THE AUSTRALIAN SYNCHROTRON ACCELERATOR PHYSICS PROGRAM

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Abstract

The Australian Synchrotron has been running normal operations for beamlines since April 2007. The high degree of beam availability [1] has allowed for an extensive accelerator physics program to be developed. The main points of this program will be presented, including student involvement at different levels and developments being made in anticipation of moving to top-up mode injections.

INTRODUCTION

The Accelerator Science Group, together with the Accelerator Operators, is responsible for the development of the accelerator systems and operational procedures to ensure reliable operations. There are a number of development projects which fall directly into the category of improving operational reliability. The Accelerator Science Group also runs a research program aimed at developing the capabilities of the group. This program aims to promote collaborations with external groups, both Australian and international. An important aspect of the interaction with Australian and New Zealand Universities is getting students involved early to increase the possibility of getting 'local' applicants with relevant experience for positions within the group for any future growth or for filling vacated positions. The following is a description of activities that will help in realizing these goals.

PROJECTS

A prime objective with the accelerator science program is to develop the capabilities of the accelerator physics group to ensure that they are able make contributions to the accelerator physics community and maintain the Australian Synchrotron as a world-class facility. This is achieved through attendance at the major particle accelerator conferences and particle accelerator schools as well as participating in machine studies periods at other synchrotrons and inviting scientists from other labs to participate in our machine studies.

Joint studies with beamline scientists are an important aspect of the program that will ensure that developments on the accelerator systems keep up with the developing needs of the beamlines. The two primary projects at present are bunch-shortening studies to provide the IR beamline with coherent synchrotron radiation and alternative optics to modify source point dimensions for alternating straight sections. The weekly beamline and accelerator meetings serve to identify other joint studies such as steering the electron beam to study beamline alignment issue.

Top-Up

The accelerator systems were designed to provide the possibility of top-up operations. There are many aspects to be addressed before considering top-up during user runs. The majority of the development projects have an impact on top-up operations. The group is actively working on optimizing and developing the accelerator systems with a view to being able to reliably run in top-up mode.

While the accelerator equipment was designed to accommodate top-up operation and it has been demonstrated in principle during machine studies shifts, there are many developments that will be necessary before top-up can be run reliably during user beam time. The radiation safety aspects of top-up will be managed by formation and regular meetings of a team that will submit progress reports to the regulator. A top-up workshop was held in Melbourne with representatives from the majority of the light sources that have implemented top-up and others that intend to. A report on this workshop and all of the presentations are available on the website.

Modelling the phase space overlap between the booster to storage ring transfer line and the beamline front ends is the first step in determining how likely it is to get injected electrons going through the opening in the tunnel wall. The initial results will determine how much more modelling is needed or if energy determining apertures in the BTS or storage ring are sufficient to ensure the shielding safety during top-up injection. This modelling will also determine what interlocks on booster extraction and booster to storage ring transfer line elements that will need to be implemented to ensure safe operation. The combination of modelling and measurement will determine if there is any need for additional localized shielding. The modelling will assume the positions of the various storage ring and front-end apertures are known. A careful survey of these apertures will be a part of the preparations for top-up. These activities are the main focus of the Top-Up Working Group which is led by the Radiation Safety Officer. The goal of this group is to get agreement from all interested parties that any risks with injecting beam into the storage ring with beamline shutters open are acceptable within the defined constraints identified by the group.

Modifying the waveguide system for the linac RF power will allow the running of the linac with a single klystron. This will offset some of the additional running costs associated with having the klystrons ready to fire. This will require a complete re-commissioning of the booster injection and ramping. A detailed study of the present injection scheme will be undertaken in order to get a better understanding of how the process works now and better alter it to suit a lower energy injection. The actual energy that will be injected will be determined by the energy obtainable once the waveguide modifications have been done. The injected current will be dependant on the lifetime and is expected to be of the order of a couple of hundred μA in single bunch mode.

The planned BTS diagnostics upgrades will form a part of the interlock system for determining if the injection efficiency is sufficient to allow continued injections. A dedicated measure of the increase in current for each shot will have to be obtained in real time. The solution for this measurement needs to be carefully designed since the increase in current is a small percentage of the stored beam. The additional fast current transformer just before the injection septa at the storage ring end of the BTS will be used as the measure of the injected current. This will allow for the possibility of having a defining aperture in the booster which doesn't affect the efficiency measurement. The additional position and beam size measurements will allow a more precise matching of the injected beam parameters to the storage ring beam. The most recent survey of the booster to storage ring transfer line clearly shows that the alignment can be improved.

Communication interrupts cause about ten percent of all injection cycles to result in no transfer of charge from the booster to storage ring. This will have to be addressed in order to ensure that the current per shot from the booster can be determined based on the storage ring lifetime to maintain a reasonable injection frequency.

The injection bump covers two cells of the storage ring and thus has several sextupole magnets included. This results in a residual oscillation of the stored beam after the injection bump regardless of the precision of the injection kicker control. This is the theoretical limit that will be the target for stored beam stability. To reduce the stored beam motion further will require more detailed studies of the sextupole effects and possible novel schemes for reducing the injection bump using pulsed multipole magnets. This will be a future activity and is not a part of the initial implementation.

