CANADIAN LIGHT SOURCE STATUS

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Abstract

The Canadian Light Source is a new, third-generation, 2.9 GeV synchrotron radiation facility located on the University of Saskatchewan campus. The facility uses an existing 250 MeV electron linac to inject into a full-energy booster synchrotron. In turn, the booster fills a compact 12-cell storage ring, which has a circumference of 171 m. Approval to proceed with construction of the facility, including at least six beamlines, was received in 1999 March. The main experimental hall, which contains the booster, storage ring and beamlines, was completed in early 200. Installation and commissioning of the booster was completed in 2002. By late summer of 2003, installation of the storage ring was complete. Storage ring commissioning started in the fall of 2003, culminating in successfully storing beam for one injection cycle on 2003 November 18. Work continues on the commissioning of the storage ring, as well as the installation of the initial suite of seven beamlines. This paper provides an overview of the Canadian Light Source design, construction and initial commissioning, highlighting some of the notable events and achievements.

INTRODUCTION

After almost a decade of work on the conceptual design and a lengthy funding campaign, the University of Saskatchewan received approval to proceed with the Canadian Light Source Project on 1999 March 31. The $141 million project included the construction of the main experimental hall, the 2.9 GeV booster synchrotron injector and electron storage ring, and at least six beamlines by 2004. Capital funding for the project came from over ten different sources including the federal government (Canada Foundation for Innovation, Natural Resources Canada, National Research Council of Canada), three provincial governments (Saskatchewan, Alberta and Ontario), three universities (Saskatchewan, Alberta and Western Ontario), the City of Saskatoon, and industry (SaskPower and Boeringer-Ingelheim).

The University of Saskatchewan created a not-for-profit company, Canadian Light Source Inc. (CLSI), as the organization to provide the technical support for the construction and operation of the facility. CLSI staff work closely with UMA Projects, a construction and project management engineering firm, to design, construct, commission and operate the light source facility.

FACILITY DESCRIPTION

Figure 1 gives a plan view of the Canadian Light Source [1], showing the linac, booster ring, transfer lines and storage ring.

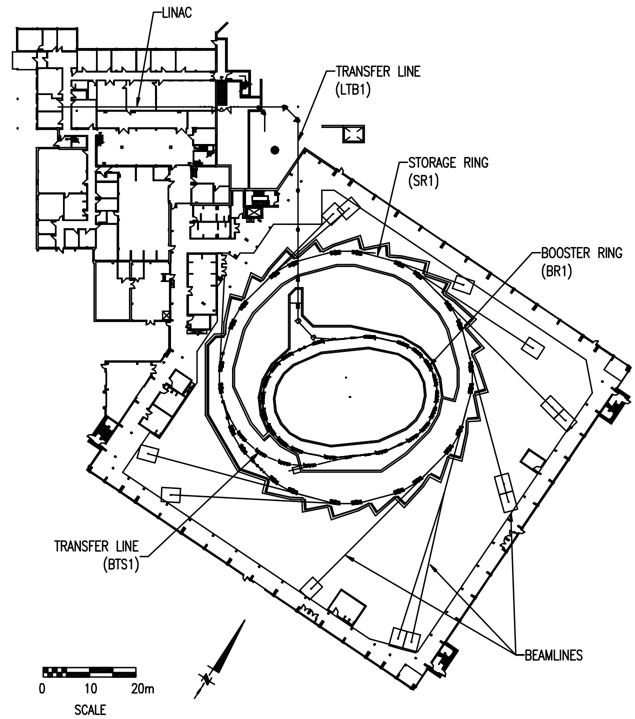

Figure 1: Layout of the Canadian Light Source facility.

Linac

The 250 MeV linac is based on the original 150 MeV linac constructed for the Saskatchewan Accelerator Laboratory for nuclear physics research in the mid-1960's, and later upgraded to 300 MeV in the 1980's. It consists of a high-current gun with a 13 MeV buncher section and six 2856 MHz rf sections that provide approximately 50 MeV gain per section. The main modifications for CLS were the addition of a video deflector to produce bunch train lengths of up to 136 ns, corresponding to 68 bunches at 500 MHz (the storage ring RF frequency) and control system.

