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LAYOUT OPTIONS FOR THE AXXS INJECTOR AND XFEL

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Abstract

A new injector is being planned for the Australian Synchrotron that is designed to feed both an upgraded storage ring and an XFEL. The desire to fit the AXXS project on the same site as the existing light source presents several layout difficulties. Several options are studied and simulations are performed to check the impact each choice has on the beam performance.

INTRODUCTION

The Australian X-Band X-Ray Source (AXXS) [1] is part of an effort to use the CLIC [2] x-band technology from CERN to develop a Free Electron Laser (FEL). A research and development collaboration has been formed [3] and a baseline design for the linac has emerged [4]. This paper explores some of the layout options that are specific to the Australian Synchrotron (AS) site in Melbourne, Australia. At this stage it will be attempted to fit the construction of an FEL to be co-located on the same site as the existing storage ring and to use the linac to inject into the new multi bend achromat (MBA) lattice that is being designed to replace the existing storage ring. Including the neighbouring car park on one side and an empty lot on the other side, there is 550 m of land available on the existing AS site (see Fig. 1).

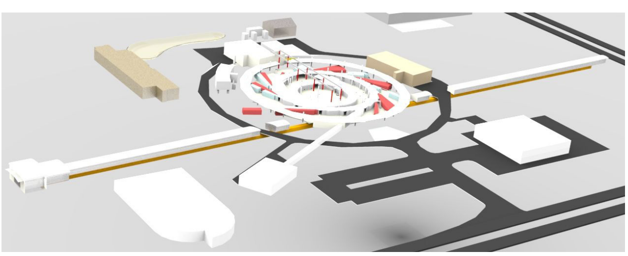

Figure 1: AS site with proposed AXXS FEL overlay.

As explained in Ref. [1], the first phase of any upgrade project is to fill out the remaining beamlines (marked in red on Fig. 1) on the existing storage ring, before replacing the storage ring with a new diffraction limited storage ring (DLSR) [5]. The AXXS linac can then replace the current injection system, necessary to inject into a DLSR which will have a very narrow magnet apertures – approximately 12.5 mm for the present DLSR designs [6] compared to 37.5 mm for the current AS ring [7].

STORAGE RING UPGRADE

The user community of over one thousand users per year is very satisfied with the operation of the current storage ring. There is high demand for beamtime and some beamlines are heavily oversubscribed – up to five times more beamtime is requested than can be provided. The first priority for the facility is to complete the build-out of the available space for beamlines, which amounts to five more insertion devices and several bending magnets. In parallel there is also a very active part of the x-ray user community in Australia who are doing research using FELs, spearheaded by the Centre for Advanced Molecular Imaging [8]. Both these factors in the Australian user community are driving the efforts on the AXXS project.

The first steps towards designing a new storage ring have been taken following the trend in MBA lattice designs [9], see for example the MAX IV facility currently being built [10]. The lattice functions for one cell are shown in Fig. 2 and the constraints that have been used are a) circumference remains 216 m to fit in the same tunnel and b) the beamline source points remain in the same location.

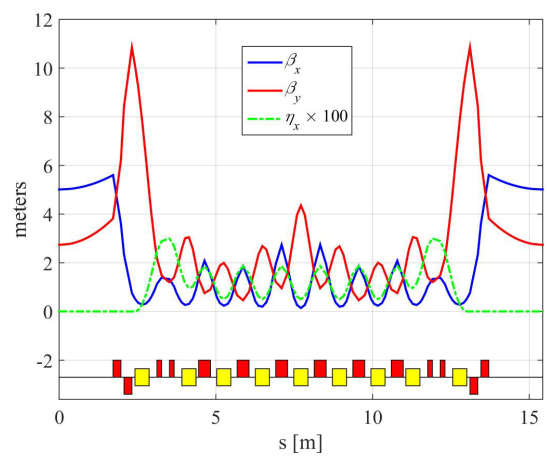

Figure 2: Lattice functions of AS MBA cell.

Some of the parameters for the MBA are listed in Table 1.

Table 1: Selected Machine Parameters for MBA Lattice Compared with Present DBA Lattice

Parameter	DBA	MBA
Beam Energy (GeV)	3.0134	3.0000
Beam Current (mA)	200.0000	200.0000
Horizontal Emittance (nm)	10.3488	0.2023
Vertical Emittance (nm)	0.1035	0.0607
Critical Photon E (keV)	8.1068	6.6371
Energy Spread (%)	0.1021	0.1047
Lin. Energy Acceptance (%)	2.1774	7.4462
α_c (10^{-3})	2.1115	0.1976
Bunch Length (ps)	23.0879	7.1781
Bunch Length (mm)	6.9218	2.1520
Horizontal Tune	13.2900	46.1038
Vertical Tune	5.2160	19.1729

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The photon output which increases by two orders of magnitude over the present storage ring are shown in Table 2. The coherence parameters where calculated following Ref. [11].

