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Status report on the Low Energy Neutron Source for 2015

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Summary. — The Low Energy Neutron Source at Indiana University first produced cold neutrons in April of 2005. Ten years after first reaching this milestone, the facility has three instruments in operation on its cold target station, and a second target station is devoted to thermal and fast neutron physics offers capabilities in radiation effects research (single-event effects in electronics) and radiography. Key elements in our success over these last ten years have been the diversity of activities we have been able maintain (which often involves using each of our instruments for multiple different activities), the close relationship we have developed with a number of major sources, and the focus we have had on innovation in neutron instrumentation. In this presentation, we will introduce some of the highlights from our most recent activities, provide an update on some of our technical challenges, and describe some of our ideas for the future.

PACS `28.20.Gd` – Neutron transport: Diffusion and moderation.
PACS `61.05.fg` – Neutron Scattering.

1. – Overview

Since it first produced thermal neutrons late in 2004, LENS has provided a flagship example of a proton-beam-based CANS facility with capabilities in materials research, neutron education, and innovation in instrumentation [1-4]. In previous UCANS and ICANS meetings we have outlined a number of the operational issues associated with a source of this design (in particular issues with RF systems, target cooling and target blistering [3, 5]). We have now found solultions to a number of these issues, although in some cases the work around has not been completely satisfactory. In this paper we give an update on some of the issues of greatest general interest and highlight some of our more important recent accomplishments. We would like to emphasize that a crucial element in the success of LENS over the years has been the close ties that we have had to the major facilities within the USA (NCNR, ORNL and LANL). This has involved joint research projects, educational programs, and joint efforts on instrumentation development.

2. – Operational issues

Target lifetime has remained a vexing problem for us over the last two years. After considerable success with our thinner target design [3], where our targets were regularly lasting longer than the o-rings we used to provide the vacum seal around them (*i.e.* 75–100 kWdays of integrated beam power), we have experienced cracking of targets after short periods of time (as short as several hours at 3 kW beam power). We have come to the conclusion that this must represent some sort of transient issue with the beam optics which leads to an anomalously intense portion of the beam spot on the target. We have not, however, been able to identify the origin of the anomaly. This experience suggests that it would be helpful to have more extensive diagnostics available for studying the proton beam near the target than was afforded by the LENS construction budget. Therefore, this should be considered to be an important lesson-learned for facilities that are currently under construction: adequate diagnostics of the accelerated beam are very useful for long term health of the facility.

In our most recent run cycle, we chose to operate at a beam power of only 600 W (since most studies for this cycle involved moderator characterizations or neutron transmission experiments, for which this power is adequate) and we ran for almost 6 weeks without a problem with the target. During this most recent run, we noticed that one of the klystrons was running with very little available overhead power, and have come to wonder if this may have been a contributing factor, as it could lead to occasional transients where the beam energy is lower than expected. This could, in turn, result in the beam passing at the wrong position through the octupoles which are designed to flatten the beam profile, but which can produce hot spots if the beam is improperly tuned. Retuning of the klystron electromagnets has significantly increased the gain of that tube, so this may provide a solution to our target problem, but we will need more experience with this new klystron tune. During our next run cycle, we intend to go back to more standard power levels (2.5 to 4 kW) with this retuned klystron to confirm these suspiscions. We are also considering the use of an anodized aluminum target in the sample position to provide a scintillation screen with which we can directly view the proton beam profile, albeit at the cost of a significant reduction of neutron flux during the tests.

3. – Instrumentation

The instrumentation suite at LENS has changed relatively little since we last provided an overview of our activities in 2013. We have added some additional monitoring to the proton beam and in-pile neutron field on the second target station. This includes a second system for integrating proton charge in each pulse of the accelerator (similar to the one we have previously been using for monitoring proton current during moderator neutronics experiments) and a low-efficiency N_2 detector mounted in the shielding surrounding the target assemby. With these systems we can monitor the dose delivered on a pulse by pulse basis and in the future we hope to combine this with *in situ* monitoring of tranisistor performance as a means for studying neutron radiation effects in silicon on time scales from several ms to several minutes. The physics relevant to radiation effects in electronics takes place over time scales from several picoseconds all the way up to several months or more, and proton-accelerator based CANS facilities may be in a unique position to provide insight in this intermediate range of time scales due to the intense neutron fields near the target, their pulsed time structure and the relatively weak gamma fields near the target. We hope to capitalize on these features of our source over the next few years.

