OPTIMISING DIAMOND INSERTION DEVICE BRIGHTNESS

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Abstract

The allocation of the insertion devices (undulators and multipole wigglers) in the hybrid DIAMOND lattice has been studied. In order to decide the optimum sites in the storage ring the brightness has been calculated for the different straight sections (high and low horizontal beta values). In all the cases the central cone brightness has been computed for the first seven harmonics. Study of the influence of the undulator and the multipole wigglers on the machine optics, both the linear and the non-linear effects, has been carried out by means of the RACETRACK code. From these results it is possible to formulate rules for the allocation of the undulators and multipole wigglers using the storage ring and insertion device specifications, although the optimum position depends on the photon energy range assumed.

1 INTRODUCTION

The present design for the DIAMOND machine consists of a hybrid racetrack DBA based lattice [1]. There are 5 different positions where insertion devices (IDs) can be located (see Figure 1). In this paper we study the optimum location for all the IDs, to achieve the highest brightness output (for the undulators) and the minimum influence in the machine dynamics, related with the linear and non-linear effects.

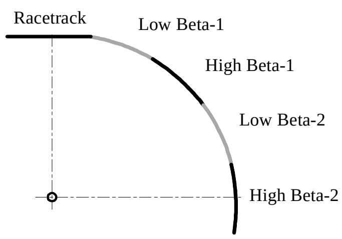

Figure 1: Basic layout of a quarter of the DIAMOND machine, indicating the different straight sections in it.

2 STRAIGHT SECTION DESCRIPTION

2.1 Machine parameters

The machine parameters required to compute the optical ID output and their machine influence are given in Tables 1 and 3. It should be noted that the coupling value assumed is 1%, which is a low but realistic value for a 3rd generation synchrotron light source, as has been shown in the DIAMOND design studies [2]. Also a 20 mm ID gap has been considered.

Table 1: DIAMOND machine parameters used to compute the undulator brightness.

E [GeV]	I [mA]	σ_E []	χ [%]	ε_0 [rad·m]
3	300	$9.6\ 10^{-4}$	1	$1.5\ 10^{-8}$

2.2 Straight section specifications

All the straight sections have a free space (L_{FS}), a doublet quadrupole close to this free space and 2 sextupole families (see Figure 2). The length for the free space is the same for the high and low beta straight sections, while in the racterack section it is about three times bigger, see Table 3. In all the IDs the distance between the corresponding QD(L,H,R) and the ID is larger than half metre, which allows the precision BPM vessel and photon absorber to be fitted.

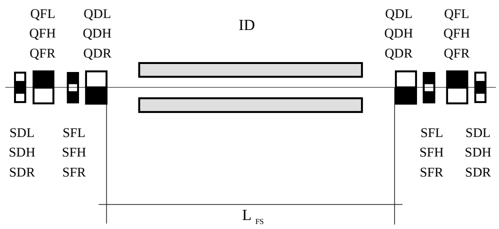

Figure 2: Scheme of the straight section in DIAMOND, where is indicated the quadrupole doublet (depending on the straight considered) and the 2 sextupole families, (the L_{FS} values are given in Table 3).

3 INSERTION DEVICE PARAMETERS

The selection of the undulator parameters has been chosen to cover the photon energy range between 5 eV up to 5 keV, and for the multipole wiggler (MPW) case to achieve a critical photon energy close to 10 keV.

For that reason three undulators have been proposed; the longest period one covers 5-200 eV (U196), the second covers 0.05-2.0 keV (U80), and finally the shortest undulator period covers 0.6-5.0 keV (U48). In Table 2 are given the geometrical and magnetic ID parameters including a 1.6 T MPW. Also is included the

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photon power density (PD), which is an extremely important parameter for the beamline design.

With these IDs we cover, from the photon energy point of view, the user requirements.

Table 2: Insertion device parameters for DIAMOND.

Name	λ [cm]	B_0 [T]	K []	N_{per} []	L [m]	PD [kW/mrad^2]
U48	4.8	0.51	2.3	93	4.464	12.4
U80	8.0	0.86	6.5	56	4.48	12.6
U196	19.6	0.22	4.0	80	15.68	4.7
W136	13.6	1.60	20.3	33	4.488	13.9

