LENS PROTON LINAC 6 KILOWATT OPERATION*

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Abstract

The Indiana University Cyclotron Facility is operating a Low Energy Neutron Source which provides cold neutrons for material research and neutron physics as well as neutrons in the MeV energy range for the neutron radiation effects studies. Neutrons are being produced by a 13 MeV proton beam incident on a Beryllium target. The LENS Proton Delivery System (PDS) is routinely operating at 13 MeV and 25 mA at 1.8% duty factor. The RF system, consisting of three Litton 5773 klystron RF tubes at 425 MHz and 1 MW each, power the AccSys Technology PL-13 LINAC. The proton beam delivers 6 kilowatts of power to the Beryllium target. Details of the beam spreading system, target cooling system, and accelerator operations will be discussed.

LENS OVERVIEW

The Low Energy Neutron Source (LENS) at Indiana University Cyclotron Facility (IUCF) is the first university-based pulsed neutron source in the U.S. LENS utilizes low energy (p,n) reactions in a beryllium target coupled to a light water reflector and cold methane moderator, to produce time-averaged thermal neutron fluxes suitable for neutron scattering and development of instrumentation. LENS has a three fold mission to perform research with neutrons, educate students in neutron science, and develop new neutron instrumentation and technology. LENS will also provide a test bed in the development of very-cold neutron sources.

LENS has two instrumented neutron beam lines: Small Angle Neutron Scattering (SANS) and Spin Echo Scattering Angle MEasurement (SESAME). The low proton energy used in LENS yields limited activation in the source, making this facility ideal for technical studies of neutron moderation and a variety of educational programs. The variable pulse length facilitates investigation of long-pulse instrumentation concepts. The low energy of the proton beam allows a lower moderator operating temperature (below 10K), giving a colder neutron spectrum.

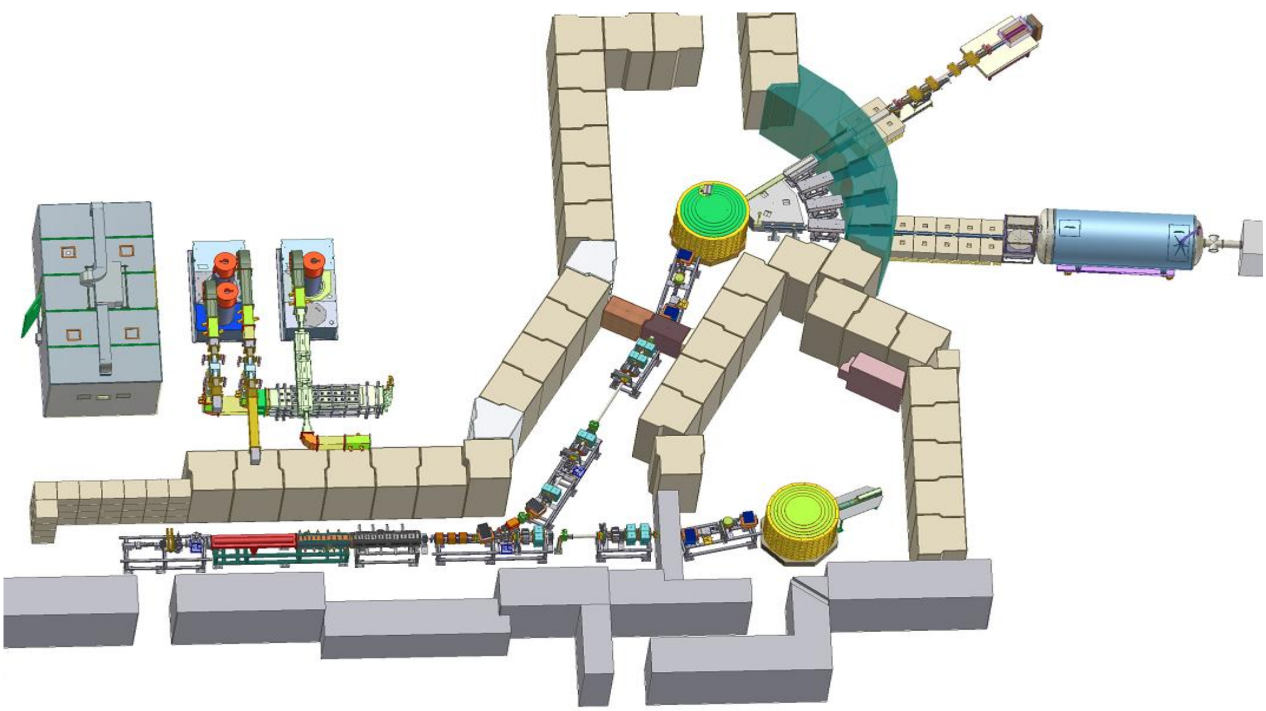

Figure 1: Layout of the LENS facility.