Booster Synchrotron

A booster synchrotron accelerates the electrons from 250 MeV to the full energy of the storage ring, 2.9 GeV. The booster uses a compact FODO lattice (102.5 m circumference) with eight straight sections, three of which are used of the rf, injection and extraction. The rf system consists of two 500 MHz, 5-cell copper cavities powered by a single 75 kW klystron amplifier, which produces an accelerating voltage of 1.7 MV. Programmable DC power supplies drive the dipole and quadrupole magnets with a 1 s cycle time. The design produces an emittance at extraction of 550 nm•rad.

The booster ring was designed at CLS and constructed as a "turn-key" accelerator by Danfysik in Denmark, and installed at CLS in early 2002. Commissioning proceeded smoothly, and was completed by 2002 September. The booster now routinely produces an average circulating current over 10 mA.

Storage Ring

The storage ring is a 12-cell Double Bend Achromat (DBA) design with the basic machine parameters as summarized in Table 1.

Table 1: Storage Ring Design Parameters

Circumference	170.88 m
Periodicity	12
Tunes ν_x, ν_y	10.22, 3.26
Momentum compaction	0.0038
Number of straights	12
Length of straights	5.2 m
β_x, β_y, η_x (at centre of straight)	8.5, 4.6, 0.15 m
RF frequency	500 MHz
Harmonic number	285
RF Voltage	2.4 MV
Energy acceptance	1.54%
Dipole field	1.354 T
Horizontal emittance	18.1 nm•rad
Energy spread	0.11%

A single cell layout is shown in Figure 2. The lattice is a very compact design with each cell tuned to allow some dispersion in the straights, which reduces the overall beam size. Each cell has two bend magnets, three families of quadrupole magnets, and two families of sextupole magnets. One family of sextupoles has extra windings for horizontal and vertical orbit correction. All sextupoles have extra windings to produce skew quadrupole fields for control of transverse coupling. As well, one sextupole family has x-y correctors for slow orbit correction. In additional there are two high-speed x-y corrector magnets in each cell. Installation of the magnets, associated power supplies and vacuum chambers started in early 2003, and the entire storage ring essentially complete by 2003 August.

The storage ring RF system uses a superconducting cavity (see Figure 3) with strong higher-order-mode damping that is based on the Cornell cavity design used in CESR-B [2]. The strong HOM damping should eliminate the need for a longitudinal feedback system in CLS. During the vertical cold test of the cavity, an accelerating field of over 12 MV/m was achieved, although only 8 MV/m is required for the design voltage of 2.4 MV. A 300 kW RF amplifier from Thales Ltd. should be sufficient to store a beam current greater than 250 mA. The RF system was installed in 2003 May, and acceptance tests completed by 2003 July.

Figure 3: CLS Superconducting RF cavity.

Initial Beamlines

Seven scientific beamlines are also in the scope of the CLS project budget. The beamline capabilities were determined through a competition of proposals from Canadian researchers. The proposals were evaluated by an international committee, and the available funds directed towards the best proposals. In addition, a facility diagnostic beamline is being constructed, using a bending magnet source point, to perform analysis of both optical and x-ray radiation for measuring the accelerator performance.

The seven beamlines and their scientific scope, in order of decreasing wavelength, are:

- Far Infrared (10 – 4000 cm^{-1}) designed for high-resolution studies of gas phase systems;
- Mid-infrared spectromicroscopy (450 – 6000 cm^{-1}) for biological and industrial applications;
- Variable-line-spacing Plane Grating Monochromator (PGM) (5.5 – 250 eV) high-flux, high-resolution for photo-emission spectroscopy and

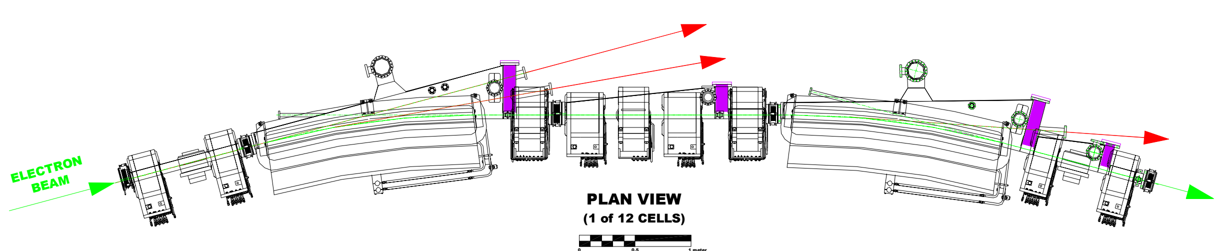

Figure 2: Layout of a single storage ring cell.

