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Author(s): Joyce. A. Goldstone

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THE MANUEL LUJAN JR. NEUTRON SCATTERING CENTER (LANSCE)

J. A. GOLDSTONE
Manuel Lujan Jr. Neutron Scattering Center
Los Alamos National Laboratory, Los Alamos, NM 87545

INTRODUCTION

High in the northcentral mountains of Los Alamos, New Mexico, is the Manuel Lujan Jr. Neutron Scattering Center (LANSCE), a pulsed-spallation neutron source located at Los Alamos National Laboratory. At LANSCE, neutrons are produced by spallation when a pulsed 800-MeV proton beam impinges on a tungsten target. The proton pulses are provided by a linear accelerator and an associated Proton Storage Ring (PSR), which alters the intensity, time structure, and repetition rate of the pulses (Figure 1).

In October 1986, LANSCE was designated a national user facility, with a formal user program initiated in 1988. In July 1989, the LANSCE facility was dedicated as the Manuel Lujan Jr. Neutron Scattering Center in honor of the long-term Congressman from New Mexico. At present, the PSR operates with a proton pulse width of 0.27 μs at 20 Hz and 80 μA, attaining the highest peak neutron flux in the world and close to its goal of 100 μA, which would yield a peak thermal neutron flux of 10^{16} n/cm^{-2}s^{-1}.

TARGET/MODERATOR/REFLECTOR SHIELD (TMRS)

The LANSCE high-performance target/moderator/reflector shield (TMRS) system, which is inside a bulk shield in Experiment Room #1 (ER-1), has an integrated design that optimizes the neutron flux delivered to the instruments. The TMRS comprises a 10-cm tung-

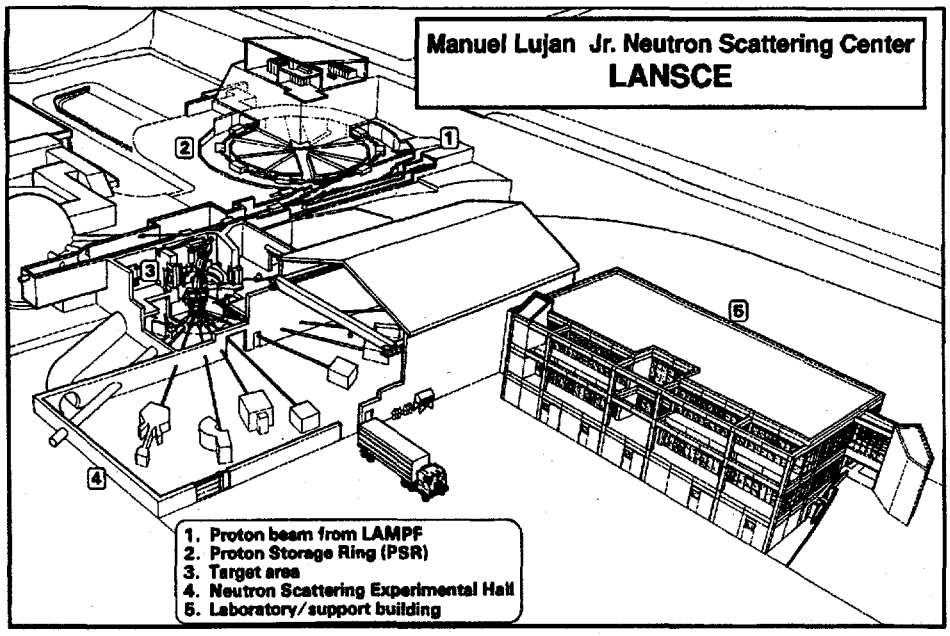

Figure 1. An artist's conception of the proton beam from LAMPF feeding into the PSR, which then sends it to the LANSCE neutron production target. The support building is shown to the right.

sten cylinder split into two unequal segments separated by a flux-trap void (Figure 2). Between the target elements are flux-trap moderators, one liquid hydrogen and three cooled water. These moderators provide an efficient and clean neutron source because they are fed from both sections of the target and only a small fraction of neutrons escaping along the beam lines avoids moderation. LANSCE has a total of 16 possible flight paths, 10 of which are instrumented. Two of the water moderators are designed for high intensity and provide neutrons to flight paths 3 through 8 in ER-1 (Figure 3), while the third one is designed for high resolution and provides neutrons to flight paths 1, 2, and 16 in Experiment Room #2 (ER-2). The liquid hydrogen moderator is maintained at approximately 20 K and services flight paths 9 through 11 in ER-2.

