Updated Plans for DIAMOND, a New X-Ray Light Source for the UK

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Plans are being made to replace the 15 year old Daresbury SRS light source with a new 3rd generation ring at an energy of 3 GeV. An earlier concept was based on a TBA lattice which permitted simple inclusion of superconducting dipoles at the centre of selected achromats. A recent design review has recommended changing to a DBA version with the addition of two super long straights. An outline design of this racetrack light source is presented here.

I. INTRODUCTION

Although the 2 GeV SRS [1] continues to provide excellent quality synchrotron radiation supporting a major national facility containing almost 40 experimental stations, it is clear that the source has insufficient space for modern insertion devices and has an electron beam emittance (120 nm.rads) which will soon be too high to conduct state-of-the-art research. A major review of the needs of the domestic research community has established that the basic specification of a new source should be to provide high brilliance photons in the Soft X-ray region (0.2 - 5 keV) and high fluxes in the Medium X-ray region (1 - 30 keV), this radiation being generated by a suite of undulators and multipole wigglers. There is an additional requirement for a small number of superconducting dipole sources to provide high photon fluxes beyond 30 keV. High brilliance radiation at photon energies up to 30 keV will be adequately catered for by the UK's share of the European Synchrotron Radiation Facility in Grenoble, see [2]. This specification taken in conjunction with realistic designs for insertion devices leads to a proposed energy for the new source of 3 GeV.

II. THE PREVIOUS DESIGN

The original concept for DIAMOND [2] [3] was a 16 cell triple bend achromat (TBA) with a circumference of approximately 300 m. The scale of the facility to accommodate sufficient insertion devices for a large national user community led to the choice of 16 cells, whilst the 3 GeV energy arose by considering the spectral output to be produced by multipole wigglers with fields peaking at around 1.6 T. TBA lattice cells were chosen for their ability to produce a high brilliance light source in addition to permitting the simple replacement, when required, of the central dipole in chosen cells by a short superconducting dipole giving the same deflection as previously. Such dipoles will provide new research opportunities by utilising the high fluxes of hard X–rays which could be accepted by experiments placed within a few metres of the source point.

This TBA version of DIAMOND was used as an example for estimating the resources and timescales which would be required to replace the SRS with a modern facility. Subsequent refinement of the scientific case for DIAMOND led to a re-evaluation of the basic lattice structure and it became clear that more appropriate solutions could be derived for the electron beam source properties and for the lengths of the insertion device straights. As a result the lattice for DIAMOND has been recently changed to a double bend achromat (DBA) cell with a resultant improved specification.

III. A DOUBLE BEND ACHROMAT

In a DBA cell the quadrupoles in the zero dispersion straight may be regarded as free parameters able to adjust the overall betatron functions of the cell whilst the quadrupoles in the dispersive straights produce the condition of zero dispersion. When the betatron stability of the cell is plotted as a function of the values of the F and D quadrupoles making up the doublets at each end of the zero dispersion straight, the familiar neck-tie diagram divides into four distinct regions. Fig 1 shows this behaviour for the DBA cell which was used as a starting point for the updated DIAMOND structure.

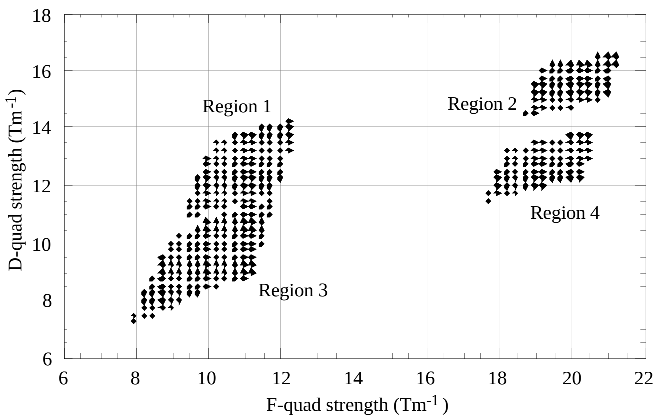

Figure 1: Stability islands of DBA cell with doublets in zero dispersion straight.

The natural beam emittance is expected to be strongly dependent on the horizontal betatron tune, but fig 2 shows how it is remarkably similar in each of the four regions. The lowest emittance results from operating at a horizontal phase advance per cell of either nearly 2π or 3π. It can be seen from fig 2 that an emittance of between 11-15 nm.rad is available over a useful region of tune space. The theoretical minimum emittance from a 16 cell DBA at 3 GeV is 6.5 nm.rad.

