COMMISSIONING OF THE GROUND TEST ACCELERATOR INTERTANK MATCHING SECTION*

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Abstract

The Ground Test Accelerator (GTA) has the objective of verifying much of the technology (physics and engineering) required for producing high-brightness, high-current H^- beams. GTA commissioning [1] is staged to verify the beam dynamics design of each major accelerator component as it is brought on-line. The commissioning stages are the 35-keV H^- injector, the 2.5-MeV radio-frequency quadrupole (RFQ) [2], the intertank matching section (IMS), the 3.2-MeV first 2-βλ drift-tube linac (DTL-1) module, the 8.7-MeV 2-βλ DTL (modules 1-5), and the 24-MeV GTA (all 10 DTL modules). Commissioning results from the IMS beam experiments will be presented.

Introduction

This paper addresses the commissioning of the GTA IMS which was designed to control emittance growth, to maintain high-beam transmission and brightness, to provide for transverse steering, and to provide longitudinal and transverse phase-space matching of the 55-mA, 2.5-MeV RFQ output beam to the first DTL-1 module. For compactness in the IMS (length ~35.5 cm), permanent magnet quadrupoles (PMQs) were used. The IMS optical elements include four PMQ variable field quadrupoles (VFQs) (range 2 to 7 T), two steering PMQs (fields 4.7 and 5.6 T with horizontal and vertical movements of ±1 mm), and two cryogenic (~ 25 K) 425-MHz rf bunchers. Further details on the IMS are given in Reference 1.

To evaluate the IMS's performance, the commissioning plan encompassed a variety of experiments. To verify the IMS steering model, beam-position centroids were measured as functions of the RFQ exit position and the IMS PMQ steerer positions. To determine the rf set points of the IMS buncher cavities with beam, measurements of longitudinal beam centroids (i.e., energy and phase) were made. Transverse and longitudinal phase space were also measured as functions of the VFQ strengths and the IMS buncher rf amplitudes and phases to verify the IMS transverse and longitudinal matching models needed for the DTL-1 commissioning.

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IMS Experiments and Results

Commissioning of the IMS was completed in April 1992. Preliminary results from the beam experiments are reported here.

Two principal GTA diagnostic systems were used for the IMS commissioning [3-4]. The first system was installed on a moveable diagnostics plate (D-plate) that was designed for use in the commissioning of the RFQ, IMS, and DTL-1. The D-plate diagnostics included (1) two sets of slits and collectors for measuring horizontal and vertical (i.e., x and y) transverse phase space and position and angle centroids (designated x or y and x' or y', respectively); (2) a toroid for measuring beam current; (3) three microstrip probes for measuring x, y, energy, and phase centroids; (4) a capacitive probe for measuring phase spread; and (5) a laser induced neutralization diagnostic approach (LINDA) [5-6] for measuring longitudinal phase space and energy and phase widths.

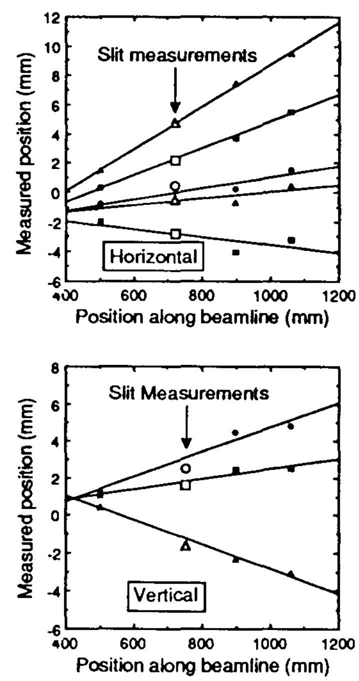

Fig. 1. Measured horizontal and vertical beam centroids along the beamline. Shown are data from the three D-plate microstrip probes and the emittance gear slit. Each line corresponds to a different steering configuration in the IMS.

