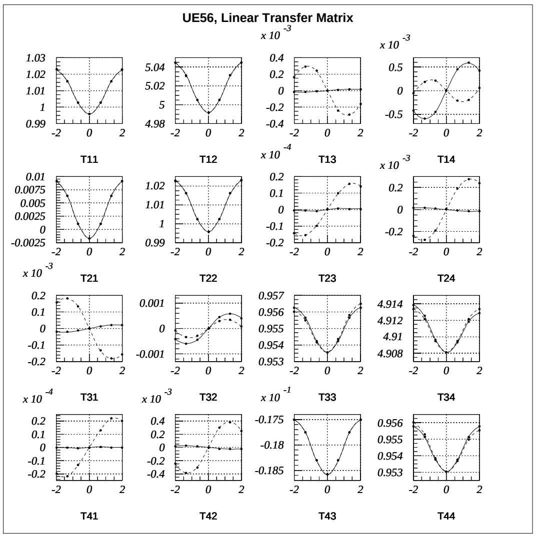

Figure 4: The sixteen plots show the elements of the linear transfer matrix of the elliptical undulators as a function of the phase shift i.e. row shift. The solid lines refer to the case where both undulators have the same helicity, the dashed lines refer to an opposite helicity.

If the two modules of the double undulator are operated with opposite helicities some of the coupling terms nearly cancel each other. The simultanious focussing in both planes for zero phase shift results from a 1 mm spacing of neighbouring magnet rows, which causes on-axis a dip in the field map. Due to the weak focussing and coupling we did not expect strong effects of the undulator on the beam dynamics.

This has been comfirmed by tracking calculations with the tracking code BETA [6]. For the calculations with the elliptical device one of the planar undulators in the high beta section has been replaced by the UE56. We have implemented a fast canonical tracking routine based on a fourth order polynomial fit of a generating function $F(q_{x_i}, p_{x_f}, q_{y_i}, p_{y_f})$ [7]. The coefficients of the fit were derived with the program WAVE. The phase shift was chosen to one. The apertures in fig. 5 show no significant differences to the reference optics with 14 various planar insertion devices. The apertures were obtained from 1000 turns, at nominal particle momentum, and no further errors activated.

Ignoring nonlinear terms of the generating function (i.e. linear tracking) we get nearly the same results. The linear part of the generating function refers to all the considered phase space and differs therefore from the linear transfer

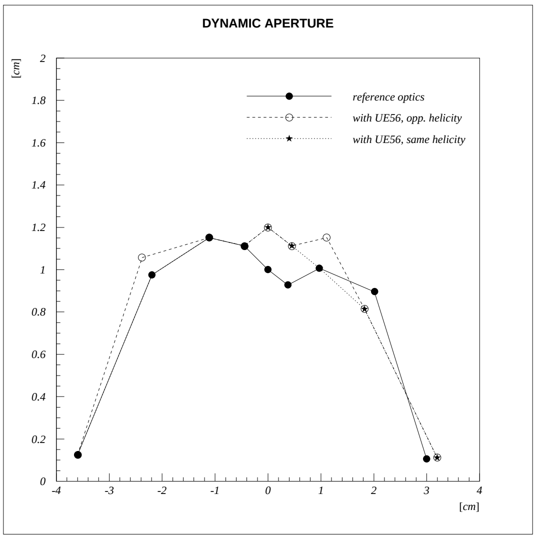

Figure 5: The figure shows the dynamic apertures for the reference optics with a standard set of insertion devices and the optics including an UE56 (two modules).

matrices of fig. 4.

In case of a stronger coupling the optics have to be adapted.

5 FUTURE PLANS

In the next step we will investigate the effects of the device on off- momentum particles and misalignment errors of the storage ring magnets. An analytical generating function has been established, and is planned to be implemented into BETA. This offers an easy variation of the device parameters within the tracking code. The effect of coupling terms on the vertical emittance will be investigated.

6 REFERENCES

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