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THE LENS PROTON ACCELERATOR

The LENS proton accelerator provides a 25 mA (peak current), 13 MeV beam with a 1.8% duty cycle, 6 kilowatts of beam power, by utilizing a PL-13 LINAC. The proton beam has a variable pulse width ranging from 10 µs to 1.0 ms and a repetition rate of 10 to 40 Hertz.

The PL-13 consists of a 3 MeV Radio Frequency Quadrupole (RFQ) followed by a 4 MeV drift tube LINAC (DTL) section and a 6 MeV DTL section for a total energy gain of 13 MeV.

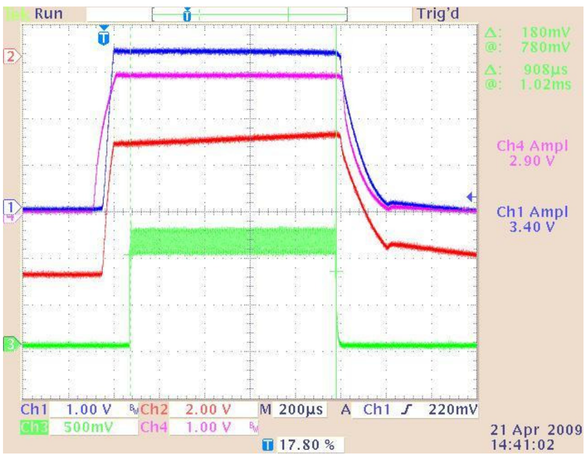

Figure 2: The Electron Current Pulse in the RF Klystrons as described in the text.

The LENS RF amplifier system uses the 1.25 MW, 425 MHz "BMEWS" klystrons to drive the RFQ / DTL structures. By utilizing a "totem-pole" modulator[1] with an "on-deck" and an "off-deck," fast klystron beam switching and RF capability is obtained. The LENS installation has two klystron modulator systems, a single tube klystron system and a two tube klystron modulator system. The klystron beam current rise time of the single tube modulator is about a 30 us (blue trace) and the 2 tube modulator has about a 75 us rise time (violet trace) as noted in Figure 2. What can be noted from these traces is that the beam currents are flat-topped. The flat-topped beam in the klystrons maintains the RF characteristics of the tube (e.g. output, gain) as well as minimizing the RF phase shift during bank voltage droop. By coupling the capacitor bank droop into the klystron modulator "on-deck" electronics, a fixed mod-anode to cathode voltage results in the flat-topped klystron beam currents. This klystron mod-anode voltage is depicted by the red trace in the Figure 2.

Figure 3 shows the proton beam pulse as measured by 2 current transformers, one at the accelerator exit (pink) and the other before the target (violet). The pulse is also monitored by a RF time-of-flight pickup shown in light blue.

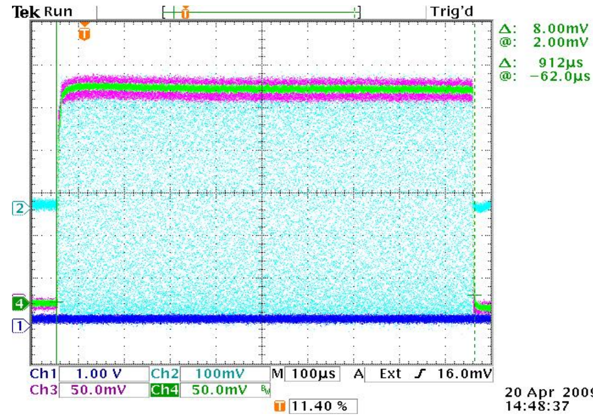

Figure 3: The 13 MeV Proton Beam Pulse as detected by 2 current transformers shown in red and green and an RF pickup shown in light blue.

PROTON BEAM OPTICAL SPREADING SYSTEM

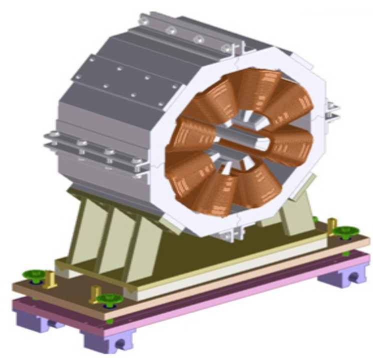

Figure 4: Octupole Magnet used for beam spreading system.

The proton beam is spread out on the target using non-linear focusing devices consisting of two octupole magnets shown in Figure 4. These magnets, one for X and the other for the Y direction, along with standard quadrupole magnets, produce a beam that is uniformly distributed across a 3 cm high by 7 cm wide area as seen in the Figure 5. With the target angled at 45 degrees relative to the proton beam, the power density on the beryllium plate is 200 Watts/cm^2 average (11 kWatts/cm^2 instantaneous).

