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Author(s): Gary J. Russell, Phillip D. Ferguson, E. J. Pitcher, Dan J. Weinacht, LANSCE-12

J. D. Court, Geoffrey L. Greene, LANSCE-DO

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Supporting Technologies for a Long-Pulse Spallation Source

Gary J. Russell*, Dan J. Weinacht, Philip D. Ferguson,
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Abstract

This is the final report of a two-year, Laboratory Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). The project is directed toward the development of the technologies required for a long-pulse, spallation neutron source (LPSS). Traditionally, spallation neutron sources have used proton accelerators that provide intense, short ($\leq 1\mu s$) pulses of high-energy protons to a spallation target. A LPSS uses a proton pulse with longer time duration ($\approx$1ms) and offers the possibility of achieving very high spallation neutron fluxes at substantially lower cost. The performance of a LPSS is very dependent on the neutronic performance of the target-moderator system. A detailed study of this performance has been carried out using Monte Carlo simulations. It should be noted that a LPSS is optimally suited to a fully coupled moderator. Neutron production per proton from such a moderator is a factor of five to seven greater than that produced by moderators used at short pulse sources. The results of these efforts have been published in a series of articles.

Background and Research Objectives

This research was intended to elucidate a number of issues associated with the design of target/moderator systems for a so-called "long-pulse" spallation neutron source (LPSS). A spallation neutron source produces neutrons by directing a high-energy, high-current proton beam onto a heavy stopping target. This target is surrounded by an appropriate moderator system to reduce the energy of the resulting neutrons to energies of interest to neutron scattering. To date, spallation neutron sources have employed "short" pulses of protons having durations on the order of a microsecond. The use of a short pulse increases the complexity and the cost of the accelerator system used to produce the protons and provides an additional technical challenge in the attainment of very high proton currents.

Los Alamos has been exploring the possibility of using the existing high-current linear accelerator (linac) at the Los Alamos Neutron Science Center (LANSCE) as the

*Principal Investigator, e-mail: russell@lanl.gov

proton source for a spallation neutron source. This linac currently has the capability to produce a total beam power of about 1MW (approximately 6 times the power of the most powerful spallation source in the world). However, the proton pulses have a duration of about 1 millisecond. Thus the neutron pulse from such a system will be considerably longer in duration than the pulse from a short pulse spallation source. The moderator for such a LPSS will have a very different character than that at a short pulse source. In particular, the long pulse source would not benefit from the use of neutronic "decouplers" to shorten the neutron pulse width. The elimination of such decouplers will lead to an increased neutron production, albeit with an increased neutron pulse width.

The primary purpose of this project was the detailed study of target/moderator systems appropriate for such a long pulse source. Such studies are a necessary precursor to any further design or R&D activities related to a long pulse source and involve a considerable amount of highly specialized and detailed neutronic calculations. A major objective of this work was the development of a "reference" target/moderator system whose performance could be used in the evaluation of the scientific utility of a long pulse source.

Importance to LANL's Science and Technology Base and National R&D Needs

Spallation neutron science and technology is one of the key strategic directions of Los Alamos National Laboratory (LANL). Los Alamos currently operates the highest power spallation neutron source in the US and, with upgrades already in progress, will have the highest peak power source in the world. LANL is also a major participant in the Spallation Neutron Source (SNS) project, a $1.3 billion dollar DOE/BES construction project. Spallation neutron sources and spallation neutron science are of major interest to LANL and the Nation. A long pulse source based at LANL would provide an important capability, would greatly assist LANL in attaining its goal of being the Nation's "Neutron Laboratory", and could provide the United States with a cost effective way of establishing a very high power spallation source.

