Ground Test Accelerator (GTA) Drift Tube Linac (DTL) Fabrication and Assembly Status*

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Abstract

The Los Alamos Ground Test Accelerator (GTA) Drift Tube Linac (DTL) is a ten module assembly of 1-m long cryogenically cooled accelerating cavities capable of accelerating a 100-mA H^- beam from 2.5 to 24 MeV. Each module is fabricated from high-conductivity copper and is operated in the 20-50K range. The DTL is designed for continuous wave (cw) operation when cooled with supercritical hydrogen or at 2% duty factor when cooled with helium.

Fabrication, assembly, and testing of the DTL modules is progressing well. All peripheral components have been fabricated and assembled in preparation for installation onto the DTL modules. The drift tube fabrication incorporating cryogenically cooled samarium-cobalt quadrupole magnets is progressing well. DTL module #1 has been assembled, cryogenically tested for alignment and frequency stability, high power conditioning completed, and the module installed onto the GTA beamline. Modules #2-5 are in various stages of cryogenic testing and high power conditioning. Modules #6-10 are in various stages of assembly, drift tube alignment, room temperature tuning, and cryogenic testing.

This paper describes the overall status of the DTL modules with regards to fabrication, assembly, testing, and the associated GTA beamline operational schedule.

Introduction

A modular, cryogenically cooled drift tube linac (DTL) is being fabricated, assembled, and tested at the Los Alamos National Laboratory as part of the Ground Test Accelerator (GTA) neutral particle beam program. The drift tube linac consists of ten, 1-meter long modules and raises the beam energy from 2.5 MeV, at the exit from the intertank matching section (IMS), to 24 MeV after the tenth module. The DTL operates at 850 MHz and is designed to deliver a 100-mA H^- beam at 2% duty factor when cooled with gaseous helium. Reference 1 provides an overall description of the DTL system and operating parameters.

Fabrication is completed on all DTL modules and peripheral components. All peripheral components are complete and are ready for installation onto the remaining DTL bodies. Drift tube fabrication is progressing well with drift tubes through module No. 7 installed and the remainder in various stages of assembly.

A typical assembled DTL module is shown by Fig. 1 and indicates the complexity of the overall assembly. The assembly consists of cryogenically cooled components, eg, dynamic rotary tuners, post-couplers, end walls, drift tubes, a moveable magnet for steering the beam, and the DTL body. All are connected to inlet and outlet cryogenic helium cooling manifolds with 54 flexible stainless steel cryogenic hoses to supply cooling to the various components.

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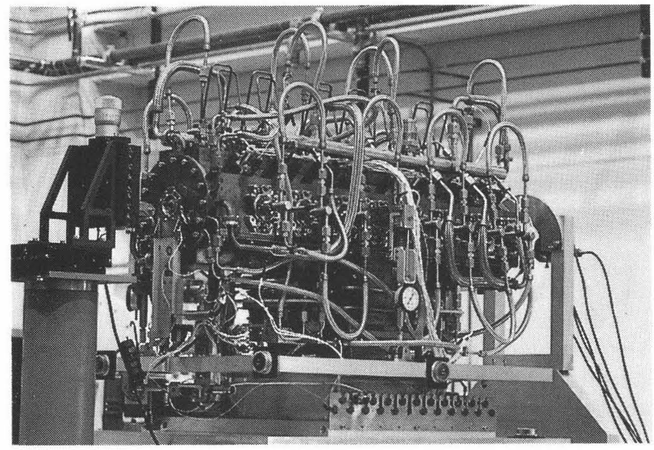

Fig. 1 Assembled DTL Module.

DTL Body Fabrication

Fabrication of a DTL copper body consists of many steps including, a) annealing of the 1000 pound OFE copper forgings, b) gun drilling of the cryogenic cooling passages, c) rough machining the body and lid, d) cleaning, e) brazing of coolant line fittings and plugs, f) coordinate measuring machine inspection of the bore and post-coupler holes, and g) final boring to close tolerance. Process development was required for many aspects of the copper body production, including gun drilling of coolant passages, brazing, and accurate machining of annealed copper. The resulting DTL bodies are then fitted with thread inserts to facilitate attachment of all peripheral components without damage to the soft copper structure.

Peripheral Components

Many peripheral components are required for assembly of a DTL module. These consist of cryogenically cooled dynamic rotary tuners, post-couplers, drift tubes, and tank end walls. Also, a beam steering magnet assembly, drift tube adjusters, slug tuners, rf monitor loops, attenuating tubes, tuning bars, cooling manifolds, and cryogenic hose assemblies are required to completely assemble a DTL module. Many of these components require brazing, welding, and close tolerance machining to meet the operational requirements of the DTL module. Of special interest are the following components:

Post-couplers. Post-couplers are tuning devices that align and stabilize the accelerator field. It is a 1/4 wavelength resonator, which when tuned to the tank frequency, provides the desired transverse stabilizing electric field for each drift tube in the DTL cavity. The small DTL cavity diameter relative to the drift tube body diameter requires that the post-coupler body is machined with an annular cutout concentric with the center stem to tune it as a

1/4 wave resonator at the tank resonant frequency. This allows the center stem to extend beyond the DTL cavity wall and still provide the localized electric field modification required near the drift tubes. The tip is rotated to align the field to the desired distribution and ramp. Rotating the tip can move the field ± 5% cell to cell.

