COMPENSATION SCHEMES FOR UNDULATOR INSERTION

P. Nghiem, M. Sommer, H. Zyngier

Laboratoire pour l'Utilisation du Rayonnement Electromagnetique,
91405 Orsay Cédex, France.

Abstract

The insertion of an undulator or a wiggler changes the vertical tune, the symmetry and the chromatic properties of a lattice. These perturbations must be compensated for, or at least reduced. Due to the large number of inserts, the portion of the machine allowed for the local corrections is much smaller in synchrotron radiation sources than in colliders.

Different schemes are proposed. Special emphasis is put on local correction which allows independent control of several inserts. Application is made to Super-ACO.

Super-ACO is a dedicated synchrotron radiation source, which can accommodate up to six undulators. The layout of the ring with the foreseen positions of these undulators is shown on Fig. 1. The undulators occupy two different kinds of locations which have very similar optics. Their difference is related to the chromatic dispersion function D. In the even numbered straight sections, the horizontal phase shift between the bending magnets is π, and therefore in the odd numbered straight sections there is no dispersion. Some attention has been paid to the practical problems which could arise with the simultaneous and independent operation of several insertion devices.

The first optical effect of an undulator is an increase of the vertical tune. At the same time, the β function is altered. This leads to a distortion of the closed orbit due to the change of the balance of dipole errors. As the symmetry of the lattice is reduced, stopbands appear around half-integer values of the tune.

For all these reasons, the optical perturbation must be compensated for. In principle, to preserve a transfer matrix, 8 parameters should be monitored : 3 for the horizontal motion, 3 for the vertical, and 2 for the off-momentum orbit. This requires 8 variable quadrupoles, but in the first place, we tried simpler schemes.

In what follows, we treat the case of the two undulators situated in straights 2 and 7. Each one has an integrated squared field of 0.8 T^2m. At 800 MeV, we represent them by vertical lenses of convergence 0.112 m^{-1}. For the so called "low emittance" optics considered, the beta functions at the undulator locations are $\beta_x \simeq 6$ m and $\beta_z \simeq 11$ m.

In the vertical plane, these two undulators change the tune by 0.171 and distort the beta function by a factor up to 2.8 (Fig. 2.).

If only one undulator is present, the easiest thing to do is to correct the tunes by using the two families of quadrupoles adjacent to the undulator. Since an undulator affects only the vertical tune, it could seem at the first glance that one family is enough, but one needs actually two families to correct the vertical tune while preserving the horizontal one. The symmetry remains not bad, and the dispersion function is acceptable. For two equal undulators, this scheme is still valid when the undulators are located in symmetrical positions. But if this is not the case, the β and D functions are heavily distorted (Fig. 3a.).

It seems then desirable that the compensation be made locally, so that each undulator is compensated separately and, as much as possible, independently. With Super-ACO this can be done, since all the quadrupoles are fitted with two sets of additional windings able to vary the gradient by about 3.5 % each.

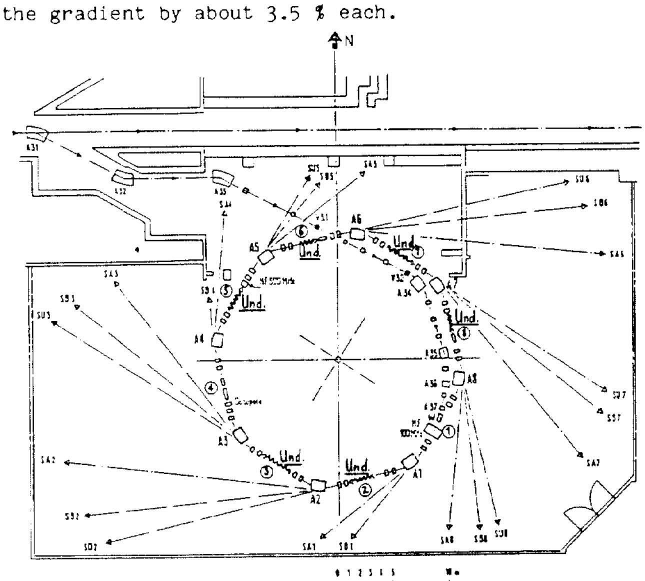


Fig. 1. Layout of Super-ACO with the foreseen undulator positions.

We then tried schemes using only the four quadrupoles located in the undulator octant, and therefore able to control 4 parameters.

One possible choice is to trim symmetrically the two doublets so that the tunes remain constant. The β values do not vary throughout the whole machine by more than 10 % (Fig. 3b.). The dispersion is not affected at all when the perturbation is situated in an odd numbered straight section, and it varies by only 4 cm for an even numbered (dispersive) straight section. This scheme is very easy to implement : it just requires to watch the tunes and keep them constant while closing the undulator.

Another possible choice is to control the distortion of the β functions, thus preserving the symmetry of the lattice. The horizontal tune then shift by about 0.014 per undulator (Fig. 3c.). Again, in the case of an even octant, the dispersion is only slightly affected.

