Design Progress on DIAMOND, a Proposed UK National Light Source

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Abstract

During the previous year the design concept of the 3 GeV storage ring DIAMOND, intended as a third generation replacement for the Daresbury SRS, has continued to evolve. A major change is the decision to adopt a DBA lattice structure but unchanged is the racetrack geometry having two 20 m long superstraights included within the sixteen cells. This new structure has an improved and optimised specification, an emittance of 14 nm-rad, and has been analysed for error tolerance and correction. Outline designs of all technical systems have been made and a fully costed feasibility study has been completed.

1 INTRODUCTION

Synchrotron Radiation (SR) research in the UK has grown to a user community of over 2000 active participants using the SRS at Daresbury. This 2 GeV source with its 300 mA current and 30 hour beam lifetime contains two high field wigglers (5 and 6 T) and a short undulator. A proposed upgrade program [1] shortly to be initiated will add two 2 T multipole wigglers (MPWs).

To remain internationally competitive SR users in the UK need a light source which is able to harness the capabilities of modern IDs. This implies a ring with a number of long straights sufficient to contain the IDs for the size of the community and with a low beam emittance to exploit the inherent properties of the IDs. The proposed DIAMOND facility has evolved since 1992 [2,3,4,5]. Surveys have shown that, although radiation of the highest brightness is required by some UK users, the majority of foreseeable research needs high flux in conjunction with only moderate brightness (by third generation standards).

DIAMOND is optimised to generate high brightness soft X-ray radiation over the photon energy range 100 eV to 3 keV and high fluxes of medium to hard X-rays between 3 and 30 keV. A superconducting dipole option will be able to extend the latter range to about 100 keV. The small fraction of users needing very high brightness hard X-rays will be catered for by the UK's access to the ESRF.

2 LATTICE

The basic parameters of the DIAMOND lattice are determined by the outline specification given above; a 16 cell structure with zero dispersion long straights of at least 5 m is required by the size of the research base, and the beam energy of 3 GeV is needed to generate the desired hard X-ray spectrum using MPWs with fields of about 1.6 T. The racetrack configuration with two 20 m straights will confer a flexibility to cater for presently speculative developments in the shape of novel undulators and FELs.

Although originally designed with a triple bend achromat (TBA) lattice, discussion with the research community indicated that a double bend achromat (DBA) would be more useful in flexibly providing differing optics solutions. These solutions would be valuable for setting optimised beta functions in individual straight sections to suit particular IDs. For example, the beta functions shown in fig 1, which represents one quarter of the storage ring, have been set with alternating high and low radial betas in the regular 5 m straights. The high beta straights would be used for undulators, with the low beta straights used for MPWs[6,16].

Table 1: DIAMOND Major Parameters

Energy	3 GeV
Circumference	345.6 m
Natural Emittance	14 nm.rad
Cell Type	DBA
Dipole Field	1.4 T
No of Cells	16
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

Producing different optics solutions calls for significant flexibility in powering the storage ring quadrupoles. In fact it has been found that, without incurring undue cost penalties, advantage may be taken of modern control and power converter technology to arrange an individual power supply for each quadrupole. Once this feature is included not only does a great variety of optic solutions become available, but the possibility arises of correcting or compensating the real error distributions in the ring.

The influence of construction and alignment errors on both the closed orbit [6] and the dynamic aperture [7] of DIAMOND have been analysed with standard methods. The effect of the two-fold superperiodicity arising from the racetrack configuration is, as expected, to increase the orbit sensitivity and decrease the dynamic aperture compared with a simple 16 cell structure. Nevertheless, a careful selection of the betatron operating point leads to a satisfactory performance with the assumption of

