Serving the Scientific and Technological Communities

The role of the NCNR as a national user facility has expanded significantly over the past few years, as the last of the instruments envisioned in the original cold neutron project has become operational. The Disk-Chopper Spectrometer, the Filter-Analyzer Neutron Spectrometer, the High Flux Backscattering Spectrometer, and the Neutron Spin-Echo spectrometer now permit U.S. scientists to carry out neutron spectroscopy with greatly improved resolution and sensitivity. The thermal perfect-crystal small angle neutron scattering instrument (USANS) has expanded the length scale available by this technique to 10^4 nm. User experiments show a steadily increasing diversification in subject area and technique, enabled by the new instruments. We anticipate that the trend will continue over the next few proposal cycles.

User participation over the past 15 years shows continuing growth (see Fig. 1). The NCNR currently accommodates more than half of all neutron users in the U.S. While the Spallation Neutron Source is being built at Oak Ridge, the NCNR continues to be the nation's premier facility for providing neutrons to the U.S. research community.

The NCNR User Program

Researchers may obtain use of NCNR neutron beam instruments in several ways, the most direct being through the formal proposal system. Approximately twice a year, a Call for Proposals is issued. After a thorough review process by external referees and by the NCNR Program Advisory Committee (PAC), approved proposals are allocated beam time. The PAC is a panel of distinguished scientists with expertise across a broad range of neutron methods and scientific disciplines. It is the body primarily responsible for proposal review and recommending user policies for the NCNR, working closely with the Center's Director and staff. Its current membership includes Sanat Kumar (Penn State University, chair), Robert Briber (University of Maryland), Michael Crawford (DuPont), Dieter Schneider (Brookhaven National Laboratory), Kenneth Herwig (Oak Ridge National Laboratory), Yumi Ijiri (Oberlin College), Michael Kent (Sandia National Laboratories, John Tranquada (Brookhaven National Laboratory), and Andrew Allen (NIST).

At the recent PAC meeting in January 2001, the PAC considered 121 proposals for SANS and reflectometry, in addition to 49 for inelastic neutron scattering. Although we expect that both categories will see increased user demand in future proposal rounds, the latter area is likely to see more growth, since the new inelastic scattering spectrometers have added capabilities previously unavailable at U.S. neutron facilities.

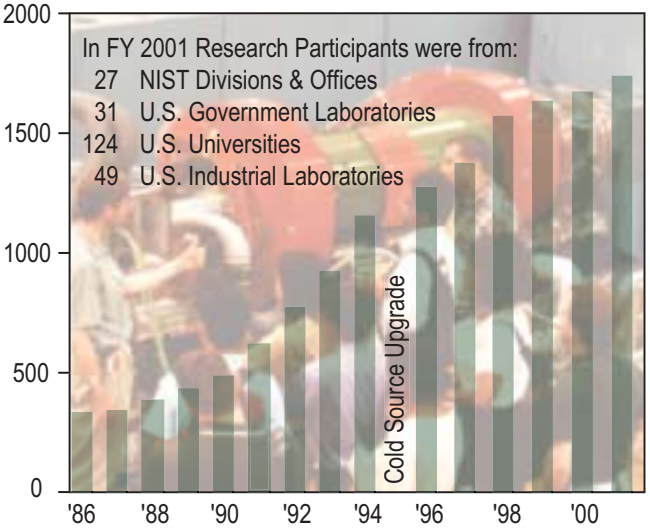

FIGURE 1. Research Participants at the NCNR.

The Center for High Resolution Neutron Scattering

The National Science Foundation (NSF) through the Center supports several NCNR instruments for High Resolution Neutron Scattering (CHRNS), a very important component of the user program. Until the present, CHRNS instruments included a 30 m SANS machine, the SPINS triple-axis spectrometer, and USANS. Approximately 40 % of the instrument time allocated by the PAC went to experiments carried out on CHRNS instruments. During the past year, the NSF approved a proposal to provide support for a substantial enlargement of CHRNS, enabling us to offer more beam time to users on the three new high-resolution inelastic scattering instruments. In the near future, another SANS diffractometer, the 8 m machine on neutron guide NG-1, which is presently used primarily for NIST programmatic research, will be upgraded to a more powerful 9 m

instrument with a new detector, and made available to users through CHRNS. The expanded suite of CHRNS instruments will provide enhanced technical support and accessibility to the user community.

Summer School on Methods and Applications of Neutron Spectroscopy

The NCNR's seventh annual Summer School on neutron scattering, held from June 18–22, 2001, focused on high-resolution neutron spectroscopy. Most of the 32 participants were graduate and postdoctoral students; we also had an undergraduate student and a professor.

