ANALYIS OF FIELD PERTURBATION DUE TO FIELD ERRORS IN AN ELECTROSTATIC STORAGE RING*

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Abstract

At IAP in Frankfurt the design of a small ring for ions of energies up to 50 keV has been made and a quarter ring section is being build up [1]. The setup of optical elements consist of two quadrupole doublets, two parallel plate 10° deflectors and one 70° cylindrical bend. An important question during the design of such a machine is the positioning and manufacturing accuracy needed for the optical elements. In order to analyze the effects on the circulating beam, calculations have been made at IAP. The dependence of the electric field on electrode displacements and mechanical errors is discussed and the effects on particle dynamics shown. The resulting fields have been used to trace particles through realistic field distributions and to compare trajectories with particles following an idealized orbit. Possible countermeasures are presented and acceptable tolerances given.

1 FRINGE FIELDS

Numerical and analytical methods to describe the particle motion usually start from the assumption that the fields in the electrodes start and end abruptly at the entrance and exit of the element. For a better description of the real trajectories, fringe fields in the different lenses have to be taken into account.

Fringe fields can be limited to the inner region of the optical elements by using grounded shields. The design of the electrostatic storage ring in Frankfurt foresees a voltage of +/- 6 kV at the electrodes of the cylindrical 70° deflector. Therefore, the 0 Volt design orbit lies in the middle plane between the plates. A grounded shield to limit the fringe field should ideally follow the curvature of the electrodes.

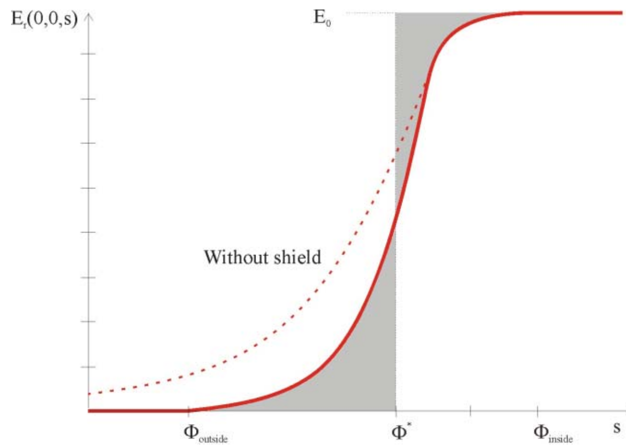

Fig. 1: Electric field at deflector exit

The remaining fringe field represent an additional bending force in comparison with an idealized field distribution. The effective field boundary can be calculated analytically [2]

$$\phi_{eff} = \phi_{innen} - \int_{\phi_{außen}}^{\phi_{innen}} \frac{E_r(0,0,\phi)}{E_0} d\phi = I_1 \cdot \frac{d}{2}$$

The value of the integral I_1 for several possible cases is shown in Figure 2.

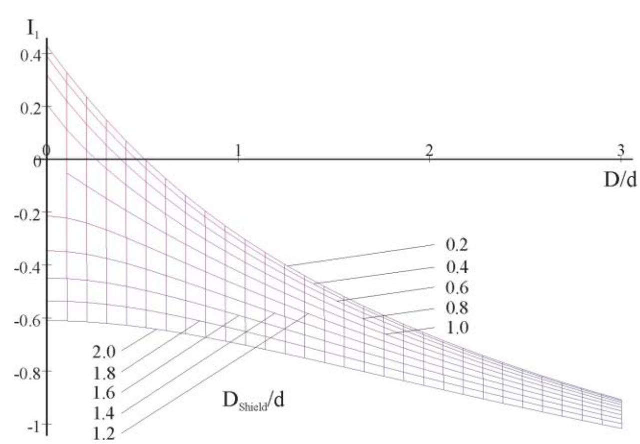

Fig. 2: Integral I_1 for different values of the diameter of the shield aperture d_{Shield}, distance shield-electrode D and aperture in the deflector d

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The additional force acting on the particles leads to a shift of all particles relative to the design orbit, which has been calculated at IAP [3]. This effect can be compensated by mechanically designing the electrodes for a smaller bending angle and proper adjustment of the electrode voltages.

The results of these calculations were confirmed in numerical simulations with the program SIMION [4]. This software allows flying single ions through realistic field distributions and helped optimising the positioning of the shields.

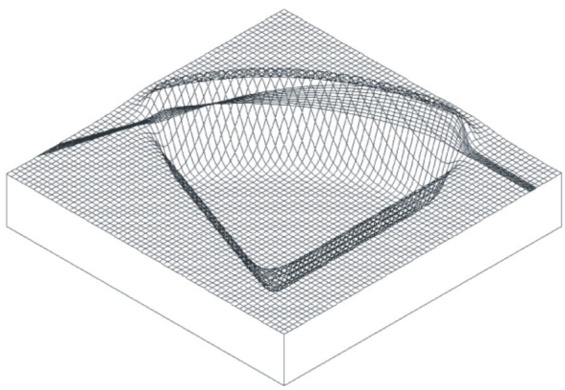

Fig. 3: Particle Trajectories through 70° deflector

2 POSITIONING ERRORS

In addition to fringe field effects, manufacturing tolerances and positioning errors can lead to unwanted motion perturbation. Especially higher order fields and a coupling between the different planes of phase space will lead to beam instabilities. In order to study these effects, numerical calculations were done, using the program MAFIA [5].