related techniques such as photo-absorption and photo-desorption;

- High-resolution Spherical Grating Monochromator (SGM) (200 – 1900 eV) for photo-electron spectroscopy and absorption spectroscopy;
- Soft x-ray SpectroMicroscopy (SM) (250 – 2000 eV) with a scanning transmission x-ray microscope and a photo-electron emission microscope for analysis of a wide range of biological, environmental and industrial materials;
- Canadian Macromolecular Crystallography Facility (CMCF) (6.5 – 18 keV) for protein crystallography; and
- Micro-XAFS (5 – 40 keV) for micro-probe and x-ray absorption fine structure (XAFS) analysis.

Insertion devices are used for all five x-ray beamlines. The ID’s include two pure-permanent-magnet undulators (185 mm and 45 mm period) for the PGM and SGM lines; a 75 mm period elliptically polarizing undulator for the SM line; a 20 mm period hybrid in-vacuum undulator for the CMCF line; and a 33 mm period superconducting wiggler for the micro-XAFS line. To accommodate the high demand storage ring straights for insertion devices, where feasible we have planned for two insertion devices in each straight. Small horizontal-steering magnets create a small chicane that results in a separation of approximately 0.6 mrad between the output of each device.

All major technical components for all beamlines and insertion devices have been ordered with final delivery expected before the end of 2004. The PGM and SGM beamlines, including the 45 mm undulator for the SGM line, are installed at this time (2004 March) and will be ready for commissioning with synchrotron light in mid-April.

STORAGE RING COMMISSIONING

Storage ring commissioning was planned in a series of two-week runs, separated by another two-week period for continuing front-end and beamline installation work that needed access to the ring tunnel. In addition, all commissioning work had to be conducted during evenings and weekends (permitting evacuation of non-essential personnel from the main hall) until radiation surveys confirmed the radiation safety on the floor.

The first commissioning run started in mid-September 2003, and on September 26 electrons were detected after one full turn in the ring. Over the next two runs, a variety of minor instrumentation and equipment problems were found and resolved. The most significant was a quadrupole magnet with the wrong polarity – despite two previous checks. When this magnet was fixed, the electron beam was stored for a full one second injection cycle the next day, 2003 November 18 (see Figure 4).

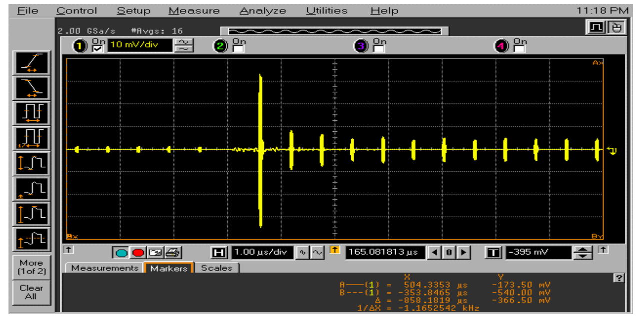

Figure 4: First stored beam at CLS.

By 2004 February up to 25 mA had been stored with a lifetime of 45 – 60 minutes, but the capture efficiency was quite low (~1%). Work on correcting the orbit was successful everywhere except for the last cell, where a horizontal excursion over 10 mm was necessary to keep the beam stored. In mid-March, the problem was traced to a damaged rf shield inside a storage ring gate valve that was obstructing most of the beam aperture. Commissioning has just resumed following replacement of the valve. Initial results show that the orbit is now correctable everywhere, the beam lifetime and capture efficiency have increased significantly.

FUTURE PLANS

Storage ring commissioning will continue with the short term goal of achieving 100 mA and a lifetime greater than 6 hours. Work will start on detailed measurements of the machine characteristics for comparison against the original design. Once an acceptable orbit has been determined, commissioning the seven beamlines and associated insertion devices will begin with the goal of having several beamlines ready for general user operation by 2005 January.

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