SYNCHROTRON-RADIATION RESEARCH

Conf-821049--3

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CONF-821049--3

DE83 001874

Synchrotron radiation is a relatively new and powerful research tool that is destined to have a major impact on scientific progress in the 1980 decade. The purpose of this note, therefore, is to tell why and how this powerful probe will induce rapid scientific advance in the decade ahead.

The intensity and brightness of radiation from synchrotron source and its broad energy spectrum from the visible light through hard x-rays has already started a renaissance in materials science, physics, chemistry and biology. By precisely tuning synchrotron radiation to specific electron energy levels, researchers are gaining new detailed knowledge of the spatial arrangement and electronic structure of atoms in materials. This knowledge promises not only to lead to advances in theory but to aid in the development of materials with physical and chemical properties tailored to meet specific needs. Experimenters are using the x rays of synchrotron radiation to study phase transformations as they occur, to measure how atoms are arranged relative to each other in solid solutions and liquids, to study the atomic structure of catalytic surfaces while the catalyst is in action, to observe the transient behavior of crystal growth or plastic deformation at milli-second intervals and to determine atomic arrangements and bonding distances from less than a monolayer of material, just to mention a few examples (see *Physics Today,* May 1981 for a more detailed discussion of these machines and the science being done). A byproduct of the unwieldy devices of medium- and high-energy physics, synchrotron radiation is rapidly becoming one of the more useful probes of the structure of matter.

*Operated by Union Carbide Corporation under contract W-7405-eng-26 with the U. S. Department of Energy

The x-rays from synchrotron radiation sources can give us information about electron energy levels and charge distributions as well as important characteristics about the geometric arrangements of atoms and molecules in matter. These parameters determine the basic physical and chemical behavior of materials. Except in a few instances, we are unable at the present time to calculate material properties entirely from first principles. It is very difficult to calculate even the simplest geometric structures. Thus we must use experimental information about the geometric structures of atoms and molecules in matter and on surfaces in advancing both our practical insights and our theoretical understanding. Property measurements of the 90-odd naturally occurring elements are relatively easy. However, most materials of technological interest consist of two or more elements in varying concentrations and the number of conceivable combinations makes such measurements an incredible task. The goal of this new thrust is a synthesis of experimental results and theoretical calculations that will help sort out the more promising trends and lead the way to further experimentation and useful application.

Advantages of Synchrotron Radiation

Synchrotron radiation sources represent a dramatic improvement over conventional x-ray machines, which have remained basically unchanged since 1913. The development of synchrotron radiation resulted in a thousandfold improvement in x-ray source brightness (photons/cm^2 sec per eV per steradian) throughout a continuous energy spectrum. With judicious use of wigglers and undulators, the level of improvement can be increased by a factor of 10^6.

Of the many probes available to study matter, x-ray synchrotron radiation offers many advantages which have compelling appeal to researchers. One enticement of synchrotron radiation is its broad and intense energy spectrum, which is pulsed and nearly linearly polarized. The most attractive property — the unique resonances that x-rays have with specific electron energy levels — is not available with other probes. Synchrotron radiation provides a continuous spectrum from which we can select, with a monochromator, an energy very near the binding energy of a bound electron. Energies are chosen to excite specific interactions involving any of the atoms throughout the periodic table. By comparison, resonances obtained with conventional electron probes are much weaker and as a consequence electron straggling energy-loss processes tend to dominate, and thus degrade the information and complicate interpretation of the data.

Although the use of the x-ray region for materials science research is still in its infancy, enough has been done to excite the imagination of researchers. Several synchrotron radiation sources are available for exploratory research in the United States. The Department of Energy operates two major facilities. One, known as the Stanford Synchrotron Radiation Laboratory, is located at the Stanford Linear Accelerator Center at Stanford University. Another, nearing completion at Brookhaven National Laboratory, is named the National Synchrotron Light Source. In addition, the National Science Foundation funds a synchrotron radiation laboratory at the University of Wisconsin and another at Cornell University. Research proposals may be submitted by industry, universities, and government agencies to obtain beam time to conduct experiments. No charge is made for beam time unless the work is proprietary.