The second system consisted of permanent beamline diagnostics. For monitoring beam transmission, the RFQ had two toroids, located in the entrance and exit endwalls, respectively. Within the IMS beamline there were (1) three microstrip probes; (2) a toroid; and (3) a Video Profile Monitor [7-8] for measuring transverse beam profiles and position centroids at the IMS exit.

As expected, beam losses in the IMS were small, with beam transmission at 97 ±2%. This was typical for most configurations of the IMS VFQs, buncher cavities, and PMQ steerers. Significant decreases in transmission occurred only for extreme VFQ and steerer settings.

As the RFQ exit position and the IMS PMQ steerer positions were varied, individually, the transverse centroids of the beam were measured with the IMS and D-plate microstrip probes and with the transverse emittance gear. Determination of the IMS steering model is in progress based on this database. Figure 1 illustrates the degree of self consistency that can be obtained with the microstrip probes and emittance gear.

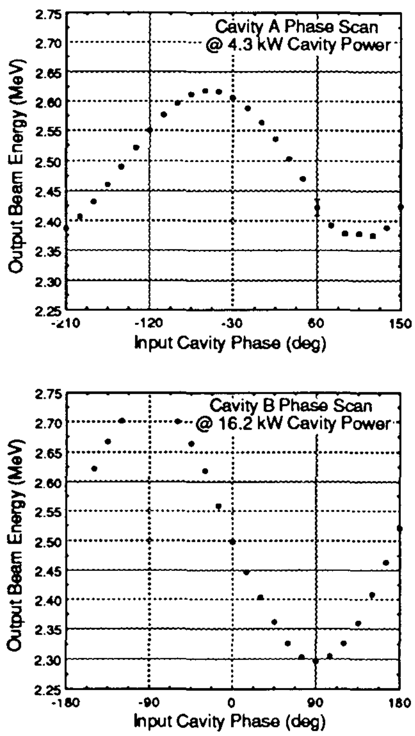

Fig. 2. Output beam energy as a function of the input cavity phase for the two IMS bunchers. Cavity A and B refer to the upstream and downstream cavities, respectively. For the data shown, the two cavities were operated at their design power levels. To operate the cavities in the bunch mode, the input cavity phase settings for cavities A and B are ~-146 and ~180 deg, respectively.

The microstrip probes provide information on the longitudinal phase-space centroids of the beam (i.e., energy and phase). These diagnostics are useful in determining the rf set points of the IMS bunchers under beam conditions. This objective was achieved with data of the type shown in Fig. 2, where the output beam energy is shown as a function of the cavity phase. In particular, the data in Fig. 2 allows us to determine the appropriate cavity input phase for beam bunching, debunching, acceleration, or deceleration. Figure 3 illustrates the type of data needed to determine the rf amplitude set point. For each cavity power, the difference in the beam output energy was measured as the cavity was changed from its acceleration to deceleration mode. The energy differences were within 2.5% of the predicted values.

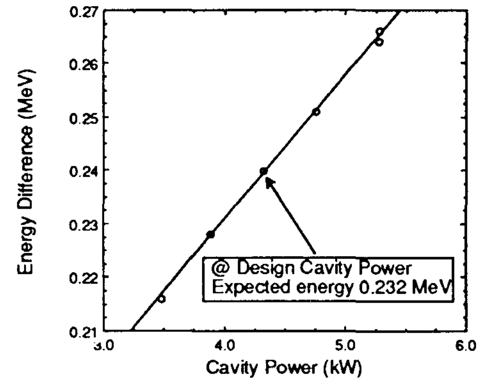

Fig. 3. Measured beam energy difference between the acceleration and deceleration modes for cavity A as a function of the rf cavity power. At the design cavity power, the expected and measured energy differences were 0.232 and 0.240 MeV, respectively.

