

PROGRESS ON NEW HIGH POWER RF SYSTEM FOR LANSCE DTL*

J. Lyles[#], S. Archuletta, J. Davis, D. Rees, P. Torrez, LANL, Los Alamos, NM, USA
D. Baca, Sandia National Laboratory, Albuquerque, NM, USA

Abstract

A new 201.25 MHz RF system is being developed for the LANSCE proton drift tube linac (DTL). A planned upgrade will replace parts of the DTL RF system with new generation components. When installed for the LANSCE-R project, the new system will reduce the total number of electron power tubes from twenty-four to seven in the RF power plant. The 3.4 MW final power amplifier will use a Thales TH628 Diacrode[®]. This state-of-the-art device eliminates the large anode modulator of the present triode system, and will be driven by a new tetrode intermediate power amplifier. In this mode of operation, this intermediate stage will provide 150 kW of peak power. The first DTL tank requires up to 400 kW of RF power, which will be provided by the same tetrode driver amplifier. A prototype system is being constructed to test components, using some of the infrastructure from previous RF projects. High voltage DC power became available through innovative re-engineering of an installed system. A summary of the design and construction of the intermediate power amplifier will be presented and test results will be summarized.

ORIGINAL DTL RF SYSTEM

The LANSCE 800 MeV linac uses an Alvarez DTL driven at 201.25 MHz to accelerate both H⁺ and H⁻ beams from 0.75 to 100 MeV for injection into a coupled-cavity linac to reach the final energy. High peak RF power (~3 MW) along with significant average power (~300 KW) is typically required from the DTL RF system. The first DTL tank is the shortest, requiring approximately one tenth of the power of the other three. All four systems use the same amplifier lineup in their RF systems: a Burle Industries 4616 tetrode is used in a pressurized RCA Y1068 amplifier for the intermediate power amplifier (IPA), driving a Burle Industries 7835V4 triode in a pressurized Continental Electronics final power amplifier (FPA). Twenty-four tubes are used for the four DTLs, with five different types including modulator tubes. Over the years, most of the downtime of the linac RF plant has been attributed to the FPA and its high-level anode modulator assembly [1]. A major refurbishment (LANSCE-R) project [2] will soon replace the 39 year old IPA and FPA stages with modern amplifiers using new power tubes having higher average power capability. The goal is to reduce the number of power tubes in use to seven, with only two unique types used in the DTL. Elimination of the power-consuming series anode

modulator will reduce operating costs, simplify the configuration and improve reliability. Having higher permissible anode dissipation in the FPA tubes should reduce the frequency of tube failures, while giving LANSCE future capabilities to increase beam time for various programs through increased duty factor.

NEW MEDIUM POWER AMPLIFIER

A Thales TH781 power tetrode has been chosen to replace the 4616 tetrode IPA stage for the modernization program at LANSCE. It is a compact pyrolytic graphite-gridded tube, with efficient anode and screen grid cooling. At 200 MHz it is specified to generate as much as 200 kW CW or 500 kW at low duty factor. We found the latter rating to be conservative.

The Thales TH18781 cavity amplifier (Fig. 1) uses water-cooling for the anode, the screen grid connection, and for the body of the cavity. It also uses forced-air cooling for the tube socket connections, the filament stem, parts of the cavity and output transmission line.

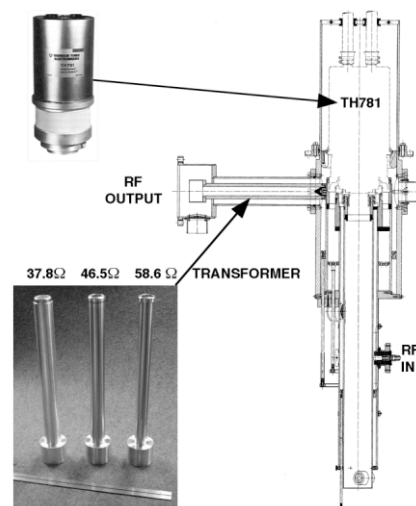


Figure 1: Thales tetrode and cavity amplifier, output transformer with various center conductors for matching.

