PROGRESS WITH THE DIAMOND LIGHT SOURCE

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Abstract

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

INTRODUCTION

Construction of Diamond, the UK's new 3 GeV, 3rd generation synchrotron light source [1,2] is progressing in-line with the original target of starting storage ring commissioning in January 2006 and being operational for users in January 2007. The main building works started in October 2003, following completion of enabling works which included extensive piling. Figure 1 is a recent view of the site, showing that steelwork will soon be finished and that roofing is well advanced. The linac and booster tunnels are now complete. The poured concrete storage ring outer walls are 95 % complete and installation of pre-cast roof beams is 50 % complete. The experimental hall slab is 20 % complete. Despite some delays, a phased access to the building for machine installation is still expected to commence on schedule this September.

Figure 1: The Diamond site, end of June 2004.

Most of the major machine components are also under construction, with nearly 60 % of the machine capital budget already committed. This report will concentrate on recent design developments, component choices and current status. Other papers at this Conference deal with accelerator physics issues [3,4], and diagnostics [5].

INJECTION SYSTEM

Linac

The parameters of the 100 MeV linac, being supplied by ACCEL Instruments G.mbH, were presented in [2]. Construction is proceeding according to programme, with equipment installation expected from Nov. 2004 to Feb. 2005, immediately followed by commissioning with final acceptance targeted for June 2005.

Booster

The concept of procuring "girder assemblies" [2] for the booster, consisting of all main magnets and vacuum vessels mounted and aligned on ready-to-install supports, in order to reduce in-house staff effort, has proved successful. Competitive bids were received and a contract has now been placed for the detailed design and construction. Prototype magnets are about to be measured and design approval has been given for the girders. First girder assemblies are expected in November 2004, with a phased delivery to DLS completing in April 2005. Installation and commissioning will be carried out by DLS.

The tender exercise for the magnet power supplies confirmed the original choice of a 5 Hz repetition rate for the booster. The dipole power converter is rated at 1 kA, 2 kV. Like all the other power converters for Diamond, it uses the ADC and controller cards developed at PSI for the SLS. The dipole power converter consists of four series units fed from a common transformer. Each unit is made up from a diode rectifier followed by a boost regulator on the input, energy storage capacitor bank and two quadrant regulator on the output. If one unit fails it can be bypassed through a switch and the power converter operated at full performance with three series units. The circuit has a high circulation power (2 MVA), with energy transferred between the magnet loads and capacitor banks. The power drawn from the AC supply is relatively small (50 kVA) and constant thanks to the operation of the boost regulator. The output regulators operates at 4 kHz and are phase displaced, giving an effective frequency at the output of 16 kHz.

RF power will be supplied by means of a single 5-cell cavity of the Petra type, driven by a 60kW IOT-based RF source. Installation and commissioning of the Booster RF system will take place in January to June 2005, with the RF source commissioned independently in the first 3 months followed by cavity installation, conditioning and acceptance.

A contract for the supply of the injection and extraction magnets and power supplies, including vacuum vessels, has recently been placed. The kicker magnets, one each for injection and extraction, will be in-vacuum to reduce power supply demands. The septa, one for injection and two for extraction, will be ex-vacuum to decouple magnet laminations from the vacuum system and minimise stray deflection from the septa.

Transfer lines

Both linac-to-booster (LTB) and booster-to-storage ring (BTS) transfer lines have now been completely designed. LTB magnets are under construction and a contract for the

BTS magnets is about to be placed. Vacuum vessels and other items, including diagnostics and supports, are being designed by DLS to simplify their integration.

STORAGE RING

Magnets

Separate contracts have been placed for dipole, quadrupole and sextupole magnets. The prototype dipole has recently been measured and accepted. The data shows that the desired field quality has been achieved: -0.05% variation in the integrated field across ±12 mm. The first quadrupole prototype will also be ready in the near future.

The design of the sextupole magnets is now substantially different to that originally proposed [1]. The proposal to use 5 single part coils with independent power supplies controlled via software to produce 3 types of corrector has been replaced by 3 circuits with more complicated compound coils with the numbers of turns in each coil chosen to produce the desired fields. The previous open design of the yoke has also been replaced by a complete magnetic yoke, in order to reduce quadrupole and 10-pole field error components and coupling between the vertical dipole and sextupole fields.

Vacuum

All major vacuum equipment contracts have now been placed and first deliveries have been made. Noble diode type ion pumps have been selected as these provide a good combination of high pumping speed and high argon stability. Mobile turbomolecular/scroll pump carts will be used for roughing out the vacuum systems, boosted by small demountable turbomolecular pumps for the front ends where close pumping cart access is difficult.

Following a review of storage ring vacuum protection, fast-closing vacuum shutters have been added to the front ends and to the BTS transfer line to reduce the storage ring vacuum recovery time following a vacuum accident in one of the beamlines or in the booster ring.

Vacuum vessels are close to the prototype stage and series deliveries are scheduled to begin in late Summer 2004. Plans and facilities for the assembly, processing and integration of these with the magnets and support girders are being finalised. The vacuum assembly and processing area for this is now operational with a UHV cleaning facility for vessels up to 2 m long and bakeout ovens for vacuum sections up to 6 m long. The procedures to be used in this area will be trialled on the prototype vacuum vessels in the next few months.

