MECHANICAL FEATURES OF A 700-MHZ BRIDGE-COUPLED DRIFT-TUBE LINAC*

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Abstract

Modern linac designs for treating radioactive waste achieve high proton currents through funneling at low energy, typically around 20 MeV. The resulting switch to a high-frequency accelerating structure poses severe performance and fabrication difficulties below 100 MeV. Above 100 MeV, proven coupled-cavity linacs (CCLs) are available. However, at 20 MeV one must choose between a high-frequency drift-tube linac (DTL) or a coupled-cavity linac with very short cells. Potential radiation damage from the CW beam, excessive RF power losses, multipactoring, and fabricability all enter into this decision. At Los Alamos, we have developed designs for a bridge-coupled DTL (BCDTL) that, like a CCL, uses lattice focusing elements and bridge couplers, but that unlike a CCL, accelerates the beam in simple, short, large-aperture DTL modules with no internal quadrupole focusing. Thus, the BCDTL consumes less power than the CCL linac without beam performance and is simpler and cheaper to fabricate in the 20 to 100 MeV range.

Introduction

Design studies conducted in the late 1980s demonstrated that modest to moderate extensions of today's high-current linac technology can be applied to high-current CW-type machines required for accelerator transmutation of waste (ATW). However, two significant areas of accelerator technology must first be developed. One is a two-legged micropulse funnel to operate at about 20 MeV; the other is a reliable device for accelerating the resulting double-frequency beam above 20 MeV. One might suppose that a standard high-frequency Alvarez DTL would suffice between 20 and 100 MeV. After all, high-frequency DTLs, such as the 425 and 850-MHz DTL's developed for the GTA program at Los Alamos, are relatively common. However, while these machines are high-current (100 mA) designs, they also are designed to operate at either low duty factor or at CW for short periods at cryogenic temperatures. All of these DTLs use Nd-Fe or Sm-Co permanent magnet quadrupoles (PMQs) inside the drift tube envelopes.

We believe that an ATW linac delivering a 200-mA CW beam requires radiation-hardened electromagnetic quads (EMQs) for energies above 10 MeV. Such EMQs will fit into drift tubes at about 350 MHz before the funnel, but will not fit into 700-MHz drift tubes downstream. Why not lower the operating frequency of the system to, say, 200-400 MHz? This frequency would undoubtedly aid the design of EMQ-equipped drift tubes and even possibly increase the ratio of bore tube to beam diameter. In this frequency range, however, the problems of designing and fabricating a coupled-cavity linac would increase dramatically, since standard brazed assemblies become extremely costly below 700 MHz. Furthermore, innovative welded sheet metal structures would also have to be developed.

Consequently, we think a linac operating at 350-700 MHz, with a funnel operating at around 20 MeV, is an excellent choice from both the beam dynamics and the fabrication standpoints, even though it is problematic in the energy range of 20 to 100 MeV. At 20 MeV, a CCL accelerating cell operating in the 700-MHz π-mode is very short (4.35 cm). The cell diameter, however, is large (33 cm). Therefore, a low-energy CCL cell consists mostly of closely set parallel walls of copper, with resulting low shunt impedance (Fig. 1). The lattice proposed for ATW consists of 10-cell tanks with intertank spaces varying from 4.0 $\beta\lambda$ at 20 MeV to 3.0 $\beta\lambda$ at 100 MeV. We feel that operating a π-mode CCL at such low energies creates brazing complexities. For example, low shunt impedance leads to high power consumption. In addition, the large number of closely set parallel cell walls may lead to multipactoring problems.

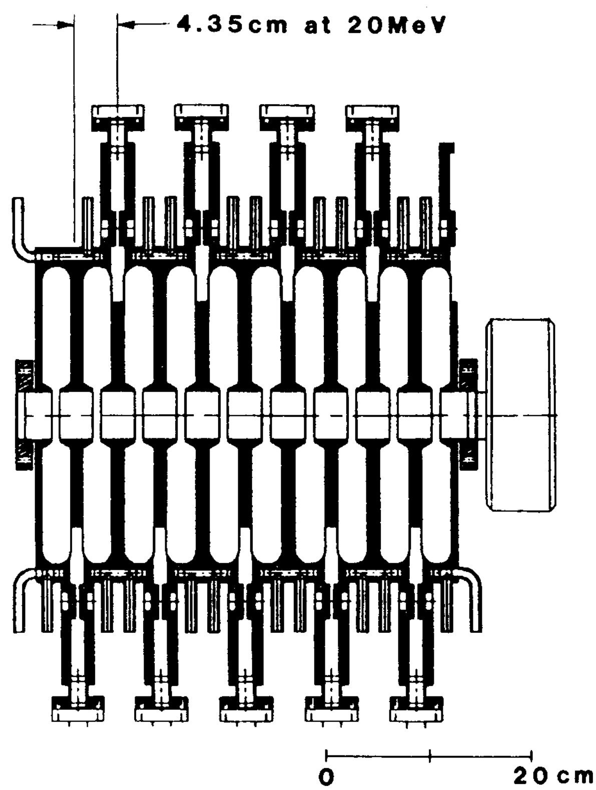

Fig. 1 A 5$\beta\lambda$ long CCL accelerator tank at 20 MeV and 700 MHz showing close end wall spacing and fabrication complexities.

