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CHROMATIC CORRECTIONS FOR LARGE STORAGE RINGS*

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Abstract

The use of the achromat concept (1) to facilitate chromatic corrections in large storage rings is illustrated. The example given in this report is a lattice for a 75 GeV/c ring with six interaction regions having a betax = 1.6 m, a betay = 0.1m and a luminosity of 1.4 $10^{32} cm^{-2} s^{-1}$. The chromatic corrections are done with four families of sextupoles, two for each transverse plane, the strengths of which are determined by the solution of four linear equations in four unknowns. The basic simplicity of the method allows on-line control of the sextupole adjustments.

Introduction

Sextupoles used in the lattice structure of storage rings for the purpose of making chromatic corrections may introduce geometric aberrations that distort the particle motion. The magnitude of these aberrations increases as the beta functions at the interaction points decrease. These distortions may be further compounded by geometric aberrations introduced by the bending magnets. Fortunately both of these degrading effects can be minimized in the following way: 1) The design of the first-order lattice containing the dipole and quadrupole components is chosen so as to minimize the magnitude of the inherent geometric aberrations. 2) The chromatic correcting elements (sextupoles) are introduced in patterns which do not deteriorate the geometric quality of the already chosen first-order lattice. It is the purpose of this paper to illustrate how this can be achieved by using some of the essential features of the second-order achromat concept (1).

Basic Lattice Design

The basic lattice is divided into three main segments: the interaction regions, a straight matching section containing only quadrupoles, and curved sections where the chromatic corrections are made. The curved sections are composed of modules, each of which has a total transfer matrix equal to the identity matrix in both transverse planes. Each module consists of six identical unit cells containing dipole and quadrupole components. Such a system is achromatic to first order and has vanishing second-order geometric aberrations. This requires the correcting section to be set at a fixed tune. However, in the example given, sufficient tuning of the ring can be achieved in the matching straight sections.

The correcting sextupoles are then introduced in pairs, the elements of each pair being identical and separated by a phase shift of pi in both transverse planes. Two such pairs are introduced in each transverse plane, with no interlacing of adjacent pairs, as shown in figure 1 below. If the intervening lattice between elements of each pair is linear, then the sextupoles do not introduce geometric aberrations at the interaction points for the on-momentum particles. The lattice is, of course, not perfectly linear because of the presence of dipoles and because of the finite length of the sextupoles. Also the cancellation of the off-momentum geometric aberrations is not exact because the phase shift between correcting sextupoles is a function of momentum. We find, however, that these higher-order residual effects are small in the example given below.

A Lattice for a 75 GeV/c Eletron Positron Ring

Figure 1 describes the lattice chosen, as a representative example for a 75 GeV/c ring for the specific purpose of illustrating the chromatic correction process. Table 1 contains the main parameters characterizing the ring. Four chromatic properties of the ring are corrected: dnux/ddelta, dnuy/ddelta, dbetax/ddelta and dbetay/ddelta. A second order matrix formalism, used in the program TRANSPORT (2), is implemented in the program DIMAT (3) which is designed for circular machine studies. The computation of the sextupole strengths involves the determination of the transfer matrix for one superperiod and the solution of a set of four linear equations with four unknowns.

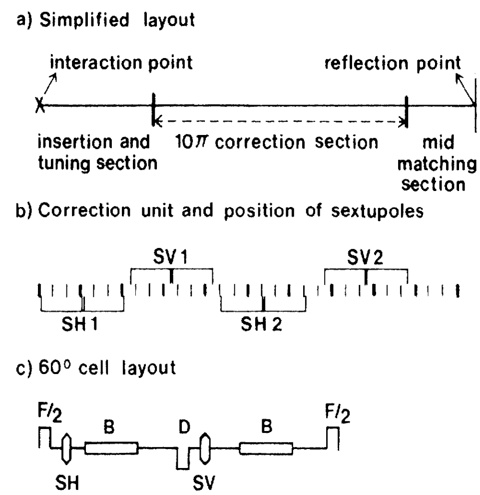

Fig.1. Ring layout

Table 1

Machine Parameters

# of interaction points		6
Radius of curvature		2.5 km
Circumference		26.0 km
Available space at interaction points		+/- 5.0 m
Interaction point values	betax	1.6 m
	betay	0.1 m
	etax	0.0 m
Tunes	nux	70.25
	nuy	67.75
Chromaticities	chix	-119.4
	chiy	-156.5
Beam sizes at interaction point	sigmax	0.460 mm
	sigmay	0.081 mm
	sigmaE	0.128 percent
luminosity		$1.4 10^{32} cm^{-2} s^{-1}$
betax max		600 m
betay max		474 m
Cell values	beta max	123.5 m
	beta min	41.6 m
	etax max	3.1 m
	phix	60 degrees
	phiy	60 degrees

Figure 2 shows the momentum dependence of the tunes nux, nuy, and the beta functions betax and betay at the interaction point, for one superperiod.