In a radical departure from the format of previous NCNR summer schools, plenary lectures were presented on the first morning only. After lunch the students were divided into four groups of eight, and each group performed an experiment using a different instrument (in one case a pair of instruments). Students learned the scientific motivation for the experiment, how the instrument works, and how to set up measurements. The instruments collected data overnight and on the following morning the data were analyzed. After lunch on each of the second, third and fourth days the groups rotated to new experiments. After lunch on the final day, eight of the students gave short presentations describing an experiment.

Students used the following instruments: the Spin Polarized Inelastic Neutron Spectrometer, the Disk Chopper Spectrometer, the High-Flux Backscattering Spectrometer, the Neutron Spin Echo spectrometer, and the Filter Analyzer Neutron Spectrometer. Together these instruments probe motions in materials over six decades in time (from approximately 10^{-7} s to 10^{-13} s) and two orders of magnitude in distance (0.1 nm to 10 nm). Test samples included a geometrically frustrated antiferromagnet, a transition metal compound with organic ligands, a "symmetric top" molecule, and a system of spherical micelles. The experiments illustrated coherent scattering, incoherent scattering, magnetic scattering, and tunneling. In evaluating the school more than 80 % of the participants described it as "excellent," and generally high ratings were received in all areas. The lectures and experiment handouts have been placed on the Web (www.ncnr.nist.gov/programs/spectroscopy/SS01/SS01_materials.html.) A short report about the summer school will appear in "Neutron News." As in the past, the summer school was jointly sponsored with the National Science Foundation, which provided financial assistance to many of the university participants.

Photography by L. A. Shuman

FIGURE 2. Seventh annual Summer School on Neutron Scattering participants analyze results with NCNR's Seung-Hun Lee (bottom left).

Collaborations

Direct collaborations on specific experiments remain a common way for users to pursue their ideas using NCNR facilities, accounting for approximately half of the number of instrument-days. The thermal-neutron triple-axis spectrometers are mainly scheduled in this way. Most of the time reserved for NIST on these and all other NCNR instruments is devoted to experiments that are collaborations with non-NIST users. Collaborative research involving external users and NIST scientists often produces results that could be not obtained otherwise.

Another mode of access to the NCNR is through Participating Research Teams (PRTs). In this case, groups of researchers from various institutions join forces to build and operate an instrument. Typically, 50 % to 75 % of the time on the instrument is then reserved for the PRT, and the remaining time is allocated to general user proposals. For example, a PRT involving ExxonMobil, the University of Minnesota, and NIST cooperates on the NG-7 30 m SANS instrument. Similar arrangements involving other PRTs

apply for the horizontal-sample reflectometer, the high-resolution powder diffractometer, the filter-analyzer spectrometer, and the neutron spin-echo spectrometer.

Independent Programs

There are a number of programs of long standing located at the NCNR that involve other parts of NIST, universities, industrial laboratories, or other government agencies.

The **Polymers Division** of the Materials Science and Engineering Laboratory has two major program elements at the NCNR. In the first, the purpose is to help the U.S. microelectronics industry in addressing their most pressing materials measurement and standards issues. In today's integrated circuits and packages the feature size on a chip is ever shrinking, approaching 250 nm, while the size of a polymer molecule is typically 5 nm to 10 nm. As feature size shrinks, the structure and properties of interfaces play an increasingly important role in controlling the properties of the polymer layers used in interconnects and packages. NIST scientists use both neutron reflectivity and other neutron scattering methods to characterize polymer/metal interfaces with regard to local chain mobility, moisture absorption, glass transition temperature and crystalline structure.

In the second program element, the objective is to understand underlying principles of phase behavior and phase separation kinetics of polymer blends, both in the bulk and on surfaces, in order to help control morphology and structure during processing. SANS and reflectivity measurements in equilibrium, in transient conditions, and under external fields, provide essential information for general understanding as well as for specific application of polymer blend/alloy systems. Customers include material producers and users, ranging from chemical, rubber, tire, and automotive companies, to small molding and compounding companies. The focus of research on polymeric materials includes commodity, engineering and specialty plastic resins, elastomers, coatings, adhesives, films, foams, and fibers.

The **ExxonMobil Research and Engineering Company** is a member of the Participating Research Team (PRT) that operates, maintains, and conducts research at the NG-7 30 m SANS instrument and the recently commissioned NG-5 Neutron Spin Echo Spectrometer. The mission is to use those instruments, as well as other neutron scattering techniques, in activities that complement research at ExxonMobil's main laboratories as well as at laboratories of its affiliates around the world. The aim of these activities is to deepen understanding of the nature of ExxonMobil's products and processes, so as to improve customer service and to improve the return on shareholders' investment. Accordingly, and taking full advantage of the unique properties of neutrons, most of the experiments use SANS or other neutron techniques to study the structure and dynamics of hydrocarbon materials, especially in the fields of polymers, complex fluids, and petroleum mixtures. ExxonMobil regards its participation in the NCNR and collaborations with NIST and other PRT members not only as an excellent investment for the company, but also as a good way to contribute to the scientific health of the Nation.