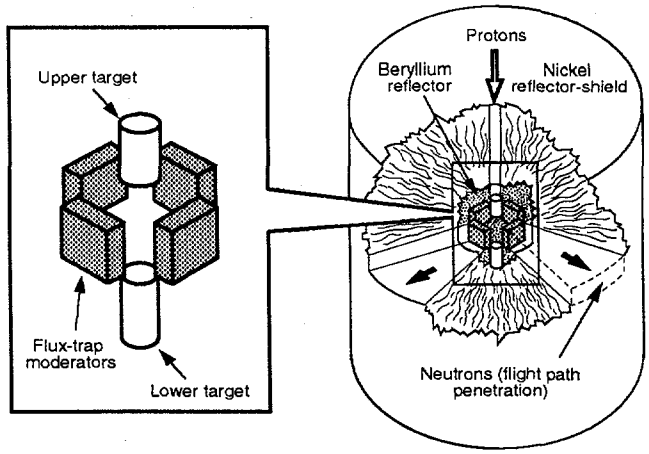

Figure 2. The LANSCE target-moderator reflector shield showing the split target and flux-trap moderators.

The neutron bursts from these moderators have nominal pulse lengths that vary from between 2 and 4 μs at 1 eV to between 20 and 100 μs at 1 meV, depending on the moderator characteristics (Figure 4). To enhance useful neutron production, a double reflector system surrounds the target: a light reflector of beryllium and a heavy reflector of nickel that augments the light reflector system and provides a high-energy neutron shield. The energy spectrum of emerging neutrons depends on the temperature, composition, and effective thickness of the moderator (Figure 4). With the addition of flight paths 12 to 15 (Figure 3), we plan an extensive upgrade of the TMRS to add 2 moderators to service the new flight paths located at a different elevation than the original 12.

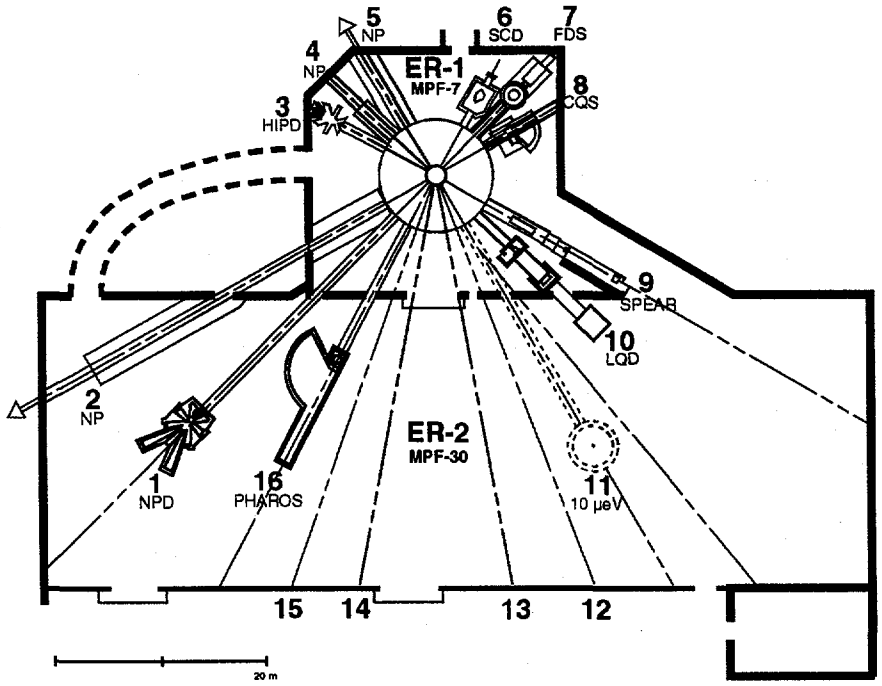

Figure 3. Layout of the instrument suite in the two adjacent LANSCE experiment rooms. NPD, HIPD, SCD, LQD, FDS, SPEAR, and PHAROS (Phase I) are established instruments and are part of the LANSCE user program. PHAROS (Phase II), the Protein Crystallography Diffractometer, and the 10-μeV Spectrometer are under construction. The flight paths for the beams are numbered from 1 to 16.

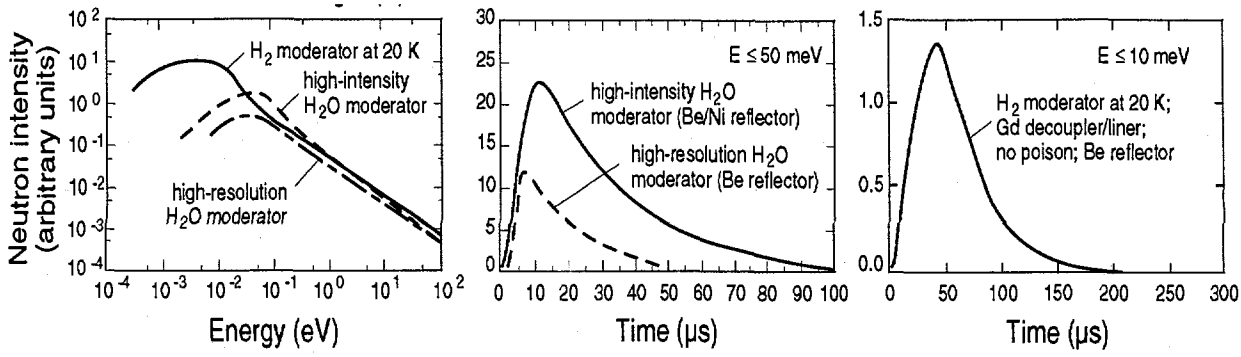

Figure 4. Examples of calculated low-energy neutron spectra and pulse widths from the LANSCE moderators.

