HIGH-POWER AMPLIFIER CONSIDERATIONS FOR TESTING THE LAMP RFQ AND FIRST DTL CAVITY*

M. Sanchez Barrueta†, W. Hall, J. Lyles, R. Bratton, J. Lewellen, Los Alamos National Laboratory, Los Alamos, United States

Abstract

As part of the LANSCE Accelerator Modernization Project (LAMP), critical portions of the proposed accelerator will be tested as proof of concept and aid in planning the installation of LAMP at Los Alamos Neutron Science Center. As part of this demonstration, the radio frequency quadrupole (RFQ) and the first drift-tube linac (DTL) cavity will be tested with beam. For this purpose, high-power RF amplifiers are being designed to meet the testing demands. This is a description of the requirements of these amplifiers and how the design is intended to meet them.

INTRODUCTION

The LAMP project endeavours to replace the ion sources, low-energy beam transport and the entire drift-tube linac (DTL) section of the LANSCE accelerator [1]. The largely unchanged 1972 structures have increasingly shown signs of obsolescence and aging that has manifested in production beam down-time. LAMP intends to address this major area of concern while reusing a large portion of the recently updated radio-frequency (RF) power plant.

Currently, the beam is accelerated to 750 keV with a Cockcroft-Walton (C-W) DC accelerator, prebunched, and injected into the LANSCE drift-tube linac. Four DTL tanks (or cavities), driven by high-power 201.25 MHz amplifiers, accelerate the beam to 100 MeV. The first cavity uses a solid-state driven TH781 tetrode amplifier and the remaining three use the combined output of two TH628L Diacrodes (double ended tetrodes for high power RF) amplifiers driven by a single tetrode amplifier.

The current LAMP design uses a DC accelerator to achieve the first 65 keV of energy, an RFQ cavity to accelerate the beam to 2.1 MeV, and six DTL cavities to accelerate the beam to 100 MeV. The current high-power RF design incorporates either a dual tetrode or a single Diacrode amplifier feeding the RFQ, and separation of the existing three dual-Diacrode amplifier stations into six individual Diacrode amplifiers. Other changes to the system include the installation of separate 90 kW solid-state power amplifier (SSPA) drivers feeding each Diacrode amplifier, as well as circulators as reflected power protection, and small changes to the existing high-voltage power supplies and capacitor banks. Additional low-level radio-frequency (LLRF) controls and cRIO-based controllers will be required to independently monitor and regulate cavity resonance and low-voltage controls.

To demonstrate the performance of the key design features, a test with a subset of components, namely the ion-sources, low-energy beam transport, RFQ, medium-energy beam transport and first DTL cavity are expected to be performed [2] in an existing accelerator building originally used to test the Low-Energy Demonstration Accelerator (LEDA) [3]. The building in question is called Accelerator Development and Experimental Facility (ADEF) and the reduced test is named LAMP in ADEF Tunnel (LAT). The description of the estimated RF power plant used to provide power to these RF cavities follows.

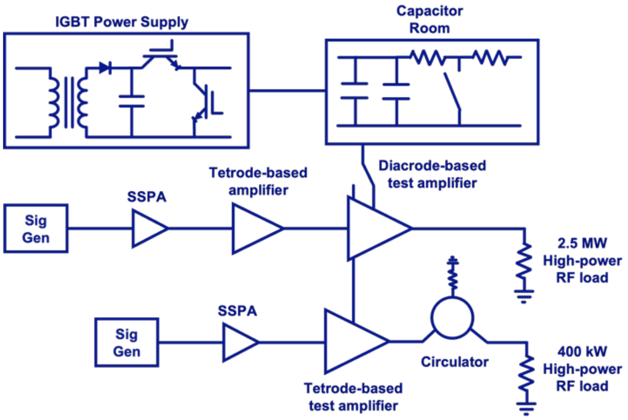

Figure 1: Block-diagram for the existing 201.25 MHz high-power amplifier test stand at LANSCE.

EXISTING TEST STAND

The original 1968 triode-based RF amplifiers for the DTL cavities experienced shortened lifetimes and adversely impacted beam availability in 2006. From 2014 until 2021, during individual maintenance periods, single RF amplifiers were upgraded to the current tetrode-driven dual-Diacrode version [3]. The expected power delivered for a single DTL cavity at LANSCE is 2.7 MW, with a 1.35 MW peak power delivered per Diacrode amplifier. All amplifier components used during the upgrades were tested under operational conditions in a test stand [4] located in the LEDA building, a block-diagram for which can be found in Fig. 1. In 2017-2020, an addition was made to the test stand to allow testing of the first drift tube linac RF amplifier [5], which due to lower power requirements, only uses a single tetrode.

The test stand is composed of an IGBT power supply providing charging current to a 225 µF capacitor bank (crowbar protection device included). A signal generator

---

*Work was performed under the auspices of the US Department of Energy by Triad National Security, LLC, under contract 89233218CNA000001.

