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A STUDY OF THE FEASIBILITY OF AN OPEN RESONATOR AS A DEVICE FOR FOCUSING A BUNCHED BEAM

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ABSTRACT

An open resonator has been investigated as a focusing device for a bunched charged particle beam. Three fundamental requirements emerged from an analysis of the problem: to find a mode with a convenient field distribution, in order to have a useful Lorentz force acting on the particles; to have a good "transit-time factor"; and to act with the same force on almost all the particles within a bunch length. While the first and the third point seem to be easily achievable, the transit time factor, which depends on the waist size, is too small. This is because the waist size cannot be reduced below a certain limit if the resonator has to be operated in a stable-mode configuration. However, since future studies may solve this problem, we will review the basic features of the open resonators, describe the eventual application in a focus scheme and give some typical parameters.

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The magnetic field will not affect the particle, as it is parallel to its velocity (Fig. 3). The particle crossing the resonator at the $x = 0$ position will suffer no deflection.

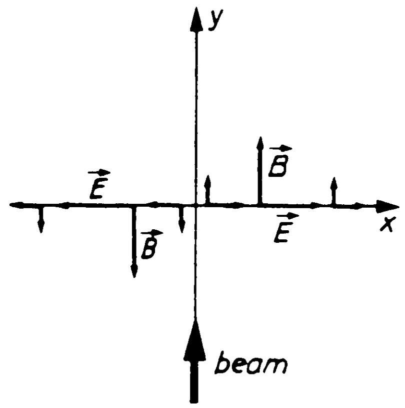

Fig. 3 Force lines of E and B for the TEM (1, 0, n) mode

As it is evident from Eq. (3), the field has a Gaussian profile on the coordinates along which the particle moves. At a fixed z value, the particle will see a sinusoidal time-varying field, whose amplitude is modulated by the Gaussian shape. The number of time oscillations the particle sees is determined by the time it takes to cross the radius of the resonator-beam. This creates a "transit time factor" which decreases the net effect of the field on the particle. In order to have the best transit time factor, we believe the best place to let the particle cross the resonator is at the waist. If a thin len approximation is used, one can evaluate the total change in transverse momentum of the particle by integrating the force over the time that the particle spends in the resonator:

$$\Delta p_{\perp} = \int_{-\infty}^{\infty} e|E(x,y)|e^{j\Omega t}\, dt \tag{6}$$

where $E(x,y)$ is expressed by Eq. (3) and Ω is the frequency at which the resonator is operated. To define an "efficiency", one can normalize the above expression to the kick a particle would get in the resonator if there were no time dependence of the fields:

$$\Delta p_{\perp}^{\circ} = \int_{-\infty}^{\infty} e|E(x,y)|dt = \frac{2e}{c} \sqrt{2\pi}\, E_0 x \exp\left(-\frac{x^2}{w_0^2}\right) \tag{7}$$

The expression

$$\eta = \frac{\Delta p_{\perp}}{\Delta p_{\perp}^{\circ}} = \exp\left(j2\pi \frac{w_0}{\lambda} - \pi^2 \frac{w_0^2}{\lambda^2}\right) \tag{8}$$

has been obtained and emphasizes the critical role played by the ratio w_0/λ in deciding if the device can be used to focus or not. Finally, as far as the finite length of the bunch is concerned, we believe that it is safe enough to assume that the resonator can be operated at a wavelength much greater than the bunch length

$$\lambda \gg \ell_B \tag{9}$$

in order to get the same effect on all the particles within the bunch length.

3. SOME NUMBERS AND CONCLUSIONS

From the previous analysis it is clear that the feasibility of the device is mainly linked to the minimum value of the ratio w_0/λ and to the maximum intensity of the electric field one can get in the resonator. While it is not difficult to have a field intensity of the order of a few GV/m, the waist size seems to be never smaller than 2.5λ. This number has been evaluated employing expression (1), for a symmetrical configuration very near to a concentric one. If one chooses

$$L = 1.9R \Rightarrow w_0 = 0.26\sqrt{\lambda R}$$

and the values R = 30 cm and λ = 3 mm which satisfy Eq. (9) together with a working frequency equal to 100 GHz, the waist size can be expressed in terms of λ (for this particular case):

$$\frac{w_0}{\lambda} = 2.6$$

If one puts this value back into Eq. (8), it is immediately obvious that the efficiency is very small. Hence the device does not seem useful, unless a way can be found to modify the field envelope in order to decrease the transit time and increase the efficiency.

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