PRECISION ALIGNMENT OF PERMANENT MAGNET DRIFT TUBES*

D. J. Liska, L. B. Dauelsberg, and G. Spalek, AT-4, MS H821
Los Alamos National Laboratory, Los Alamos, NM 87545

Summary

The Lawrence Berkeley National Laboratory (LBNL) technique of drift-tube alignment has been resurrected at Los Alamos for the precision alignment of 1-cm-bore drift tubes that carry high-gradient rare-earth-cobalt quadrupoles. Because the quadrupoles cannot be switched off, this technique is not applicable to a drift-tube assembly, but tests indicate that individual magnetic centers can be detected with a precision of ±0.003 mm. Methods of transferring this information to machined alignment flats on the sides of the drift-tube body are discussed. With measurements of drift tubes designed for a 100-mA, 425-MHz drift-tube linac, we have detected offsets between the geometric and magnetic axes of up to ±0.05 mm following final assembly and welding. This degree of offset is serious if not accommodated, because it represents the entire alignment tolerance for the 40-cell tank. The measurement equipment and technique are described.

Description of Method

The LBNL technique is shown in Fig. 1. It was used around 1974 to align the electromagnetic quads of the machined drift tubes. In this application, a tungsten** wire is suspended horizontally through the entire tank, and individual quads are turned on one at a time. By adjusting the support points of the wire, the offset positions of the magnetic centers could be plotted and an alignment scheme devised. Then, individual drift tubes were adjusted to bring them into acceptable alignment with a predetermined position of the pulsing wire. A diagram of the pulser electronics (Fig. 2) is shown as constructed at Los Alamos.

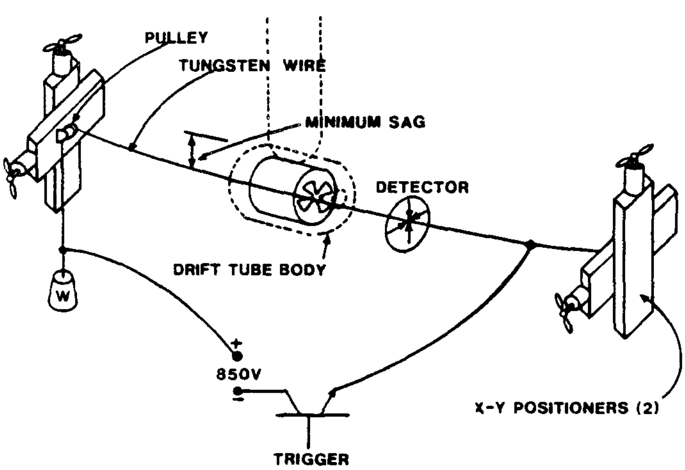

Fig. 1. Alignment of drift-tube quadrupoles using pulsed wire.

*Work performed under the auspices of the U.S. Dept. of Energy and supported by the U.S. Army Strategic Defense Command.
**Tungsten was used in the LBNL method because of its high strength-to-density ratio, thus permitting the catenary equations to be reduced to a simple quadratic approximation.

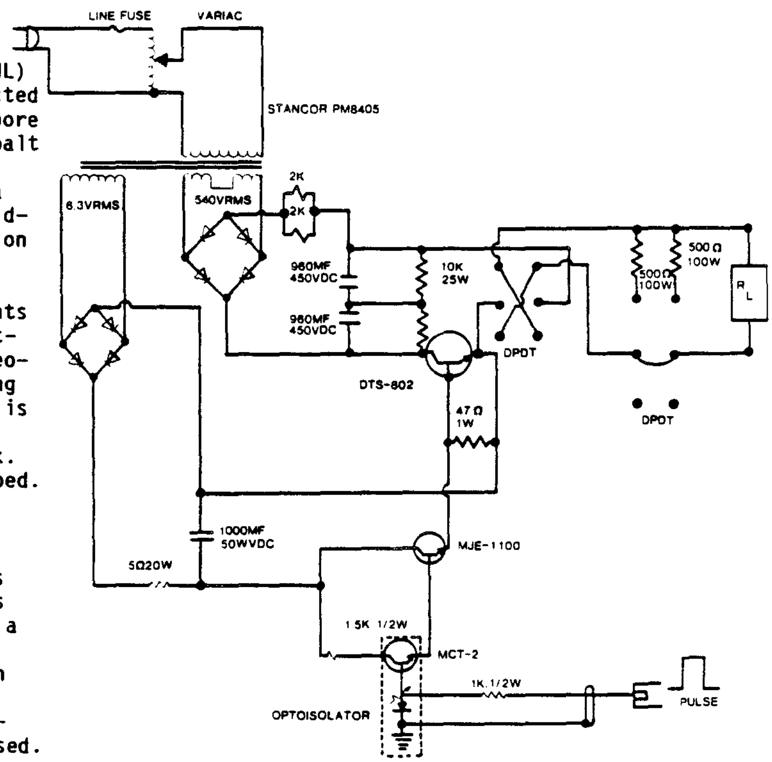

Fig. 2. Electronics for taut-wire pulser.

Application to PM Quadrupoles

With the new permanent-magnet (PM) quadrupoles used in today's intense linacs, the traditional LBNL method no longer applies. Now, the magnetic centers must be found in each individual drift tube, and overall alignment precision must be determined by accurately using these data to bias each drift tube during installation. Thus, the technique becomes a record-keeping task. Individual magnetic centers cannot be checked after installation.

