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THE ADVANCED LIGHT SOURCE

R.C. Sah

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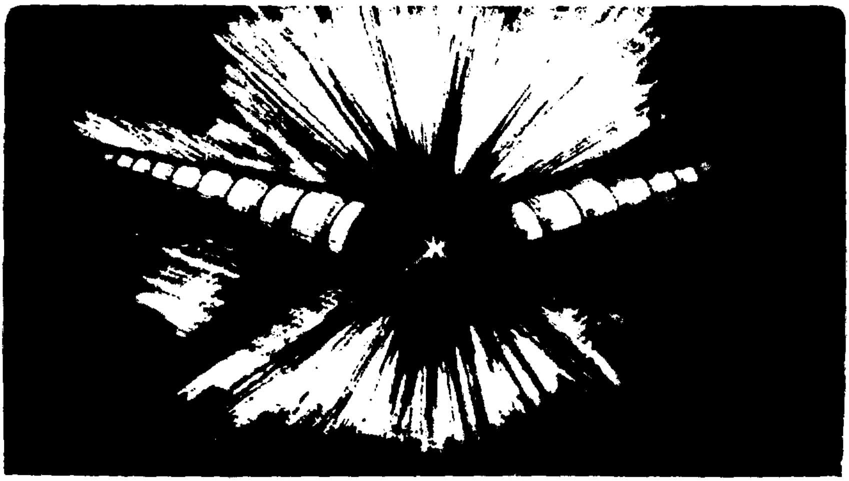

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Summary

The Advanced Light Source (ALS) is a new synchrotron radiation source which has been proposed by Lawrence Berkeley Laboratory. The ALS will be a key component in a major new research facility, the National Center for Advanced Materials. The ALS will consist of an electron linear accelerator, a "booster" synchrotron, a 1.3-GeV electron storage ring, and a number of photon beam lines. Most or all photon beam lines will originate from wiggler and undulator magnets placed in the 12 long straight sections of the ALS. A very low electron beam emittance will provide photon beams of unsurpassed spectral brilliance from specially-designed undulators, and a high radiofrequency will produce very short pulse lengths.

Introduction

The Advanced Light Source (ALS) is a new synchrotron radiation facility which will be constructed at Lawrence Berkeley Laboratory. It will be the centerpiece of the National Center for Advanced Materials (NCAM), which will be a major new national center for materials research. NCAM will include three new laboratories in addition to the ALS.

The ALS consists of a 1.3-GeV electron storage ring, an injector system, a number of synchrotron radiation source devices (wigglers and undulators), and many photon beam lines.

The design of the Advanced Light Source has been optimized to achieve two major goals. This facility is designed to provide intense photon beams (especially in terms of spectral brillance) in the nominal energy range 0.1 eV to 5000 eV, and the ALS is designed to provide very short pulses of synchrotron light (tens of picoseconds) for the many experiments with timing requirements in this range. In order to achieve these goals, the storage ring incorporates twelve long straight sections in which special magnetic devices, wiggler and undulators, will provide intense beams of synchrotron light. Over the past few years, substantial advances have been made in the design, construction, and use of wigglers and undulators, and it is now clear that these insertion devices must be used to produce the most intense photon beams. At the ALS, most or all of the photon beams will originate at wigglers and undulators, and few storage ring bending magnets will be used as synchrotron radiation sources. The design of the ALS has been carefully adjusted to provide an extremely small electron beam emittance, so that the photon beam intensities would be maximized. A high radiofrequency has been selected to provide short electron bunches and, therefore, short pulses of synchrotron light. Furthermore, complete flexibility will be provided to store different numbers of electron bunches in the storage ring, so that synchrotron radiation experiments with varying requirements for dead-time between photon pulses may be accommodated.

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Parameters and Performance

The major parameters of the Advanced Light Source are given in Table 1. The most prominent features are the many long straight sections for insertion devices and the extremely small electron beam emittance. In order to provide flexibility to meet the varying requirements of experimenters, the storage ring will have the capability of being operated at electron energies from 0.9 GeV to 1.9 GeV.

