Australian Synchrotron

Australian Synchrotron Development Plan
Project Submission Form

Section A: Summary and Proponent Details

Project Title

Accelerator Development Systems

Spokesperson

Name	Greg LeBlanc
Institution	Australian Synchrotron Company
Email	greg.leblanc@synchrotron.org.au
Phone	+61 (0)3 8540 4209

Executive Summary (approx. 100 words)

Gun development is an important area for pushing towards low emittance electron sources. An electron gun test stand is proposed to be built in the linac tunnel. This project would enhance the capabilities of the accelerator physics and engineering groups and would allow for extensive collaborations with other research institutes and university groups. The project would increase our in-house capabilities and increase local industry participation in the precise machining needed for producing the accelerating structures and integrated magnet systems. The existing infrastructure would decrease the total costs and the project would have no impact on normal operations. This is the first stage in an accelerator development program which would lay the foundations for a THz radiation source and an IR/VUV FEL.

With an RF photocathode electron gun generating electron pulses < 200 fs in duration at 1-3 MeV in energy it is possible to put a radiator (bend magnet) to generate temporally and spatially coherent synchrotron radiation between 10 to 100 cm^{-1} (0.3 to 3 THz) with an intensity that is currently unavailable using conventional sources such as photoconductive emitters. With the addition of an accelerating section to accelerate the electrons to between 10 and 30 MeV the photon flux would increase due to relativistic effects that collimate the beam in the forward direction. Such a source would add to the capability of the high resolution far-IR beamline currently at the Australian Synchrotron and complement already existing laser sources in Australia (e.g. University of Adelaide's Tray Group).

While a hard x-ray FEL is considered to be too ambitious a project for Australia at present, an IR/VUV FEL is a project of interest to the Australian and New Zealand synchrotron user community. Putting a short super-conducting accelerating structure to accelerate the beam from the gun test stand would produce a beam that could be used to drive such a source.

All of these projects form the basis of the accelerator science program and would help to attract students from both physics and engineering. Priority would be given to in-house engineering and manufacture as far as practical in order to develop the capabilities of the Australian Synchrotron engineering and technical personnel.

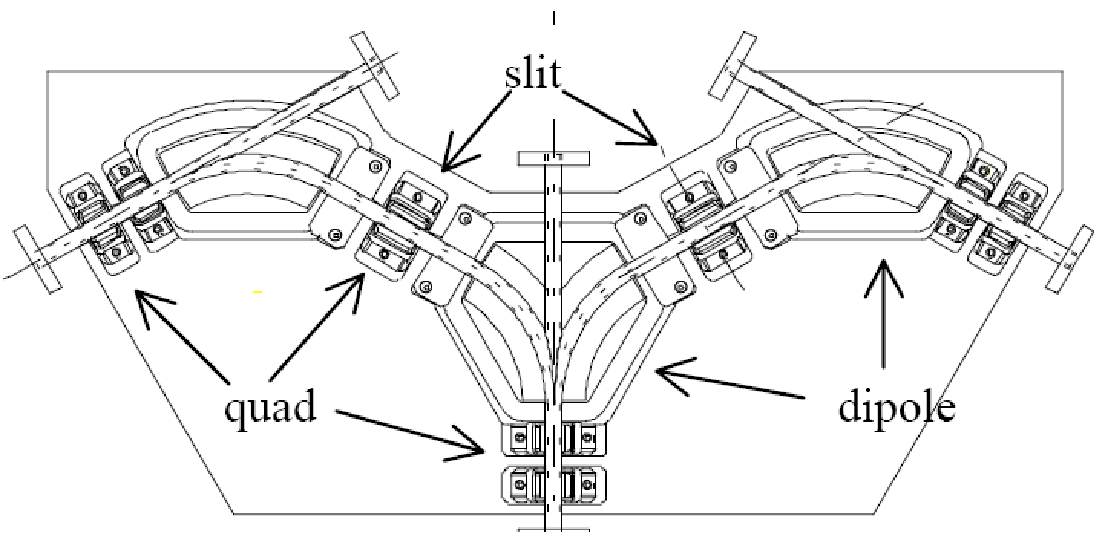
Other proponents (add more rows if necessary)

