ALADDIN, PRESENT AND FUTURE*

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Abstract

The Synchrotron Radiation Center (SRC) at the University of Wisconsin-Madison operates a 1 GeV electron storage as the synchrotron radiation source, Aladdin. Operation at 800 MeV (200 mA) or 1 GeV (180 mA) is the standard for the user experimental periods. The present status of the ring will be discussed. Improvement of the stored beam lifetime by implementation of a fourth harmonic rf cavity, ring corrections for a high field permanent magnet undulator, and the global orbit control system will be presented. Future plans for Aladdin include the installation of two electromagnetic undulators (one already undergoing magnetic field measurement), full implementation of an infrared beamline, and a 120 kV electron gun for the Aladdin microtron injector.

1 ALADDIN STATUS

Aladdin is a 1 Gev electron storage ring [1] dedicated to synchrotron radiation. It is operated under contract to the National Science Foundation by the University of Wisconsin, Madison. It has been in operation since 1985, and, in many respects, it performs at the level of third generation synchrotron radiation sources.

1.1 Ring Operations

A typical week begins with a 5-day period, each day of which is divided into four user shifts with 12 hours for operation at 800 MeV and 8 hours for 1 GeV. The remaining four hours per day, from 8 am to noon, are used mostly for user beam time at 800 MeV, but are available for special uses by prior arrangement at a scheduling meeting held each Monday at noon. Each user shift begins with ring injection that lasts about 20 minutes. Weekends are available for special beams such as low current (nanoamp) beams used for calibration experiments, ring maintenance, or for making up unscheduled down time. Three such user weeks in succession comprise a "quantum", and represent the smallest block of time that an experiment can be given. Approximately nine times each year, a single week is set aside for: major ring hardware upgrades; maintenance that may require more than several hours and could be delayed until one of these machine weeks; and accelerator studies.

1.2 Aladdin at 800 MeV

While Aladdin is a 1 GeV storage ring, most of the operating time for user beams is at 800 MeV with dedicated shifts from noon to 6 pm, and 6 pm to midnight during the normal user weeks. Most beams start out at about 200 mA and have a current-lifetime product of about 950 mAh. The stored beam lifetime, would be lower were it not for regular use of the harmonic cavity (see § 1.5). Typical measured source sizes from the bending magnets are $\sigma_x = 480$ µm, and $\sigma_y = 91$ µm, whereas calculated source sizes at the middle of undulators in the middle of long straight sections are $\sigma_x = 849$ µm, and $\sigma_y = 63$ µm.

1.3 Aladdin at 1 GeV

Usual 1 GeV beams during users weeks are from midnight to 8 am, 5 days per week. The main users of the higher energy flux are the X-ray lithography and MEMS (MicroElectroMechanical Systems) programs. Currents are kept below 180 mA to limit the synchrotron radiation power delivered to the vacuum chamber. The current lifetime product is about 1150 mAh. Typical measured source sizes from the bending magnets are $\sigma_x = 560$ µm, and $\sigma_y = 160$ µm, whereas calculated source sizes at the middle of undulators in the middle of long straight sections are $\sigma_x = 1061$ µm, and $\sigma_y = 79$ µm.

1.4 Beamlines

Figure 1 shows a schematic layout of Aladdin. There are 29 active beamlines One of the active beamlines makes use of the original, pure permanent magnet, LBL/SSRL undulator that was installed on Aladdin in 1986 [2]. Another undulator beamline that utilizes a commercially built permanent magnet device is the source for a plane grating monochrometor (PGM) beamline [3,4]. This undulator and beamline will cover the photon energy range of 8 eV on the fundamental to 240 eV on the 5th harmonic. The commissioning of this line is nearly complete, and users are expected in several months. An electromagnetic undulator [4] is also installed on the ring, and its beamline is nearing completion. A new high resolution beamline built for the Canadian Synchrotron Radiation Facility (CSRF) is being installed.

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The Center for X-ray Lithography (CXrL) has 6 beamlines for its own use. There is one beamline dedicated to MEMS work, and a new beamline is used for biofluorescence experiments by the Aladdin Biofluorescence Center (ABC).

The newest beamline is an infrared (IR) line that utilizes the edge radiation [5,6] of a dipole magnet. During the commissioning of this line it became clear that 60 Hz (and its harmonics) noise and 720 Hz noise from the main dipole power supply were seriously compromising the full utility of the line. Most of the 60 Hz noise was found to be coming from user power transformers. After relocating the transformers the 60 Hz spectral component of the radiation was reduced by almost an order of magnitude. A source of the 720 Hz beam noise has been identified as the large filter choke, located 60 cm from the electron beam orbit, in the dipole power circuit. This choke will soon be moved and should further reduce beam noise.

1.5 Recent Operational Enhancements

A global feedback system has been operational since mid 1996. Prior to the implememntation of the system, the slow drift of the stored beam would be as much as 100 μm over a user beam fill. With the global feedback system active, typical orbit drifts, as measured at the source points in the dipoles, are kept within ±5 μm against slow perturbations (≤0.2 Hz). This system is now always used during user beams.

One aspect of using such a system is that the beam stability is tied directly to the long and short term positional stability of the beam position monitors (BPM's) themselves. In Aladdin the BPM's are placed in a continuous section of vacuum chamber that includes a quadrupole doublet and a dipole. The BPM's are located in the quadrupole part of the section. Because of construction tolerances, many of the chamber sections are in contact with the quadrupole poles, and they shift in position as the quadrupoles are powered. Section 2.2 discusses the steps being taken to stabilize the BPM's.