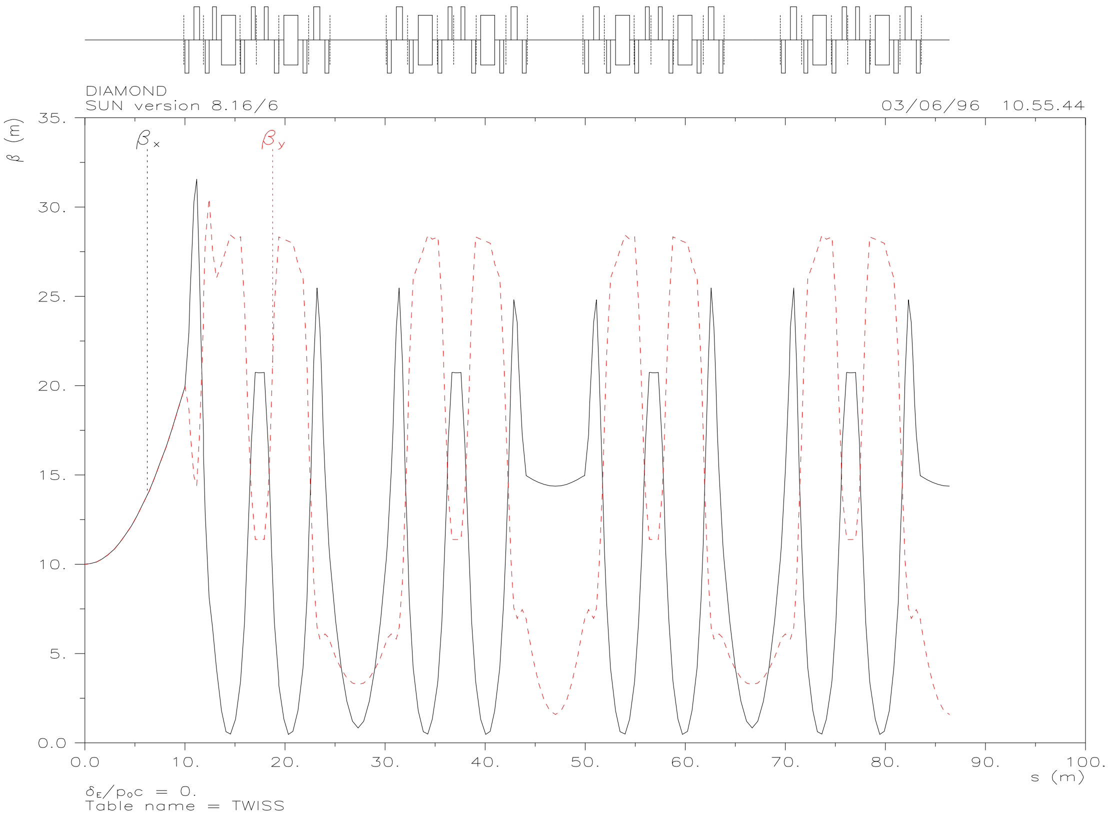

Fig 1: Beta functions around one quarter of DIAMOND

challenging, but attainable, construction tolerances. The basic lattice parameters for such a working point are given in table 1.

3 ACCELERATOR SYSTEMS

Outline designs of the major technical systems of DIAMOND have been made at a level sufficient to permit reasonable cost estimates to be produced. These initial designs are reported elsewhere in these Proceedings; magnets [8,9], RF [10], vacuum [11], and controls [12]. Conventional solutions in all systems will produce the required beam performance. It is clear, however, that state of the art beam position measurement, correction and control (including the use of feedback) will be mandatory to achieve photon beam stability with the specified accuracy of one tenth of the beam dimensions.

In order to assist the attainment of high position stability, hysteresis in the storage ring magnets will be minimised by employing full energy injection. A booster synchrotron for 3 GeV has therefore been designed [13] and will be located within the main building which will house the facility. The pre-injector for the booster, probably at an energy of 50 MeV, has not yet been confirmed but could be either a linac or microtron.

4 SOURCE PERFORMANCE

DIAMOND is specified to produce 300 mA with its complement of MPWs and up to four superconducting dipoles in the lattice. The beam lifetime required by the users is >20 hrs. All systems are being designed to meet this basic specification.

The beam emittance at the chosen working point is about 14 nm-rad [6] and it is intended to achieve an emittance coupling ratio [14] between the vertical and horizontal of 1%. This is a goal which will be aimed for after an initial exploratory phase with a larger coupling of perhaps 3% during which the storage ring behaviour will be measured and analysed.

The beam source dimensions for the 1% coupling situation are given in table 2. Lower emittances could be obtained, for example with optics having finite dispersion in the ID straights, as has been demonstrated by other third generation sources [15], but it likely that this option would only be exploited if the user emphasis moves away from MPWs.

