NEW METHODS FOR DISPERSION MEASUREMENT AND CORRECTION FOR 12GeV CEBAF *

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Abstract

This paper discusses methods for dispersion measurement and correction for the Continuous Electron Beam Accelerator Facility (CEBAF) for the 12GeV era. New methods will be compared with methods used during the 6GeV era. New software tools which implement the new methods will be discussed, along with a method for automating dispersion measurement and correction. New dispersion measurement and correction methods and tools are being implemented to provide more deterministic results and to reduce machine setup time.

INTRODUCTION

The horizontal dispersion D_x describes the transverse displacement $x(s)$ of a particle as a function of its relative momentum deviation δ, via

$$x(s) = D_x(s)\delta. \qquad (1)$$

The vertical dispersion is defined analogously [1].

At CEBAF, correction of dispersion is essential for robust operation. Dispersion growth from pass to pass causes a growth in beam size and amplification of perturbations along the machine making the machine overly sensitive to small energy fluctuations [2].

Sources of dispersion errors in CEBAF include quadrupole misalignments, dipole misteering, corrector fields, and mispowering induced mismatches [3].

To measure dispersion, we measure the difference orbit as a result of a beam energy change. To induce a beam energy change, either a 30Hz AC modulation or a DC kick is applied to an analog input of the gradient feedback loops of a set of RF cavity control modules [4]. The resulting difference orbits can either be viewed on the beam position monitor control screens or plotted using high level software tools.

Dispersion in CEBAF is corrected using assigned pairs of orthogonal quadrupoles. There is a pair of orthogonal knobs in each spreader and recombiner to correct vertical dispersion, and a pair of orthogonal knobs in each recirculating arc to correct horizontal dispersion.

Figure 1 shows the design dispersion pattern in CEBAF. The peaks in η_x (black) are in the horizontal bends of the recirculating arcs, and the peaks in η_y (red) are in the vertical bends of the spreaders and recombiners.
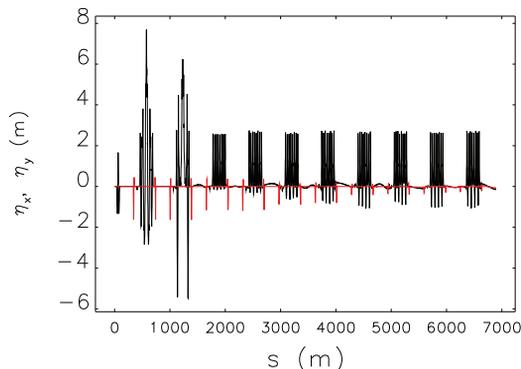
Figure 1: CEBAF design dispersion.

INTERFACE

The present tools for measuring and correcting dispersion at CEBAF are rather clumsy to use. The process involves navigating through multiple control system screens to apply momentum kicks and monitor the difference orbits for each segment of the machine, and the operator has no sense of the overall dispersion errors in the machine.

To help streamline the process of dispersion measurement and correction, a new software tool has been developed to provide the operator with a compact, comprehensive view of the measured dispersion in the entire machine. The controls for applying the momentum kicks are also included to provide the operator with one consolidated GUI for performing dispersion measurements. Figure 2 is a screenshot of the GUI displaying an example dispersion measurement. Note that the plots show the measured dispersion with a green trace, and the design dispersion with a dotted white trace.

The tool provides three different methods for measuring dispersion. The first two, mentioned above, apply a 30Hz AC or DC kick directly to the gradient feedback loops of a particular set of RF cavities. The third method applies a DC kick to a selected set of cavities via their gradient setpoints in the control system. The advantage of the third method is that any set of cavities can be selected, whereas the first two methods are tied directly to one set of cavities by hardware. The ability to select any set of cavities provides flexibilty in the case of hardware problems with the usual cavity set.

AUTOMATED DISPERSION CORRECTION

An automated routine for dispersion correction at CEBAF was developed which uses the simplex method for function minimization of Nelder and Mead [5] as implemented in
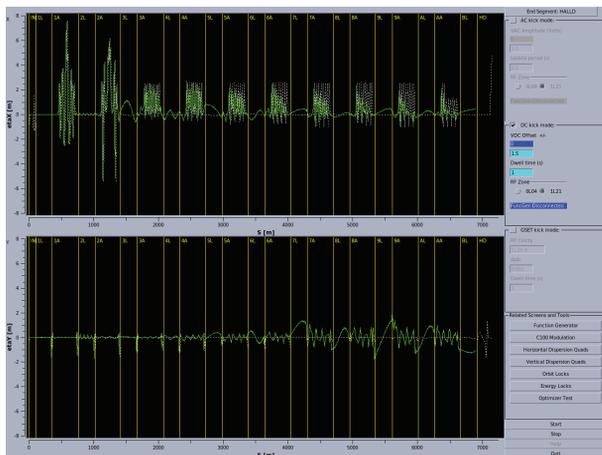
Figure 2: Dispersion Measurement GUI displaying an example dispersion measurement.

the GNU Scientific Library's (GSL) multidimensional minimization routines [6].

