

STATUS AND UPGRADE PLAN OF 250 MeV LINAC AT CLS

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Abstract

The Canadian Light Source (CLS) 250 MeV linac, originally constructed in the 1960's, serves as the injector for the 2.9 GeV synchrotron radiation facility [1] located on the University of Saskatchewan campus. The linac has operated reasonably well for routine operation of the light source. However, the long-term goal of operating the CLS storage ring in top-up mode will place increased demands on the linac for stability and availability that cannot be met with the existing system.

Consequently, an upgrade is planned over the next two years to get higher beam stability, reliability and reproducibility. In this paper, the existing linac system will be described and the planned upgrade will be reported.

INTRODUCTION

The 150 MeV linac, with three Varian accelerating sections, was originally constructed in the mid-1960's for nuclear physics research in the Saskatchewan Accelerator Laboratory. In the 1980's, the linac was upgraded to 300 MeV with the addition of three SLAC-type accelerating sections.

In 1999, the nuclear physics research program was shut down, and the linac was incorporated into the injection chain for the 2.9 GeV synchrotron storage ring of Canadian Light Source. In this upgrade the control system was partially modified to use the EPICS system with the exception of the electron gun and modulator high voltage control. The timing, trigger system and instrumentation were also upgraded. Linac operation for the injector only requires short bunch trains (less than 200 ns) with repetitions rates less than 2 Hz. Extensive changes to the modulators were made including the pulse-forming-networks (PFNs) the high voltage power supplies and thyatrons. Some ion pumps and CCGs were upgraded in the vacuum system. About 15% of the magnet power supplies were changed to fit new requirements. The video deflector was modified to produce bunch train lengths of up to 136 ns, corresponding to 68 bunches at 500 MHz. Figure 1 shows the 250 MeV linac tunnel with the 220 kV electron gun.

LINAC STATUS

Linac Structures and Parameters

The linac consists of a high-current gun with a buncher section (manufactured by Haimson) and six 2856 MHz rf sections, and is operated at 250 MeV. After the linac, there is an Energy Compression System (ECS), which reduces the 1% energy spread from the linac by a factor of 10, followed by a transport line to the 2.9 GeV booster synchrotron for the main storage ring.

The electron gun can provide up to 1A beam current at 220 keV. In normal operation, the gun emits 125 mA peak beam current. The buncher section compresses the bunch phase to about 12° and increases beam energy to 13 MeV [2]. Beam current at this point is about 70 mA. There are three Varian style acceleration sections that can provide approximately 50 MeV and three SLAC style sections which provide 40 MeV per section. Each section is supplied RF power by an ITT 8568 klystron.

The linac main parameters are listed in Table 1. The linac is shown in Fig. 1. The linac control schematic is shown in Fig. 4.

Table 1: General parameters of the CLS injector linac.

Type of structure	TW disc-load WG
Frequency	2856 MHz
Length of section	3 m and 5 m
Total number of section	3(3m) & 3 (5m)
RF source	
Peak power of klystron	20 MW
Number of klystrons	6
RF pulse length	2.5 μ s
Main Linac Beam	
Energy	250 MeV
Beam Current	60 mA
Beam Pulse Length	2 ns ~136 ns
Repetition Rate	1 Hz
Energy spread (without ECS)	<1.0%
Energy spread (with ECS)	0.1%



Figure 1: CLS 250 MeV linac.

Operations

After four years of operations following commissioning of the storage ring, routine injections use a 250 MeV, 60 mA beam, and 2 ns to 136 ns variable bunch train length. The bunch length is selected by a video deflector, corresponding to the requirements of the storage ring injection or the light source users. Figure 2 shows the beam currents from the linac. The red (top) trace is the signal picked up from a toroid, located just after the end of the linac, which has some distortions at the rising and falling edges caused by the toroid slow time response. The blue (bottom) trace shows the signal from a FCT installed after the small rf section used for the Energy Compression System (ECS). The current uniformity along the bunch train is quite good, with typically less than 10% variation.

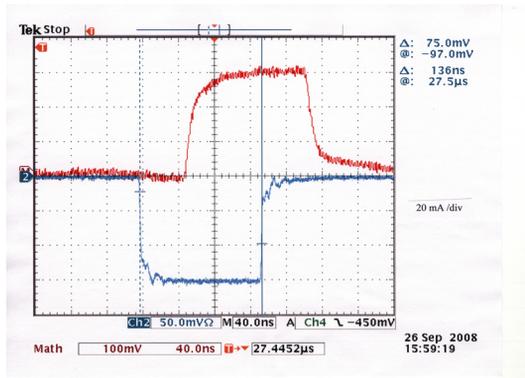


Figure 2: Linac beam current.

During normal storage ring operations, the linac is used only for about 15 minutes every 12 hours. Figure 3 shows the typical daily performance of CLS storage ring. In addition, an in-line beam stop can be placed in the linac-to-booster transport line to allow independent linac operation between storage ring injections. When operated in this mode, the linac operation has been quite reliable with less than 10% of storage ring down-time attributable to the linac.

