Proposals for New UK Light Sources

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Abstract

The Daresbury SRS was the first dedicated high energy light source in the world and has been operational since 1981. Despite several upgrades the facility will not be able to compete for many more years with the new generation of advanced sources and a review has recently been undertaken of the future needs of the UK synchrotron radiation user community. The conclusion is that the SRS should eventually be replaced by two new rings that will satisfy all users when combined with the availability of the ESRF in Grenoble. A 700 MeV ring (SINBAD) would provide high brilliance radiation from 5-200 eV and its racetrack design permits advanced FEL development. A more direct SRS replacement, the 3 GeV facility DIAMOND, would give high flux from 100 eV to at least 50 keV, together with high brilliance in the soft x-ray region. DIAMOND also incorporates a novel upgrade feature by progressive installation of superconducting bends. Detailed plans and the status of both projects are reported.

1. INTRODUCTION

The exploitation of synchrotron radiation for research in the UK started parasitically on the high energy physics ring NINA more than twenty years ago. This was followed by the construction at Daresbury of the SRS, the first dedicated high energy light source in the world, based on a 2 GeV electron storage ring. This second generation facility has operated for users since 1981 and in 1987 a major upgrade to its lattice enabled the brilliance to be enhanced substantially [1]. This national facility now has 41 experimental stations on its 12 beamlines and supports about 1500 active users in some 200 groups. Beams in excess of 300 mA are routinely provided with a lifetime of about 30 hours [2]. Three insertion devices provide either soft x-ray undulator output or very high photon energies from two superconducting wigglers, the latest of which has only recently been commissioned [3].

The scientific health of the UK programme in this area is reviewed at regular intervals. In 1986 a need for a higher brilliance soft x-ray source as a complement to the SRS was first identified and a decision was also taken subsequently to join the ESRF project. Over the next few years feasibility studies of the proposed new source culminated in a design optimised for output in the range 5-1000 eV [4] that became known as DAPS (Daresbury Advanced Photon Source). This was based on a 1.2 GeV racetrack ring that could also operate at 500 MeV for VUV users or for free electron laser (FEL) applications. However by 1992 it had become clear that the SRS itself had a limited future scope for further development and its possible replacement must also be assessed.

2. A NEW STRATEGY

Since 1992 a further major review by funding agencies has taken place with terms of reference to cover UK requirements over at least the next 10 years and from this a new strategy has emerged. The highest priority is now seen to be the replacement of the SRS and previous DAPS proposals have therefore been withdrawn. As an initial step the whole SRS user community was consulted on its present and predicted future experimental needs. This survey showed that there was a requirement for high quality synchrotron radiation over the full range from about 5 eV up to at least 50 keV but that it was not evenly distributed. Much the greatest demand (about 60 %) is in the region from 4-30 keV with only 20 % of users below 100 eV and most of the remainder in the intermediate soft x-ray range. Perhaps more surprising is that only a small minority of users forsee a need to focus beams onto extremely small samples below 100x100 μm^2 and that high flux and not high brilliance is emphasised by most users.

In assessing how best to meet this demand it is necessary to recognise the contribution from the ESRF, in which the UK is a partner supporting 14 % of the costs and receiving in return a *pro rata* access. This 6 GeV source delivers high brilliance radiation above 1 keV and the UK users might eventually expect access to 4 dedicated beamlines, a number approximately matching the identified national user demand for extreme brilliance at high energies. However a large demand remains spanning a wide spectral region that cannot be fully optimised on a single storage ring because undulators can only cover a restricted energy range, given existing technological limitations on magnet periods and gaps. Typically a 30:1 ratio of optimised output is available, based mainly on 1st and 3rd harmonics, so that the conclusion must be that two rings are necessary for this task. At the low energy end selection of 700 MeV gives excellent high brilliance radiation from below 10 eV, giving some overlap with lasers, to about 200 eV. In the case of a new x-ray source the requested high flux can be provided by extensive use of multipole wigglers; assuming an optimum field strength of 1.5 T then an electron beam of 3 GeV is needed to deliver a critical energy of 10 keV for the specified usable output range up to about 30 keV. In such a medium energy ring undulators will also provide high brilliance sources from about 150 eV up to around 5 keV and thus guarantee useful overlap with the other two rings. This three ring scenario is now the accepted basis for future provision of synchrotron light to the large UK user community; the low energy ring has been called SINBAD and the medium energy one DIAMOND. Feasibility studies reported here are at an early stage but have allowed reasonably accurate cost estimates to be prepared and the scientific case to be examined in considerable detail.