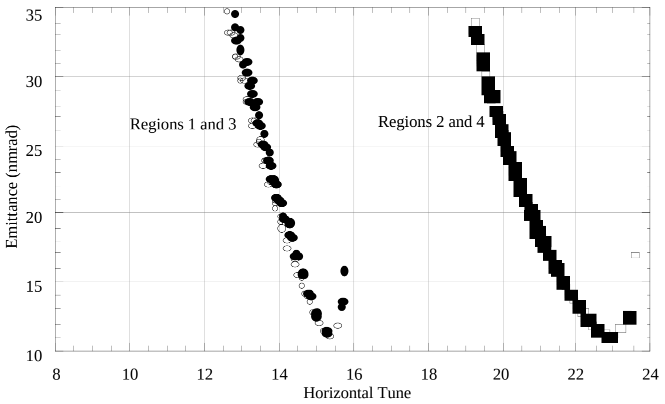

Figure 2: Variation of emittance with tune in different stability regions.

The betatron functions in the zero dispersion straights tend to take distinct values in the different regions of stability. Regions 2 and 4 have very low horizontal beta, whilst regions 1 and 3 have high beta. A range of vertical beta values, from low to high, is available in the regions. It is possible that selection of an operating region could be decided by the requirement for specific insertion devices to be matched to specific beta values. The DBA cell for DIAMOND was selected to be in region 2 to provide a low horizontal beta of less than 1.0 with a vertical beta of about 2.0

IV. FULL FEATURE LATTICE

The basic cell was then subjected to a series of modifications to produce a facility which meets the full specification of the end users. The most important of these requirements are:

a) Flexible control of beamsize in the insertion device straights. This is necessary to ensure that any conceivable insertion device, (multipole wiggler, undulator, wavelength shifter) can have the optimum beam size or divergence to produce the best source characteristics. It has been achieved by changing the doublets in the insertion device straights to triplets. Initially a very symmetric solution has been selected which sets high and low betas in alternate long straights.

b) Super-long straights. These will enable novel insertion devices to be accommodated in the long term future. Additionally they will allow the testing of new devices when configured in a by-pass mode, thereby minimising the impact of testing on the facility operation. Two super-long straights with free lengths of about 20m have been matched into the 16 cell ring by stretching two of the high beta insertion device straights and adding additional quadrupoles.

c) Superconducting lattice dipoles. As an upgrade route, future substitution of normal dipoles by equivalent deflection superconducting dipoles receives strong user support. Only selected cells would be treated, with a maximum limit of 4 cells. An interim high symmetry solution has been evaluated and is presented here, with replacement of both dipoles in each of 4 cells. Other options will be studied involving the substitution of only one dipole per cell.

The overall lattice for half of the new DIAMOND structure, incorporating all the above mentioned features, is shown in fig 3. It can be seen that a high degree of symmetry has been maintained and that the lattice functions remain well behaved. The major parameters of the source are listed in table 1.

TABLE 1

DIAMOND Major Parameters

Energy	3 GeV
Circumference	340 m
Natural Emittance	16.4 - 27.6 nm.rad
Cell Type	DBA
Dipole Field	1.4 T; (4.35 T)
No of Cells	16
Straight Length	14 x 5 m; 2 x 20 m
Betatron Tunes (h,v)	18.24, 6.63
Natural Chromaticities (h,v)	-46.9, -27.6
Beam Current	300 mA

V. SOURCE PERFORMANCE

The performance of DIAMOND, as measured by its photon output, will be the combination of the performance of the storage ring and of the insertion devices. These need to be well matched to their scientific application and are ideally designed to a precise specification. At this stage, therefore, it is only possible to describe the generic parameters of the insertion devices which could be installed in DIAMOND. These are listed in table 2. The performance of the ring itself is assumed to be as stated in table 1, and is realistically based on the results obtained by recent 3rd generation sources.

TABLE 2

Projected Insertion Devices

ID	Period (mm)	N	K (max)	Length (m)
U80	80	56	6.5	4.5
U48	48	93	2.3	4.5
U21	21	95	0.8	2.0
MPW-1.6	136	33	20.3	4.5

