LANSCE Accelerator Update and Future Plans

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Abstract. Several multi-year accelerator system upgrades have recently been completed at LANSCE that will ensure the long-term future of beam operations to its users and to prepare for a planned next-generation signature facility (MaRIE) based on multi-probe capabilities. Present LANSCE accelerator operations will be discussed. A summary of the recent upgrades completed and future plans will also be presented. This work is supported by the United States Department of Energy, National Nuclear Security Agency, under contract DE-AC52-06NA25396.

1. Introduction

The Los Alamos Neutron Science Center (LANSCE) accelerator complex continues to support a diverse set of users, providing an extraordinary opportunity for U.S. science and technology programs. With its unique capability to accelerate and deliver two beam species simultaneously to multiple users and to provide peak neutron fluxes that span nearly 16 orders of magnitude in neutron energy, LANSCE supports three major Department of Energy (DOE) stakeholders: Defense Programs (DP), Office of Science (SC), and Office of Nuclear Energy, Science and Technology (NE) that support operations at LANSCE that enhance the U.S. nuclear weapons program, basic science including new scientific capabilities, and the U.S. radioisotope production capability. Unique irradiation capabilities are also provided for industry users. Recently completed RF system upgrades have enabled a return to 120-Hz accelerator operations and other multi-year system upgrades will ensure the long-term future of LANSCE beam operations to support current and future programs.

A simplified layout of the LANSCE accelerator complex comprised of an 800-MeV proton linac, a proton storage ring (PSR) and multiple experimental areas is shown in Figure 1. Simultaneous H⁺ and H⁻ beams are delivered with flexible time structures to the experimental areas. Only the H⁻ beam is accelerated to 800 MeV. The H⁺ beam is diverted at 100 MeV to the Isotope Production Facility (IPF) which helps satisfy the national need for biomedical radioisotopes. Other experimental user facilities at LANSCE include: the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center), which exploits a moderated neutron source (meV to eV) primarily for neutron-scattering research; the Weapons Neutron Research (WNR) facility, which uses an unmoderated neutron source (keV to 800 MeV) for research in nuclear science and technology and industrial irradiations; a dedicated facility for proton radiography (pRad) at 800 MeV (Area C); Area B, which produces the most intense source of ultra-cold neutrons (UCN) in the world, and; Area A (currently inactive).

During the 2016-2017 Run Cycle, 547 unique users were supported through approved and scheduled proposals at the pRad, Lujan Center, and WNR facilities. An overall accelerator availability of 86% was achieved. The IPF facility produced enough Strontium-82 for approximately 120,000
cardiac images and Actinium-225 was investigated for cancer therapy. Thirty two dynamic proton radiography experiments were supported and 119 WNR and Lujan experiments were completed that advance the knowledge of total fission cross sections for uranium and plutonium. Materials science experiments at LANSCE have focused on understanding the performance of additively-manufactured materials. Experiments at the WNR “Blue Room” have contributed to developing radiation-hard electronics needed for the Large Hadron Collider (LHC) upgrade and beam delivery to the WNR “Ice House” continues to support single-event-upset measurements for the semiconductor industry.

![Figure 1. Schematic layout of the LANSCE accelerator complex including the linac sections and the experimental areas. Also shown is a table of the possible beam parameters that can be delivered to each area.](image)

2. LANSCE accelerator improvements

2.1. LANSCE linac risk mitigation (LRM)

Multiyear accelerator system upgrades that began in fiscal year 2009 were completed in fiscal year 2015, completing the funded LANSCE Linac Risk Mitigation project. The investments made enabled a return to 120-Hz beam operations that were previously limited to 60 Hz due to deterioration of the output power capability of the Burle 7835 power triode used in the RF amplifier system of each 201.25-MHz drift-tube linac (DTL) module. Three of four of these high-power RF systems were replaced with new diacode-based systems [1]. Also included in the LRM project scope was the procurement of 45 new, 805-MHz klystrons to be installed as required due to failing end-of-life units, remediation of some accelerator structures and supporting equipment, magnet and other power supplies, and implementation of modern, maintainable EPICS-based instrumentation and controls. A partially funded, longer-term project goal is to replace the obsolete and aging Cockcroft-Walton-based injector systems with modern Radio-frequency Quadrupole (RFQ) accelerator based injectors. Investments made from 2009-2015 span most major LANSCE accelerator systems. The total fiscal year 2009-2015 funding for LRM upgrades was approximately $140 M (US).

