UNEXPECTED MATCHING INSENSITIVITY IN DTL OF GTA ACCELERATOR*

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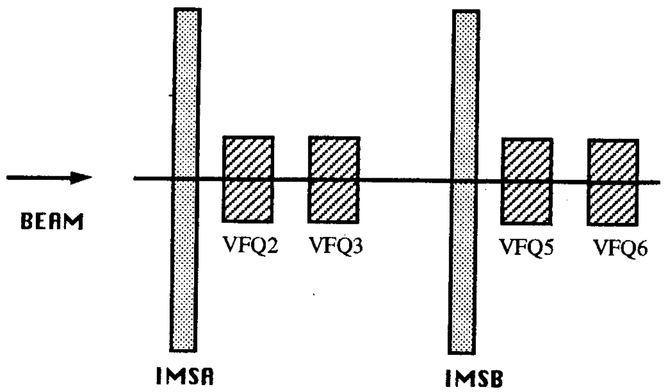

Figure 1. Schematic diagram of IMS

Abstract

The Intertank Matching Section (IMS) of the Ground Test Accelerator (GTA) contains four variable-field quadrupoles (VFQs) and is designed to match beam exiting the Radio-Frequency Quadrupole to the first tank of the Drift-tube LINAC (DTL-1). By varying the VFQ field strengths to create a range of beam mismatches at the entrance to DTL-1, one can test the sensitivity of the DTL-1 output beam to variations in the DTL-1 input beam. Experimental studies made during commissioning of the GTA indicate an unexpected result: the beam exiting DTL-1 shows little variation for a range of mismatches produced at the entrance. Results of the experiment and simulation studies are presented.

I. INTRODUCTION

The Ground Test Accelerator [1] at Los Alamos is a linac that was designed to produce an accelerated H^- beam of high intensity. Initial commissioning tests on the first Drift-Tube Linac section (DTL-1) of the accelerator produced a beam with an energy of 3.2 MeV. The configuration of the accelerator preceding DTL-1 included a source followed by: an injector, a low-energy beam transport section (LEBT), a Radio-Frequency Quadrupole (RFQ), and an Intertank Matching Section (IMS) . The IMS (see fig.1) included 4 Variable-Field Quadrupoles (VFQs) and 2 longitudinal bunchers (IMSA and IMSB) for the purpose of matching the beam exiting the RFQ to the entrance of DTL-1

An experiment (DTL-1 Experiment) was conducted to produce a wide variety of beam configurations at the entrance to DTL-1. The purpose was to see how the transmission and Courant-Snyder parameters of the transmitted beam would be affected by changes in mismatch at the entrance to DTL-1. The beam was changed at the DTL-1 entrance by using different tunes of the VFQs contained in the IMS. The experiment showed surprisingly small changes in the beam exiting DTL-1 in spite of what were believed to be large changes in the mismatch of the beam entering DTL-1.

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Table I

Courant-Snyder (C-S) parameters for input beam at simulation starting point. β_x and β_y are in units of mm/mr. β_z is in deg-keV.

α_x	β_x	α_y	β_y	α_z	β_z
-5.4196	.66466	.24527	.06301	.08726	.86140

These observed changes at the DTL-1 output were much smaller than are predicted by the beam transport codes TRACE3D [2] and PARMILA [3]. A possible explanation was that the mismatch of the beam at the DTL-1 entrance was not changing by the amount originally believed. An experiment (IMS experiment), therefore, was conducted with DTL-1 replaced by a diagnostics station located just downstream of the IMS, in order to study characteristics of the beam exiting the IMS.

II. INPUT BEAM AND MATCHED BEAM

Simulation work calculated Courant-Snyder parameters for comparison with measured values. We began all simulations at a starting point located immediately upstream of the IMS. In the case of GTA, the IMS was positioned adjacent to the RFQ, and there was not room to place a diagnostic station between them to give a direct measurement of beam characteristics at this starting point. Our best estimate of the beam characteristics at the RFQ exit, therefore, came from emittance-scan measurements taken in the IMS experiment that replaced the DTL-1 tank with a beam-diagnostics station (ES5) located downstream of the IMS across a drift space. TRACE3D code was applied to these measurements to back-trace the beam across the drift space to the desired simulation starting point. The Courant-Snyder parameters for the starting-point input beam are presented in Table I.

The characteristics for the beam matched to the DTL-1 at its entrance were determined [4] by using TRACE3D to match to the 7th focusing period of the DTL-1. This beam was then back-transported using TRACE3D to determine its Courant-Snyder parameters at the DTL-1 entrance. Those Courant-Snyder parameters are presented in Table II.

