LINAC WAVEGUIDE UPGRADE AT THE AUSTRALIAN SYNCHROTRON LIGHT SOURCE

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Abstract

The Australian Synchrotron Light Source (ASLS) uses a 100 MeV linac as the start of the acceleration chain for the injector. The two main accelerating structures of linac are normally fed by independent pulsed klystrons. A recent upgrade to the waveguide system has allowed for a single klystron to power both accelerating structures. While this operation mode delivers a reduced total beam energy, the operation of only a single klystron results in less wear and enhanced robustness against klystron breakdown. Commissioning results of single klystron operation of the linac are shown and future benefits are detailed.

INTRODUCTION

The Australian Synchrotron Light Source (ASLS) uses a full energy injector system comprising of a 100 MeV linac and 3 GeV booster synchrotron to inject beam into its storage ring. The full energy injector allows for 'top-up' mode operation of the storage ring, which requires frequent, small injections of beam to keep the storage ring current within a few percent of maximum at all times. Top-up operation at the ASLS is currently being implemented and should start being used for user beam by mid 2012.

Successful long term Top-up operation of a light source requires a high level of reliability of the injector system. It also creates much more wear on the systems, as they are now required to operate continuously. One such system that has a limited lifespan is the Linac RF, particularly the klystrons. A klystron tube will start to fail after operating for a certain length of time and needs periodic replacement. Since they are expensive items, any way of reducing the use of these klystrons will have great cost benefits. With this in mind, the RF distribution waveguide system for the ALSL linac has been modified to allow a single klystron to power the whole linac, albeit at a reduced final beam energy. This paper will outline the modifications made and the commissioning results from this modification.

LINAC OVERVIEW

General Specifications

The linac accelerates the electron beam from a gun energy of 90 keV to 100 MeV. The various bunching and accelerating structures are powered by two separate 35 MW pulsed klystrons operating at a frequency of 3 GHz. The 90 keV pulse from the electron gun is first bunched in the Primary Buncher Unit (PBU) and Final Buncher Unit (FBU) where it reaches a final energy of 3 MeV before undergoing main acceleration to 100 MeV in two 5-metre accelerating structures. The linac was delivered by the company ACCEL (now RI Research Instruments) and the design is based on the SLS [1] and DLS linacs [2]. Early comissioning results of the ASLS linac can be found in [3] and a summary of the general specifications is shown in Table 1.

Table 1: Linac specifications

Quantity	Specification
Beam Energy	100 MeV
RF Frequency	2.997 GHz
Repetition rate	1 Hz
RMS Emittance	50 π mm mrad
Single/Multi-bunch pulse length	1/150 ns
Single/Multi-bunch pulse charge	$>$ 0.5/4 nC

RF Distribution

The two pulsed klystrons feed the power into the accelerating structures via a waveguide system shown in Figures 1 and 2. The first klystron feeds power to the PBU, FBU and first Accelerating structure, with two successive power splitters used to distribute the correct amount of power to each section. Phase shifters are used in the waveguide segments leading to the PBU and FBU to individually adjust their RF phases relative to the other accelerating sections. The Second Kystron feeds power directly to the second accelerating structure only. The waveguides are filled with SF_6 gas at a pressure of 2 bar, to help prevent arcing during pulsed operation. They are also thermally stabilised with cooling water to maintain matching and phase stability.

WAVEGUIDE UPGRADE

Waveguide Modification

The waveguide distribution was modified to include an additional power splitter, phase shifter and directional coupler, as indicated by the dotted box in Figure 1. The new power splitter now connects the two klystron distribution systems and allows the second klystron to now power all structures simultaneously. An extra phase shifter is required to allow for the RF phase of the second accelerating structure to be scanned against the other structures independently. The directional coupler is not currently integrated, but will be used in an upgraded RF phase monitoring system. The new waveguide components were installed inside the linac tunnel in December 2010 and can be seen in Figure 3.

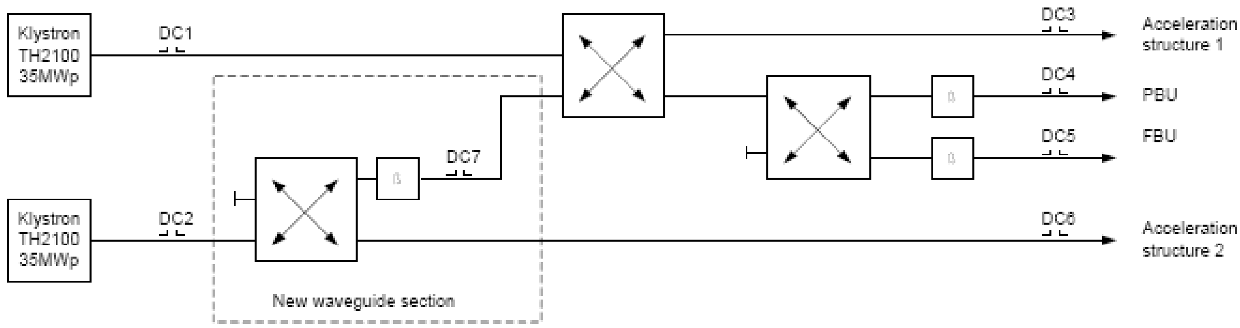

Figure 1: Schematic of the Linac RF distribution system. New waveguide componets are shown in side the dotted box. New section contains one hybrid, phase shifter and directional coupler and associated waveguide sections.

Figure 2: Linac and RF waveguide distribution inside the linac tunnel. The waveguides are hung from the roof and couple to the accelerating structures from above.

Figure 3: Linac and RF distribution after waveguide modification. The new power splitter and phase shifter can be seen just left of the centre of this image. The additional waveguide can be seen extending left, below the original piece.

