REAL TIME DISPERSION MEASUREMENTS AT THE MIT BATES LINAC*

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Abstract

The MIT-Bates Linear Accelerator Center comprises a 1GeV electron linac/recirculator system, beam lines to two main experimental halls, and a pulse stretcher/storage ring. Proper tuning of the beam requires the transverse dispersion to be zero, or some specified non-zero value, at all locations along the beam lines. Dispersion measurements are made by correlating beam positions measured by BPMs, with energy measurements made using a BPM in a region of known non-zero dispersion. Data are acquired continuously from the BPMs and displayed on a graphical user interface in real time. This allows the accelerator operators to set dispersion quadrupoles and sextupoles so that the first and second order position and angle dispersions have their correct values at all points along the beam line. Details of the system design and operation are presented.

1. INTRODUCTION

The proper setup of any beamline requires that a number of conditions be satisfied. These include making sure the beam is on the correct trajectory, that the focussing and optics are as desired, and that chromatic terms are set to the specified values. To help the accelerator operators efficiently set the elements affecting the transverse dispersion, we have implemented a system for making real-time dispersion measurements. The system consists of appropriately located beam position monitors, a data acquisition system, and a graphical user interface to display the data, analyze it, and display the results.

The following describes details of the implementation of the dispersion measuring system, along with operational results.

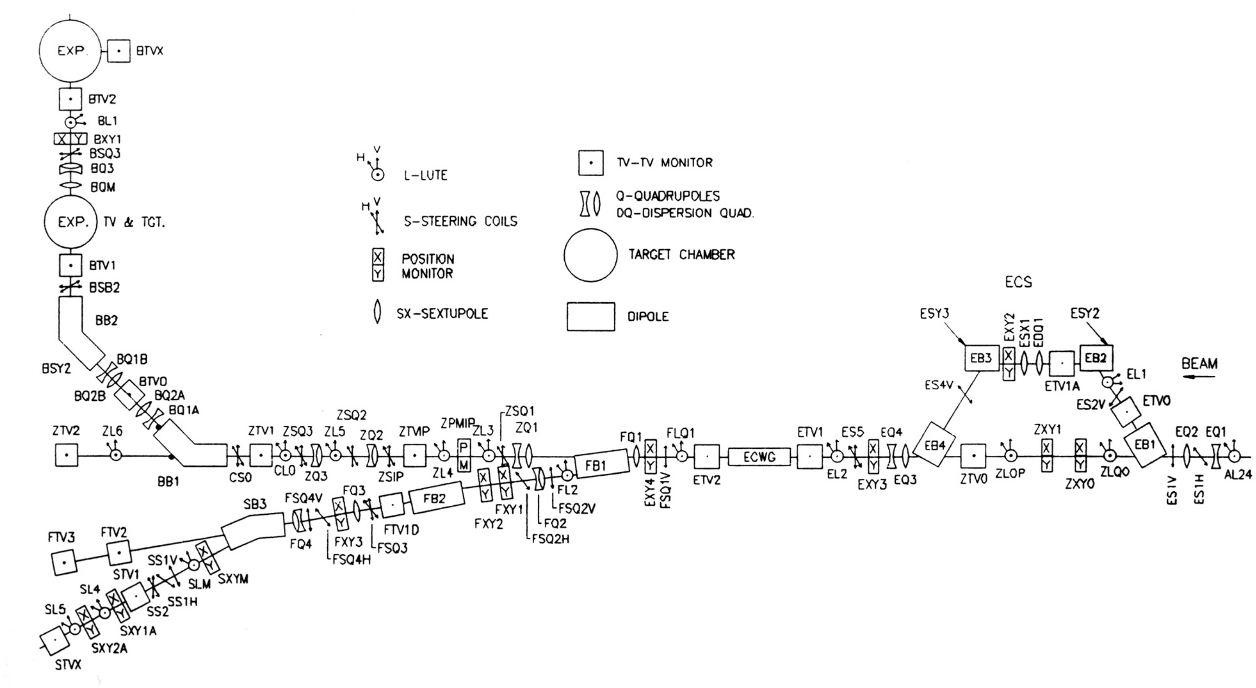

Fig. 1 Layout of the Bates beam switchyard showing the elements used to measure the dispersion

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2. SYSTEM DESCRIPTION

The key elements of the dispersion measuring system are several beam position monitors (BPMs), located in the beam switchyard. One of these monitors is located in a region of known dispersion, and is used to determine the deviation of the beam energy with respect to the nominal energy. Two additional BPMs are situated at or near the location where we wish to measure the dispersion. By measuring the beam position at these monitors, as a function of energy, we can determine how the beam position and angle vary with energy.

The layout of the Bates switchyard beamlines is shown in Figure 1. In the offset leg of the Energy Compression System (ECS) chicane, the horizontal dispersion x/δ = 33 mm/%. A BPM, designated EXY2, is situated in this position, and used for the energy determination. Other BPMs are placed at various locations in the switchyard, allowing us to measure the dispersion at these locations. For example, the BPMs designated EXY3 and EXY4, located just past the ECS chicane, allow us to measure the dispersion at that location.

In typical operation, the beam is delivered from the linac in 16 µs pulses. Data is acquired from the BPMs on a pulse-by-pulse basis, with a maximum acquisition rate of 4 Hz. The analog-to-digital converters for all the BPMs used in the measurement are read by the same Local Area Computer on the Bates control system. By monitoring the sequence number associated with the digitization process, it is possible to guarantee that all BPMs have acquired data during the same beam pulse. This removes the effects of pulse-to-pulse energy variations from the data analysis. The data is broadcast over the control system network, making it available at any computer on the network.

