STATUS OF ENGINEERING DEVELOPMENT OF CCDTL FOR ACCELERATOR PRODUCTION OF TRITIUM*

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Abstract

The Coupled-Cavity Drift Tube Linac (CCDTL) is a relatively new RF accelerator structure which plays a major role in the APT Low-Energy Linac (LEL) design. Engineering development is pushing ahead on several fronts, including thermal management, fabrication procedures, cavity and coupling slot tuning, high-power prototype fabrication and testing, supports and alignment, vacuum, and provisions for beam diagnostics. Fabrication of the CCDTL Low-Beta Hot Model is nearly complete, and high-power RF tests will commence soon. In 1999, we will begin the fabrication of 11 meters of CCDTL to be added to the Low-Energy Demonstration Accelerator. In 2001, it will take the 100 mA beam from 6.7 MeV to 10.05 MeV, producing the world's most powerful proton beam. We are also starting the design of a CCDTL 96 MeV Hot Model to demonstrate cooling of an intermediate-beta version of the structure. The 14 cm-long, 9 cm diameter 96 MeV drift tube dissipates roughly 5 kW. This all leads to the final mechanical design of the 113 m long CCDTL for the APT plant linac.

1 INTRODUCTION

The CCDTL concept was invented in 1994 [1] to answer the stringent demands of the waste-transmutation and tritium production accelerator applications. Although several low-power aluminum "Cold Models" have been built and tested, no CCDTL has yet been operated at high power or with particle beam. Before taking that step, there are many "trivial" engineering details which must be worked out. This would be a significant effort, even if the first application were low power. Some unique fabrication and tuning methods must be developed, while vacuum pumping, cooling, resonance frequency control, and RF interfacing must be adapted from similar systems used on common Coupled Cavity Linacs (CCLs).

This paper presents the status of this engineering effort, without giving much background about how we got here, or why. The following discussion covers topics, results, and plans in four areas: mechanical prototype tests, RF cold models, the CCDTL Low-Beta Hot Model (LBHM), and the APT Low-Energy Demonstration Accelerator (LEDA), phase 3A (6.7-8 MeV) and 3B (8-10 MeV)[2].

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2 ARCHITECTURE

The APT LEL has evolved significantly since the presentation of the Conceptual Design, mostly in response to practical engineering considerations.[3][4] There are still three distinct types of CCDTL (single 2-gap, single 3-gap, and double 2-gap segments) to carry the 100 mA proton beam from 6.7 to ~100 MeV, but the transition points have been moved to eliminate mixing of types within a RF module. This mixing caused a variety of mechanical issues in earlier versions of the design, but there is not enough space to discuss them here.

Marked changes in the focusing period were made to provide needed empty space for magnets and beam diagnostics in the 10-to-50 MeV range. This in turn prompted a change from 6-cell to 7-cell CCL segments in the >100 MeV portion of the LEL [4].

This lattice change indirectly causes a "tolerance stack-up" problem in the CCDTL which is remedied by changing to 3-cell bridge couplers to join the brazed sections (see below). This solution does not work in the 10-to-21 MeV portion, where the 3-gap CCDTL type is used.

3 RF STRUCTURE MATERIALS AND FABRICATION METHODS

Several of the CCDTL's new mechanical features have been under development for the last three years. Most have to do with either fabricating or cooling drift tubes. We have previously reported on the design and predicted performance of coolant passages within the drift tubes[5]. Recently, we have performed experimental measurements which suggest that these passages are actually much more effective than originally thought[6]. We will be repeating these measurements on drift-tube prototypes from a different part of the LEL to further prove the cooling scheme before actual RF structures are built.

Material properties and brazing continue to be areas of concern, primarily with vacuum and RF attachments to OFE copper structures. Originally, we had chosen to use alumina-dispersion strengthened (Glidcop™) copper for all components which are exposed to RF and require strength, such as drift-tube stems and accelerating cavity flanges. Until recently, large equatorial flanges were planned to join the 1-to-1.6-m-long brazed sections into long RF modules. The aforementioned tolerance stack-up problem made it easy to choose to eliminate the flanges from the design, but, as previously mentioned, we have not found a practical alternative for the 10-to-21 MeV portion of the LEL. For now, at least, there are about 15 of these flanged joints still in the plan.