Table 1. Advanced Light Source Parameters

Injector	
Linac Energy	50 MeV
Booster Energy	0.05 to 1.3 GeV
Booster Circumference	67.2 m
Booster Electron Current	7-13 mA
Booster Cycle Rate	1 Hz
Storage Ring	
Electron Energy	1.3 GeV (1.9 GeV max)
Electron Current (nominal)	400 mA
Circumference	182.4 m
Design Horizontal Emittance	6.8×10^{-9} π m-rad
No. of Superperiods	12
No. of Long Straight Sections	12
Length of Long Straight Sections	6 m
Max. Horiz. Beta	13.3 m
Max. Vert. Beta	13.3 m
Horiz. Tune	13.8
Vert. Tune	7.8
Horiz. Chromaticity (natural)	-32.0
Vert. Chromaticity (natural)	-17.5
Radiofrequency	499.65 MHz
Harmonic Number	304
Bunch Length (nominal)	35 ps
Vac. Ch. Horiz. Aperture	±32 mm
Vac. Ch. Vert. Aperture	±24 mm
Dipole Field (1.9 GeV)	1.60 T
Max. Quad. Gradient (1.9 GeV)	22.9 T/m
Energy Loss per Turn (dipoles only, 1.9 GeV)	291 keV

Figure 1 shows a portion of the electron storage ring. The two bending magnets in each of twelve superperiods, in combination with the single quadrupole magnet QF located between the two bending magnets, provide achromatic deflection of the electron beam, as can be seen in Figure 2. Therefore, the momentum dispersion is zero everywhere else in the storage ring, including the long straight sections. This design produces a low value of momentum dispersion at the bending magnets, which results in a very small value for the electron beam horizontal emittance. The quadrupole triplets placed at both ends of each long straight section are used to control the beta functions within the long straight sections and to adjust the betatron tunes. This design provides considerable flexibility in tuning. For example, studies have shown that this lattice can readily be adjusted to compensate for the substantial vertical edge focusing of a superconducting wiggler magnet.

Sextupole magnets are located at the short straight sections adjacent to the QF quadrupole magnets. There are thirty six sextupoles placed in these twenty four short straights, so there is a minor violation of the twelve-fold symmetry of the storage ring.

Photon beam lines which have very small acceptances are required for many of the most advanced experiments (those which need precise energy resolution, for example). For these beam lines, spectral bril- liance is a good figure of merit for the intensity of a synchrotron radiation source. The bend magnets at the ALS are photon sources with spectral brilliance as high as a few times 10^{14} photons per second per $(mm)^2$ per $(mr)^2$ per (0.1 percent bandwidth). Wiggler magnets at the ALS provide peak spectral brilliances around 10^{16}, in the same units; and un- dulators can attain spectral brilliances in the range 10^{17} to 10^{19}. The undulators produce photon beams with energies from about 10 eV to about 5 keV, and operation of the storage ring at 1.9 GeV extends the undulator photon energies to about 10 keV.

Photon flux, which is measured in units of photons per second per (mr horizontal angle) per (0.1 percent bandwidth), is a better figure of merit for photon beam intensity, for experiments which can use large-acceptance photon beam lines. The ALS bend magnets can provide photon fluxes around a few times 10^{12}, and the ALS wiggler magnets can provide photon fluxes about 100 times higher. At an electron energy of 1.9 GeV, the maximum usable photon energy from a superconducting wiggler magnet is about 40 keV.

Storage Ring Mechanical Systems

Figures 3 through 5 show cross-sectional views of the magnets in the storage ring. All of these magnets are designed to leave room for a wide, flat vacuum chamber, which is required to allow the "fan" of synchrotron radiation to emerge from the storage ring. As can be seen in Figure 1, synchrotron radiation which is radiated by a wiggler or undulator placed in a long straight section must pass through several magnets before it emerges from the storage ring. Figure 5, which shows the storage ring sextupole magnet, also shows a cross-sectional view of a special vacuum chamber. The synchrotron radiation from bending magnets is allowed to pass through a slot (1 cm high) into an "antechamber", where the radiation strikes a target. Differential pumping then provides a much better vacuum in the main chamber, where the electrons circulate, as compared with the vacuum in the antechamber, where most of the gas is produced by the synchrotron radiation.

Storage Ring Electrical Systems

The magnet power supplies for the ALS consist of "chopper" supplies, which are very similar to those used at PEP. The radiofrequency accelerating system operates at about 500 MHz, and about 3 MV of accelerating voltage is required to provide short bunches and a long beam lifetime.

The accelerator control system is entirely computerized and is based upon a system of microcomputers. This design provides high performance through the use of parallel processing. Furthermore, the use of distributed intelligence greatly simplifies software development.

