OVERVIEW OF DIAMOND IDs FOR PHASE I

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Abstract

Diamond Light Source is a 3GeV synchrotron currently under construction in the UK, which will be operational in early 2007. It is a third generation light source comprising 22 usable straight sections for insertion devices. Phase I beamline construction will include seven Insertion Devices: five PPM in-vacuum undulators, one APPLE-2 device and one 3.5T superconducting wiggler. This paper describes the current status of construction and magnetic measurements of the Phase I devices.

INTRODUCTION

The production of the Insertion Devices (IDs) for the Phase I beamlines is now at an advanced stage, with one in-vacuum device and one multipole wiggler already installed in the ring. The intention has been to produce the majority of the conventional (i.e. non superconducting) IDs ‘in-house’. Of the six conventional IDs, five will have been assembled and shimmed in the Diamond ID laboratory. To overcome resource limitations, the components for one in-vacuum device have been shipped to Danfysik for magnetic assembly and shimming, with the final vacuum assembly taking place at Diamond. A summary of the construction and magnetic correction methods used in the Diamond ID laboratory, along with the results obtained so far, is presented in this paper. The progress of the superconducting wiggler is also briefly summarised.

CURRENT DEVICE STATUS

Superconducting Wiggler: SCW

A 45 pole, 60mm period, 3.5T peak field wiggler has been delivered to the Diamond site by the Budker Institute of Nuclear Physics (BINP). This device, intended to cover the 20-100keV range for the ‘Extreme Conditions’ beamline, has successfully completed the factory and site acceptance tests, and has now been installed into the ring. The field specification of 3.5T has been comfortably met, with a maximum peak field of 3.8T observed during the factory test. The device has been constructed to achieve a LHe ‘zero boil off’ by using two extra 4.2K cryocoolers to cool the current leads at 60K and 4K, and reduce residual heat input to the helium vessel to near zero. These are in addition to two cryocoolers used to cool the radiation shields and the copper liner of the beam tube. Initial measurements at the factory test indicate that the device will only need to be refilled once every six months. Hence refills can be completed using a simple transfer dewar which will be lifted into the tunnel during shutdowns. This greatly simplifies the provision for He services that would otherwise be required if He top ups were to be made during storage ring operation.

APPLE-II Devices

A 2.2m long 64mm period APPLE-II device has been completed, intended for use by the Nanostructures beamline. The device achieves a peak field of 1T at a minimum gap of 15mm, and covers the energy range between 80 eV and 1.5 keV for linear polarisation (operating up to the third harmonic), and between 101 eV and 1.3 keV for circular polarisation,.

The beamline will ultimately be supplied by two APPLE-II modules with an electromagnetic phase shifter placed in the centre. Assembly of the second module will begin after the remaining Phase I devices are completed.

In-vacuum Devices

Two in-vacuum devices have now been completed, with one installed in the ring (U23IVb), and one currently being baked-out (U21IV). A third (U23IVa) is undergoing the final step of the magnetic correction process (field integral correction), before vacuum assembly can begin. These devices are all intended for use in the three protein crystallography beamlines, and will cover the energy range from 4 keV to 25 keV. The final two devices will comprise a U27IV for the ‘Materials and Magnetism’ beamline, and another U27IV for the ‘Micro-focus Spectroscopy’ beamline, both covering the range (3-20keV). All of the components for the final three devices have now been delivered. One of the U27s was sent to Danfysik for final assembly and shimming, and awaits shipment back to Diamond, having achieved the required magnetic performance. The second U27 is currently being assembled in the Diamond ID laboratory.

ASSEMBLY PROCESS & METHODOLOGY

The ID laboratory contains a 5.5 m 3-Axis Hall probe bench, supplied by the ESRF, which has the support plinths for a flipping coil positioned at either end. This allows measurements of the field and the field integral to be made without having to align the ID to individual flipping coil or Hall plate benches. The flipping coil currently has a length of 3.5 m, but can be extended to 6 m if required.

The in-vacuum devices are assembled according to the following philosophy. A sort order is calculated using a simulated annealing code [1] from Helmholtz coil measurements made by the manufacturer. The magnets are then mounted into single block holders, and assembled onto the support girders with the use of an independent assembly bench, which is equipped with an optical ruler to allow accurate block positioning. This allows one device to be assembled whilst another is being measured and corrected.

