Status of the Insertion Devices for BESSY II

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1 INTRODUCTION

The Synchrotron Radiation Light Source BESSY II * [1] is a third generation machine with an emittance of $\epsilon_x = 6 \cdot 10^{-9}$. It has a sixteen fold symmetry. Fourteen straight sections are available for the installation of insertion devices. There are seven high and seven low beta sections with a usable length of 4.2 m and 3.4 m respectively. This article focusses on the permanent magnet undulators and wigglers.

2 INSERTION DEVICES

The permanent magnet undulators and wigglers will be designed, constructed and assembled at BESSY whereas the manufacturing of all components will be done outside.

A minimum vacuum gap of 16 mm has been decided which determines a minimum magnetic gap of 20 mm. If possible the 16 mm chambers will be replaced by 12 mm chambers later in time.

Tab.1 shows the insertion devices which will be built during the next few years. The number included in the ID-name indicates the period length in mm. The first insertion devices will be built in the following order: U-49a, U/W-125a, UE-56a, U-41, U/W-125b, U-49b, UE56b. A U-180 electromagnetic undulator has already been bought by the Physikalisch-Technische Bundesanstalt for radiometric applications.

The U-49 undulator (hybrid) has the shortest period length which is compatible with a 16 mm vacuum gap and hence a 20 mm magnetic gap.

The undulator U-125 (hybrid) extends the tuning range to the low energy region down to 11 eV at K=6.4. The same device can be operated also in a wiggler mode (W-125) with K=12.8 and a characteristic energy of 2.1 KeV at 1.7 GeV electron energy.

The undulator U-41 (hybrid) is optimized for microscopy applications. It will be installed in a low beta section since the spatial flux density is higher by a factor of 3.8 compared to a longer device in a high beta section. Even with a minimum magnetic gap of 20 mm the U-41 will cover the C, N, O K-edges with the first harmonic. The first and third harmonic, however, do not overlap. When the 12 mm chamber is being installed a reduced magnetic gap of 16 mm provides an overlap of the first and third harmonic.

The undulator UE-56 [2] (pure permanent magnet device of the Sasaki type [3]) is optimized for the production of right and left handed circularly polarized light as well as horizontally and vertically polarized light. Two undulators with a chicane are installed into a long straight section. One undulator produces left handed the other one right handed circularly polarized light. Polarization switching will be done with a chopper downstream in the beamline.

Table.1 Insertion devices for BESSY II. Units: period length λ_0 in mm, total length L in m, magnetic and vacuum gap in mm, energy range in eV

Name	U-125	U-49	U-41	UE-56
λ_0	125	49	41	56
periods	32	84	81	2 x 31
L	4.0	4.12	3.35	1.68
m. gap	20	20	16	20
v. gap	16	16	12	16
1st H.	11-195	136-497	173-595	119-435
K	6.4-0.5	2.5-0.5	2.4-0.5	2.5-0.5
3rd H.	160-439	408-1120	518-1338	357-980
K	2.5-1.0	2.5-1.0	2.4-1.0	2.5-1.0
5th H.	267-595	679-1518	863-1814	595-1328
K	2.5-1.3	2.5-1.3	2.4-1.3	2.5-1.3

3 SUPPORT AND DRIVE SYSTEM

The total length of a long (high beta) insertion device is 4.2 m. In the longitudinal direction the magnetic structure is splitted into two parts which has several advantages: reduced thermal sensitivity, reduced weight of the I-beams, simpler and less expensive machinig of the I-beams, simpler handling and assembling of the magnetic structure and more flexibility (double undulator). The two structures are separated by a gap of only a few tenth of a mm in order to avoid an additional endpole compensation at the interface. The two modules can be driven synchronously. The modules can be driven independently in case two different devices are realized. This will be done for the UE-56 which will be a double undulator.

The complete device is mounted on a common cast iron base frame which rests on three feet. This frame supports four cast iron C-structures. Each of the four C-structures carries two screw units which are rigidly coupled from top to bottom and which are driven by one servo motor. The gap is measured and adjusted at four different locations. A four axis controller receives the information of four linear encoders and drives the four servo motors in a feed back loop.

The low beta insertion devices will have a length of only 3.4 m. The magnetic structure will not be splitted in longitudinal direction and hence only two C-structures, two servo motors and four screw units are needed. Basically, the support and drive system will consist of the same mechanical parts except for the base frame which has to carry only two C-structures.

