BEAM DYNAMICS AND RF CAVITY DESIGN OF A STANDING/TRAVELING-WAVE HYBRID PHOTOINJECTOR FOR HIGH BRIGHTNESS BEAM GENERATION

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Abstract

A hybrid structure of the standing and travelling wave is being developed. To get rid of the complexity of the dual feed coupler, a single-side feed coupler is designed by using HFSS. The dipole and quadrupole can be minimized by tuning the dummy port width and the distance of the racetrack centres, respectively. The leak field from the input port is found to be the problem and inextinguishable by the cavity tuning. The beam dynamics are calculated by using PARMELA with HFSS field. The deflection is 3.9 mrad in *x* direction. This large value is due to the low energy of 2.9 MeV in the hybrid gun.

INTRODUCTION

The hybrid photoinjector of travelling and standing wave structure is being developed jointly by the collaboration of UCLA/INFN/Univ. Roma[1,2]. It consists of the hybrid gun and linacs. The hybrid gun is designed to be a compact high brightness beam source by taking an RF gun and a travelling wave linac into one structure as shown in Figure 1.

It was designed to have dual feed couplers. However, the RF system became complex with the structure. To avoid the complexity, we are seeking the possibility of single-side feeding couplers.

In this paper, we discuss the dipole and quadrupole components in the single-side coupler and the effect on the beam dynamics.

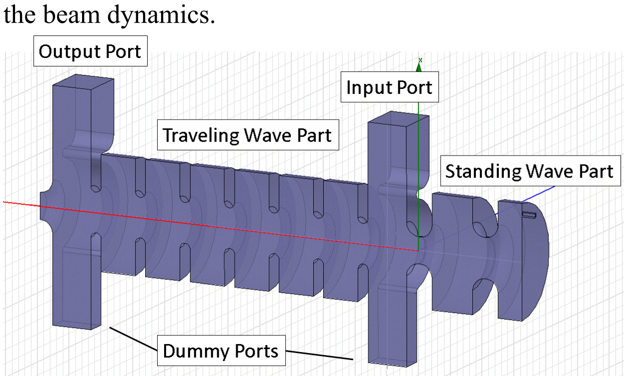

Figure 1: Hybrid gun.

HYBRID GUN

The hybrid gun has the standing wave part and the travelling wave part. Since two structures are weakly coupled on axis, it is almost the same as a single travelling wave structure. It means there is no reflections which is observed at feeding standing wave structures. This enables to remove a circulator from the input port side. This is important when it is applied to the accelerators operated at higher RF frequency where no high power circulator available.

The standing wave part acts as an RF gun, so that high quality beams are produced. The travelling wave part is a velocity buncher. To put the beam at proper phase in it, the coupler length is chosen as 5/24 of the RF wavelength. Note that there is 90-degree phase advance from the standing wave part to the travelling wave part.

The amplitude of the electron field along the beam axis is shown in Figure 2. The peak field in the standing wave part is 60 MV/m. This value is lower than 120 MV/m of that of normal RF guns. It is because the velocity bunching is effective in the low energy region.

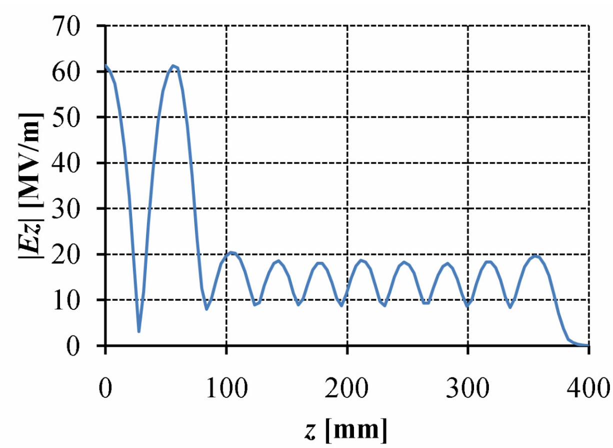

Figure2: Amplitude of the electric field on the beam axis.

COUPLER DESIGN

The single-side feed coupler are designed as in Figure 3. The cavity has a racetrack shape and the dummy port is placed to reduce the dipole component. The important parameters are also shown in Figure 3. 'awg' is the width of the dummy port. This parameter affects the dipole component. 'drc' is the distance of the racetrack centres. By tuning it, the quadrupole component can be minimized. 'bc' is a radius of the racetrack and 'w' is the width of the coupling slot. These two parameters are used to tune the reflection and the phase advance in the travelling wave structure.