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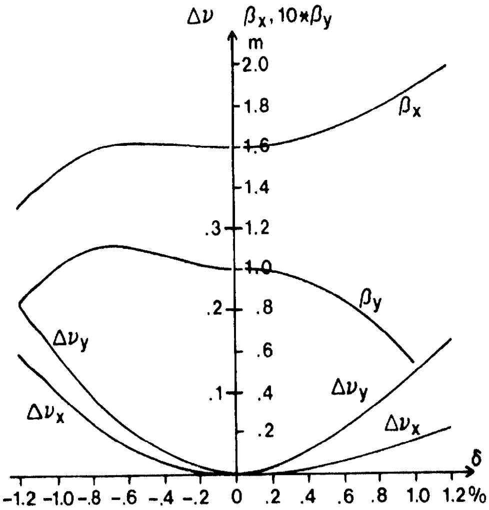

Fig.2. Tunes, betas vs. momentum for ideal setup

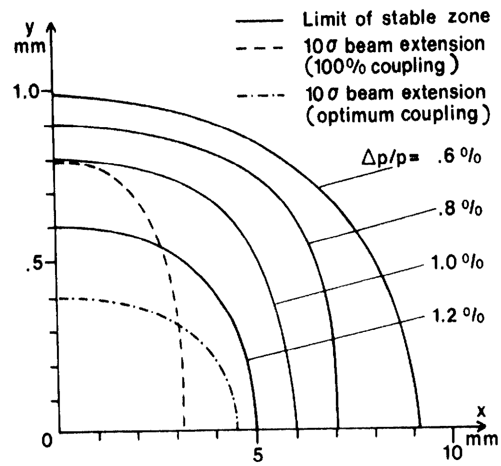

Fig.3. Stability diagram - ideal case

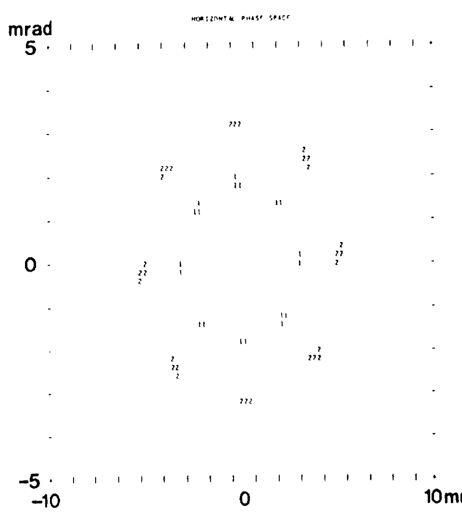

Fig.4. Tracking of $10\sigma_{xy}$, $7\sigma_{xy}$ on momentum particles

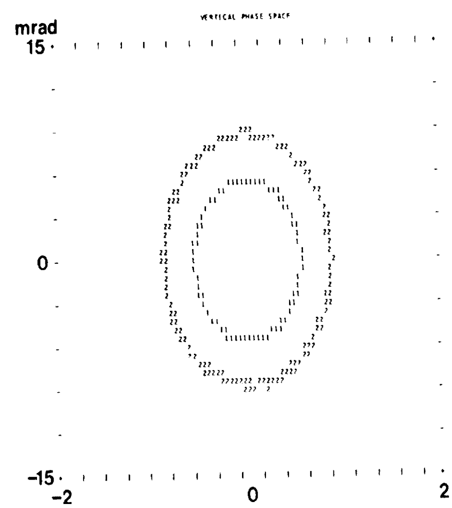

Fig.5. Tracking of $10\sigma_{xy}$, $7\sigma_{xy}$ on momentum particles

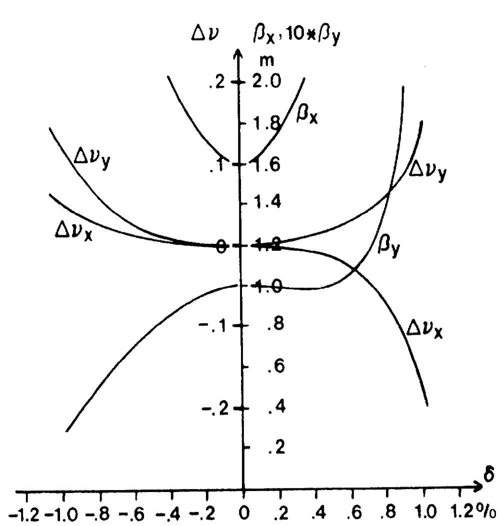

Fig.6. 59° cells-tunes-β^* values

Particles were traced around the lattice to determine the zone of stability at the interaction point. Figure 3 shows the result of this tracing (100 turns of a full lattice) of particles for relative momenta deviations of 0.6, 0.8, 1.0, and 1.2 percent dp/p. Figures 4 and 5 depict the phase space motion in both transverse planes for the on-momentum particles. As can be seen from these graphs, the motion is close to linear. The curves are elliptical which illustrates that the geometric aberrations in the system are small.