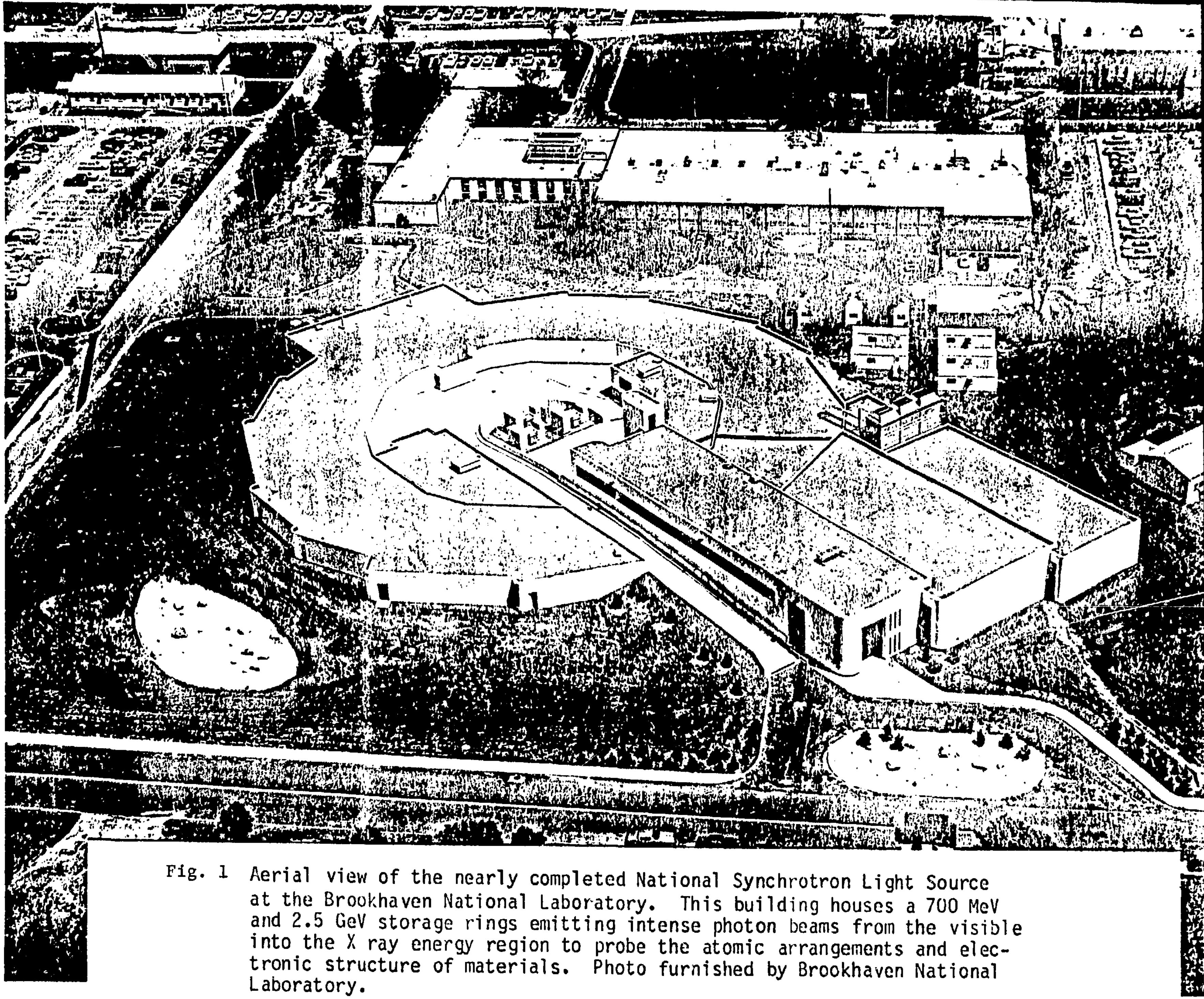

Fig. 1 Aerial view of the nearly completed National Synchrotron Light Source at the Brookhaven National Laboratory. This building houses a 700 MeV and 2.5 GeV storage rings emitting intense photon beams from the visible into the X ray energy region to probe the atomic arrangements and electronic structure of materials. Photo furnished by Brookhaven National Laboratory.

