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OVERVIEW OF ACCELERATOR PHYSICS STUDIES AND HIGH LEVEL SOFTWARE FOR THE DIAMOND LIGHT SOURCE

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Abstract

Diamond is a 3 GeV synchrotron light source under construction at the Rutherford Appleton Laboratory in Oxfordshire (UK)[1]. The accelerator complex consists of a 100 MeV linac, a full-energy booster and a 3 GeV storage ring with 22 straight sections available for insertion devices. Installation of all three accelerators has begun and linac commissioning is due to start in summer 2005. This paper will give an overview of the status of the installation and the progress in accelerator physics studies. The Diamond facility is expected to be operational for users in 2007.

INTRODUCTION

The installation of the Diamond accelerator complex started in winter 2004 and is progressing simultaneously for the different accelerators and transfer lines. The present status can be summarized as follows.

Linac: The linac is manufactured by ACCEL instruments, with Diamond providing linac beam diagnostics, control system hardware and standard vacuum components.

The linac high-power RF system includes two 3 GHz modulator units, each with one Thales TH2100 klystron driven by a pulsed preamplifier and a thyratron-switched LC line-type pulse-forming network. Installation of this RF system began in late 2004, and the hardware is now complete and ready for high-power testing in May 2005. Commissioning of the electron gun and bunching and accelerating structures will follow high-power RF commissioning, with beam tests scheduled for summer 2005.

LTB: Installation has commenced, and completion of the transfer line in the linac vault will be required before linac beam commissioning can start.

Booster: The first booster girders assemblies, supplied by Danfysik, have been installed in the booster tunnel. Girder installation will continue over summer 2005. Installation of the booster amplifier is now complete and high-power testing into the dummy load is imminent. The booster cavity is presently under manufacture by ACCEL and manufacture of the low-level RF system at ELETTRA is close to completion.

BTS: Detailed design of the BTS is near completion, and magnets have been ordered for delivery in mid-summer, with installation due for completion later this year.

Storage ring: Girder installation has begun in the storage ring and three 300 kW Thales amplifiers have been installed in the RF hall. Superconducting cavities of the Cornell type have been manufactured by ACCEL and are under test at the manufacturer.

In preparation for the accelerators commissioning, significant progress has been made in the construction of high level software for physics applications. At the same time beam dynamics studies have continued to clarify the outstanding accelerator physics issues and to assist the final design of several accelerator components.

HIGH LEVEL SOFTWARE

The Diamond control system is based on EPICS and will use Channel Access as the interface to all machine data. The high level software for physics applications and commissioning has been developed by simulating the access to the Diamond magnet power supplies and electron beam position monitors in an interface, called the Virtual Accelerator, based on the Tracy-II tracking code wrapped into EPICS device support. This provides a realistic simulation of the electron beam properties and has allowed the early development of commissioning and control applications for all three accelerators.

The Diamond project is making extensive use of a suite of Matlab tools for the design of the accelerator physics applications, based on the Accelerator Toolbox (AT) [2], MiddleLayer [3] and Matlab Channel Access (MCA) [4], developed and successfully applied at SPEAR and ALS. The MiddleLayer database has been set up for Diamond, and many of the applications available have been tested on the Virtual Accelerator. Fig. 1 shows a snapshot of the "orbitgui" application [5] that will be used at Diamond for orbit display, correction and to set orbit bumps.

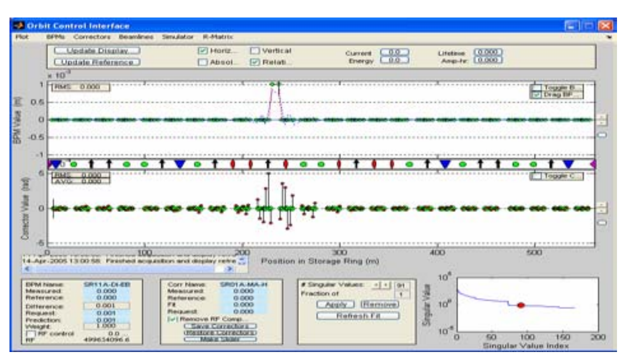

Figure 1: Orbitgui application used at Diamond.

Most of these applications can be equivalently used for storage ring and booster commissioning and operation. Independent development of Matlab physics applications has also been pursued in areas not covered by MiddleLayer, such as beam control in the transfer lines, linac emittance and energy spread measurements which will be used for the linac acceptance tests. Fig. 2 shows a snapshot of a Matlab graphical interface to control the beam optics in the transfer line.

