IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

REDESIGN OF THE LAMPF TRANSITION REGION*

O. Sander, A. Browman, E. Bush
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Summary

We describe the redesign of the transition region (TR) that functions as a transport section for the H^+ and H^- beams between the LAMPF 201.25-MHz drift-tube (DT) and 805-MHz side-coupled (SC) linacs providing a 7.98 cm longer flight path for one beam so that both beams have the correct phase for capture in the SC linac. In the new TR both beams from the DT linac are independently matched to the acceptance of the SC linac. The relative phase adjustment between the two beams has been simplified and is now accomplished with just one control. A straight-through section has been added to facilitate beam studies under less complicated conditions. The aperture has been increased to reduce beam losses. Diagnostic equipment allows measurement of the transverse output emittance of the DT linac. We discuss both the criteria placed upon the beam in the TR and the predicted performance in matching a variety of beam shapes from the DT linac to a variety of SC accelerator acceptance shapes.

Limitations of the Old TR

The original transition region[1] (TR) is shown in Fig. 1A. Operations using it over the past several years have uncovered several areas where improvements are needed. Although the eight quadrupoles provided are theoretically sufficient to match both H^+ and H^- beams, both beams pass through four of the quadrupoles so the dual-beam matching problem is highly coupled. In many cases a change in the characteristics of one beam can require quadrupole settings that make it impossible to match the other beam. Furthermore, the magnet apertures, while sufficient to contain a single well-steered and matched beam, are not large enough to include the beam centroid and width variations necessary to properly steer and match both H^+ and H^- beams. When the path length of the TR is adjusted both the phase and steering of the beam is affected. The beam must then be recentered in the SC linac. This process is slow and interrupts both beams so it is not undertaken as often as it should be.

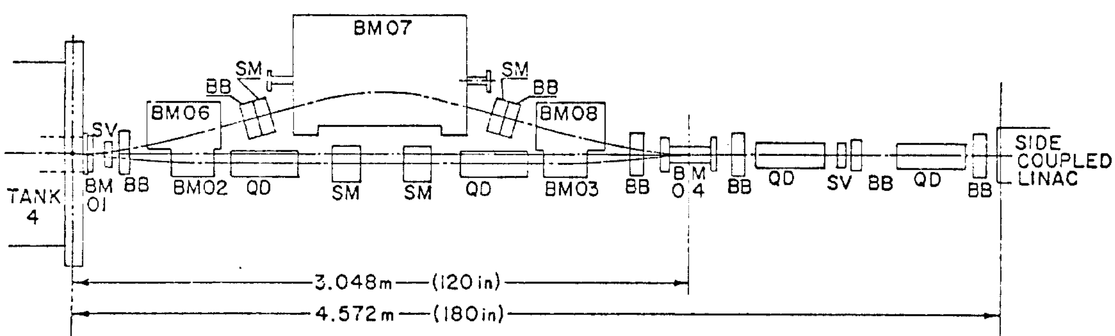

Fig. 1A
ORIGINAL TRANSITION REGION

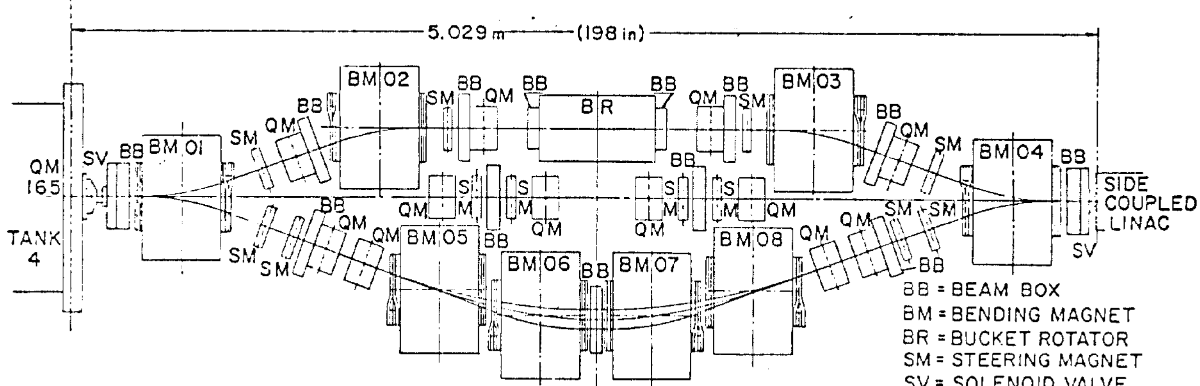

Fig. 1B
PROPOSED TRANSITION REGION

*Work sponsored by United States Department of Energy.

The result of these weaknesses is that tuning the TR is quite time consuming, and compromises involving imperfect matching or increased losses are frequently necessary. So far, the compromises have been possible, although a nuisance, because the H^- beam has had small currents (<10μA) and its losses and mismatches can be tolerated. In the future when both beams have similar intensities, it will be necessary to match, steer, and adjust the phase of each beam correctly.