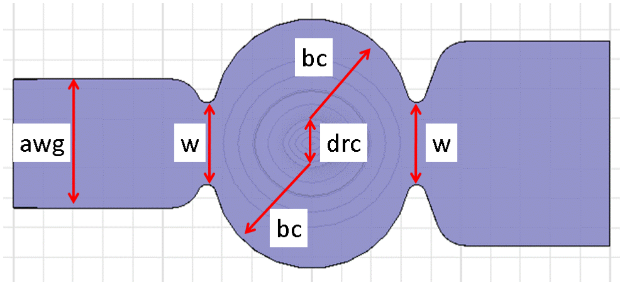

Figure 3: Coupler design.

MINIMIZE THE DIPOLE AND QUADRUPOLE COMPONENTS

The 3D design of the hybrid gun was made on HFSS[3]. The dipole and quadrupole components are calculated from the Fourier series of *Hf* around the centre of the coupler. As it is RF field, both of the real and imaginary part are considered. In the following discussion, the real part is in-phase of the fundamental component (n = 0) of the Fourier series.

Quadrupole Components

'drc' which makes the quadrupole component minimized is searched. Figure 4 shows the phasor diagram of the field gradient of the quadrupole components. Each point corresponds to certain value of 'drc'. As it looks there is some fixed imaginary components, only real part of the field gradient is taken and Figure 5 is made. 'drc' is proportional to the real part of the quadrupole components.

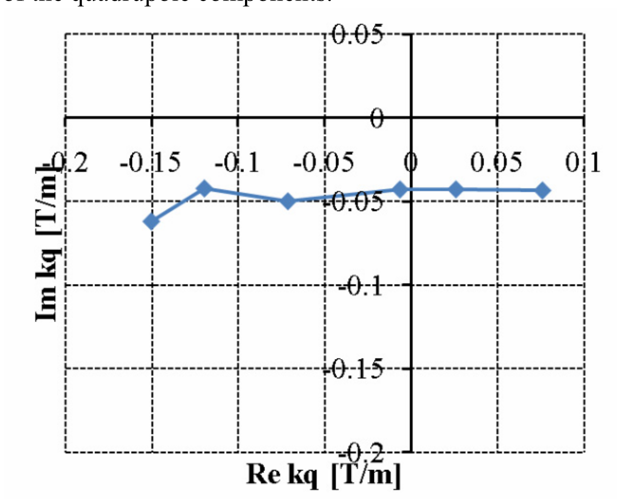

Figure 4: Dipole component.

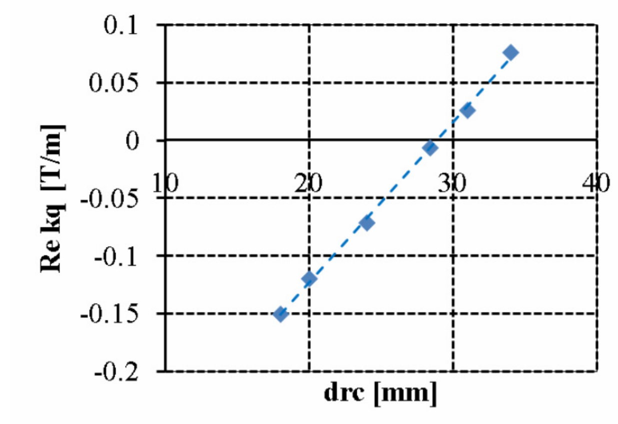

Figure 5: Real part of the dipole component with the distance of the racetrack centers.

Dipole Components

Two case is calculated. One is 'awg' = 50 mm, the other is 'awg' = 32.8 mm. The latter one is considered to be a minimum 'awg' as 'awg' = 'w'.

Phasor diagram of the dipole component is shown in Figure 6. 'drc' is also varied and plotted there. It does not affect the dipole components.

The dipole components also looks to have a fixed imaginary component, we have not calculated sufficient data points, though.