III. EXPERIMENT DTL-1 TUNES

A particular configuration of field settings for the VFQs of the IMS constitutes what is called a “tune” of the IMS. In the DTL-1 Experiment, the IMS was set to a variety of tunes that, in

Table II

Courant-Snyder parameters of matched beam at input to DTL-1. β_x and β_y are in units of mm/mr. β_z is in deg-keV.

α_x	β_x	α_y	β_y	α_z	β_z
-2.3258	.2015	1.2949	.0862	-0.1892	.2665

Table III

Variable-field quadrupole field strengths (GL) and x mismatch factors (see ref. [5]) at the DTL-1 entrance for the tunes used in the DTL-1 Experiment. Field strengths are given in Tesla.

Tune	VFQ2 (T)	VFQ3 (T)	VFQ5 (T)	VFQ6 (T)	mmf_x
R1	5.583	4.884	6.288	6.136	.19
R2	4.830	5.635	5.667	6.174	1.00
R3	3.864	5.635	5.635	4.830	1.20
R4	3.542	5.635	5.474	4.693	1.44
R5	4.347	5.635	4.959	5.831	1.83
R6	6.054	2.898	3.474	2.840	2.99
R12	5.583	4.884	6.288	6.136	0.39
OLD	4.954	4.674	5.644	5.892	0.91

simulations, were predicted to give a matched beam as well as a wide range of mismatch factors (mmfs) [5]. Field values for these tunes are given in Table III. For all tunes except OLD, the longitudinal bunchers IMSA and IMSB operated at power levels of 1.58 and 6.75 kW respectively. In the OLD tune, buncher powers were 4.34 kW and 16.70 kW.

Simulation-determined mismatches at the entrance to the DTL-1 were calculated by using TRACE3D to transport the input beam of Table I from the exit of the RFQ through the IMS. The intended range of simulation-determined mismatch factors (relative to matched beam) was from $mmf_x = .2$ to $mmf_x = 3.0$ in x. However, in the actual experiment the mismatch of $mmf = 3.0$ (tune R6) could not be run because it resulted in fast protects that shut off the beam.

IV. MISMATCH AT THE DTL-1 ENTRANCE

For each tune of DTL-1 Experiment, Table III also presents the calculated mismatch value (relative to matched beam) of beam entering the DTL-1. These values were derived by using TRACE3D to propagate the input beam of Table I through the IMS. We modeled the SMQs in the IMS with soft-edged fringe fields. We know from TOSCA field calculations [6] that the soft-edged model corresponds closer to what physically exists, and steering-model studies [7] indicate that the soft-edged model provides better agreement between simulation and measurements. At the DTL-1 entrance, the range of mismatch values occurring during the DTL-1 Experiment is computed to be in the range of $mmf = .19$ to $mmf = 1.83$.

V. MEASURED VS. SIMULATION

For the DTL-1 Experiment, we have compared output-beam mmfs from experimental measurements with those calculated from simulation. This comparison was performed at the DTL-1 exit. All mismatch factors were calculated relative to matched beam parameters. Comparisons were made for all the different IMS tunes which were used in the DTL-1 Experiment.

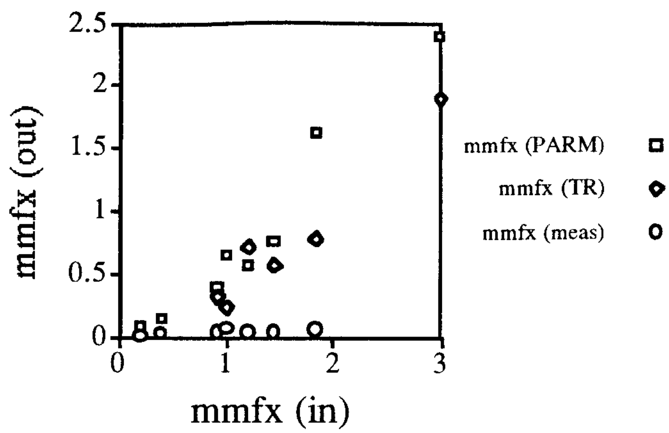

Figure 2. Dependence of mismatch at DTL-1 exit on mismatch at DTL-1 entrance.

All experimentally-determined mismatch factors are based on Courant-Snyder parameters measured at the ES6 location. Experimentally-determined mmfs cited at the DTL-1 exit were calculated by back-tracing ES6-measured parameters over a drift space to the DTL-1-exit location. Simulation-determined mismatch factors were calculated using TRACE3D to transport beam from the RFQ exit to the DTL-1 entrance, and then TRACE3D and PARMILA were used independently to transport the beam through DTL-1 to the DTL-1-exit.

