STATUS UPDATE ON THE LOW-ENERGY DEMONSTRATION ACCELERATOR (LEDA)*

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Abstract

As part of the linac design for the accelerator production of tritium (APT) project, we are assembling the first approximately 10-MeV portion of this cw, 100-mA proton accelerator. The primary objective of this low-energy demonstration accelerator (LEDA) is to verify the design codes, gain fabrication knowledge, understand beam operation, and improve prediction of costs and operational availability for the full 1000- to 1700-MeV APT accelerator. This paper provides an updated report on this past year's progress that includes extensive beam tests of the LEDA injector using the Chalk River Injector Test Stand (CRITS) radio-frequency quadrupole (RFQ) accelerator. The CRITS RFQ produces a cw, 100-mA, 1.25-MeV RFQ output beam. We also report on fabrication, assembly, tuning, and installation of the 6.7-MeV LEDA RFQ; installation and testing of the 350-MHz RF system; fabrication of the high-energy beam transport (HEBT); installation (as well as prototype testing) of the LEDA ogive beam stop; and upgrades to the facility. First tests with the 6.7-MeV, 100-mA, cw beam from the RFQ are scheduled for late fall, 1998. References are given to many detailed papers on LEDA at this conference.

1 INTRODUCTION

This overview paper summarizes activities completed and initiated on LEDA since the publication of ref. [1]. LEDA is designed as a prototype [2] of the first 10- to 20-MeV portion of the APT linac [3] that will be built at Savannah River. LEDA's beamline components now include a 75-keV proton injector, a 6.7-MeV RFQ, a HEBT, and a beamstop (Fig. 1). Initially, a 10 MeV CCDTL (coupled-cavity drift-tube linac, a hybrid between a standard DTL and a CCL structure) will be added after the RFQ tests are complete.

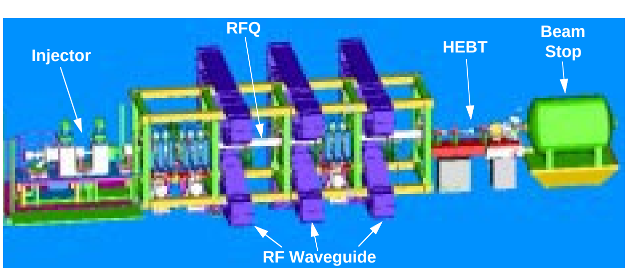

Fig. 1. Conceptual layout of the LEDA accelerator, showing the injector, RFQ (behind waveguides), HEBT, and beamstop.

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Even though the output energy is low (10 MeV), the average beam power (1.0 MW) of LEDA will rank it with the LANSCE accelerator as the two highest power proton linacs in the world. Clearly, radiation shielding and power handling are important design issues. We summarize the LEDA status as of early August, 1998.

2 SUBSYSTEM DESCRIPTION

Injector:

The injector must match a dc proton beam of at least 110 mA at 75 keV into the RFQ. A 2.45-GHz microwave proton source, a single-gap extractor, and dual magnetic solenoids provide this beam. The ion source requires only 500-800 W to create a suitable plasma from which a beam having >90% proton fraction and >30% gas efficiency is extracted [4]. The single-gap, spherically convergent extractor provides a beam with emittance <0.2 π mm-mrad (normalized).

The low-energy beam transport (LEBT) uses two solenoids and two steering coils to ensure a proper match into the RFQ. A well-cooled variable-iris device is used to control injected current [5], and a microwave power modulator is used to provide beam pulsing [6] for commissioning and beam-tuning activities. Multiple extended beam runs with this injector have shown it capable of the required current, emittance, and stability. Measured erosion rates show a predicted maintenance-free lifetime exceeding 400 hours. The LEBT physics design [7, 8] is in good agreement with the mechanical design [9] and detailed measurements [10]. The LEDA injector is now installed in the beam tunnel (Fig. 2).

