

# THE INITIAL INSERTION DEVICES FOR THE DIAMOND LIGHT SOURCE

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## Abstract

The first eight DIAMOND beamlines have now been agreed. Insertion devices must be tailored to meet the needs of each of these beamlines and so it is now clear what form the first insertion devices for DIAMOND will take. Six of the devices will be short period, small gap undulators designed to reach between approximately 5 to 20 keV with the use of high harmonics. Four of these devices will take advantage of in-vacuum technology to enhance their spectral outputs. One insertion device will be a superconducting multipole wiggler with a peak field of 3.5 T, designed to provide large flux in the 20 to 100 keV region. The final insertion device will be a variable polarization undulator providing light in the soft X-ray region of 80 to 1500 eV. This paper will describe the insertion devices selected for each beamline with brief justification.

## 1 INTRODUCTION

DIAMOND [1] is a 3rd generation synchrotron light source for the UK that is optimised for the use of Insertion Devices (IDs). Located in the field free spaces of the 5 or 8 m straights these IDs will be the primary photon sources for the scientific research programme and the detailed specification and design of each one will be strongly related to its scientific application. In September 2001 eight beamlines were chosen to be the first complement of beamlines on DIAMOND although it is likely that only seven will be funded immediately (the so-called 'Day 1' beamlines). The spectral requirements for each of these eight beamlines have since been discussed at a number of external working groups with various ID options presented. By March 2002 the ID for each beamline had been identified.

## 2 INSERTION DEVICE SELECTION

### 2.1 Very High Energy Beamline

This beamline will support research into materials under extreme conditions. The beamline will consist of two experimental areas; the first experimental area requires high flux over 20 to 100 keV and the second between 20 and 40 keV. Each experimental area will accept 1 mrad of beam, the higher energy one will be centred on axis with the other one being centred 1.5 mrad off axis. The total power produced by the insertion device is a concern. Until detailed front end design and optics design has been carried out it has been decided to limit the power produced by the insertion device to a total of 20 kW at 300 mA of beam current.

The photon flux over the energy range 20 to 100 keV has been calculated for superconducting MPWs with a peak magnetic field between 3.0 and 3.5 T. The period of each MPW was chosen with reference to a three dimensional magnet model based upon the MAX II design parameters [2]. The ID length was varied as a function of field and period to limit the total power to 20 kW.

The results of these flux calculations show that although the 3.0 T SC MPW provides greater flux at 20 keV the 3.5 T SC MPW does provide enhanced flux at the highest energies. The 3.5 T SC MPW has been selected for this beamline because of the high energy photon performance and also because the lower energy photons have a flatter profile with horizontal angle for the second (off axis) experimental area. A summary of the parameters for all of the selected IDs will be given in Section 3.

### 2.2 Materials Beamline

This beamline will be a high resolution diffraction beamline for the study of materials and magnetism. The flux transmitted through a 100  $\mu$ rad (horizontal) x 25  $\mu$ rad (vertical) beamline aperture has been maximised over the required photon energy range of between 3.4 and 20 keV. Low divergence of the beam in both planes is essential and this implies the use of an undulator rather than a multipole wiggler.

Three types of undulator have been compared; a 5 m device with a 15 mm magnet gap, a 2 m device with a 10 mm magnet gap and a 2 m in-vacuum (IV) device with 7 mm magnet gap. A direct comparison between the optimum of each type of undulator is given in Figure 1. The flux into the beamline aperture for undulators with  $\sim 3$  degree phase errors has also been calculated.

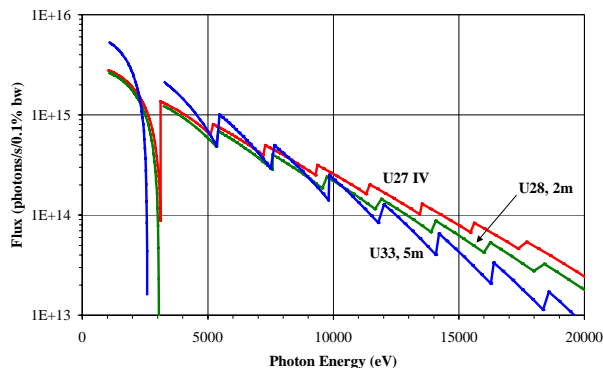


Figure 1. Spectral flux comparison between a 27 mm period in-vacuum undulator, a 28 mm period, 2 m undulator and a 33 mm period, 5 m undulator.

The lower divergence with the longer ID is significant and this is considered to be sufficiently attractive when compared to the rather marginal flux differences between the three ID types to tip the balance in favour of the U33, 5 m undulator.