Experimental Facilities

The detailed specifications concerning the radiation source devices (wigglers and undulators) and the photon beam lines to be constructed at the ALS are being developed with the guidance of potential ALS users. However, tentatively we anticipate that 4 undulators and 2 wigglers will be constructed, with 6 more radiation source devices to follow eventually. Many photon beam lines are being planned to use the radiation from these source devices.

ALS Building

The 184-Inch Cyclotron Building at LBL will be used to house the ALS. Existing utilities will be used, and the major new addition will be a building extension required to provide adequate space for the ALS and its beam lines. New laboratory buildings will also be components of NCAM, and they will be located conveniently close to the ALS building.

Reference

"Preliminary Design Handbook for the Advanced Light Source", Lawrence Berkeley Laboratory Report, PUB-5082, November 1982.

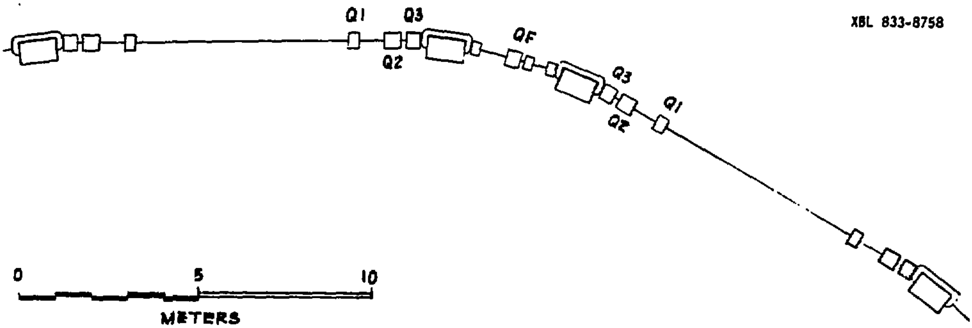

Figure 1. ALS Electron Storage Ring

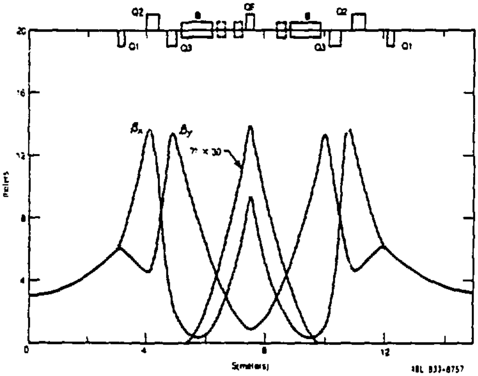

Figure 2. Storage Ring Lattice Functions

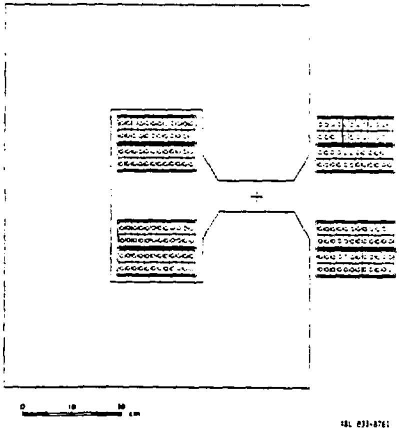

Figure 3. Storage Ring Bending Magnet

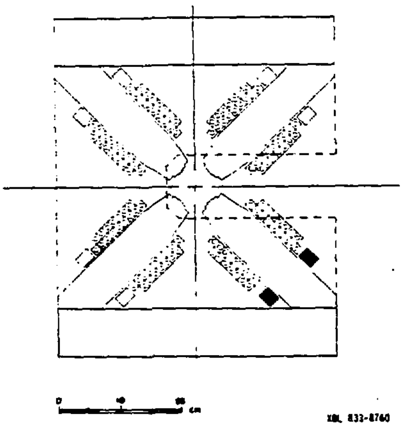

Figure 4. Storage Ring Quadrupole Magnet

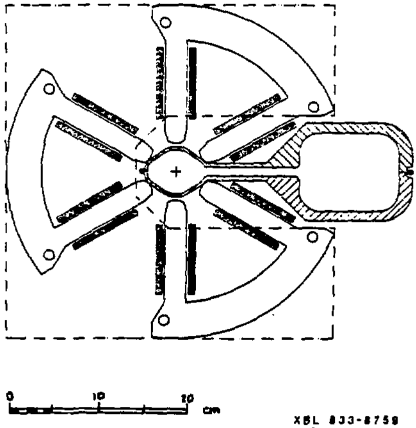

Figure 5. Storage Ring Sextupole Magnet