†msb@lanl.gov

provides the exciting waveform amplified by a successive SSPA and tetrode-based amplifier into the final Diacrode based amplifier and load. This section of the test stand is used to verify the operation of RF and high-voltage components used in all DTL power systems. A photograph of the major RF components of the test stand can be found in Fig. 2.

The capacitor bank can alternatively provide power to a solid-state driven tetrode-based amplifier that has the capabilities to demonstrate operation of any DTL cavity 1 component to full production power.

Figure 2: Existing high-power RF amplifier test stand for DTL modules.

POWER REQUIREMENTS

The estimated power required by the LAMP RFQ and DTL1 cavities is 430 kW and 366 kW, respectively. Considering additional power losses due to the input coupling loop, the RF coaxial line and ferrite of the circulator, the estimated power required for both RF amplifier is between 400 and 600 kW. To accelerate beam through both the RFQ and first DTL cavity, two RF amplifiers are required with independent amplitude and phase control. One of these cavities can potentially be fed by the existing Diacrode test stand; an additional amplifier will be needed to provide power to the other structure. We also anticipate conditioning all LAMP DTL cavities (2-6) full power (1-2 MW) in the tunnel. On top of that, all other high-power RF components will utilize the test stand to demonstrate full production capabilities.

The estimate for the power required for the RFQ and conditioning DTL2-6 is well within the capabilities of the existing test stand, used currently for short periods of time to test 2.5 MW pulsed operation and to test Diacrode tubes and amplifier components to more that 25 % over their nominal requirements in operation at LANSCE.

CHANGES TO TEST STAND

The RF power will need to be driven by a LLRF system to provide fast feedback and feedforward control for beam loading compensation. A high-power circulator will be installed at the output, to be tested to full operational capabilities and a coaxial switch will allow independent testing of LANSCE and LAMP components to the 1-2 MW nominal values and operation of the RFQ. Controls will have to be modified to allow use of the test stand with a signal generator when the cavity is not in a functional state (i.e. being conditioned), and must also be aware of the state of the coaxial switch. A set of hardware interlocks will be placed to simultaneously allow operational flexibility and perform safety and machine controls to disallow any undesirable state. Major changes to the test stand can be seen in Fig. 3.

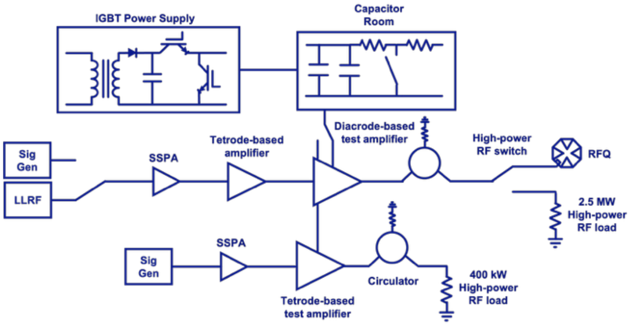

Figure 3: Amplifier test stand reconfiguration to provide power to the RFQ test stand while maintaining current testing capabilities.

ADDITIONAL RF AMPLIFIER

An additional RF amplifier will be needed for the excitation of the first DTL cavity. The required power can be achieved with minimal redesign via either of two topologies; other solutions are also being considered. The merits of these are under discussion.

Both topologies involve an upgrade to an existing LAMP power supply and the procurement of a capacitor bank and related control systems modeled after the existing capacitor bank for the test stand. This is required to provide the high-voltage DC power for either of the amplifier solutions proposed. Photographs of the capacitor room are presented in Fig. 4 and its major electrical components are shown in Fig. 5. Additionally, both proposed systems would utilize a 90 kW solid-state power amplifier (SSPA), in order to ensure sufficient drive power and test the SSPA required for LAMP.

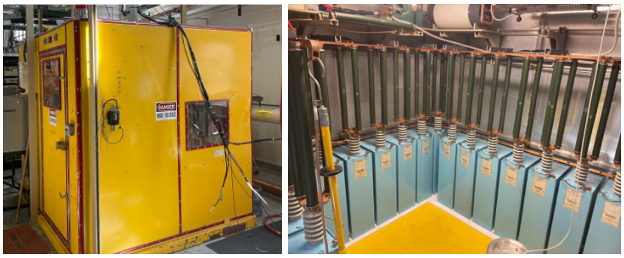

Figure 4: Outside photo of the capacitor bank used in the current amplifier test stand (left) and capacitor arrangement inside bank (right).

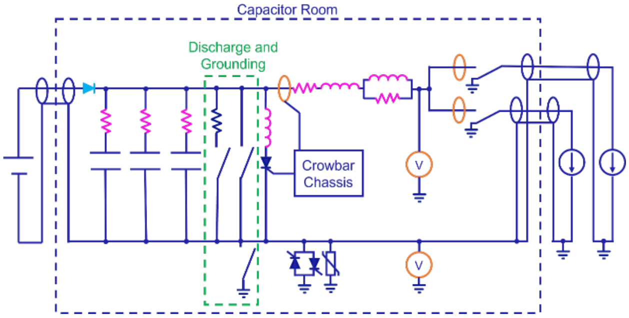

Figure 5: Schematic representing the electrical connections and major component for the capacitor bank and related components.

