PROGRESS WITH THE DIAMOND LIGHT SOURCE PROJECT

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Abstract

The current status of the detailed design and construction of the UK's new 3rd generation light source, Diamond, is described.

INTRODUCTION

The Diamond Light Source is a new medium-energy high brightness synchrotron light facility which is under construction on the Rutherford Appleton Laboratory site in Oxfordshire, U.K. The evolution and progress of the Diamond project has been reported regularly at accelerator conferences [1,2,3]. The basic design is contained in the Design Specification Report which was published in June 2002 [4]. Table 1 lists the main parameters of Diamond. Injection of the storage ring is by means of a 100 MeV Linac and full energy booster synchrotron.

Table 1. Main parameters of the Diamond storage ring

Energy	3 GeV
Circumference	561.6 m
Lattice	24 cell DBA 6 fold symmetry
Current	300 mA
Lifetime	> 10 h
Emittance (H,V)	2.7, 0.03 nm
No. of straights available for insertion devices	22

At the end of March 2002 Diamond Light Source Ltd. was formed under a Joint Venture Agreement between the UK Government and the Wellcome Trust and the project moved into the construction phase, with an approved, fixed, budget for the facility which includes an initial complement of 7 insertion device beamlines. Significant progress has been made since then with detailed design, specification and procurement, in line with the agreed project plan which is based on starting user operation in January 2007. The first contract for the machine has been let (the Linac) and Calls for Tenders have been issued for the storage ring quadrupoles, superconducting cavities and amplifiers.

BUILDINGS AND FOUNDATIONS

The consultants for the design of the buildings and services, JacobsGIBB Ltd., were appointed in January 2002. Scheme design was completed in July 2002 and detailed design is now complete in some areas and close to overall completion. This has required a great deal of interaction with the machine team to define details of the layout of the machines and transfer lines, and in particular the radiation shielding, personnel labyrinths, control and instrumentation areas and service routes etc. Figure 1 shows the overall layout.

In January this year the Main Contractor, Costain Limited, was appointed under a two-stage contract. The first-stage covers the enabling works (and other services) which started on-schedule in March 2003. The main works are due to start in October 2003. A key date for the project as a whole is the start of machine installation which is scheduled for September 2004.

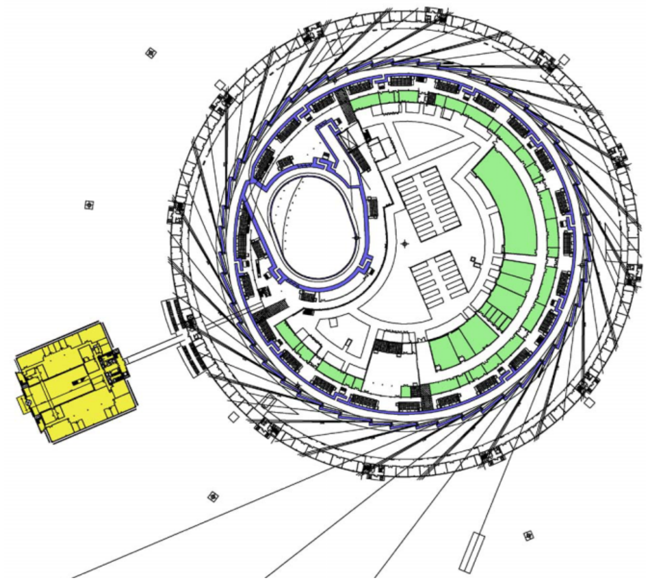

Figure 1. Layout of the Diamond Light Source

One of the design development areas that has involved a close interaction with both machine and beamline designers has been the issue of the foundations. It has been known for some time that extensive piling would be necessary to achieve the tight specification on differential settlement which was originally set at 0.1 mm/10m/year for the storage ring (0.25 mm for the experimental hall). During 2002 a detailed set of site investigations was carried out involving cone penetration tests, trial boreholes, test piles, analysis of soil samples etc. to gain further information about the nature and variability of the subsoil on the Diamond site. In addition, measurements of response to various dynamic excitations were made in order to calibrate a numerical model that was used to determine the relative merits of different foundation solutions in terms of vibration behaviour. In parallel with this, various simulations of the effect of settlement on the machine [5] and beamlines were made.

