A RACETRACK LATTICE FOR DIAMOND

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Abstract

DIAMOND is a proposed 3rd generation 3 GeV synchrotron radiation source for the UK. Flexibility in the lattice is provided by alternating high and low radial beta insertion straights and also by the inclusion of two super-long straights of about 20m free space. This paper presents the details of the lattice and also covers other issues such as closed orbit correction, matching of the racetrack straights and inclusion of superconducting dipoles.

1 INTRODUCTION

DIAMOND is a proposed, 3rd generation, medium energy, synchrotron light source. The basic requirements, to provide high brilliance photons in the soft X-ray region (0.2 - 5 keV) and high flux in the medium X-ray region (1-30 keV) have been met by a 3 GeV machine with 14 long straight sections of 5 m and 2 super-long straights of 20 m. The project is described in detail in reference [1].

2 THE LATTICE

2.1 General

The lattice is based on a hybrid DBA design [2], with two 20 m super-long straight sections. The lattice consists of 16 DBA cells with alternating high and low radial betatron functions at the centre of the long straight sections. The high radial beta function is required for injection [3]. The 20 m straights replace two of the high beta straights giving a racetrack design.

The general layout and component spacing has evolved from the desire to produce a compact design which never-the-less could accommodate all the components needed to fully meet the specifications of a third generation light source. For instance the magnet-magnet separation in the insertion straights are the minimum practical given the requirement for beam position monitors, photon stops, flanges, valves, coil overhangs etc.

The component layout for half a standard cell and for half of a super-long straight are shown in Figure 1. In total, there are 12 families of quadrupoles required to provide the ability to tune the machine and match the various straight sections. There are two families of chromatic sextupoles and six families of harmonic sextupoles. The position of the chromatic and harmonic sextupoles has been chosen to optimise the dynamic aperture [4].

2.2 Design Aims

The lattice has been designed to give some flexibility to change the tune point and the beta functions in the insertion straights. The current working point has been optimised to fulfil the following conditions.

1. Radial emittance of less than 17 nm.rad without superconducting dipoles
2. Zero dispersion in the ID straights
3. Tune point chosen to maximise the dynamic aperture.
4. Symmetry in the lattice functions across the achromatic arcs.

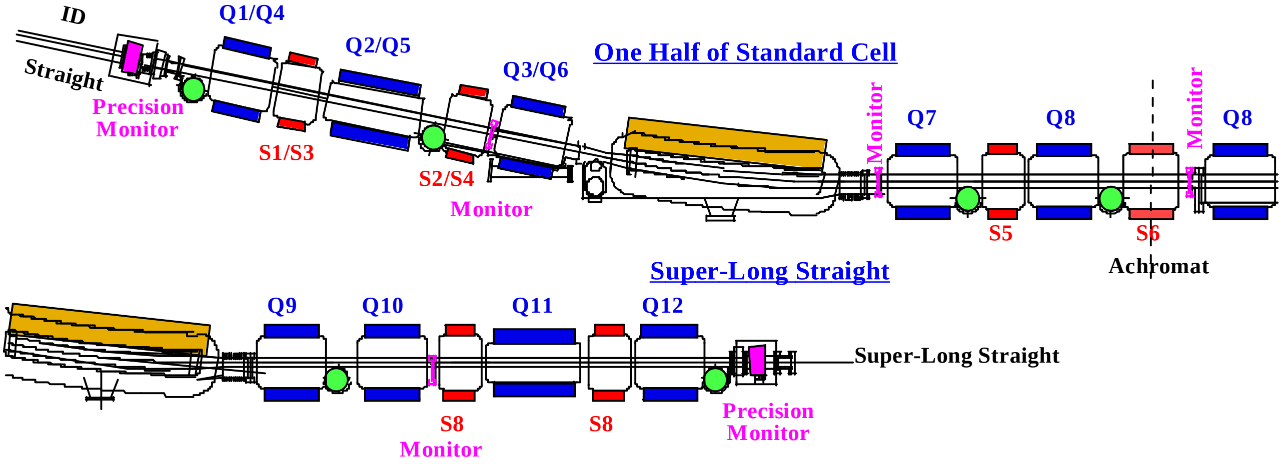

Figure 1: DIAMOND Layout

5. Maximum betatron functions < 35 m
6. Betatron functions at the centre of the straights as listed in Table 1.

Table 1: Beta functions
at the centre of the ID straight sections.