Advantages of the New TR

A new TR was desired that would incorporate the following improvements: 1) independent matching of both beams, 2) increased aperture, 3) simplified relative phase adjustment, 4) greater steering ranges for both beams, 5) more and better located beam diagnostics, 6) a "straight-through" line, 7) standard, conservative magnet design, and 8) space reserved for a longitudinal lens or "bucket rotator."

After several iterations, we arrived at the design shown in Fig. 1B. It was necessary to move the first SC linac module 46 cm downstream to accommodate all the improvements and still keep the bending magnet fields less than 1.2 T, thereby avoiding excessive stripping of the H^- beam. Although very crowded the new TR satisfies the eight criteria listed above and also appears to be buildable. The upper beam line in Fig. 1B has been named the "short track" and the lower beam line has been named the "long track." In our present design, the H^+ beam traverses the short track and the H^- beam traverses the long track.

Independent matching is achieved with separate sets of quadrupoles for each beam. The aperture has been increased from 3.0 to 4.9 cm. The relative phase adjustment has been simplified by using one power supply to provide current in series to all the windings in bending magnets BM01 through BM04 and to half the windings in bending magnets BM05 through BM08. A second power supply provides current in series to the other halves of the windings in the latter magnets. The resulting fields from these two currents are opposing in magnets BM05 and BM08 and add in magnets BM06 and BM07. This arrangement has two significant advantages. First, for small drifts in the two power supplies the angles and positions of the beams at the SC linac will be unaffected. Second, the relative phase and flight path of the beam traversing magnets BM05 through BM08 can be adjusted with just one knob controlling the output current of the second power supply. The steering ranges have been extended by increasing the distance between each pair of steering magnets. Additional diagnostics allow us to measure both the emittance at the exit of the DT linac and the emittance at the entrance of the SC linac and have the increased resolution that is needed for our present high-brightness beam. The magnets have been standardized so that only one bending, quadrupole and steering magnet design will be required.

Beam Dynamics Studies

Beam dynamics studies were made of the new TR to verify that the following criteria were satisfied: 1) a variety of exit beam shapes from the DT linac can be matched to a variety of input acceptance shapes at the SC linac, 2) necessary quadrupole field gradients are easily obtainable, 3) the beam envelopes have limited variations in size, 4) the beam diameter containing more than 90% of the current is less than one third the pipe i.d., and 5) a matched output is relatively insensitive to errors in field gradients and magnet positions. The quadrupole placement was dictated by space limitations and not by what would best satisfy our beam dynamic conditions. Only a few quadrupole placement configurations are possible.

We used the matching code TRANSPORT[2] to find TR quadrupole solutions that match the beam from the DT linac to the acceptance of the SC linac. Convergence of the TRANSPORT code to an acceptable solution, as defined above, depends on whether the initial values of the quadrupole fields are sufficiently close to the desired solution. Because the many TR bending magnets complicate the beam dynamics with their non-negligible amounts of vertical focusing, the correct estimation of the starting quadrupole fields is very difficult. Therefore, we made systematic four-dimensional searches for solutions by independently varying each of the four initial quadrupole fields. We expect that all acceptable solutions were found in these searches. During these searches, we found more than ten types or families of solutions with some quadrupole configurations. We used the graphics option in TRACE[3] to examine the beam envelopes of these families, and often three or four "good" families would satisfy the beam size and envelope criteria.

For each track of the TR we mapped the ranges of input and output beam shapes that could be successfully matched by the good families. We required that the input range of a good family had to include the measured beam parameters at the exit of the DT linac and that the output range had to include the beam parameters of the acceptance of the SC linac.

We examined a number of quadrupole configurations and found that the arrangement of magnets shown in Fig. 1B best satisfied the above criteria. We increased the input range of acceptable solutions by adding quadrupole Q165 into the last drift tube of the DT linac and by changing the field gradients in the final five quadrupoles in this linac. Representative beam envelopes in the short track, the long track, and the straight-through section are shown in Figures 2A, 2B, and 2C respectively.

As a result of the successful analytical studies, we have begun the detailed design of the magnets, vacuum system, support structures, electrical system and cooling system. In order to minimize accelerator downtime, the entire new TR will be constructed and tested outside the beam channel and then installed during a shutdown period. The installation of the new TR is presently planned to occur in late 1982 or early 1983. A detailed study of the new TR and its beam dynamics can be found in Reference 4.

References

1. D. A. Swenson, "The Transition Region," Los Alamos National Laboratory internal memo, MP-3-75, February 24, 1969.

2. K. L. Brown, et. al., "TRANSPORT: A Computer Program for Designing Charged Partticle Beam Transport Systems," SLAC-91, Rev. 2, May 1977.

3. K. R. Crandall, "TRACE, An Interactive Beam Transport Program," Los Alamos National Laboratory Report, LA-5332-UC-28, October 1973.