The results of this work confirm that even to achieve a settlement performance that is within an order of magnitude of that originally specified a piled solution is

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necessary. The next most significant factor in determining the performance of the foundation is whether a deliberate void is formed between the slab and the piles. A compromise is necessary between better static behaviour (favouring a void to isolate the slab from the shrink/swell movement of the ground) and dynamic behaviour (favouring direct contact between the slab and the ground to reduce vibrations). The final choice is to include a void, since contact with the ground can also lead to an unwanted localised upward heaving between the piles, the “pincushion” effect, introducing significant angles which could adversely affect both machine and beamline operation. A moderately thick slab (600 mm for the experimental hall) and close pile spacing (3 m) were then chosen, particularly to improve the dynamic behaviour, but which also serves to reduce differential settlement. Finally, to avoid the introduction of localised differential movements between source and experiment, the experimental hall and storage ring tunnel slabs will be joined.

LINAC

Table 2. Main parameters of the Diamond Linac

Energy	100 MeV
Multibunch charge	≥ 3 nC
Multibunch length	300 ns
Single bunch charge	≥ 1.5 nC
Normalised Emittance (1σ)	≤ 50 mm mrad
Energy spread (total)	≤ ± 1.5 %

The 100 MeV Linac pre-injector will be supplied by ACCEL Instruments GmbH under a turn-key contract. DLS will however supply vacuum, controls and diagnostic equipment in order to standardise components across the facility. The main parameters of the Linac are given in Table 2. Single- and multi-bunch modes of operation will be provided and both of these will be possible in top-up mode, with charges as low as 50 pC, and with flexible pulse formats, within the maximum repetition rate of 5 Hz.

BOOSTER

An outline booster lattice design was presented in [4,6] based on a two-fold symmetric 44-cell FODO structure with 8 missing magnets, producing zero dispersion regions for injection (single-turn on-axis), extraction (single-turn), RF and diagnostics. Since then the design has been refined in much greater detail, in particular to define aperture requirements and study non-linear dynamics including the effects of eddy-current induced sextupole fields. A small change has also been made in circumference to optimise synchronisation with the storage ring. The main parameters of the booster are given in Table 3.

The aperture calculations take into account beam size and residual closed orbit errors after correction of magnet alignment errors, and include further allowances for tune point variation, effects of ground motion and other effects. This results in a beam-stay-clear (BSC) aperture (total) in the dipoles of 44 mm (horizontal) x 16 mm (vertical). Dynamic aperture calculations including the effect of induced eddy currents show that a thin-walled vessel is not needed and that a 1 mm stainless steel vessel can be used even at the nominal cycling frequency of 5 Hz (see Fig. 2). Taking into account suitable shape and alignment tolerances leads to a nominal vacuum vessel internal dimensions of 46 x 17.2 mm and a final magnet gap, including a 0.3 mm thick layer of material for electrical isolation, of 21 mm.

Table 3. Main parameters of the Diamond Booster

Peak Energy	3 GeV
Circumference	158.4 m
Lattice	44 cell FODO 8 missing dipoles
Current (max)	6 mA
Tunes	7.16, 4.11
Chromaticity	-0.3, -6.2
Emittance (3 GeV)	135 nm rad

In the straight sections a constant aperture will be used defined by the maximum in the F and D quadrupoles. The resulting BSC is 50.4 x 17.8 mm. Internal vacuum vessel dimensions of 52 x 24 have been chosen to produce a more readily achievable vacuum vessel cross-section without affecting the magnet inscribed radius. Allowing for a 1 mm gap between vessel and poles leads to inscribed radii of 21 mm in the quadrupoles and 24 mm in the sextupoles. Dimensions in the injection and extraction regions have not yet been finalised.

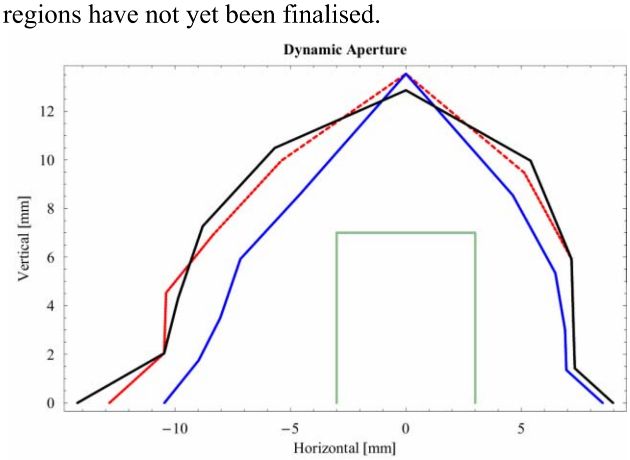

Figure 2. Dynamic aperture in the booster at injection energy and zero chromaticity, taking into account eddy current fields, for on-momentum (red) and off-momentum (-1.5 %, black, + 1.5 % blue) particles. The reference point is at the symmetry point in the region of zero dispersion. The box indicates the required aperture for beam size.