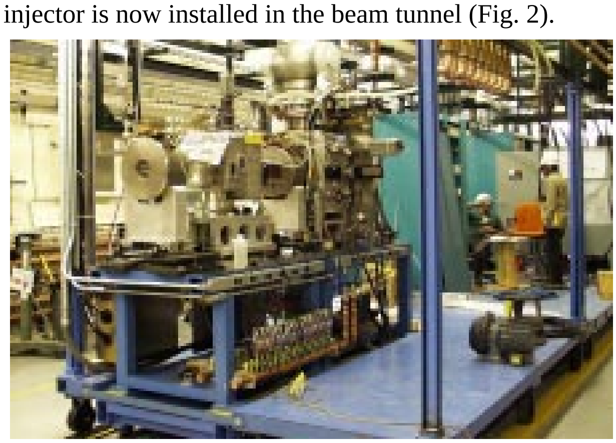

Fig. 2. LEDA injector installed in the beam tunnel.

The LEDA injector was used to inject a 50 keV proton beam into the CRITS RFQ. Beam operation with this 1.25-MeV cw RFQ is summarized in several papers at this conference [11, 12, 13]. Beam currents up to 100 mA were accelerated by the CRITS RFQ [12]. A modification of the source-plasma 2.45-GHz microwave power feed lowers the rms noise on the output proton beam to < ±1% [14]. Also, an on-line method for measuring the proton fraction of the hydrogen beam confirms the previously-measured ~90% H^+ fractions [15].

RFQ:

LEDA's RFQ [16-18] is unique in terms of its long physical length (8 meters), high output energy (6.7 MeV), large beam power (670 kW), and cooling requirements (1.2 MW). It is constructed as an all-brazed, 100% copper (OFE) structure, assembled from eight separate 1-meter-long sections [17]. When in operation, its only active resonance control is by modulation of the input water temperature.

Of the eight separate sections, three are used for 350-MHz RF power feed [19] via four 250-kW coupling irises (12 total) and three sections provide vacuum pumping. Each section includes 16 static slug tuners, used only for tailoring the initial field distribution. Fabrication of the LEDA RFQ [20], the vacuum system [21, 22] and the resonance-control cooling system [23] is complete; this equipment is installed in the LEDA beam tunnel (Fig. 3); and the RFQ RF-field tuning procedure is complete [24].

Fig. 3. LEDA RFQ installed in the beam tunnel.

CCDTL:

This new 700-MHz structure [25] captures features of a DTL and a CCL, using either one or two simple drift tubes inside each π-mode cavity. Test results [26] for a CCDTL "cold model" confirms the 2-gap to 3-gap transition section for the LEDA CCDTL. A CCDTL 'hot model' has been fabricated to test structure cooling and response [27]. The LEDA CCDTL will be installed after the LEDA RFQ has been commissioned and tested.

RF Power Systems:

Three 1.2-MW, 350-MHz, cw RF-power systems are installed to power the RFQ [28-30]. The first of three 700-MHz, 1.0-MW systems that will be used to test the CCDTL have also been installed [29]. A 95-kV IGBT (insulated-gate, bi-polar) power supply that will drive the 700-MHz klystrons is being developed [31]. Each of sixteen 350-MHz RF vacuum windows have been tested at power levels >950 kW [32]. During operation, twelve of these windows will be run at power levels up to 250 kW each. The high-power RF system is ready for RF conditioning of the LEDA RFQ.

Low-Level RF Systems:

The LLRF controls system will perform a number of functions including: set and maintain the proper phase and amplitude of all accelerating cavities [33], distribute reference signals along the beam line, monitor cavity resonance condition, and provide many field signals from cavity pickup loops.

Controls:

LEDA is using a distributed control system based on EPICS [34, 35]. Many LEDA sub-systems have localized control with dedicated PLCs (programmable logic controllers), but all operational status and control commands can be accessed through the EPICS operator interfaces. An EPICS station and all peripherals have been controlling the LEDA injector for more than three years. An automated control routine provides prompt, hands-off, full-beam recovery from injector high-voltage sparkdowns. The safety and protection systems are monitored using EPICS - in the case of the fast-protect system the beam is shut down within 10-20 μsec of an interrupt and the first fault is recorded by EPICS.

HEBT and Beam Stop:

The HEBT safely transports and matches the RFQ output beam to the high-power beamstop. The HEBT (described in [36]) contains beam diagnostics that allow confirmatory measurement of the beam parameters.