LANSCE INSTRUMENTS AND ASSOCIATED RESOURCES

LANSCE has more modern spectrometers than any other DOE neutron scattering center. Of the 10 operational instruments, 7 are for condensed-matter research and 3 are for nuclear physics. Two more spectrometers for condensed-matter research are planned. Table 1 describes the characteristics of each instrument for condensed-matter research, and the following text highlights these characteristics.

The two neutron powder diffractometers, the *High-Intensity Powder Diffractometer* (HIPD) and the *Neutron Powder Diffractometer* (NPD), serve complementary purposes—high intensity and high resolution, respectively. Both powder diffractometers accommodate low-temperature (10 K) to high-temperature (1000 K) ancillary equipment.

The HIPD is intended primarily for crystallographic and magnetic diffraction studies of samples that are very small or located in extreme environments of temperature or pressure and for studies of liquids and amorphous solids. It offers exceptionally high data rates with nearly three decades of range in momentum transfer or d-spacing. High-quality measurements can be made on samples weighing 100 mg or less. This instrument is also appropriate for experiments that require time-resolved diffraction measurements. A pressure cell capable of achieving a pressure of 30 GPa is also available for use in HIPD; this pressure represents the highest attainable for neutron diffraction experiments within the United States.

The NPD design allows for studies of complex structures, internal strain measurements, and studies in which precise data are needed to extract electron distributions for x-ray/neutron comparisons. The d-spacing resolution ($\Delta d/d = 1 \times 10^{-3}$) for NPD is the highest resolution of any neutron powder diffractometer in the United States. A large sample chamber accommodates sample environments of many types, such as a liquid helium cryostat, a vacuum furnace, and a closed-cycle helium refrigerator. Over the past few years, we have developed a strong program with industrial users to measure internal, both applied and residual, strains. In support of this work on the NPD, we built a beam collimation and sample manipulation system mainly for residual stress measurements and a stress rig that provides uniaxial compression or tension up to ±1000 MPa and at the same time is capable of heating components to approximately 1200 K in vacuum.

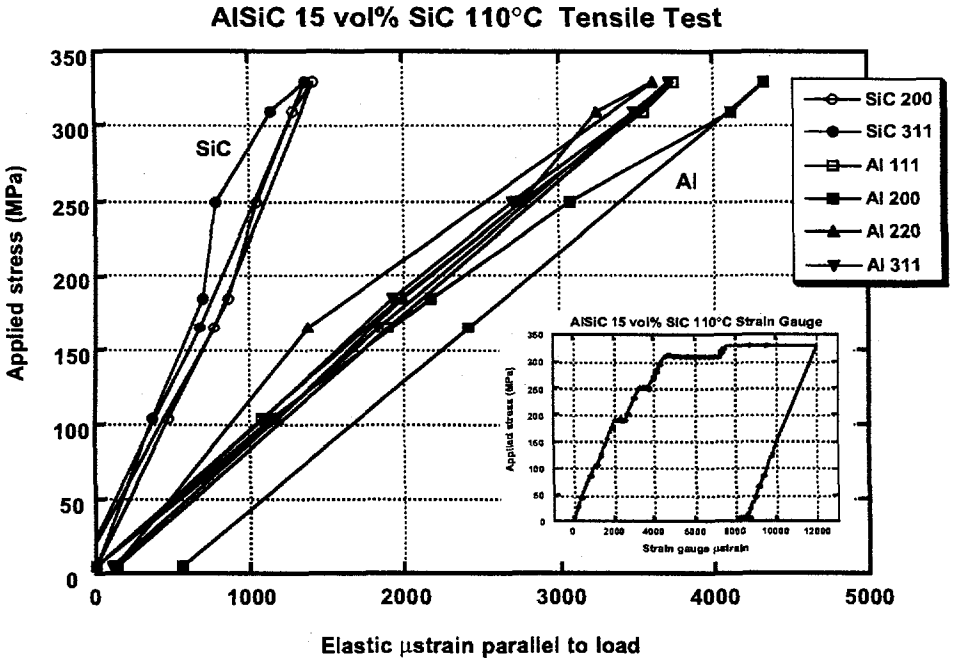

Figure 5. Strain relative to initial material state in a uniaxial tension test of an Al 6091 (T6) 15 vol% SiC particulate MMC. The inset shows the macroscopic strain recorded by a strain gage.