Integrating the two waveguide distribution systems also involved combining the SF_6 and water distribution circuits, which were formerly separate systems. Small modifications were required, but now result in a simpler overall system, with easier maintenance.

Single Klystron Mode Commissioning Results

For single klystron mode operation, the first klystron is switched off and all power is supplied by the second klystron, which is set to maximum power output. The new power splitter is set up to supply the same power to the PBU,FBU and first accelerating structure as is normally supplied during dual klystron operations. The remaining power left from the second klystron is then sent to the second accelerating structure, resulting in about half of the nominal power in the second accelerating structure.

Measurements of the beam in the linac to booster transfer line indicate a mean energy of 74 MeV and a one sigma energy spread of 0.76% at nominal electron gun settings. The energy spread is roughly double the value obtained during dual klystron operation and contributes to a lower booster capture efficiency. The lower efficiency is not a major limitation however, as a move to top-up operations will mean that only small amounts of current are required out of the booster at any one time. The energy spread may also be reduced with further linac optimisation work in this mode.

Preliminary work has done to capture the lower energy beam into the booster for ramping to 3GeV. The beam has been successfully captured and stored with the booster magnets set to a 74 MeV beam energy (no ramping), as shown in figure 5.

Capture has also been obtained with the booster magnets ramping. The standard 100 MeV - 3 GeV ramp was used and simply scaled down to 74 MeV starting energy. Currently, the beam is lost during the start of the ramp processes and beam can only be circulated for the first 50 milliseconds of the 600 millisecond ramp. Maintaining beam

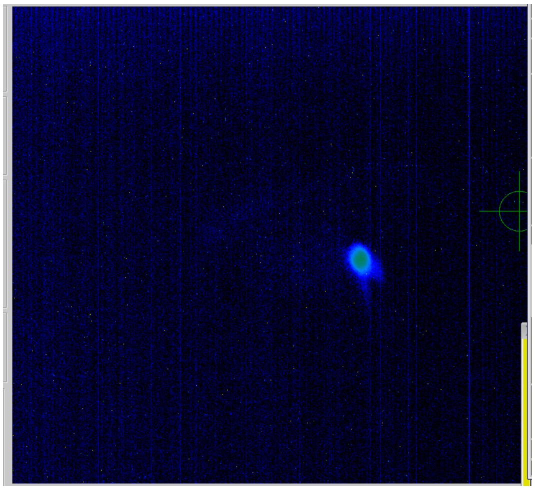

Figure 4: Single klystron mode linac beam as seen on a diagnostic screen in the Linac to Booster transfer line.

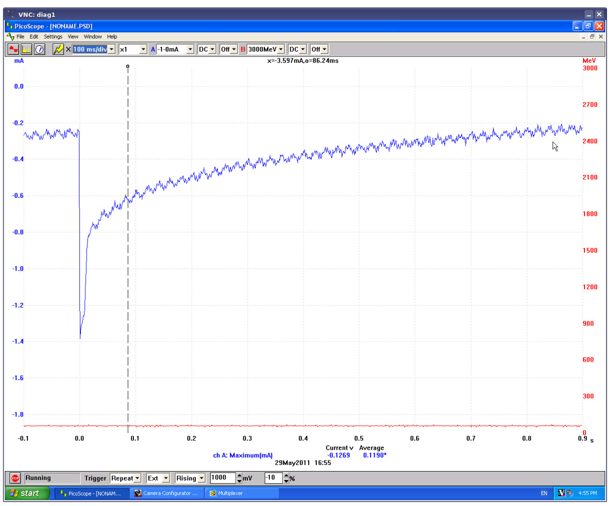

Figure 5: Current recorded on the booster DCCT over a period of one second after injection of the linac beam during single klystron operation. The large initial current loss is likely due to the increased energy spread of the beam.

through the start of the booster ramp was a process that took some time to fine tune during initial commissioning of the Australian Synchrotron booster. Eddy currents induced when the magnets begin ramping combined with the low beam rigidity means that careful tuning is required. Work is still in progress to achieve a full energy ramp of the single klystron mode beam.

CONCLUSION AND FUTURE PLANS

The upgrade of the linac waveguide system was undertaken successfully. A single klystron was used to power all accelerating structures and produce an 74 MeV electron beam with 0.7% energy spread.

There are a number of additional upgrades that are planned for the linac to build upon the extra capabilities allowed by this waveguide upgrade and provide extra flexibility and reliability for top-up operations. These are:

- Addition of a further power splitter and phase shifter. These will be positioned to allow for the first klystron to power the second accelerating structure. This will add the flexibility of allowing either klystron to power the linac, giving immediate redundancy in the case of the failure of a klystron.
- Automation of the motor control for the power splitters and phase shifters. The current motor control system for the power splitters does not allow for remote control as it was originally envisaged that the power splitters should not need to be moved once set up correctly. A new system will be commissioned that will incorporate all the new and old motors into a single interface and allow for remote control of the power splitters.
- A RF phase and Amplitude measurement system. Currently there is no information available about the relative phase of the different accelerating structures apart from what the phase shifter have been set to. Apparent phase drifts have been observed in the linac and have to be periodically corrected. The planned monitoring system will feedback real time phase and power reading to the control room to allow for continuous monitoring of the state of the accelerating systems and alert operators to any drifts in phase or power.

In the immediate future, work will continue on modifying the booster ramp to allow the 74 MeV beam to be ramped up to 3 GeV, and injected into the storage ring. This work is expected to be completed by the end of the year.

Once this ramp is completed and top-up operation commences, routine operation of the linac in single klystron mode will become the normal mode of operation. The other klystron will be rested to extend its lifetime and save on power consumption.

REFERENCES

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