### 2.3 Macromolecular Beamlines

Three beamlines will be dedicated to protein crystallography. The same beamline aperture has been used to select the ID as for the materials beamline but over the slightly different photon range of 5 to 25 keV. Also, specific key photon energies that correspond to particular element edges have been identified and the flux has been maximised at these values as far as possible. The three most important edges are Se K (12.658 keV), Hg L<sub>3</sub> (12.284 keV) and Pt L<sub>3</sub> (11.564 keV). At least one of the three beamlines is likely to include a side-station at some point in the future. This will operate at one or two fixed photon energies. This is likely to be served by a separate insertion device in a chicane arrangement.

In DIAMOND at photon energies in the range ~100 eV to ~10 keV an undulator generally outperforms a MPW. However, beamlines which demand higher energies than this must seriously consider using an MPW. A comparison between an MPW and an undulator is given for this beamline example in Figure 2 where the flux emitted by the MPW into the small beamline aperture has been calculated. This shows that for small beamline apertures, of the order of the size of the undulator central cone, an undulator outperforms the MPW up to ~25 keV in flux terms.

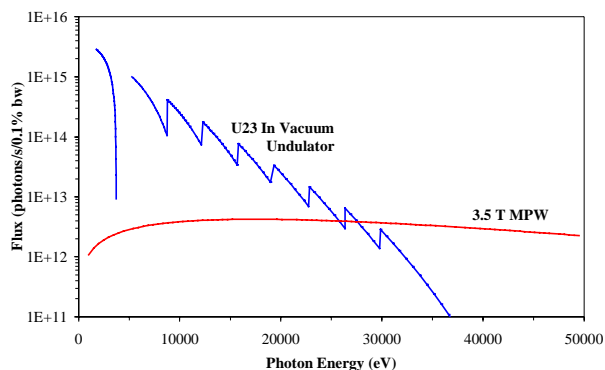


Figure 2. Photon flux in the central cone of a 23 mm period in-vacuum undulator and integrated over a 100  $\mu$ rad x 25  $\mu$ rad aperture for a 3.5 T MPW.

As for the materials beamline, three types of undulator have been compared; a 5 m device with a 15 mm magnet gap, a 2 m device with a 10 mm magnet gap and a 2 m in-vacuum device with a 7 mm magnet gap. In this case the advantage of the in-vacuum undulator was significant and therefore a 23 mm period IV undulator has been selected for two out of the three beamlines. The third beamline will also be an in-vacuum undulator of the same length but it may opt for a shorter period to enhance the higher energy radiation at the expense of tunability. Then, if DIAMOND performs beyond the present specification

and allows the 7 mm minimum gap to be reduced further during operations a shorter period device would have significant advantage. This is a somewhat risky approach but can be justified for a user community which has three very similar beamlines.

### 2.4 Microfocus XAS Beamline

This beamline will be a medium energy microfocus beamline for X-ray spectroscopy. An undulator is proposed because high flux levels are required in a small phase space area with minimal power being absorbed by the beamline elements. The flux generated by the undulator in the central cone has been maximised over the beamline photon energy range of the beamline, which is between 1.5 and 20 keV. The advantage of the in-vacuum undulator is significant and therefore a 27 mm period IV undulator has been selected for this beamline.

### 2.5 SXR for Nanostructures Beamline

This will be a soft X-ray beamline dedicated to the study of nanostructures. An undulator is required that can provide variable polarization and high flux over the prime energy range of the beamline which is between 200 eV and 1300 eV. In particular, left and right circular and linear horizontal and vertical are required to be available. The photon energy range in linear polarisation mode needs to be wider, covering 80 to 1500 eV.

An APPLE 2 device has been assumed for this beamline as it matches the ID requirements well. Once the decision for the APPLE 2 technology is made the choice of period is quite straightforward. In fact, the requirement for horizontal polarization down to 80 eV is the limiting factor and this requires a period of 64 mm for a 5 m device with a 15 mm gap.

### 2.6 Non-Crystalline Diffraction Beamline

This beamline will be dedicated to non-crystalline diffraction. The same beamline aperture has been used to select the ID as for the materials beamline but over the slightly different photon range of 6.5 to 20 keV. The beamline must also be able to operate at one key photon energy that does not fall within the photon energy range, the Calcium K edge (4.04 keV). Low divergence of the beam in both planes is necessary in order to minimise the smearing at the detector and this implies the use of an undulator rather than a multipole wiggler.

As for the materials beamline, three types of undulator have been compared. The 5 m, 15 mm gap device was rejected because of the relatively poor performance at the high photon energy end. Also, the advantage of the in-vacuum undulator is not considered significant in this case when compared to the increased cost and risk to the storage ring vacuum and therefore a 27 mm period conventional undulator has been selected for this beamline.

