Title
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Publication Date
1990-08-01

Approved by [illegible]

ESG-101

THE ADVANCED LIGHT SOURCE AT THE LAWRENCE BERKELEY LABORATORY*

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The Advanced Light Source (ALS), a national facility currently under construction at the Lawrence Berkeley Laboratory (LBL), is a third-generation synchrotron light source designed to produce extremely bright beams of synchrotron radiation, in the energy range from a few eV to 10 keV. The design is based on a 1 - 1.9 GeV electron storage ring (optimized at 1.5 GeV), and utilizes special magnets, known as undulators and wigglers (collectively referred to as insertion devices), to generate the radiation. In this paper we describe the main accelerator components of the ALS, the variety of insertion devices, the radiation spectra expected from these devices, and the complement of experiments that have been approved for initial operation, starting in April 1993.

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

1. Introduction

During the past two decades, utilization of electromagnetic radiation in the vacuum-ultraviolet and soft x-ray regions of the spectrum have played an increasingly important role in the study of many physical, chemical and biological processes. In the latest generation of synchrotron light sources,[1] extremely bright radiation is produced through the interaction of very small emittance electron (or positron) beams with special magnets known as undulators. The Advanced Light Source (ALS), fig.1, currently under construction at the Lawrence Berkeley Laboratory, is a national user facility designed specifically to provide beams of unrivaled brightness in the photon energy range between a few eV to around 2 keV [1]. It is based on an electron storage ring (nominal energy 1.5 GeV with an emittance less than 10 nm-rad), and 4.5 m long undulator magnets that have alternating transverse magnetic fields of up to 1 Tesla, with periods ranging from 4 to 10 cm. The upper energy range of radiation available from the ALS will be pushed to higher energies (around 10 keV) by the use of higher field (2 T) magnetic devices known as wigglers. The facility is expected to start operation for users in April 1993.

In this paper we describe the main accelerator components of the ALS, the variety of undulators and wigglers (collectively known as insertion devices), and the radiation spectra expected from these devices. In an companion paper at this conference (Robinson), the radiation spectra and experimental facilities are described in more detail, and the ways in which potential users can gain access to the facility are discussed.

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[1] Thus far in the history of synchrotron radiation facilities there have been three "generations". The first facilities were parasitic on the accelerators used for high energy physics. The second were dedicated sources, but built mainly around the utilization of bend magnet radiation. The new, third-generation, facilities are based around storage rings that have a very small electron beam emittance, and produce radiation through the electrons interaction with the periodic magnetic fields of undulators.

2. The Accelerator Systems

The accelerator systems of the ALS comprise a 50 MeV linac, a 1.5 GeV booster synchrotron, and a storage ring that is optimized for an energy of 1.5 GeV, but is capable of operation anywhere between 1.0 and 1.9 GeV.

The linac is a conventional 2 section, S-band (3 GHz), constant impedance structure, fed by a gun and bunching system that is capable of producing single S-band bunches with a charge of greater than 2 nC per bunch [2]. Beam from the linac is transported to the booster by the linac-to-booster (LTB) line, which matches the optical characteristics of the beam (including momentum dispersion), to those required in the booster. Injection into the booster utilizes a fast switching kicker magnet (fall time less than 100 ns) to give single-turn, on axis injection, similar to the system used in the Damping Rings at SLAC. Table 1 lists the main parameters of the linac.

The booster synchrotron [3] has a 75 m circumference with a four-fold symmetry, missing-magnet, FODO lattice as shown in fig.2. Three of the four straight sections formed by the missing dipole magnets are used for injection, extraction and the single 500 MHz accelerating cavity. Acceleration of the beam to 1.5 GeV takes approximately 0.4 seconds, after which the beam is extracted, again in a single turn, by a fast kicker magnet and a pair of pulsed magnetic septa. Once extracted from the booster the beam is transported to the storage ring by the booster-to-storage ring (BTS) line, which matches the optical characteristics of the two circular accelerators. Table 2 lists the main parameters of the booster synchrotron.