Simultaneous high-temperature and applied-load measurements are valuable for characterizing composites that may operate in temperature regimes above ambient. For example, many of the automobile applications of Al/SiC such as connecting rods, brake rotors, or drive shafts are expected to experience sustained or periodic temperature fluctuations. Measuring phase strains while applying static loads provides insight into the mechanisms and onset of relaxation and load transfer. Figure 5 represents measured strains in a uniaxial tension test on an Al 15 vol% SiC material. Diffraction methods measure elastic strains; thus, nonlinearity in plots of applied loading versus elastic strain in individual phases of a composite indicates load transfer. Although nonlinearity does not clearly identify the active mechanisms, it does offer a test for material models. In addition to measuring all the lattice reflections in both phases, the ability to simultaneously measure parallel and perpendicular strain is a strong reason for performing these measurements at a pulsed source; simultaneous parallel and perpendicular strain measurements cannot easily be achieved at a monochromatic source.

The *Single Crystal Diffractometer* (SCD) can be used to determine the crystal structures of any material that crystallizes with lattice spacings less than 20 Å, such as metals, intermetallics, molecular-hydrogen complexes, and minerals. The SCD has been used to study the structure of organometallic molecules that show a unique binding of H_2 molecules; crystal structure changes at solid-solid phase transitions; twinned or multiple crystals; the texture analysis of polycrystalline materials that have been subjected to extreme geological environments; and crystal structures of materials under pressures of 1 to 2 GPa. The instrument operates by scattering neutrons from the crystalline sample onto an area detector (position-sensitive; ^{3}He gas-filled counter), and the wavelengths of the neutrons are determined by their time of flight (TOF) from the source to the detector. To collect all the required data for a particular crystal, the orientation of the sample can be changed by rotations about ϕ and ω. The instrument measures a large volume of reciprocal space at one time and, therefore, can be used for studies of unknown incommensurate structures, diffuse scattering, and so forth. The SCD accommodates nonambient sample environments.

Data analysis for all three diffractometers uses a versatile crystallographic analysis code, the General Structure Analysis System (GSAS), developed at LANSCE. GSAS is especially useful for simultaneously refining x-ray and neutron diffraction data. This technique is a powerful tool for determining crystal structures because it combines the advantages of x-ray data, which precisely defines lattice parameters and the positions of "heavy" atoms, and neutron data, which determines light atom positions, site occupancies, and thermal parameters. GSAS also has the capability to refine the direction and magnitude of the moments in ordered magnetic structures; the ability to combine data sets allows simultaneous refinement of both chemical and magnetic structures. Recently, we combined both high- and low-resolution neutron TOF diffraction data taken on two different instruments (NPD and HIPD). We found that the magnetic ordering in some ternary uranium alloys is accompanied by a change in the atomic positions, which leads to a change in the crystallographic symmetry of the material. GSAS is very widely distributed within the international scientific community with approximately 400 users worldwide and is recognized as one of the premier crystallographic data analysis systems.

The *Low-Q Diffractometer* (LQD) is designed for studies of structures with dimensions in the range of 10 to 1000 Å. The LQD is useful in addressing problems of critical phenomena, colloid structure, biomolecular organization, phase separation, and phase morphology and molecular conformation in polymers. Experimenters have performed work on shear-induced orientation effects and on the structure of shear-induced complex fluid structure using the couette-geometry shear cell. LANSCE users have also done work on the morphology of pressure-induced phases in fluids using a pressure cell. This cell is capable of pressures up to 3 kbar over a temperature range between 253 K and 393 K. A significant feature of the LQD is that a broad range of Q is measured in a single experiment without any changes in instrument configuration. Because an intense source of long-wavelength ("cold") neutrons is required for LQD, a liquid hydrogen moderator is used to produce a neutron spectrum that peaks at about 2.4 Å and has a usable flux from 0.3 to 20 Å. A novel feature of the LQD is a gravity focuser that transmits only neutrons with trajectories that would hit the instrument beam stop if they were not scattered by a sample. This device is needed as long as wavelength neutrons, which fall significantly under the influence of gravity, would otherwise hit the detector below the beam stop and adversely effect the spectrometer's resolution. LQD is competitive with reactor-based small-angle instruments at moderate Q and is more suitable when a wide Q range is required.

The *Surface Profile Analysis Reflectometer* (SPEAR) is designed to study solid/solid, solid/liquid, solid/gas, and liquid/gas interfaces. SPEAR's moderated neutrons are collimated into two beams inclined downwards at angles of 1.5° and 1.0° to the horizontal that converge at a common sample position, which is 8.73 m from the moderator. A specially designed shutter allows the beams to be operated either independently or simultaneously. The vertical resolution of each beam ($\Delta\Theta/\Theta$) is ±5% for horizontal surfaces and the horizontal resolution ($\Delta\Theta$) is +0.25°. A t-zero chopper, which interrupts the beam during the initial flash of high-energy neutrons and gamma rays, significantly reduces the background that limits reflectivity measurements. A frame-overlap chopper, which defines the wavelength band (1 to 16 Å or 16 to 32 Å) to be used, suppresses frame-overlap background problems. Polarizing supermirrors and spin-flippers can be inserted into the beam line before and after the sample position when polarized neutrons and analysis of the polariza-