Table 2: Selected Photon Source Point Parameters for MBA Lattice Compared with Present DBA Lattice

Parameter	DBA	MBA
Straight β_x (m)	9.6081	5.0123
Straight β_y (m)	2.4065	2.7362
Straight η_x (m)	-0.0090	0.0000
Dipole β_x (m)	0.3798	5.6031
Dipole β_y (m)	32.9444	3.8175
Dipole η_x (m)	0.0610	0.0000
Straight σ_x (μm)	396.3306	31.8413
Straight σ_y (μm)	19.8297	10.5212
Straight $\sigma_p x$ (μrad)	41.2387	6.3527
Straight $\sigma_p y$ (μrad)	8.2401	3.8451
Dipole σ_x (μm)	100.2144	14.2369
Dipole σ_y (μm)	73.3692	7.9691
Dipole $\sigma_p x$ (μrad)	247.4920	50.0080
Dipole $\sigma_p y$ (μrad)	7.2838	11.2224
Assuming 2 m undulator for the straights		
Assuming single particle flux is the same		
0.1 keV Coh. Frac. Straight (%)	2.3672	41.4588
MBA brigher by a factor		18
0.1 keV Coh. Frac. Dipole (%)	1.5713	39.0600
MBA brigher by a factor		25
1.0 keV Coh. Frac. Straight (%)	0.1368	7.4919
MBA brigher by a factor		55
1.0 keV Coh. Frac. Dipole (%)	0.0461	5.1809
MBA brigher by a factor		112
5.0 keV Coh. Frac. Straight (%)	0.0103	1.2723
MBA brigher by a factor		124
5.0 keV Coh. Frac. Dipole (%)	0.0026	0.4514
MBA brigher by a factor		175
10.0 keV Coh. Frac. Straight (%)	0.0030	0.5009
MBA brigher by a factor		168
10.0 keV Coh. Frac. Dipole (%)	0.0007	0.1301
MBA brigher by a factor		190

LINAC INJECTOR AND FEL

In order to efficiently inject into a new MBA lattice the present booster synchrotron injection system will need to be replaced with a lower emittance injector. The planned x-band linac would serve the purpose as both a full-energy injector to the storage ring and a front-end to an FEL. Several options are being explored at the moment and some are outlined below.

Option 1: Linac at Storage Ring Level

Perhaps the simplest option is to have the linac on the same level as the existing storage ring, the drawback being that the transfer line will have to pass through the path of a future beamline. The shielding and tunnel construction will also need to be considered since it will be passing through the user experimental hall (See Fig. 3). The new beamlines which are being planned are shown in red in Fig. 3 and as mentioned previously are the top priority for future upgrades.

The linac is drawn in at 6 GeV assuming the user community would like a hard x-ray FEL, significant reduction in length can be achieved is a 3 GeV soft x-ray FEL is required. A hairpin or 90-degree bend in the linac could also be considered to reduce the total length. A longer linac-to-storage ring transport line could be used to offset the linac so it is not pointing directly at the storage ring. The problem of crossing future beamlines and the existing 150 m medical imaging beamline still exist. Also under consideration if a future soft x-ray or even UV FEL is required, would be to have a smaller separate building to house a new machine and decouple from the existing storage ring. The MBA lattice could then be injected from for example a lower emittance booster ring hanging in the storage ring tunnel like at the Swiss Light Source.

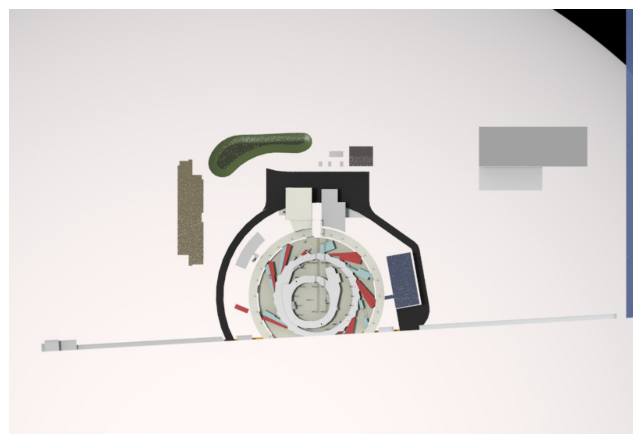

Figure 3: Top view of AXXS.

Option 2: Linac Underground

The most common and practical from many points of view is to house the linac below ground level and transport the beam up to the storage ring at ground level. This technique was used previously at for example ELETTRA [12] or PAL [13] and more recently at MAX IV [14]. Fig. 4 shows a possible path for a linac tunnel under the current storage ring, again showing the location of future beamlines in red. On either side of the building a dig and cover method can be used for the linac tunnel construction, however some engineering effort and expense would be required to tunnel under the building.

A transport line would bring the 3 GeV beam up from the linac for a vertical injection into the storage ring at full energy. In the case of a 6 GeV linac this extraction point from the linac would be some distance from the storage ring injection point and a gentle approach angle can be used. The storage ring concrete floor is 600 mm thick so some consideration would need to be given to the engineering and cost of cutting a penetration for the transport line.