4 UNDULATOR BRIGHTNESS

4.1 Brightness calculation

One of the most important figures of merit for a 3rd generation synchrotron light source is the brightness that one can achieve with the IDs, particularly with the undulators. The brightness can be defined as the ratio between the spectral flux (number of photons per second in a 0.1% bandwidth) and the volume (in terms of the phase space) where these photons have been produced. For an individual harmonic, n, the brightness is given by:

$$B_n = \frac{F_n}{V_{PS}} \tag{1}$$

where F_n is the photon flux and V_{PS} is the 'volume' of the electron and photon phase space in the plane perpendicular to the observation axis, and can be calculated by:

$$V_{PS} = 4\pi^2 \cdot \Sigma_X \cdot \Sigma_Y \cdot \Sigma'_X \cdot \Sigma'_Y \tag{2}$$

$\Sigma_{X,Y}$ and $\Sigma'_{X,Y}$ are the effective source sizes and effective source divergences in the perpendicular directions of the observation point. These magnitudes can be computed by means of:

$$\Sigma_{X,Y} = \left[\varepsilon_{X,Y} \cdot \beta_{X,Y} + \frac{\lambda_n \cdot L}{(4\pi)^2}\right]^{1/2}; \quad \Sigma'_{X,Y} = \left[\varepsilon_{X,Y} \cdot \gamma_{X,Y} + \left(\frac{\lambda_n}{L}\right)\right]^{1/2} \tag{3}$$

From equation (1), and due to the fact that F_n does not depend on the lattice characteristics, for a given harmonic and for a particular undulator, the source brightness is inversely proportional to the volume of the source size. For that reason for a given undulator length (L) and for a fixed photon wavelength (λ_n), the brightness depends on the location of the ID in the machine ($\beta_{X,Y}$ and $\gamma_{X,Y}$). So for the DIAMOND machine, one of the criteria to choose the ID location will be the highest brightness achievable in each case.

4.2 ID Brightness depending on its location

In terms of the horizontal beta function in the centre of the straight section there are three types of straight in DIAMOND: low beta, high beta and racetrack (for the longest straight section). In Table 3 are listed the beta function values for each section (both planes), and the ID that has been located in it. It should be noted that the low and high beta criterion is only valid for the horizontal plane, and it is opposite for the vertical one.

Table 3: DIAMOND straight section parameters required to calculate the undulator brightness.

Name	β_H [m]	β_V [m]	L_{FS} [m]	ID
Low Beta	0.83	3.26	5.84	W136
High Beta	14.38	1.6	5.84	U48,U80
Racetrack	10	10	19.94	U196

Figure 3 shows the brightness for the U48 undulator. The maximum brightness is achieved when U48 is located in the high beta straight, for all the photon energy range.

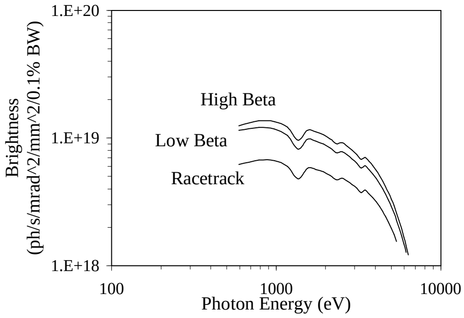

Figure 3: Brightness versus photon energy for the U48 undulator, depending on the straight section where it is located.

However, for the U80 case (Figure 4), the maximum brightness is obtained in the low and high straight depending on the photon energy range considered. In this case, if the ID is going to be used in the 50-400 eV range, it may be better to locate it in the low beta straight, otherwise it is better to put it in the high beta one.

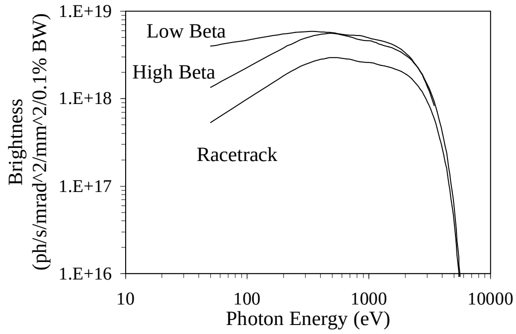

Figure 4: Brightness versus photon energy for the U80 undulator, depending on the straight section where it is located.

5 ID INFLUENCES IN DIAMOND

5.1 Linear ID effects

The insertion device effects in the machine (linear and non-linear) have been computed using the RACETRACK code [3]. In order to obtain a fast answer and as a first order approximation, the insertion device model chosen has been as a linear element.

For all the cases, the linear machine changes are smaller in the high beta than in the low beta section. This is because, in the linear approximation, the ID introduces a vertical focusing on the beam. This variation should be smaller for low beta (vertically), and this corresponds in DIAMOND with the high beta section (see Table 3). The highest vertical tune shift value, due to a single ID, has been 0.02 (for W136 case).