For tests at 6.7 MeV, the beam will impinge on a nickel ogive beamstop [37] that is mounted inside an aluminum vessel that contains borated water (Fig. 4) to provide excellent shielding against prompt neutrons. Preliminary calculations indicate this ogive beamstop apparatus will be suitable for use at 8- and 10-MeV operation with the CCDTL sections.

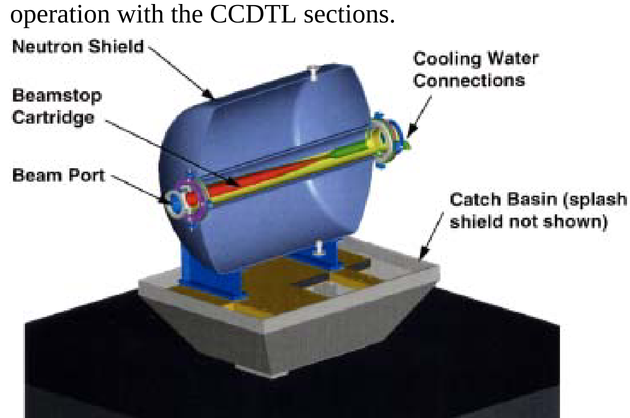

Fig. 4. LEDA ogive beamstop.

Beam Diagnostics:

The LEDA (mostly non-interceptive) diagnostics [38] measure and characterize the beam position [39] and the beam profile [40]: they also measure the beam current to obtain the RFQ transmission. This information will be used to operate the LEDA accelerator and to confirm the accelerator component designs.

Facility Modifications:

LEDA is installed in, and will be operated in, a pre-existing building that has a 140-m-long buried beam tunnel. The upgrades required to provide >10 MW of ac power and cooling water are nearly complete.

Safety Systems and Analysis:

A safety analysis document (SAD) has been prepared, reviewed, and approved. The LEDA accelerator readiness assessment is scheduled for this September. Operational run-permit is incorporated into the EPICS control system, with scores of interlocks to ensure that components and systems operate only when the risk of equipment damage is very low. A hard-wired fast-protect system ensures the near-immediate (10- to 20-μs) turnoff of the beam in event of beam spill as detected by fast ionization chambers. Totally separate from both these equipment safety systems, a personnel access control system (PACS) ensures that all personnel are excluded from the beam tunnel whenever beam or high rf power might be present. This PACS is very similar to the recently upgraded system in use at LANSCE.

3 SUMMARY

The LEDA project is on schedule to progressively assemble and test major components of a high-power, cw accelerator, first at 6.7 MeV, then 8 MeV, and then at 10 MeV. The possibility of testing the APT plant CCDTL at up to 20 MeV remains.

4 REFERENCES

[1] J. D. Schneider and K. C. D. Chan, “Progress Update on the Low-Energy Demonstration Accelerator (LEDA),” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 5W024 (in press).

[2] J. D. Schneider, “APT Accelerator Technology,” Proc. XVIII Int. Linac Conf. (Geneva, 26-30 Aug. 1996), pp. 22 -26.

[3] G. Lawrence and T. Wangler, “Integrated Normal-conducting/Super-conducting High Power Proton Linac for APT,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 5W020 (in press).

[4] J. D. Sherman *et al.*, Rev. Sci. Instrum. **69** (1998) 1003-1008.

[5] L. Hansborough *et al*., “Mechanical Design for the LEDA Low-Energy Beam Transport System,” to be published.

[6] T. Zaugg *et al*., “Operation of a Microwave Proton Source in Pulsed Mode,” this conf.

[7] H. V. Smith *et al*, “Simulations of the LEDA LEBT H^+ Beam,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 6W022 (in press).

[8] L. M. Young, “Simulations of the LEDA LEBT with H^+, H_2^+, and e^- particles,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 6W023 (in press).

[9] L. Hansborough *et al*., “Mechanical Engineering for the LEDA Injector,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 6W020 (in press).

[10] R. Ferdinand, *et al*., “Space-Charge Neutralization Measurement of a 75-keV, 130-mA Hydrogen-Ion Beam,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 6W010 (in press).

[11] G. O. Bolme *et al.*, “Proton Beam Studies with a 1.25 MeV, CW Radio Frequency Quadrupole LINAC,” this conf.