Fiscal year 2014-2015 investments focused on DTL Module-2 and Module-4 diacode amplifier installation (see Fig. 2) and procurement of components needed to replace the Module-3 system in fiscal year 2016. Also, a new computer-controlled water cooling system was installed on DTL Module 2; other modules will be upgraded in future years. New industrial controls (cRIO) were installed for the full DTL, with partial implementation in the 805-MHz coupled-cavity linac (CCL). Facility
improvements needed to support new digital low-level RF (dLLRF) controls systems were also completed.

![Figure 2. DTL Module-2 201.25-MHz diacode based high power RF amplifier.](image)

2.2. Beyond LRM
Accelerator improvements are now funded on an annual basis based on impact to operations and available budget. Fiscal year 2016 efforts focused on installation of the final diacode-based high-power RF system for DTL Module 3, completing additional controls and timing system modernization, implementation of a dLLRF system for all DTL modules, and continuing upgrading magnet power supplies and vacuum systems. Improvements to WNR Target 4 (see Fig. 1) included installation of remote pump controls to eliminate unnecessary entry into a radiation area and associated beam downtime to recover a tripped pump. Target 1 improvements included implementation of the only in-situ hydrogen ortho/para measurement capability of its kind in the neutron community [2]. A newly installed Feschenko Bunch Shape Monitor (shown in Fig. 3 below) has also been installed at 41.3 MeV in the DTL [3] and is being used to tune up the linac. Although significant progress has been made, completing the remaining scope of work in an expected flat-budget environment will require careful planning. Additional investments in out-years are needed to complete these improvements and to sustain operations and maintain high availability.

![Figure 3. Left: Feschenko bunch shape monitor installed between DTL tanks 3 and 4. Right: Typical H\(^+\) bunch-shape data at 41.3 MeV, 1 Hz, 150 µs.](image)

3. Focusing on the future
Several investments targeted at improving beam delivery to LANSCE users and to enhancing capabilities have be initiated. These are discussed in detail below.
3.1. \textit{H} beam delivery enhancements

It has long been the goal to improve the LANSCE multi-cusp \textit{H} ion source performance. A modest development program using measurements performed at the Ion Source Test Stand (ISTS) has been initiated to reach higher peak output currents and to extend the source lifetime beyond its nominal 28 days [4]. Also, presently the two LANSCE beams are combined in a common main buncher cavity whose phase and amplitude settings are a compromise for the two beams before injection into the DTL at 750 keV. Installation of a de-buncher cavity in the \textit{H} transport line upstream of the main buncher is being considered to decouple the two-beam bunching and capture; implementation could improve the peak beam current delivered to WNR and pRad by up to 50%. Improving the \textit{H} chopper rise time and phase control could further improve beam delivery to these areas and to Target 1.

3.2. Proton Storage Ring (PSR) and Target 1 options

Operation of the PSR at 30 Hz (normal operation is at 20 Hz) at short pulse durations (30 ns) was explored recently and is being considered as a potential routine mode of operation for the future. Pulse stacking in the PSR has also been considered recently to enable a new class of nuclear physics experiments at WNR that require very short, intense pulses to better resolve nuclear resonance phenomena. The present Target 1 will reach its end of life in the next 5 years. A new target configuration is being considered that will provide higher energy neutrons for nuclear science [5]. Preliminary calculations indicate that simple geometry changes to the present target configuration can increase neutron fluxes in the desired energy ranges. Design of the new target is expected to begin in 2018 with installation of the new target potentially as early as 2020.

3.3. 100-MeV isotope production improvement project

The LANSCE Isotope Production Facility (IPF) is the sole user of the 100-MeV \textit{H} beam and operates at an average beam current of up to 225 µA. During the past year a project to enhance several operational aspects of the IPF has been completed and installation is currently underway [6]. Enhancements include an improved window design capable of operation up to 300 µA with new temperature and window deflection diagnostics, an active and adjustable collimator (fixed collimation previously), shown in Fig. 4 below, with beam spill monitoring and active cooling for thermal management, new selectable raster patterns, a new beam profile and emittance measurement capability with <1 mm resolution, a 1% accuracy beam-current measurement capability over the range of 100 nA to 500 µA, and real-time beam energy monitoring (50 keV resolution). Commissioning is expected during resumed beam operations in June 2017.

