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

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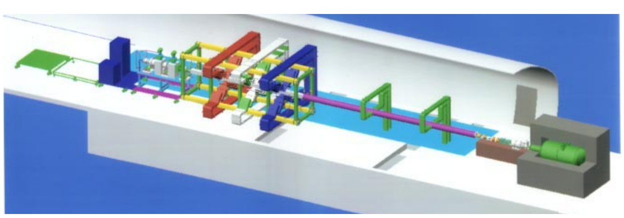
Abstract

As part of the linac design for the accelerator production of tritium (APT) project, we are assembling the first approximately 20 MeV portion of this cw proton accelerator. Primary objective of this low-energy demonstration accelerator (LEDA) is to verify the design codes, gain fabrication knowledge, understand LEDA's beam operation, and be able to better predict costs and operational availability for the full 1700 MeV APT accelerator. This paper provides an updated report on this past year's progress that includes beam tests of the 75 keV injector, fabrication of the 6.7 MeV radio-frequency quadrupole (RFQ), preparation of the facility, procurement and assembly of the rf system, and detailed design and documentation of many pieces of support equipment. First tests with the 6.7 MeV, 100 mA, cw beam from the RFQ are scheduled for late 1998. References are given to many detailed papers on LEDA at this conference.

1 INTRODUCTION

This overview paper will present only an executive summary of the many activities completed and underway on LEDA, the low-energy demonstration accelerator. In the process, we will reference the many recent publications and the several papers at this conference that provide much detail on LEDA activities.

LEDA is designed as a prototype [1] of the first approximately 20 MeV portion of the accelerator production of tritium (APT) accelerator [2] that will be built at Savannah River. Prototyping the first 20 MeV should significantly increase our confidence in this critical space-charge dominated structure [3,4,5]. LEDA's beamline components will include a 75 keV proton injector, a 6.7 MeV RFQ, and approximately 20 MeV of CCDTL coupled-cavity drift-tube linac), a hybrid between a standard DTL and a CCL structure.



Conceptual layout of the LEDA accelerator, showing injector, RFQ (behind waveguides), a section of the CCDTL, and the shielded beam stop.

Although being built at Los Alamos, and being led by Los Alamos personnel, LEDA represents a collaboration between several organizations. Major participants include: Westinghouse Savannah River Corporation, Lawrence Livermore National Laboratory, Allied Signal, Brookhaven National Laboratory, and heavy involvement by the APT Prime contractor, Burns and Roe Enterprises teamed with General Atomics. LEDA is intended to become the confirmatory prototype for the plant accelerator.

Even though output energy is low (20 MeV), the average beam power (2.0 MW) of LEDA will rank it as the highest power proton accelerator in the world. Clearly, radiation shielding and power handling are important design issues.

Most equipment ordering and detailed design on LEDA began in November, 1995, although some conceptual design was begun earlier. In the following paragraphs, we summarize the LEDA status as of early May, 1997.

2 SUBSYSTEM DESCRIPTION

Injector:

The LEDA injector is, at this time, the only fully operational part of the beamline hardware. This injector must supply a dc beam of at least 110 mA of protons at 75 keV into the radio-frequency quadrupole (RFQ) accelerator. The operational injector uses a 2.45 GHz microwave ion source, a single-gap extractor, and dual magnetic solenoids to provide this beam. The ion source requires only 500-800 Watts of power to create a suitable plasma from which a 90% proton beam with >30% gas efficiency may be extracted [6].

The single-gap, spherically convergent extractor provides a beam with emittance of less than 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 will be used to control injected current, and a microwave power modulator will be used to provide beam pulsing. Multiple extended beam runs with this injector have shown it capable of required current, emittance, stability; and measured erosion rates show a predicted maintenance-free lifetime exceeding 400 hours. LEBT physics design

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[7,8] is in good agreement with mechanical design [9] and detailed measurements [10].

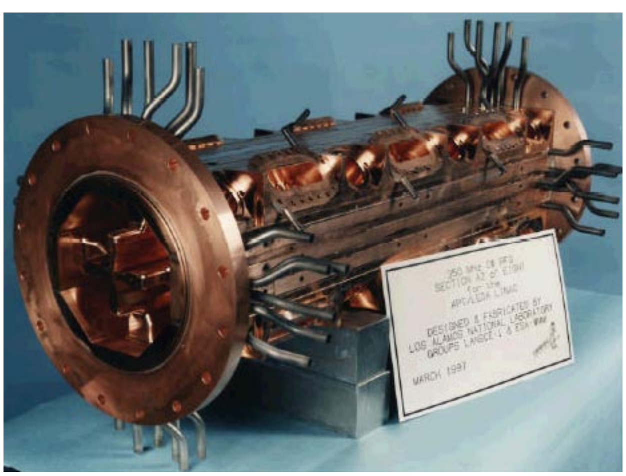
During the summer of 1997, the LEDA injector will be used to inject a 50 keV proton beam into the CRITS (Chalk River Injector Test Stand) RFQ. Beam operation with this 1.25 MeV cw RFQ will provide an additional confirmation of injector beam quality and will help to verify RFQ design codes.

