LA-UR -85-1332

CONF-850504--13 RECEIVED BY OSTI MAY 06 1985

MASTER

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--85-1332

DE85 010753

TITLE A 3λ/4 POST COUPLER FOR DRIFT-TUBE LINACS

AUTHOR(S) J. H. Billen, J. A. Garcia, J. M. Potter
and G. Spalek

SUBMITTED TO 1985 PARTICLE ACCELERATOR CONFERENCE
Accelerator Engineering and Technology
Vancouver, British Columbia
May 13-16, 1985

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

A 3λ/4 POST COUPLER FOR DRIFT-TUBE LINACS*

J. H. Billen, J. A. Garcia, J. M. Potter, and G. Spalek, AT-1, MS H817
Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Summary

New permanent magnets for quadrupole focusing make possible smaller drift tubes in drift-tube linacs (DTLs), resulting in higher shunt impedance. However, ordinary post couplers cannot stabilize a DTL whose drift-tube-to-wall spacing exceeds one-quarter wavelength (λ/4) by more than a few per cent for the accelerating mode frequency. We have built and tested post couplers that operate in the 3λ/4 mode. These 3λ/4 post couplers, when substituted for λ/4 couplers, had similar stabilization properties. In addition, the coupling between post and drift tube, and the post's resonant frequency can be independently adjusted.

Introduction

Post couplers have been used to stabilize the accelerating field in DTLs for many years. They were developed at Los Alamos[1] in the late 1960s for the 200-MHz DTL portion of LAMPF. Post couplers operate successfully in two other machines similar to LAMPF: at CERN[2] and at Fermilab.[3] However, not all DTLs can be stabilized using conventional λ/4 post couplers. Post couplers did not stabilize the field in two low-power DTLs we have studied. One was a 16-gap structure operating at 367 MHz; the other was a 425-MHz, 40-gap structure. In addition, Bentley reported[4] that post-coupler stabilization was unsuccessful in the 200-MHz New England Nuclear (NEN) linac.

The main difference between DTLs stabilized by post couplers and DTLs in which post-couplers are ineffective is the electrical length between the drift tube outer radius and the tank wall. (Electrical length refers to distance measured in units of the wavelength of the operating rf mode.) In stabilized DTLs, the drift-tube-to-wall spacing S is usually less than λ/4, although in one of the CERN linac tanks, S was 2.7% greater than λ/4. In the two low-power models, S was 10% greater than λ/4, and in the NEN machine the spacing S ranged from 25 to 36% greater than λ/4.

These observations suggest that capacitance between the post coupler tip and the drift tube is the dominant coupling mechanism between the post-coupler modes and the higher order TM_{01X} modes of the linac. This coupling mechanism is illustrated in Fig. 1. The post coupler is essentially a quarter-wave resonator capacitively loaded on the end. If the spacing S is ~λ/4 or slightly less, a post protruding into the tank, but not in contact with the drift tube, is shorter than λ/4. Neglecting the end capacity, this post would be resonant above the operating frequency. However, the capacitive loading both lowers the post coupler frequency and provides the necessary coupling to the drift-tube modes. Too large a spacing S means a larger gap and hence less coupling. Ungrin et al.[5] found in low-power tests that stabilization was not possible with large spacing S (24% over λ/4), but it was achieved in three other cases for which S was 1.13, 1.02, and 0.87 quarter wavelengths.

*Work supported by US Department of Energy.

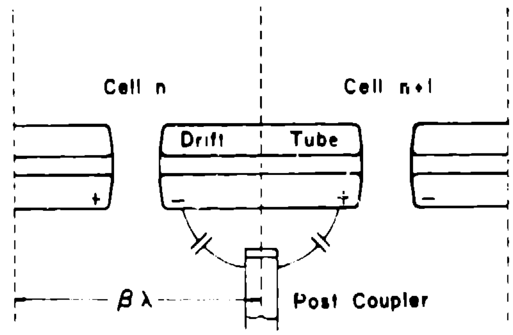

Fig. 1. Schematic view of the coupling mechanism between post coupler and drift tube. All individual cells of the linac (two of which are shown here) are strongly coupled in a linear chain. The post couples to two adjacent cells in such a way that the post coupler remains unexcited for equal field strength in the two cells.

Tilt Sensitivity

A tilt-sensitivity measurement indicates the effectiveness of post couplers in stabilizing the field. In this procedure, a change in the accelerating gap length in an end cell of a multicell cavity causes a frequency shift Δf from the cavity resonant frequency f_0. One then adjusts the opposite end-cell gap to cause an opposing frequency shift -Δf, restoring the operating frequency to f_0. The standard bead-pull technique determines the resulting axial electric-field profile. The tilt-sensitivity parameter for a cell of the linac is defined as

$$T = \left(\frac{X_P - X_U}{X_U}\right)\frac{1}{\Delta f} , \qquad (1)$$

where X_U is the maximum field amplitude in the cell for the unperturbed case, and X_P is the maximum field amplitude when the end cells are perturbed by ±Δf as described above. Figure 2 shows the tilt sensitivity for a 40-gap, 550-MHz, low-power DTL model with and without post couplers. This structure can have a post coupler opposite every other drift tube. The post couplers alternate side to side and their positions are indicated by the long tick marks.