The repetition rate of the injection system, 1 Hz, will permit filling the storage ring to its nominal operating current of 400 mA in about two minutes. It should also be noted that the injection system is designed so that the storage ring can be filled in several different modes. For example, all 328 rf buckets in the storage ring can be filled uniformly, or some number of buckets can be left empty if it is found that this helps to alleviate ion trapping. Also, it is possible to fill just one, or a few, bunches to serve the requirements of time resolved studies.

The storage ring is designed as a third-generation synchrotron radiation source, that is, it has long, dispersion free, straight sections for the inclusion of insertion devices, and a small natural beam emittance (3.5 nm-rad), so that the spectral features of the undulator radiation are determined primarily by the properties of the undulator. Its magnet lattice, with a circumference of 196.8 m, contains twelve achromatic arcs (joining the dispersion free straights), each containing three gradient bend magnets, six quadrupoles and four sextupoles, in the so-called triple bend achromat (TBA) arrangement. Figure 3 shows one period of the magnetic structure, and its associated lattice functions. The main parameters of the storage ring are listed in Table 3.

Injection into the storage ring takes place entirely within one straight section. This extremely tightly packed straight contains four fast kicker magnets (to move the circulating beam towards the injection septa), and two pulsed magnetic septa to direct the beam from the BTS line into the storage ring. A second straight section is occupied by two rf accelerating cavities, operating at 500 MHz, which leaves ten straights available for insertion devices.

A unique vacuum system design [4] will maintain the base pressure in the storage ring to about 10^{-10} torr, and give a dynamic pressure (with loading from synchrotron radiation at the nominal 1.5 GeV/400 mA circulating current) of 10^{-9} torr.

3. Insertion Devices and Beamlines

As we described above, there are 10 straight sections available for insertion devices. In collaboration with the user community, the ALS project has specified the design parameters for three undulators and one wiggler magnet. The major parameters of these devices are shown in Table 4, and the spectral brightness associated with the undulators is shown in fig. 4. In addition to radiation from insertion devices, there are also four ports in each arc section (48 ports in all), through which radiation can be extracted from bend magnets.

In order to obtain useful radiation in up to the fifth harmonic, the undulators are specified with extremely fine tolerances on the magnetic field quality. To meet this challenge a hybrid design (precision steel poles driven by permanent magnet material) has been adopted, with special algorithms developed to sort and place the permanent magnet material within the device. Four insertion devices (2 U5.0's, 1 U8.0 and 1 W16), will be built as part of the construction project. Funding for other devices is currently being sought by user groups. In addition, the construction project is ~~also~~ funding the design and construction of two beamlines, one associated with the U5.0 undulator and the other with the U8.0. As part of this exercise, generic "front ends" and optical systems have been developed. A particular challenge for the beamline designers arises from the low emittance and high intensity (which together give high brightness) of the photon beams. In order to transport the beam with high efficiency the optical components must be made with tolerances that push the state of the art. For example, surface roughness of 5 Å and tangential slope errors of less than 1 ~~m~~μrad for condensing mirrors are required, and it should be noted that these characteristics must be maintained under power loadings from undulator radiation of several kW/cm^2.

The primary responsibility for experimental apparatus and data acquisition systems (i.e., all equipment downstream from the exit slit of the monochromators) rests with the users.

4. Summary

Upon its completion in 1993 the Advanced Light Source will become the worlds brightest source of radiation in the energy range between a 10 eV and 2 keV. With a full complement of ten insertion devices and a potential for forty eight bend magnet beamlines, the ALS represents a tremendous investment in the future of science in the U.S.A., that should pay dividends well into the next millennium.

[1] 1-2 GeV Synchrotron Radiation Source, Conceptual Design Review. LBL PUB-5172 Rev., July 1986

[2] R.H. Miller, C.H. Kim and F.B. Selph, Design of a Bunching System for High-Intensity Electron Linac. LBL-25237, proceedings of 1988 European Accelerator Conference.

