SYNCHROTRON LIGHT SOURCES

The human eye is uniquely adapted to see only a very limited form of light. Not surprisingly, this light is of a form that best illuminates the surface of the earth. Of all the light forms produced by the sun, this light, falling within the visible spectrum, is most capable of penetrating a thick atmosphere, reflecting off of, and resolving well, objects we need to see. The light and the eye are ideally matched to serve the special purposes of living organisms.

Likewise, scientists probing the physical attributes of atoms and molecules find most useful special forms of light ideally suited for "viewing" objects of this size and scale. Although technically known as synchrotron radiation, named after the early laboratory machines in which its presence was first observed, it is really just another form of light.

It encompasses a broad range of "colors" or wavelengths of light. In its most useful form, it cannot be seen by the human eye. Its optimum band of operating wavelengths lies just beyond the deep blue and violet end of the visible spectrum.

Aided by Basic Energy Sciences research, a number of premier facilities now produce this light with great brightness and versatility. Just as the microscope ushered in an era of new discovery, so too are the instruments of these facilities ushering in their own. Although still in a period of relative infancy, these facilities have already had major impacts on basic research programs of leading industries, universities, and Government laboratories.

Further, their value extends beyond basic research. More than a dozen major United States corporations are using these facilities for industrial research, ranging from x-ray lithography in the manufacture of computer chips to the development of catalysts in the refining of petrochemicals.

Synchrotron radiation is produced as a natural consequence of accelerating electrically charged particles, such as electrons or, in some advanced light sources, their sister particles, positrons. The simplest machines accomplish this by accelerating the charged particles to a velocity near the speed of light (186,000 miles per second) and simultaneously forcing them with powerful magnets to follow a circular or curved path in what is now known as a storage ring.

The acceleration which produces the radiation stems from the force that "holds" the particle, like a rock swung overhead on the end of a string, in its circular path and keeps it from flying away. The resulting radiation is emitted tangentially to the curved path and so-called "beam lines" of light emerge through ports or windows in the evacuated tube which encloses the ring.

What makes this light so valuable? There are at least four compelling advantages. Most importantly, the lengths of its waves, measured from crest to crest, and their corresponding energies, are about the same as the characteristic structures and features of individual atoms, molecules and the atomic lattices of solids. As a result, the interactions of light with matter in this realm are unusually strong and revealing.

A single atom, for example, may be 2 Angstroms in diameter. One Angstrom is one ten-billionth of a meter, which is about two one-trillionths of an inch. The strength of an electronic bond between two atoms is strongly determined by its length, which may be on the order of 1 Angstrom. A molecule may be a thousand times as large.

In so-called photon (light ray) transmission and scattering experiments, wavelengths of synchrotron radiation are short enough to bracket these dimensions nicely. Typically, they fall within a range of 0.01 to 3,000 Angstroms, yielding excellent resolution for a variety of needs. The wavelengths of visible light, by contrast, are too long. They range in length from 4,000 (blue) to 7,000 (red) Angstroms.

In so-called photon absorption and spectroscopy experiments, the energy levels of synchrotron radiation can be precisely tuned to match that of the desired physical interaction. This allows scientists to select special wavelengths, eliminate others, and use slight variances in wavelengths for a host of investigative purposes.

A second advantage is that synchrotron light is extremely bright. Operated essentially as a light bulb, the radiant output of energy from a synchrotron light source focused on an experimental target can be as much *10,000 billion times brighter* than that of the ordinary 100-watt variety!

This extreme brightness makes experiments go hundreds and thousands of times faster, thus allow-