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THE CANADIAN LIGHT SOURCE: AN UPDATE

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Abstract

The Canadian Light Source (CLS) is now under construction. It will be a third generation source capable of producing photon beams for a variety of research applications. The CLS has four principal components: a 250 MeV linac, a full energy booster, a storage ring, and an array of beam lines serving interests ranging from infrared light to hard x-rays. The 2.9 GeV storage ring has a compact design made up of twelve double bend achromats incorporating twelve 5 m straights for injection, RF and insertion devices (IDs). RF power for the storage ring will be supplied by a single superconducting cell operating at 500 MHz. Construction and commissioning should be complete by the end of 2003 and an initial complement of five IDs and three bend magnet sources supplying light to eight beam lines and eleven experimental end stations is anticipated. Photon beams with high brightness will be achieved through a combination of low electron beam emittance (18 nm-rad), high circulating current (500 mA), small vertical coupling and a variety of undulator magnets. The use of small gap undulators will result in bright beams at photon energies up to 20 keV.

1 INJECTION SYSTEM

Electrons for the CLS are supplied by a 250 MeV linac. This linac has been in operation for over 30 years as part of the Saskatchewan Accelerator Laboratory. The linac, operating at 2856 MHz will produce a pulse train of up to 132 ns in length. A 500 MHz chopper will create 68 electron "packets" for efficient injection into the 2.9 GeV booster. The energy spread of the electron beam from the linac will be compressed [1] to about ±0.15%. This energy spread eases the beam transport[2] to the booster and further increases the booster injection efficiency.

The booster[3] accelerates the electron from 250 MeV to the full energy of the storage ring, 2.9 GeV. The beam extracted from the booster is expected to have an average current of 10 mA for the duration of the pulse train. The booster repetition rate is 1 Hz. Pulse trains from the booster will be stacked in the storage ring, tail to tail over (3x68=)204 buckets, and up to an average circulating current of 500 mA.

The booster, now under construction at Danfysik in Denmark, will be installed in August, 2001 and commissioned by the end of the year.

2 STORAGE RING

The storage ring has been described in detail earlier[4,5]. Although the basic lattice remains unchanged, the circumference has been lengthened to 170.9 m in order to increase the length of the dipole magnets and the straight sections. The basic machine parameters are given in Table 1.

Table 1. Basic Parameters of the 2.9 GeV CLS lattice.

Circumference	170.88 m
Periodicity	12
Tunes: ν_x , ν_y	10.22, 3.26
Momentum compaction	0.0038
Straights Length β_x , β_y , η_x (functions at center)	 5.2 m 8.5, 4.6, 0.15 m
RF frequency harmonic number energy acceptance	500 MHz 285 1.54%
Dipole field	1.354 T
Horizontal emittance	18.1 nm-rad
Energy spread	0.111%

The basic cell structure produces a fairly compact lattice with twelve straight sections available for injection, RF cavity and insertion devices. Each cell is a double bend achromat (DBA) detuned to allow some dispersion in the straights and thus reduce the overall beam size. As well as the two bend magnets each cell has three families of quadrupoles magnets and two families of sextupole magnets (see ref. 4). One family of sextupoles has extra windings so they can be used as both horizontal and vertical orbit correctors. All sextupoles have extra windings so they can be used as skew quadrupoles for coupling control. In addition to the sextupole correctors there are 24 X-Y corrector magnets.

2.1 Magnets

The dipole magnets are currently under construction and will be delivered to the CLS site by the end of 2001. They are curved magnets with an arc length of 1.87 m. To supply vertical focusing the dipoles have a gradient of 3.87 T/m @ 2.9 GeV.

At the time of writing the prototype magnet is being measured on the precision measurement facility[6] at the Laboratori Llum Sincroto (LLS) at Barcelona, Spain.

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The contract for the quadrupole and sextupole magnets has recently been awarded and construction will begin soon. All quadrupoles have the same cross-section using an open-sided "C" design. Two different lengths of quadrupoles are required for the three families. All the sextupole magnets are identical and use a "C" configuration. Details of the magnet designs are given in reference 7.