Table 2: Beam sizes at source points

	σ(x)mm	σ'(x)mr	σ(y)mm	σ'(y)mr
superstraight	0.337	0.043	0.039	0.004
high beta	0.463	0.031	0.015	0.010
low beta	0.107	0.134	0.021	0.007
dipole centre	0.086	0.205	0.065	0.002

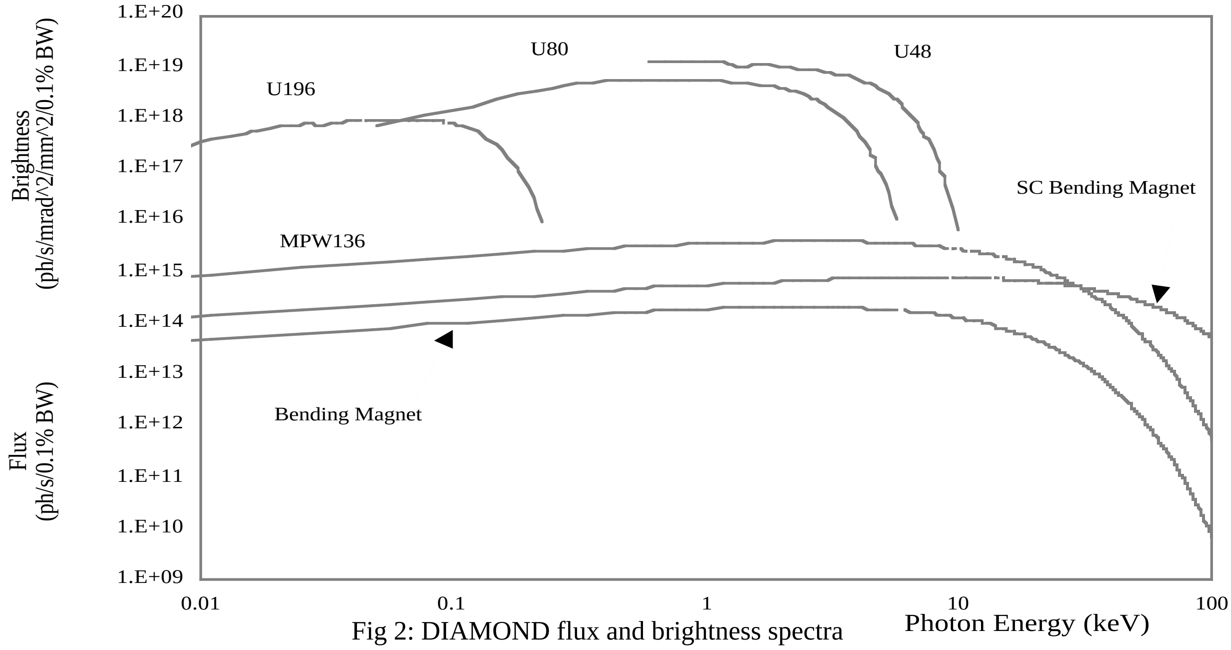

Fig 2: DIAMOND flux and brightness spectra

Superconducting dipoles are an option for a future upgrade in which up to four of the normal lattice dipoles would be replaced by high field(4.5 T) magnets giving the same lattice bend. The re-matching of cells with high field dipoles has been studied [6]. The advantage of such sources over high field wavelength shifters is that a much wider fan of radiation can be accepted, albeit with an experiment which is only a few metres from the tangent point within the storage ring tunnel. Schemes have been designed which prove the feasibility of such ideas.

The flux spectra to be obtained from the normal dipole magnets, superconducting lattice dipoles and MPWs are shown in fig 2. Realistic horizontal collection angles of 10, 40 and 3 mr respectively are taken for the three sources. Also shown are the brightness spectra to be obtained from typical undulators in DIAMOND [16].

5 STATUS

A feasibility study and preliminary cost estimate for DIAMOND was prepared in September 1995. It covered construction of the facility over a 5.5 year period, including 12 IDs, their associated beamlines and experimental stations. Although this plan has not been submitted for approval, the strong scientific case for a new source has been acknowledged and the funding bodies are discussing ways in which such a £100+M project can be financed and supported in the UK.

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