A METHOD FOR LEBT AUTOMATION*

J. Sredniawski, L. Solensten, R. Schmidt, J. Porter, Y. Ng, C. Lom
Grumman Aerospace Corporation
Bethpage, NY 11714 USA
W. Newman
AMTEX Computer Systems
Islip Terrace, NY 11752 USA

I. INTRODUCTION

A generic method of Low Energy Beam Transport (LEBT) automatic tuning is under development that can be applied toward any pulsed beam accelerator using a radio frequency quadrupole (RFQ) with an adjustable solenoid-type LEBT. The purpose of this control scheme is to self-optimize the beam transport through the RFQ for any operating condition of the accelerator. This system is useful for an accelerator that operates over a range of currents. For a constant current machine, the system is useful to dynamically correct any drifts with time. This system is being developed on a beamline that uses a dual solenoid LEBT; however, the same system can also be used on a beamline with a single solenoid. This paper describes the mechanical and electrical design of the system and the algorithms used for the tuneup.

II. SYSTEM DESCRIPTION

The beamline diagnostics arrangement and controls are shown in Figure 1. The harps used for a pre-optimization algorithm are located between the two solenoids. For a single solenoid system, the harps should be located upstream and downstream of the solenoid.

The two sets of pin probes located near the RFQ input aperture are made from 60 mil tungsten wire. Wire was used instead of flat scraper blades because of the required uniformity between probes needed to obtain accurate signals. In addition, the tips of the pin probes were ground for uniform shape. A current measuring toroid is positioned between the pin probe arrays for measurement of the RFQ input beam (Ref 1). Figure 2 is a photograph showing this diagnostic arrangement. The pin probes nearest the RFQ are located so that when the beam is properly matched, they would barely see the edge of the beam halo. A protective cover is provided over the front of the first pin probe array to shield the delicate signal wire connections.

The electronics signal conditioning for both the harps and the pin probes are very similar. Shown in Figure 3, each harp wire or pin probe is connected to a current-to-voltage converter stage. Additional stages provide voltage gain and filtering functions. The signals are stored in the sample-and-hold amplifiers until they can be read by the channel multiplexer into the analog-to-digital converter. The digitized signals are then processed by the computer as part of the analysis, control, and display system.

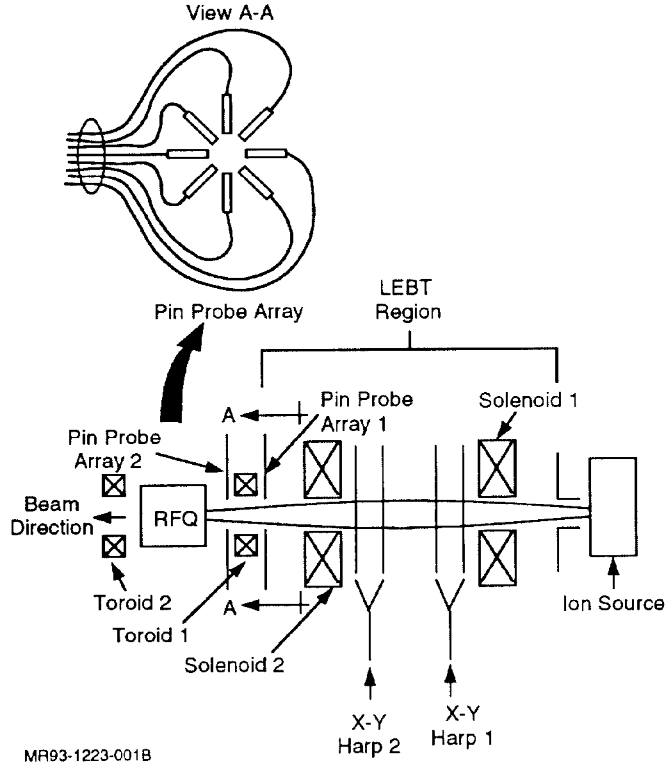


Figure 1. Schematic of LEBT diagnostics.

