

THE INFLUENCE OF THE MAIN COUPLER FIELD ON THE TRANSVERSE EMITTANCE OF A SUPERCONDUCTING RF GUN

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Abstract

The field disturbance in the RF coupler plane increases the transverse emittance of RF electron guns. This effect has been calculated for the Rossendorf superconducting RF gun. For 10kW beam power the increasing is smaller then 5%.

INTRODUCTION

In the last years a number of projects for linacs with high average current and high brightness electron beams has been started at different laboratories [1]. The beam parameters of linacs are mainly determined by the injector. Today photo cathode RF guns are the most advanced type of electron injectors. They are able, to produce high peak currents and low emittances, which is necessary for FEL application [2]. However their low duty factor can limit the performance of superconducting accelerators. The more elegant way is to combine the high brightness of RF guns with the low RF losses of superconducting cavities. The idea of an RF gun with a superconducting cavity (SRF gun) was proposed by Piel et al. [3]. After this, R&D activities on this topic have been continued at the FZ Rossendorf [4] with the first successful operation of a SRF photo injector in 2002 [5]. Now several SRF photo injector projects are under development in different laboratories. In this paper we will discuss a special feature of this injector and take as an example the Rossendorf SRF gun.

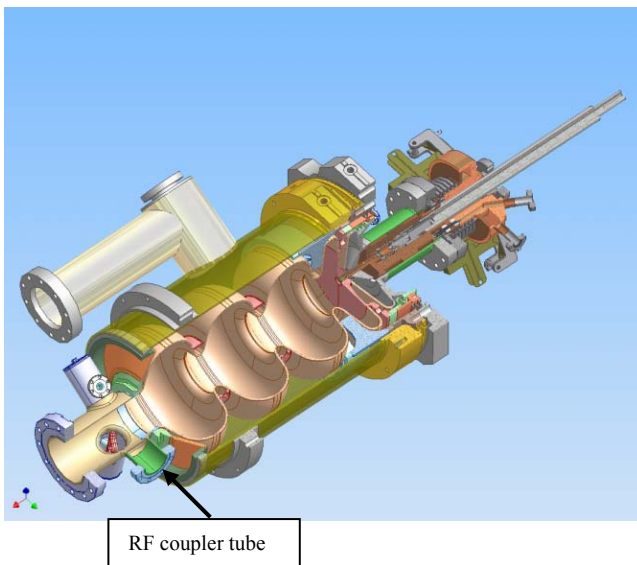


Figure 1: The gun cavity of the Rossendorf SRF gun.

THE GROWTH OF TRANSVERSE EMITTANCE

One side of the cavity of the Rossendorf SRF gun is closed by the back wall of the gun cell, which contains the photo cathode. Therefore all couplers and antennas must be on the other end of the cavity. The beam tube of this end is occupied by the RF input coupler, by two HOM couplers and by a flange, which contains the pick-up antenna. The gun cavity and a drawing of the coupler plane are represented in Fig.1 and Fig. 2.

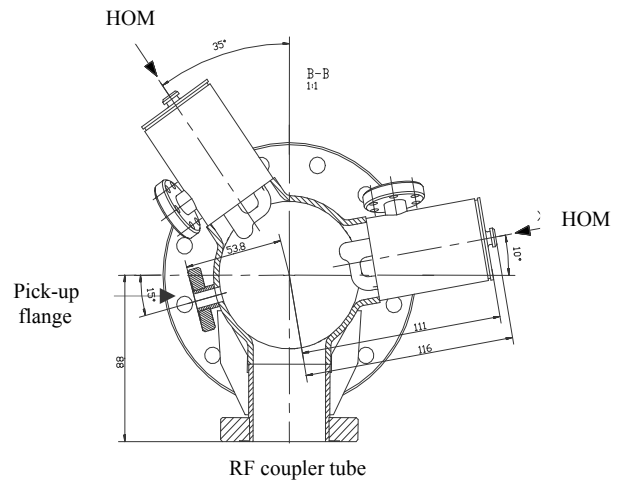


Figure 2: Coupler plane of the gun cavity

In this geometry the outgoing electron bunches are deflected by a dipol field created by the power input of the RF coupler. If this dipol field would be static, one has to correct only the beam direction outside of the gun. The time-dependent RF field deflect the different slices of the bunch in different directions and increases the transverse emittance. In order to describe this effect, in perturbation theory the following formula has been derived [6]

$$\delta\epsilon_t = 2\pi\sigma_t\sigma_z eV_{acc}/(E_0\lambda_{RF})|\text{Re}(v_t)\sin(\varphi) + \text{Im}(v_t)\cos(\varphi)| \quad (t = x,y) \quad (1)$$

for the change $\delta\epsilon$ of the transverse emittance.

