

PREFACE

Large synchrotron facilities in basic and applied research



The discovery of X-rays just over 100 years ago electrified the world. In 1895, after weeks of intense work, Roentgen brought his wife into his laboratory and took an amazing photograph of the bones in her hand and the ring on her finger. As the famous photograph showed, X-rays could “see” inside the human body without surgery.

Since that time, X-rays have become an indispensable tool in medical diagnosis and in radiation therapy. With the further developments by von Laue and Braggs, X-rays also became crucial in the study of the structure of matter, and at least ten Nobel Prizes have been based in part on experiments performed using X-rays. The quest to make ever more detailed studies of matter has led to the need for ever more intense sources of X-rays.

In the 1960s, scientists realized that the synchrotron radiation emitted from electron accelerators built for high energy physics provided a very intense, broad-band source of photons, both in the vacuum ultraviolet and X-ray regions of the spectrum. At first, biologists, chemists, and condensed matter physicists used these accelerators as “parasites”—taking advantage of this excess photon radiation.

At Brookhaven National Laboratory, we recognized early on that the use of synchrotron radiation was growing rapidly and that an accelerator dedicated solely to the production of synchrotron radiation was needed in the U.S. A close collaboration between the accelerator physicists who had built our Alternating Gradient Synchrotron, a proton accelerator, and the condensed-matter physicists in the Physics Department led to a unique accelerator design that satisfied the need for a low-emittance lattice and for the inclusion of long straight sections in the ring for insertion devices such as wigglers and undulators.

The late Renate Chasman and the late G. Kenneth Green designed the “double-focusing achromat,” or what is more commonly known as the Chasman-Green lattice. The lattice is the periodic arrangement of magnets that bend, focus and correct the electron beam. Chasman and Green's simple yet elegant design formed the basis for the National Synchrotron Light Source (NSLS) at Brookhaven in New York and the Photon Factory in Japan. These facilities were completed in the early 1980s and have been the two largest synchrotron sources in the world in terms of the number of users and of experimental stations. Today, new synchrotrons based on the Chasman-Green lattice are being built in France (ESRF), in the U.S. (APS), and in Japan (Spring-8).

The availability of synchrotron sources around the world has literally led to the rebirth of X-ray physics. Researchers are studying the absorption and scattering of X-ray light to determine the properties of matter such as crystal structure, bonding energies of molecules, details of chemical and physical phase transformations, electronic structure and magnetic properties. A number of new techniques have been developed specifically to use the brightness and the broad-band nature of synchrotron sources. There is chemical and element-specific information in the absorption spectra of materials, information that can be

used to give three-dimensional images of materials component by component, or to give an impression of the local environment around impurities inside or on the surface of a crystal.

The properties of synchrotron light are well-matched to the study of surfaces. Studies of the differences between the bulk of a crystal and its surface in terms of structure and electronic properties have led to a new understanding of surfaces on the atomic level. Surfaces are also key to understanding technologically important processes such as catalysis and corrosion—the chemical and petroleum industries use Brookhaven's NSLS to develop new catalysts.

The electronics industry, both in the United States and in Japan, has made extensive use of the NSLS and the Photon Factory to study the properties of bulk semiconductors and especially the properties of interfaces between various layers in semiconductor devices. In both countries, as industry looked for ways to make smaller and smaller features in computer chips, companies turned to synchrotron sources to develop X-ray lithography. Their success led individual companies in both countries to develop their own synchrotron sources, specifically designed for the production of the next generation of computer chips.

In the biological sciences, it is estimated that a new protein structure is determined every day, and a growing number of these are done using synchrotron radiation. At the NSLS and the Photon Factory, at synchrotron sources around the world, more than a dozen beam lines are devoted to structural biology.

Looking to the future, a short-wavelength free-electron laser (FEL) operating in the vacuum ultraviolet range will serve to bridge the gap between what can be provided by conventional laser technology and synchrotron radiation sources. Brookhaven anticipates developing an FEL-based facility to serve users in fields as diverse as photobiology, materials science, and chemical, surface and solid-state physics. In many ways, the new facility will be orders of magnitude above existing sources: Peak power will be one gigawatt; wavelengths will range from 300 down to 70 nanometers; and short duration pulses will be measured in femtoseconds—sufficiently short and intense to allow “snapshots” of chemical reactions to be taken, even as they occur.

There has been tremendous growth in the field of synchrotron radiation during the last 20 years, and I look forward to seeing further developments in both accelerator design, such as FELs, and in new uses of synchrotron light,



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