The reason why the two preceding schemes give comparable results can be understood by inspecting the analytical formulae for lattice perturbations

$$\Delta\nu = \frac{1}{4\pi}\int \Delta K(s')\beta(s')ds'$$

$$\Delta\beta = \frac{-\beta}{2\sin 2\pi\nu}\int \Delta K(s')\ \beta(s')\ \cos 2[\Phi(s')-\Phi(s)+\pi\nu)]\ ds'$$

These formulae mean that the source term is $\Delta K.\beta$ for the tune perturbation, and $\Delta K.\beta.\exp(i2\Phi)$ for the β function. The tune compensation using symmetrical quadrupoles cancels the imaginary part of the β perturbation, and the difference between the two schemes arises solely from the difference between cos 2ϕ and 1. This difference is not big since in the straight sections of Super-ACO, the phases do not vary much. Concerning the dispersion, its shape is obtained in the regular lattice by ensuring the symmetry of the even numbered octants, together with the phase shift between the centers of the bends. The local tune compensation does not alter heavily these conditions.

For practical purposes, the schemes listed above should be sufficient. However, a total compensation for an even numbered octant of Super-ACO has been studied. The perturbation is now strictly confined, so that several insertions can be manoeuvered independently, even if they are strong. But this covers a long portion of the machine (Fig. 3d).

Each of the schemes presented here has its advantages and its drawbacks. The global compensation is easy to implement. It is the only one which does not require special windings, but its use is limited to a small number of weak undulators. The local tune compensation is also easy to accomplish, but supposes that the local β's are not too small (the symmetry of the lattice is not too perturbed). The local β compensation looks attractive when the residual tune shift remains low, but if this is not the case, recovering the tune by the use of the main quadrupole destroys the independence. The complete compensation is probably too space consuming to be implemented.

The choice of the scheme to be used will depend for each special case on the relevant conditions : strength of the perturbation, optics, available correcting elements. In the case of Super-ACO, the best compromise seems to be the local tune compensation.

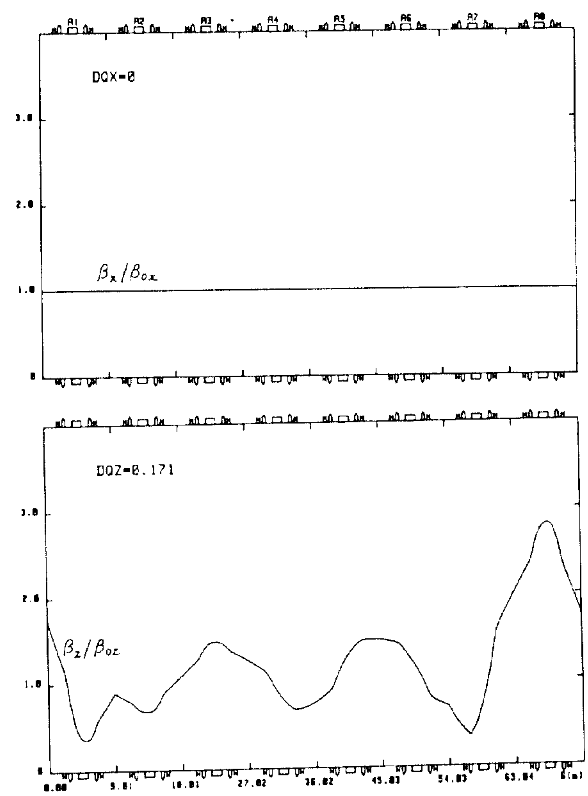
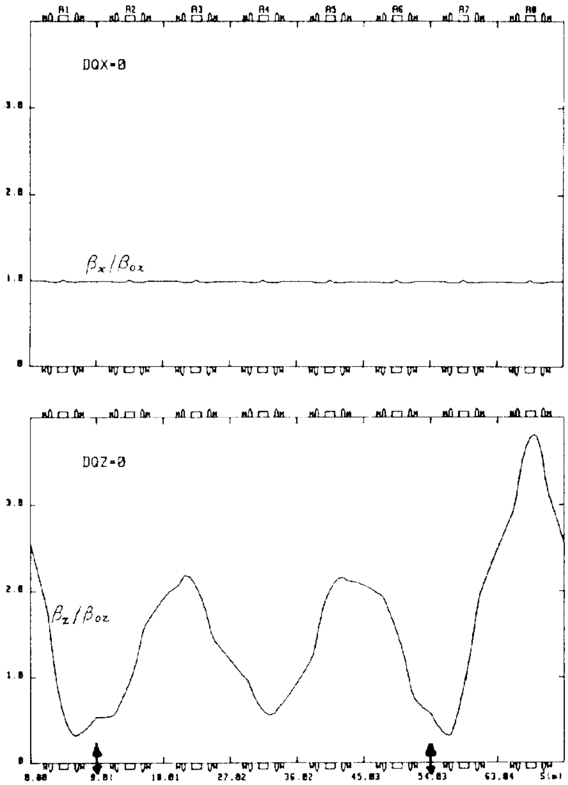
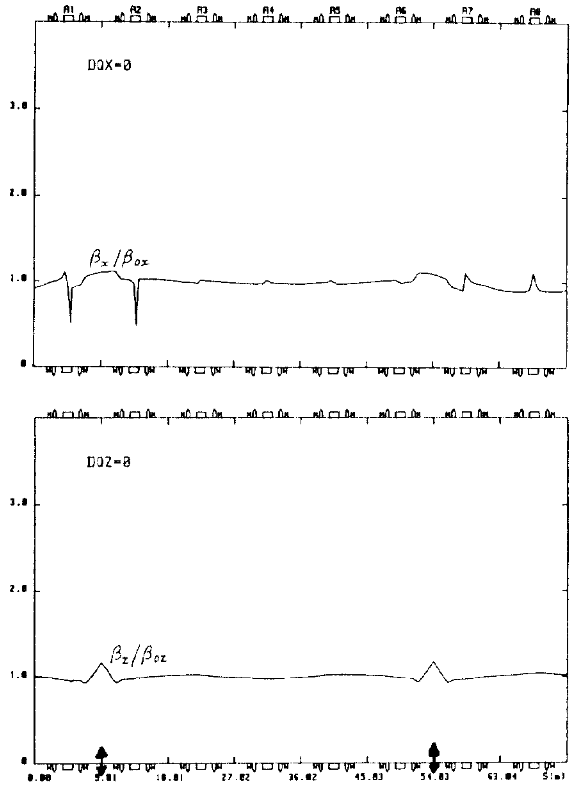


