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PLANS FOR AN AUSTRALIAN XFEL USING A CLIC X-BAND LINAC

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Abstract

Preliminary plans are presented for a sub-Angstrom wavelength XFEL at the Australian Synchrotron light source site. The design is based around a 6 GeV x-band linac from the CLIC Project. One of the motivations for the design is to have an XFEL co-located on the site with existing storage ring based synchrotron light source. The desire and ability of the Australian photon science community to win beamtime on existing XFELs has lead to this design study to plan for a future machine in Australia. The technology choice is also driven by the Australian participation in the CLIC collaboration and the local HEP community.

BACKGROUND ON THE AUSTRALIAN SYNCHROTRON

The Australian Synchrotron (ASLS) [1] is a 3 GeV third generation storage ring based light source that has been in operation since 2007. The accelerator complex consists of a full energy injection system with a 100 MeV linac and a 3 GeV booster synchrotron which operates at a maximum of 1 Hz repetition rate injecting at full energy into the storage ring [2].

User operation currently runs in top-up mode with a maximum beam current of 200 mA. The storage ring lattice is a 14 cell DBA with dispersion leaked into the straight to reduce the horizontal emittance to 10 nm rad [2]. Setting the emittance coupling to 1% and running only three of the four 500 MHz room temperature RF cavities results in a lifetime of 24 hr during operations. Every three minutes a single shot is injected into the storage ring to maintain a current stability of less than 0.2% during top-up. The initial suite of beamlines that are currently in operation take up less than half of the capacity of the storage ring (6 of a possible 12 ID beamlines and 3 of a possible 11 dipole beamlines). The immediate priority is to populate the full compliment of beamlines to maximise the use of the light source, as outlined in the proposal for the next phase of beamlines [3]. Presently, plans are being made for a possible upgrade path to improve the x-ray beams available to the Australian scientific community from both storage ring and FEL sources.

AXXS A FUTURE LIGHT SOURCE FOR AUSTRALIA

AXXS (Australian X-band X-ray Source), pronounced *axis*, is strategically planned to extend the life of the present storage ring x-ray beamlines and provide new high brightness short pulse XFEL beamlines. It is based on the conceptual design from the CLIC FEL collaboration [4] and will fit on the current ASLS site as shown in the concept drawing in Fig. 1. Over the next decade the existing storage ring should be equipped with the maximum number of beamlines and some beamline should be upgraded. Once this process is complete, to extend the life and to maximise the use of these beamlines, the storage ring should be upgraded to a low emittance MBA lattice. A linac facility based on the CLIC x-band technology should be developed in parallel to the new beamline development on the existing storage ring. The linac will then be ready to fulfill the dual requirements of injecting a low emittance beam into a new low emittance storage ring at full energy and produce short bunches required for future XFEL beamlines.

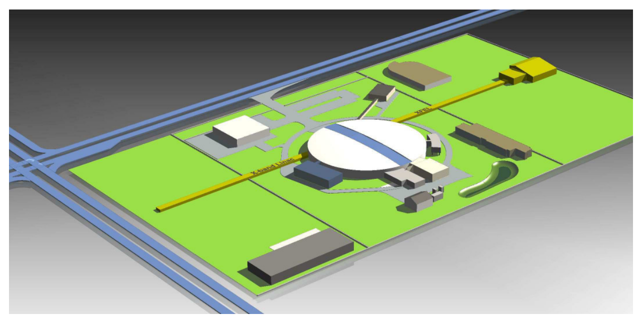

Figure 1: AXXS site layout at ASLS.

INTERNATIONAL COLLABORATION

The accelerator physics community in Australia is relatively small but growing strongly since the arrival of the Australian Synchrotron. Australia boasts as one of its finest the late Sir Mark Oliphant [5] who was a pioneer of building accelerators and invented the synchrotron acceleration principle [6, 7]. The first accelerator in Australia was brought into operation in 1938 [8] but the field suffered a downturn in the late twentieth century before the current revival lead by the 3 GeV storage ring light source, which set record low vertical emittance [9]. The rebuild strategy has been to join international collaborations like CLIC at CERN while building up the local community through the formation of the Australian Collaboration for Accelerator Science (ACAS) [10]. ACAS has, amongst other activities, run accelerator physics schools [11] which have attracted students into accelerator research and resulted in several PhD theses. The long term goal of the program is to develop the capability to upgrade the existing facilities, design new facilities and train scientists to develop and operate the medical and industrial accelerators in Australia. The initiative into accelerator physics research has received strong support from

