Dr. 454
MASTER

VERTICAL DISPERSION CORRECTION

G. Parzen

June 30, 1978

ACCELERATOR DEPARTMENT

BROOKHAVEN NATIONAL LABORATORY
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BROOKHAVEN NATIONAL LABORATORY

UPTON, NEW YORK 11973

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ABSTRACT

A method for correcting the vertical dispersion is proposed in which the vertical closed orbit is primarily displaced at locations where the sextupole chromaticity correctors are placed in order to generate the skew quadrupole fields needed to correct the vertical dispersion. The results of a computer simulation study indicate that this method is feasible for ISABELLE, where a maximum displacement of the vertical closed orbit of about 2.0 mm is required.

INTRODUCTION

The presence of field errors can introduce vertical dispersion¹ of the closed orbit, a dependence of the vertical closed orbit on the particle momentum, into an accelerator which is intended to have median plane symmetry. This note suggests the possibility of correcting the vertical dispersion by vertically displacing the closed orbit, rather than using the more direct method of exciting skew quadrupoles² that have to be especially provided for this purpose. If the accelerator has strong sextupole fields, which are usually required for chromaticity correction, then the skew quadrupole fields required to correct the vertical dispersion can be obtained by vertically displacing the closed orbit at the locations where the sextupole fields exist. Vertical orbit displacement at the quadrupoles can also be used to correct the vertical dispersion. This method of correcting the vertical dispersion is feasible if the vertical displacement of the closed orbit required is not excessive. Computer simulation studies show that the vertical dispersion can be corrected at the six crossing points in ISABELLE with a maximum vertical displacement of the orbit of about 2.0 mm, and the correction can be done without moving the orbit at the 6 crossing points. This method then appears workable for ISABELLE. A similar approach is being developed by M. J. Lee³ for use at PEP.

THEORY

The theory may be summarized by the equations given below. Further details will be given in a future report.

Correction of the closed orbit may be done by writing the vertical orbit displacement at the monitors labeled by the index K as

$$Y(K) = Y_A(K) + \Delta Y(K) ,$$

where $Y_A(K)$ is the initial or measured displacement and $\Delta Y(K)$ is the correction produced by the dipole correction coils. $\Delta Y(K)$ is given by

$$\Delta Y(K) = \sum_J A(K,J) D(J) ,$$

$$A(K,J) = \frac{[\beta_y(K) \beta_y(J)]^{\frac{1}{2}}}{2 \sin \pi \nu_y} \cos[\pi \nu_y - |\psi(K) - \psi(J)|] ,$$

$$D(J) = L_J B_J / B\rho .$$

$\psi(K)$ is the vertical betatron phase at point, K. B_J and L_J are the field and length of the correction dipoles at point J. The other symbols have their usual meanings.

The strengths of the correctors, $D(J)$, are determined by the minimization equation

$$\delta \cdot \sum_K Y^2(K) = \delta \cdot \sum_K [Y_A(K) + \sum_J A(K,J) D(J)]^2 = 0 .$$

In order to also correct the vertical dispersion, we write the vertical dispersion at point L as

$$Y_p(L) = Y_{p,A}(L) + \Delta Y_p(L) ,$$

1. A. Piwinski, DESY/PETRA-Kurzmitteilung, N.29(1976) and A. Chao, 1975 ISABELLE Summer Study, BNL 20550, p. 386.
2. R. Chasman and M. Month, BNL Report, ISA 76-10 (1976).
3. M. J. Lee, PEP Technical Memo PTM-134 (1978).

where $Y_{p,A}(L)$ is the initial or measured dispersion, and $\Delta Y_p(L)$ is the correction produced by the dipole correction coils. $\Delta Y_p(L)$ is given by

$$\Delta Y_p(L) = \sum_J C(L,J) D(J) ,$$

$$C(L,J) = \sum_M A(L,M) (L_M/B\rho) (B_0^2 b_2 X_p - G)_M A(M,J) - A(L,J) .$$

L_M , $B_0 b_2 X_p^2$, and G are the length, the sextupole field, and the gradient of magnet M . The points labeled by L are the points at which the vertical dispersion is to be corrected. For ISABELLE these points are the 6 crossing points where the beams cross.