Although the chromaticity change is not a linear effect, its changes have also been assessed since RACETRACK allows computation of the chromaticity if the ID model chosen is linear. The highest shift has been 0.05 for the largest K value (W136) if it is placed in the low beta straight (high beta vertically), as expected.

5.2 Dynamic aperture

The dynamic aperture (DA) calculation has been done using the ‘Stable Area’ option in the RACETRACK code. The DA calculating point has been the central point of the racetrack straight section. A single on-momentum particle and 1000 turns has been chosen as the tracking parameters. The tune has been adjusted with the doublet quadrupole (see Figure 2), and the chromaticity has been compensated by the sextupoles located in the achromat section.

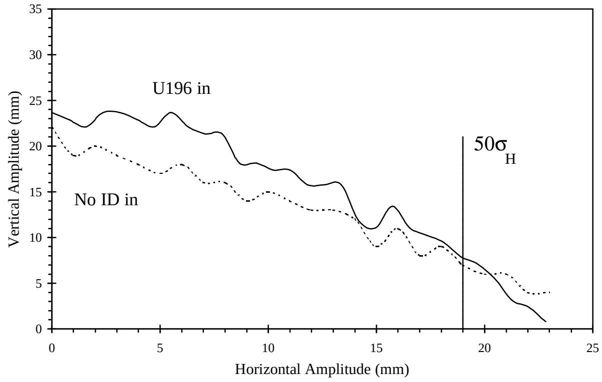

Figure 5: Dynamic aperture for an on-momentum particle and an undulator in the racetrack straight (U196).

To study the influence of the IDs in DIAMOND three pessimistic cases have been considered: a very long undulator in the racetrack straight (U196), the highest K value (W136) in the position where the linear effects are largest, and all the IDs listed in Table 2 together.

In Figures 5 to 7 are presented the dynamic aperture results for these examples. In all the figures are plotted the dynamic aperture scaled with the square root of beta and the corresponding DA when no ID is located in the machine (dashed line). It should be noted that the value of 50 times the horizontal electron beam size in the racetrack section is smaller than the DA.

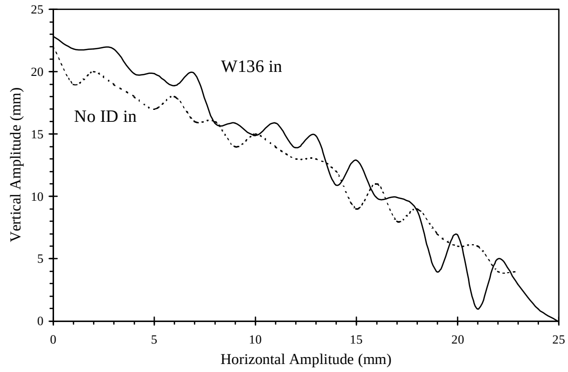

Figure 6: Dynamic aperture for an on-momentum particle and a MPW in the low beta straight (W136).

The dynamic aperture obtained is slightly bigger for all the studied configurations than the case with no ID in the machine [4]. This fact can be explained from the low symmetry bare machine that we initially have. However, further studies will be done with a more realistic ID model in order to refine these results.

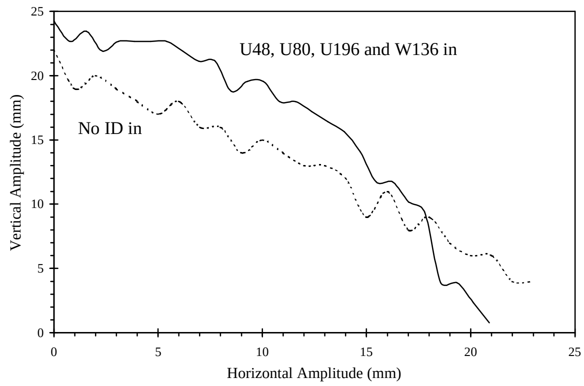

Figure 7: Dynamic aperture for an on-momentum particle and all the IDs proposed (see Table 2).

6 CONCLUSIONS

The optimum position of the undulators in the DIAMOND machine depends on the photon energy range. But for the undulators proposed in this paper, the best place corresponds to the high beta straight. The linear effects of the IDs is very small when they are considered separately. Finally, the dynamic aperture does not change significantly when all the ID are included.

REFERENCES

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[4] ‘Optimisation of the Dynamic Aperture of DIAMOND’, H. L. Owen, M. Muñoz, S. L. Smith, these Proceedings.