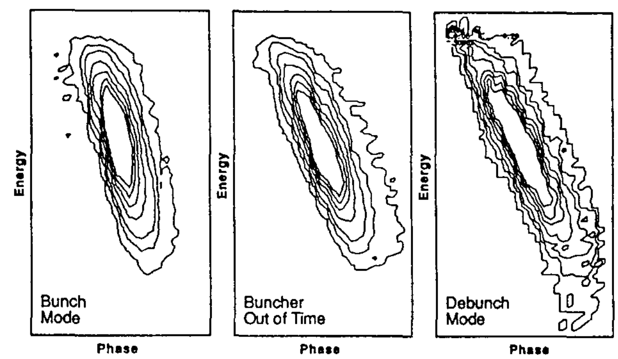

Fig. 4. IMS longitudinal phase-space distribution dependence on the operational mode of cavity A.

The database for establishing an IMS matching model was obtained by measuring the transverse and longitudinal phase-space distributions as functions of the four VFQ field strengths and the two IMS buncher rf amplitudes and phases. The full analysis of these data is still in progress. Preliminary results for the situation where the IMS VFQs and rf bunchers are set at their nominal design values give rms normalized transverse emittances that are a factor of ~2.1 and ~1.9 times design for x and y, respectively. The longitudinal emittance is consistent with that coming out of the RFQ. Qualitatively, the longitudinal phase-space distributions change as expected when the mode of operation for either IMS cavity is varied from bunch mode to debunch mode or to being out of time with respect to the beam pulse (Fig. 4).

Reference 2 showed the RFQ input and output currents and transmission dependence on time in the macropulse. Although beam transmission varies in time, the RFQ and IMS output transverse emittances do not (see Fig. 5). The same is true for the CS parameters, as illustrated in Fig. 6, where the time dependence of the mismatch factor MM [9-10] is shown. A value of MM = 0 has been arbitrarily assigned to one measurement at 25 μs.

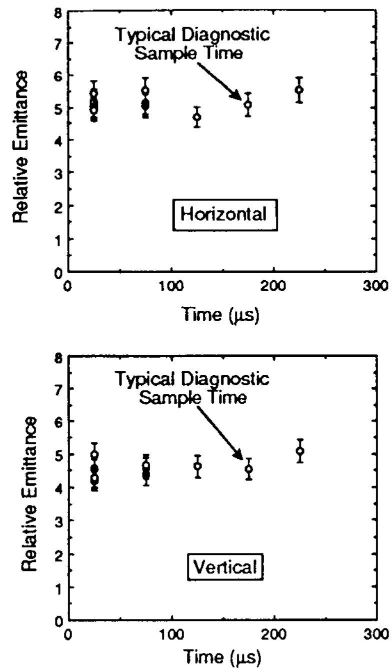

Fig. 5. Relative normalized rms transverse emittance (IMS output beam) versus time within the macropulse (end of macropulse corresponds to zero time). Data for both transverse planes are shown. The error on the emittance measurement is ~7%; the background subtraction is the dominant component of the error.

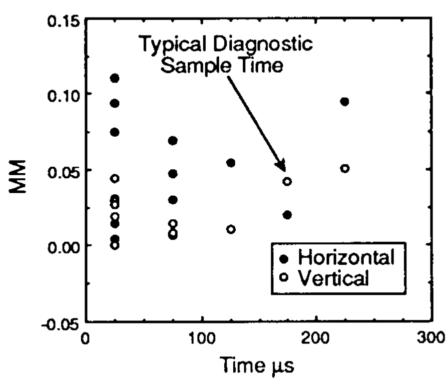

Fig. 6. Horizontal and vertical MM (IMS output beam) versus time within the macropulse. Maximum MMs are ~0.1 in x and ~0.05 in y indicating no significant changes in the CS parameters during the macropulse.

Summary

Commissioning of the IMS has been completed and it is now fully operational. During the commissioning, the injector and RFQ operations were shown to be reliable. Extensive beam measurements have been made and analysis has been started to establish steering and matching models for the DTL-1 module commissioning. Qualitatively, the performance of individual IMS components is correct. Preparations are underway for the beginning of DTL-1 commissioning in the near future.

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