[3] F. Selph, A. Jackson, and M.S. Zisman, Injection System Design for the LBL Synchrotron Radiation Source. LBL-22191. Proceedings of the 1987 IEEE Particle Accelerator Conference.

[4] K. Kennedy, T. Henderson and J. Meneghetti, Vacuum System for the ALS. LBL-25980. Proceedings of 1989 IEEE Particle Accelerator Conference.

Table 1

Main parameters of the ALS linac

Energy		[MeV]	50
Repetition Rate	(nominal)	[Hz]	1
	(maximum)	[Hz]	10
Radiofrequency		[MHz]	2997.9
Emittance (rms)		[π m-rad]	1.1×10^{-6}
Pulse Length		[ns]	100
Average Current		[mA]	125
Momentum Spread (rms)		[%]	0.4

Table 2

Main parameters of the booster synchrotron

Injection Energy	[MeV]	50.0
Peak Energy	[GeV]	1.5
Cycle Rate	[Hz]	1.0
Beam Properties at 1.5 GeV:		
Natural Emittance (rms)	[m-rad]	1.4×10^{-7}
Energy Spread (rms)		6.3×10^{-4}
Bunch length (rms)	[mm]	30.5

Table 3

Main parameters of the storage ring

Energy	(Nominal)	[GeV]	1.5
	(Minimum)	[GeV]	1.0
	(Maximum)	[GeV]	1.9
Current	(multibunch)	[mA]	400
	(single bunch)	[mA]	7.6
Beam Parameters at 1.5 GeV:			
Natural Emittance		[nm-rad]	3.5
Bunch Length		[mm]	3.6
Energy Spread			6.5×10^{-4}
Rad^n loss/turn		[keV]	91.5

Table 4

Parameters for the initial complement of insertion devices for the ALS

Name	Period (cm)	No. of periods	Photon Energy range (eV)[a]	Critical energy (keV)
Undulators				
U8.0	8.0	61	5.4-220 [16.2-660] [27-1100]	-
U5.0	5.0	98	52-380 [156-1140] [260-1900]	-
U3.9	3.9	123	169-500 [507-1500] [845-2500]	-
Wiggler				
W16.0	16.0	16	-	3.1

[a] The photon energy range of the fundamental and of the third and fifth harmonics (shown in brackets), when the electron-beam energy is 1.5 GeV.

Figure Captions

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 2a. One superperiod of the ALS triple-bend achromat lattice.

Fig. 2b. Horizontal and vertical beta functions and dispersion for one superperiod of the storage-ring lattice.

Fig. 3. Magnets in one quadrant of booster. B, bending magnet; QF, QD, quadrupoles; SF, SD, sextupoles.

Fig. 4. Spectral brightness as a function of photon energy for the three undulators. Each undulator curve is the locus of narrow peaks of radiation, tuned by altering the undulator gaps. Separate curves are shown for the first, third, and fifth harmonics of each undulator.