Other components of the CLS are in the final design stage. These include the injection septum, injection kickers, X-Y orbit correctors. An injection septum prototype built at Danfysik indicates that a septum with very low leakage (≈ 2 T-m) should be possible.

2.2 Vacuum System

To achieve adequate beam lifetimes a pressure of one nanotorr is required. The system will use discrete absorbers. These absorbers will intercept approximately 98% of all photons produced by the dipole magnets, while the remaining photons will be passed down the beam lines. Due to the heat loads it is expected that Glidcop® will be used as the absorber material. The absorbers will be removable for access to the absorber or for replacement. With discrete absorbers the ultimate base pressure should be achieved quicker than with distributed absorbers. This base pressure is a function of thermal out-gassing and pumping speed. Prior to installation the vacuum chambers will be baked to reduce the thermal desorption rates. No "in-situ" bake out system is planned.

The vacuum system provides one port per dipole and one insertion device (ID) port for each straight section. The latter port will accommodate two IDs in each straight. The majority of the vacuum system will be constructed of stainless steel. Previous experience, high mechanical strength and ease of welding all outweigh the benefits of aluminum's high thermal and electrical conductivity. Construction of the chambers will be similar to that of other labs (e.g. ANKA, BESSYII, SLS). ID chambers may be constructed of aluminum or copper.

The general shape of the chamber includes the electron beam chamber, neck and antechamber. The neck dimensions provide low chamber impedance, a large enough gap for unrestricted exit of photons, suitable conductance for pumping and allowance for all magnet pole tips. The majority of the electron chamber has a fixed geometry. Any change in the shape will be accomplished using a minimum 5:1 ratio transition piece to minimize RF impedance. As well, flanged connections will have either an inserted RF shield or minimized gap to reduce impedance.

2.3 Orbit Control

Global beam position correction will be accomplished with 48 horizontal and 48 vertical orbit correctors. Extra vertical correction (per unit phase advance) is required because of the stringent requirements to position the much smaller vertical beam size. Details of the position correction are given in reference .

Global and local coupling correction[8] will be accomplished with 36 skew quadrupole magnets.

3 RF SYSTEM

The CLS storage ring RF system will operate at 500.00 MHz and will use a HOM damped superconducting (SC) RF cavity based on the Cornell cavity design used in CESR[9]. The Cornell design features a low-impedance, large aperture niobium cavity which allows potentially beam-perturbing HOMs to propagate out of the cavity volume to HOM loads located external to the cavity where they can be very effectively damped. The CLS expects to avoid the use of a longitudinal damping system with the Cornell-type cavity.

The Cornell cavity has proven its reliability through its service in CESR and is well suited for use in high current storage rings. Current work at Cornell has demonstrated RF powers in excess of 260 kW of power per cavity delivered to the circulating beam with future plans to increase this value in the near future. As a rough guideline, the CLS storage ring will require approximately 110 kW or RF power per every 100 mA of circulating beam. Thus, one installed cavity will allow the CLS to operate at currents in excess of 200 mA with the possibility of greater currents in the future.

The Cornell cavity design is capable of large gradients, with operation in the 6 to 10 MV/m range considered almost routine. The CLS requires an RF voltage of 2.4 MV, which places us in the middle of that range (8 MV/m). The CLS has opted to begin operation with one Cornell-type SC RF module installed in the storage ring and one full module to act as a spare in case of a major system malfunction. Future operations may employ the second cavity to operate in the CLS storage ring when very high current operation is desired.

Using a SC RF system offers many challenges to the CLS. Expertise in the area of SC and cryogenics is a must to ensure reliable operation. As well, unlike many others using SC cavities, the CLS will be commissioning with SC cavities installed. Extra attention will have to be given to the cavity operation under the poorer vacuum conditions expected in the early commissioning phases of the machine.

