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ADVANCEMENT OF LANSCE FRONT END ACCELERATOR FACILITY*

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Abstract

The LANSCE accelerator started routine operation in 1972 as a high-power facility for fundamental research and national security applications [1]. To reduce long-term operational risk, we propose to develop a new Front End of accelerator facility. It contains 100-keV injector with 3-MeV RFQ, and 6-tanks Drift Tube Linac to accelerate particles up to energy of 100 MeV. The low-energy injector concept includes two independent transports merging H^+ and H^- beams at the entrance of RFQ. Beamlines are aimed to perform preliminary beam bunching in front of accelerator section with subsequent simultaneous acceleration of two different beams in a single RFQ. The paper discusses design topics of new Front End of accelerator facility.

LANSCE ACCELERATOR FACILITY

The layout of the existing LANSCE accelerator facility is shown schematically in Fig. 1. The front end is shown bordered by a dashed blue line. The accelerator is equipped with two independent injectors for H^+ and H^- beams. Each injector has a Cockcroft-Walton type generator and an ion source to produce either positively charged protons (H^+) or negatively charged hydrogen ions (H^-) with a final energy of 750 keV. Two independent beamlines deliver H^+ and H^- beams, merging at the entrance of a 201.25 MHz Drift Tube Linac (DTL). The DTL performs acceleration up to the energy of 100 MeV. After the DTL, the Transition Region beamline directs the 100 MeV proton beam to the Isotope Production Facility (IPF), while H^- beam is accelerated up to the final energy of 800 MeV in an 805 MHz Coupled Cavity Linac (CCL). The H^- beams, created with different time structures imparted by a low-energy chopper are distributed in the Switch Yard to four experimental areas: Lujan Neutron Science Center equipped with the Proton Storage Ring (PSR), Weapons Neutron Research (WNR) Facility, Proton Radiography Facility (pRad), and Ultra-Cold Neutron Facility (UCN). The accelerator operates at 120 Hz repetition rate with 625 µs pulse length. Parameters of all beams are presented in Table 1. Figure 2 illustrates new Front End facility, which consist of RFQ-based injector and new Drift Tube Linac.

BEAM TIME STRUCTURE

A unique feature of the LANSCE accelerator facility is acceleration of four H^- beams (differing in time structure) and one H^+ beam. This is achieved by a combination of chopper and RF bunchers. Figure 3 illustrate the time structure of LANSCE beams. Figure 4 shows the time pattern of beam cycles. The H^- chopper, which creates various time

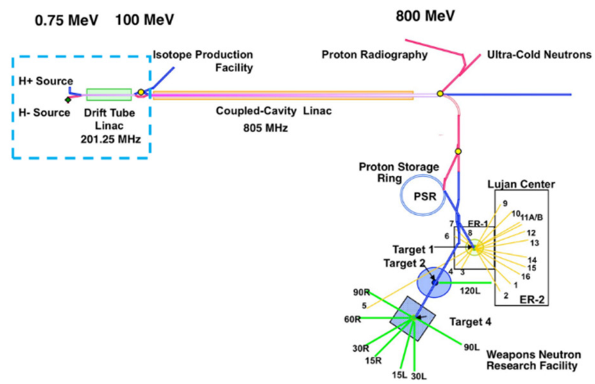

Figure 1: Overview of the existing LANSCE accelerator and user facility complex.

Table 1: Beam Parameters of LANSCE Accelerator

Area	Rep. Rate (Hz)	Curent/ Bunch (mA)	Average Current (µA)	Average Power (kW)
Lujan	20	10	100	80
IPF	100	4	230	23
WNR	100	25	4.5	3.6
pRad	1	10	<1	<1
UCN	20	10	10	8

structure of H^- beams, is located downstream of the H^- Cockcroft-Walton column. It consists of two traveling-wave helix electrodes, which apply a vertical kick to the beam. The chopper is normally energized so that no beam gets through. An electrical pulse of various length between 36 - 290 ns travels along the chopper allowing the unchopped part of the beam pulse to pass through. The minimum width of chopper pulse is determined by the chopper risetime, which is about 10 ns. Following the chopper, the leading and trailing edges of the beam are bent vertically.