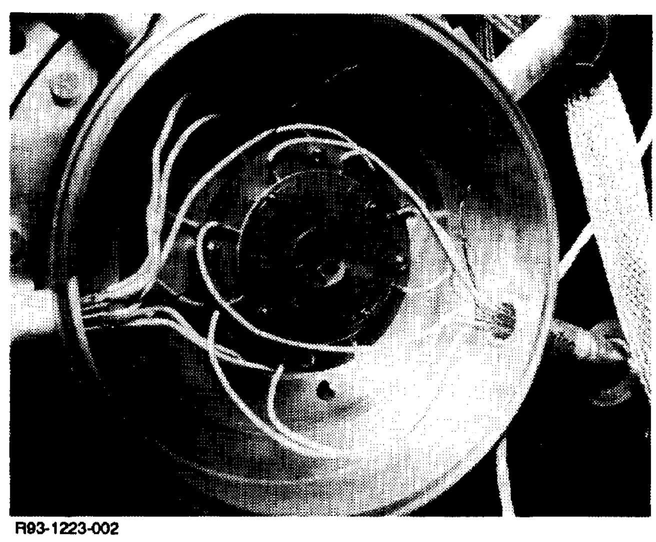


Figure 2. Pin probe array at RFQ entrance.

*This work was conducted under Grumman IR&D project 7256-2709.

0-7803-1203-1/93$03.00 © 1993 IEEE

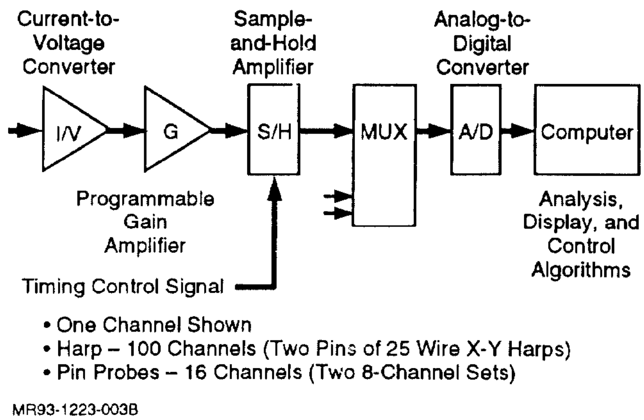


Figure 3. Harps and pin probes block diagram.

III. OPERATION

A logic flow chart of the control system operation is shown in Figure 4. The LEBT optimization algorithm consists of the following four states:

- State 0 – Manual mode, LEBT optimization on/off control
- State 1 – Pre-optimization, harp signal interface
- State 2 – Focus and steering, pin probe signal interface
- State 3 – Fine steering, toroid signal interface.

A. Pre-Optimization (State 1)

The pre-optimization step uses the harps to set up the initial beam focus from the first solenoid and to perform any gross steering that may be required. This is accomplished by analyzing the X and Y profiles and positions from the harp data as displayed in Figure 5. In the case of a two solenoid system as presently used, the current of the first solenoid is ramped until the total beam width of the downstream beam, as seen by harp two, is essentially the same as the beam width defined by harp one. This produces a parallel beam between the two solenoids. A similar condition can be set up with a single solenoid as well. It can be seen from Figure 5 that the downstream beam profile is not as peaked as the upstream profile. This is a normal condition for a low energy transported beam and is of no consequence since the control algorithm only uses the total beam width at this point. The control sequence now examines the crude centroid position of the beam in the second harp and makes any minor steering adjustments that are necessary to position the beam approximately on downstream center. This starting condition is necessary to be able to achieve a useful signal on the pin probes. If the beam is too big and unfocused at the RFQ entrance, the signals on the pin probes will be very low and essentially the same on each probe wire.

B. Focus and Steering (State 2)

For all of the following steps, the set point of the first solenoid is kept constant at the value previously defined. For a single solenoid system, the solenoid current will not be permitted to drop below the value previously defined. At this point, the current of solenoid two is ramped, while the signals on the first pin probe array are monitored for beam size, as shown in Figure 6. The intent is to make the beam disappear from the pin signals. A mild amount of steering correction is also applied to maintain the beam on center, as indicated by the magnitude of the relative pin

