Los Alamos Science

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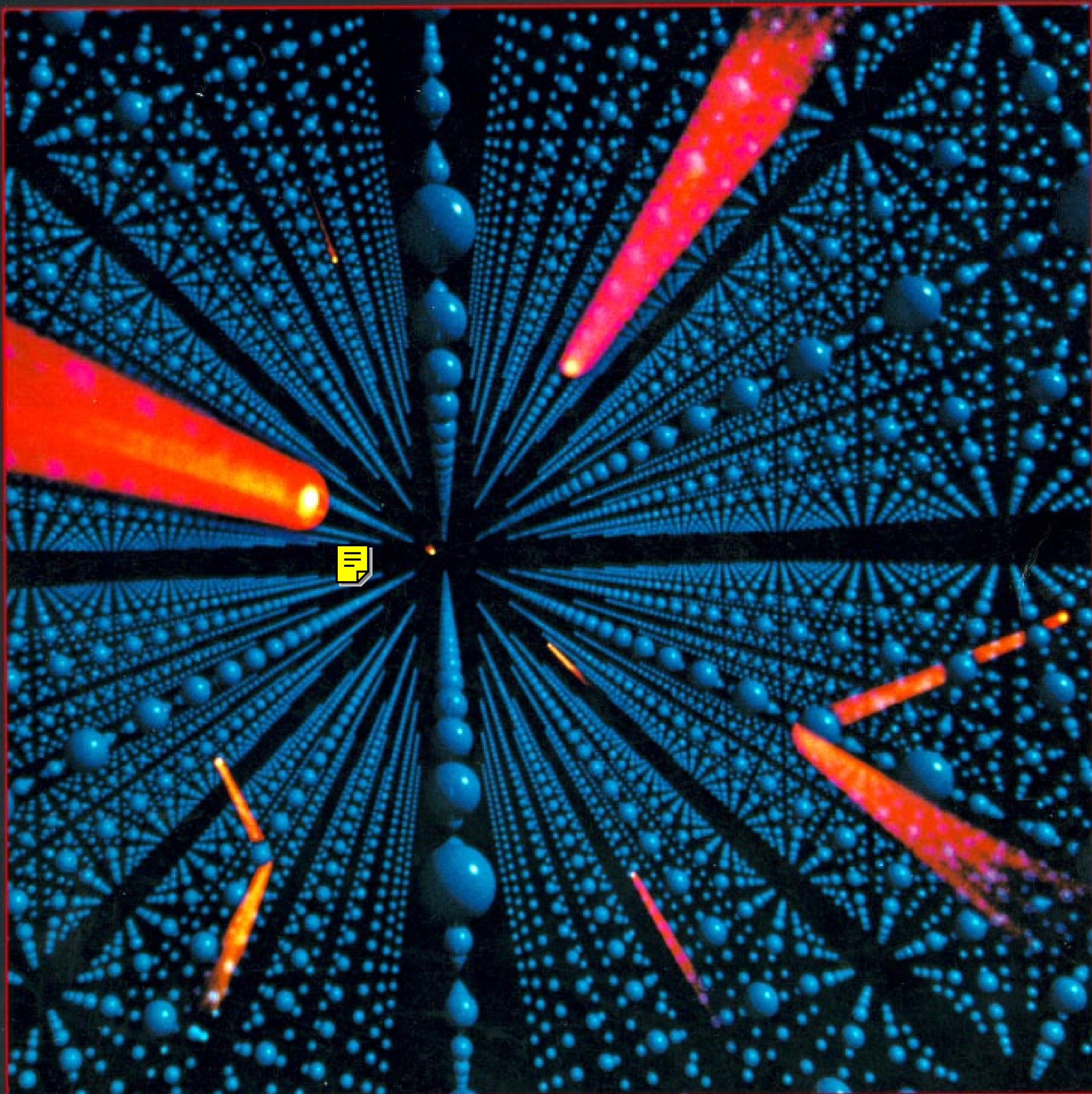
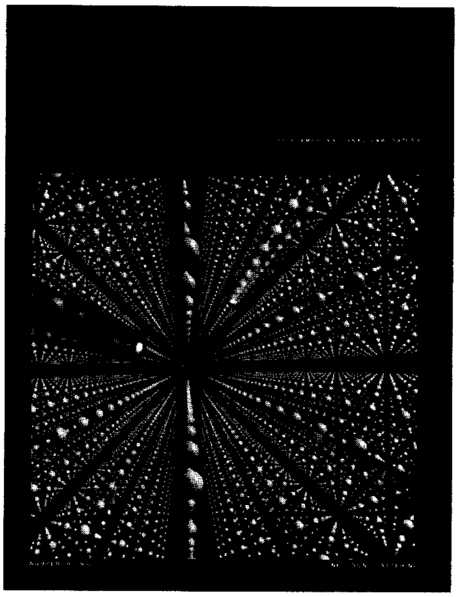


NUMBER 19 1990

NEUTRON SCATTERING



Artist's conception of neutrons flying through matter. Low-energy neutrons (red) scatter to new trajectories by interacting with the atomic nuclei (blue). Since the nuclei are small, the neutrons see mostly empty space and scattering are rare. Cynthia L. Boone created the computer art using Alias software. The 14,000 nuclei were generated by 50 translations of an original lattice plane.