[12] J. Sherman *et al*., “Development and Test Results of the Low Energy Demonstration Accelerator (LEDA) Proton Injector on a 1.25 MeV CW Radio-Frequency Quadrupole,” this conf.

[13] H. V. Smith *et al*., “Comparison of Beam Simulations With Measurements for a 1.25-MeV CW RFQ,” this conf.

[14] P. Balleyguier *et al*., “Suppression of the 1-MHz Beam Current Modulation in the LEDA/CRITS Proton Source,” this conf.

[15] J. Kamperschroer *et al*., “Doppler-Shift Proton Fraction Measurement on a CW Proton Injector,” this conf.

[16] L. M. Young, “An 8-m-Long Coupled Cavity RFQ Linac,” Proc. 1994 Int. LINAC Conf. (Aug., 1994, Tsukuba, Japan), 178.

[17] D. Schrage *et al*, “A 6.7-MeV CW RFQ Linac,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 2W025 (in press).

[18] L. M. Young, “Simulations of the LEDA RFQ 6.7-MeV Accelerator,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 6W024 (in press).

[19] R. Valdiviez *et al*., “The Mechanical Design and Fabrication of a Ridge-Loaded Waveguide for an RFQ,” this conf.

[20] D. Schrage *et al*., “CW RFQ Fabrication and Engineering,” this conf.

[21] S. Shen *et al*, “APT/LEDA RFQ Vacuum Pumping System,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 4P017 (in press).

[22] K. Kishiyama *et al.*, “Testing of Vacuum Pumps for the APT/LEDA RFQ,” this conf.

[23] R. Floersch and G. Domer, “Resonance Control Cooling System for the APT/LEDA RFQ,” this conf.

[24] L. Young and L. J. Rybarcyk, “Tuning the LEDA RFQ 6.7-MeV Accelerator,” this conf.

[25] R. L. Wood *et al.*, “Thermal/Structural Design and Fabrication Development of High-Power CCDTL and CCL Structures,” Proc. XVIII Int. Linac Conf. (Geneva, 26-30 Aug. 1996) pp. 752-4.

[26] M. Cole *et al.*, “Test Results for a Cold Model of a CCDTL Two-gap to Three-gap Transition to be used in the Accelerator Region,” this conf.

[27] R. L. Wood *et al.*, “Status of Engineering Development of the CCDTL for Accelerator Production of Tritium,” this conf.

[28] D. Rees *et al.*, "Design, Operation, and Test Results of the 350-MHz LEDA RF System," this conf.

[29] D. Rees *et al.*, “Accelerator Production of Tritium 700-MHz and 350-MHz Klystron Test Results," this conf.

[30] W. T. Roybal *et al.*, “LEDA RF Distribution System Design and Component Test Results,” this conf.

[31] J. Bradley *et al.*, "Design, Construction, and Operational Results of the IGBT Controlled Solid State Modulator High Voltage Power Supply used in the High Power RF Systems of the Low Energy Demonstration Accelerator of the Accelerator Production of Tritium (APT) Project," this conf.

[32] K. Cummings *et al.*, "Results and Lessons Learned from Conditioning 1-MW, 350-MHz Coaxial Vacuum Windows," this conf.

[33] A. Regan, *et al.*, “LEDA LLRF Control System Characterization,” this conf.

[34] L. R. Dalesio *et al.*, Nucl. Instrum. Meth. In Phys. Research **A352** (1994) 179-184.

[35] M. Moore and R. Dalesio, “A Development and Integration Analysis of Commercial and In-House Control Subsystems,” this conf.

[36] W. Lysenko, J. D. Gilpatrick, and M. Schulze, “High-Energy Beam Transport Beamline for LEDA,” this conf.

[37] T. VanHagan *et al.*, “Design of an Ogive-Shaped Beamstop,” this conf.

[38] J. D. Gilpatrick *et al.*, “LEDA and APT Beam Diagnostics Instrumentation,” Proc. 1997 Particle Accelerator Conf. (Vancouver, 12-16 May 1997), Paper 8P058 (in press).

[39] J. D. Gilpatrick *et al.*, “LEDA & APT Beam Position Measurement System: Design and Initial Test Results ,” this conf.

[40] J. F. O’Hara *et al.*, “Design and Development of the LEDA Slow Wire Scanner Profile Measurement,” this conf.