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ACCELERATOR DEPARTMENT
Informal Report

DYNAMIC SURVEY OF A BEAM TRANSPORT SYSTEM

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MASTER

Abstract

A method for obtaining the geometry of a beam transport system is described. It depends on changing the strengths of the components in a known way and observing the corresponding displacements of the beam.

Problem

Find the relative transverse positions of beam axis and quadrupole axes in a transport system.

Method

Vary each of the quadrupoles in the system in a known way and observe the associated displacements of the beam axis at the exit by means of a beam position monitor (PM). After the system geometry has been found, it may be situated in absolute space by means of a PM at the input of the system and the PM at the exit already mentioned.

Equipment

Input beam that is known to be stable in position and direction, some form of position monitor, variability of quadrupoles.

Theory

Our basic assumption is, that the transfer matrix between the quadrupole whose position is to be measured and the PM at the system exit is known. It follows from quadrupole gradients and drift lengths and may be calculated to an accuracy that depends on the accuracy with which these quantities are known.* Let us assume that the transfer matrix for one plane is

$$[M] = \begin{bmatrix} a & b \\ c & d \end{bmatrix} .$$

* J.P. Blewett suggested turning the downstream quads off in order to make the calculation of the transfer matrix easy and therefore reliable. It may not always be possible to do so because it might cause beam scraping due to increased beam dimensions or to displacement of the beam outside the aperture of the PM.

Since the position of the beam axis with respect to the quadrupole does not depend on its strength and is not coaxial with it in general, changing the quadrupole strength with a factor α by changing its excitation by that factor will change only the beam direction. This change in direction $\Delta x'_q$ produces a beam displacement Δx_e at the exit which may be measured with the PM there without reference to the location of its axis with respect to the system axis. Thus we have $\Delta x'_q = \Delta x_e / b = \frac{e}{p} \ell \Delta B$ where e is the electronic charge and p the particle momentum. It follows that the integrated magnetic field at the beam axis in the quadrupole is:

$$\ell B = \frac{p}{e} \frac{\Delta x_e}{b} \frac{1}{\alpha - 1} ,$$

where $\alpha = Q_2/Q_1$.

If the gradient in the unperturbed quad is known to be

$$G = \ell \frac{\partial B}{\partial r} ,$$

we have for the distance between the axes of quad and beam

$$x_q = \frac{\ell B}{G} = \frac{p}{e} \cdot \frac{\Delta x_e}{b} \cdot \frac{1}{(\alpha - 1)G} ,$$

and for the bend in the beam axis due to this misalignment

$$x'_q = \frac{\Delta x'_q}{\alpha} = \frac{\Delta x_e}{\alpha b} .$$

Performing this exercise for each quad individually one obtains the shape of the beam axis as a succession of straight lines with known lengths (center-center distances between quads) connected by bends of known magnitude x'_q . This beam axis passes at known locations through the PM's at input and exit. Via the x_q , the quad centers are located with respect to the beam axis. The result of such a survey could be sketched as in Fig. 1.

Fig. 1

Although we described the method for only one reference direction, one would in practice work in both transverse reference directions at the same time. Doing this one would need seven readings per quad: initial quad current, horizontal PM, vertical PM, changed quad current, changed horizontal PM, changed vertical PM, initial quad current restored.

When measuring the AGS matching line, which contains 6 quads, we need $6 \times 4 = 24$ successive beam axis positions. Therefore use of a single shot PM would be quicker and more convenient than a multiple shot one (as the scanning wire SEM boxes are).

JC:ph
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