tion state of the beam scattered by a sample are required. The wavelengths of polarized neutrons vary from 2 to 7Å. Measurements of the four possible scattering cross-sections (++, —, +-, and -+) to reflectivities as small a few times 10^{-5} have been achieved from samples 6.5 cm^2 in size after 24 hours of exposure to the neutron beam. A goniometer at the sample position allows solid samples to be accurately tilted in order to change the angle of incidence of the beam relative to the reflecting surface. For samples that must be isolated from external sources of vibration, a vibration isolation system (Newport Corporation) supports the sample and actively dampens vibrations transmitted through the floor or air. Two detector systems are currently available: a single ^3He detector for low-reflectivity studies or a single linear position-sensitive detector with 2-mm resolution for studies of off-specular scattering.

Recently, using a novel Poiseuille cell with SPEAR, we have studied the effects of shear on an absorbed polymer due to flowing solvent. We have found that only under the conditions of high polymer concentration in a poor solvent is there a change in polymer conformation due to shear at rates of 500 sec^{-1} or less. This change corresponds to chain stretching that has an unusually long relaxation time constant.

By restricting the final neutron energy to the band-pass of cooled Be or BeO filters, the *Filter Difference Spectrometer* (FDS) can determine the energy transferred to the sample. FDS then effectively scans the incident neutron energy as a function of TOF. The instrumental response of the broad-band filters is removed from the data by either a hardware deconvolution (the Be-BeO filter difference) or a numerical deconvolution with a variable band-pass. In addition, a maximum entropy (MaxEnt) method may also be applied to reconstruct the scattering function. These data analysis methods provide an instrumental resolution of 1.5 to 2% of the energy transfer over most of the range of the spectrometer. Of particular interest is the very large solid angle of the detector in this instrument, which makes it very suitable for measurements requiring high sensitivity (for example, dilute systems and molecules on surfaces) . Because the energy transfer varies in a fixed way with momentum transfer, FDS is best used to observe excitations with little or no dispersion.

As part of our ongoing program to study the dynamics and geometries of extremely short hydrogen bonds, we have been able to identify the vibrational modes of the H-bond proton in quinolinic acid ($C_7H_3H_2NO_4$) using oriented single crystals. The system contains two hydrogen bonds, a weak N-H...O intermolecular H-bond and a very strong O···H···O intramolecular H-bond. The latter is highly asymmetric with OH distances of 1.163 and 1.238 Å. Because the orientation of the molecules in the crystal is such that the H-bond always points in the same direction, the H-bond vibrations can be obtained by inelastic neutron scattering (INS) studies of single crystals with the H-bond aligned either parallel or perpendicular to Q. INS vibrational spectra collected on FDS for three orientations of the crystals at a temperature of approximately 12 K are shown in Figure 6 in the form of the MaxEnt reconstruction. Together with our previous data from substituting deuterium for the H-bond protons, we can readily assign the H-bond vibrational modes as follows: the out-of-plane bending mode γ(OH) at 1029 cm^{-1} and the in-plane bending mode δ(OH) at 1570 cm^{-1}. The asymmetric stretch ν_{as}(OH) for this short H-bond may be located at very low frequencies (596 cm^{-1}). These assignments agree with those expected from correla-

tions of H-bond vibrational frequency versus geometry.

The chopper spectrometer, *PHAROS*, is available for low-angle studies, such as neutron Brillouin scattering and magnetic excitations. The instrument provides 0.5% incident energy resolution for incident energies between 50 meV and 2 eV. We completed Phase I of the spectrometer, which consists of an evacuated, shielded flight path for low-angle scattering: $1° < \phi < 10°$. In 1993, we performed our first successful experiments at room temperature and 100 K on the classic metallic glass $Mg_{70}Zn_{30}$, reaching lower momentum transfers than had ever been achieved before. We also performed test experiments on other systems: TiH_2, KHF_2, UO_2, and $TmBa_2Cu_3O_7$, observing the clear crystal-field levels in the latter system. The 20-m^3 vacuum vessel for the secondary flight path of Phase II was delivered 3 years ago. When this vessel is installed, the spectrometer will become a high-resolution, general-purpose chopper spectrometer with 10 m^2 of detectors covering scattering angles between -10° and 140°. PHAROS will then accommodate the full range of inelastic scattering experiments—phonon densities of states, magnetic excitations, momentum distributions, crystal-field levels, chemical spectroscopy, and measurements of $S(Q,\omega)$ in disordered systems. In addition, the low-angle detectors will be used at distances between 4 and 10 m, with scattering angles down to 0.65°, thus making it suitable for high-resolution inelastic studies at low Q.