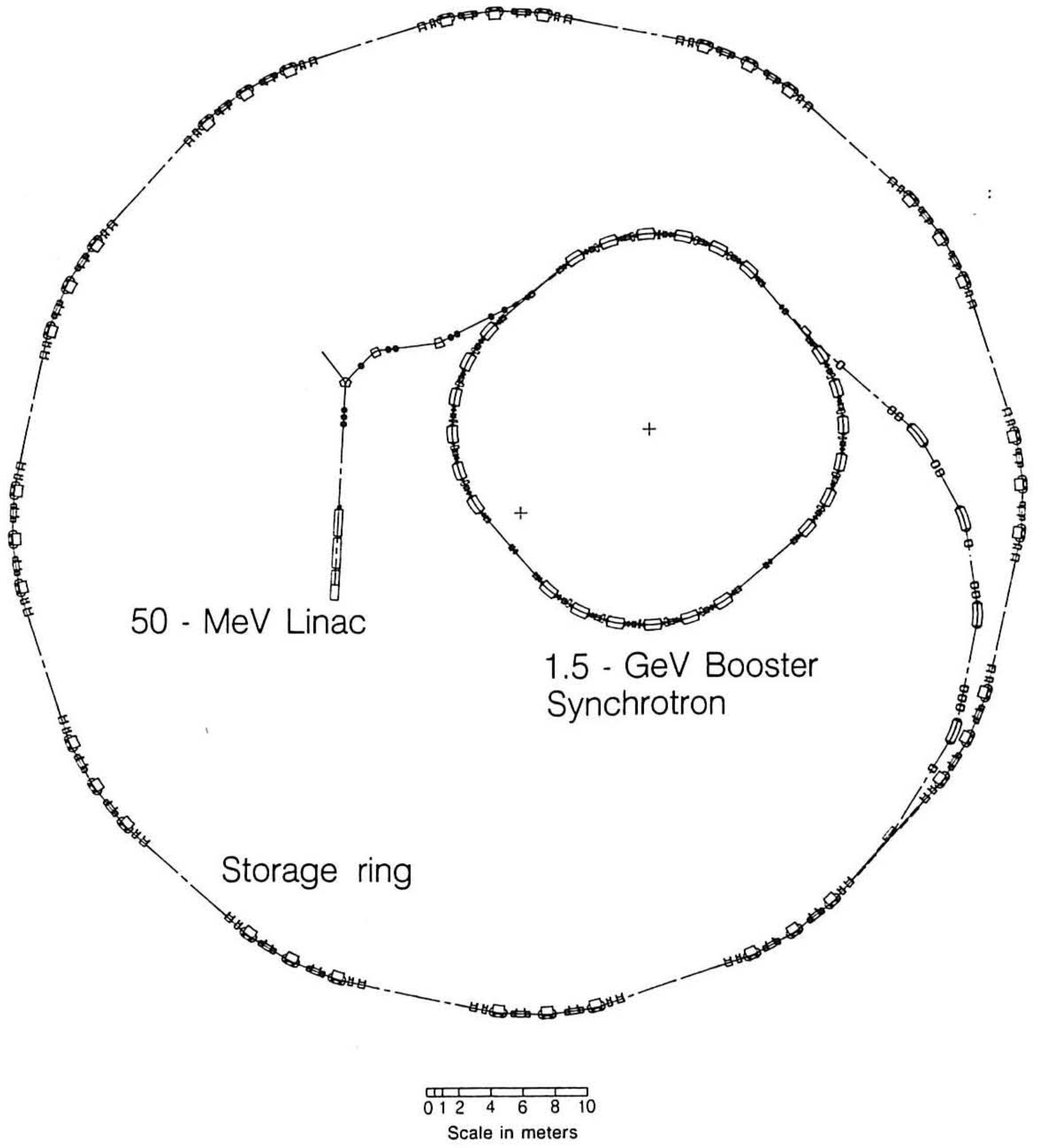

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