The Lujan Center receives 20 Hz x 625 µs pulses of H^- beam with 10 mA/bunch peak current, corresponding to average current of 100 µA and average beam power of 80 kW (see Figure 3a). This beam is chopped within a time interval of 290 ns every 358 ns, which is the revolution time for the Proton Storage Ring. After accumulation, the beam is extracted to the moderated neutron spallation target at the Lujan Center. The 70-ns gap allows for extraction and injection of the beam.

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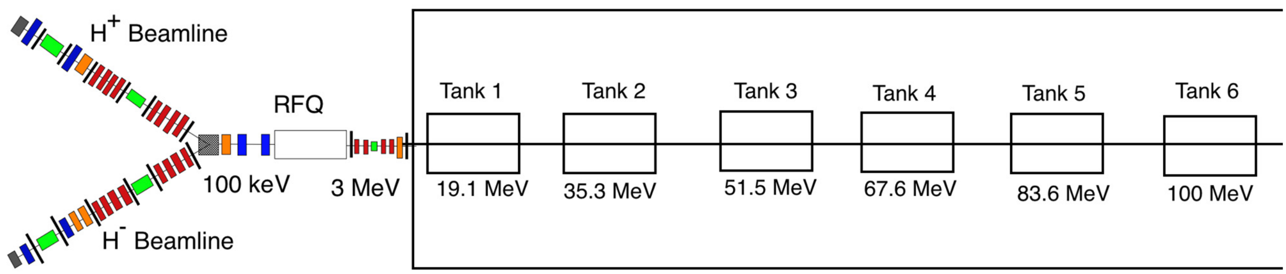

Figure 2: Layout of the new 100 MeV LANCE Front End Accelerator Facility.