### 3 SUMMARY

Table 1 summarises the proposed first eight insertion devices for 'Day 1' operation on DIAMOND and the brightness of all of these devices is plotted in Figure 3. Each of the IDs has been selected after extensive consultation with the anticipated user communities. The beamline energy ranges are dominated by a majority wanting to cover from a few keV to ~20 keV. These will all be met by short period, small gap undulators working at high harmonics. To provide the best quality radiation at these high photon energies, four of the first eight IDs will be in-vacuum undulators.

The procurement phase for DIAMOND has now started and these IDs must be available for installation by about the end of 2005. The selection process for the next batch of beamlines has already started and it is anticipated that between 2 and 4 additional IDs will be required per year during the first few years of operation.

### 4 REFERENCES

- [1] V. P. Suller, "Status of the DIAMOND Project", these proceedings.
- [2] D. Leblanc et al, "The Max Wiggler", Proc EPAC 2000, pp2334-2336.

Table 1. Summary of the parameters of the first insertion devices for DIAMOND.

Name	Beamline	Technology	B <sub>Max</sub> (T)	K <sub>Max</sub>	Period (mm)	N <sub>Periods</sub>	Length (m)
MPW60	VHE	SC MPW	3.5	19.6	60	16	1.0
U33	Materials	Und	0.54	1.66	33	149	5.0
U23 IV a	PX	IV Und	0.70	1.49	23	85	2.0
U23 IV b	PX	IV Und	0.70	1.49	23	85	2.0
U23 IV c	PX	IV Und	0.70	1.49	23	85	2.0
U27 IV	XAS	IV Und	0.80	2.02	27	72	2.0
HU64	SXR	Helical Und	0.57	3.4	64	75	5.0
U27	NCD	Und	0.70	1.76	27	72	2.0

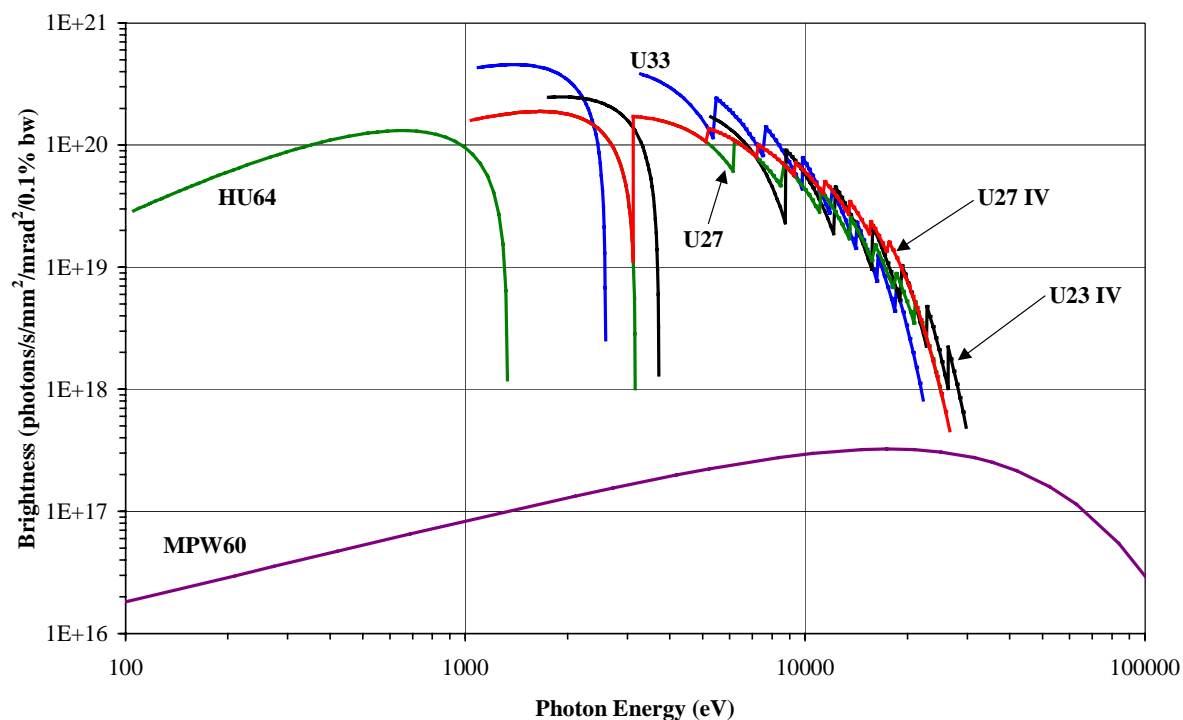


Figure 3. The spectral brightness for the first insertion devices for DIAMOND.