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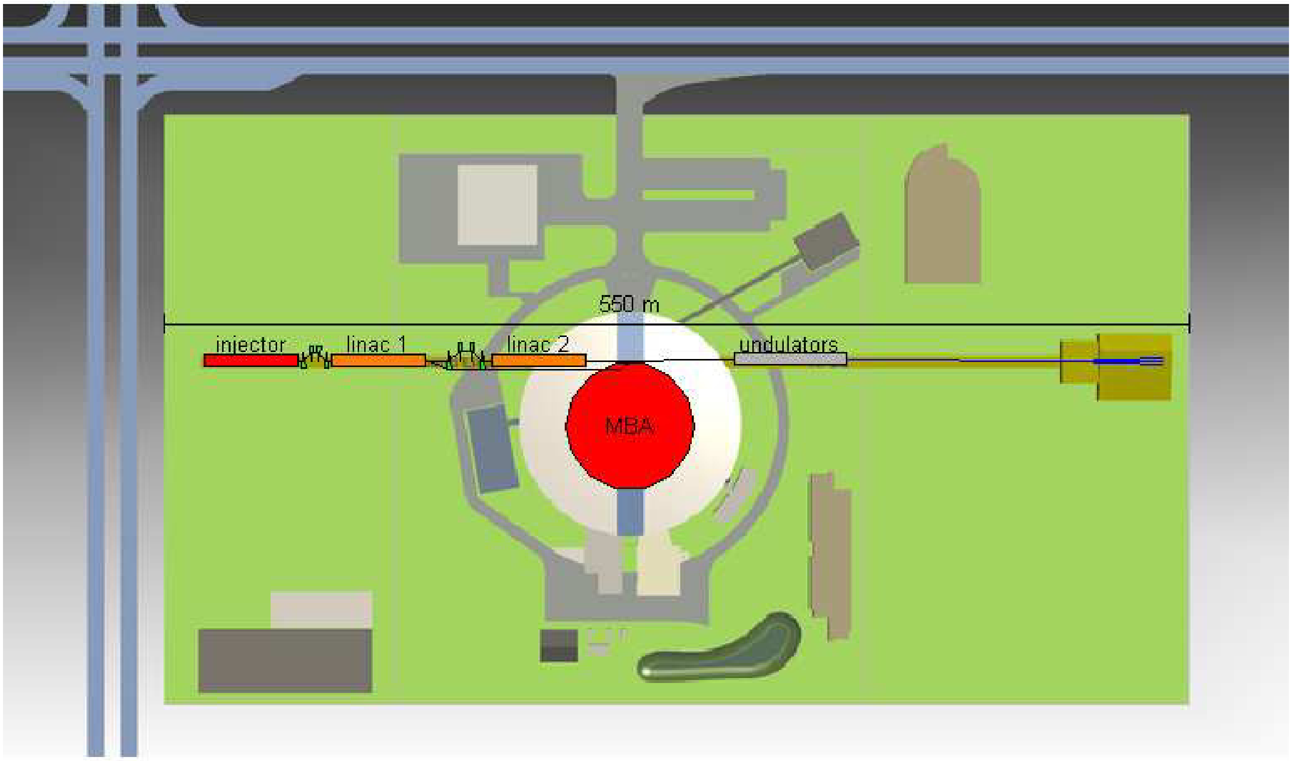

Figure 2: AXXS site layout at ASLS with accelerator schematics.

the local High Energy Physics (HEP) community, who are active collaborators in the discovery of the Higgs particle through the Centre of Excellence for Particle Physics at the Terascale (CoEPP) [12] and naturally support a future linear collider for HEP.

CLIC X-BAND LINAC

As part of the accelerator research program to develop a future linear collider for particle physics beyond the LHC, the CLIC collaboration [13] based at CERN have released a CDR for a 3 TeV linear accelerator based on 12 GHz x-band technology. It proposes a room temperature linac with a novel drive beam power system to achieve high power and high gradients to reach the terascale. Using the CLIC Test Facility (CTF3) an accelerating gradient of 100 MV/m has been demonstrated with a breakdown rate of 10^{-7} on a small scale of only a few modules each 230 mm long. The AXXS project is designed to be one of the first large scale x-band facilities, however without the novel drive beam system but rather a high power, high efficiency klystron powered linac as proposed for a first phase of CLIC [14].

