THE VERTICAL DISPLACEMENT OF THE CLOSED ORBIT DUE TO THE CLEARING FIELD

The Storage Ring Model is provided with a "clearing field" for the extraction of positive ions created by gas scattering. The clearing field will be produced by "clearing electrodes" with DC potentials, placed at the bottom of the vacuum chamber. The other electrode will be the vacuum chamber itself. For each magnet sector two separate clearing electrodes are foreseen. They extend from the centre of the bending magnet, in both directions, to the outer edge of the two quadrupole lenses. The straight sections will have no clearing electrodes. Here we anticipate that the trapped ions will diffuse, due to their thermal velocity, into one of the clearing field regions.

The two clearing electrodes can be either at the same potential or on opposite potential compared to the vacuum chamber. The question arose, whether an alternating clearing field is necessary or whether the two electrodes could be connected inside the vacuum chamber. The latter solution would free one of the vacuum ports between bending magnet and quadrupole lenses and give the possibility of having two movable targets, one from inside and one from outside on the same azimuthal position. This, finally, would allow us to measure the gammas from both kinds of targets on the same scintillator-photomultiplier observation point.

The minimum strength of the clearing field, necessary to avoid neutralisation of the beam, depends on the beam density. It has been shown in PS/Int. AR/60-14 that

$$E_{\text{min}} = 24 \frac{dI}{dR}$$ (34)
where $E_{\text{min}}$ is the minimum strength of the clearing field in V/cm and $dI/dr$ the current per radial beam width in A/cm. Hence a circulating current of 400 mA/cm requires a clearing field of 10 V/cm. Unfortunately, the clearing field will also displace the closed orbit of the electrons in the vertical direction. This imposes an upper limit to the clearing field.

The attached diagrams show the distortion of the closed orbit, calculated for a clearing field of 10 V/cm. $Z$ is the vertical displacement and $s$ the path length measured on the central orbit. The parameters used for the calculation are the focal strength of the quadrupole lenses $\delta_{QL} = \pm 0.975 \text{ m}^{-1}$ and the focal strength of the edges of the bending magnet $\delta_E = +0.213 \text{ m}^{-1}$ and the length of the orbit sections as indicated in millimetres on the diagram.

The influence of the clearing field can be expressed by a constant term in the transfer operator for a travelling section

$$\begin{pmatrix} Z_1 \\ Z'_1 \end{pmatrix} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} Z_0 \\ Z'_0 \end{pmatrix} + C \begin{pmatrix} L^2 \\ 2L \end{pmatrix}$$

where $L$ is the length of the section and

$$C = -\frac{e}{2Me^2} \frac{E}{E} = -(10^{-6} \text{ Volt}^{-1}) E$$

The upper curve in the upper diagram shows the closed orbit for the case, in which both electrodes have the same potential and the lower curve the closed orbit for a clearing field that is alternately $-E$ and $-E$, where the absolute field strengths in both cases are the same. The lower diagram is an enlarged picture of the closed orbit for an alternating clearing field.
It is somewhat surprising that even in the case of an alternating clearing field, where the mean field is zero, the closed orbit is always higher than the central orbit. The displacement scales with the strength of the clearing field. Hence, if the polarity of the alternating clearing field is changed to $-E$ and then $+E$, the closed orbit will be always below the central orbit.

The closed orbit displacement is mainly limited by the vertical aperture of the pulsed inflector, which is 4 mm. Hence, an alternating clearing field of $\pm 10$ V/cm with a maximum displacement of 0.5 mm can be tolerated, but a non-alternating field of 10 V/cm with its maximum displacement of 3.5 cm is excluded. In this case the clearing field cannot be higher than 1.4 V/cm which reduces the possible current density of a non-neutralised beam to about 50 mA/cm.

Conclusion

An alternating clearing field allows a field strength of 10 V/cm and a current of 400 mA per cm of radial beam width. A non-alternating clearing field, which would give the possibility of connecting the two clearing electrodes, allows a field strength of 1.4 V/cm and a current of 50 mA per cm.

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