Scientific Approach and Accomplishments

Spallation neutrons are created when the high-power proton beam from an accelerator is directed onto a target/moderator system comprised of a dense stopping target and a (typically hydrogenous) moderator. Each proton typically creates 10-20 high-energy (10s to 100s of MeV) neutrons in the target. These are then slowed to meV energies in the moderator. Such meV neutrons are of great utility in condensed matter research using neutron scattering. A key characteristic of most spallation sources is the pulsed nature of the neutrons emerging form the source. In this, spallation neutron sources differ fundamentally from continuous reactor sources. The neutron pulse from a spallation source is roughly characterized by its intensity (peak or average), its duration (in time), and its neutron energy distribution. Each of these characteristics is dependent on the nature of the initial proton pulse and the details of the target/moderator system. The usefulness of the spallation source for neutron scattering science depends critically on matching the performance of the source (i.e. the nature of the neutron pulse) to the requirements of the spectrometer(s) or neutron scattering instrument(s) that are to be installed at the spallation source.

Traditionally, spallation neutron sources have been optimized for high resolution experiments using thermal (or higher energy) neutrons. Spallation sources optimized for such work are commonly known as "short pulse" spallation sources. The current source at LANSCE, the IPNS source at Argonne National Laboratory, and the ISIS source in England all have this character. Such sources use a very short proton pulse (on the order of 1 microsecond) and surround the neutron moderators with neutronic "poisons" (highly absorbing materials) to ensure that the neutron pulse has a short time constant. Short-pulse spallation sources typically provide neutron pulses with characteristic time constants of many tens to, perhaps, one hundred microseconds. Short-pulse spallation sources provide neutron pulses that are well matched to a number of neutron scattering applications.

Notwithstanding the many attractive features of short-pulse spallation sources, it is important to recognize that the same design features that are necessary to obtain a short pulse inevitably decrease the overall intensity and increase the cost and technical complexity of the facility. The same neutron poisons that are required to shorten the neutron pulse also reduce the overall intensity of the pulse. The short proton pulse requires a more complicated and expensive accelerator complex, typically including a storage ring. Finally the short proton pulse delivers an extremely high peak power to the spallation target requiring far more sophisticated target design.

For some time it has been recognized that not all spallation neutron applications require the use of a short pulse. In particular, the important field of cold neutron scattering has much less demanding requirements on the nature of the neutron pulse. It has been suggested that there is a wide range of scientific investigations that could be addressed with a pulsed neutron source having a neutron pulse duration on the order of one millisecond. Such a long-pulse spallation source would be a potent compliment to short-pulse and reactor sources.

Because the anticipated neutron pulse is longer than typical moderation times, the neutronic poisons of the short pulse source are unnecessary. The removal of such poisons increases the total number of neutrons produced by a factor of five to seven (depending on the details of the moderator). Because the desired neutron pulse is now on the order of a millisecond, it is not necessary to "time compress" the proton pulse using a storage ring. This feature has the duel advantage of eliminating the need for an expensive component of the accelerator complex and allows the target a much higher acceptance from the linac. Finally, because the power in the proton beam is delivered to the target in a millisecond, rather than a microsecond, thermal shock issues in the target are significantly simpler that in the case of the short pulse source.

The work carried out in this LDRD project concerned the detailed examination of the technical issues associated with a LPSS based on the existing LANSCE linac. The detailed calculations presented in the publications noted below provide a conceptual design for such a long pulse source that includes target moderator design, neutronic performance, and overall plant design.

Publications

1. Russell, G., Pitcher, E., Ferguson, P., and Patton, B. "Long Pulse Spallation Source Neutronic Performance," *Journal of Neutron Research* **6**, 33-62 (1997).

2. Russell, G., Ferguson, P., Pitcher, E., and Court, J., "Split-Target Neutronics and the MLNSC Spallation Target System," Applications of Accelerators in Research and Industry, ed. J.L.Duggan and I.L. Morgan, AIP Press, New York, 1997.

3. Russell, G., Weinacht, D., Pitcher, E., and Ferguson, P., "A Long-Pulse Spallation Source at Los Alamos: Facility Description and Preliminary Neutronic Performance for Cold Neutrons," Los Alamos National Laboratory Report LA-UR-97-5037 (1997).