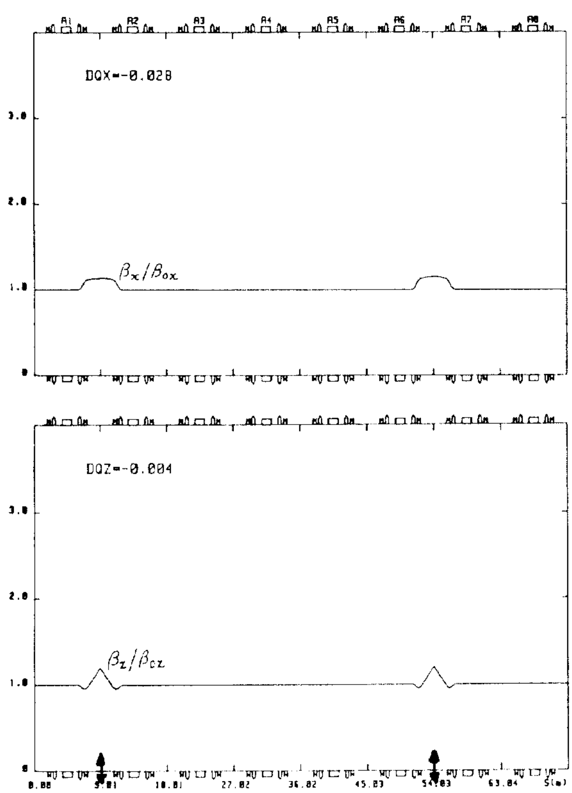
Fig. 2. Relative change of β and tune variation due to two undulators of 0.8 T^2m in straight sections 2 and 7.



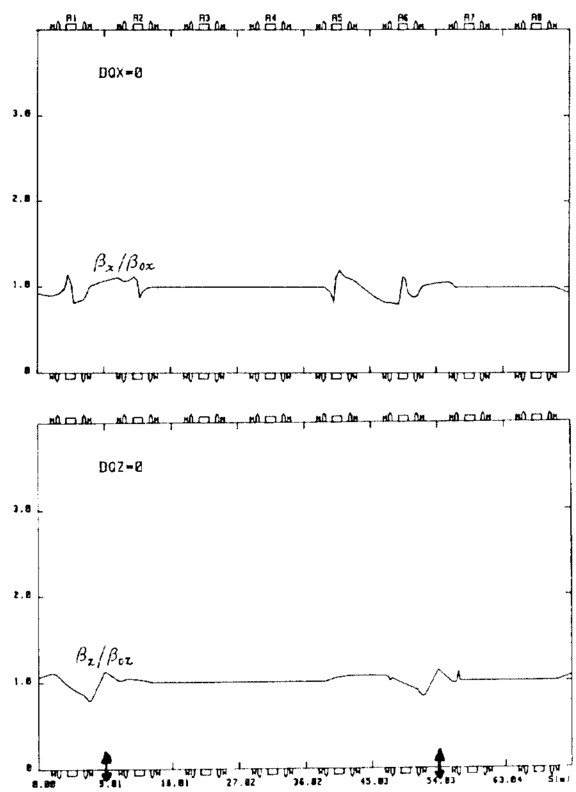
(a)



(b)



(c)



(d)

Fig. 3. Relative change of β and tune variation for different compensation schemes. The arrows indicate the undulators positions.