A compact new amplifier was assembled using the TH18781 and tested for our applications. Cooling system, power supplies and protective interlocks were controlled using an Allen Bradley Flexlogix programmable controller. A 4616 tetrode power amplifier was temporarily used as a driver to provide the TH781 with up to 25 kW of input power. A high power coaxial output load was assembled using two existing 200 kW CW resistor loads paralleled using a 3 dB hybrid power splitter.

* Work supported by the NNSA, US Department of Energy under contract DE-AC52-06NA25396.

jtml@lanl.gov

Intermediate Power Amplifier Application

The TH781 was tested with sufficient output to cathode-drive an FPA at 120 to 150 kW. This is compatible with the new TH628 FPA under development at LANSCE. The output matching of the amplifier is implemented using a series $\lambda/4$ coaxial line transformer, shown in figure 1. This length of 7.94 cm OD coaxial line transitions to a 15.56 cm OD flanged connector at 50 Ω . In order to operate at the lower power levels efficiently with improved gain, the center conductor ID of the transformer was changed, to raise the impedance presented to the anode. The original transformer characteristic impedance was 37.8 Ω , and two additional transformers were constructed with $Z_0 = 46.5$ and 58.6 Ω . The low Z transformer is required when operating over 300 kW, to reduce the anode voltage swing at high power for best tube and cavity reliability. Numerous tests were conducted with variations of operating parameters to obtain the best linearity, while maintaining acceptable efficiency and gain. With the 58.6 Ω transformer, optimal anode voltage was 14 kV DC, and current was 6.4 Amps quiescent, and 20.4 Amps peak at 159 kW pulsed power. Stage gain was 16 dB with 54.5% DC to RF efficiency.

Final Power Amplifier Application

In the early days of LAMPF (predecessor to LANSCE), two type 4616 tetrodes were originally used to drive the first DTL tank for a 4.64 MeV energy ramp, using a quadrature hybrid combiner without a circulator. There was difficulty balancing the two amplifiers, driven by a cascade of small tetrodes, keeping matched phase and gain, while driving the resonant DTL load after the combiner. In 1974, one larger RCA 4664 tetrode was configured to drive the DTL. This arrangement remained until 1987 when the tube was no longer available from the manufacturer. In 1988 the RF amplifier chain used for tanks 2 through 4 (4616 \rightarrow 7835) was duplicated for tank 1, eliminating further problems. The anode and filament voltages of the 7835 FPA were reduced to operate the amplifier at 15% of its normal output power. This system is "overkill" for the application, consuming considerable power for the 7835 filaments and modulator.

The new TH781 amplifier will also work as a stand-alone amplifier with a coaxial circulator to drive the first DTL tank. This single amplifier would replace the existing cascade of tetrode IPA and triode FPA, along with anode modulator. Power requirements for this application are 305 kW for the DTL structure, or a total of 403 kW, including 98 kW for 21 mA of peak beam current. Additional headroom will be needed for circulator and transmission line losses, plus control margin. Figure 2 shows the general arrangement.