The positioning accuracy of the gap drive system has been specified to be $\pm 3\mu m$. This tight tolerance is needed in the scanning mode of operation, when the monochromator and the undulator are driven in parallel. For absorption and excitation experiments it is essential to keep the source characteristic constant during subsequent scans which leads to the requirement that the detuning of the undulator may not exceed 1/10 of the width of the fifth harmonic. Even with the inclusion of emittance and energy spread the line width of the fifth harmonic of the U-49 is only 1/250 which leads to the specification of $\pm 3\mu m$.

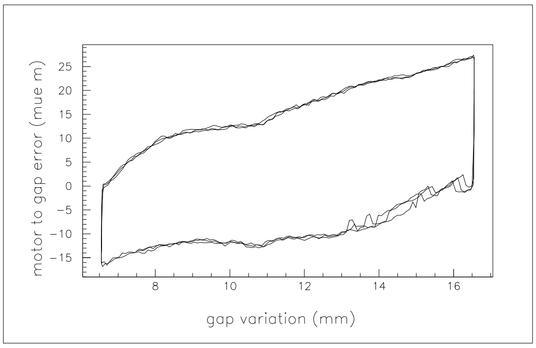

Figure 1: Backlash of the drive train

Table.2 Performance of the BESSY II prototype support and drive system

	Meas.	Spec.
minimum step size	$\leq 1\mu m$	$3\mu m$
gap reproducibility	$1\mu m$	$3\mu m$
backlash, feedback not active	$20\mu m$	—
backlash, feedback active	$1\mu m$	$5\mu m$
deviation between two gaps at rest	$\pm 1\mu m$	$\pm 3\mu m$
deviation from ideal path during gap drive	$\pm 1\mu m$	—
difference between two gaps during gap drive	$\pm 2\mu m$	$\pm 3\mu m$

The prototype support and drive system of a long undulator has been assembled and tested and it meets and even exceeds specifications. The results are summarized in table.1. To simulate the magnetic forces during testing two screw unit pairs have been preloaded with spring columns that apply a force of 15 kN each. During the tests the linear encoders are mounted onto the spring columns. The backlash of the mechanical system is $20\ \mu m$ (fig.1). It is well compensated once the system is operated in a feed back mode. The positionig accuracy is $1\mu m$ even if the direction of motion is reversed (fig.2) Two drive trains have been measured simultaneously during motion from a 20 mm to 60 mm gap and vice versa. The relative gap difference never exceeds $\pm 2\mu m$. On a smaller time scale the control cycle of the motor controller is visible (fig.3).

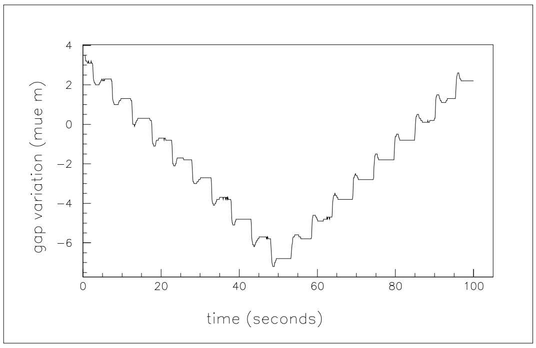

Figure 2: Positioning accuracy of the drive system

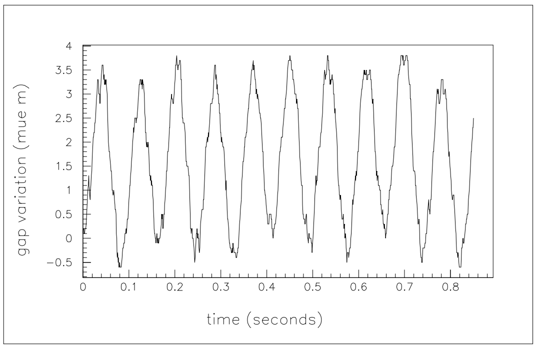

Figure 3: Difference of two gaps during parallel motion of two drive trains

4 U-49 UNDULATOR

4.1 Single Block Measurements

The periodic part of the magnetic structure consists of 1032 magnet blocks. All blocks have been rotated around two orthogonal axes inside a Helmholtz coil. The induced voltages have been taken on the fly. After correction for speed variations all three dipole components have been derived (main component:$\sigma = 0.53$ %, angular deviations $\leq \pm 1.5\ deg$ hard edge). The reproducibilities of the fully automatized measurement system over the measurement period for all blocks of 4 weeks was $\leq \pm 0.1$ % for the main dipole component and $\leq \pm\ 0.1\ deg.$ for the angular deviation.