4 INSERTION DEVICES

Ten straight sections are available for IDs. To maximize the number of ID beam lines, nine straights will have two IDs with a chicane separating the beams by 1.25 mrad.

An initial set of IDs is in the design stage: An in-vacuum undulator with 22 mm period, 5 mm minimum gap and 145 poles will cover the photon energy range from 6 to 18 keV; a 45 mm period undulator with a minimum gap of 12.5 mm and 53 poles; and a 185 mm period undulator with 19 poles and 25 mm minimum gap will share the same straight and cover photon energy ranges from 250 to 1900 eV and 5.5 to 250 eV respectively. A helical APPLE-II undulator with 75 mm period, 15 mm minimum gap and 43 poles will deliver circularly polarized light from 100 to 1000 eV and linearly polarized light from 100 to 3000 eV. Finally a high energy wiggler will cover the photon energy range up to 40 keV. The wiggler parameters are not yet fixed.

IDs are being designed to be used with APS type ID vacuum chambers.

5 BEAMLINES

The initial complement of beamlines has been chosen to serve the needs of the diverse community of Canadian Synchrotron light users. Approximately one third of our community uses IR light and one third are protein crystallographers. To satisfy the research requirements of this community, the following photon beamlines have been proposed and will be built in the first phase of our program. Beamlines are first sorted by source point type and then within each category by photon energy. The beamlines are all nearing the end of preliminary design, and it is intended that they all be operational by the end of 2003.

5.1 Bending Magnet beamlines

A facility diagnostic beam line using visible light from a bending magnet source will be built. This line will initially provide light to a fast gated CCD camera to aid in facility commissioning; ultimately, some of the visible light from this source will be switched to a streak camera as well. We anticipate building a simple pinhole camera to operate with X-ray photons and provide continuous measurement of the storage ring phase space ellipse parameters.

A far IR beamline designed for high resolution studies of gas phase systems will be built, as will a mid IR spectromicroscopy beamline. This latter line is anticipated to have a large component of biological and industrial applications.

5.2 Insertion Device beamlines

A varied line spacing plane grating monochromator beamline is planned to operate, with three gratings, over the range from 8 to 250 eV. This beamline will have good brilliance properties and high resolution (>10000) over its energy range.

A high resolution spherical grating monochromator beamline is planned to operate, again with three gratings, over the energy range from 200 to 1900 eV. This beamline is intended to duplicate the capability, with much higher brilliance, of the existing Canadian SGM beamline at the Synchrotron Radiation Center in Madison, Wisconsin.

A soft x-ray spectromicroscopy beamline will use a plane grating monochromator (a co-development project between the Canadian Light Source and the Advanced Light Source in Berkeley) and an elliptically polarized undulator to delivery arbitrarily adjustable polarized photons in the energy range from 200 to about 2000 eV. This line will have two endstations, one a scanning transmission x-ray microscope and the other a photoemission electron microscope. The line is strongly influenced by the successful STXM and PEEM applications at the ALS.

A protein crystallography beamline will be built using a small gap in-vacuum undulator to deliver high brilliance photon fluxes in the energy range from 6000 to 18000 eV. The design of this beamline is being done in cooperation with the Advanced Photon Source in Chicago, and it will bear a strong resemblance to the new protein crystallography beamline currently being built by the SER-CAT at the APS.

A general purpose XAFS/microXAFS beamline will be built using a wiggler to deliver high photon fluxes in the energy range from 3500 to 40000 eV. This beamline will deliver stable high fluxes of photons into a spot as small as about 10 microns square. It is our intent to ultimately build an undulator based hard x-ray microprobe to complement this facility.

6 REFERENCES

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[8] L.O. Dallin, “Local Transverse Coupling Control”, these proceedings.

[9] S. Belomestnykh et al., “Commissioning of the Superconducting RF Cavities for the CESR Luminosity Upgrade”, PAC 1999, p. 980.

[*] CLS Technical Design Notes can be seen at: http://www.cls.usask.ca/research/technotes.shtml