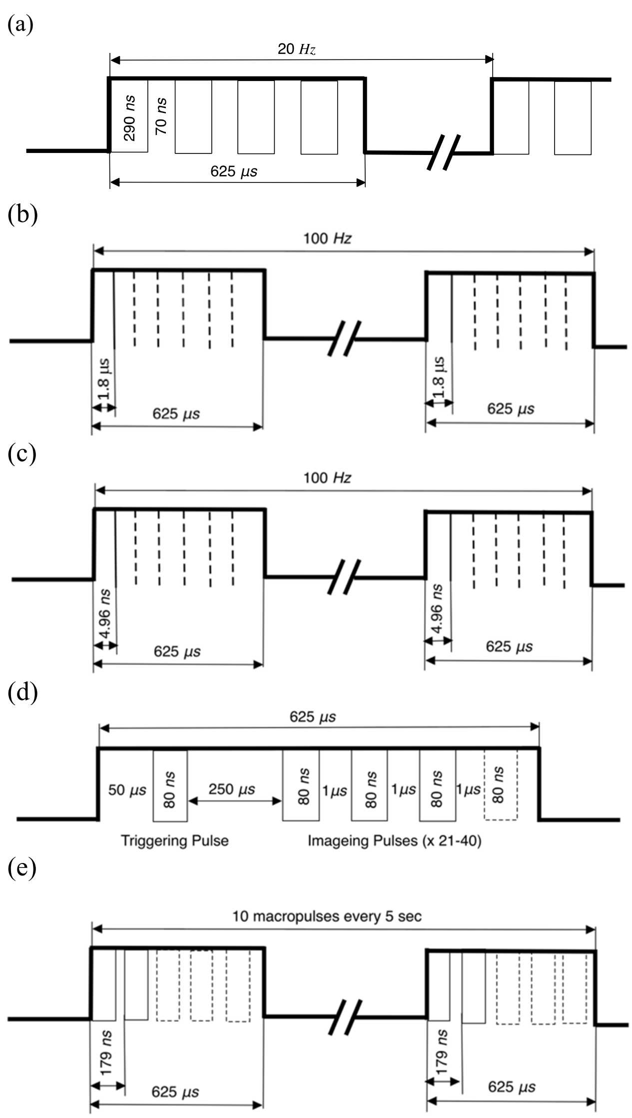

Figure 3: Time structure of LANSCE beams: (a) Lujan-PSR, (b) Weapons Neutron Research Facility, (c) Isotope Production Facility, (d) Proton Radiography Facility, (e) Ultra Cold Neutron Facility. Vertical dotted lines illustrate single bunches.

Another H- beam, delivered to Weapons Neutron Research Facility (WNR), shares the same 100 Hz x 625 µs pulses (that is, both beams are accelerated simultaneously) with the 100-MeV proton beam, delivered to the Isotope Production Facility. The WNR beam is a sequence of single 201.25 MHz bunches, separated by time interval of 1.8 µs within the standard 625-µs macro-pulse (see Figure 3b). The WNR bunch is created by the combination of a short 36 ns chopper pulse and the Low-Frequency Buncher. Because of that specific combination, the WNR bunches typically contain about 2.5 times more charge than the standard H- linac bunch.

The IPF proton beam is a sequence of 201.25 MHz bunches separated by an RF period of 4.96 ns accelerated within the 625-µs macro-pulse (see Figure 3c). This beam has an average current of 250 µA and energy of 100 MeV, corresponding to an average beam power of 25 kW delivered to the IPF target.

H- beam is delivered to Proton Radiography Facility by "stealing" single 625 µs macro-pulses of H- beam from WNR. A typical pRad structure consists of a triggering pulse followed closely by sequence of short (80 ns) pulses separated by time interval 1 µs for radiographic imaging (see Fig. 3d).

H- beam is delivered to the Ultra Cold Neutron (UCN) research facility and it consumes 10 Hz x 625 µs every 5 sec, which is approximately equivalent to 2 Hz of continuous operation (see Fig. 3e). The UCN beam "steals" these cycles from WNR beam, and they are accelerated in the same RF pulses with IPF beam.

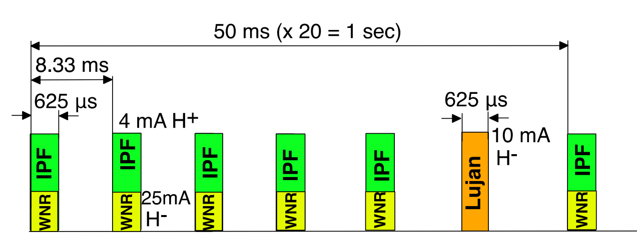

Figure 4: Layout of Lujan/WNR/IPF beams. Beams delivered to pRad or UCN facilities, "steal" their time cycles from WNR beam.

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RFQ INJECTOR

Figure 5 shows the conceptual layout for the new 3-MeV injector. Parameters of new injector line are presented in Table 2. The planned low-energy injector includes two independent, nearly identical beamlines for H^+ and H^- beams, merged into a common beamline in front of the RFQ. Each beamline contains deflector, chopper, pre-buncher, Low Frequency Buncher (in the H^- only), solenoids and quadrupoles accompanied by emittance measurement stations to match the beam to key beamline points.

Besides the basic focusing elements, there are additional proposed beamline elements: 4 steering magnets, 5 beam current monitors, 2 beam stops, and 2 vacuum valves in each leg. The steering magnets are used to make fine adjustments to the beam direction. The current monitors are used to measure beam current along the beamline and are used in the Hardware Transmission Monitor (HWTM) system to control beam losses. The beam stops are used to terminate beam propagation during beam tuning. The vacuum isolation valves allow work on individual sections of the beamline without disturbing the vacuum in the other sections and to close beamline in case of pressure excursion. Beam collimators are placed in front of RF cavities, chopper, and RFQ to remove outlying transverse particles, or beam halo.