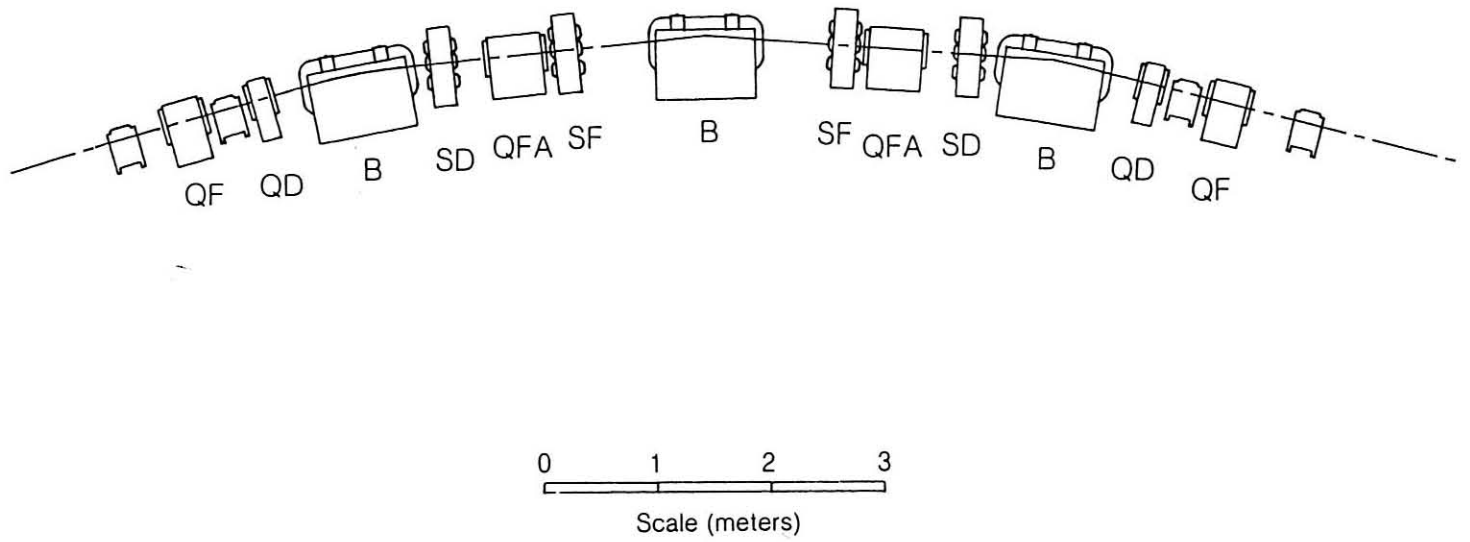
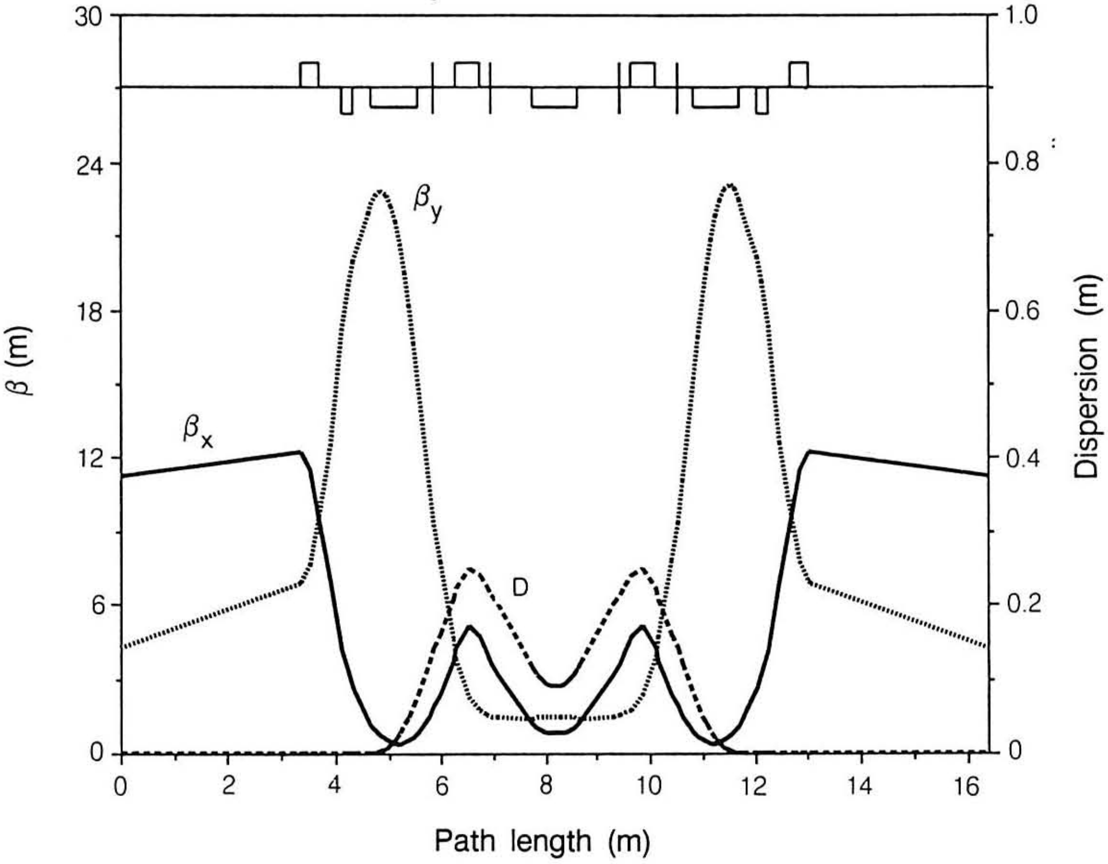
Fig. 1