3.4. \textit{H} \textit{RFQ} to replace the Cockcroft-Walton (CW) injector

A test stand is being assembled to test a new 4-rod, 750-keV, 201.25-MHz RFQ to replace the aging and obsolete \textit{H} CW injector [7]. The test stand will include the ion source, low-energy beam transport, RFQ, medium-energy beam transport downstream of the RFQ, and diagnostics needed to inject beam into the LANSCE DTL. High power RF tests of the RFQ are expected to begin in the next few months.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{Adjustable collimator mock-up with complete set of cooling tubes.}
\end{figure}
3.5. Automation and enhanced diagnostics and controls
Operational efficiencies can be obtained through automation of several accelerator controls and optimization functions typically performed by trained accelerator operators. Application of automated processes and modern control algorithms using improved instrumentation and diagnostics are being explored. Interactive codes based on fast GPU processors are being developed that may soon allow automatic system and safety interlock checks, beam tuning and beam optimization, and upset recovery [8]. Automating processes at the H injector including ion source peaking and controlling cesium transfers is also being investigated [9], as is automated RF cavity conditioning.

3.6. Resumed 800-MeV beam operations to Area A
Since the completion of the LAMPF nuclear physics program in the mid 1990’s, no 800-MeV protons have been delivered to experimental Area A. However, recently there has been renewed interest in using Area A and several viable options have been explored. At present a relatively low-cost, Low-Power Proton Source (LPPS) facility is being proposed [10]. The LPPS targets urgent needs of the national security and space science radiation effects communities that qualify components for use in space. The facility would be operated at a nominal average current of 100 nA (6.25 x 10^{11} protons/sec) delivered at a 1-Hz repetition rate using the 625-µs LANSCE beam macropulse length. Dual energy operation at 200 MeV and 800 MeV is being considered. The LPSS is expected to require only a modest beam transport line and experimental configuration in Area A. The project is currently under review. Implementation will require 2-3 years, including full implementation of a 100-MeV IPF kicker system to inject the proton beam into the CCL and an upstream beam chopper at 750 keV to limit the average beam current.

3.7. Matter-radiation interactions in extremes (MaRIE)
A next-generation signature facility (see Fig. 5) based on multi-probe capabilities is being planned at LANSCE that will be the first in a new generation of game-changing scientific facilities for the materials community [11]. The new Matter-Radiation Interactions in Extremes (MaRIE) facility will be used to discover and design the advanced materials needed to meet 21st-century national security and energy-security challenges by providing the tools to develop next-generation materials that will perform predictably in extreme environments. Materials samples will be synthesized and characterized at the mesoscale, and their dynamic behavior characterized in time-dependent extreme conditions by use of both imaging and diffractive scattering with multiple probes at multiple spatial and time scales. The MaRIE facility includes a new 12-GeV electron linac to drive a 42-keV X-ray free-electron laser (XFEL) coupled with the existing proton-beam capabilities of the LANSCE proton linac, new experimental halls, and materials fabrication/characterization facilities. A pre-conceptual design has been completed and performance requirements have been defined to meet a broad range of experimental needs. The project has received Critical Decision 0 (CD-0; approved mission need) and is now on the path to CD-1 (completion of an analysis of alternatives and approval of alternative selection) and is preparing for the Conceptual Design Report. Completion of the MaRIE project is expected in the 2025-2030 time frame.

4. Summary
There continue to be several challenges ahead for sustaining LANSCE operations today and building the foundation for tomorrow. Our short-term (1-5 years) efforts will be focused on maintaining stable funding for operations, on completing remaining subsystem enhancements as discussed earlier, and to continue to improve alignment of our operations with present experimental missions and to build new capabilities synergistic with the long-term MaRIE vision. In the 5-10 year timeframe, focus will be on installation of a new Target 1 optimized for nuclear science needs, enhanced uses of proton radiography, and evaluating the needs for LANSCE capabilities in the MaRIE era. Beyond these will be the transition to an integrated MaRIE facility and optimizing performance and value to the new expanded user base that is expected to result.
Figure 5. Pre-conceptual layout of the MaRIE facility. Note the location of the existing LANSCE proton linear accelerator (shown in blue) relative to the new MaRIE XFEL.

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