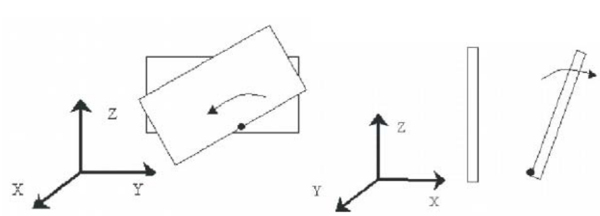

Fig. 4: Definition of twisting angles of one of the parallel plate deflectors' electrodes

In the calculations, one of the electrodes was kept fixed, while the other was twisted in steps of one degree around a fixed point. The result for the relative field change after a turn of 3 degrees is given in Figure 5.

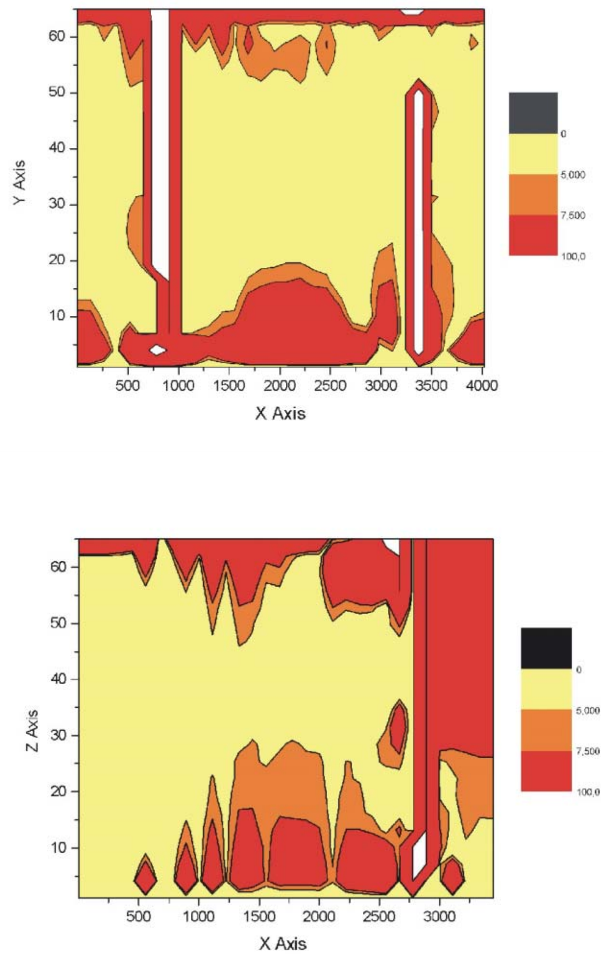

Fig. 5: Relative field change after a twist of 3 degrees around x- resp. y direction in the 10° deflector

As can be seen, even larger twisting angles do not change the uniformity of the field in the central region of the deflector where the beam is circulating. For a beam size of *r=5mm* numerical calculations resulted in envisaged storage times of a few seconds and stable operation could be guaranteed. Considerable changes only occurred close to the electrodes and would not affect the particles' motion.

In the case of the electrostatic quadrupole shown below, the ideal electrode shape had to be approximated by cylindrical electrodes.

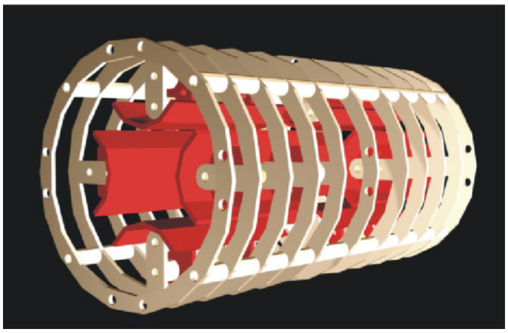

Fig. 6: Schematic view of the electrostatic quadrupole

The differences to the ideal field distribution are negligible when the radius is chosen as radius $r=1.1468 \cdot r_{ap}$.

To study the effects of positioning errors, the electrodes were then twisted in the two ways shown in Figure 7.

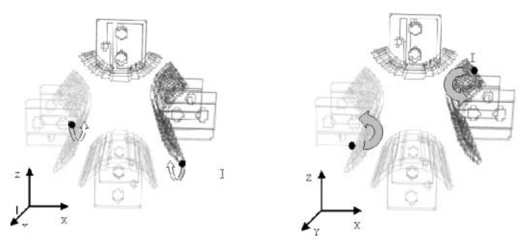

Fig. 7: Definition of the rotating angles in the case of the electrostatic quadrupole

The resulting relative field change is given in Figure 8.

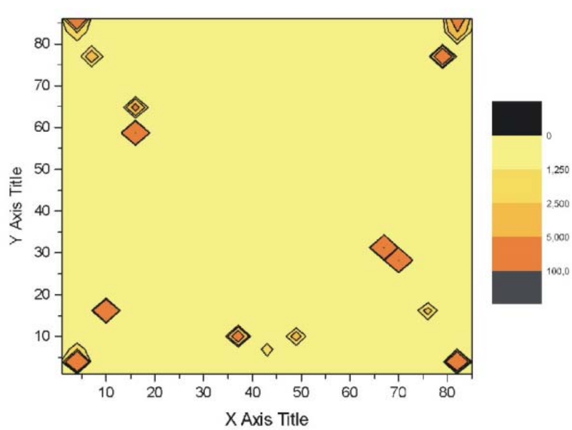

Fig. 8: Relative field change in the electrostatic quadrupole after 3° rotation around y axis

The MAFIA calculations showed no principal differences in the two considered directions of rotation.

Numerical calculations with adjusted voltages show that the effects in ion trajectories due to positioning errors could be compensated and allow stable operation.

3 ACKNOWLEDGEMENTS

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