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Part 1. Introduction to Neutron Scattering

Part II. Neutron Scattering Research at LANSCE:

NEUTRON SCATTERING

What is neutron scattering? Why is it becoming more and more useful in both basic and applied science? And why are materials scientists, in particular, very worried about its future in the United States? At first glance the technique appears forbidding. You shine a large number of neutrons on a sample, but—because neutrons have no electric charge-only a very small fraction are scattered. Therefore generating measurable signals requires a great deal of ingenuity. Also, the neutrons are expensive to produce and are available at only a small number of specialized facilities. It seems like the last technique to choose-except that its results are so valuable. For many questions in condensed-matter physics, in biology, in chemistry, and in the study of modem synthetic materials, neutron scattering is the only technique that provides answers.

Unlike x-rays, neutrons "see" light and heavy elements equally well, interact with the magnetic moments of electrons, and detect atomic vibrations as well as average atomic positions. These properties make neutrons a unique and extremely versatile probe of material structure and dynamics. A look at the table of contents will convince you—measurements of the structure of high-temperature superconductors, of the Bose condensate in liquid helium, of the change in shape of the protein calmodulin as it mediates involuntary muscle contraction, of the catalytic effect of metal atoms on the dissociation of molecular hydrogen, of the fractal structures of precursors to today's materials, of the layered structures of polymer films, of residual strains in metals and ceramics—and these diverse topics are a sampling of the work at only one facility. High-intensity neutron beams, high-resolution spectrometers, and computerized data acquisition and analysis systems are opening a wide range of phenomena to more precise study, especially in materials technology and other fields tied to economic growth.

Although the promise of neutron scattering is growing, its future in the United States is uncertain. At present, all but two neutron-scattering centers are located at aging nuclear reactors whose budgets are escalating every year to pay, not for research and upgrades, but for enhanced safety. Moreover, access to those facilities has not been easy in the past. Even now, few university scientists use the technique—many fewer than in Europe. But a change is in the works. In the early eighties a user program began at the Intense Pulsed Neutron Source at Argonne National Laboratory, and in 1987 the Los Alamos Neutron Scattering Center (LANSCE) officially opened its doors to users from academia and industry. (Both facilities house accelerator sources, which produce pulsed neutron beams by a nuclear reaction called spallation.) A cold-neutron research center is being built at the National Institute of Standards and Technology, and a spectrometer upgrade at the Brookhaven High-Flux Reactor is planned. The response to these initiatives has been gratifying. For example, more than 140 outside users mounted experiments at LANSCE last year—and this year's participation is even greater. A technique that was practiced by a small community of professionals is now accessible to "amateurs" from industry and academia.

Experience at the Los Alamos facility is proving that data obtained at pulsed neutron sources can compete with data obtained at reactors. Five years ago when several new spallation sources were just coming on line, conventional wisdom said that small-angle neutron scattering, which requires intense beams to measure the sizes and shapes of biological macromolecules and colloidal particles, could be done well only at reactors. Today small-angle experiments work as well at LANSCE as at the best reactor sources in the world, except for the very smallest angles. Powder-diffraction experiments here are also highly effective; for example, polycrystalline samples weighing less than 50 milligrams have yielded excellent data. And Los Alamos researchers are leading the way in using spallation sources for reflectometry, one of the newest applications of neutron scattering. These successes reflect the high neutron flux available here as well as the efficient utilization of that flux through innovative spectrometer design. LANSCE and other pulsed sources are demonstrating that they can more than fulfill their original promise.

With all its successes the Los Alamos source is not without problems. Beam availability during 1990 has so far been less than last year because of budget cuts, investment in environmental and safety precautions, and some accelerator problems. Also, though LANSCE generates a higher peak flux than any other spallation source, it has yet to achieve the design value. Nevertheless this year's users report they are getting better data in less time than they could elsewhere.

What of the future? Since neutron scattering is a signal-limited technique, progress depends on building higher-intensity neutron sources. The U.S. neutron-scattering community plans to build a state-of-the-art research reactor, the Advanced Neutron Source, which will deliver five times greater neutron fluxes than today's most powerful research reactors. The new reactor, still in the design stage, should begin operation around the turn of the century. Construction will cost about one billion dollars, and increasingly stringent safety regulations will make it very costly to run. The decision to build the advanced reactor was made several years ago, before spallation sources had proven their worth. We asked Roger Pynn, the director of LANSCE, whether in light of recent progress he thought the next-generation facility ought to be a spallation source. His answer: "If societal concerns should make it impractical to build and operate a research reactor, then an advanced spallation source could meet the needs of the community without raising as many safety and environmental issues, But, for a balanced program, the country needs sources of both types." Whatever happens in the long run, it is clear from the presentations in this issue that neutron scattering is a fertile and expanding field and that LANSCE is providing inspiration for the future in the areas of technical innovation, opportunities for young people, outreach to the larger scientific community, and tangible scientific results.

The editors thank all the authors and the numerous other scientists who contributed their thought and energy to the contents of this volume. It was a pleasure for us to learn about the technically difficult but thoroughly absorbing world of neutron scattering.

Necia Grant Cooper