The predicted mismatches for tunes R1-R5, R12, and "OLD tune" are presented in figure 2. The spread in simulation-determined mismatches at the DTL-1 exit does not differ greatly from the spread at the DTL-1 entrance. The smallest mismatches occur for R1, the tune that is predicted to provide matched beam. The largest mismatches occur for tune R5, and are approximately 10 times larger than those for matched beam. The average mismatch for non-matched tunes is $\overline{mmf_x} = 1.19$.

Figure 2 shows that both the predicted mismatch values calculated by TRACE3D and those calculated by PARMILA show a similar dependence on input mismatch values. In contrast, the actual DTL-1 measured values shown in figure 2 are insensitive to input mismatch. For tunes other than the matched tune, the measured mismatches are at least a factor of 10 smaller than the predicted values. Taken at face value, the data indicates that the DTL-1 produces an output beam with constant Courant-Snyder parameters regardless of the mismatch of the beam input to the DTL-1.

The lack of change in output beams might be thought to indicate a problem with the system controlling the VFQ settings. For instance, if some failure caused VFQ fields to not be varied, then the input beam to the DTL-1 would not have changed. Archived data show that the magnet encoder values were changing for the various tune changes. The way the magnet control system operates also strongly suggests that the magnet fields must have varied as requested or else warning messages would have been detected. In addition, when we attempted to run at

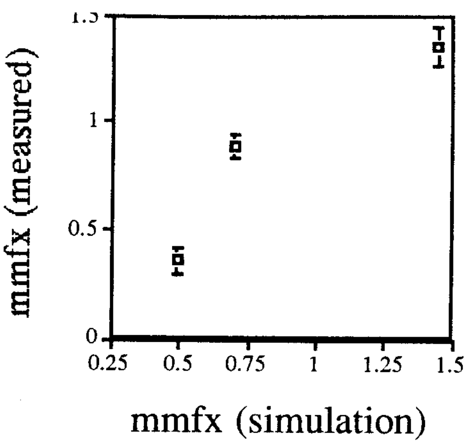

Figure 3. Dependence of IMS experiment mismatches

the R6 tune which is predicted to give a mismatch of 3.0 at the DTL-1 entrance, we were unable to run because of fast protects. So in that particular case it seems obvious that the VFQ's fields were being changed and that the change was such that the resultant beam was scraping enough to set off the fast protects.

VI. IMS EXPERIMENT

If the VFQs were being properly varied in the DTL-1 Experiment, then what can explain the constancy of the beam at the DTL-1 output? One possibility is that the different IMS tunes do not produce the wide range of mismatches, at the entrance to the DTL-1, that are predicted by simulation. Unfortunately, when the DTL-1 was in place, space limitations prohibited the slit and collector diagnostic at the IMS exit from being installed, thus eliminating our ability to directly measure beam characteristics at the DTL-1 entrance.

To study whether parameters at the DTL-1 entrance were changing for different IMS tunes, we performed the IMS Experiment. During this experiment, DTL-1 was replaced by a diagnostics station, and transverse-emittance scans were made at the ES5 location 369.1 cm downstream of the IMS endwall. The location point for the DTL-1 entrance in th DTL-1 Experiment had been 35.0 cm downstream of the IMS endwall. In the IMS Experiment, these two locations were separated by drift space only. Figure 3 presents a comparison of simulation-based and measured Courant-Snyder parameters for the IMS Experiment at the ES5 location. Uncertainties are given for the measured values based on the actual spread of repeated measurements.

Measured mismatch values presented in figure 3 track simulation-determined values for all 3 tunes tested. Since the maximum mismatch at the DTL-1 entrance is only on the order of $mmf = 1.0$, one might ask whether this more limited variation could have resulted in the highly similar beams observed in the DTL-1 Experiment. To answer this question, simulation codes were used to transport the αs and βs of figure 3 through the DTL-1 to ES6. The mismatches based on the extrapolation of IMS-experiment data are larger than those observed in the DTL-1 Experiment.

VII. CONCLUSIONS

Matching studies in the DTL-1 experiment were designed to test the effect of mismatches at the entrance to the DTL-1 on beams exiting the DTL-1. When the experiment was performed, the observed results gave an unexpected result: that the beam exiting the DTL-1 showed little variation for the different mismatches produced at the entrance. Simulations show that the variation in input beams should have produced a larger variation in output beams than was observed. A possible explanation is that the DTL affects the beam in some way so as to produce the same output beam independent of input beam.

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