The storage ring kicker alignment directly affects the coupling of the horizontal injection bump of the stored beam into the vertical plane. The reduction of vertical aperture with small in-vacuum undulator gaps require this coupling to be minimized. The coupling will be measured for each kicker based on turn-by-turn beam motion and correlated with survey data.

The automatic monitoring and fault response system being developed by the operators will be an integral part of the top-up process. This system will be further developed based on the results of fault frequency measurements during top-up development runs that will be a regular pert of the machine development shifts coming up. Some of the necessary studies can be scheduled during user beam provided the equipment being used in the injection system does not disturb the stored beam for the users on the beamlines.

Each of the beamlines needs to determine what effect the injection process has on their measurements. This will be an ongoing activity to make sure that the improvements in the quality of the injection process and the sensitivity of the beamlines are understood. The timing system developments for those beamlines that will need a masking signal will need to be tailored for each beamline based on these measurements.

Transverse Bunch-by-Bunch Feedback System

The storage ring suffers from the resistive-wall instability [2]. At present we combat the instability by increasing the vertical chromaticity to 11. This requires rather strong sextupoles and a bunch-by-bunch feedback system [3] is being implemented in anticipation of future modifications to the straight sections for insertion devices.

The system being developed will also provide the opportunity to remove any given bunch by positive feedback. This will be useful in providing a pure single bunch separated from the rest of the bunch train that can be used for time-resolved experiments on the beamlines. It will also be useful in studying different fill patterns and their affect on instability thresholds which will make it a tool for accelerator science studies.

Injection System Developments

There are numerous developments that will be made to the injection system. All of them are aimed at optimizing the injection system for eventual top-up operations.

The waveguide system for the linac will be modified to allow for running the linac from any one or both of the klystrons. This will be important when considering the spare holding and costs of top-up operations. Related to this is the development of a lower energy injection and ramping of the booster.

The BPM diagnostics have been improved [4] to the point where they are useful for measuring response matrices. This is needed for further optimization of the booster ramp.

The booster ramp was implemented using an excel spreadsheet. This puts restrictions on how the ramp can be developed further. Bringing the ramp tables into epics is required to remove these restrictions. A student project was conducted looking into the variation in tunes along the ramp and improvements were made [5].

Storage Ring Beam Diagnostics

David Peak is developing electron beam diagnostic tools for the Australian Synchrotron storage ring as part of his Ph.D. at The University of Melbourne. The research is based on the transverse bunch-by-bunch feedback technology which can be used to extract valuable data for diagnosing the stored beam. Measurements will be made to characterize the instabilities observed in the storage ring using the bucket-targeting injection studies. The physics of bunch instabilities will also be explored to develop bunch cleaning techniques using positive feedback through the bunch feedback system. This project should result in a detailed understanding of the physics that causes the beam instabilities that are observed and the fine tuning of the feedback system that is used to combat them.

Linac Control for FEL Operations

Evelyne Meier is doing her Ph.D. studies in a joint Australian Synchrotron, Monash University, and Synchrotrone Trieste project. A combined neural network and PI feedback system has been demonstrated on the linac [6]. This work has led to her being awarded beam time on the LCLS in Stanford to further develop the technique before the linac for the Fermi FEL project at Trieste is available.

Third year projects for Monash University

Third-year physics students work on projects over the 13 week periods. The students are expected to spend ~12 hours per week working on the project and will be graded and receive credits towards a degree for the work.

Honours projects for Monash University

An honours student from Monash University is developing a novel interferometer [6] to measure the electron beam size. This is intended to become a permanent diagnostic. It was discovered that the aperture in the optical diagnostic beamline front end is limiting the measurement.

Professional Experience Students

There have been a number of students from RMIT that have spent 20 days doing projects with the accelerator physics group. This activity will continue and has already led to one of these students being awarded a summer scholarship to work on a particle loss model.

University of Melbourne Undergraduate Studies

A practical application study has been developed as part of the undergraduate program at the University of Melbourne. This involves giving a seminar and some preparatory work to students who then come to the synchrotron to make measurements.

Joint research projects, external

The storage ring skew quadrupoles provide a unique opportunity to minimize the coupling of the horizontal and vertical betatron oscillations. This results in an extremely small vertical emittance [8] which is of interest for the development of damping rings for the future collider projects.

Future Development Projects

The following projects have been identified as possible developments to expand the capabilities of the Australian accelerator physics community being developed through the student projects being conducted with the local universities. The first two are included in the strategic plan.

An electron gun test stand could be built in the linac tunnel. There is spare capacity in the linac RF amplifiers that could be used to power a laser cathode RF gun. The planned upgrade of the waveguide system will make it easier to implement this. The existing infrastructure would decrease the total costs of building up a gun test stand and this could be used to attract other groups to collaborate. Gun development is an important area for pushing towards low emittance electron sources. This could be extended to include the development of a source of THz radiation.

While a hard x-ray FEL is considered to be too ambitious a project for Australia at present, an IR/VUV FEL is one of the future projects that could be of interest to the Australian and New Zealand synchrotron user community.

A diagnostics and development beamline could be built using an insertion device as the source. This could use one of the short straight sections where the RF cavities are. This beamline would enable development and testing of beamline components. This would include both the optics and detectors. Future user beamline developments could be tested on this beamline before being installed, reducing the impact on the user program. Development of a short period super conducting undulator as the source would be of interest to the engineering group as well.

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