For these reasons, we have proposed a different accelerating structure for the 20-100 MeV range. We propose to simply replace the CCL tanks with large-bore DTL tanks that provide the same gain in real-estate energy per unit length but that contain drift tubes without

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quadrupoles. To build this DTL, we coupled the tanks with resonant couplers and named it the bridge coupled DTL (BCDTL).

Description of the BCDTL

Figure 2 shows a five-tank BCDTL for 20 MeV; Figure 3 shows an individual tank with bridge-coupler and intertank hardware. Each accelerating tank is 5 βλ long (43.5 cm at 20 MeV) and holds four single-stem drift tubes. The tanks are coupled at their center planes with partitioned bridge couplers to prevent field droop in the coupled system. Because the tanks are so short, no post couplers are needed. In addition, because the drift tubes do not carry quadrupoles, alignment can be coarse (± 0.5 mm). Between the tanks we placed a standardized beam tube equipped with a rad-hard quadrupole singlet, a BPM, a steering magnet, a bellows, and metal-sealed quick disconnect flanges. A vacuum valve was also added between modules.

Unlike a standard Alvarez DTL, the BCDTL drift tubes do not carry quadrupoles, so the bore can be opened up to large diameters (4-5 cm) to provide a large aperture ration for the CW beam. This increase in aperture ratio results in low transit time factors (0.52 to 0.59). As a result, the accelerating field levels must be increased to E0T = 1.8 MV/m to retain the desired gain in real-estate energy, 1 MV/m. However, because the drift tubes have no quadrupoles, the DT walls can be thinned for improved rf efficiency. All that is needed is enough copper for the cooling channels.

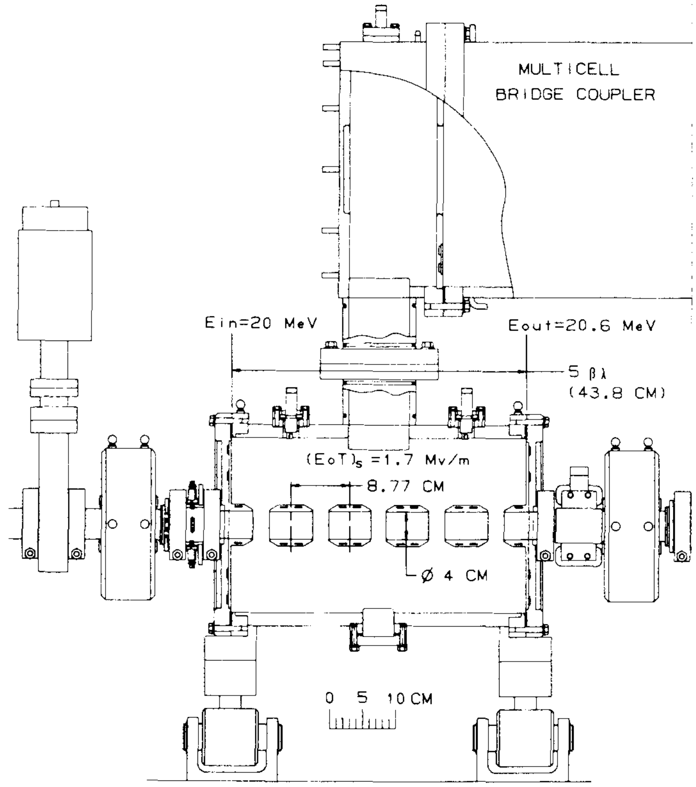

Fig. 3 Internal structure of the 20.6-MeV 700-MHz BCDTL accelerating tank (5 βλ long).