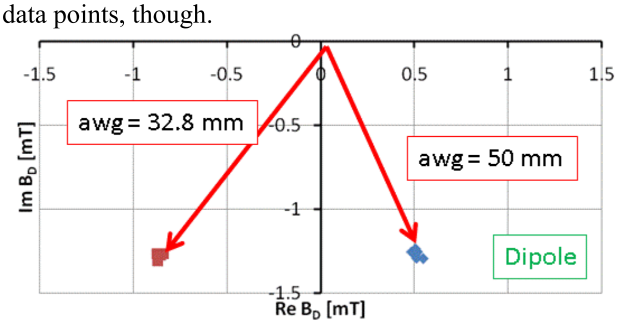

Figure 6: Dipole component.

Source of the Imaginary Component

In both case, there seemed to be fixed imaginary components. As it is out of phase by 90 degree, we guess it comes from the outside of the cavity.

To show it, Hy field from the dummy port to the input port are shown in Figure 7. The minus region of x is the dummy port side and the other is the input port. As you see, there are imaginary component leaking from the input port into the cavity.

To decrease this component, 'w' have to be small. We cannot choose 'w' arbitrarily, however. It requires another design.

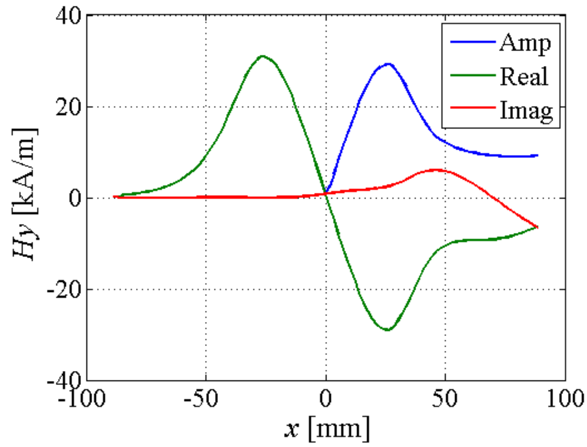

Figure 7: Hy along the coupler center from the dummy port to the input port. The blue line shows the amplitude of Hy, green the real part, and red the imaginary part.

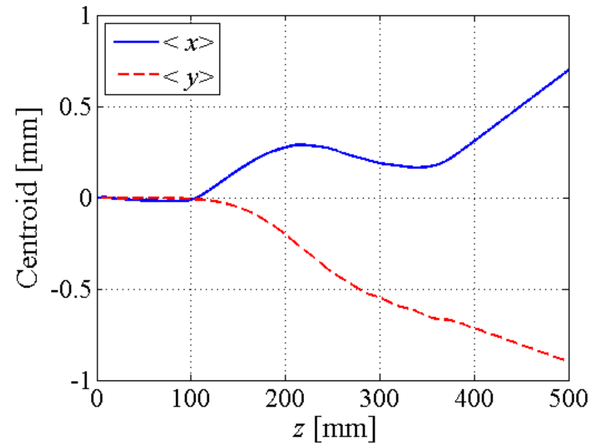

Figure 8: Centroid of the beam. The blue, solid line is that of horizontal (the input port direction) distribution and the red, dashed line is that of the vertical one.

Beam Dynamics Simulation

We found put off the dipole and quadrupole component, however, we proceed to simulate the beam dynamics with the field, anyway.

PARMELA[4] was used for the simulation. The field from the HFSS are imported.

Figure 8 shows the centroid of the beam. As there is solenoid field, the beam is also deflected in y direction. The deflection angle is 3. 9 and -1.8 mrad for x and y, respectively.

The reason for this large deflection is that the beam energy is 2.9 MeV in the hybrid gun. If it is accelerated to higher energy, it might not matter.

SUMMARY

The hybrid gun with single-side feed couplers are designed by using HFSS. Tuning the width of the dummy port and the distance of the racetrack centres minimize the dipole and quadrupole components, respectively, in the coupler. There is inerasable components which comes from the leak of input port field. The beam dynamics with 3D field from HFSS is simulated to examine their effects by using PARMELA. The deflections were 3.9 mrad in x direction. It is large because the energy is as low as 2.9 MeV. Post-acceleration may clear the problem.

REFERENCES

[1] J. B. Rosezweig, et al., "Beam Dynamics in a Hybrid Traveling Wave/Standing Wave Photoinjector", in the Proc. of 2006 Adv. Accel. Concepts Workshop, Lake Geneva, WI, July, 2006 (AIP, 2006).

[2] A. Fukasawa et al., "A Hybrid Standing Wave-Traveling Wave Photoinjector", in the proceedings of FEL'08, TUPPH040 (2008).

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