During shimming, the upper and lower arrays are first corrected individually. To achieve this, the girders are opened out to the maximum gap of 66 mm, and measurements made 2.5 mm above the surface of each array. Once acceptable trajectory and phase results are produced for each array, they are then brought together to allow shimming to start on the combined field. Careful attention is given to any gap dependent variations introduced (for example) by girder deflections produced under the varying magnetic load. This is found to occur mainly at the device ends, and can have a large impact on the phase error results, so care must be taken to ensure that phase corrections applied at 5 mm gap are also valid at larger gaps.

The devices are trajectory shimmed using a combination of blocks flips (to both the V and H blocks), and block swaps between the mounted and spare H blocks only. Our experience found that this method is very effective, even when the initial 'as built' device field required extensive correction. Once the trajectory correction is complete, phase shimming is performed using the standard method of raising or lowering the H blocks.

The final step is to correct the off-axis integral errors using "magic fingers". Four holders were used per device, positioned at the entrance and exit ends of each array. The total correction was hence split equally between the entrance and exit holder pairs. Each holder allowed 21 magnetic disks to be positioned at different heights above or below the device mid-plane. The effective spacing between the disk centres was 3.5 mm, as the disk positions were arranged into two intersecting rows.

The magic finger correction was applied using a simulated annealing code [2] and fine adjustments were made via an iterative process of measurement and adjustment after attachment.

The procedure for the APPLE-II device construction differed from this. Magnets were mounted in single block holders, but were assembled onto the girders directly whilst they were attached to the structure. Location pins which were accurately machined at the manufacturers were used to position the blocks. Shimming was carried out using small vertical and horizontal block shifts, as described in [4], to simultaneously correct the trajectory and integral errors. Magic fingers units were also used, in a similar procedure to that described, for the in-vacuum undulators.

ID MEASUREMENT RESULTS

A brief overview of some of the results of the magnetic measurements and correction methods are given in the sections below. Table 1 gives a summary of the phase and trajectory results for the three devices completed so far.

APPLE-II: HU64

The trajectory achieved at the minimum gap of 15 mm for the horizontally polarised mode (zero device phase) is shown in Fig.1. After magic finger correction, the phase variation of the on-axis field integrals is shown in Fig.2.

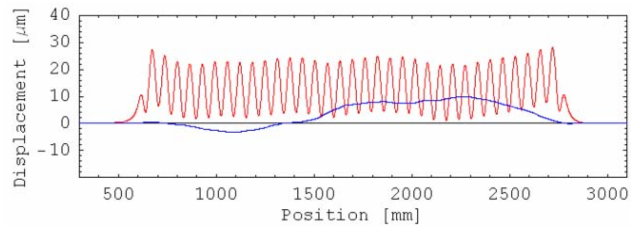

Figure 1: HU64 horizontal (red) and vertical (blue) trajectory at 15mm at zero device phase.

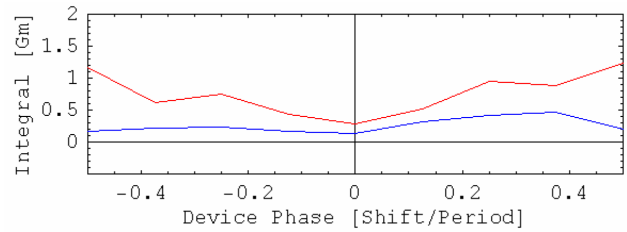

Figure 2: Variation of HU64 on-axis field integral with device phase. Iz (red) and Ix (blue)

From Fig.2 it can be seen that over the full phase range, the max change to the on-axis field integrals is ΔIx = 0.34 Gm, and ΔIz = 0.88 Gm.

In-Vacuum: U23IVb, and U21IV

The magnetic measurement results are shown below in Figs. 3 to 5 for U21IV at 5 mm and 7 mm gap. Initially operation is expected at a min gap of 7mm, but ultimately it is expected that 5 mm will be achieved. Tables 1 and 2 below summarise the properties of both the U21IV and U23IVb devices.

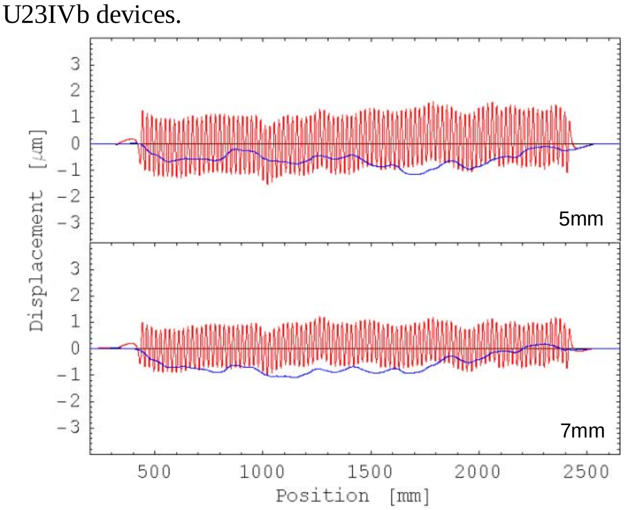

Figure 3: U21 Horizontal (red) and vertical (blue) trajectory at 5 mm and 7 mm Gap.