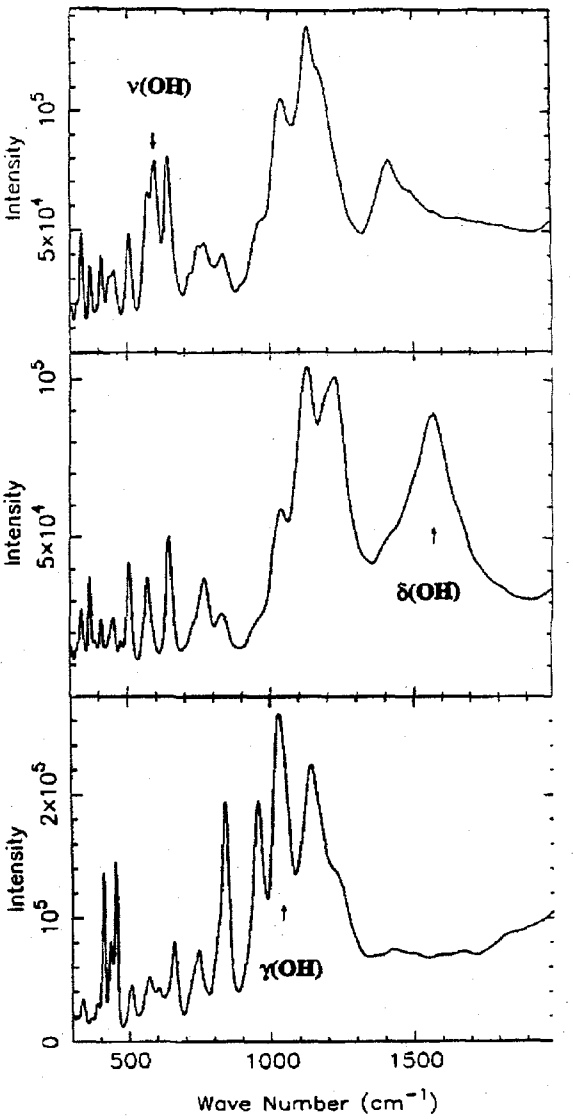

Figure 6. Oriented single crystal vibrational spectra obtained on FDS. The orientations of Q are (top to bottom): parallel to H-bond; perpendicular in-plane; and perpendicular out-of-plane (of the molecule).

A wide variety of labs with associated equipment are available to users at LANSCE for preparation and experimentation. These labs include 10,000 Class clean chemistry, x-ray, chemistry, materials, user, and surface physics. A machine shop and rooms for camera/drafting projects, cryogenics research, data analysis, and computer support are also available.

Future Spectrometers

The *Protein Crystallography Diffractometer* is designed to study protein crystals. These studies include the localization of enzymatically active hydrogen atoms and solvent mol-

ecules and ions. This diffractometer will employ the Super Laue technique that uses the time slicing sequence to select a wavelength band width wide enough to cover Bragg peaks but not wide enough to cause overlapping reflections. A large position sensitive detector and focusing optics will ensure optimal data collection with data collection times of weeks rather than the present months. An area detector will allow the analysis of diffuse scattering as well as the collection of the conventional Bragg peaks.

The *10-μeV Spectrometer* is a new TOF backscattering instrument for quasi-elastic and high-resolution inelastic spectroscopy. This spectrometer is designed for studies of diffusion and low-frequency dynamics. The incident neutron energy is measured by TOF through a long incident flight path of 30 m. The energy of the scattered neutrons (about 2 meV) is determined by backscattering from a large analyzer consisting of single crystals of mica or silicon. We will install the instrument on flight path 11, which is one of the three flight paths viewing the liquid-hydrogen moderator. The neutron beam will be brought out to the sample position with a straight 6×6-cm^2 ^{58}Ni guide ending in a supermirror-coated converging section, which focuses the beam to a 3×3-cm^2 area at the sample. To eliminate the background from the initial burst of high-energy neutrons and gamma rays, we will install a t-zero chopper. A second chopper will serve to define the energy-transfer range for the spectrometer. The combination of the moderator and the guide maximizes the neutron-flux incident on the sample in the energy region between 1 meV and 4 meV. Examples of future experiments are reorientational and tunneling motions in molecular crystals, motion of molecules on surfaces, and dynamics of simple biological systems.

FACILITY IMPROVEMENT PROJECT

At LANSCE, we are pursuing an ongoing facility development and improvement effort to ensure a healthy and productive facility. With reliability imperative to the successful outcome of an experiment at a neutron source, LANSCE has begun a $35 million project of facility improvements. The first phase of this project was funded by DoD in fiscal year (FY) 1994 at the $15 million level. We expect the remaining $20 million to complete the project in FY 1995. The goals of the project are as follows:

- A capability for routine and sustained operation of LANSCE for approximately 8 months per year by FY 1998;
- Beam availability of 85% or more by FY 1998;
- Less than 5% unscheduled beam down time from beam-off intervals longer than 8 hours;
- Personnel access to all experiment areas during beam delivery;
- Installation of a new neutron production target that can provide 16 neutron beams (instead of the 12 currently available);
- Improved cost-effectiveness of beam delivery through improved maintenance and deployment of modern technology;
- 100 μA of protons delivered to the neutron production target; and
- Reduced rates of beam loss on accelerator components and reduced radiation exposure to personnel.