The die pressed magnets have been grinded in two batches with sligtly different mechanical tolerances as we observed during inspection by using a coordinate measurement machine at BESSY. The rms value of the dipole moment within one batch is only 0.30 % [4].

All blocks have also been scanned with a Hall probe on a 3-d coordinate measurement machine in order to optain information of block inhomogenities. For each block a two dimensional map in a distance of 8 mm and 18 mm has been taken. In a first step the scans have been reduced to a few numbers which are proportional to the dipole components. The numbers show a strong correlation to the Helmholtz coil data (fig.4) [5]. Next, the dipole components derived from Helmholtz coil measurements will be subtracted and the inhomogenities will be studied. This work is in progress.

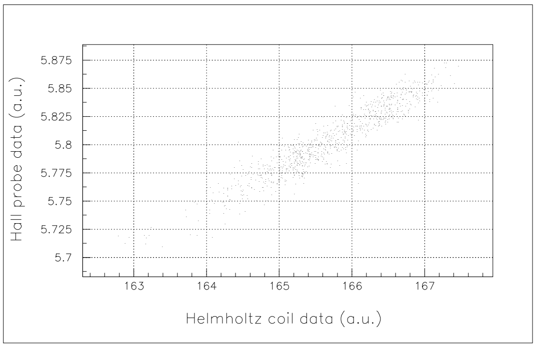

Figure 4: Correlation between Helmholtz coil data and Hall probe data

4.2 *Magnet Sorting*

The impact of the individual dipole errors on the magnetic field in the midplane (discribed by scaling factors) have been determined with TOSCA. The Helmholtz coil data as well as the scaling factors have been used in a simulated annealing code to optimize the block configuration.

The cost function consists of a weighted sum of the rms optical phase error, the rms field strenth under the poles and the integrated field errors along 11 transverse positions. The magnet structures on the upper and the lower beam are optimized independently.

The sorting code is flexible and can be easily adapted to various magnet geometries since many details are defined in external parameter files rather than hardwired in the code itself: magnet geometry, response functions, weigting factors for cost function components, allowed operations and other control parameters for the simulated annealing procedure.

4.3 *Field Data of the First Assembled Structure of the U-49*

The magnetic structure of the U-49 consists of 12 section. Six of them are bolted onto the upper and six onto the lower beams. The first assembly section has been completed and first data have been taken (fig.5 and fig.6)

Truncating the end fields the rms field error of the center 9 periods is 0.27 %. This number is expected to decrease further by a factor of $\sqrt{2}$ if the structure will be completed. Fig.5 shows the second field integral with a low walk off. In fig.6 the optical phase of the first harmonic in units of $2 \cdot \pi$ is plotted. Even with the inclusion of the systematic endpole effects the rms phase error is only 0.9 deg.

During assembly the tight tolerances of the individual mechanical parts have been controlled carefully. No mechanical sorting or mechanical shimming has been performed. It turns out that for this structure the magnetic specifications are exceeded without any magnetic shimming.

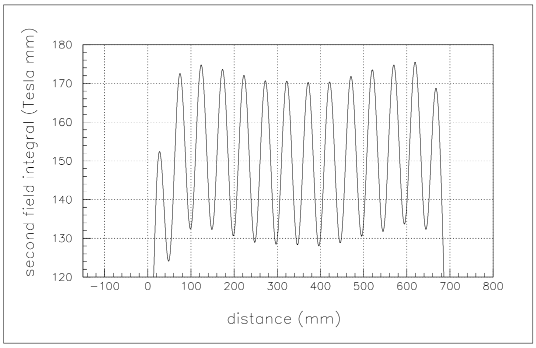

Figure 5: trajectory (a.u.)

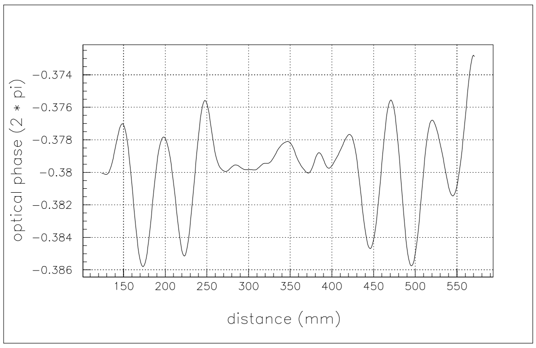

Figure 6: optical phase

5 REFERENCES

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* Funded by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie and by the Land Berlin