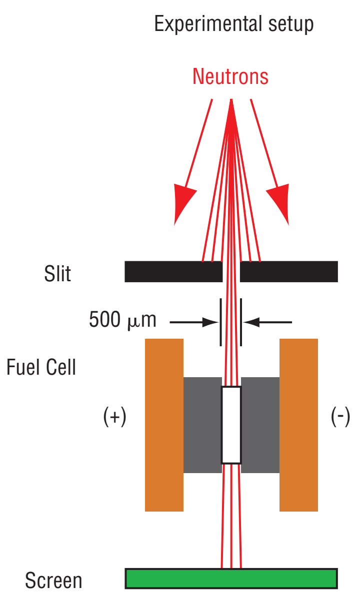
NEUTRON INTERFEROMETRY AND OPTICS FACILITY (NIOF)

A neutron interferometer (NI) is analogous to a classical Mach-Zehnder type optical interferometer and it is the only device that allows direct measurement of the phase of a neutron wave. The first neutron interferometer was operated over two decades ago in Vienna, Austria. In the USA, a very successful NI group has been operating at the University of Missouri-Columbia for the last two decades. Gravitationally induced quantum interference of neutron waves, 4π spinor rotation of neutrons in a magnetic field, and observation of the Aharonov-Casher effect (neutron analog of the Aharonov-Bohm effect for electrons) are among the seminal experiments that were carried out during this period. By measuring the phase shift of the neutrons that pass through a sample it is possible to accurately determine the neutron refractive index, *n*, of the material. The NI method of determination of *n* is, for the most part, independent of the microscopic details of the sample and perhaps the most accurate method that is available today. The refractive index, n, of many solids (e.g. uranium, chromium, vanadium) and gases (hydrogen, helium etc.) that are important to condensed matter and solid state physics have been measured and are being measured today.

The NIST Neutron Interferometry and Optics Facility (NIOF) is one of the premier facilities for neutron optics research. Located in the NCNR guide hall, it uses single crystal neutron interferometers (perhaps the best in the world today) with exceptional phase stability and fringe visibility that are crucial for the success of experiments in both fundamental and applied research. This exceptional performance is in part attributed to the state-of-the-art thermal, acoustical and vibration isolation system that has been successfully designed and built during the past few years.

During the past year the NIST NIOF has provided unique research opportunities for both applied and fundamental research and a diverse selection of experiments have been successfully carried out. Two Ph.D. dissertation researches were completed during this period and six articles have been written for publications. Research collaborations have been established with the University of Missouri-Columbia, the Hahn-Meitner-Institute, the University of Innsbruck and Exxon.

Special effort has been made to apply neutron-imaging techniques for industrial research. The NIOF is equipped with a high resolution CCD type 2-D position sensitive neutron detector to perform high-resolution neutron radiography of samples using a mono- or a poly-energetic energetic neutron beam. Early performance tests of a neutron tomography station have been successfully carried out. In addition to radiography, many other types of diffraction imaging experiments may be performed at the



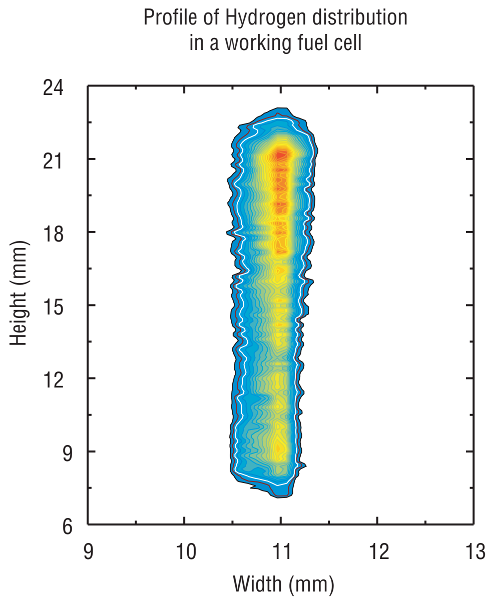


FIGURE 1. Experimental setup and neutron image of the water gradient inside a fuel cell.