USER PROGRAM AND FURTHER INFORMATION

In the past, LANSCE was funded by the DOE/Office of Basic Energy Sciences (OBES) as a national user facility for basic research in condensed-matter sciences. LANSCE issued a call for proposals, and two program advisory committees determined the acceptable proposals. The Internal Program Advisory Committee considered proposals for the programmatic effort at Los Alamos and the joint IPNS/LANSCE External Program Advisory Committee examined proposals from universities, industry, and national laboratories. While no funding is available from OBES in FY 1995, we are trying to obtain support from Energy Research for the national user program.

In FY 1995, LANSCE is funded by the DOE/Defense Programs for science-based stockpile stewardship (SBSS). Proposed experiments under the SBSS program will be reviewed by a panel of scientists and members of the defense community. Program priority will be evaluated in addition to scientific merit. The SBSS program recognizes the importance of basic, applied, and industrial research activities at LANSCE in addition to its program. Through an informal user program, researchers outside the SBSS program will continue to have access to the facility by collaborating with the instrument scientists. LANSCE is also a designated user facility at Los Alamos. User Facility Agreements negotiated with the University of California through the Los Alamos Industrial Partnership Office allow for both nonproprietary and proprietary research to be conducted at LANSCE.

Applications are invited from participating research teams (PRT), which wish to increase their access to the facility in exchange for a financial participation in the construction of a neutron instrument or ancillary equipment. A PRT that constructs an instrument will have sole use of a beam line during instrument construction and control of 70% of the beam time for a three-year period thereafter. The remaining beam time will be made available to general users through the program advisory committees. At the end of each three-year period, continuation of PRT status will be evaluated by LANSCE management with advice from the appropriate program advisory committee. Arrangements for PRT participation that does not involve construction of a complete instrument may be negotiated.

Requests for further information should be directed to the LANSCE Scientific Coordination and Liaison Office, LANSCE, MS H805, Los Alamos National Laboratory, Los Alamos, NM 87545, USA or user_program@lansce.lanl.gov. LANSCE information will also be available on World Wide Web. Available publications include progress/experiment reports, a user brochure, and a periodic newsletter. Proposal forms can also be obtained by contacting the Liaison Office. Specific information on the suitability of a particular instrument to an experiment is best obtained by directly contacting the appropriate instrument scientist at the address above or at the telephone number or e-mail address indicated in Table 1.

ACKNOWLEDGMENTS

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Table I. LANSCE neutron scattering instruments.

HIPD

Wavelength range	0.20–10.0 Å		
Beam width	0.3-1.0 cm, variable		
Beam height	0.3-5.0 cm, variable		
Q range	0.1–60 $Å^{-1}$		
d-spacing range (approximate) and resolution	± 14°	2.0–33.6 Å	3%
	± 40°	0.84–13.7Å	1.0%
	± 90°	0.40–6.65Å	0.5%
	± 153°	0.25–4.75 Å	0.3%
Moderator	Chilled water at 283 K		
Sample environment	13–300 K, closed-cycle refrigerator; 10 GPa high-pressure cell; vacuum furnace to 1000 K		
Sample size	0.005–4 cm^3		
Experiment duration	5 minutes to 1 day, depending on the sample size		
Instrument scientist	Robert Von Dreele		
Telephone	505-667-3630		
E-mail	vondreele@lanl.gov		

NPD

d-spacing range (approximate) and resolution	± 20° (future)	1.2–15.8 Å	0.91–1.5%
	± 45° (future)	0.65–7.6 Å	0.37–0.62%
	± 90°	0.35–4.2 Å	0.25%
	± 148°	0.25–3.1 Å	0.15%
Moderator	Chilled water at 283 K		
Sample environment	10–300 K, closed-cycle refrigerator; room-temperature-access liquid-He dewar, 1.2–300 K; compact stress rig with heating to 1200 K; vacuum furnace to 1000 K; manipulation and collimation system		
Maximum beam size at sample	5 cm in height × 1 cm in diameter		
Experiment duration	8 to 48 hours		
Instrument scientist	Joyce Goldstone		
Telephone	505-667-3629		
E-mail	jag@lanl.gov		

SCD

Wavelength range	0.5–5 Å
Beam diameter at sample	5.5 mm
Time resolution	~1%
Maximum lattice constant	~20 A
Detector	1 multiwire (25 cm × 25 cm) at 90°
Detector resolution	2.5 mm
Moderator	Chilled water at 283 K
Sample environment	10–300 K
Sample size	0.25–25 mm^3
Experiment duration	1/2 day to 3 days per octant
Instrument scientist	Robert Sheldon
Telephone	505-665-0144
E-mail	rsheldon@lanl.gov