Drift Tubes. Drift tube fabrication consists of many steps to produce a completed drift tube assembly. The basic process includes machining of the OFE copper components for the drift tube body, E-beam welding the coolant channel sleeve and stem, final machining the magnet cavity, installing the permanent magnet quadrupole and cover plate, E-beam welding the cover plate, final machining the outside surface, inspection, and pressure and leak testing. The completed drift tube has tooling flats machined to very close tolerances on the outside surface and the stem is accurately aligned to the drift tube body to allow accurate alignment of the drift tube in the DTL module.

Flexible Cryogenic Hoses. Commercial flexible stainless steel cryogenic hoses were obtained with tube stub-outs on each end for welding fittings. The tubes are pre-bent to the required angle for custom fitting to the DTL module during installation. The ends are trimmed, and fittings butt-welded with a WeldLogic® PA-100C automatic tube welder. The resultant flexible hose assemblies are helium leak checked, pressure tested, and installed on the DTL module between the inlet and outlet cooling manifolds and the appropriate peripheral components to provide cryogenic helium coolant to the cooling circuits.

Room Temperature Alignment

The initial installation of the drift tubes provides only a rough mechanical alignment of the drift tubes within the DTL body. Since a very close alignment of drift tube magnetic centers is required for operation of the DTL on the beamline, a procedure, described by reference 2, using an electrically pulsed taut-wire is utilized to achieve an alignment tolerance within a 0.002-in. diameter zone for all drift tube magnetic centers. The drift tubes are also positioned very accurately in the axial direction within ± 0.001-inch of their nominal location using a laser interferometer.

Room Temperature RF Tuning

The cavity rf tuning consists of several operations which are used to set the cavity frequency. The overall cavity frequency is set by adjusting the thickness of the tuning bars, which adjusts the cavity volume to resonate at the proper frequency. This process uses three sets of aluminum tuning bars of different thicknesses, alternately, inside the cavity to determine the effect of tuning bar thickness on cavity frequency. The frequency and height of the aluminum bars provides data to generate a curve used to machine the actual copper bars to the required thickness for final installation into the cavity. Also, the dynamic tuner paddle frequency shift is calibrated to determine the available tuning range and set to mid-range for dynamic tuning capability on the beamline.

The method used to make the electric field measurements utilizes a beadpull apparatus to perturb the electric field in the gaps between the drift tubes, whereby a metallic bead on a monofilament line is pulled through the drift tube centers at a constant rate. The bead displaces the field in the gaps as it moves through the cavity. This causes a cavity frequency shift proportional to the amount of field displaced by the bead. Monitoring the frequency shift allows the cavity field to be mapped. The cavity field is then adjusted using this data from the beadpull measurements by rotating the post-coupler tips to attain the desired field distribution and drift tube accelerating ramp gradient. The cavity field stability is checked by attempting to tilt the field down on one end and up on the other end by de-tuning the end cells. The field is then tilted in the opposite direction. The difference in this tilt comparison indicates the stability.

Coupling of the rf power from the waveguide to the DTL module is determined and the opening or iris from the waveguide to the cavity is machined to the required size to provide the desired rf power coupling.

The cavity Q is proportional to the rf power dissipation in the cavity from electrical resistivity effects from the cavity surface and any rf seals. This parameter is measured at room temperature and at cryogenic temperature so that a comparison can be made to determine the Q-enhancement at cryogenic temperature. This provides an indication of the rf power dissipation that can be expected for operation at cryogenic temperature.

Final Assembly and Cryogenic Testing

Final assembly consists of several steps, primarily related to achieving proper cryogenic coolant flow for operation in the Low Power and High Power cryogenic test beds and on the beamline. The drift tube cooling circuits are welded using the WeldLogic® PA-100C automatic tube welder and the inlet and outlet lines are connected to the previously installed cooling manifold. All other cooling lines are installed to the post-couplers, rotary tuners, and module cooling circuits. Flow orifices are also installed in each cooling circuit to provide flow equalization and minimize the use of cryogenic helium. After final assembly, a pressure test is conducted at 410 psig and a final helium leak test is made.