An rf cavity [7] running on the 4^{th} harmonic of the main rf system is used to lengthen the bunch and, hence, the stored beam lifetime. The bunch length is almost doubled, going from $\sigma_s = 425$ ps to 800 ps, increasing the lifetime by 80%. An added bonus of harmonic cavity usage is the almost complete absence of coupled bunch instability [8]. The cavity is powered and can keep the bunch length constant from full ring currents down to about 40 mA.

The radiation source for the PGM beamline is a permanent magnet undulator [4]. The undulator itself has 9 steering coils to correct the vertical and horizontal orbits through the device. These corrections are programmed, via a lookup table keyed to the undulator gap (field), to straighten the orbit through the device. A measure of the resulting improvement was that the fifth harmonic flux increased from 70% to more than 90% of its theoretical value. An additional skew quadrupole winding is used to correct coupling caused by the undulator as a function of gap. By shunting some current around four of the ring quadrupoles (two upstream and two downstream of the undulator) the lattice functions can be corrected so that the maximum tune shifts are $\Delta\nu_x \leq 0.0001$ and $\Delta\nu_y \leq 0.0007$ for any gap of the undulator. The shunted currents are also keyed to the undulator gap. In conjunction with the global feedback, over the entire operational range of the undulator, the maximum vertical closed orbit variation at other source points around the ring is ±5 μm, and the maximum throughput variation observed by other beamline users is about 1.5%. This throughput variation is the result of source size variation, an expected result of $\beta_y(s)$ for vertical and also some ε_x variations due to the incomplete lattice function correction. Since some users require throughput variations ≤0.1%, the lattice correction scheme will need to be improved.

2 FUTURE PLANS

2.1 Insertion Devices

An electromagnetic undulator will be installed on Aladdin in the fall. This undulator, combined with a normal incidence monochromator, will cover the photon energy range of 8 eV to 40 eV. A second electromagnetic undulator is planned, probably to be installed in late 1998.

2.2 Ring Upgrade

A major effort is underway to understand the sources of noise in the stored beam and to implement measures necessary to increase beam stability. During the fall of 1997 large sections of the main ring vacuum chamber will be replaced. The design of the new sections will address some long standing difficulties of operation. The principal benefit will be the decoupling of the chamber that passes through the quadrupole doublets from the chamber that fits in the dipole gap by means of a newly installed bellows. The quadrupole chamber, which contains the BPM’s, can then be firmly attached to bedrock via the quadrupole stands, and not subject to motion and stress resulting from dipole section movement, thus optimizing beam stability. A second modification of the new chamber is the addition of separate ion clearing electrodes. The present BPM’s are also used as clearing electrodes. The electronics necessary to isolate the ion clearing high voltage (up to 1200 V) from the stripline beam signal is not conducive to high resolution beam position measurements. The new BPM’s are more robust, able to withstand baking and synchrotron radiation heating with negligible distortion.

As mentioned in Section 1.4, a program to rid the beam of noise from power line frequencies and its harmonics is well underway. The next most likely place to clean up power line noise is in the main ring rf system. After that each subsystem will be carefully evaluated to determine its contribution to any beam noise.

A new 120 kV electron gun line is designed and will be built as the replacement injector for the Aladdin microtron. The new gun will have a gridded structure so that it can be modulated at the 50 MHz frequency of the main ring rf system. This will allow efficient filling of the rf buckets, and include the possibility of filling various bunch patterns. The high voltage is necessary to ameliorate beam size growth due to space charge forces, a problem with the present 35 KeV gun.

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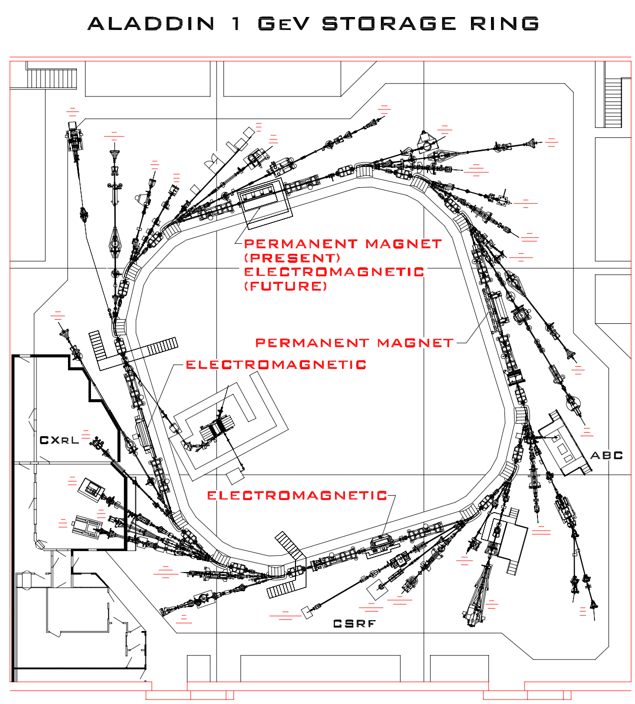

Figure 1: Aladdin plan view: present and future undulators; several user program areas, i.e. CXrL, CSRF, ABS.