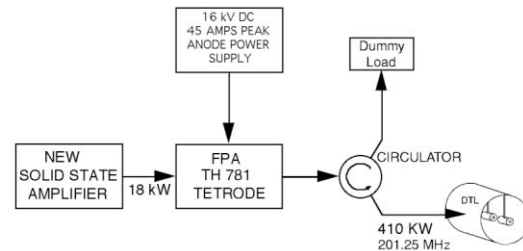
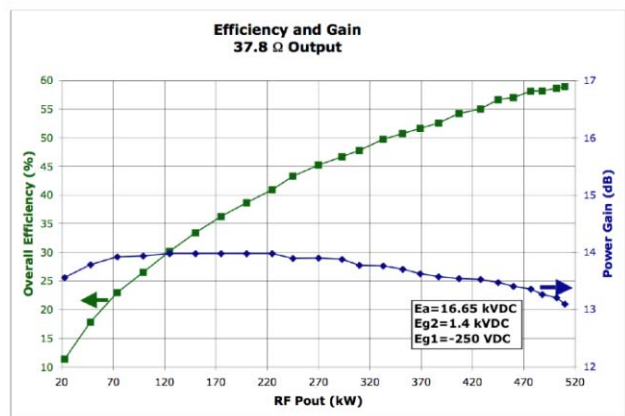
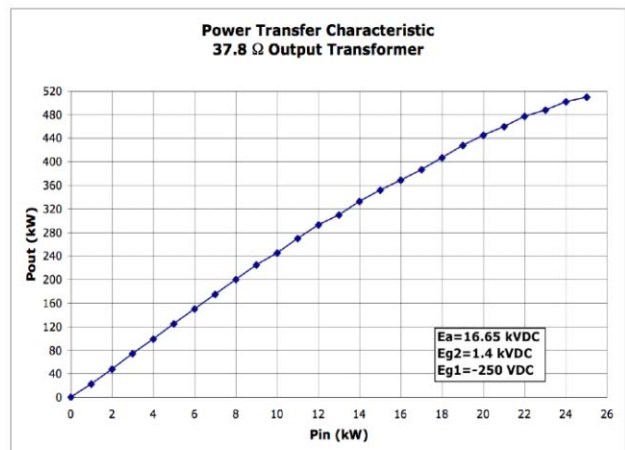


Figure 2: New RF system for DTL tank 1.

Test results with the low impedance transformer are plotted below. Anode voltage was 16.5 kV DC, and anode current was 7 Amps quiescent, and 44 Amps peak at 407 kW pulsed RF output, with a class AB₂ operating point. Stage gain was 13.5 dB with 54.7% DC to RF efficiency.



Figures 3a (top) and 3b (bottom): DTL tank 1 FPA test

RF DRIVER STAGE

There are two variations of driver/preamplifier required. The existing solid-state drivers at LANSCE are capable of 5.5 kW peak at 15% DF and will be redeployed to drive the new IPAs for DTL 2-4. A new solid-state amplifier will be required to drive the FPA at DTL 1, with a maximum power rating of 24 kW. We wish to avoid tube technology at this power level, due to a diminishing commercial market and concerns for long-term availability of devices. This linear amplifier is commercially available, using a modified version of a modern band-IV analog television transmitter.

HIGH POWER TEST SYSTEM

The advantages of using the Thales TH628 double-ended tetrode, or Diacrode[®], for the FPA driving DTL tanks 2 – 4 has been discussed previously, along with the development of the cavity amplifier at LANSCE [3][4][5]. Considerable thought has gone into making an amplifier to produce 3.4 MW peak power at 15% duty factor, at the Los Alamos elevation (2133 m above sea) without pressurization. We are building a high power test facility for this amplifier that will also be used for component and tube testing for the LANSCE-R DTL RF system. The project has been able to reuse a facility with ample power and water-cooling utilities that was part of the Low Energy Demonstrator Accelerator for APT. The general layout of the test area is shown in figure 4, with the FPA surrounded by a permanent work platform, and the new capacitor bank adjacent to a circulator under test. A photo inset shows the interior of the capacitor bank. It contains 225 μF , charged to 28 kV DC, along with a crowbar device and resistors.