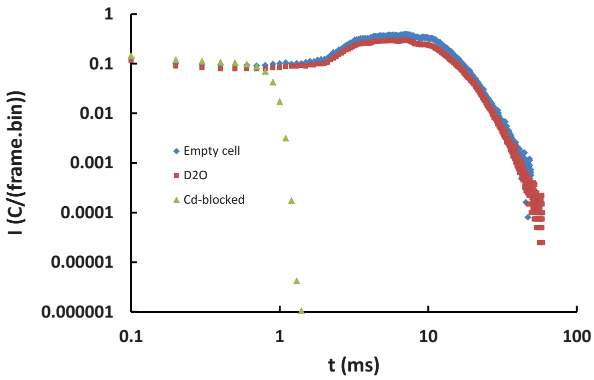

Fig. 1. – Count rates on the LENS SANS instrument in "Total cross section" mode with a ^{3}He detector. The background count rate in this mode, operating at 10 Hz, is approximately 3×10^{-7} counts/frame per 100 μs bin.

Over the last couple of years we have also continued to demonstrate the flexibility of our instrumentation suite. Our SANS instrument has been used in studies of complex fluids [6] and block-copolymers [7] as well as in support of our development of spin manipulation devices (checking the transmission and scattering properties of materials for windows and Meissner screens) and components for various fundamental nuclear physics experiments. Preliminary measurements on our instrument have also played a key role in securing beam time at major facilities to study nanotube composites and a variety of polymer composite systems. As we have reported previously, this instrument can also be reconfigured as a time-focussed spectrometer for measuring emission time distributions as well as measurements of neutron total cross sections. In the former case, we have recently demonstrated a roughly 3 order of magnitude dynamic range in measuring peak shapes [8]. In this mode, we run the accelerator with a 10 μs pulse width and 40 Hz repetition rate, but we have been able to distinguish changes in moderator impulse responses as small as 2 to 3 μs at neutron energies near 25 to 70 meV. We also note that we have demonstrated the abilty to demount and remount the detector and crystal for this mode of operation without having to adjust the detector position or crystal orientation to optimize the time focused condition.

As described in more detail in another paper in these proceedings [9], for the measurement of total cross sections, we have demonstrated the capability to measure σ_{tot} to energies below 0.1 meV at variable temperature. In this mode of operation, we reduce the accelerator frequency to 10 Hz with a 150 μs pulse width. This combination of parameters extends the bandwidth to below 0.1 meV while simultaneously allowing reasonable measurements above 1 eV for checking the normalization of the data against known free-gas results. In cases where greater precision is needed at either the high or low energy extremes of this range, we could combine results with either longer pulse widths or a higher frequency (to provide greater count rates at low energies or high energies respectively). We perform these measurements with a 2.5 cm diameter 50 kPa presure ^{3}He detector viewing the beam through a roughly 1.5 cm^2 hole in a BN shield, a secondary flight path length of 57 cm, and an efficiency of roughly 9% at $\lambda = 0.1$ nm. This combination subtends a solid angle of only 0.46 msR, limits dead time corrections to less than a few percent near the peak in the spectrum, and yet provides an essentially black detector at the longest wavelengths accessible to the apparatus (roughly 4 nm) [9].

Background count rates with the facility running in this mode are roughly 0.2 c/min in this detector, and typical count rates, along with the Cd-blocked beam spectrum are shown in fig. 1. In this figure, the background rate lies roughly a factor of 3 below the lower limit of the vertical axis. Even at $\lambda = 3.5\,\mathrm{nm}$, the count rate in the direct beam is some 30 times this dark rate. This suggests to us that CANS facilities such as LENS are ideal places for conducting total cross-section measurements as part of a coherent program is evaluating materials effects in nuclear data over neutron energies from below 0.1 meV to 1 eV or higher.

Perhaps the most significant activity in instrumentation at LENS over the last several years, however, has been our program developing in neutron spin-manipulation technology using superconducting components to produce and shape the magnetic fields performing the manipulation [10]. The devices we have demonstrated include a cryoflipper for performing spin flips on large area (up to $18\,\mathrm{cm}^2$ or more) white beams [11], a device for performing spherical neutron polarimetry in transition mode (such as SANS and radiography [10]), and Wollaston prisms [12], which can be used to encode neutron trajectories or position into the neutron spin. These devices can be used to introduce novel contrast mechanisms into radiography and perform phonon focusing to increase the resolution available in measuring the lifetime broadening of elementary excitations in materials [13] among other applications. Over the next several years we will continue to develop these technologies and expand their applications.

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