Straight Type		
High b_r	$12<b_r<15$	$b_v<2.5$
Low b_r	$b_r=1.5$	$b_v<2.5$
Racetrack	$b_r=10$	$b_v=10$

The optimisation was carried out using the matching routines in the program MAD[5]. The requirement to maintain symmetry across the achromatic arc means that in general any change to the lattice requires the use of all 12 quadrupole families to rematch the lattice functions. The lattice functions for the chosen tune point are shown in Figure 2 and the main parameters listed in Table 2.

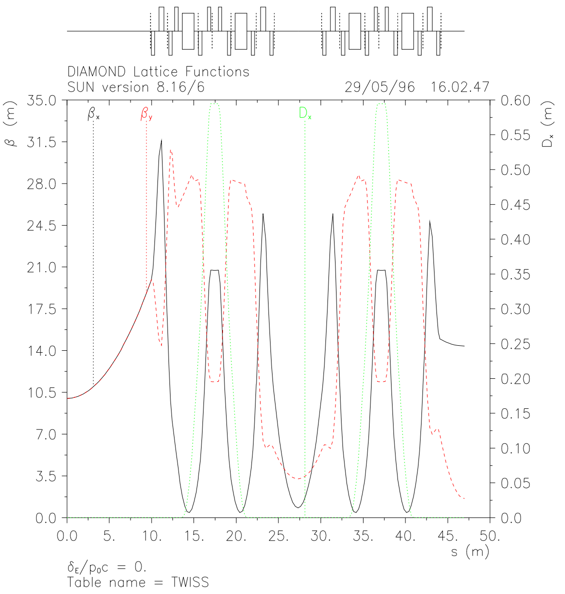

Figure 2: Lattice functions for chosen working point

Table 2 : DIAMOND main parameters

Energy	3 GeV
Circumference	345.6 m
Natural Emittance	14 - 28 nm.rad
Cell Type	DBA
Dipole Field	1.4 T; (4.35 T)
No of Cells	16 = 2+6+8
Straight Length	14 x 5 m; 2 x 20 m
Betatron Tunes (h,v)	18.73, 6.86
Natural Chromaticities (h,v)	-57, -26
Beam Current	300 mA

3 SUPERCONDUCTING DIPOLES

As part of the strategy to build a machine with significant potential for upgrade, the possibility of replacing one or more of the conventional dipoles with superconducting ones has been investigated. These would then serve to provide shorter wavelength output without using up an insertion device straight. The design of these magnets has already been considered [6] and a field of 4.35 T has been chosen to give the required spectral output.

It is envisaged that the dipoles would be replaced in pairs in a super-period consisting of two cells. Three possible options for the placement of dipoles within the lattice are illustrated in Figure 3.

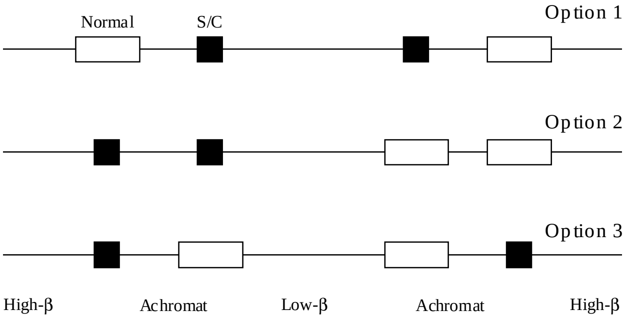

Figure 3: Position options for superconducting dipoles.

For each of the options the lattice was re-optimised to minimise the effects of the superconducting dipoles. The emittance increase on the replacement of four magnets was around 50 % for each of the three options.

Further non-linear work is necessary to decide on the best option and also to assess the minimum number of dipoles that can be replaced at any one time.