RFQ:

LEDA's RFQ [11] is unique in terms of its long physical length (8 meters), high output energy (6.7 MeV), large beam power (663 kW), and cooling requirements (1.27 MW). It is constructed as an all-brazed, 100% copper (OFE) structure, assembled from eight separate 1-m long sections [12]. When in operation, its only active resonance control is by modulation of input water temperature.

Of the eight separate sections, three are used for 350 MHz rf power feed via four 250 kW coupling irises, three are used to provide vacuum pumping. Each section includes ports for 16 static slug tuners, used only for tailoring initial field distribution. Design and fabrication of the main structure is being done by and at Los Alamos. Livermore National Laboratory (LLNL) is responsible for the vacuum system [13], and Allied Signal's Kansas City Plant is doing the resonance-control cooling system. Specialists from Northrup/Grumman Corporation assisted with structural and thermal analysis, design reviews, and tuning.

At this point, the first two sections of the RFQ have seen the final fabrication steps; all others are in advanced stages of machining and brazing. These first three completed sections are leak-tight, dimensionally correct and appropriately tuned for rf fields. The eight sections of the complete RFQ will be assembled into four tuned segments, with inter-coupling plates to distribute RF power. Assembly of the entire structure should be complete in January, 1998, and first beam should be seen 6--11 months thereafter.



First completed 1-m long section of the LEDA RFQ.

CCDTL:

This new 700 MHz structure [14] promises to capture the best features of a DTL and a CCL, using either one or two simple drift tubes inside each π-mode cavity. All quadrupole focus magnets are outside the drift tubes and cavities, so alignment is not critical. Extensive measurements with a 'cold-model' calibrated our 3-D design codes and helped to tailor the coupling slots between all cavities. Within the next few months, a 'hot model' will be used to test structure cooling and response.

RF power systems:

LEDA will require a number of approximately 1-MW cw rf power systems [15] to power the RFQ and CCDTL cavities. Three 1.2 MW 350 MHz systems will feed into the RFQ. Three 700-MHz 1.0 MW systems will be needed for the CCDTL. In addition, LEDA facilities will be used to qualify and test all rf system components.

The first two 350 MHz klystrons have been shipped to Los Alamos, two 1-MW circulators have arrived, and the first transmitter (klystron electronics) is on hand. The first high-voltage power supply should ship soon. Meanwhile, crews at Los Alamos are assembling and checking all available components and support systems. Two 350 MHz rf vacuum windows were tested [16] with power levels of 950 kW. During operation, these windows will be run at 250 kW. During the last several months of 1997, we will be testing all rf components and preparing the setup of the three 350 MHz stations [17] needed for supplying power to the RFQ.

Low-level rf systems:

The sophisticated controls and electronics of the LLRF system will set and maintain proper phase and amplitudes of all accelerating cavities [18,19], distribute reference signals along the beam line and provide many feedback signals from the cavity and beam pickup devices.

Controls:

LEDA will use a distributed control system. EPICS was originated for GTA and has since been highly developed by use at the APS (Advanced Photon Source) and Jefferson Lab, in addition to nearly 50 world-wide locations, plus embraced and enhanced by at least three commercial ventures. Many systems will have localized control with dedicated PLCs, but all operational status and control commands can be accesses through the EPICS operator interfaces. Input/output controllers or IOCs will provide this local interface (through VXI and VME hardware) and provide links into the centralized database-driven communication. An EPICS station and all peripherals have been controlling the LEDA injector for more than the past two years. Automated control routines provide a prompt and complete hands-off, full-beam recovery from any interruption such as a high-voltage sparkdown.

Beam transport and beam stop:

The purpose of LEDA's beamline components after the accelerator are to safely carry the beam to a high-power dump, and to do confimatory measures of beam parameters. Initial testing will be done with a very simple transport line [20], merely to confirm RFQ performance. Later, a magnetic lattice similar to that used with the CCDTL can help to predict the critical matching between the different structures.

For tests at both 6.7 MeV and 11 MeV, the beam will impinge either on graphite tiles or a nickel-plated copper plate. This beam stop plate will be mounted inside a large vacuum vessel and surrounded by one-meter thick magnetite concrete to shield against both prompt and residual neutrons and gammas. A linearized 2-D beam rastering system [21] will be used to uniformly distribute the beam power over the beam stop surface.