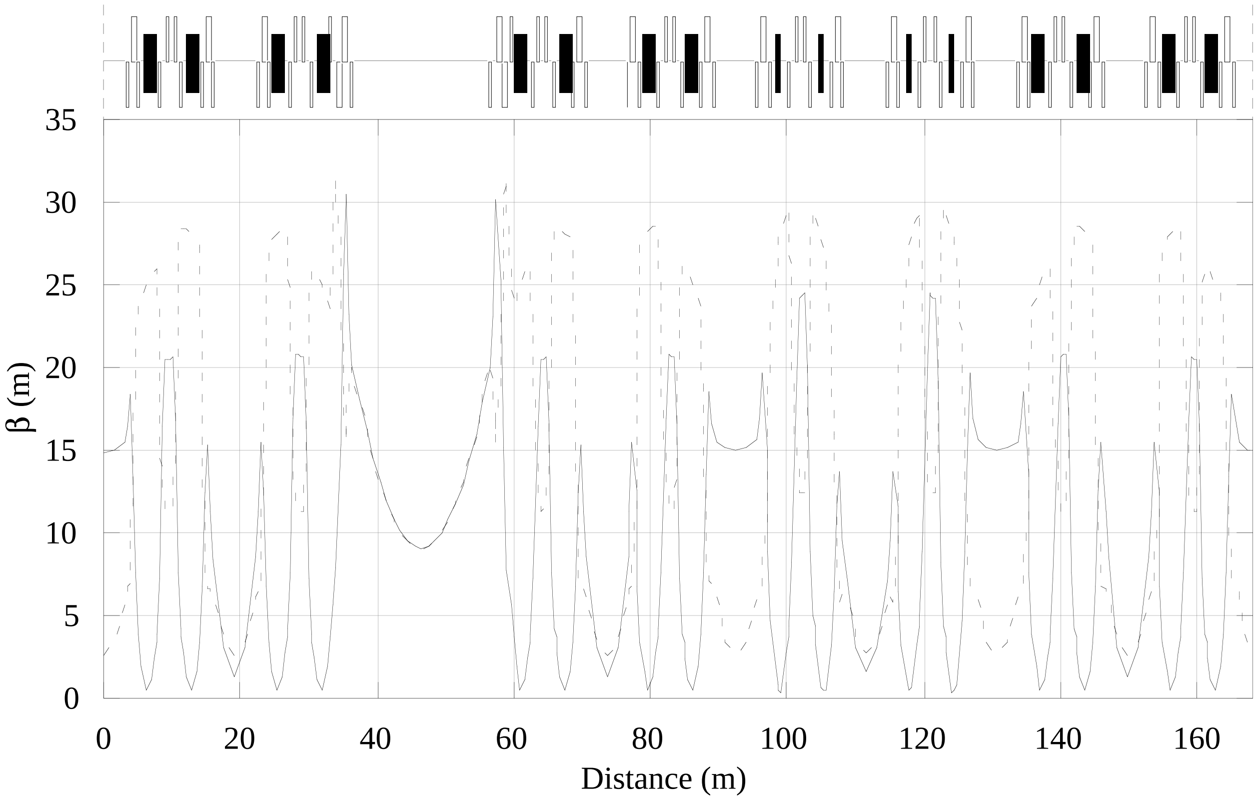

Figure 3: Lattice functions of normal, superconducting and long straight cells. The solid line shows the horizontal, the short dashes the vertical beta function.

The computed brilliances of the various sources which will be employed in DIAMOND are shown in fig 4.

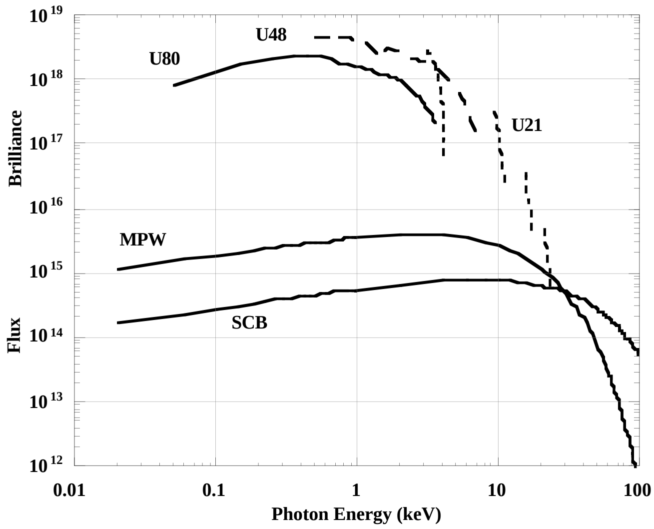

Figure 4: Flux (ph/sec/0.1% bandwidth) for the multipole wiggler (MPW) and superconducting dipoles (SCB); Brilliance (flux/mm^2/mrad^2) from the undulators.

VI. STATUS AND FUTURE PLANS

A re-estimated proposal for this updated version of DIAMOND will be submitted to the UK funding bodies in Autumn 95. If financial approval is obtained, the earliest likely starting date for construction would be in April 97. The intervening period will be used to continue lattice refinement, paying particular attention to its non-linear behaviour and to the effects of insertion devices. Engineering design of all major systems will also be carried out in this period. A 5 year construction period is foreseen, leading to first scheduled operation in 2002.

VII. REFERENCES

[1] P D Quinn, Proceedings of the 4th European Particle Accelerator Conference, London, 1994; pp 648-650: World Scientific Publishing, Singapore.

[2] V P Suller, Journal of Synchrotron Radiation; Vol 1, pp 5 - 11, 1994

[3] M W Poole and V P Suller, Proceedings of the 4th European Particle Accelerator Conference, London, 1994; pp 621-623: World Scientific Publishing, Singapore.