The strengths of the correctors, $D(J)$, are now determined by the minimization equation with 12 constraints

$$\delta \sum_K Y^2(K) = \delta \sum_K [Y_A(K) + \sum_J A(K,J) D(J)]^2 = 0 ,$$

$$Y_p(L) = Y_{p,A}(L) + \sum_J C(L,J) \cdot D(J) = 0 ,$$

$$Y(L) = Y_A(L) + \sum_J A(L,J) \cdot D(J) = 0 .$$

$Y(L)$ is the vertical orbit displacement at the L labeled points, and we are requiring that the vertical orbit at these points not be changed when we correct the vertical dispersion, since the vertical orbit displacement may have been previously set to maximize the luminosity and to minimize the differences in the relative vertical positions of the two beams at these points.

Another possible formulation of the minimization equations to correct the vertical dispersion is:

$$\delta \cdot \left\{ \sum_K Y^2(K) + \lambda \sum_L Y_p^2(L) \right\} = 0 ,$$

or

$$\delta \left\{ \sum_L [Y_A(K) + \sum_J A(K,J) \cdot D(J)]^2 + \lambda \sum_L [Y_{p,A}(L) + \sum_J C(L,J) D(J)]^2 \right\} = 0 ,$$

to which we can add the constraints

$$Y(L) = Y_A(L) + \sum_J A(L,J) \cdot D(J) = 0 .$$

The parameter λ has to be chosen empirically to get the correct balance between correcting the orbit displacement and correcting the vertical dispersion. For the case of the ISABELLE accelerator, both formulations of the minimization problem worked equally well.

COMPUTER SIMULATION RESULTS

The computer program CLOSORB was used to simulate an accelerator with a set of random field errors that produce errors in the vertical orbit displacement and in the vertical dispersion. The orbit errors were then corrected in two steps. In the first step the orbit displacement was corrected, and in the second step dipole correctors were changed to correct the vertical dispersion at the 6 crossing points while

minimizing the resulting orbit displacements, and while not moving the orbit at the 6 crossing points.

Table I lists results of computer simulation runs that simulate 10 ISABELLE accelerators having different initial field errors. Table I shows $Y_{\max}$ the maximum vertical closed orbit displacement, when only Y is corrected and then when both Y and Y_p at the crossing points are corrected without moving the orbit at the crossing points. In order to correct the vertical dispersion, one finds that the maximum orbit displacement needs to be increased from 0.2 mm to about 2.0 mm with 90% probability. The dipole field correction needed to correct the orbit displacement is about 400 G, and in order to also correct the vertical dispersion the maximum dipole correction required remains about 400 G, although some of the correctors have to be changed by as much as 180 G.

TABLE I

Results of 10 computer simulation runs showing the vertical displacement required to correct the vertical dispersion in ISABELLE. $Y_{\max}$ is the maximum vertical closed orbit displacement around the accelerator. $Y_{p,\max}$ is the maximum vertical dispersion at the 6 crossing points, $B_{\max}$ is the maximum dipole correction required, $\Delta B_{\max}$ is the change in the dipole correctors when Y_p is corrected in addition to Y.

Run	Y Corrected			Y and Y_p Corrected			
	$Y_{\max}$ (mm)	$Y_{p,\max}$ (mm)	$B_{\max}$ (gauss)	$Y_{\max}$ (mm)	$Y_{p,\max}$ (mm)	$B_{\max}$ (gauss)	$\Delta B_{\max}$ (gauss)
1	0.22	28	386	0.50	0	387	44
2	0.20	54	285	0.80	0	328	82
3	0.21	43	303	1.5	0	304	129
4	0.24	62	341	2.1	0	336	184
5	0.22	46	407	1.2	0	355	127
6	0.21	61	299	1.2	0	309	121
7	0.26	46	309	0.98	0	309	85
8	0.25	34	370	0.67	0	368	66
9	0.23	47	350	1.0	0	351	107
10	0.19	60	306	1.2	0	326	122

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