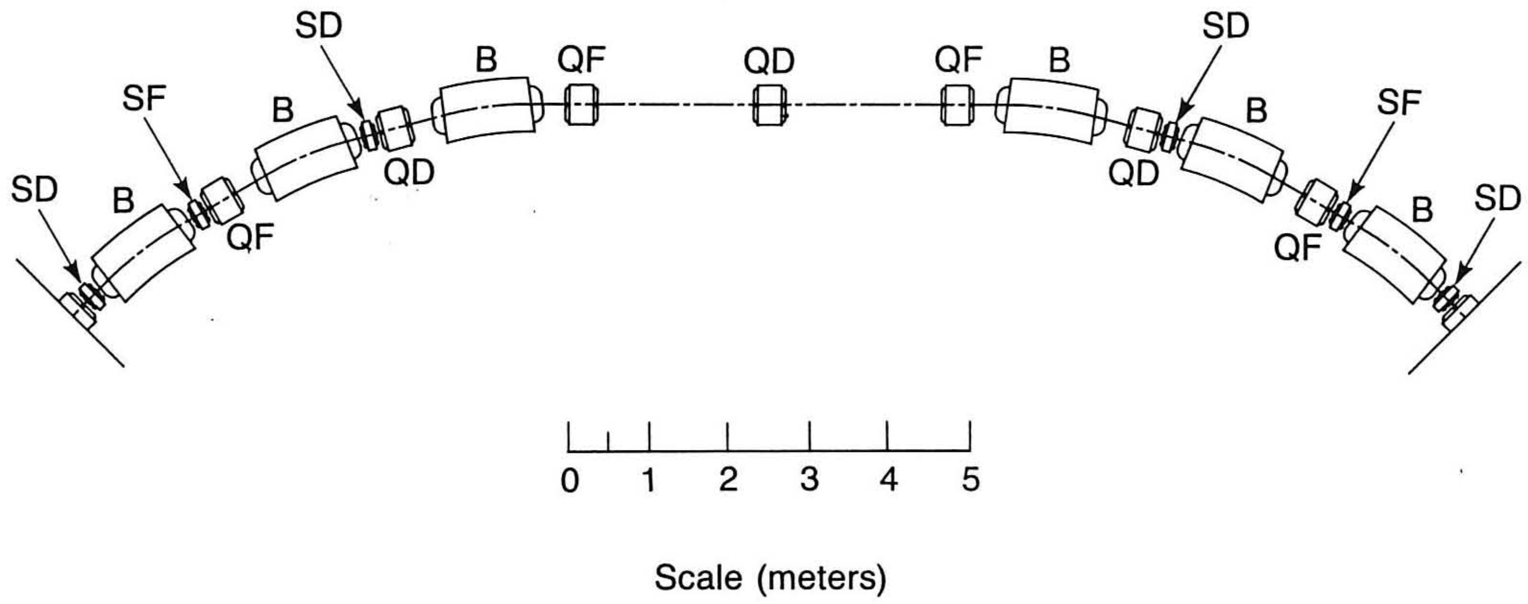
XBL 893-7089

Fig. 2a



XBL 893-7088

Fig. 2b



XBL 865-6243