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NIOF. Researchers from Exxon have exploited the convenience of this facility for both hydrogen fuel cell research and for studying hydrocarbons. For the first time the water gradient inside a working fuel cell has been successfully imaged (Fig.1). Results from these experiments have allowed verification of theoretical predictions of water transport mechanism in a working fuel cell [1]. Researchers from the University of Innsbruck, Austria, have also used this facility to study the diffraction of neutrons (λ = 0.235 nm) from macroscopic objects ~0.1 mm in size. Finally, a semi-finalist in the 57th Westinghouse Science Talent Search has demonstrated the Neutron Phase Contrast Imaging technique.

The first successful neutron interferometric measurements of scattering length density in polymer thin films (1<μm) have been carried out in collaboration with the NIST Polymers Division (Fig. 2). This technique is independent of calibration standards and complex mathematical modeling of the physical process of interaction. This measurement has opened the possibility of using NI as an important tool for establishing well defined densities of thin films that is critical in many analysis techniques in surface physics research [2].

An important experiment has been carried out to verify the recent predictions of quantum entanglement of the nuclear states in a mixture of fluids. The existence of such entanglement would suggest that the refractive index, '*n*', of a mixture cannot be calculated from only knowledge of the fractional abundances and indices of the constituent elements. If this suggestion were true, the implications would be profound for many neutron scattering techniques. A NIOF experiment measured scattering length density, Nb, for various mixtures of H_2O and D_2O. It had been proposed that for these mixtures a 5%-10% deviation from the traditional theory might occur because of quantum entanglement of H and D at room temperature. However, within the statistical fluctuation of the experimental data, which was of order 0.4%, no deviation from traditional theory has been observed [3].

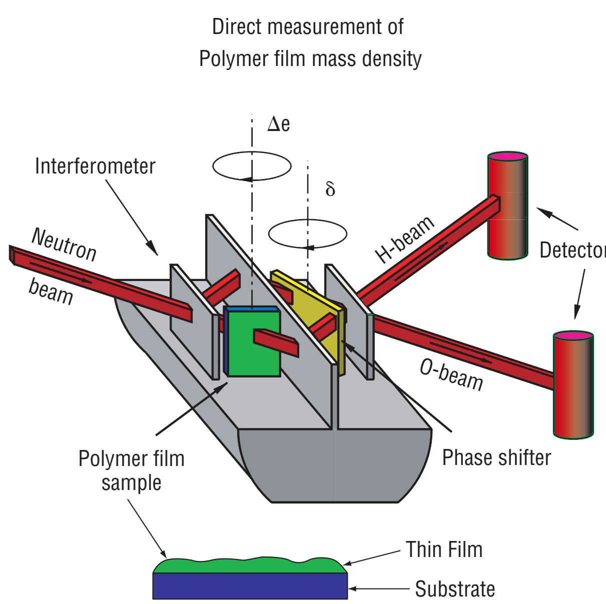

FIGURE 2. Schematic of the polymer thin film measurement setup.

The capability of the facility has been augmented by the addition of a transmission neutron polarizer and RF gradient flipper. Neutron polarization in excess of 98% has been obtained with thermal neutrons. This new capability was exploited in an experiment which observed the 4π spin rotation symmetry of the neutron wave function. This experiment was unique in that the neutron guide field was gently rotated by 180° allowing the neutron spin direction to adiabatically follow the field. This experiment provides the first ***direct*** observation of 4π spin rotation symmetry of neutrons under space rotation.

New experiments are being done such as the measurement of the internal charge structure of the neutron and measurements of mass densities of thin films as a function of thickness. Planned are scattering length measurements of samples (such as D_2 gas) important for many body nuclear calculations. Future plans also include constructing large separated-section interferometers. Such interferometers are crucial for phase transition studies in samples and fundamental physics experiments with at least an order of magnitude more sensitivity than what is possible today.

REFERENCES

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