Current areas of design work include the ID vessels, ID make-up vessels and the vacuum monitoring, control and interlock systems.

Girders

The magnets and vacuum system in the arc regions will be pre-assembled on 72 girders, 3 for each of the 24 cells. The girders, up to 6 m long, will be mounted on motorised bases, following the SLAC design concept as developed by SLS [6,7]. A prototype long girder, and its base units, has been delivered to DLS and has just completed a series of dimensional, deflection and vibration tests. The results show that 30 micron straightness and flatness has been achieved in the reference grooves. A measurement of deflection under load was performed by means of dummy weights which simulate the weight and centre of gravity of the different magnets (Fig. 2). The results show larger than expected deflections which although unlikely to affect the performance are being investigated with the supplier.

Figure 2: Prototype girder undergoing tests in the new Diamond assembly building.

Vibration measurements have been taken and data is currently being processed to establish the natural modal frequencies and the transfer functions from the ground through the assembly to the magnet centres. The design aim is for 1st natural frequency to be above 30Hz.

RF System

The RF system will comprise initially two superconducting cavities each rated to 300 kW and an accelerating voltage of 2 MV. These can supply enough power for operation at the design current of 300 mA even with a full complement of insertion devices (IDs). Due to the power limitation of the cavity coupler a third cavity is required for 500 mA operation. Table 1 gives the relevant parameters for operation with no IDs, with the 7 selected IDs for Phase 1 beamlines, and also with a full complement of 22 IDs.

Table 1: RF System Specifications

	No IDs		7 IDs		22 IDs	
Total losses (MeV/turn)	1.05		1.25		1.78	
Beam Current (mA)	300	500	300	500	300	500
Beam Power (kW)	315	525	375	625	534	890

The cavities are currently being manufactured with the first two modules due to be delivered during the summer of 2005 and the third cavity during 2006.

The RF amplifiers will be capable of supplying up to 300 kW to each cavity. Each consists of four 80 kW IOTs with their outputs combined in a waveguide combiner. The IOTs are protected by coaxial reject loads on the combiner by a 300 kW circulator and load capable of dissipating the full reflected power. The factory test of the first amplifier will commence during July 2004 with all three systems being delivered by end of October 2004.

The selected cryogenic plant will be capable of a guaranteed 450 W of refrigeration with a modest (2.4 g/s) use of liquid Nitrogen to pre-cool the heat-exchanger, sufficient for three cavity operation. The plant is being designed to allow an additional cold-box to be connected to increase the refrigeration power. This will enable additional equipment such as a third harmonic cavity and superconducting wiggler to be cooled by the same plant. Variable refrigeration capacity down to 200 W, with a corresponding reduction in power consumption, will be achieved by fitting the compressor with a variable frequency driver. The refrigeration plant will be delivered and operational by the summer of 2005 prior to installation of the superconducting cavities.

Control System

The overall design of the EPICS-based control system is complete [8] and the detailed design and procurement phase is underway. Contracts have been placed for VME64x crates, Motorola MVME5500 processor boards, Industry Pack carriers and other I/O modules, and timing modules. Standard PLC-based units for control and protection of the vacuum system have been designed and are being manufactured. Installation of controls hardware including networking will start in late 2004.

Recent work has included development of a virtual accelerator using the Tracy libraries [9] interfacing to an EPICS IOC through device support. This is enabling the early development of physics applications, written in Java and MatLab using the Accelerator Toolbox [10], and interfacing to the virtual accelerator via the naming and Channel Access API that will eventually interface to the real accelerator.

Diagnostics

A novel BPM electronics system has been selected based on direct AD conversion of the button signals and digital signal processing in a FPGA. Due to its combination of input multiplexing and four channel processing it will be capable of delivering sub-micron resolution as well as sub-micron beam current dependency at fast feedback bandwidths. The same system will be used for the booster and transfer line BPMs and is described in more detail, along with the other diagnostic systems, in an accompanying paper [5].

Injection System

The layout of the 8.3 m injection straight has recently been updated [3] to accommodate collimators which will act as defining apertures for top-up operation in order to localise electron loss. This was necessary because there is insufficient space in the arcs and all other straight sections (apart from RF) will eventually incorporate an ID, and since radiation safety considerations precludes simultaneous operation of an ID beamline with collimators in the same straight as the ID.

The kicker magnets will be ex-vacuum with coated, ceramic vacuum vessels producing a symmetric bump of maximum 16.7 mm. The choice between an in- and ex-vacuum septum will depend on the response to the current call for tender for these magnets.

Insertion Devices

Table 2: Phase 1 ID Specifications

Name	Period (mm)	Number of Periods	K_{Max}	Length (m)
SCW	60	23	19.6	1.5
U33	33	147	1.63	4.9
U23 IVa,b	23	85	1.49	2.0
U21 IV	21	93	1.24	2.0
U27 IV	27	72	2.02	2.0
HU64	64	33	3.44	2 x 2.2

Table 2 lists the main parameters of the first 7 IDs required as part of the Phase 1 construction. There are 4 in-vacuum (IV), 2 ex-vacuum permanent magnet devices and 1 superconducting wiggler (SCW). Contracts have been placed for 2 pre-production support systems and control systems which are nearing completion. These will be used to construct the first in-vacuum device U23 and one section of the APPLE2 HU64, before proceeding to the production series. A call for tender has been issued for a turn-key superconducting wiggler.

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