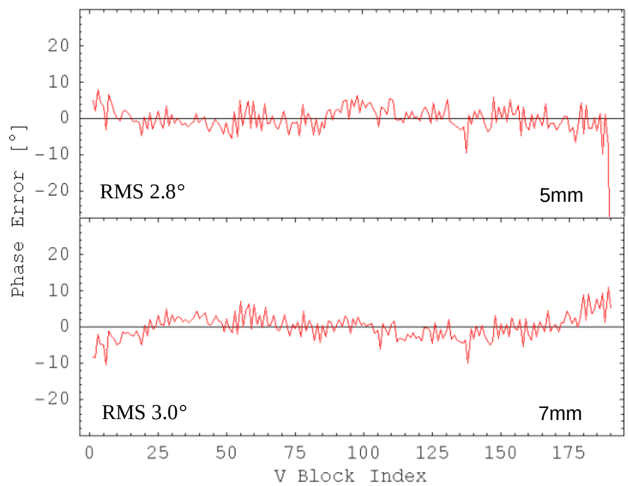

Figure 4: U21 Phase error at 5 mm and 7 mm gap.

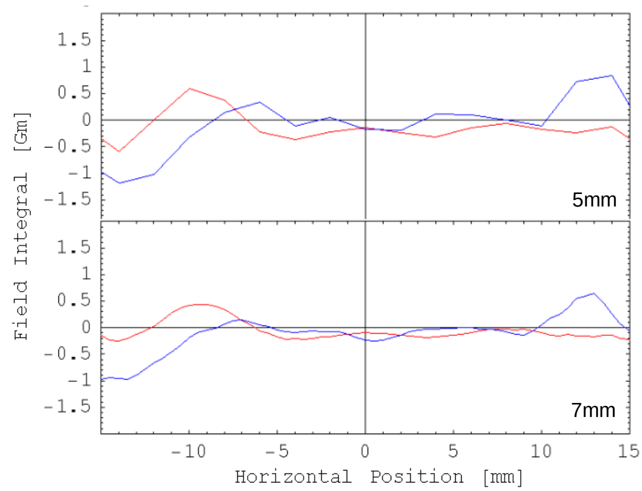

Figure 5: U21 Field integral transverse variation at 5mm and 7mm gap, Ix (blue) and Iz (red).

Table 1: Summary of in-vacuum device results.

Note: RMS Trajectory is computed from the values of the average trajectory evaluated at the device poles.

Device Property		**U21IV**		**U23IVb**	
		Horizontal	**Vertical**	**Horizontal**	**Vertical**
RMS Traj. Straightness	5mm gap	0.2 µm	0.3 µm	0.7 µm	0.7 µm
	7mm	0.1 µm	0.4 µm	0.5 µm	0.5 µm
	10mm	0.2 µm	0.6 µm	0.5 µm	0.3 µm
Max. 1st Integral Change	7-30mm gap	0.05 Gm	0.07 Gm	0.15 Gm	0.07 Gm
Max. 1st Integral Change	5-30mm gap	0.1 Gm	0.07 Gm	0.26 Gm	0.09 Gm
Max. 2nd Integral Change	7-30mm gap	0.38 Gm^2	0.44 Gm^2	0.3 Gm^2	0.05 Gm^2
Max.2nd Integral Change	5-30mm gap	0.48 Gm^2	0.74 Gm^2	0.52 Gm^2	0.1 Gm^2
RMS Phase Error	5mm gap	2.8°		2.7°	
	7mm	3.0°		2.4°	
	10mm	2.6°		1.7°	

CONCLUSION

Three of the seven Phase I Insertion Devices are complete and have achieved satisfactory magnetic performance. Construction is proceeding with the target of installing all devices by the end of August.

ACKNOWLEDGMENTS

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REFERENCES

[1] Kindly provided by B. Diviacco, Sincrotrone Trieste
[2] "Multiple trim magnets for field integral correction of APPLE type undulators", B. Diviacco et al, Sincrotrone Trieste Internal Report ST/SL-04/01.