MBA LATTICE UPGRADE

To improve the performance of the full compliment of beamlines at ASLS a new low emittance MBA lattice is proposed as an upgrade to the storage ring. This proposal works with the constraints that the existing tunnel and source points will be utilised and the beam energy remains at 3 GeV. Following a MAX IV style approach to the magnet engineering it is believed a 216 m circumference ring with a 400 pm rad horizontal emittance can be constructed in the existing storage ring tunnel. The parameters of the MBA design are shown in Fig. 3 and Table 1. The present injector system consisting of a linac and a booster synchrotron will have too large an emittance to inject into a new MBA lattice and could not provide the beam for an FEL, so it will be replaced by a full energy linac injector. A transfer line at the end of linac 1 shown in Fig. 2 will be used to inject a 3 GeV beam into the storage ring.

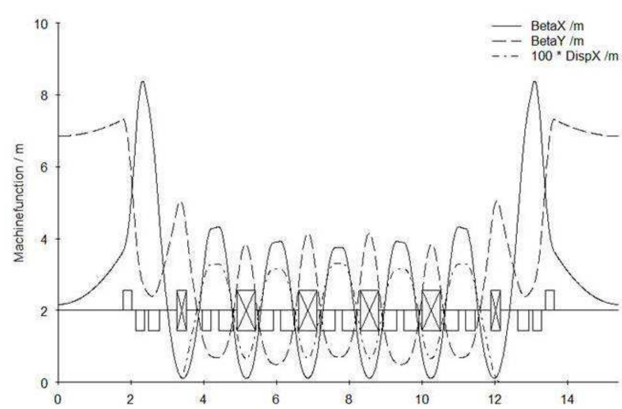

Figure 3: ASLS MBA lattice upgrade proposal.

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Table 1: MBA Parameters

Parameter	Unit	Value
ϵ_0	pm	431
Q_x		40.26
Q_y		19.20
Q'_x		-91
Q'_y		-45
δ_E		0.0013
$L_{straight}$	m	3.4
L_{dipole}	m	0.5
θ	degrees	5.143 ($2\pi/70$)
$\epsilon_{TME,min}$	pm	206

UNDULATOR SIMULATIONS

FEL simulations have been performed using the SIMPLEX code [15] to explore some possible undulator designs for AXXS. Some candidate parameters are listed in Table 2 with the pulse energy shown in Fig. 4.

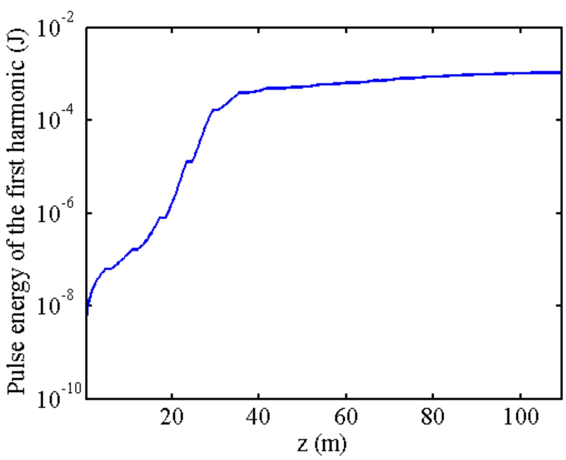

Figure 4: AXXS undulator x-ray power output simulations using SIMPLEX.

Table 2: Undulator Simulation Parameters

Parameter	Unit	Value
Electron energy	GeV	6
Bunch length	μm	7
Bunch charge	nC	0.25
Energy spread		5×10-5
Undulator period	mm	15
K		1.9
L_{sat}	m	27.24
P_{sat}	GW	18.64
λ_1	nm	0.1526
Peak Brilliance		2×10^{33}

CONCLUSIONS

AXXS is a proposal to provide improved light sources to Australian x-ray users by exploiting the existing facilities at ASLS and leveraging the strong international collaboration with the accelerator community to build a state-of-the-art facility.

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