

## CONSTRUCTION PLANS FOR THE LENS PROTON LINAC\*

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### Abstract

The Low Energy Neutron Source (LENS) at Indiana University will provide moderated neutrons in the meV energy range for materials and neutron physics research as well as MeV energy range neutrons for creating a high flux neutron test environment. Neutrons will be generated by colliding 13 MeV protons with a Be target. Since December 2004, using an existing AccSys PL-7 RFQ and DTL, we have been able to deliver a 0.5% duty factor, 10 mA, 7 MeV beam to a Be target mounted next to a 3.6K methane moderator. In 2007, an additional 7 MeV to 13 MeV DTL section will be added and klystrons will be used to power the RFQ and DTL sections. This will improve the output to about 3% duty factor with 20 mA at 13 MeV. A new 75 keV, 150 mA proton injector and 100 mA, high duty factor RFQ is being constructed to replace the original 3 MeV RFQ at a later date. The peak beam current available from the new injector and RFQ will increase to 50 mA with a duty factor of at least 5% or up to 100 mA with lower duty factor. In addition, a conceptual plan has been developed for a 13 MeV to 22 MeV DTL which will boost the maximum instantaneous flux available from the neutron source up to about  $10^{12}$  n/s/cm<sup>2</sup>.

### LENS UPGRADE PATH

A description of the LENS accelerator project may be found elsewhere [1-4]. The two primary uses of the accelerator will be to generate a low energy flux of neutrons for materials and neutron scientists [5] and to provide a higher energy neutron flux for a radiation effects program (NREP) [6]. The NREP program a part of the accelerator construction has been supported by the Department of Defense through NAVSEA Crane. Two separate targets will be installed for these two primary users, a high energy, high instantaneous flux target for the NREP users and a target surrounded by a custom moderator optimized for materials physics (particularly large scale structures).

LENS is now in operation [1] but is limited to a low neutron flux due to a low average proton current and energy of only 7 MeV. An upgrade path to increase the neutron flux by more than two orders of magnitude is outlined in Table 1. During the next phase of operation the PL-7 will be upgraded to 13 MeV and powered by three klystrons. Further improvements will be realized by increasing the duty factor of the klystrons by adding a more powerful modulator supply and by installing a new 100 mA, 3 MeV RFQ which is presently under construction. Details of these upgrade components are described below.



Figure 1: Layout of the Phase 4 LENS project with a 13 MeV, 100 mA proton accelerator shown installed. The 3 MeV RFQ is 3 meters long. The 13 MeV Phase 2 version will require 3 klystrons and a conceptual 22 MeV Linac would require 5 klystrons.

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*Present Status*

The LENS RF system currently consists of 2 Litton 5773 Klystron RF tubes which run at 425 MHz and 1 MW RF power each. These tubes are powered by a 1 A, 100 kV high voltage power supply which charges an 11  $\mu$ F capacitor bank. This capacitor bank discharges 60 A as the klystron tubes fire. A high voltage crowbar protection system dissipates 99.9% of the stored energy by shorting the capacitor bank when a fault occurs. The 2 MW of RF power from the klystrons are delivered to the accelerator cavities in waveguide through RF circulators. The existing system has delivered RF power into dummy loads. A digital low level RF control system which will control the RF power levels, phase and frequency is being developed and tested. Shortly the system will be connected to the accelerator for cavity and full beam development.

The NREP beamline and TMR exists and is in operation. A beamline and target moderator/reflector (TMR) system is being installed for neutron and materials science. This beamline starts near the exit of the accelerator with a 60 degree achromatic bend composed of two 30 degree dipoles with an intervening quadrupole magnet. The beamline continues with a non-linear beam spreading system which utilizes octupole magnets similar to the existing beamline.

The beamline ends at the TMR after two 12 degree dogleg bends which insure that backstreaming neutrons do not activate the accelerator.

*13 MeV DTL Capability*

A 13 MeV upgrade is under construction and will be completed in 2007. An AccSys Technology, Inc. [7] fabricated DTL will accelerate beam from the PL-7 up to 13 MeV. The DTL will connect directly to the PL-7 with no matching section. The 1.8 m long DTL section will consist of about 17 drift tubes and will require 450 kW of peak power at 425 MHz to reach operating field strengths. Additional power will be required for the beam. RF will be coupled into the Linac inductively using a water cooled drive loop. A third 1 MW 425 MHz klystron will be added and will deliver power through a waveguide isolator to a 3 1/8" coax adaptor and a length of coax to the drive loop. The DTL is designed to operate at a duty factor of up to 6% and accelerate at least 50 mA peak

current of protons. The beam pulse width can be varied from a few microseconds up to 1.3 ms, limited by the operating capability of the klystrons. Initially the 13 MeV upgrade will be limited to a modest 1% duty factor.

*The New 100 mA RFQ and 75 keV Injector*

Detailed designs for a 150 mA, 75 keV proton injector and a 100 mA RFQ have been completed. The proton injector design is based on ion source technology used at IUCF on the 210 MeV cyclotron [3] and on a 25 keV proton injector [4] in use on the present LENS accelerator. The design and development of these existing ion sources and the design of the 75 keV source is based on work done at Los Alamos National Laboratory [8]. The injector is designed to transport and match over 100 mA of protons into the acceptance of the new RFQ.