3. SINBAD

Since SINBAD would serve only about 20 % of the UK synchrotron radiation community it is most important to pursue a design that is economically matched to this level of demand whilst at the same time providing an internationally competitive source with longer term development potential. The proposed design is illustrated in simplified form in figure 1 which shows its principal features. It has 8 double bend achromat cells of which 2 are needed for injection and rf purposes so that a total of 6 high brilliance undulators in dispersion free straights is envisaged. This should provide up to 12 high quality user stations and it will of course be possible also to utilise the bending magnet output up to and beyond 1 keV.

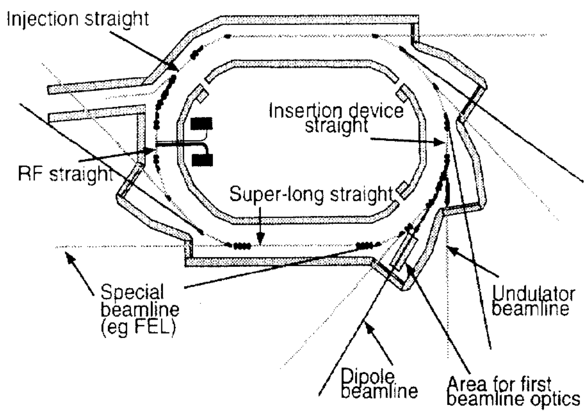

Figure 1. Layout of SINBAD

The 8 cell solution also produces an acceptably small value of electron beam emittance that can be set to 5-10 nm-rad, permitting diffraction limited optical experiments throughout the specified photon energy range. In the design of the racetrack storage ring it was possible to make extensive use of experience gained previously with the very similar DAPS lattice [5,6]. A set of the most important parameters is listed in Table 1.

Table 1
SINBAD Parameters

Energy	700 MeV
Current	300 mA
Circumference	116 m
Straights	3 m, 15 m
Emittance (h,v)	10 nm, 1 nm
Tunes (h,v)	7.8, 2.6
Lifetime	5 h

The working point in this example has been chosen to provide ease of operation and high circulating current and results in a conservative emittance value well above the theoretical minimum of about 3 nm-rad for an 8-cell DBA lattice at 700 MeV. Nevertheless it produces small source dimensions even for the pessimistic emittance coupling assumed in this example.

A feature of the ring is its racetrack geometry that makes available two exceptionally long 15 m straights. Flexible matching to the normal cells requires four quadrupoles at each end of these special straights and the resultant lattice functions are shown in figure 2.

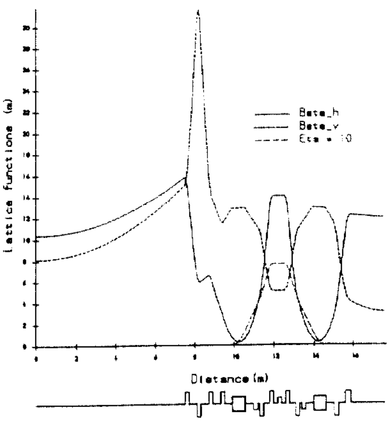

Figure 2. Lattice functions in SINBAD

If necessary the lattice can be switched to an alternative mode with much lower horizontal beta values at the insertion device locations.

Maintaining adequate lifetime is always a challenge in such relatively low energy, third generation storage rings. With realistic momentum apertures of 2-3 % the Touschek lifetime for single bunch operation can be made acceptable even at 50 mA, although exact estimates depend on the degree of bunch lengthening assumed. A single rf cavity will supply the required peak voltage and the electron beam power losses are moderate. For the more usual multibunch case the overall lifetime is dominated by elastic gas scattering losses in the vertical plane. This process will determine the minimum allowed gaps in the undulators and for 5 hour lifetimes suggests 10 mm for this aperture.

The SINBAD superstraights will allow the development and testing of novel insertion devices having very long periods or special polarisation properties. By adding a switched bypass a further important flexibility becomes available since devices potentially harmful to the circulating beam can then be installed. Examples include minigap undulators to extend the radiation output range and also advanced designs of free electron laser. An energy of 700 MeV is ideally matched to the requirements for developing an FEL in the XUV region, giving the potential for high power coherent output up to at least 20 eV.

