DESIGN OF A MODIFIED DISK LOADED TYPE FOR ELECTRIC FIELD FOCUSING

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Abstract

A proposal for low emittance beam with a modified disk loaded wave-guide is presented. The disk loaded type has slant disks, and is used with standing wave of π-mode and/or $\pi/2$-mode. The influence of the slant disks appears to be imbalance between focusing force and defocusing force in the radial component of electric field. The integration of the force in radial direction suggests that focusing effect exists.

At the early stage of acceleration when β is smaller than one, this configuration enable to keep low emittance and suppress emittance growth. The problem for this disk loaded type experiment is complexity of configuration, but it is not impossible. Manufacturing technologies become enough to make complex high accuracy products.

Introduction

In this paper I shall present a proposal of new disk-loaded wave-guide. So-called 'Disk loaded' type has typically used for electron linac and has been deeply studied.

Recently, linac is required higher energy, higher current and higher luminosity in the field of high energy physics and material science.

Many other type of cavities had been developed, but this conventional type 'Disk loaded type' still has several advantages, therefor many electron linacs adopt Disk loaded type all over the world.

The relative advantages of Disk loaded type is in this simplest structure and spacial thrift. The new type of Disk loaded type proposed in this paper may abandon one of the advantages in exchange for acquisition of electric focusing effect. Electric field focusing, instead of magnetic field, has fairly merit of low emittance holding, if it used on the early stage of acceleration.

There are two ways to establish a low emittance beam. One is to compose extra accurate beam optics with consideration of higher order modes of magnets and flinging effects. Necessarily, the cost of those magnets is so expensive and the alignment is very difficult. The other way for producing a low emittance beam is quick acceleration into higher energy, where the particles are not able to change the velocity. My motivation of this proposal was appeared in this view point.

Design concept

In standing wave type, accelerating electric field of conventional disk loaded type deform bunches into cone shape. If the center of bunches are just put on a crest of phase, forward particles receive force of focus and backward ones receive defocusing force. After all, focus and defocus are almost canceled each other. Furthermore, when a particle phase slips from crest to synchronous phase phasepartilentegration of radial component should always be defocus. Ordinary, the beam was suppressed from divergence by elctro-magnetic-force with multipole magnets. If it is possible to deny divergence with electric field, there is a probability of emittance decrease.

The new type of disk loaded type is shown in Fig.2, compared with a standard type of Fig.1. The cross sectional view consists of round shape corners for higher shunt impedance, and disks have acute angle for the plane which is vertical to axis. Cause of this angle, balance between focus and defocus is broken, and the electric focusing field enhanced.

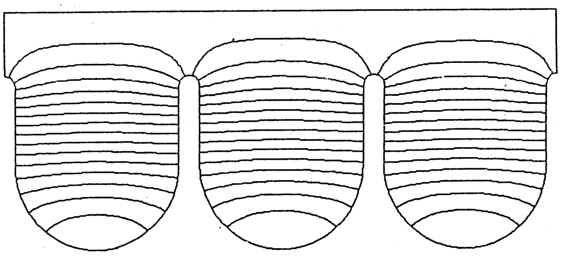

Fig.1 Side view of conventional structure of DAW. This is modified type for high shunt impedance at SLAC.

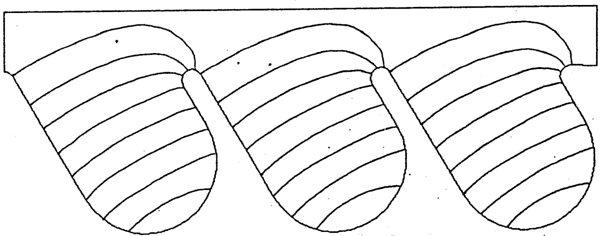

Fig.2 Side view of the electric focusing structure. Bunches travel from left to right.

Computation

The electric field lines of the structure which has slant disks are calculated by SUPERFISH on PC. It is not established to obtain the accurate separatrix of each cell, but approximately enough for field lines.

Numerical model

I present a simple model of the focusing effect for numerical estimation. Based on the result of FEM calculation as Fig.3, radial component of electric field near axis Er is assumed as (Fig.4):

$$Er = Er_0 \cos(\pi X^n) \qquad \text{---(1)}$$

where

$X = x/D$: normalized axial distance

and 'n' is the number related with the slant angle of disks, when disks are perpendicular to axis the 'n' is one. The condition of 0<'n'<1 corresponds that the disks are concave toward the outlet, and 'n' > 1 stands on the condition of Fig.2.