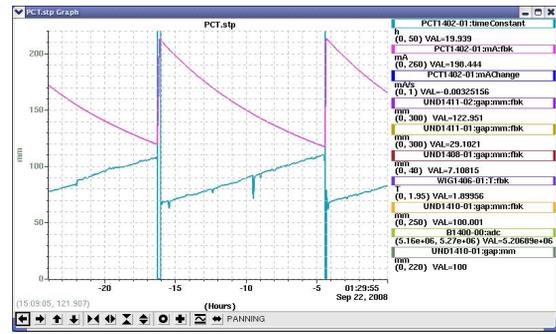


Figure 3: CLS storage ring daily performance. Current is routinely filled to 250 mA every 12 hours. The top trace shows the current decay between refills. The bottom trace shows the beam lifetime.

However, after a period of a few weeks, the operating point for the linac tends to drift, resulting in reduced injection efficiency into the storage ring and requiring some time to re-optimize the linac operation. As well, some linac and rf system components are over 40 years old and are nearing or at the end of their useful operating lifetime. CLS is now considering top-up operation of the storage ring, which requires continuous operation of the linac at a very low repetition rate (~ 0.01 Hz). This places much greater demands on the stability and reliability of the linac.

Thus, most of the following issues need to be addressed for good long-term operation in top-up mode:

- Linac average output energy changes slightly over time.
- The beam energy spread grows over time reducing injection efficiency.
- Beam energy changes from shot to shot, resulting in large variations in current injected into the storage ring.
- Some acceleration sections are quite old and were operated with bad vacuum conditions for many years,.
- Several rf power source parts have no available replacements.
- The Varian section's expected lifetime was about 20 years, but now they have already worked for over 40 years.
- Unfortunately, because of space limitations in the 1980's upgrade, the six modulators were installed into the original three modulator cabinets, which has caused serious cross-talk between modulator pairs.
- Electron beam diagnostics are inadequate for automatic control and effective optimization.

UPGRADE PLAN

A linac upgrade plan has been developed to address these problems for future operation, and will be implemented over the next two years.

RF System

- Four new acceleration sections will replace the existing three Varian sections and a vacuum-contaminated SLAC section. This will both reduce the VSWR trips and solve bad vacuum condition problem.
- A new solid-state RF drive amplifier will replace the existing klystron amplifier.
- All high-voltage modulators will be replaced to stabilize the beam energy jitter which is caused by cross-talk in the modulator triggering circuits.
- Phase detectors and a feedback system will be incorporated to stabilize the beam energy.

Control System

- All controls will be upgraded to the EPICS system.

Beam Diagnostic System

- All toroids used to measure the beam currents will be replaced by either fast toroids or fast current transformers.
- All beam profile monitors will be replaced.
- An Emittance measurement device will be considered.

Vacuum System

- Replacement of all old ion pumps and ion pump controllers.
- Installation of more CCGs and TCGs to monitor pressure in all sections,
- Replacement of all vacuum valves.

Power Supplies

- All old DC magnet power supplies will be replaced to stabilize the beam parameters and increase the operation reliability.

REFERENCES

- [1] L. Dallin, R. Berg, J. Bergstrom, M. de Jong, X. Shen, R.M. Silzer and J.M. Vogt, "The Canadian Light Source Status and Commissioning Results", EPAC2004, p. 2269.
- [2] J. Haimson, "13 MeV Injection Linear Accelerator Model HRC-735 Instruction and Maintenance Manual", August 1989.

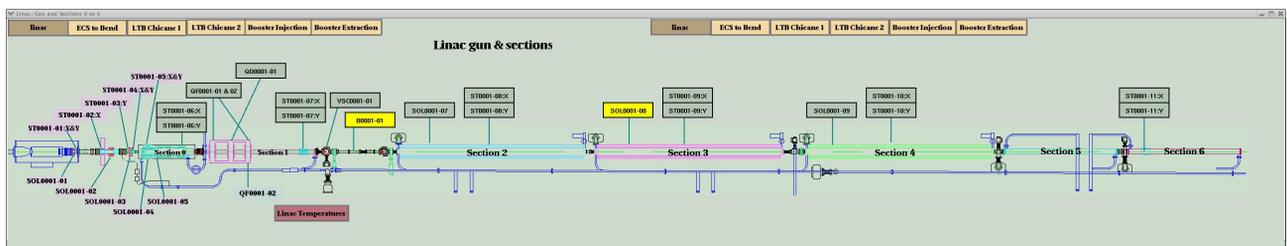


Figure 4: Layout of the CLS linac as shown on the control console. Layout shows linac sections, steering magnets, and focusing magnets. Gun and buncher controls need to be updated to be part of the EPICS operating system.