Outline magnet designs based on these apertures have now been produced and vacuum calculations performed to demonstrate feasibility of the proposed pumping scheme. An outline engineering layout of the magnets and vacuum system has also been produced, covering everything except the injection, extraction and RF cells. A Call for Tender for these magnet and UHV vacuum assemblies, mounted on ready-to-install girders which make up 137 m of the booster circumference, will soon be made. Figure 3 shows the outline design for one such assembly. This strategy was chosen in order to make best use of the limited in-house resources, while still allowing DLS to maintain control of the overall system and profit from specialised manufacture for the injection and extraction elements, power supplies, RF system, controls and diagnostics etc.

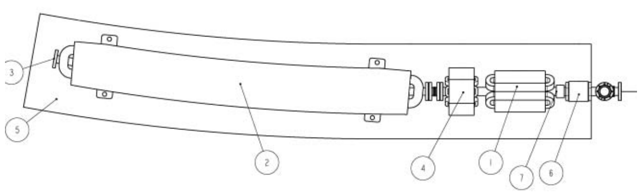

Figure 3. Booster magnet and vacuum assembly unit.

The outline magnet designs are sufficient to fix the power supply parameters and allow procurement to proceed in parallel. The power supplies will be of a switched-mode type to enable the flexibility needed for top-up injection. Since the resulting peak output voltage of the dipole supply of 2.05 kV is quite high (with the nominal peak current of 870 A for 3 GeV operation plus a 10 % working margin and assuming a biased-sine wave excitation at 5 Hz), cost and reliability issues become a concern and so a reduction of the repetition rate is presently under consideration.

STORAGE RING

A change in philosophy of the engineering layout has recently been agreed, namely to incorporate the dipole magnets on the girders whereas they were previously separate. This has several advantages such as allowing more pre-assembly work, minimising the number of handling operations in the ring building, improving relative alignment of the dipoles and crotch vessels with respect to the straights, and easing the design and operation of motorised girder positioning system. It also reduces the number of vacuum connections to be made between externally baked assemblies from 4 to 2 in each achromat. The design philosophy remains that there will be no in-situ bakeout (except of ID vessels), as discussed and reconfirmed at a recent international workshop [7]. Figure 4 shows the largest of the modified girders, 6 m long and weighing an estimated 16.7 T. Further work has also been carried out to refine the pumping scheme. Figure 5 shows the layout of the vacuum system for a complete achromat, with manual valves to allow future front-end installation without letting-up the ring.

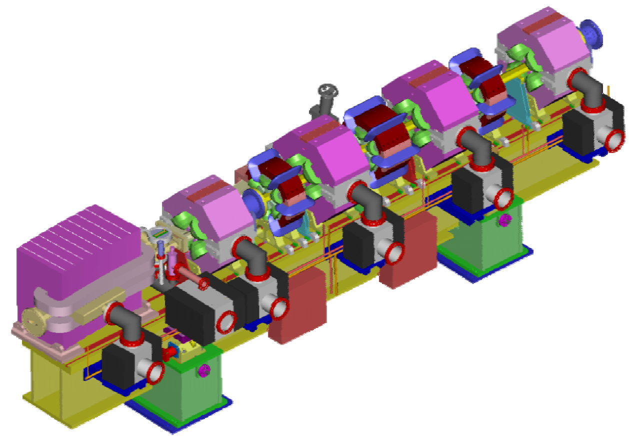

Figure 4. Extended storage ring girder assembly

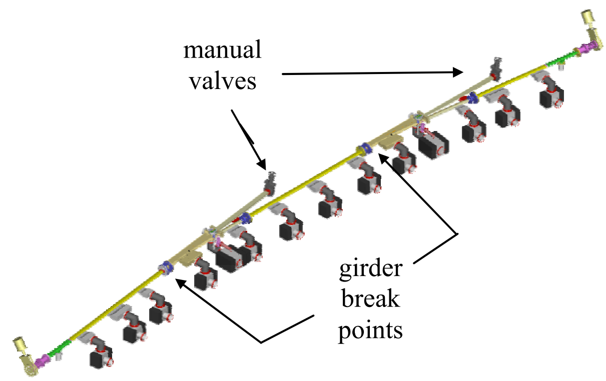

Figure 5. Vacuum system assembly for one achromat.

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