Our first attempts at brazing OFE drift tubes and Glidcop™ stems into OFE cavities were very good, but recent attempts have had some problems. The 50-50 Au-Cu braze alloy has produced all leak-tight joints, but they do not look like the kind of clean cosmetic joints we want inside a high-power RF cavity. Although copper plating is expected to help, this added step may tip the scales back toward plated stainless steel.

There have also been several improvements made in our machining and braze fixturing which should insure good parts in our future fabrications.

The vehicle for much of this development is the LBHM, a 1-m-long piece of CCDTL corresponding to 7.6-8.8 MeV in the original LEDA design. At the time of this conference, all of the pre-tuning fabrication and brazing are complete, and cavity and slot tuning activity is about half complete. Following tuning, the assembly will go through its final assembly braze, be installed on its test stand, and tested at up to 135% of its intended RF fields.

4 RF STRUCTURE TUNING

Although 2-D and 3-D modeling can give us a very good understanding of the CCDTL cavities, we find that simple, relatively inexpensive aluminum "cold models" are the only sure way to determine complex 3-D properties like coupling coefficients and frequency dependency on coupling. Several cold models have been built to simulate various cavities in the 6.7-10 MeV range and we have developed many refinements in our testing and tuning methods[7].

These methods are being put to the test in the tuning of the LBHM, now underway. Despite our earlier cold modeling, we have encountered several new problems. Specifically, although the coupling slot predictions are very close, the accelerating cavity frequency predictions are off by more than 5MHz in some cases (<1%). Since the LBHM will not be used with beam, we have aggressive ways to deal with this, but this will not be acceptable on LEDA. Apparently, extrapolations from too few cold models is not a good idea, and 2MHz tuning range might not be enough, even with better data.

Our approach for LEDA phase 3A is to build more cold models, matching the 6.7 and 8 MeV endpoints, in hopes that interpolation over a short range of β will yield cavities which are closer to the target frequency. The 6.7 MeV Cold Model has already been built and is being very thoroughly tested. An extensive 8 MeV Cold Model has been designed, but we are waiting to see what new data will come from the 8 MeV LBHM and the 6.7 MeV cold model before starting fabrication. We hope to complete all work on these new cold models by December 1998.

5 ELECTROMAGNETIC QUADRUPOLES (EMQ)

The spatial constraints placed on the LEL EMQs are very stringent, requiring an innovative approach to their design. A 2-fold symmetric geometry has been developed, several prototype versions have been built and tested, and a "final" LEDA version is in the final design stage.

Because of the large number of magnets, and the overall congestion of all areas around the beam line, alignment of the magnets after installation could be a problem. For this, and to minimize personnel radiation exposure, we will be pre-aligning all of the magnets off-line, to a common standard, on semi-kinematic mounts. The calibration and pre-alignment standard has been designed, and is being assembled by General Atomics.

6 SUPPORTS AND ALIGNMENT

All alignment-critical components are mounted on hardened rails within the linac tunnel. The ultimate alignment of these components depends on the stable "straightness" of these rails. The rails are mounted atop rigid steel chassis, ranging from 2 to 4 meters in length, which are placed end-to-end for the entire length of the LEL. An afocal optical system is used to straighten the rails to within 25 µm. Internal optics and loading hardware provide means to sense and correct the mid-point deflection of each chassis, which will return the rails to within 10 µm of its original shape for almost any conceivable loading condition[8].

A detailed design and prototype are the next step. LEDA hardware is due by December 1999.