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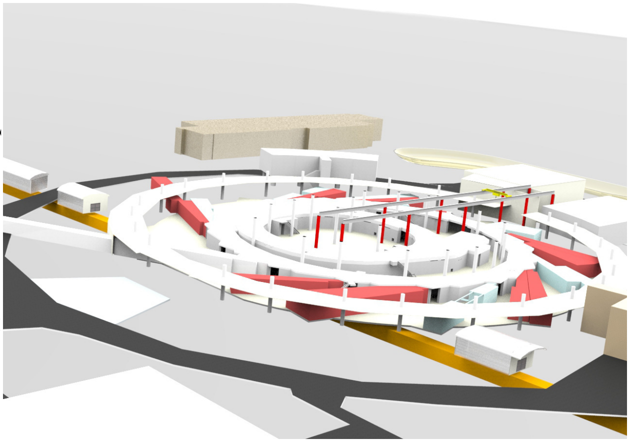

Figure 4: AXXS linac passing under storage ring.

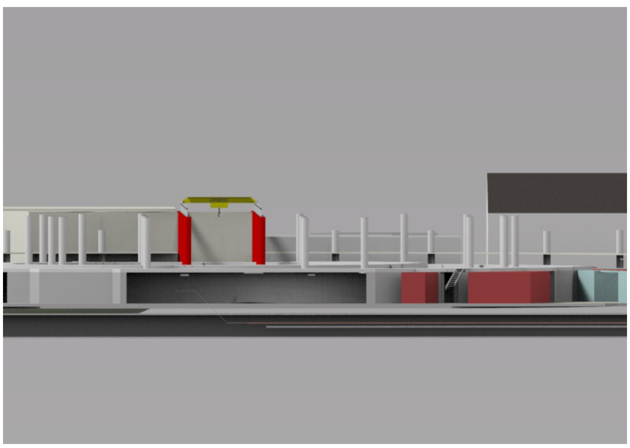

Figure 5: Schematic side view of injection from underground.

Further reduction in the length of the linac to reduce cost and the amount of excavation required is being explored by using novel linearisation schemes [15]. These models deviate slightly from the baseline design and use an all x-band linac instead of a low energy s-band injector into an x-band linac. Similar concepts can be explored if for example the linac would only be used as an injector for a new MBA, relaxing the requirements of the beam needed to drive and FEL.

Option 3: Green Field Site

If the user community grows sufficiently and can get the support, it is also possible to look at a green field site for a future FEL. The current designs seem more economical and realistic but in the future it may be possible to consider a completely new facility.

CONCLUSION

Studies are ongoing to develop an upgrade plan for the Australian Synchrotron including a new MBA lattice for the storage ring and a new x-band linac to inject the ring and drive an FEL. Engineering models have been prepared to accommodate the CLIC XFEL Collaboration baseline designs on the existing site in Clayton. Some novel schemes have been developed to further reduce the length of the linac and more detailed designs will be developed into a design report.

REFERENCES

[1] M. J. Boland *et. al.*, "Plans for an Australian XFEL Using a CLIC X-band Linac", THPME081, Proceedings of IPAC2014, Dresden, Germany (2014).

[2] CLIC Collaboration website: http://clic-study.web.cern.ch/

[3] X-band FEL Collaboration website: http://xbandfel.web.cern.ch/

[4] A. Aksoy *et. al.*, "Conceptual design of a X-FEL facility using CLIC x-band accelerating structure, these proceedings", THPRO025, Proceedings of IPAC2014, Dresden, Germany (2014).

[5] R. Hettel, "DLSR design and plans: an international overview", J. Synchrotron Rad. 21, 843 (2014).

[6] D. Einfeld *et. al.*, "First multi-bend achromat lattice consideration",J. Synchrotron Rad. 21, 856 (2014).

[7] J.W. Boldeman and D. Einfeld, "The physics design of the Australian Synchrotron storage ring", Nucl. Instrum. and Methods A521, 306 (2004).

[8] Centre for Advanced Molecular Imaging website: http://www.imagingcoe.org/

[9] M. Eriksson *et. al.*, "Some small-emittance light-source lattices with multi-bend achromats", Nucl. Inst. and Meth. A 587, 221 (2008).

[10] M. Eriksson *et. al.*, "The MAX IV Synchrotron Light Source", THPC058, Proceedings of IPAC2011, San Sebastian, Spain (2011).

[11] Z. Huang, "Brightness and coherence of synchrotron radiation and FELs", MOYCB101, Proceedings of IPAC2013, Shanghai, China (2013).

[12] D. Einfeld and F. Lazzourene, "The Elettra Linac-to-storage ring transfer line", Proceedings of EPAC1990, 1294 (1990).

[13] I. Ko and M. Yoon, "Design of Beam Transfer Line and Injection System of Pohang Light Source", Proceedings of PAC1991, 2700 (1991).

[14] MAX IV Detailed Design Report, Sec. 2.7.2, http://www.maxlab.lu.se/maxlab/max4/index.html

[15] T. Charles *et. al.*, "Comparison of Bunch Compression Schemes for the AXXS FEL", TUPWA005, *These Proceedings*, IPAC2015, Richmond, USA (2015).