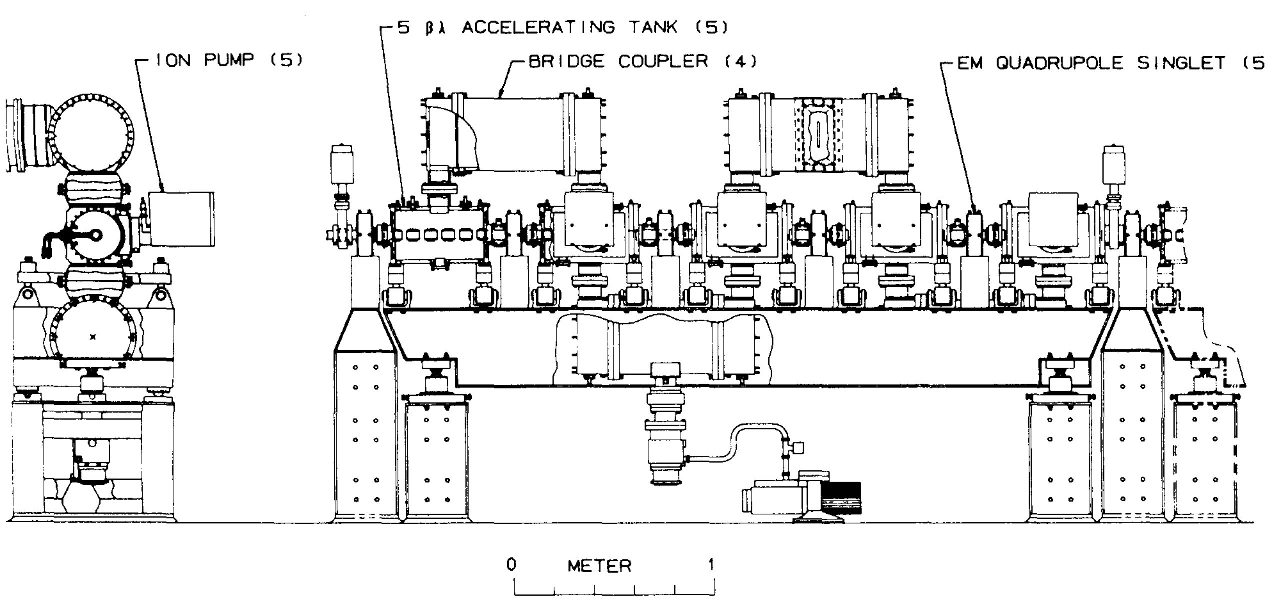

Fig. 2 5 tank 20-22.9 MeV, 700-MHz bridge-coupled DTL module.

Transverse beam control is provided by the lattice EMQ singlets between the tanks. In all respects, the BCDTL performs like an equivalent CCL, but it consumes less power and is considerably simpler and cheaper to fabricate in the 20 to 100 MeV range.

Table 1 compares the BCDTL's operating characteristics with those of an equivalent CCL. The BCDTL's physics design as applied to ATW is provided in another report by Garnett et al. [1].

TABLE 1
Comparison of CCL and BCDTL Operating Parameters in the Energy Range of 20 to 100 MeV

	CCL	BCDTL
No. of tanks	88	88
Tank length	5 $\beta\lambda$	5 $\beta\lambda$
No. of cells/tank	10	5
Cell length	1/2 $\beta\lambda$	1 $\beta\lambda$
Intertank spacing	3.5-2.5 $\beta\lambda$	4-3 $\beta\lambda$
Aperture radius (cm)	2.5	-2.25
ZT^2 (MΩ/m)	3.5-22.8	22.8 - 23.3
E_0T, structure (MV/m)	1.7	1.8
$\varphi\sigma$	ramped, -40^o to -30^o	ramped, -40^o to 30^o
Focusing lattice	FODO	FODO
Effective quad length (cm)	4.74	4.74
Quad. gradients (KG/cm)	3.72 -3.53	3.47-3.28

Advantages of the BCDTL

The BCDTL provides the following advantages over the CCL in the 20- to 100-MeV energy range:

(1) A structure that can be readily built at modest cost,
(2) Ease of tuning and alignment,
(3) Higher ZT^2 at the lower energy end, and
(4) Higher operational reliability.

In addition, the BCDTL permits the introduction of the π-mode CCL at a conservative and proven energy range of 80 to 100 MeV. The Los Alamos Meson Physics Facility (LAMPF) begins using its 805-MHz CCL at 100 MeV. Using LAMPF as a precedent, we also chose to switch over from BCDTL to CCL at 100 MeV. The BCDTL offers a significant cost advantage because of its simpler and therefore cheaper structure.

To properly couple the tanks in phase and to permit iris coupling with the drive waveguide, the BCDTL requires five-cell bridge couplers, which, at 100 MeV are expensive to implement because of their length. The added expense, however, is a relatively minor disadvantage considering the benefits to be gained with a multicell bridge coupler at 100 MeV, including freedom from unwanted rf modes and a relative insensitivity to the coupling slots.

Conclusions

In our design studies of ATW-class linacs, we plan to use a 700-MHz bridge-coupled DTL in the 20- to 100-MeV energy range as an alternate to a CCL. We feel that this structure will provide fabrication and cost advantages in this energy range because it has higher shunt impedance at lower energies, even though it suffers from high-power densities at point-specific areas and requires long bridge couplers if the design is carried to 100 MeV. Overall, we feel it is an advantageous structure for ATW.

References

[1] R.W. Garnett, D. Liska, et al, "Design and Simulation of Bridge-Coupled DTL Structure for the 20- 80 MeV Region of a Proton Linac for Accelerator Transmutation of Waste (ATW)," (to be published in the 16th International LINAC Conference Proceedings, Ottawa, Ontario, August 23-28, 1992).