J. Synchrotron Rad. (1994). **1**, 1–4

Overview on Synchrotron Radiation and the Need for the *Journal of Synchrotron Radiation*

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Introduction

Synchrotron radiation is an outstanding tool in many branches of science. A stunning combination of properties can be brought to bear on a wide variety of technically challenging scientific problems. The generation and harnessing of synchrotron radiation involves common and overlapping instrumentation and methods in different applications. Diffraction methods, whose development has been served by the International Union of Crystallography (IUCr) for nearly 50 years, have made a major impact in molecular research across traditional subject boundaries. In a similar way, synchrotron radiation is extensively used for investigating chemical, biological, geological and physical systems, and for characterizing new materials. Thus, synchrotron radiation is also having an impact right across the sciences, furthering an interdisciplinary approach to science, and rapidly developing its own community.

Aims and scope of the *Journal of Synchrotron Radiation*

In view of the leading-edge science carried out at these advanced photon sources, it is very often the details of the instrumentation and methods, and the associated performance benchmarks that are of paramount importance for the success of much of the science undertaken. Also, the importance of the cross-fertilization of ideas and developments between different fields of synchrotron radiation research cannot be over-emphasized, as many of the problems associated with the development of instruments and methods are common. These problems include high heat loads on optical elements, high data rates, as well as the storage and analysis of large amounts of data. The *Journal of Synchrotron Radiation* aims to provide the natural home for the reporting of source developments, and new aspects of instrumentation, methods and applications, irrespective of the synchrotron radiation technique or the region of the spectrum used. Thus, in this way, the journal will promote the rapid exchange of information across the whole of the synchrotron radiation community.

The IUCr has taken this initiative because the diffraction community has a strong vested interest in synchrotron radiation, and therefore in harnessing the best features of synchrotron radiation instrumentation and methods. We, and the IUCr, believe that the full benefit of this initiative can only be felt if the *Journal of Synchrotron Radiation* serves the whole of the synchrotron radiation community, across its full spectrum, rather than covering the hard X-ray region alone. This diversity is reflected in the format and scope of the journal and was ensured by conducting the widest possible consultations. Thus, we have approached synchrotron radiation representative organizations and directors of synchrotron radiation facilities, and have made presentations and solicited comments at a wide

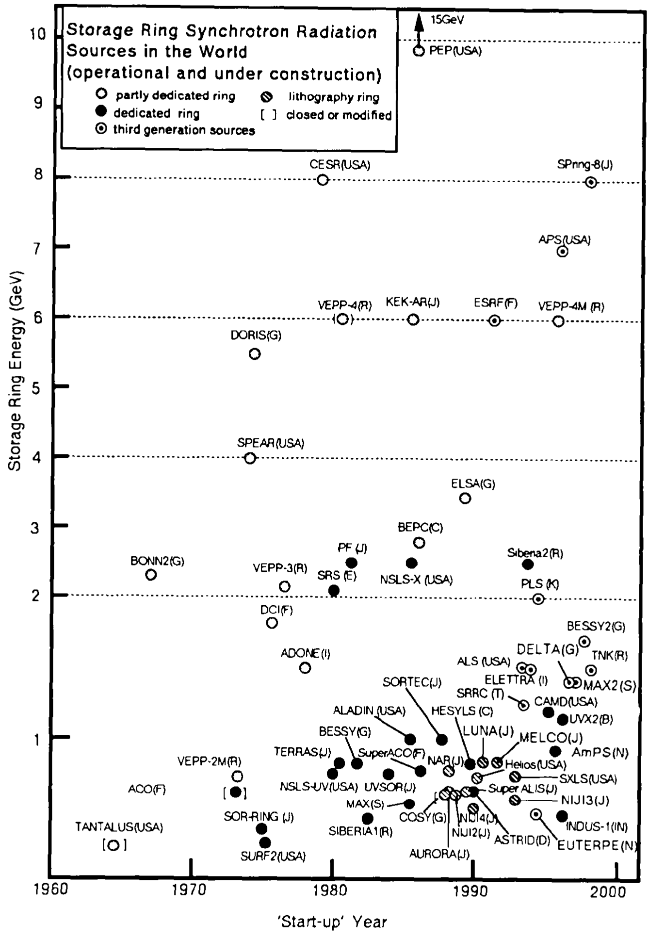

Figure 1
The evolution of storage-ring synchrotron radiation sources over the decades, as illustrated by their increasing number and range of machine energies (based upon V. Suller, *Proceedings of the EPAC Conference*, Berlin, 1992).

variety of synchrotron radiation conferences. The Editorial Board reflects this breadth of representation and provides wide-ranging coverage of the interests of the synchrotron radiation community.