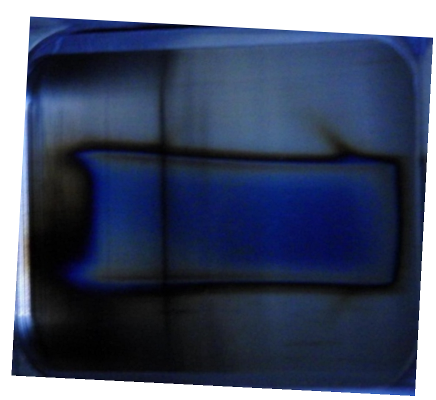

Figure 5: Beam profile on target.

The Beryllium target is a 4mm thick flat plate design that is directly cooled by water flowing across the back surface at 10 gpm. The water system is constructed of mostly aluminum piping chosen for its minimal activation and avoiding copper to minimize galvanic interactions. Sodium Nitrite is added to the water to minimize corrosion of the water system

THE TARGET-MODERATOR-REFLECTOR (TMR)

The LENS/TMR is designed as a source of cold and thermal neutrons that is both highly efficient and intense while remaining low in background neutrons. The design, shown in Figure 6, was optimized using the MCNP series of Monte Carlo codes.

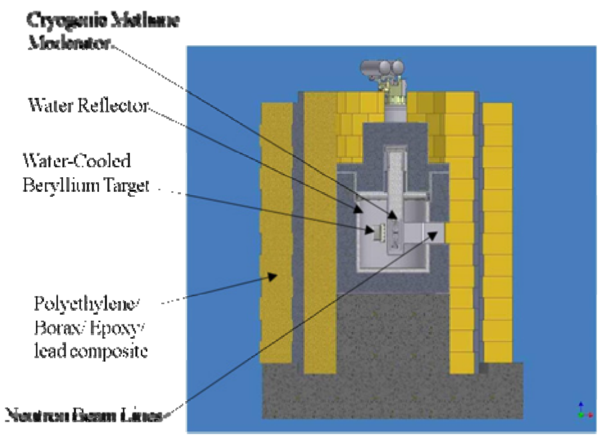

Figure 6: LENS target moderator and reflector design.

The moderator, tightly coupled to the Be target/neutron source through a slab geometry, sits inside a 50 cm diameter water reflector. The target is inclined to the proton beam at 45° to limit the thermal load and also reduce the fast neutron flux in the SANS beam line. The water reflector is separated from the shielding layers by a borated decoupler to limit activation of the primary lead gamma shield. The plot in Figure 7 shows the measured low energy neutron intensity from our 12x12x1 cm methane moderator at 6K.

The moderator and the TMR shielding was designed to allow frequent changes to the moderator system facilitating a moderator research program.

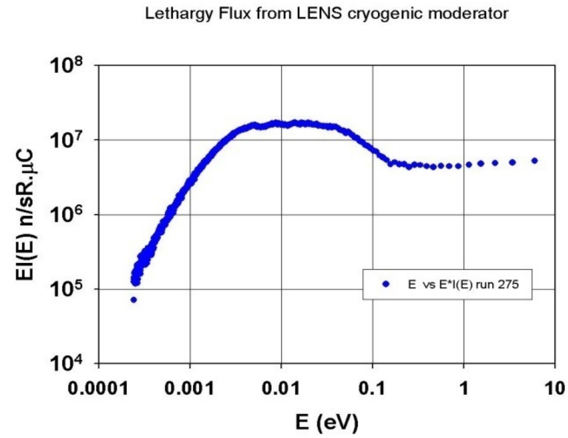

Figure 7: :EMS measured neutron flux from the cryogenic methane moderator.

SUMMARY

The LENS facility at IUCF is operational providing neutrons beams for neutron sciences. The proton accelerator has been reliably producing protons beams of 4kWatts beam power on target. After simple improvements in shielding and klystron reliability LENS will be routinely delivering 6kWatt beams.

The neutrons from LENS are being used for small angle neutron scattering (SANS) which is in the final stages of commissioning. The SESAME instrument has started taking neutrons and is in the initial stages of commissioning. Several experiments investigating the properties and improvements in neutron moderators have been completed and more are in progress.

REFERENCES

[1] Fast totem-pole grid-catch mod-anode modulator for the Indiana University “LENS” klystron RF amplifier system: W.A. Reass, W.T. Roybal, J.L. Davis, T. Rinckel, V.P. Derenchuk, 2008 IEEE International Power Modulators and High Voltage Conference, Las Vegas, NV, pp 235-237.