Name	Institution	Email address
Mark Boland	Australian Synchrotron	Mark.Boland@synchrotron.org.au
Rohan Dowd	Australian Synchrotron	Rohan.Dowd@synchrotron.org.au
Eugene Tan	Australian Synchrotron	Eugene.Tan@synchrotron.org.au
Elsa van Garderen	Australian Synchrotron	Elsa.vanGarderen@synchrotron.org.au
David Zhu	Australian Synchrotron	David.Zhu@synchrotron.org.au
David Tokel	Australian Synchrotron	david.tokell@synchrotron.org.au
Michael Cheah	ANBF	cheah@anbf2.kek.jp
Peter Kappen	Latrobe	p.kappen@latrobe.edu.au
Lars Thomsen	Australian Synchrotron	lars.thomsen@synchrotron.org.au
Jeffrey Roll		bnjroll@bigpond.com
David McLellan		wisdom_management@bigpond.com
Chris Ryan	CSIRO	chris.ryan@csiro.au
Robert Evans	CSIRO	Robert.Evans@csiro.au
Glenn Davis	Francis Lord Optics	sales@flo.com.au
Christopher Chantler	UNIMELB	chantler@unimelb.edu.au
Karen Siu	Monash	karen.siu@sync.monash.edu.au
Matias Daniel Rodriguez	ANU	matias.rodriguez@anu.edu.au
Wilfred Fullagar	Monash	Wilfred.Fullagar@sci.monash.edu.au
Gorgie Huff		biohuman@netspace.net.au
Brooke Hamilton	DIIRD	brooke.hamilton@diird.vic.gov.au
Lianna Sliwczynski		LJSliw7@gmail.com

Section B: Detailed Description

B1: Description of Proposed Beamline/Development Project

The electron gun test stand consists of an integrated magnet system, vacuum system, RF distribution system, laser and diagnostics to accommodate the testing of an RF photocathode electron gun. The system will have the capability of having two different guns under test. It is based on the gun compression system developed at MAX-lab [S. Werin et al, EPAC 2000]. There is sufficient room in the linac tunnel to accommodate the system which addresses the shielding requirements. There is also spare capacity from the linac klystrons to provide the RF power needed for the gun. The equipment racks for the diagnostics and magnet power supplies can be placed on the roof of the linac tunnel. Using the integrated magnet system simplifies the support structures needed. The figure below shows an example of the magnet and vacuum chamber system for a test stand. The dipole magnets and mounting surfaces for the quadrupole poles are machined out of solid blocks of steel. The vacuum chamber gets sandwiched between the two halves. The guns can be mounted on the left and right flanges. The magnets form an achromat which allows for energy defining slits in the dispersive region between the two dipoles. The ports on the top allow for normal incidence of a laser beam. The center port on top would allow for future studies of the interaction of a laser with the electrons. The diagnostics would be mounted on the bottom port. The whole system is less than two meters across and a half meter thick and can be mounted vertically to minimize the footprint in the linac tunnel.



The THz source that is proposed will be similar in nature to the facilities in Shanghai and in Stanford (SUNSHINE [1]). The actual layout will depend strongly on the design of the gun- test stand. The particle accelerator system would consist of six primary components:

1) An RF photocathode electron gun operating at 3GHz to generate pulses < 200 fs in length and > 20 pC per bunch (part of the gun test stand project),
2) Linear accelerator and solenoids to accelerate the compressed bunches to between 10 and 30 MeV (optional),

3) Magnets for focusing, steering, bunch compression and generating synchrotron radiation (quadrupoles, correctors, dipole magnets)

4) Vacuum equipment, and

5) Diagnostic equipment

- Cavity BPM for measuring the beam position,
- ORT screen to use CTR to measure the bunch length with an interferometer [1] [2], or a deflection cavity and YAG screen,
- FCT, wall current monitors and faraday cups for charge detection,
- Energy defining slits,
- phase measurement on the RF waveguides for feedback systems, and
- Thermal detector to monitor the temperature of the cathode.

The layout would be similar in nature to the one in Shanghai as shown in Figure 1 below and would require approximately 10 m^2 of floor space within a “concrete bunker” for radiation shielding. In all cases the technology is well understood and has been well developed over the years. This design would also make use of the 3GHz klystrons that we currently use for the Linac.