Synchrotron radiation sources and instrumentation

The first synchrotron radiation beam was seen in 1947 (Elder, Gurewitsch, Langmuir & Pollock, 1947), and the

Figure 2
An aerial view of Spring-8, Harima Science Garden City, Japan.

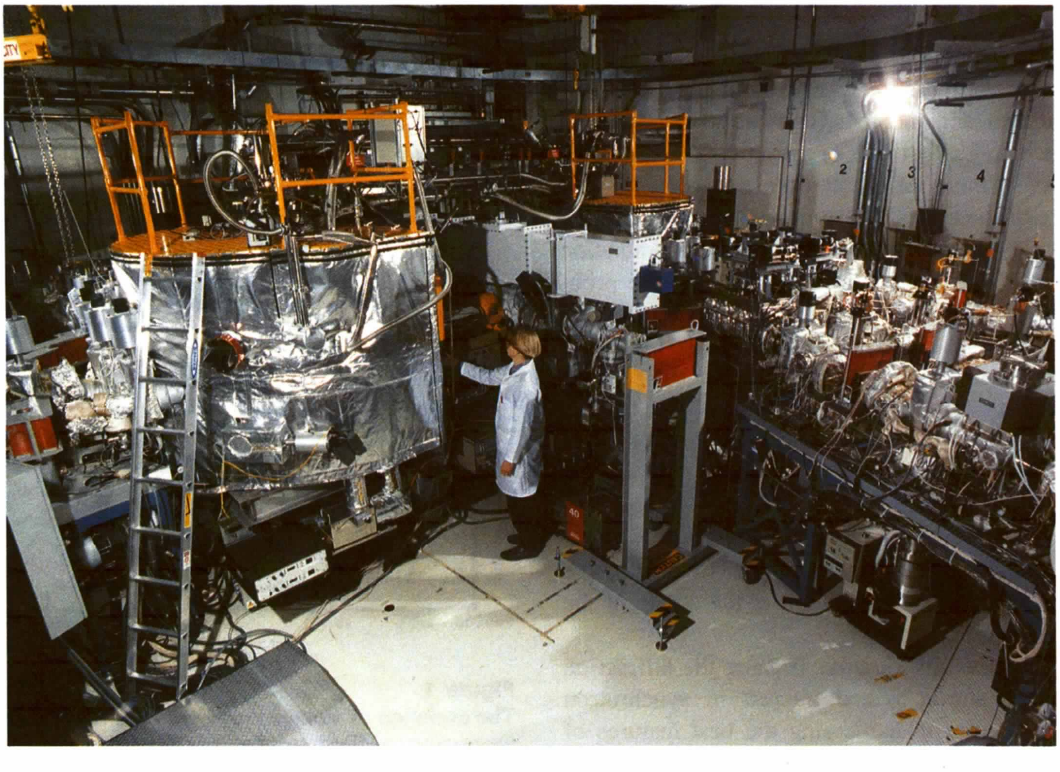

Figure 3
A view of Helios-1 at IBM (photograph kindly supplied by Dr M. N. Wilson, Oxford Instruments, UK).

following decades have witnessed the clear broad utility of synchrotron radiation. Indeed, sources themselves have evolved (Fig. 1); initially from parasitic first-generation synchrotron radiation machines, then to purpose-built second-generation dedicated sources, and now to third-generation brilliance-optimized sources (Fig. 2). A fourth generation holds the promise of either more flux- or coherence-driven sources and/or more widely spread, specialized, compact sources such as Helios (Fig. 3).

The first synchrotron radiation facility became available in 1961, when the National Bureau of Standards in Washington modified its 180 MeV synchrotron to incorporate a beamline, where a programme to measure the absorption spectra of rare gases between 80 and 600 Å was launched (Madden & Codling, 1963). During the last 30 years hundreds of synchrotron radiation beamlines and instruments have become available at a wide variety of synchrotron radiation sources.

Beamline instrumentation has evolved, and to a large extent has kept pace with the advances in accelerator technology. Initially, apparatus was transferred from laboratory X-ray, VUV, visible and infrared light sources. Developments then included the specification, production and use of much larger optical elements. In general, their size has been realised without loss of quality. Indeed, finer surface-finish and shape-definition tolerances have been obtained. However, precision mechanical engineering is currently being tested to the limits with large circumference third-generation machines with their associated long beamlines. Some of the insertion devices on these sources also produce tremendous thermal loads.

Detectors represent one of the most challenging areas of instrumentation. An often recurring theme is the difficulty of combining a variety of desirable properties simultaneously, *e.g.* high spatial or energy resolution with high count rate. Both electron and photon detectors have substantially improved with time, *e.g.* multi-element solid-state X-ray detectors with high energy resolution and high count rate. Also area detectors such as image plates, multi-wire area detectors and charge-coupled devices (CCDs) have become available.