4 CLOSED ORBIT DISTORTIONS

4.1 Sensivity to Errors

As part of an assessment of component specifications a preliminary study has been made of the effects of component errors on closed orbit distortions and their correction. The dominant errors which contribute to closed orbit distortions are transverse misalignment of quadrupoles, roll angle misalignment of the dipoles and field imperfections in the dipoles

The expected generated RMS orbit distortions due to quadrupole position errors are given by

$$\Delta x,y^{CO}_{rms} = \Delta x,y_{rms} \frac{\sqrt{\beta_{x,y}}}{2\sqrt{2}\ Sin\left(\pi Q_{x,y}\right)} \left\{ \sum_i (kl)_i^2 \beta_{i_{x,y}} \right\}^{\frac{1}{2}}$$

where,

$\Delta x, y_{rms}$:RMS Quadrupole displacement

kl_i :integrated quadrupole strength

$Q_{x,y}$:the betatron tunes

$\beta_{ix,y}$:the β - functions at the quadrupole

$\beta_{x,y}$:the β - functions at the observation point

x,y :Horizontal,vertical plane.

The amplification factor is defined as

$$A_{x,y} = \Delta x, y^{CO}_{rms} / \Delta x, y_{rms}$$

The quadrupole amplification factors for DIAMOND are around 100. These are as expected for a high focusing machine with many quadrupoles. Assuming RMS errors of 0.1 mm in quadrupole transverse position, relative dipole roll angle error, $\Delta\phi/\theta$, of 5×10^{-4} and relative dipole field error of 5×10^{-4}, the expected RMS closed orbit distortions are around 11 mm horizontally and 16 mm vertically .

The program MAD was used to model these errors and Figure 4 shows the closed orbit distortions for five different sets of random errors.

4.2 Global Closed Orbit Correction

At the moment it is assumed that adequate closed orbit correction can be obtained from additional coils in all the sextupoles[7]. These would provide both horizontal and vertical correction. This correction scheme has four monitors in each of the insertion straights and three in the achromatic arc as shown in Figure 1. The monitors provide both horizontal and vertical orbit position information. Figure 5 summarises the correction achieved, using MAD, for 20 different machines. The correction is achieved assuming RMS monitor position errors of 0.1mm. It may be possible to reduce the number of monitors and correctors if required, particularly in the vertical plane.

4.3 Local Closed Orbit Correction

The corrector requirement for four magnet local bumps to set the position and angle at the photon source points have been assessed. At the moment it has been assumed that such corrections would be made using the coils in the sextupoles however if there is a requirement for very fast correction then other schemes will have to be considered.

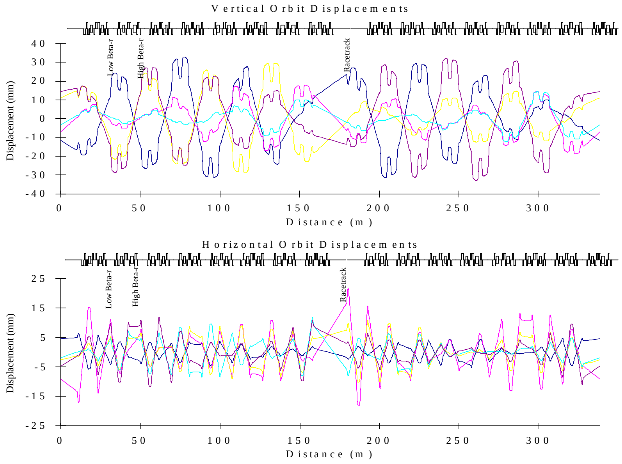

Figure 4: Orbit distortions for five example machines

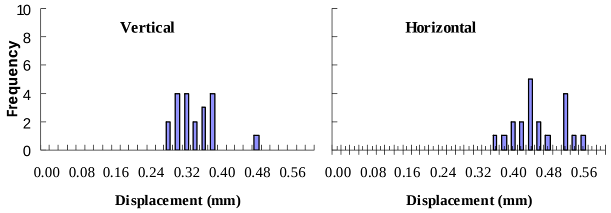

Figure 5: Maximum orbit errors after correction for 20 different machines.

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