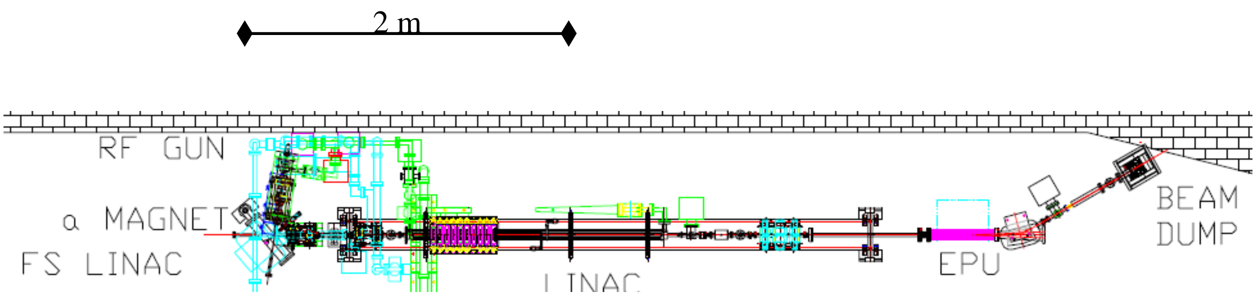


Figure 1 Layout of THz source in Shanghai [2].

In such a system the spectral content is broadband and is dependent on the bunch length of the electrons. For a 300 fs (0.1 mm) bunch we expect to peak at around 30 cm^{-1} with the intensity reduced by a factor of 100 at 100 cm^{-1}.

In principal the method of generating THz radiation in this way is similar to that of a photoconductive emitter and so the spectrum would share similarities. In an emitter a laser source generates charge carriers on the emitter that are then accelerated by a bias voltage across a very small gap. The difference here is the gain in the power with a larger accelerator. The radiated power, P, is proportional to the relativistic γ^4 and in the case of 30 MeV electrons we have a factor of $60^4 = 1.3\times10^7$ compared to emitters (< 1 MeV). There are of course other factors to consider such as the differences in the repetition rate and the peak power per pulse. Normal conducting linear accelerators will only be able to achieve repetition rates of 10-50 Hz whereas superconducting linear accelerators will be able to achieve > 1 MHz and thus increase the integrated power.

With the previous developments it would be straight forward to implement an IR/VUV FEL. With the addition of one undulator with resonator mirrors after a 20 MeV accelerating section it would be possible to generate radiation between 25 and 250 um. With the addition of a second accelerating structure and undulator and resonator pair 40 MeV electrons will generate radiation in the 3-40 um range. The repetition rate would depend on the design of the accelerating structures and the electron gun where a normal conducting copper structure should expect 10-50 Hz repetition rates while superconducting structures would achieve rates > 1 MHz.

B2: Applications and Potential Outcomes to Australian Scientific Community

The project will help to enhance the profile of the accelerator group and attract collaborators. Due to the combination of electron beam optics, resonant RF structures, lasers, vacuum technology, and diagnostics, the project will attract engineering and physics groups. The vacuum system could be designed and built in-house enhancing the capabilities of the engineering and technical staff. The magnet structures would be developed together with local industry which has precision machining capabilities. Many aspects of the development of the systems would involve students, which serves to grow the accelerator physics community in Australia and New Zealand. The development of a THz source and IR/VUV FEL made possible by having the test stand would position the community to stay abreast of developments in these areas. Research into new low emittance electron sources could also be conducted.

The THz source would complement the High Resolution Far-IR Beamline at the Australian synchrotron and additionally provide a more powerful source to the THz research community in Australia. Additionally the short time structure of the 10 to 30 MeV electron bunches can be used for time resolved pump probe experiments.

The IR/VUJV FEL source would compliment the IR beamline at the Australian Synchrotron providing a powerful source for the IR research community. Additionally the short time structure of the 10 to 30 MeV electron bunches can be used for pump probe experiments on the femtosecond timescales.

B3: Match to Selection Criteria

The primary needs met with this project are the development of an accelerator physics community in Australia with collaborations with engineering faculties and local industry.

The existing infrastructure in the shielded tunnels and klystrons greatly reduce the total cost involved with developing this system.

This infrastructure would allow for leading edge research into electron sources as well as the interaction of the lasers and electron beams.

Basing the system on an existing operational system ensures that there would be no problems in getting the system built in three years.

This project will develop on along with the electron gun test stand and will utilise the klystrons that are currently powering the Linac.

There are no sources of this magnitude in currently in Australia and would thus certainly advance the research in areas that require higher intensities.

Much of the design is freely available from contacts available to the Accelerator Physics group at the AS. Fabrication is complex but straight forward and can be done locally.

B4: Potential Users

The potential users for this system would be all of those groups that have indicated a willingness to collaborate with the accelerator science and engineering groups at the Australian Synchrotron. These include the University of Melbourne School of Physics, the Monash University School of Physics, the Australian National University, ANSTO, The University of Adelaide T-ray Group, High Resolution Far-IR Beamline, and CSIRO.