LQD

Wavelength range	0.2–15 Å at 20 Hz
Scattering angle	6–60 mrad
Q range	0.003–0.5 $Å^{-1}$
Sample size	
Single-aperture collimator	10 mm × 13 mm
Multiple-aperture collimator	24 mm × 27 mm
Detector	1 multiwire, 59 cm in diameter
Moderator	Liquid hydrogen at 20 K
Sample environment	Air; vacuum; closed-cycle refrigerator; pressure cell (up to 3 kbar); shear cell; or user supplied
Experiment duration	20 minutes to 12 hours
Instrument scientist	Rex P. Hjelm, Jr.
Telephone	505-665-2372
E-mail	hjelm@lanl.gov

SPEAR

Moderator-to-detector distance	12.38 m	
Wavelength frames at 20 Hz	$1 < \lambda < 16$ Å and $16 < \lambda < 32$ Å	
Q range (horizontal sample)	$0.007 < Q < 0.3$ $Å^{-1}$	
Beam cross section at sample position	5 mm high × 50 mm wide (1° beam)	
(maximum sample acceptance)	7.5 mm high × 50 mm wide (1.5° beam)	
Moderator	Liquid hydrogen at 20 K	
Neutron flux at sample position for 1.5° beam at 60 μA	$1 < \lambda < 6$ Å	3.4×10^5 n/cm²/s
	$6 < \lambda < 16$ Å	3.3×10^5 n/cm²/s
	$16 < \lambda < 32$ Å	2×10^5 n/cm²/s (sample)
Detectors	Single ^{3}He tube or 2-mm resolution linear ^{3}He position-sensitive detector	
Minimum reflectivity	$<10^{-6}$	
Sample Environment	solid/liquid interface cells; UHV evaporator; UHV oven; Langmuir trough; electromagnet; controllable humidity oven; and solid/liquid interface Poiseuille shear cell	
Experiment duration	30 minutes to 6 hours	
Instrument scientists	Greg Smith	Mike Fitzsimmons
Telephone	505-665-2842	505-665-4045
E-mail	gsmith@lanl.gov	fitz@lanl.gov

FDS

Energy-transfer range	100–5000 cm^{-1} (13–620 meV) *The range can be extended to elastic scattering*
Q range	1.5–17 $Å^{-1}$
Energy-transfer resolution	1.5% –6.5%, depending on data treatment
Beam size at sample	10 cm high × 2.5 cm wide
Detectors	60 ^{3}He (1.3 cm in diameter)
Filter analyzers	5 Be, 5 BeO, each subtending a scattering angle of 18°; refrigerated
Moderator	Chilled water at 283 K
Sample environment	10–300 K, closed-cycle refrigerator; furnace temperature limit 673 K; Be-Cu pressure cell to 20 kbar

Sample size	0.5–100 g
Experiment duration	2 hours to 2 days
Instrument scientist	Juergen Eckert
Telephone	505-665-2374
E-mail	juergen@lanl.gov

PHAROS

Moderator-chopper distance	18 m
Chopper-sample distance	2 m
Moderator	Chilled water at 283 K
Chopper frequency	600 Hz
Chopper diameter	10 cm
Chopper slit spacing	1 mm or more
Sample size	up to 5 cm × 7.5 cm
Incident energy resolution	$\Delta Ei/Ei = 0.5\%$
Phase I	1 m^2 of detectors at 3.5 m; $1° < \phi < 10°$
Phase II	9 m^2 of detectors at 4 m; $-10° < \phi < 140°$; 1 m^2 of detectors in forward scattering position at 4–10 m
Instrument scientist	Robert Robinson
Telephone	505-667-3626
E-mail	rrobinson@lanl.gov

Protein Crystallography Diffractometer

Unit cell size	120 A
Xtal sample size	1–3 mm
Wavelength range	1–6 Å
Flight path length	7–12 m
Sample to detector length	700 mm
Focusing optics	toroid or double-mirror system
Beam size	6 mm
Area detector	1.5-mm resolution, 120° cylindrical, 200 mm in height
Counting rate	1 million/s/sectors
Wavelength shaping	T0 and T1 choppers
Instrument scientist	Benno Schoenborn
Telephone	505-665-4105 or 665-2033
E-mail	schoenborn@lanl.gov

10-μeV Spectrometer

Quasi-elastic scattering	
Elastic energy	2 meV
Q range	0.035 $Å^{-1}$ –2 $Å^{-1}$
Resolution	10 μeV
Inelastic scattering	
Energy transfer range	0–50 meV
Q range	1 $Å^{-1}$–7 $Å^{-1}$
Resolution	1% of incident energy
Moderator	Liquid hydrogen at 20 K
Sample size	3 cm × 3 cm
Instrument scientist	Torben Brun
Telephone	505-667-8841
E-mail	torben@lanl.gov