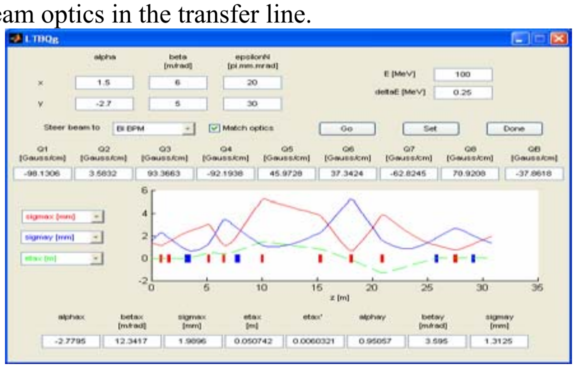

Figure 2: Optics control GUI for the LTB

Another area where Matlab applications have been developed is the analysis of turn–by–turn data from the 168 BPM system in the storage ring and the 22 BPMs in the booster. The Diamond BPM system [6] will be capable of simultaneously delivering data with different bandwidths useful for turn-by-turn (534 kHz), closed orbit feedback (10 kHz) and display (10 Hz). The expected resolution in turn–by–turn mode will be better than 10 μm r.m.s. under a wide range of current and fill pattern regimes, allowing experimental investigation of the non-linear beam dynamics. The NAFF and SUSSIX codes [7] for post-processing turn–by–turn data have been linked to a MATLAB script and allow the extraction of information on the detuning with amplitude, frequency maps and on the spectral content of the betatron oscillations.

BEAM DYNAMICS STUDIES

The analysis of the non-linear dynamics for the non-zero dispersion lattice of the Diamond storage ring is reported in a companion paper [8]. We report here the results of the application of a sorting strategy to the booster dipoles, the assessment of collimation systems for the BTS and the storage ring and the first results of the analysis of the effect of IDs on the beam dynamics.

Booster Dipole Sorting

A sorting method based on simulated annealing [9] has been applied to the booster dipoles, in order to minimise closed orbit distortions. The improvement in the r.m.s. closed orbit is found to be significant, as shown in Fig 3. Sorting has been carried out using dipole field measurements at 330 MeV, where the beam size is still large and the magnetic measurements have less noise. Sorting is also envisaged for the storage ring dipoles once the magnetic field measurements are available.

Collimation Studies

As Diamond will utilise top-up operation, collimation systems have been included in the BTS and storage ring for controlling bunch dimensions and losses. Pairs of horizontal and vertical collimators have been placed in the BTS at nearly $\pi/2$ phase advance for emittance collimation, while another collimator is located in a high dispersion region in the BTS for energy collimation. This system has proved to be effective in collimating the incoming beam from the booster assuming a wide range of possible extraction errors.

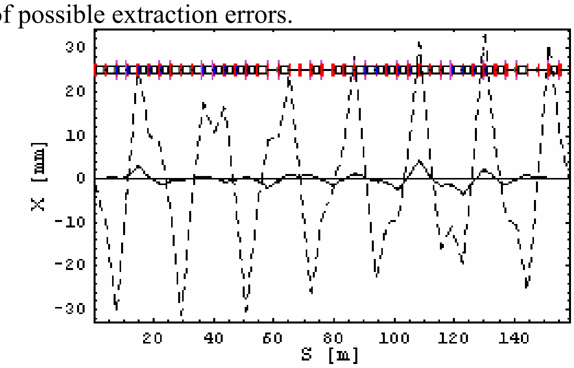

Figure 3: Closed orbit distortion for sorted dipole magnets (solid line) and worst-case (dashed line) error distributions in the booster

A collimation system is also planned in the storage ring: one vertical and one horizontal collimator are placed in the injection straight before and after the fourth injection kicker respectively to concentrate Touschek losses at a single point. Fig, 4 shows the loss distribution as a function of collimator aperture.

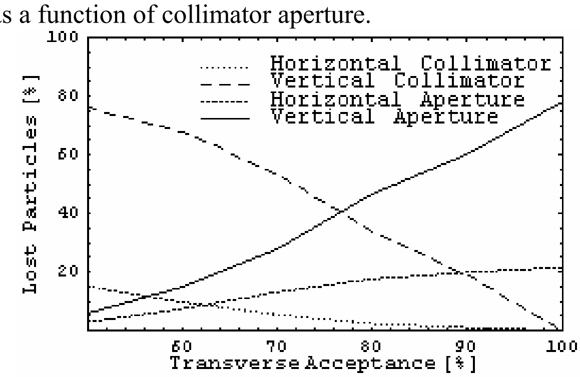

Figure 4: Percentages of total particle losses occurring at the collimators ("collimator") and elsewhere in the storage ring ("aperture") as a function of the relative transverse acceptance: 100% means collimator wide open, 50% means 12.2 mm in H and 4.5 mm in V half apertures.

It is clear that the collimators are capable of collecting a large fraction of the total losses, the majority of which are in the vertical plane.

Injection efficiency has been determined as a function of bunch length, horizontal and vertical injected beam emittance, phase error and separation between the stored and injected beams. Due to synchrotron motion, an injection energy acceptance of about ±2% is needed to fully accommodate the injected bunch length of 2.6 cm,

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as shown in Fig 5. It has been verified that a horizontal emittance of 225 nm.rad (compared to the nominal value of 150 nm.rad for the booster) can be fully accepted into the storage ring. Over 99% efficiency can still be achieved with collimators set to the previous minimum values.