Sample environment and perturbation is undergoing increased sophistication as experiments become more ambitious. Examples include high pressure and environmental chambers for materials research, and the initiation of processes in biological samples, such as muscle contraction and enzyme catalysis. On the other hand, containment of supersonic beams of molecular gases, in a windowless region of the spectrum, has offered particular challenges at UHV synchrotron radiation sources.

Synchrotron radiation methods and applications

Synchrotron radiation methods, applied to the areas of diffraction, spectroscopy and imaging, have several common themes.

In the X-ray and XUV region, the fine tuning of the wavelength extracted from the synchrotron radiation spectrum is used for spectroscopy at the *M*-, *L*- and *K*-absorption edges and to optimize anomalous scattering in diffraction. The tuning capabilities available at synchrotron radiation sources with imaging techniques have given rise to the idea of chemical state imaging in the soft X-ray and XUV region, and is beginning to be applied to bio-molecules and materials. Wavelength contrast is also the basis for synchrotron radiation transvenous angiography at the iodine *K*-absorption edge and microtomography of industrial materials.

The high intensity of synchrotron radiation beams can be harnessed for problems of small sample volume, dilution of a metal centre and/or fine rastering in imaging applications. Furthermore, processes with low cross-section can now be studied by the use of the high intensity. In the X-ray region, these include weak diffraction effects such as magnetic and nuclear scattering. Many opportunities exist to exploit the polarization of the beam for the study of directional effects in a whole variety of systems. Circular dichroism experiments in the soft X-ray region have already made a notable contribution to our understanding of surfaces, magnetic materials and paramagnetic centres of proteins.

The application of synchrotron radiation to diffraction experiments with crystals, powders, fibres or solutions has greatly extended the scope of such studies. In biological crystallography, the structure determination of huge viruses (*e.g.* the cancer virus SV40 of 500 Å diameter) has become possible due to the high intensity and collimation at short wavelengths, and that of proteins has become more effective by the use of a variety of anomalous-scattering techniques (*e.g.* multiwavelength anomalous diffraction). Also, problems of small crystals, *e.g.* of some medically important drug-design targets where crystallization can be difficult, have been ameliorated. Similar techniques and approaches are now also expanding in chemical crystallography.

Spectroscopic methods cover the whole of the synchrotron radiation spectrum. In the XUV region, for example, much insight has been gained on the band structure of pure and mixed solids by observing the properties of ejected photoelectrons using the well defined polarization characteristics and continuous spectral nature of synchrotron radiation. In the X-ray region, XAFS and SEXAFS yield details of the local order around a spectroscopic centre such as a metal atom. Thus, irrespective of the sample state, detailed information has been gained on diverse materials such as metalloproteins, surfaces and glasses. There is close interplay between XAFS and crystallography. Indeed, XAFS is a special case of diffraction, where the modulations in the absorption spectrum are observed due to the diffraction of the photoexcited electron from the neighbouring atoms. In this way, the XAFS technique encompasses features of diffraction and spectroscopy.

Rapid data collection has opened up time-resolved studies of a wide variety of processes. These are, for example, based on quick monochromatic techniques such as QuEXAFS or large-angle rotation techniques in crystallography. Alternatively, the full spectrum of multipole wigglers and bending magnets can be used directly in dispersive EXAFS, synchrotron Laue crystallography and energy-dispersive diffraction.

Imaging techniques, using soft X-rays, are perhaps the most demanding technically and thus have been slower to develop. In one application involving the exploitation of the so-called water window, the wavelength range between the carbon and oxygen K edges (44 and 23 Å, respectively) is used to enhance the contrast between cells and organelles, and their aqueous environment. One of the most tantalizing prospects of all is for direct X-ray holographic imaging using coherent X-rays. Currently, these possibilities are restricted to soft X-rays, but prospects exist for the production of coherent hard X-rays.

Invitation to the synchrotron radiation community

The *Journal of Synchrotron Radiation* aims to provide a focus for the whole of the synchrotron radiation community so that the details of any development in one field are easily available to another. Hence, the journal will facilitate the cross-fertilization of ideas and encourage novel applications. In this Inaugural Issue we have assembled a variety of articles. Many, but obviously not all, aspects of the field of synchrotron radiation and machines, and the associated beamline instrumentation, methods and applications are represented. This issue therefore serves as a guide and invitation to the community for the submission of papers for the regular issues of the *Journal of Synchrotron Radiation*, the first of which will be published in January 1995.

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