Additionally, a four-part collimator (jaw) is placed before bender magnet to remove part of the un-chopped beam and for tuning purposes. The common beamline contains a bending magnet, the Main Buncher, and pair of solenoids to match beams to the RFQ, one steering magnet, a beam stop, and a vacuum valve. A number of ion pumps are placed along the beamline to provide distributed pumping. The typical vacuum required is 10^{-6} Torr to avoid H^- beam stripping and provide a necessary level of space charge neutralization on residual gas.

DRIFT TUBE LINAC

After the RFQ, beams are accelerated in the Drift Tube Linac from 3 MeV up to 100 MeV. The DTL structure in this conceptual design is selected to be the classical Alvarez structure, the most effective in this ion energy range. The proposed DTL is divided into 6 tanks each with a length of 7.5 m. Relatively short sections of the new DTL, compared to that of our existing DTL tanks (~18…19 m), are required for sufficient separation of the fundamental RF mode of 201.25 MHz from higher order modes. The additional modularity of this scheme may also help to address serviceability concerns with the present system (e.g., the inability to replace or easily service a module if the structure fails). Serviceability will continue to be a design goal for the DTL sections in the future stages of this project.

For this concept, the accelerating gradient is selected to be 2.15 MeV/m. Beam focusing is performed by Permanent Magnet Quadruples (PMQ) placed inside the drift tubes, which do not require electromagnetic power. RF power for the DTLs will be delivered by recently developed 201.25 MHz RF power stations using Diacrodes

Table 2: Parameters of LANSCE Injector

Ions	H^+/H^-
Ion sources extraction voltage	100 keV
RFQ energy	3 MeV
Beam capture	0.9
Repetition rate	120 Hz
Max beam peak current	50 mA
Average current	1 mA
Beam pulse	625-1000 µs
Normalized rms emittance	0.03 π cm mrad

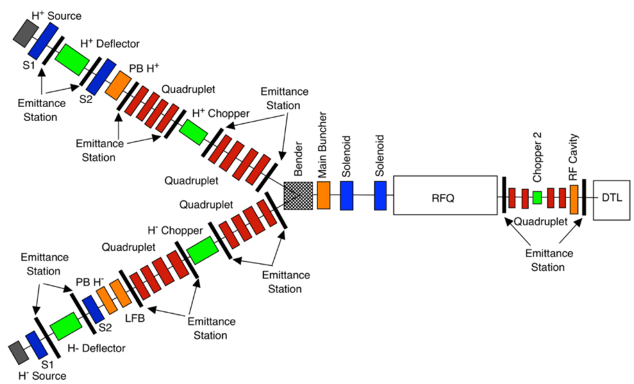

Figure 5: Layout of the new RFQ - based 3-MeV injector.

amplifiers [2]. Each Diacrode amplifier has maximum peak power of 1.8 MW and maximum duty factor of 15%. Currently, three pairs of Diacrode amplifiers are combined into 3 units to feed Modules 2, 3, 4 of our existing Drift Tube Linac. In future DTL, they will be separated as six 201.25 MHz RF amplifiers to supply power for the 6 new tanks. These tetrodes will reuse existing infrastructure including water-cooling systems, coaxial transmission lines, high voltage power supplies, and capacitor banks.

A pair of amplifiers would operate from a common High Voltage capacitor bank and transformer/rectifier unit. The total Direct Current (DC) power needed are 644 kVA (for Tanks 1 - 2), 714 kVA (for Tanks 3 - 4), and 800 kVA (for Tanks 5 - 6). This assumes 58% DC to RF power efficiency with maximum duty factor of 15%. All of the Diacrode power amplifiers can supply the stated power to accelerate beam with peak current 35 mA, which is 2 times more than that required for nominal continuous 1-MW average beam power operation.

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