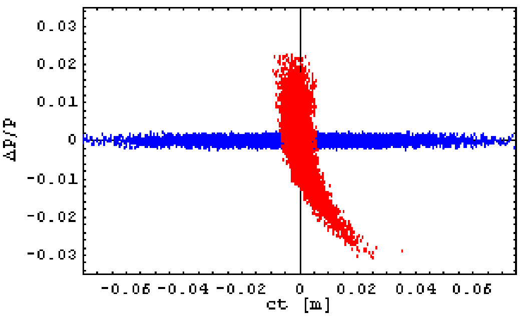

Figure 5: Longitudinal phase space of injected beam at injection (blue) and after 48 turns (red).

Insertion Devices (IDs)

Modelling of IDs in the first phase of ID installation (phase 1) has been performed using explicit symplectic integration in AT [10] and the kick map method [11] implemented in Tracy-II (SOLEIL version [12]).

Several schemes for the compensation of linear optics distortion caused by the IDs have been analysed. As an example Fig. 6 shows the application of the LOCO [13] algorithm to the Diamond lattice with all the phase 1 IDs. The residual β-beating can be compensated to about 1% in the entire ring except in the region close to the IDs. The main cause of linear optics deformation is the high field multipole wiggler MPW60 (3.5 T). Compensation is achieved by varying the quadrupole gradients within ±9% of their initial value.

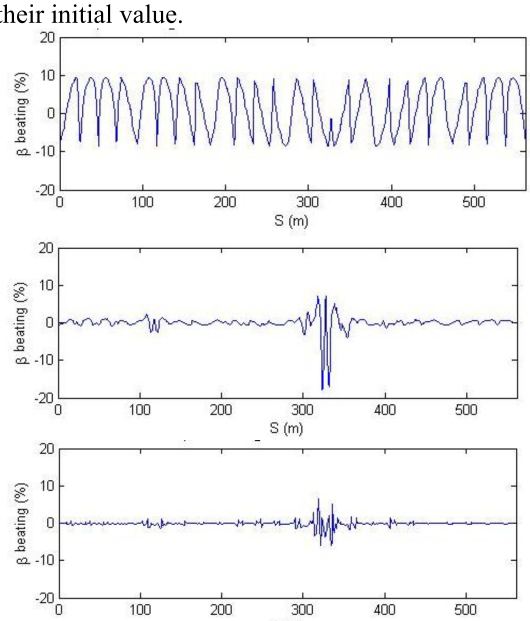

Figure 6: Compensation of β-beat with LOCO. Vertical β-beat without compensation (top), vertical β-beat with compensation (middle), horizontal β-beat with compensation (bottom).

Diamond phase 1 IDs have also been studied using the kick map representation. Mapped IDs are described by interpolation tables which provide the kicks experienced by the particle as a function of its coordinates when passing through the device. This description is more general and can be more accurate than the analytical description by a mathematical formula. It is assumed that the IDs are optimised so that the beam does not experience the effect of residual field integrals. In this case only the second order field effect enters in the description of the mapped ID [11].

Table 1 shows the results of the 6D Touschek lifetime computations for two types of phase 1 IDs including a helical device (HU64) in all possible polarization modes and a multipole wiggler (MPW60). The lifetimes are computed in the presence of realistic coupling errors of 1% [8]. There is no significant effect due to these IDs on the Touschek lifetime. The reduction is about 12% in the cases of MPW60 and HU64 in the vertical polarisation mode. The study with the in-vacuum undulators and the analysis of the effect of all Phase 1 IDs together is in progress, including the Frequency Map Analysis of their effects on the beam dynamics.

Table 1: Touschek lifetime computations for selected IDs

	6D Touschek lifetime	
Bare lattice	8 h	
HU 64 (undulator)	H-mode	7.8 h
	V-mode	7.1 h
	C-mode	7.6 h
MPW60 (S/C Wiggler)	7 h	

CONCLUSIONS

We have presented an overview of the accelerator physics activity at the Diamond Light Source and the status of the installation of the Diamond accelerator complex. Installation of Diamond hardware and development of software applications are proceeding together, and are consistent with booster commissioning in late 2005 and storage ring commissioning in early 2006. Finally we would like to acknowledge the fruitful collaboration with many scientists at ALS and SPEAR3 that helped us in setting up the Matlab MiddleLayer tools at Diamond.

REFERENCES

[1] DIAMOND Synchrotron Light Source. Report of the Design Specification, CCLRC, June 2002.
[2] A. Terebilo, PAC 2001, p. 3203.
[3] J. Corbett et al., PAC 2003, p. 2369 (2003).
[4] A. Terebilo, 8th ICALEPCS p. 253 (2001).
[5] J. Corbett, A. Terebilo, PAC 2001, p. 813 (2001).
[6] G. Rehm et al., EPAC 2004, p. 2765.
[7] J. Laskar et al., Physica D, **56**, 253, (1992); R. Bartolini and F. Schmidt, CERN-SL **98-017** (AP), 1999.
[8] M.Belgroune et al, this conference.
[9] M. Abo-Bakr, G. Wuestefeld, EPAC 1996, p1314.
[10] Y. Wu et al., Phys. Rev. E 68, 046502, (2003).
[11] P. Elleaume, EPAC 1992, p. 661.
[12] L. Nadolski, private communication.
[13] J. Safranek, Nucl. Inst. and Meth. **A338**, 27, (1997).