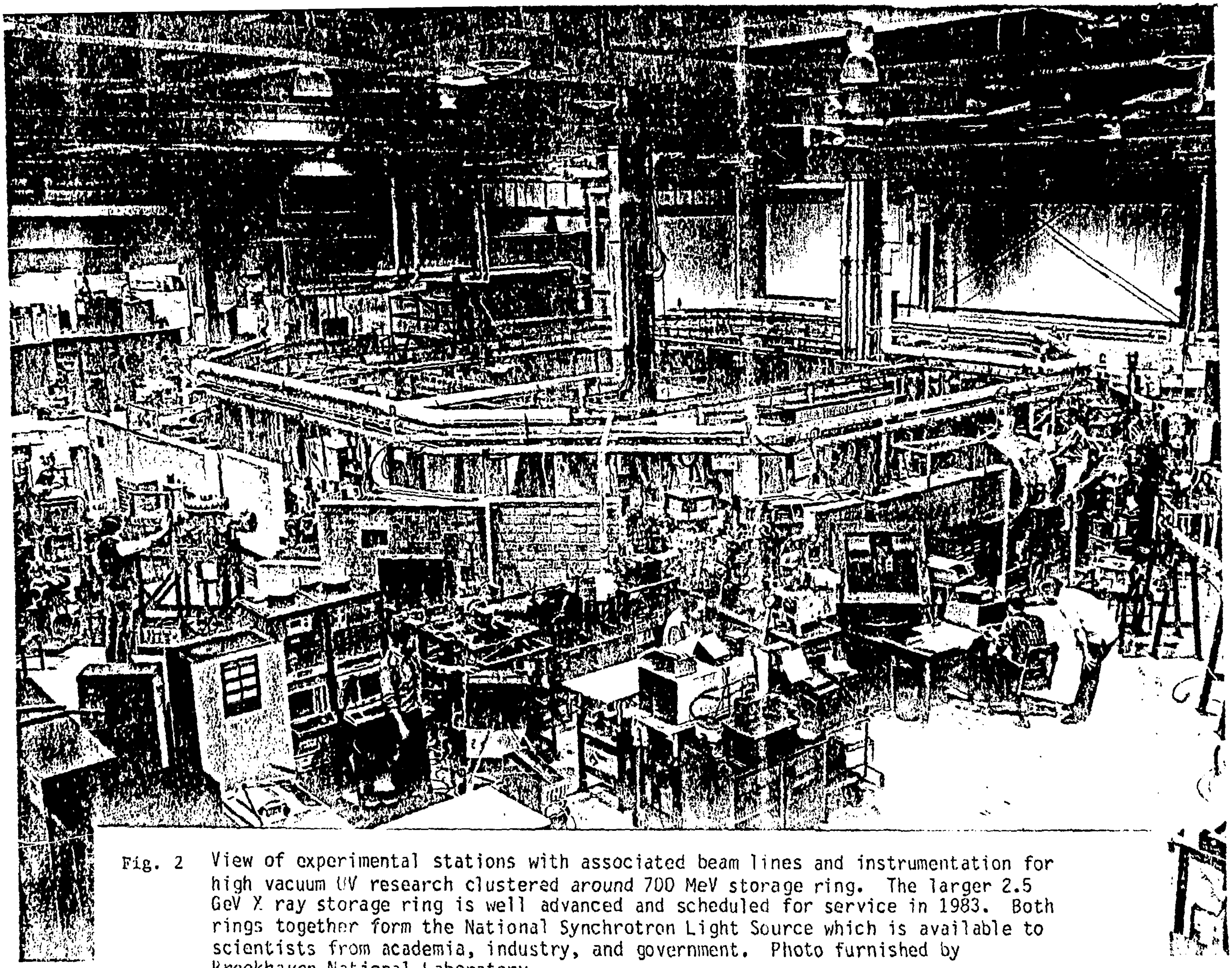

Fig. 2 View of experimental stations with associated beam lines and instrumentation for high vacuum UV research clustered around 700 MeV storage ring. The larger 2.5 GeV X ray storage ring is well advanced and scheduled for service in 1983. Both rings together form the National Synchrotron Light Source which is available to scientists from academia, industry, and government. Photo furnished by Brookhaven National Laboratory.