7 RESONANT FREQUENCY CONTROL/ COOLING AND VACUUM SYSTEMS

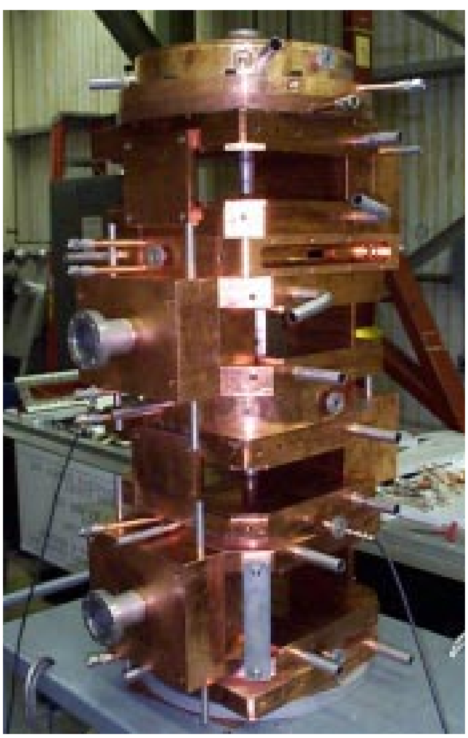
Again, the LBHM has been the vehicle for development. A cooling and resonant frequency control system has been fully implemented in miniature, by Allied Signal, for use on the 30-40 kW LBHM. The test of this system is one of the key objectives of the LBHM.

A brute-force approach has been taken for the vacuum system for the LBHM, but a conceptual design for the LEDA CCDTL vacuum system is under development at

LLNL. For maximum cost/performance and reliability, each 2 to 4 m chassis will have a dedicated large diameter manifold with 2 to 4 large ion pumps and one turbo pump attached. Detailed design of the LEDA Phase 3a hardware will commence soon, followed by fabrication, ready for installation in January 2000.

8 CCDTL LOW-BETA HOT MODEL EXPERIMENT

The LBHM will be the first high-power test of the CCDTL concept, and the driving force for fabrication and tuning method development. Various aspects of this effort are covered in the previous sections. The main objectives include the refinement of cooling and resonance control system designs, and to measure the system's ability to cope with errors in local coolant flow rates. We expect to install the completed LBHM in Oct 98, and to complete high power experiments by January 99. This data will be immediately applied to the design of the LEDA and plant accelerators.



9 LEDA PHASE 3A CCDTL DESIGN

While we await the completion of the cold modeling effort, we have proceeded with the mechanical design of the 5 meters (24 accelerating segments with 20 "sideways" coupling cavities in four brazed sections, plus the three 3-cell bridge couplers) of LEDA Phase 3a CCDTL. Unigraphics™ Parametric Solid Modeling™ is used heavily, allowing us to "complete" most of the drawings without the final dimensions. Once the missing values are finalized, software will read the physics dimensions from spreadsheets, and the models and drawings will be automatically updated. Again, we are hoping for completion of the cold models by Dec. 98, the cavity tables by Jan. 99, and completion of the LEDA Phase 3A drawing package by Feb. 99, fabrication to commence immediately afterward.

10 96 MEV HOT MODEL

Most of the work described above is aimed at the low-energy end of the CCDTL, since that will be built and operated first. But the worst case thermal problems are at the other end of the CCDTL. We are planning to build and test a 1.4m-long high-power prototype of the final two CCDTL segments (@ 96 MeV) to address this part of the parameter space. Fabrication is expected to begin by mid-1999, with tests to begin by early-2000.

The drift tubes in the 96 MeV cavity are roughly the size of a beverage can and dissipate ~5 kW of RF power. This drift-tube will require a very dense coolant passage network. Prototypes are being fabricated now, and cooling experiments conducted as before.

11 CONCLUSION

Despite less than overwhelming funding to date, significant progress has been made toward the systematic completion of the APT LEL design. Key design topics have been, or soon will be, explored, leading to the completion of the LEDA Phase 3a CCDTL over the next two years. Subsequent steps are planned to cover any and all remaining topics.

12 REFERENCES

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