Cryogenic Taut-wire Alignment and Steering Magnet Adjustment. The DTL module is installed into the Low Power Cryogenic Test Bed (LPCTB) for cryogenic operation as shown by Fig. 2. A taut-wire alignment apparatus similar to the initial alignment apparatus, but modified to operate in vacuum, is installed. Taut-wire measurements are made at room temperature and atmospheric pressure to verify the initial alignment. Measurements are made again at room temperature and vacuum to establish a baseline for vacuum operation, and again at cryogenic temperature to determine what effects occur from room temperature to 20K. Also, the steering magnet movement is monitored from room temperature to 20K to evaluate the change in position due to the differential thermal contraction of the steering magnet mounting arm. The differential contraction is approximately 0.010-in., and the steering magnet assembly is shimmed to compensate for this movement at cryogenic temperature. Ref. 3 provides additional information regarding the testing setup and results.

Cryogenic Tuning. Cryogenic tuning is also conducted in the LPCTB. Following disassembly of the taut-wire alignment apparatus, the cryogenic beadpull apparatus is installed into the vacuum vessel. The beadpull is used to make an electric field distribution measurement at room temperature and again under vacuum to check out equipment

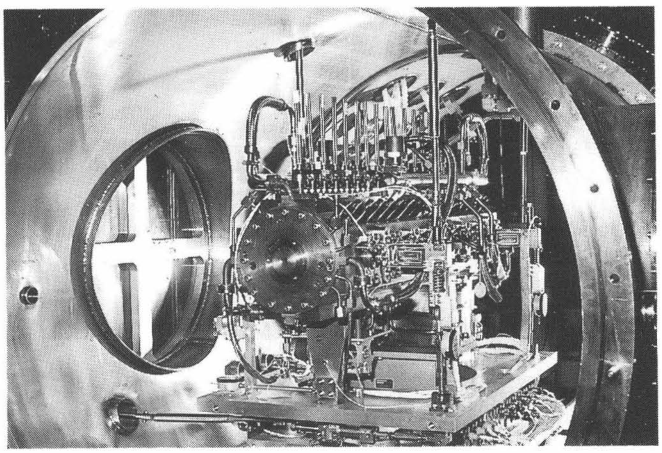

Fig. 2 DTL Module Installed in the LPCTB.

and verify the initial field determination made in the tuning laboratory. Measurements are made again at 20K to evaluate the cavity frequency and to operate the rotary tuner through its dynamic tuning range. Also, the cavity Q is measured to determine the Q-enhancement between room temperature and 20K.

Cryogenic Hi-Power Conditioning. High power conditioning of a DTL module is a process in which the rf power level and pulse length are increased to effectively "process" the surface of the waveguide and DTL cavity to reduce and/or eliminate multipacting and high-voltage breakdown. It is believed that as the power level is increased, progressive stages of surface outgasing and secondary electron emission are reduced, thus enabling eventual achievement of the desired operating conditions. High power conditioning has progressed very well through DTL module #3. Figure 3

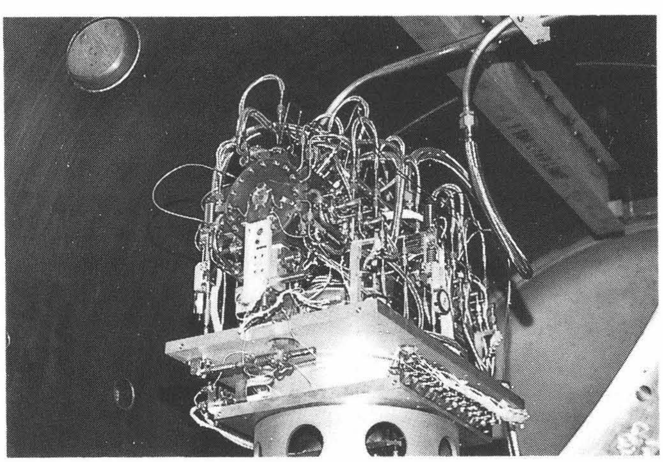

Fig. 3 DTL Module Installed in the HPCTB.

Summary

shows a DTL module installed in the High Power Cryogenic Test Bed (HPCTB) for high power conditioning. Ref. 4 provides more detail regarding the conditioning process and results.

The DTL subsystem of the GTA project has overcome many technical obstacles related to the fabrication, assembly, and testing of the modules. Currently the production of these modules is proceeding smoothly and should provide operational DTL modules as required by the GTA schedule. Cryogenic alignment checkout and high power rf conditioning is planned for all modules before installation onto the GTA beamline. This testing is also proceeding on schedule and is providing modules ready for assembly on the GTA beamline for future beamline experiments.

The initial offline testing of the first DTL module produced cryogenic operational results well within the required performance specifications for operation on the GTA beamline. This module was then assembled on the GTA beamline for characterization and beam transport testswith the othr beamline components, including the injector, radio-frequency quadrupole (RFQ), and the intertank matching section (IMS).

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