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DESY - H 3

LONG STRAIGHT SECTION FOR STORAGE RINGS AND A.G. SYNCHROTRONS, WITH ZERO CLOSED ORBIT FUNCTION AMPLITUDE

Summary:

A long straight section magnet structure is suggested for storage rings and A.G. synchrotrons, which has the following optical properties:

a) Symmetry about the central (interaction) point.
b) Unit transformation matrix for the horizontal coordinate (x).
c) Negative unit transformation matrix for the vertical coordinate (z).
d) The overall dispersion and its derivative are zero.
e) The dispersion at the central (interaction) point may be adjusted to have zero closed orbit function amplitude there.

According to b), c) and d), the straight section may be inserted into any AG magnet structure without affecting the amplitude function and the closed orbit function in this structure.

Introduction:

Long straight sections with quadrupole focusing have been considered by Collins[1], Edwards[2], Robinson[3] and the Stanford-Storage-Ring group[4]. Edwards has shown that for a simple structure the focusing can be adjusted so that the amplitude function is not affected by the insertion, but the closed orbit function will be disturbed.

The somewhat more complex structure described here overcomes this difficulty and, in addition, permits to have zero equilibrium orbit amplitude for particles off the reference momentum along the entire free central length. This may, for example, be a desirable feature in storage rings, constituing a decoupling of beam interaction and synchronous oscillations.

Description:

The structure was designed on the DESY - analog computer. It has an overall length of 21.12 m and is symmetric about the central (interaction) point at s = 10.56 m. Each half structure consists of 4 quadrupoles and 2 rectangular deflecting magnets. The spacings, lengths and strengths of these magnets are given in table I in the following units, respectively:

length l (m)

quadrupole strength $k\ (m^{-2}) = \frac{e}{p_o} \left. \frac{\partial B_z}{\partial x} \right|_{z=x=0}$

deflecting magnet strength $\frac{1}{\varrho}\ (m^{-1}) = \frac{e}{p_o} \left. B_z \right|_{z=x=0}$

The values are computed only to show the validity of the principle; for practical application they would have to be redetermined with higher accuracy.

Table I

Element	-	Q	-	M	-	Q	-	M	-	Q	-	Q	-
l (m)	0.30	0.70	0.30	1.60	0.30	0.70	0.30	0.80	0.30	0.70	0.30	0.70	3.56
k (m^{-2})		-0.693				+0.646				-1.002		+0.500	
$\frac{1}{\rho}$ (m^{-1})				+0.199				+0.138					

↑ central (interaction) point

The length of the free central region between the inner quadrupoles is 7.12 m.

Particle trajectories

The principal trajectories in both coordinates, together with the focusing structure k (s) and the deflecting structure $\frac{1}{\varrho(s)}$, are shown for the first half structure in the adjacent figure. It is apparent from these trajectories that