3λ/4 Post Couplers

Although this low-power model has S = 0.244λ and is easily stabilized by λ/4 post couplers, it provided an opportunity to test a new post-coupler design that uses the 3λ/4 resonant mode. Figure 3 shows end views of a DTL with a conventional λ/4 resonator and two different 3λ/4 resonator designs. Rotation of the asymmetric tab (at the end of the post) positions the post opposite the electrical center of the drift tube.

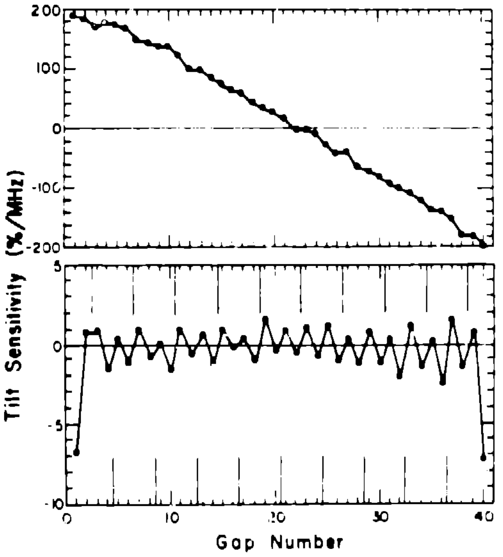

Fig. 2. Tilt sensitivity (T) measurements for a) no post couplers and b) nineteen $\lambda/4$ post couplers tuned for zero average slope. The posts (at positions indicated by long tick marks) couple to every other drift tube and alternate from one side of the DTL to the other. The sawtooth pattern results from tuning the post couplers to achieve an overall average value of zero for T.

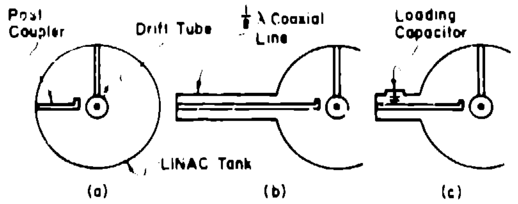

Fig. 3. DTL end views showing (a) a $\lambda/4$ post coupler, (b) a $3\lambda/4$ post coupler using a $\lambda/2$ coaxial line, and (c) a $3\lambda/4$ post coupler using a capacitively loaded coaxial line. The capacitor in (c) is adjusted to make the coaxial line approximately $\lambda/2$ long electrically, thus conserving space outside the linac tank.

We installed a $3\lambda/4$ post coupler of the Fig. 3b design in Position 32-33 (that is, opposite the drift tube between Gaps 32 and 33). By fixing the length of the coaxial line to be $\lambda/2$ (27.2 cm), we could tune the post coupler in the same manner as we tuned the $\lambda/4$ couplers, namely by adjusting the length of the post. The behavior was indistinguishable from that of a $\lambda/4$ post coupler. An alternative tuning method would fix the post length (and hence the post-to-drift-tube gap) and adjust the length of the coaxial line.

The exact geometry of the coaxial line is not important as long as the post coupler resonates at the correct frequency. We, therefore, experimented with a loaded transmission line (see Fig. 3C) only 12.5 cm long for the post coupler at Position 36-37. The capacitor (variable between 3 and 20 pF) was connected between the inner and outer conductors about halfway along the coaxial line. The capacitor's residual inductance was low enough (~3.5 nH) not to be self-resonant near the DTL's operating frequency. Figure 4 shows tilt-sensitivity curves for two settings of the capacitor on post coupler 36-37. In the upper curve, the post-coupler frequency is above optimum; in the lower curve, it is below optimum.

Despite the rather open geometry of the DTL, Fig. 4 shows that individual post couplers have predominantly a local effect on the tilt sensitivity. These curves are complicated somewhat by the use of post couplers at every other (rather than every) drift tube. However, one may study the effectiveness of a single post coupler by observing the local slope of the curve. For example, let us define the local slope of the tilt sensitivity as the slope of a straight line fitted to T versus position for the four gaps nearest a particular post coupler. This slope is zero when the post couplers are properly tuned. Figure 5 shows the local slope of T at Position 36-37 as a function of loading capacitance for several post-to-drift-tube gap sizes. For each gap size, the "tuned" capacitance setting corresponds to zero slope. Increasing the gap shortens the post and raises the coupler's resonant frequency and, thus, requires more loading capacitance to bring the coupler back into tune. The slope of these tuning curves is an indication of the coupling strength. The post coupler must be tuned more accurately as the gap size increases, indicating weaker coupling. This is exactly the problem observed with $\lambda/4$ couplers for large drift-tube-to-wall spacings.