The **Nuclear Methods Group** (Analytical Chemistry Division, Chemical Science and Technology Laboratory) has as its principal goals the development and application of nuclear analytical techniques for the determination of elemental compositions with greater accuracy, higher sensitivity and better selectivity. A high level of competence has been developed in both instrumental and radiochemical neutron activation analysis (INAA and RNAA). In addition, the group has pioneered the use of cold neutron beams as analytical probes with both prompt gamma activation analysis (PGAA) and neutron depth profiling (NDP). PGAA measures the total amount of a particular analyte present throughout a sample by the analysis of the prompt gamma rays emitted during neutron capture. NDP, on the other hand, determines concentrations of several important elements (isotopes) as a function of depth within the first few micrometers of a surface by energy analysis of the prompt charged particles emitted during neutron bombardment. These techniques (INAA, RNAA, PGAA, and NDP) provide a powerful combination of complementary tools to address a wide variety of analytical problems of great importance in science and technology, and are used to help certify a large number of NIST Standard Reference Materials.

During the past several years, a large part of the Group's efforts has been directed toward the exploitation of the analytical applications of the guided cold-neutron beams available at the NIST Center for Neutron Research. The Group's involvement has been to design and construct state-of-the-art cold neutron instruments for both PGAA and NDP and provide facilities and measurements for outside users, while retaining and utilizing our existing expertise in INAA and RNAA.

The **Center for Food Safety and Applied Nutrition**, U.S. Food and Drug Administration (FDA), directs and maintains a neutron activation analysis (NAA) facility at the NCNR. This facility provides agency-wide analytical support for special investigations and applications research, complementing other analytical techniques used at FDA with instrumental, neutron-capture prompt-gamma, and radiochemical NAA procedures, radioisotope x-ray fluorescence spectrometry (RXRFS), and low-level gamma-ray detection. This combination of analytical techniques enables diverse multi-element and radiological information to be obtained for foods and related materials. The NAA facility supports agency quality assurance programs by developing in-house reference materials, by characterizing food-related reference materials with NIST and other agencies, and by verifying analyses for FDA's Total Diet Study Program. Other studies include the development of RXRFS methods for screening foodware for the presence of Pb, Cd and other potentially toxic elements, use of instrumental NAA to investigate bromate residues in bread products, and use of prompt-gamma NAA to investigate boron nutrition and its relation to bone strength.

The **Neutron Interactions and Dosimetry Group** (Physics Laboratory) provides measurement services, standards, and fundamental research in support of NIST's mission as it relates to neutron technology and neutron physics. The national and industrial interests served include scientific instrument calibration, electric power production, radiation protection, defense nuclear energy systems, radiation therapy, neutron radiography, and magnetic resonance imaging.

The Group's activities may be represented as three major activities. The first is Fundamental Neutron Physics including magnetic trapping of ultracold neutrons, operation of a neutron interferometry and optics facility, development of neutron spin filters based on laser polarization of ^{3}He, measurement of the beta decay lifetime of the neutron, and investigations of other coupling constants and symmetries of the weak interaction. This project involves a large number of collaborators from universities and national laboratories.

The second is Standard Neutron Fields and Applications utilizing both thermal and fast neutron fields for materials dosimetry in nuclear reactor applications and for personnel dosimetry in radiation protection. These neutron fields include thermal neutron beams, "white" and monochromatic cold neutron beams, a thermal-neutron-induced ^{235}U fission neutron field, and ^{252}Cf fission neutron fields, both moderated and unmoderated. The third is Neutron Cross Section Standards including experimental advancement of the accuracy of neutron cross section standards, as well as evaluation, compilation and dissemination of these standards.

Several universities have also established long term programs at the NCNR. The **University of Maryland** is heavily involved in the use of the NCNR, and maintains several researchers at the facility. **Johns Hopkins University** participates in research programs in solid-state physics and in instrument development at the NCNR. The **University of Pennsylvania** is working to help develop biological applications of neutron scattering. It is also participating in the second stage construction of the filter analyzer neutron spectrometer, along with the **University of California at Santa Barbara, DuPont, Hughes,** and **Allied Signal.** The **University of Minnesota** participates in two PRTs, the NG-7 30 m SANS and the NG-7 reflectometer. The **University of Massachusetts** also participates in the latter PRT.