Sensitivity Analysis

The above analysis is based on the realization of a perfect unity transfer matrix for each of the correcting sections, and on the absence of interlacing of the sextupole pairs. Using the program DIMAT we estimate how exactly these assumptions have been met. Figure 6 gives the same results as those given in figure 2 but for a lattice where the curved sections have a phase advance of 59 degrees per cell.

There is a significant change in the tunes and especially in the beta functions as a function of momentum. (The overall tune for the on-momentum particles was held constant.) The zone of stability is reduced for the 59 degree/cell case. This is evident in figure 7. However the deterioration of the momentum dependence of the tunes and beta functions is more severe than it is for the stability diagrams.

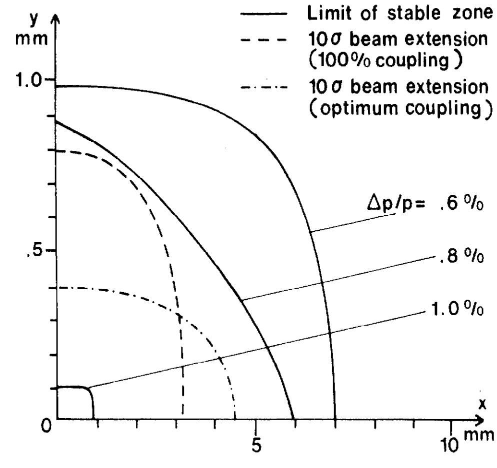

Fig.7. Stability diagram - 59° cells

Figures 8 and 9 give the same results for a machine having interlacing of two pairs of correcting elements. (one horizontal pair and one vertical pair are interlaced.) From these figures it can be seen that interlacing of the correcting sextupoles is very detrimental to the stability diagrams.

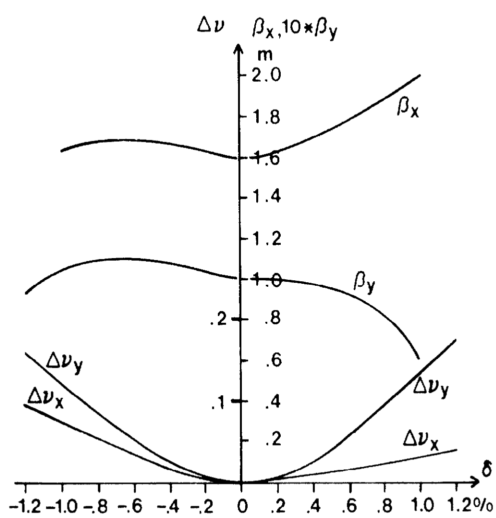

Fig.8. Interlacing of two sextupole pairs

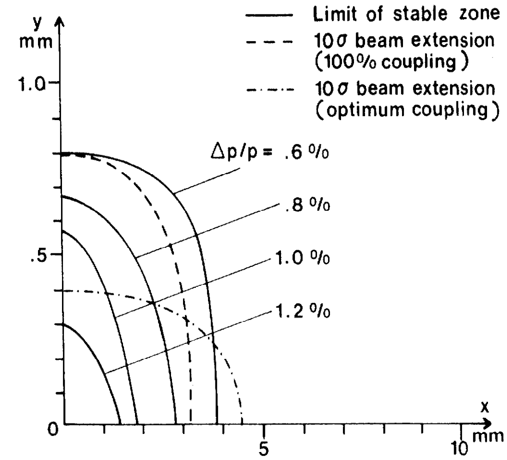

Fig.9. Stability diagram - interlacing

Conclusions and Suggestions

We feel that the above results are sufficiently encouraging to warrant further studies. Analysis of possible ways of reducing the higher order momentum dependence of the tunes and of the beta functions by the choice of the first-order lattice design seems in order. We also wish to emphasize that the above lattice is only an example to illustrate the chromatic correction technique used here. The value of the method now needs to be explored for other possible machine parameters to determine the limits of applicability of this technique.

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