4. O. R. Sander, "The New TR and its Beam Dynamics." Los Alamos National Laboratory, MP-DO internal memo in progress.

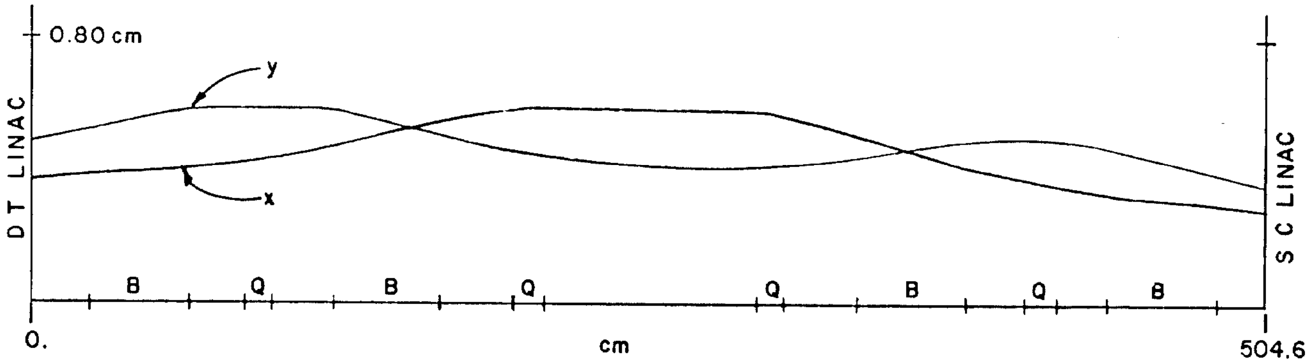

Fig. 2A
SHORT TRACK

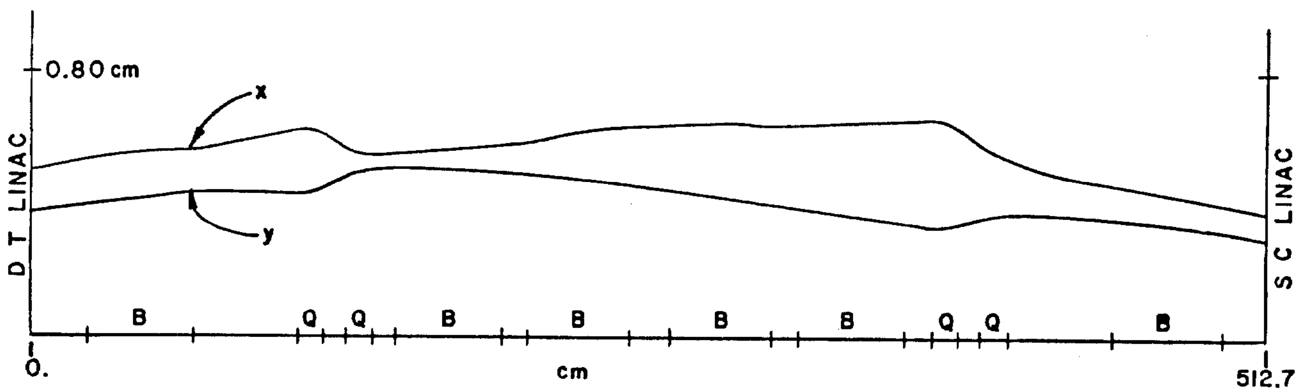

Fig. 2B
LONG TRACK

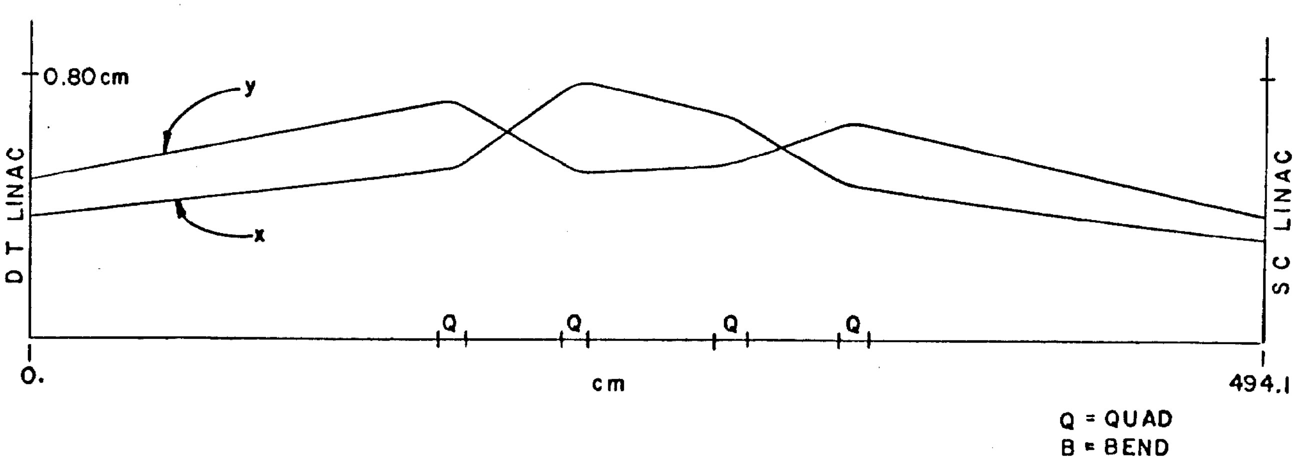

Fig. 2C
STRAIGHT-THROUGH

Fig. 2

BEAM ENVELOPES