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THE ADVANCED LIGHT SOURCE—A NEW TOOL FOR RESEARCH IN ATOMIC PHYSICS*

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September 1990

Paper Presented at the 5th International Conference on the Physics of Highly-Charged Ions, Giessen, West Germany, September 10–14,1990

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*This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098

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Abstract

The Advanced Light Source, a third-generation national synchrotron-radiation facility now under construction at the Lawrence Berkeley Laboratory in Berkeley, California, is scheduled to begin serving qualified users across a broad spectrum of research areas in the spring of 1993. Undulators will generate high-brightness, partially coherent, plane polarized, soft x-ray and ultraviolet (XUV) radiation from below 10 eV to above 2 keV. Wigglers and bend magnets will generate high fluxes of x-rays to photon energies above 10 keV. The ALS will have an extensive research program in which XUV radiation is used to study matter in all its varied gaseous, liquid, and solid forms.

I. Introduction

The availability of intense, tunable, collimated, polarized radiation in the x-ray and ultraviolet regions of the spectrum has driven the evolutionary development of dedicated facilities optimized for the generation of synchrotron radiation. The newest, third-generation synchrotron sources are based on the use of an electron or positron storage ring specifically designed to have very low emittance and several long straight sections containing insertion devices (wigglers and undulators). The combination of a very-low-emittance storage ring with optimized undulators makes possible the generation of radiation with a spectral brightness that is a factor of 20 or more over that of existing, second-generation sources, depending on the spectral range. Around the world, construction of several third-generation sources is either under way or planned. They include the Advanced Light Source (ALS) at the Lawrence Berkeley Laboratory [1]. The project is scheduled to be completed in April 1993.

II. Accelerator

An overall layout of the facility's accelerator complex, which consists of a 50-MeV linac, a 1-Hz, 1.5-GeV booster synchrotron, and an electron storage ring, is shown in Fig. 1. The ALS lattice has 12 long straight sections that are joined by 12 achromatic arcs, each containing three bending magnets. The ALS produces electron beams that are bunched, with a bunch spacing of 2 ns and a length is 35 ps. For particular experiments—for example, those involving time-of-flight measurements—it will be possible to have only one or a few circulating electron bunches in the storage ring.

III. Photon Sources

The ALS lattice is optimized for the use of insertion devices. The periodic magnetic field of an insertion device bends the electrons into an approximately sinusoidal trajectory in the horizontal plane, causing the emission of synchrotron radiation, as shown in Fig. 2. Ten full straight sections are available for undulators and wigglers up to 4.5 m in length. Operating at 1.5 GeV, the ALS is optimized for insertion-device operation in the XUV spectral regions. The design performance of insertion devices that cover the ALS spectral range shown in Fig. 3. Three undulators span the soft x-ray and ultraviolet spectral regions when the ALS operates at 1.5 GeV, and a wiggler extends spectral coverage into the x-ray region beyond 10 keV. Between them, the undulators will be able to excite the K shell of elements through silicon and the L shell of elements up to krypton, while the wiggler will be able to excite the L shell of nearly every element in the periodic table.

The spectral range of the undulator is scanned by varying the undulator magnetic field. The wiggler, which operates with a high magnetic field, generates a broad continuous spectrum extending into the hard x-ray region near 10 keV. High-quality synchrotron radiation will be available from the 24 bend-magnet ports as well.

IV. Insertion-Device Beamlines

Low-emittance storage rings and insertion devices have created new challenges for designers of UV and soft x-ray optics. The attainment of highr resolution by use of small slits also becomes practical (the spectral-resolution goal of monochromators in undulator beamlines is $\Delta E/E \approx 10^{-4}$). Undulator beamlines at the ALS are based on the spherical-grating monochromator system with water-cooled gratings. Because of the low emittance of the ALS storage ring, the monochromator can accept the entire undulator beam in most cases, even at a slit-width of 10 μm.

V. Atomic Physics and Highly Charged Ions

The ALS will be a national user facility that is open to all qualified scientists and technologists. Participating research teams (PRTs) consisting of investigators with related research interests from one or more institutions will be assigned privileged access to the facilities it helps develop for its own research program. A substantial fraction of the beam time at every beamline will be allocated to independent investigators by means of a proposal-review process.

The ALS is particularly well suited for research on tenuous targets, as, for example, occurs in atomic physics and chemistry, in which targets are often gas-phase, beams, or an excited population. A few examples are photon-ion interactions, in which either the ion beam after the collision 2], or electrons emitted are detected; these ions can be highly charged. Other examples are coincidence experiments [3], where low collection efficiencies require intense photon beams; experiments with actinide targets, where material is either scarce or highly radioactive; and laser-excited targets [4]. Many other applications in atomic physics have been considered [5].

Highly charged ions can be produced by photon impact; these ions are very cold [6], and could be used for a variety of collisions and especially spectroscopy experiments. These ions could aslo be stored in a trap [7].