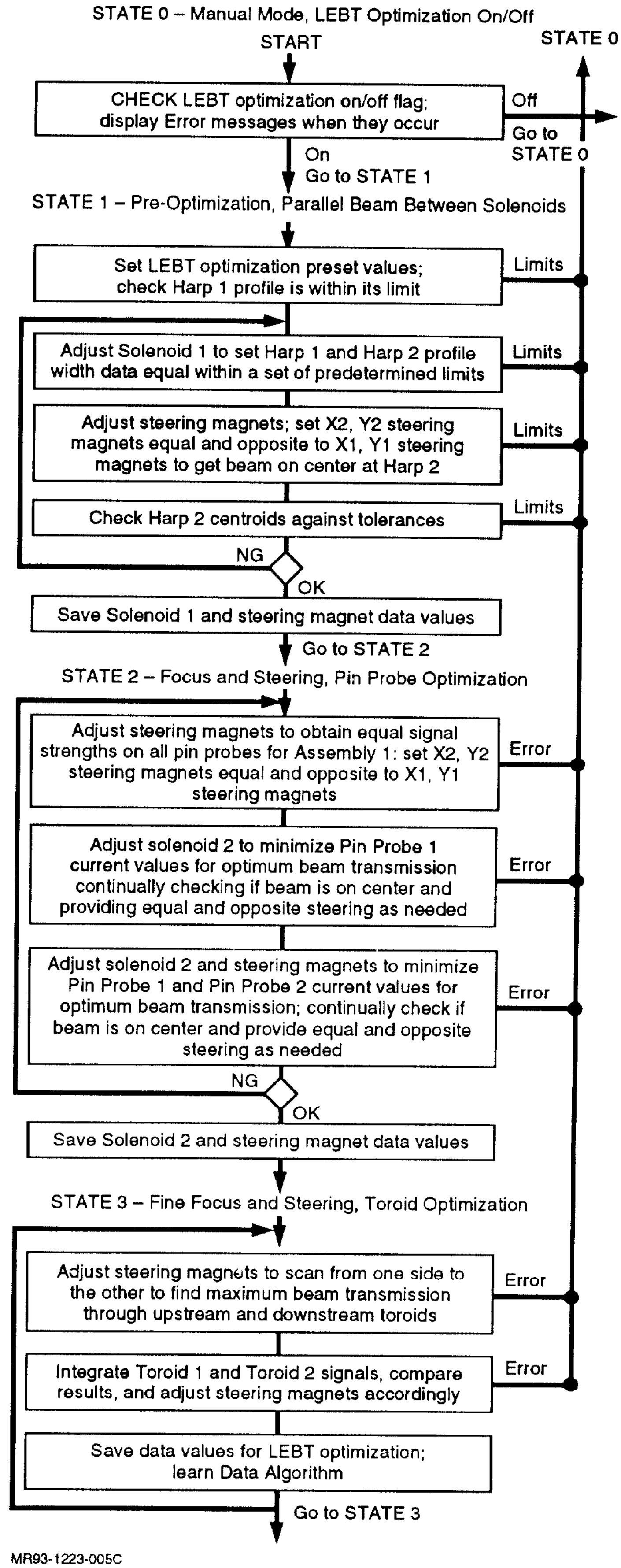
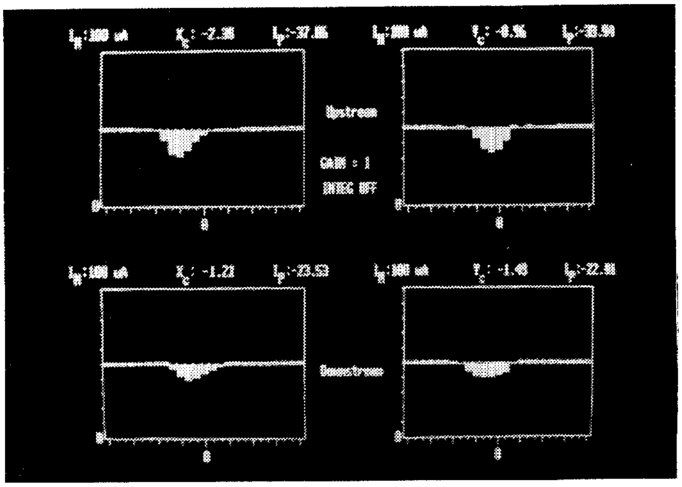


Figure 4. Control system logic flow chart.



R93-1223-006
930312-6

Figure 5. Harps for parallel beam pre-optimization.