The idea is to minimize the RMS of the difference orbit, resulting from a momentum kick, through a given machine segment using the assigned pair of dispersion correction quadrupoles for that segment. The task is essentially to minimize a function of two variables, the function being the RMS of the difference orbit, and the variables being the quadrupole excitations.

The automated routine uses the iterative minimizer provided in the GSL cited above to empirically find an optics solution that minimizes the dispersion in a given segment. The function provided to the minimizer uses the quadrupole excitations as input, applies the momentum kick, and computes the RMS of the difference orbit. The minimizer adjusts the quadrupole excitations iteratively until a minimum RMS is found within a specified tolerance.

The automated routine is incorporated into the software interface described in the previous section to provide the operator a visualization of the progress of the automated dispersion correction.

SIMULATION

The automated dispersion correction routine was tested first by simulation using `elegant` [7]. The input files for simulation with `elegant` were generated from the CEBAF Element Database with `ced2elegant` [8]. For each iteration of the minimizer, the quadrupole settings computed by the minimizer, along with a momentum offset, were applied to the `elegant` deck. Running `elegant` would then produce a difference orbit from which the RMS was computed and fed back to the minimizer. The process repeated until a solution was reached that minimized the RMS of the difference orbit within a specified tolerance.

Figures 3 and 4 show the before and after dispersion plots for a simulated dispersion measurement and correction. A 20% quadrupole excitation error was introduced to generate a vertical dispersion error at the entrance of the first recir-

culating arc (the region labeled "1A" on the plots). The automated dispersion correction routine was able to correct the error in thirteen iterations, in approximately ten seconds per iteration. One should certainly expect the automated correction to run much more quickly on the real machine since the overhead of running `elegant` at each iteration would not be present.

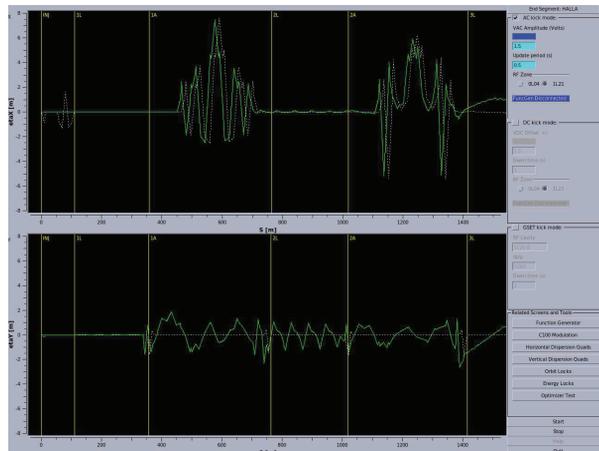

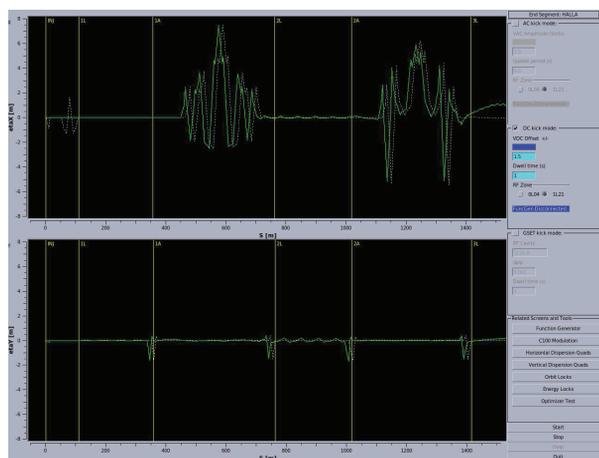Figure 3: Simulated dispersion measurement with a vertical dispersion error.

Figure 4: Simulated dispersion measurement after automatic correction.

TESTING

Due to constraints of the experiment schedule at CEBAF, opportunities for testing the new tool were rather limited. From the testing that was performed, it was determined that the automated correction routine does work as it did in the simulations, and that further testing and development is worthwhile and would be necessary in order to incorporate the new tool into operations.

CONCLUSION

New software tools and methods intended to streamline the dispersion measurement and correction process at CE-

BAF were presented. The automated dispersion measurement and correction routine has been proven to work, and will require more testing and development for it to be incorporated into the operations toolset.

ACKNOWLEDGMENT

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