The dispersion measuring system is controlled from a graphical user interface, written in C, using X-windows and Motif, and run on DEC Ultrix workstations. When the program is first started, it prompts for the location at which the dispersion is to be measured, then sets the appropriate BPMs to the correct data acquisition mode, and begins acquiring data. At any time, the operator may request an analysis of the data. This involves fitting a parabola to the position data as a function of energy, and the angle data as a function of energy. The results are the first and second order dispersion elements, x/δ, x/δ^2, θ/δ, and θ/δ^2. Other program options include switching between measuring the dispersion in the horizontal and vertical dimensions, clearing the data and restarting acquisition, stopping data acquisition, restarting acquisition after stopping, making a hardcopy of the measurements and analysis, or exiting the program.

3. OPERATIONAL RESULTS

To make a dispersion measurement, the accelerator operator starts up the dispersion program. In order to accurately determine the dependence of the beam position or angle on the energy, it is necessary to scan the beam energy over some range, typically 0.5%.

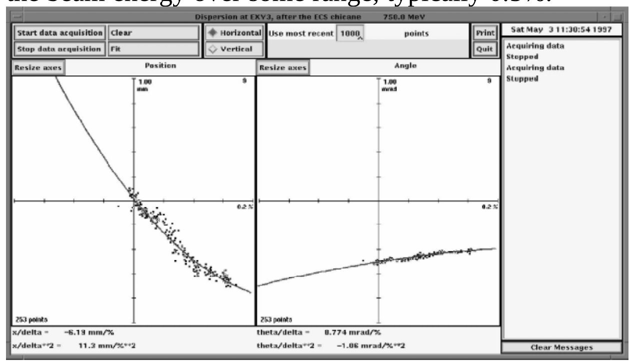

Fig. 2 Measured horizontal dispersion after the ECS chicane with the sextupole ESX1 set to -3.00 A

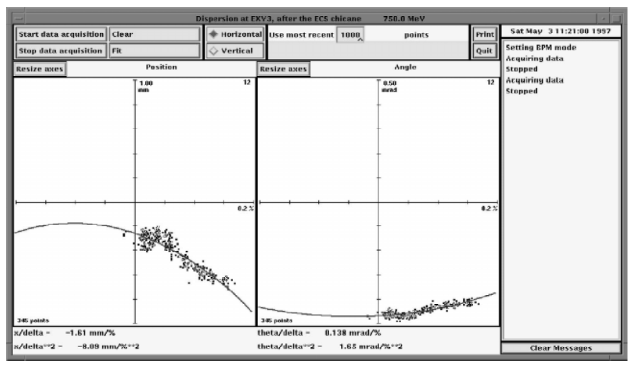

Fig. 3 Measured horizontal disperion after the ECS chicane with the sextupole ESX1 set to +0.155A

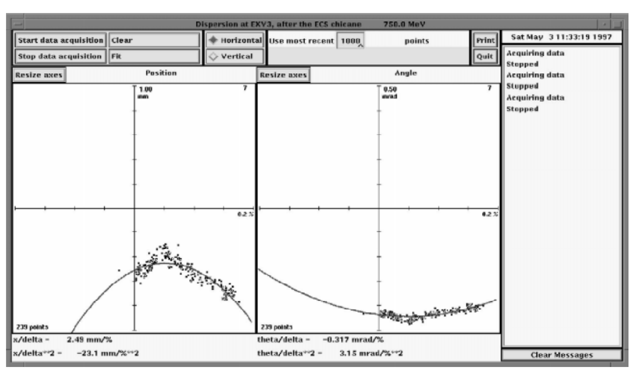

Fig. 4 Measured horizontal dispersions after the ECS chicane with the sextupole ESX1 set to +3.00 A

This is accomplished by varying the phase of the RF from one of the klystrons powering the latter part of the linac. As the energy is varied, and data acquired, the points are plotted in real-time on graphs of position versus energy and angle versus energy. Once the operator feels he has data over a large enough range of energy, and of sufficient quality, he can fit a parabola (or optionally a straight line) to the data. If the dispersion is out of spec, upstream dispersion quads or sextupoles are adjusted, until the desired values are achieved.

Measurements of the horizontal dispersion after the ECS chicane are shown in Figures 2-4, for different settings of a sextupole located in the chicane. The effect of the sextupole on the second order dispersion is clearly shown in the figures. This is an example of how the dispersion program can be used to set elements which control the chromatic aspects of a beamline tune.

The BPMs are calibrated with an RF source, and the calibration is then verified using the beam and a well known beam position measuring device, such as a wire scanner or a calibrated steering coil. The BPMs are capable of ±0.1 mm resolution, with a usable range of ±10mm. For a typical measurement of x/δ at a BPM, this gives a precision of 0.3 mm/%.

Using transport theory, the results of the measurement can be propagated to any desired location. This is done in situations where the BPMs are not located at the point at which we are trying to achieve the desired dispersion. For example, setting x/δ and θ/δ to zero at an experimental target is done using two BPMs upstream from the target, and propagating the measured results to the target.

4. SUMMARY

We have implemented a system for making beamline dispersion measurements in a convenient and efficient manner. It makes use of three beam position monitors. One of the BPMs is in a region of finite, known, dispersion, to act as an energy monitor. Data is acquired through the accelerator control system, and then displayed and analyzed in real time through a graphical user interface. The system allows the accelerator operators to readily achieve the specified values for the dispersion (zero or otherwise) by adjusting the appropriate beamline components. It is now in routine use.