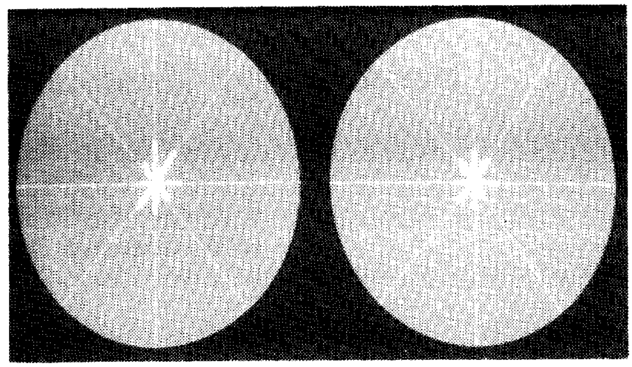
signals. These loops are nested so that a flip-flop between them is continually in process. This is due to the rotational effects of a solenoid system. Once the signals on the first pin probe drop below a set threshold, the second and more fine pin probe array is used to continue the above process. This is done until all the pin probe signals go essentially to zero, plus or minus a set tolerance band. The tolerance band must be established on the actual beamline installation by experimentation, since it may be sensitive to factors such as installation tolerances, EMI of the installed system, etc.

C. Fine Steering (State 3)

At this point, the pin probes and harps have been used to the best of their potential, yet the optimum beam transport through the RFQ may still not have been obtained. A very fine raster algorithm is now employed to literally hunt and peck the beam steering in a random pattern while observing the RFQ transmission by means of the upstream and downstream current toroids. A series of limits in each direction are attempted and stored in a dynamic data file which is used to peak the transmission value. This is all done for constant RFQ field amplitude, which is the extent of the LEBT control logic. If the radio frequency (RF) field or the beam current are changed in any significant way, the control logic is such that a series of checks for all of the previously described sequences and conditions is initiated once again.

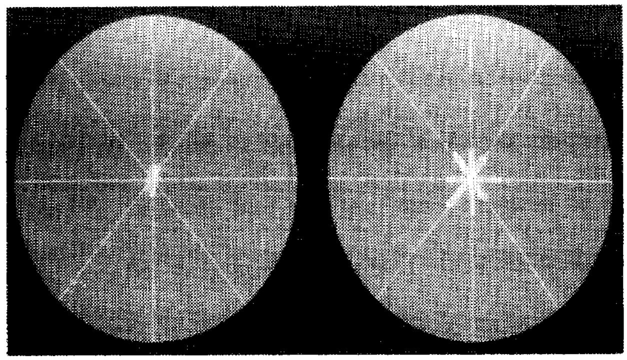
IV. CONCLUSIONS

The diagnostics described have been implemented and tested at Grumman on the front end of a pulsed beamline. So far, using the man in the loop to carry out the control logic flow, LEBT tuneup has been successful. We are now coding the steps for final implementation and qualification. This approach of automating the man in the loop has been used in the past on our ion source control system to provide a reliable automatic optimization technique (Ref 2). Future work will include automation of the RF amplitude and phase of the various accelerating structures downstream of the RFQ.



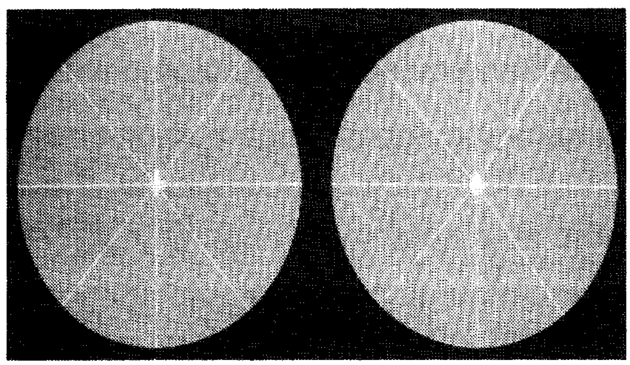
930312-5

(A) Parallel beams



930312-4

(B) Partially focused



930312-2

Pin Probe 1 Pin Probe 2

(C) Fully focused

R93-1223-007

Figure 6. Beam configurations.

V. REFERENCES

[1] J. F. Power, "Compact Cryogenic Toroid for Beam Current Measurement," *NPB Symposium*, Monterey, CA (July 1989).

[2] Y. Ng, et al., "Automatic Optimization of the Output Beam from a Small Pulsed Volume Source," *NPB Symposium*, San Diego, CA (April 1990).