Beam Diagnostics:

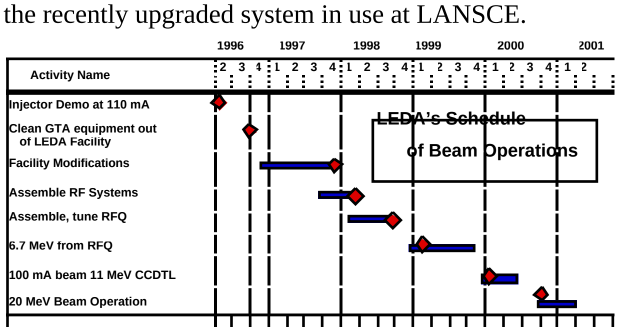
An important and essential feature of LEDA is the use of extensive (mostly non-interceptive) diagnostics [22] to measure and characterize the beam position [23,24], phase and energy [25]. This information will be used to confirm and refine accelerator designs.

Facility Modifications:

LEDA is being assembled and will be operated in the former GTA (Ground Test Accelerator) facility. This experimental structure, with a 140 m long buried beam tunnel, was built to house a 100 MeV, 100 mA, 5% DF accelerator. It is thus generally appropriate for LEDA, but requires upgrades to greater than 10 MW of ac power and cooling water.

Safety Systems:

Operational run-permit will be incorporated into the EPICS control system, with scores of interlocks to ensure that components and systems are operated only when the risk of equipment damage is very low. A hard-wired fast-protect system will ensure the near-immediate (10--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) will be used to ensure 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.



An environmental assessment (EA) was completed and approved for LEDA more than one year ago. Other than the increased use of ac power and water for cooling, environmental impacts from LEDA are extremely minor. Meanwhile, a draft safety analysis document (SAD) has been prepared and reviewed. This SAD is complete except for some refinements on the beamstop radiation calculations.

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 11.2 MeV, and finally at approximately 20 MeV. This collaboration of several national laboratories and international industries should advance significantly the technology of high-current, high-power accelerators.

4 REFERENCES

[1] J. D. Schneider, "APT Accelerator Technology," Proc. XVIII Int. Linac Conf. (Geneva, 26-30 Aug. 1996), pp. 22--26
[2] G. Lawrence, et al, "Integrated Normal-conducting/Super-conducting High Power Proton Linac for APT," this conf.
[3] L.M. Young, "Simulations of the LEDA RFQ 6.7-MeV Accelerator," this conf.
[4] L. M. Young, "Equipartitioning in APT Linac," this conf.
[5] S. Nath, et al, "Beam Dynamics Design for the APT Integrated Linac," this conf.
[6] J. D. Sherman *et al.*, "Development of a 110-mA, 75-keV Proton Injector for High-Current, CW Linacs," Proc. XVIII Int. Linac Conf. (Geneva, 26-30 Aug. 1996), pp. 701-3.
[7] H.V. Smith , et al, "Simulations of the LEDA LEBT H+ Beam," this conf
[8] L. M. Young, "Simulations of the LEDA LEBT with H+, H2+, and e- particles," this conf.
[9] L. Hansborough *et al.*, "Mechanical Engineering for the LEDA Injector," this conf.
[10] R. Ferdinand, *et al.*, "Space-Charge Neutralization Measurement of a 75-keV, 130-mA Hydrogen-Ion Beam," this conf.
[11] L.M. Young, "An 8-m Long Coupled-Cavity RFQ Linac," Proc. 1994 Int. LINAC Conf. (Aug., 1994, Tsukuba, Japan), 178.
[12] D. Schrage, et al, "A 6.7 MeV CW RFQ Linac," this conf.
[13] S. S. Shen, et al, "APT/LEDA RFQ Vacuum Pumping System," this conf.
[14] 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.
[15] D. Rees, "Design of 250-MW CW RF System for APT," this conf.
[16] K. Cummings, "Experimental Evaluation of 350 MHz RF Accelerator Windows for the Low-Energy Demonstration Accelerator," this conf.
[17] J. Bradley, "An Overview of the Low Energy Demonstration Accelerator (LEDA) Project RF Systems," this conf.
[18] Y. M. Wang, et al, "Algorithm and Implementation of APT Resonant Control System," this conf.
[19] A. Regan, et al, "APT LLRF Control System Model Results, " this conf.
[20] R. E. Shafer et al, "Overview of the APT High-Energy Beam Transport and Beam Expander"., this conf.
[21] C. R. Rose, et al, "A 200-A, 500-Hz, Triangle Current Wave Modulator and Magnet Used for Particle-Beam Rastering," this conf.
[22] J. D. Gilpatrick, et al, "LEDA and APT Beam Diagnostics instrumentation, " this conf.
[23] C. R. Rose, et al, "The LEDA Beam Position Measurement System," this conf.
[24] C. R. Rose, et al, "Description and operation of the LEDA Beam Position Measurement Module," this conf.
[25] J. F. Power, et al, "Design of a VXI Module for Beam Phase and Energy Measurements for LEDA," this conf.