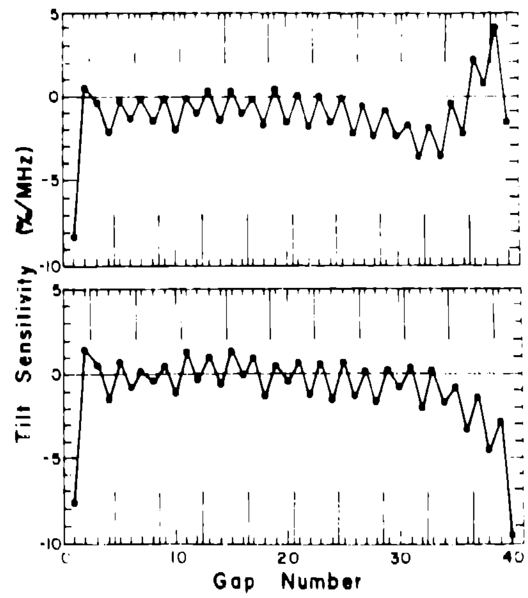

Fig. 4. Tilt-sensitivity measurements for (a) 11.6 pF and (b) 12.4 pF capacitance on the $3\lambda/4$ post coupler installed at Position 36-37. The post-to-drift-tube gap size was 1.3 cm.

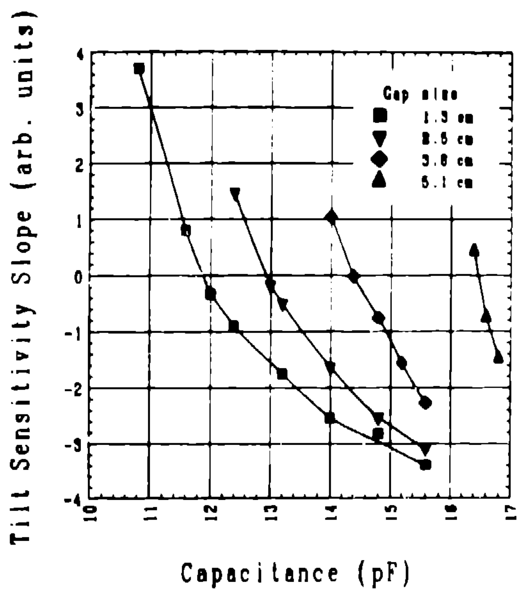

Fig. 5. Local slope of the tilt-sensitivity curve near the 3λ/4 post coupler versus loading capacitance. Zero slope corresponds to the post coupler properly tuned. For larger post-to-drift-tube gaps, coupling is less; hence, the tuning rate is very steep near the stabilization point.

Conclusion

We have shown that stabilization of DTLs is possible using 3λ/4 post couplers. They offer advantages over λ/4 couplers in that the coupling strength and post resonant frequency may be adjusted independently, and one may take advantage of the higher shunt impedance afforded by small drift tubes. The main disadvantage is a more complicated mechanical structure. Power losses associated with a given tuning error will be larger for 3λ/4 post couplers than for λ/4 couplers because of a somewhat poorer Q of 3λ/4 post couplers. Before implementing the 3λ/4 design on an operating DTL, we plan to perform further tests on a full-power model.

References

1. D. A. Swenson, E. A. Knapp, J. M. Potter, E. J. Schneider, "Stabilization of the Drift Tube Linac by Operation in the π/2 Cavity Mode," Sixth International Conference on High Energy Accelerators, Sept. 11-15, 1967 Cambridge Electron Accelerator Laboratory report CEAL-2000 (1967) 167.

2. E. Boltezar, "Mechanical Design of CERN New Linac Accelerating Structure," Proc. 1979 Linear Accelerator Conference, Brookhaven National Laboratories report BNL 51134 (1979) 392.

3. D. E. Young, "Construction Progress and Initial Performance of the NAL 200-MeV Linear Accelerator," Proc. 1970 Proton Linear Accelerator Conference Fermilab National Accelerator Laboratory report (1970) 15.

4. R. F. Bentley, "New England Nuclear Corp. Linear Accelerator Progress Report," Proc. 1981 Linear Accelerator Conference, Los Alamos National Laboratory report LA-9234-C (1981) 349.

5. J. Ungrin, S. O. Schriber, and R. A. Vokes, "Post-Coupler and Stem Current Measurements for High Current CW Drift-Tube Linacs," IEEE Trans. Nucl. Sci., 30 (3) (1983) 3013.