Scientists desiring to do research at the ALS can submit a proposal to form a new insertion-device or bend-magnet team, they can request to join an existing team, or they can submit a proposal to do research as an independent investigator. Interested persons should contact the author for additional information.

VI. Acknowledgments

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Division of Materials Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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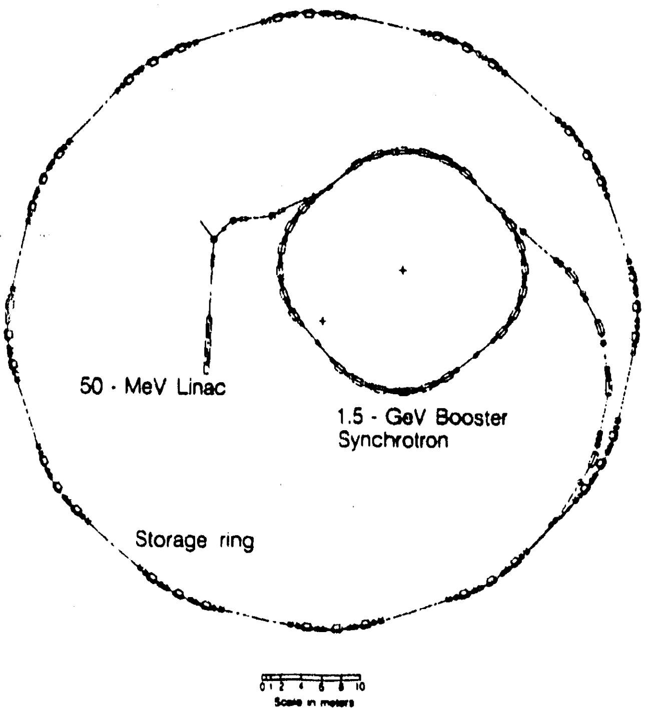

FIG. 1. Layout of the ALS accelerator complex showing the placement of the 50-MeV electron linear accelerator, the 1.5-GeV booster synchrotron, and the storage ring.

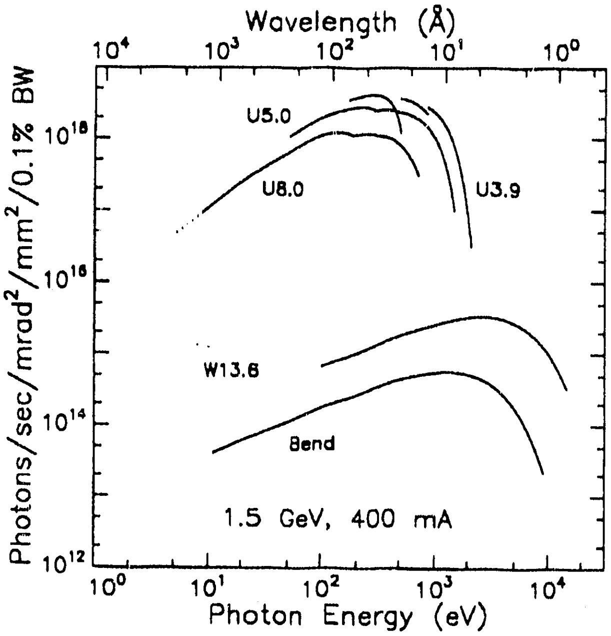

FIG. 3. Spectral brightness as a function of photon energy for proposed ALS undulators, wiggler, and bend magnet. Performance envelope for each insertion device is shown. This figure was calculated using $\varepsilon_x = 10^{-8}$ m-radian; effects of electron energy spread and undulator errors are relatively small on the scale of the figure and have not been included.

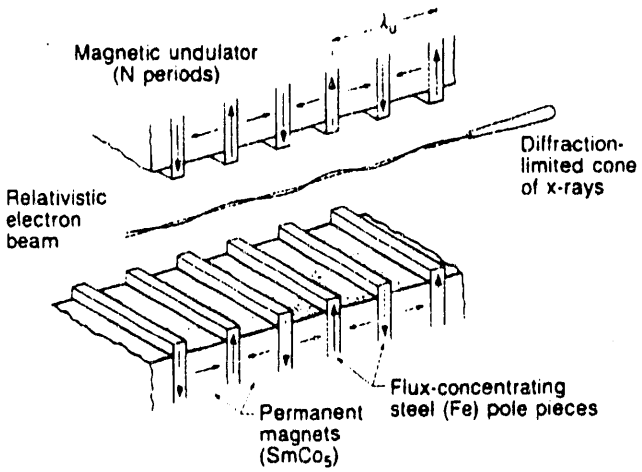

FIG. 2. Schematic drawing of a periodic magnet structure (an undulator) of period λ_u and with a number of periods, N. The oscillations of the electron beam passing through the structure produce ultraviolet and soft x-ray radiation (photons) of high spectral brightness.

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