The layout in figure 1 shows a small but full energy synchrotron injector situated where it has no interference with the user beam lines. A variant has also been assessed where the existing SRS injector could be shared since this has the advantage of utilising an available building and existing VUV experiments could also be transferred easily to the new ring.

Horizontal source dimensions at the insertion straights are under 300 μm and much smaller vertically. Close-in first optical elements allow a large fan to be accepted from bends.

4. DIAMOND

The new medium energy source would serve a much larger community of users than SINBAD and a 16 cell ring has been selected, allowing up to 4 soft x-ray undulators and 8 multipole wigglers in the zero dispersion straights. In addition to an injection straight at least one other will be needed for the high power rf system and a second has been provisionally allocated to permit high beam currents to be supported. A novel feature of the facility will be the optional inclusion of superconducting bends [7] as part of the main lattice rather than as insertions in the straights, allowing the latter to be reserved for the specialised high flux or brilliance devices. The high field bends can added as and when required in a phased manner. A triple bend achromat (TBA) has been chosen [8] in preference to the alternative DBA because its centre dipole is able to be changed more readily as part of a facility upgrade programme. The principal design parameters are summarised in Table 2.

Table 2
DIAMOND Parameters

Energy	3 GeV
Current	300 mA
Circumference	300 m
Straights	16 x 3 m
Emittance	10-50 nm-rad
Tunes (h,v)	16.7, 7.6
Lifetime	10 h

With no superconducting bends the 10 nm-rad is a conservative figure and does not represent the ultimate performance of this lattice, but it does allow flexibility in selecting the operating parameters for high current running. The emittance inevitably increases when cells have conventional dipoles exchanged for superconducting ones : for 8 such cells with 4.5 T magnets the overall emittance will be doubled [7}. Further details on this lattice are given in an accompanying paper [8], including the matching of the two types of cell to minimise perturbations.

The radiated energy loss will be increased significantly when the ring has as many as 10 multipole wigglers with fields of at least 1.5 T and with superconducting magnets enhancing this further it can reach 1.5 MeV per turn, so that the rf system must provide up to 4.5 MV and 500 kW. Two 3-cell cavities [9] could meet this demand in a single straight but it would be wise to reserve a second one for longer term current upgrades.

Recent results on modern light sources (eg ESRF, ALS, ELETTRA) have demonstrated that the use of positrons is unnecessary as any residual ions can be successfully removed by appropriate choice of bunch spacings. It has therefore been assumed that DIAMOND will use a conventional injection scheme from an electron synchrotron, possibly at full energy.

DIAMOND will be able to reverse the trend on many 3rd generation sources by permitting much closer beam line optical elements and consequently larger radiation collection angles. This is a particular advantage of the geometry of the short superconducting magnets with tight bending radius.

5. OVERVIEW AND STATUS

The multi-source scenario put forward here is very well optimised to UK user needs over the full spectral range and this is summarised in figure 3. The spectral curves are

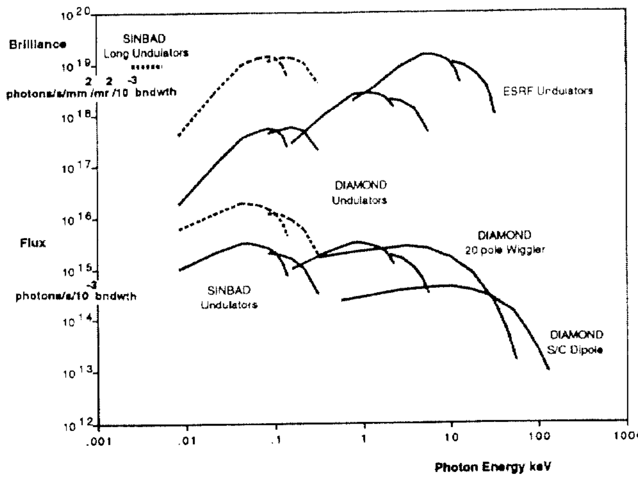

Figure 3. Flux and Brilliance Range of Sources for UK Users

envelopes for a full range of devices and also take no account of upgraded electron beams and undulators, either at ESRF or on SINBAD and DIAMOND.

After a series of reviews the strength of the scientific case has been recognised and funding is now being actively sought. The highest priority has been awarded to DIAMOND and it is hoped that a decision on a full design study is imminent.

6. REFERENCES

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