One possibility is to use a Diacrode amplifier at reduced power capabilities. Due to the amplifier operating at a set-point well below its capabilities, a reflected power protection such as a circulator will not be needed. The block-schematic representing this topology can be found in Fig. 6. The second possibility is to use the combined output of two tetrode amplifiers where the RF drive provided by the SSPA would be split, amplified, and recombined to provide power to the DTL cavity. This solution would require the use of circulators. The block-schematic representing this can be found in Fig. 7.

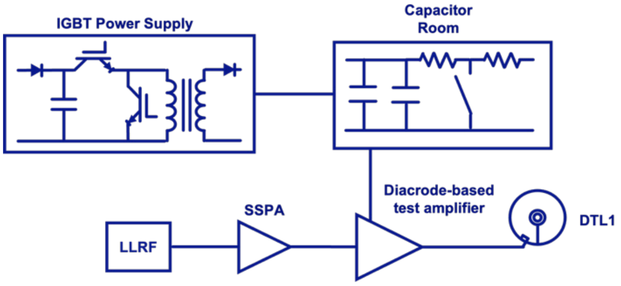

Figure 6: First possible topology for first DTL cavity amplifier system.

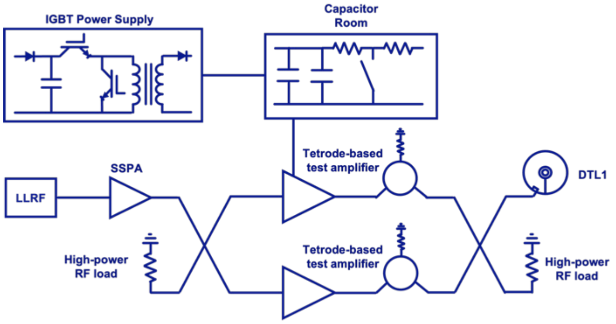

Figure 7: Second possible topology for first DTL cavity amplifier system. Possibility of 2 separate circulator devices presented, other solutions are being considered.

Additional fast (μs range for RF and high-voltage faults) and slow (ms range low-voltage controls and water and air cooling) controls will be implemented as well as a separate LLRF system. Hardware interlocks will be used to perform safety and machine controls and disallow any undesirable state.

ONGOING EFFORTS

Specifications are being produced and procurement is ongoing for all major updated components for LAT and LAMP including the 90 kW SSPA amplifier, the high-power RF switch, the 2 MW capable circulator [6], the capacitor room and other major components. The potential use of 12” EIA coaxial line for RF power transmission to the RFQ cavity, its RF losses and mechanical supports are being considered for both the LAT and LAMP applications. Additionally, alternate current prime power requirements are being calculated to determine any necessary changes to the building infrastructure.

CONCLUSION

This paper presents a summation of the recent changes to the power requirements in the LAT accelerating cavities and the ongoing considerations to provide RF power and control sufficient for testing the accelerator proof of concept and the cavity RF conditioning. Major components are being procured and the major topologies addressing the power requirements are being discussed.

REFERENCES

[1] K. Bishofberger *et al.*, “Overview of the LAMP Conceptual Design”, presented at the IPAC'26, Deauville, France, May 2026, paper WEP4317, this conference.

[2] R. Thornton *et al.*, “LAT: a 9-MeV prototype “front-end” for the LANSCE Accelerator Modernization Project”, presented at the IPAC'26, Deauville, France, May 2026, paper WEP4318, this conference.

[3] H. V. Smith, J. D. Schneider, and R. Sheffield, “Low-Energy Demonstration Accelerator (LEDA) test results and plans,” in *2001 Particle Accelerator Conference*, Ed., in PAC-01, vol. 5. IEEE, pp. 3296–3298. `doi:10.1109/pac.2001.988089`

[4] J. T. M. Lyles *et al.*, “Design of a New VHF RF Power Amplifier System for LANSCE”, in *Proc. IPAC'10*, Kyoto, Japan, May 2010, paper THPEB062, pp. 4014-4016.

[5] J. T. M. Lyles *et al.*, “New RF System for First Drift Tube Linac Cavity at LANSCE”, in *Proc. NAPAC'19*, Lansing, MI, USA, Sep. 2019, pp. 703-706. `doi:10.18429/JACoW-NAPAC2019-WEPLM49`

[6] D. Dimitrov *et al.*, “Perspective on Procurements of Major Components for the LANSCE Accelerator Modernization Project (LAMP)”, presented at the IPAC'26, Deauville, France, May 2026, paper WEP4322, this conference.