S. P. Kapitsa. *Present and future sources of synchrotron radiation.* Synchrotron radiation (SR) arises in electron synchrotrons and storage rings and extends practically all the way from the far infrared through the visible and vacuum ultraviolet ranges to the hard x-rays. The exceptional properties of SR attracted the attention of investigators from widely scattered scientific fields, and later from engineering and medicine. The number of papers on SR subject matter has recently been doubling every year. The requirements that will be made of future specialized machines—SR sources—and instrumentation trends in this field of physical experimentation have been elaborated by joint interdisciplinary commissions on SR in the Soviet Union, the United States, and Western Europe.

SR is noncoherent, representing a random sum of the radiations from independent scattering of electrons by photons of the electromagnetic field. There is interest in obtaining induced SR in the submillimeter and infrared ranges or even in visible light, despite the existence of lasers.

The well-established nature of SR makes it possible to treat a beam of electrons radiating in a magnetic field as an effective luminosity standard that resembles a black body with $T \sim 10^6 - 10^7 °$.

An important practical application for SR has been found in the manufacture of integrated-circuit components by microlithography. The problem of forming an image with SR has stimulated the development of optical components based on glancing-incidence mirrors and the use of zone plates. A new generation of crystal monochromators in which the degree of monochromatization has been raised to 10 meV at 10 keV (10^{-6}) has appeared. After monochromatization, the intensity of SR, even on existing machines, is 100–1000 times greater than the effective spectral intensity of the most powerful x-ray tubes. New possibilities have been demonstrated in the study of biopolymers, and the anomalous absorption makes it possible to determine scattering phases and thus to arrive at more definite interpretations of complex structures. Note is taken of x-ray structural research at high pressures, which uses the scattering of the continuous spectrum through a constant angle with energy analysis of the scattered SR.

Studies of surfaces are becoming highly important in solid-state physics along with the traditional optical measurements, which yield details of band structure and exciton emission. Study of photoemission from atoms, molecules, and solids is productive. Inelastic scattering of SR can be used to study the spectra of elementary excitations (phonons and magnons) in solids.

Inelastic scattering of x-rays and study of the fine structure of absorption edges have led to the rapid development of the EXAFS method. It yields information on the immediate surroundings of a given atom in a chemical compound, lattice, amorphous solid, or solution. X-ray structural methods based on SR have become a powerful tool in elementary analysis. The intensity and polarization of SR in the infrared region of the spectrum, in combination with the methods of Fourier spectroscopy, are opening up interesting opportunities. In contrast to the situation in atomic and solid-state physics, there have as yet been few pro-

TABLE I. Storage rings as sources of synchrotron radiation.

Designation	Location	E, GeV	R, m	I_A	$\mathscr{E}$, eV
N-100	Khar'kov	0.10	0.5	1300	10
Tantalus I	Wisconsin, USA	0.24	0.64	100	48
SURF II	Washington, USA	0.24	0.83	30	37
INS–SOR II	Tokyo, Japan	0.30	1.1	200	54
ACO	Orsay, France	0.54	1.11	150	333
VOPP-2M	Novosibirsk	0.67	2	100	350
Brookhaven I BNL	Upton, USA	0.70	1.90	1000	400
Aladdin	Wisconsin, USA				
Bessi	West Berlin	0.8	1.78	1000	500
ADOHE-PULS	Frascati, Italy	1.5	5.0	60	1 500
PAMPUS	Amsterdam, Netherlands (projected)	1.5	4.17	500	1 800 (7 500)
SRS	Daresbury, England	2	5.55	1000	3 200
Brookhaven II BNL	Upton, USA	2.5	8.17	1000	3 200
VÉPP-3	Novosibirsk	2.2	6.15	100	3 800
Photon factory PF	Tsukuba, Japan	2.5	8.0	500	4 300
Ersiné	Erevan, projected	2.5	6.4	750	5 000
DORIS	Hamburg, FRG	3.5	12.12	100	7 850
)CI	Orsay, France	1.8	3.82	400	3 390
ÉPP-4	Novosibirsk	6	33	100	14 200
SPEAR	Stanford, USA	4	12.7	60	11 200
Cornell	Ithaca, USA	8	32	100	35 000
PETRA	Hamburg, FRG	19	170	90	75 000
PEP	Stanford, USA	15	200	100	44 000

posals for the use of SR in nuclear physics.

The development of at least two types of electron storage rings is currently envisaged. At a diameter of 5–6 meters and $\lambda_s \approx 40$ Å, a small 600–1000 MeV machine will have a low SR power—up to 1 kW—at a beam current up to 0.5–1 A in a wavelength range extending to 5 Å. The second type of machine is a large storage ring to operate down to 0.5–0.2 Å in the x-ray range at energies of 2–2.5 GeV and currents up to 1 A; it will have a diameter of ~30–50 m, with the SR power in the hundreds of kW. The next generation, or the next larger-scale unit, is seen as an SR source with an energy of 3–4 GeV and a current of 0.1 A. However, the most powerful colliding-beam installations (VÉPP-4, Cornell, PETRA and PEP) can, for the time being, meet the high-energy SR requirements that are now foreseen. The SR-source concept is based on the principle of separation of functions of its magnetic sustem, in which the following elements will be provided: 1) deflecting magnets, 2) focusing quadrupoles, 3) sextupole magnets that offset cubic nonlinearities and 4) magnetic systems for generation of SR, superconducting magnets, wigglers, sidulators, and microwave fields and beams from lasers mounted in linear gaps of the orbit, where focusing elements minimize the beam cross section to ensure maximum brightness of the SR source.

The development of photon counters and image-recording methods that permit use of on-line computers with extensive automation of work with the SR is assuming great importance. On the whole, the cost of modern experimental equipment for SR experiments will ultimately exceed the cost of building the SR sources themselves. Organization of SR research will require the development of new forms of interdisciplinary collaboration between specialists in various areas. We may conclude that SR gives us new light with which to illuminate the most complex and perhaps the most vital objects of our immediate surroundings, where powerful centralized SR sources are becoming a decisive factor in the development of experimental research.

The material of this paper was published in the proceedings of the Sixth All-Union Conference on Charged Particle Accelerators (Dubna, 1978) and was presented at the Fourth General Conference of the European Physical Society (York, 1978).

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Translated by R. W. Bowers