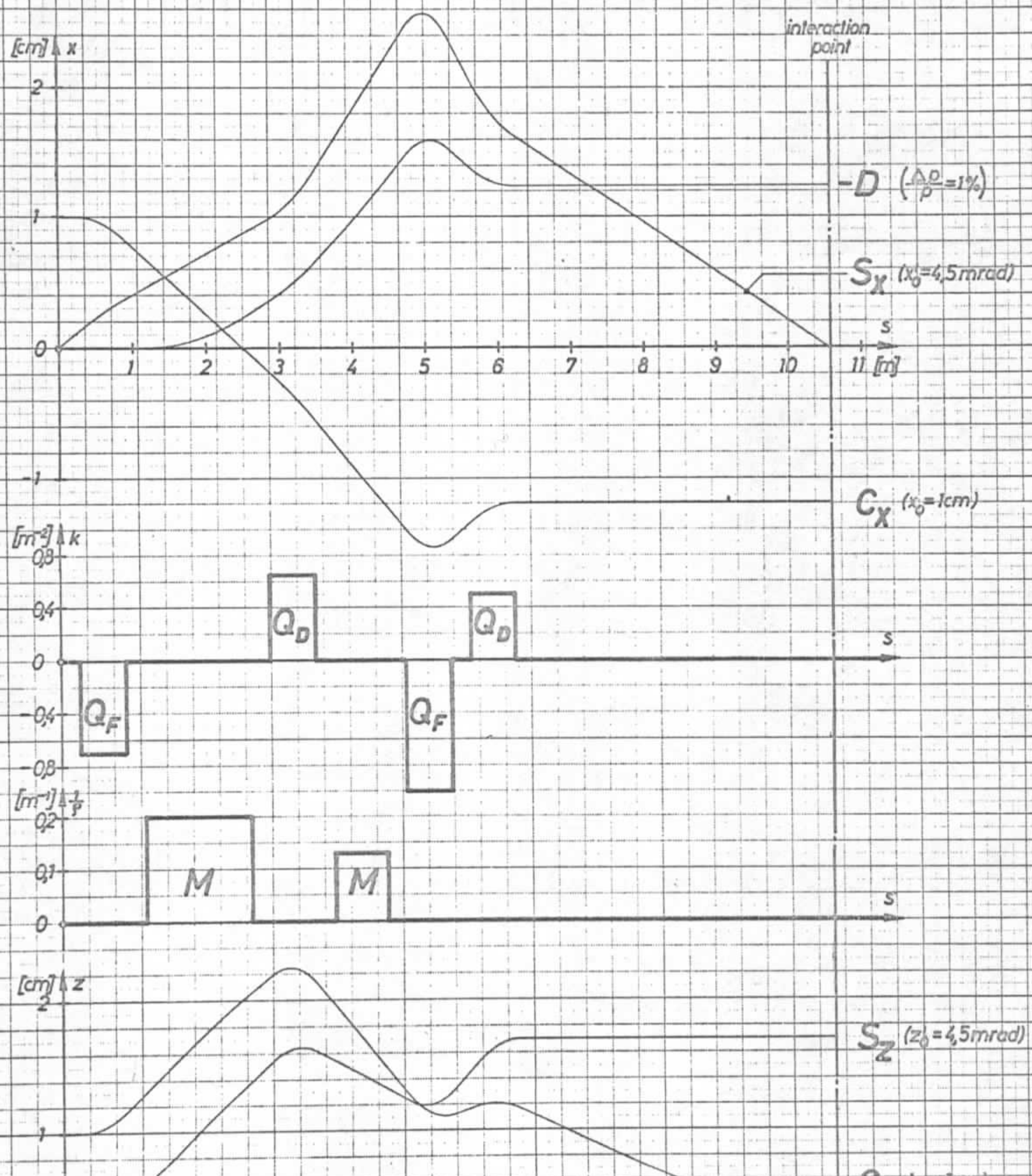
- the overall transformation matrix in x is $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$
- the overall transformation matrix in z is $\begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}$
- the overall dispersion is zero
- the slope of the dispersion trajectory D(s) at the end of the structure and in the central straight region is zero

Consequently, upon inserting two such straight sections into a magnet ring, its number Q_x of horizontal betatron wavelengths will be increased by two, while Q_z will be increased by one.

The overall bending angle of the 4 deflecting magnets depends on the amplitude of the closed orbit function at insertion point, i.e. at the beginning or end of the straight section structure. If, for example, its amplitude is about 1 cm per percent at this point, an overall bending angle of about 48° must be chosen in order to have zero closed orbit function amplitude at the central (interaction) point. The values of $\frac{1}{\varrho}$ given in table I roughly refer to this example; they allow a maximum particle momentum of 3 BeV/c for a maximum field strength of 20 KG. For different closed orbit amplitudes at insertion point, the overall bending angle must be adjusted by changing the strengths of the two types

Symmetric Long Straight Section with Zero Closed Orbit Function at Interaction Point

(one half shown only; rectangular magnets)



of deflecting magnets proportionally. If the closed orbit function has zero slope at insertion point its amplitude is thus made to vanish not only in the central point, but along the entire free region between the inner quadrupoles.

In the case of our example, two straight section structures together would provide a deflection of slightly more than 90°, so that the remaining ring structure would have to give a total deflection of the order of 270° only.

Preliminary conclusion for e^--e^+ storage ring

For e^--e^+ storage rings, it is thought to be worthwhile studying a simple ring structure such as the Frascati storage ring type (which has very small closed orbit and amplitude functions), combined with two long straight section structures of the type discussed above as interaction regions.

References:

1) T. L. Collins, CEA - 68, Cambridge (1961)

2) D. A. Edwards, CSDS - 3, Cornell (1962)

3) K. W. Robinson, CEAL-TM-118, Cambridge (1963)

4) SLAC storage ring proposal, Stanford (1964)