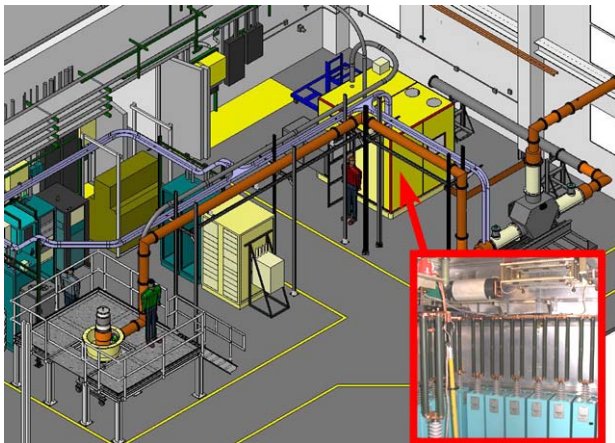


Figure 4: High Power Test Area

The charging power supply is required to provide up to 30 kV at 40 Amps DC. This represents a respectably large and costly unit. The idle LEDA accelerator facility contained two-megawatt CW beam supplies, made by Continental Electronics [6]. They make use of a novel method to gain high efficiency without resorting to mains frequency SCR phase control for regulation. With a series stack of 96 small 1.1 kVDC power supplies, each powered by a separate isolated transformer secondary, the overall unit could provide up to -95 kV at 21 Amps. With some re-engineering done by the manufacturer, the wiring of the individual IGBT-switched power modules was reconfigured to make a power supply capable of up to 45 kV at 40 Amps, with the negative terminal grounded as required for a gridded tube. The photograph in figure 5a shows the interior of the power supply cage with the stacks of IGBT-switched power supplies in two large frames, and the primary transformers in the foreground. A block diagram of the modified power supply is shown in figure 5b. Reconfiguring this power supply saved considerable expense and time for the project.

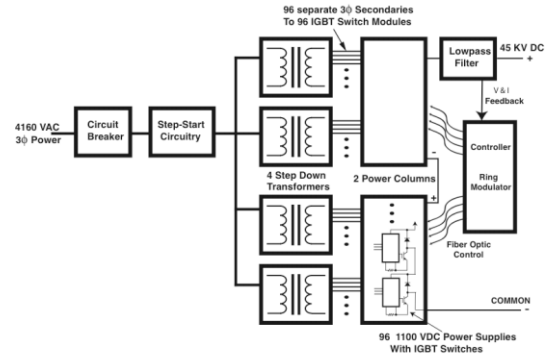
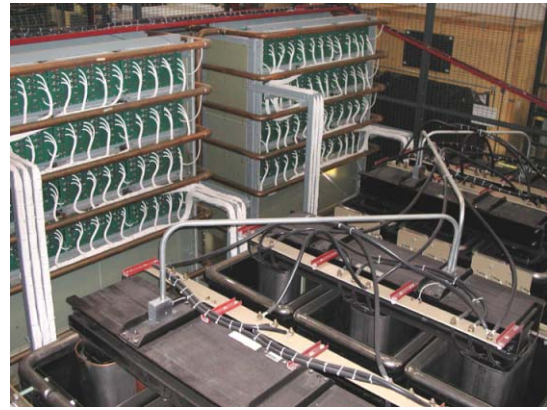


Figure 5a (top) and 5b (bottom): Converted power supply

CONCLUSION

Many components of the DTL 201.25 MHz RF system will be replaced, as a new generation of RF amplifiers is being built for LANSCE-R. The IPA has been developed and tested satisfactorily. A high power test facility is being built to allow full-power testing of a new FPA and associated components, that will later be installed at the DTL during the installation phase of LANSCE-R.

REFERENCES

- [1] K. Young, G. Bolme, J. Lyles et al., "LANSCE 201 MHz and 805 MHz RF System Experience", PAC'07, Albuquerque, June, 2007, to be published.
- [2] D. Rees, G. Bolme et al., "LANSCE RF System Refurbishment", PAC'07, June, 2007, to be published.
- [3] J. Lyles, C. Friedrichs, M. Lynch, "New High Power 200 MHz RF System for the LANSCE Drift Tube Linac", LINAC'98, Chicago, August, 1998, pp. 228-230.
- [4] J. Lyles, D. Clark, J. Davis et al., "Progress on the New 200 MHz RF System for the LANSCE DTL", PAC'01, New York, April, 2001, pp. 996-998.
- [5] J. Lyles, S. Archuletta, G. Bolme et al., "A New 201.25 MHz High Power RF System for the LANSCE DTL", EPAC'02, Paris, June, 2002, pp. 2329-2331.
- [6] J. Bradley, D. Rees et al., "Operational Experience with Two Types of 2 MW HVDC Power Supplies on LEDA", PAC'99, New York, 1999, pp. 1010-1012.