The accelerator test stand (ATS) drift-tube linac (DTL), a flat-gradient (1.95 MV/m), 100-mA, 425 MHz H^- machine was aligned in this way. The quadrupole specifications were

Field gradient = 175 T/M

Aperture = 1.220 cm

Effective length = 2.54 cm

Figure 3 shows the test apparatus with one of the drift tubes installed. Because individual units are tested, the wire can be suspended vertically and need not be tungsten. Motions of the wire are detected by two pairs of LED/detector pickups mounted orthogonally to each other on the principal X-Y axes of the drift-tube transverse plane. The drift tube is mounted on a two-axis positioner that can be adjusted to center the quadrupole axis on the wire within acceptable tolerance limits. Current pulses are fired down the wire with about 700-mA peak and 1-ms duration. Adequate response can be detected to register offsets between the wire and the quadrupole axis of ±0.003 mm.

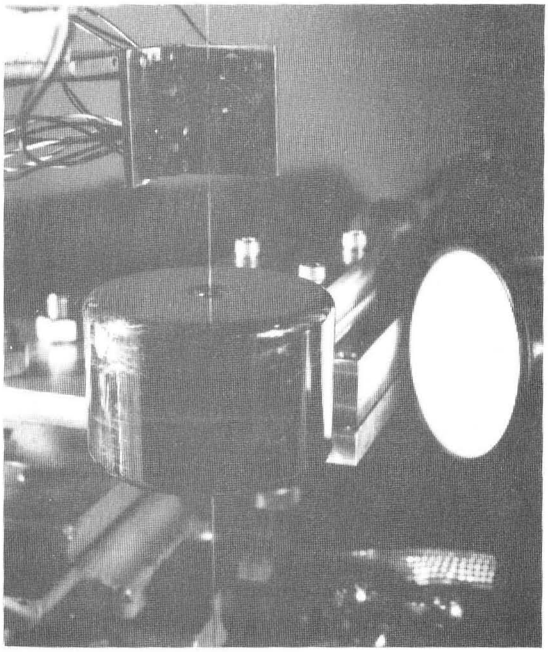

Fig. 3. Laboratory setup of drift tube under test.

Final Installation Precision

Although the magnetic centers can be reproducibly detected to within ±0.003 mm, it is difficult to transfer this precision to a solid surface on the drift-tube body. Considerable thought has gone into this difficulty, and a simple measuring device has been invented as shown in Fig. 4. With this device and the use of precision transits, it is possible to transfer the final wire position along the drift tube X-Y axes to alignment flats machined into the drift-tube body. A typical tabulation of results is shown in Table I. It can be seen that the offset between the drift-tube geometrical center and the quadrupole axis is about the same alignment precision as that required for the linac itself, the average offset being 0.03 mm. Even so, the ultimate alignment precision following installation cannot be held closer than ±0.05 mm. However, this precision is acceptable for ATS objectives. A further complication in ATS was that copper plating had rendered the alignment flats nonuniform; therefore, a light machine cut had to be made before the full potential of this technique could be realized.

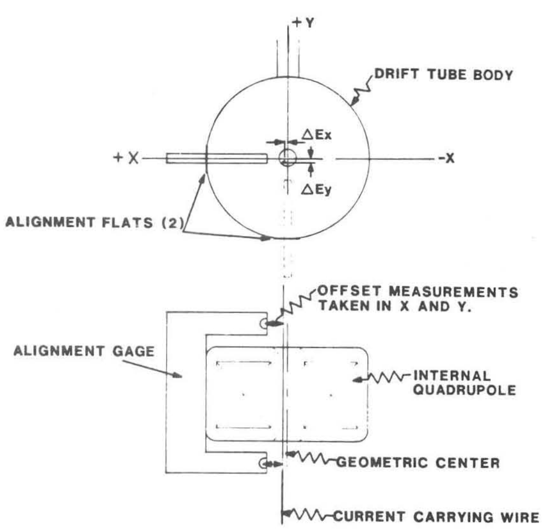

Fig. 4. Alignment jig for measuring magnetic-axis offset.

Table I

ATS-DTL MAGNETIC AXIS OFFSETS

(Dimensions in mm)

Drift Tube No.	ΔE_x	ΔE_y
1	+0.046	+0.082
2	+0.039	+0.019
3	+0.043	-0.025
4	+0.017	+0.012
5	-0.038	+0.051
6	-0.046	-0.051
7	+0.050	-0.070
8	+0.062	+0.031
9	-0.013	-0.025
10	-0.050	+0.006
11	-0.020	-0.025
12	-0.044	+0.090
13	+0.026	+0.062
14	+0.031	+0.062
15	-0.005	0.000
16	-0.015	-0.007
17	+0.051	0.000
18	-0.045	-0.015
19	+0.012	+0.050
20	-0.007	+0.044
21	-0.038	+0.018
22	+0.051	+0.038
23	+0.031	+0.062
24	-0.011	+0.006
25	-0.026	-0.051
26	-0.000	-0.025
27	-0.040	+0.011
28	-0.021	-0.056
29	-0.017	+0.047
30	+0.025	+0.084
31	-0.007	+0.011
32	+0.030	+0.013
33	+0.076	+0.051
34	-0.032	-0.019
35	+0.057	+0.054
36	-0.055	+0.097
37	-0.020	+0.001
38	-0.013	+0.038
39	+0.006	-0.006

Conclusions

Tests have shown that a taut-wire alignment technique patterned after an early LBNL innovation can be used to accurately align the drift-tube magnetic axes of today's high-intensity DTLs. Magnetic-center detection of ±0.003 mm is possible, and an overall alignment of drift tubes in a linac structure to ±0.05 mm has been achieved.