The 100 mA RFQ was designed by Lloyd Young with physicists and engineers from TechSource, Inc. [9]. Construction of the RFQ is being undertaken by Accel Instruments GmbH [10] in Germany. The basic features of this accelerator are that it is designed to provide 50 mA of 3 MeV protons at the entrance of the AccSys PL-7 DTL or 100 mA to a new DTL designed for high transport efficiency. The maximum average current is 5 mA while the peak and average operating power are 1 MW and 65 kW respectively. The 425 MHz power is slot coupled into the RFQ through a waveguide vacuum window and the tune controlled by cooling water temperature. The designed choke current is 200 mA which results in a transmission better than 90%. Figure 1 shows the layout of the LENS facility with the 13 MeV DTL and the high intensity injector and RFQ installed.

*High Power Modulator*

In order to realize an increase in the duty factor, a higher power modulator will be installed. During the early stages of the LENS project, IUCF salvaged a considerable amount of equipment from the Ballistic Missile Early Warning System (BMEWS) site at Clear AFS in Alaska. Modulator power supplies with an output voltage and current of 110 kV and 4 Amperes were obtained and transported to Indiana. These power supplies must be refurbished and an AC substation installed before they may be used to power the klystron modulators. In addition, a second capacitor bank and crowbar system must be installed. In this case, one

Table 1. Upgrade Path for the LENS Proton Linac. The upgrade to LENS Phase 2 will be completed in 2007.

Phase	Proton Energy	Comments	Peak Proton Intensity	Average Current	Duty Factor (beam)	Status	n-flux (n/s/cm <sup>2</sup> ) 1 MeV equiv.
1	7 MeV	Present Configuration	10 mA	0.03 mA	.004	Existing	1.0 x 10**8
2	13 MeV	Klystrons and DTL added	20 mA	0.15 mA	.010	Under construction.	2.2 x 10**9
3	13 MeV	4 Ampere, 100 kV power supply added	20 mA	0.38 mA	.024	Future	5.0 x 10**9
4	13 MeV	New RFQ and 75 keV, 100 mA proton injector	50 mA	1.2 mA	.024	RFQ under construction.	1.6 x 10**10

klystron will operate with a 1 Ampere supply and the remaining two will be supplied with a 4 Ampere supply. This will increase our possible duty factor by 2 1/2 times.

### Beam Transport and Diagnostics

In order to minimize the thermal effects on the target of the full power beam, a non-linear beam line [2] has been constructed and is being tested as a method of spreading the beam uniformly over the Be target. At the highest average beam currents, there is a definite chance of melting through the Be target into the 30 gpm water cooling system. We have designed and are using wire harps to monitor the beam size and shape (Figure 2) albeit with very low duty factor. This diagnostic, used with a beam stopping viewer and several beam position monitors gives information necessary to develop the octupole beam spreading system. When phase 4 is implemented, we will rely on profile monitors based on the scintillation light emitted by injecting Xenon gas into the vacuum system.

During high intensity operation, non-interceptive capacitive pickups will be used to measure the energy and beam positions. Electronics have been developed that digitize the beam signal and measure the phase at the fundamental frequency, with no down conversion or mixing, providing a “real time” measurement. They are designed to be sensitive at the fundamental frequency. Log amp detector electronics will be used for signal processing.

Real time parameters of the proton beam hitting the Be target is the essential information for analysis of the LENS performance. A Bergoz Current Transformer (CT) installed in the location close to the Be target will provide such an information. This CT and another CT installed at the end of the DTL are planned to be a part of the Beam Spill Control System (BSCS). The BSCS is supposed to detect any unwanted beam loss and take action to save the equipment.

### ACKNOWLEDGEMENTS

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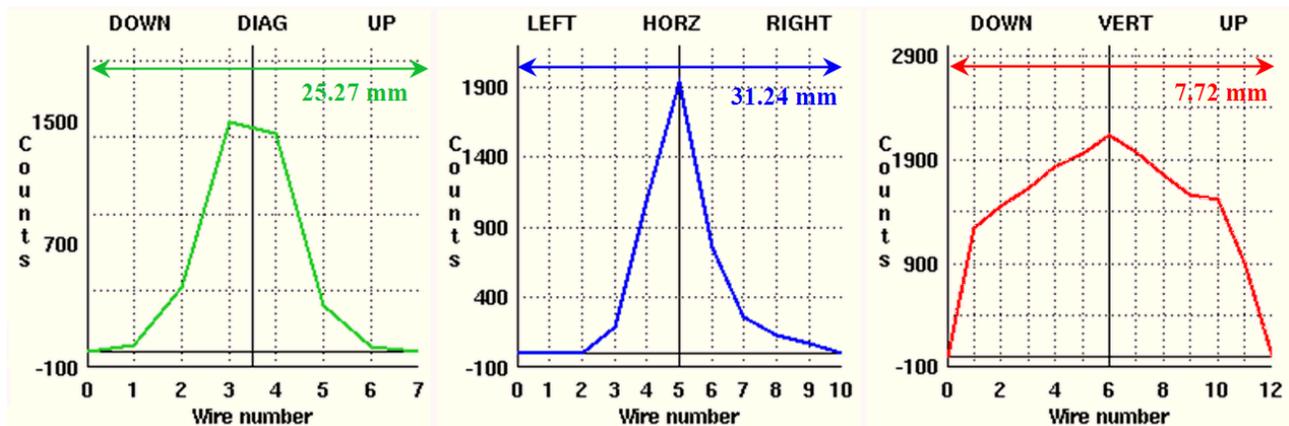


Figure 2: A screen capture of one of three harps in the NREP beam line. The beam pulse width is limited to 50  $\mu$ s in order to avoid damaging the 20 micron diameter wires.