Fig. 3

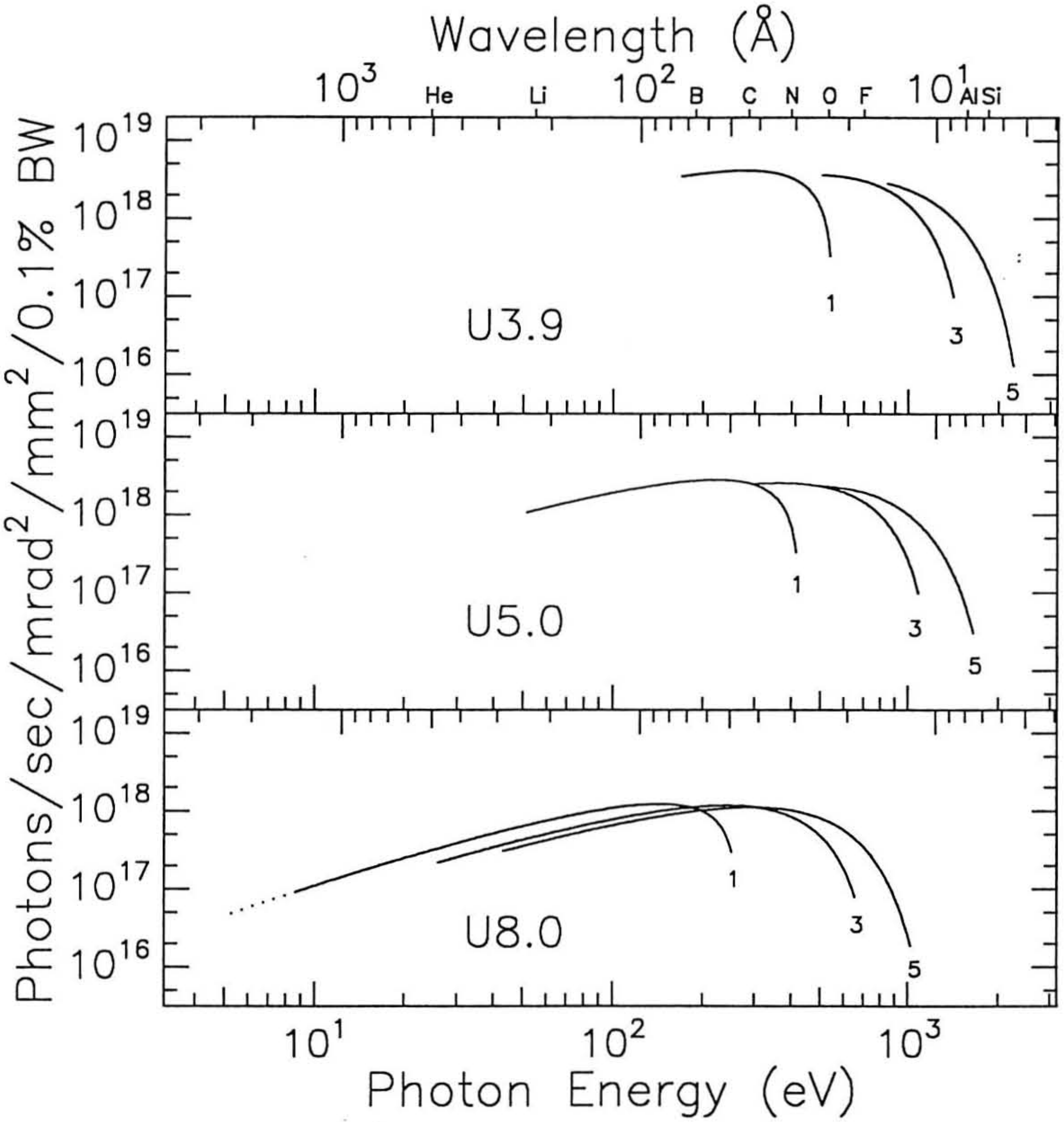


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Fig. 4