This electric field of π-mode standing wave propagates in the disk loaded type and a accelerated electron receives radial electric force Er(x,t):

$$Er(x,t) = Er_0 \cos[\pi(x/D)^2] \sin \omega t$$

$$D = \frac{c}{2f}$$

then

$$Er(X) = Er_0 \cos(\pi X^2) \sin \pi X \qquad \text{---(2)}$$

The total focusing effect is obtained as an integration of X: from 0 to 1. This equation under assumption that particle phase is crest shows curves as Fig.5. It is obvious that the focusing effect exists. Because that the slant type must be use in the beginning of acceleration, Fig.6 is shown a actual condition =0.85, and the focusing effect is still enough.

Evaluation

Using eq.(2), momentum increment of focus and defocus is calculated by integration, and the proportion are :

$$\text{when } \beta=1, \qquad \frac{dP(\text{focus})}{dP(\text{defocus})} = 6.69$$

$$\text{when } \beta=0.85, \qquad \frac{dP(\text{focus})}{dP(\text{defocus})} = 2.86$$

However, in case of the conventional type at β=0.85, the proportion of momentum increment is 0.56, namely, it is divergence effect.

Conclusion

This new structure of disk loaded type divides a little part of accelerating field into focusing field. Therefore, acceleration efficiency decreases in comparison with conventional type. Nevertheless positive suppression of emittance is inevitably desire for future accelerators.

Acknowledgment

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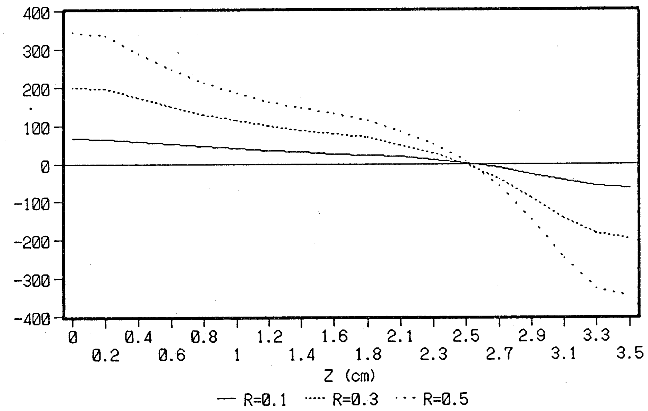

Fig.3 Mutual magnitude of radial components of electric field at three different radius from axis.

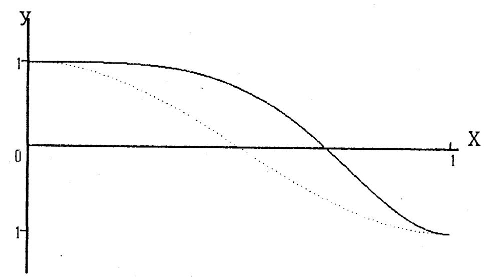

Fig.4 y = cos(πX^2) is shown as a line, and y = cos(πX) is shown as a dotted line. X =x/D, D:axial length of one cell.

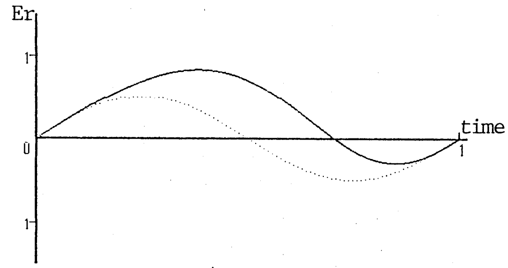

Fig.5 Radial component of electric field, which received by a synchronous particle as β=1. The dotted line shows radial component of conventional DAW.

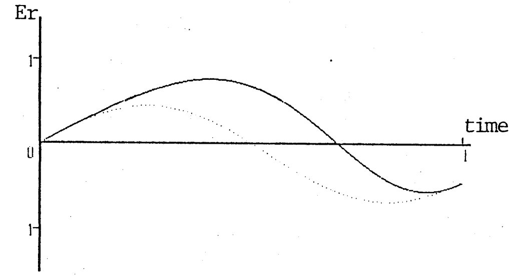

Fig.6 Radial component of electric field, which received by a synchronous particle as β=0.85.