# Neutron Scattering Facilities

## Portfolio Description

This activity supports the operation of two neutron scattering facilities: the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL), which is a high flux research reactor; and the Spallation Neutron Source (SNS) at ORNL, which is the most powerful pulsed spallation neutron source in the world.

## Scientific Challenges

As new areas of science open up that are impacted by neutron scattering research, new instrumentation capabilities must be developed at the neutron scattering facilities and existing instrumentation must undergo a continual upgrade and refinement process to provide optimal capabilities for the user program and to enable world-class scientific research. Many of the current and future developments focus on increased effective intensity using new detector technology and focusing optics, increased resolution using long-wavelength neutron beams, and new sample environment capabilities.

## Projected Evolution

Neutron scattering will continue to play a central role in the growth of BES programmatic science. The set of instruments associated with these facilities provides unique scientific and technical capabilities that serve the needs of the scientific community. These facilities necessarily must be kept in an optimal operational condition with increasing availability of user time in order to maintain and increase the tremendous scientific achievements they have facilitated.

## Significant Accomplishments

Since the late 1940s, BES and its predecessors have been the major supporter of neutron science in the United States, from the earliest work of Clifford Shull and E. O. Wollan at ORNL's Graphite Reactor in the 1940s to the Nobel Prize in Physics shared by Clifford Shull and Bertram Brockhouse in 1994 for their work on neutron scattering. DOE has developed research reactors and spallation sources as high-flux neutron sources for neutron scattering research, including diffraction, inelastic scattering (spectroscopy), reflectivity, and imaging, and has helped pioneer virtually all the instruments and techniques used at these facilities world-wide. Because of the neutral charge and magnetic moment of the neutron, neutrons penetrate most materials with minimum absorption and, via their scattering from both the nuclei and the magnetic electrons, three-dimensional atomic and magnetic structures can be obtained. In addition, thermal neutrons have energies comparable to phonon and magnon excitations in solids, and thus can provide dynamic information via inelastic scattering. Neutrons possess other unique properties including sensitivity to light elements, which is invaluable to polymer, biological, and pharmaceutical research.

Neutron scattering studies have been crucial to a detailed understanding of many materials and properties including:

- The structure and dynamics of new classes of high-temperature superconductors,
- The structure of proteins utilizing the sensitivity of the technique to light elements in concert with light source data,
- The study of interfacial effects in magnetic thin films and superlattices using neutron reflectivity,
- The determination of complex polymer structures,

- Examination of porous materials including oil-bearing shales, and
- Non-destructive property measurements of automotive gears, brake disks, airplane wings, engines, and turbine blades utilizing the high penetrating power of neutrons for industrial applications.

**Unique Aspects**

The DOE neutron scattering facilities are the most advanced facilities of their kind in the world. Together, they serve over 1,300 users annually from academia, Department of Energy (DOE) national laboratories, and industry. These neutron scattering sources represent the largest collection of such facilities operated by a single organization. Conception, design, construction, and operation of these facilities are among the core competencies of the BES program.

**Mission Relevance**

These facilities were born from the most fundamental of needs, i.e., the need to characterize materials at the atomic and molecular level. In order to understand, predict, and ultimately control materials properties, it is necessary to determine the atomic constituents of materials, the positions of atoms in materials, and how the materials behave under the influence of external perturbations such as temperature, pressure, magnetic or electric field, and chemical change. A large number of experimental and theoretical tools are used to achieve these ends. In the last two decades, the experimental demands have motivated the development of large-scale powerful user facilities that are too complex and expensive to develop, construct, and operate by individual institutions and/or companies. Such highly sophisticated tools are by their nature centralized and staffed with specialists who provide expertise to the user community to optimize the scientific benefit of the facility. The development, construction, and operation of these facilities are one of the most important missions and core competencies of BES. The scientific accomplishments of these facilities are reflected in the large number of publications appearing annually in the most important scientific journals.

**Relationship to Other Programs**

- This activity has very strong interactions with many areas of BES programmatic research. This includes research in condensed matter and materials physics, chemistry, soft matter materials, geosciences, high-pressure science, environmental sciences, engineering, biosciences, and many other disciplines.
- Interaction also exists with other parts of the Office of Science, notably the Office of Biological and Environmental Research and the Office of Nuclear Physics, and with other areas of DOE, notably the National Nuclear Security Administration and the Office of Energy Efficiency and Renewable Energy.
- There are frequent contacts with other federal agencies in order to better coordinate efforts in optimizing beamlines and instruments. This also includes national and international user facilities such as the National Institute of Standards and Technology (NIST) Center for Neutron Research, Institut Laue-Langevin (ILL) in France, ISIS in the United Kingdom, Japan Proton Accelerator Research Complex (J-PARC) in Japan, and the future European Spallation Source (ESS) in Sweden. The objectives are to share experiences and to make optimal use of present facilities.
- In addition to scattering research, HFIR has ongoing programs for the production of important medical and industrial isotopes and for studying the effects of neutron irradiation on nuclear materials for fission and fusion reactors