Here E_0 is the energy of the electron bunch, V_{acc} is the accelerating field strength, φ is the beam phase in the coupler plane and σ_t and σ_z describe the width and the length of the bunch in gaussian approximation. The deflection parameter v_t ($t = x,y$) is obtained by averaging the RF field along the symmetry axis of the cavity.

$$V_z = \int dz E_z$$

$$V_x = \int dz(E_x + cB_y), V_y = \int dz(E_y + cB_x) \quad (2)$$

$$v_x = V_x / V_z, \quad v_y = V_y / V_z$$

FIELD CALCULATION

For the determination of v_t we have performed three-dimensional field calculation using the MAFIA code. The shape of the gun cavity is described in [7]. The gun cell near the RF coupler and the diameter of the beam tube corresponds to the TESLA geometry. Fig. 3 shows the undisturbed RF field in the last cell and Fig. 4 gives the perturbation, caused by the power flow of the coupler.

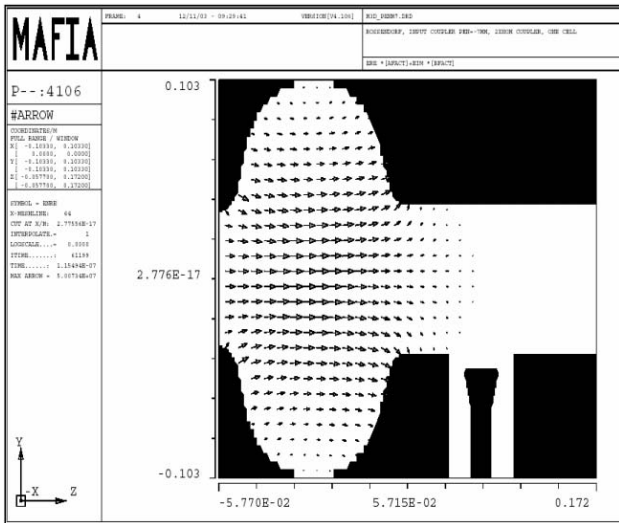


Figure 3: The undisturbed RF field of the last cavity cell

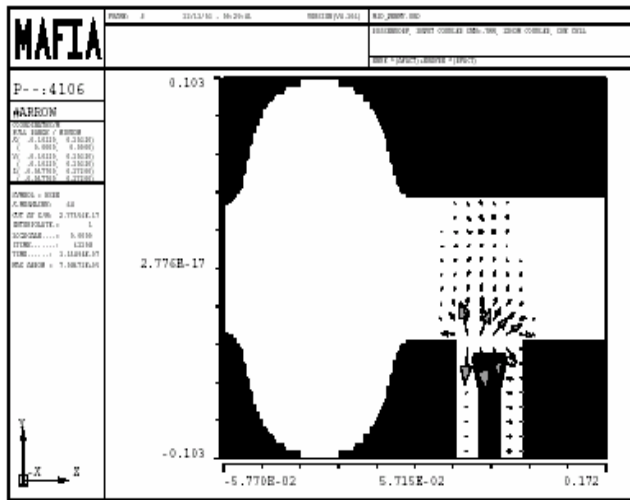


Figure 4: The field perturbation caused by the RF coupler

The RF field is normalized to $V_{acc} = 25$ MV/m, which corresponds to an electron energy of 9.5 MeV. For a beam power of 10 kW the external quality factor Q_{ext} is $2.2 \cdot 10^7$.

Fig.5 shows the real and imaginary part of the field perturbation.

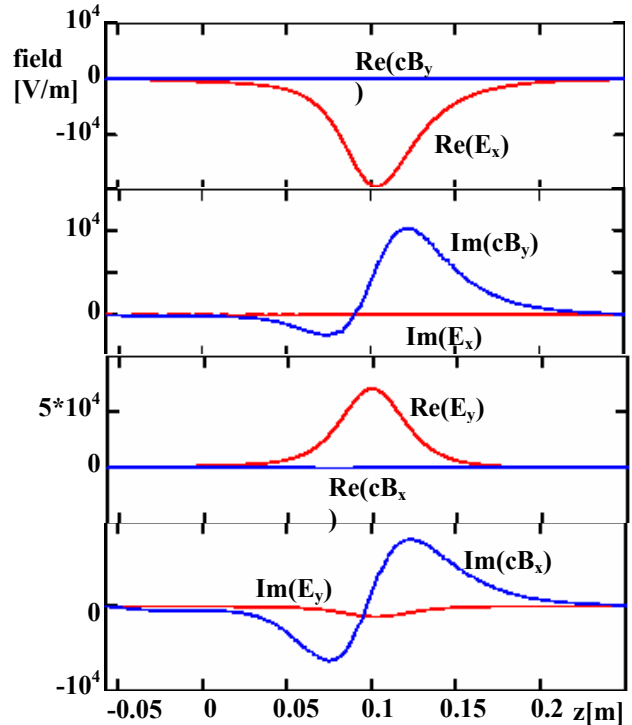


Figure 5: The RF field perturbation in the vicinity of the coupler plane

Using the definition of eqs.(2) and integrating the fields, the following values for the deflection parameters are obtained:

$$v_x = 5.386 \cdot 10^{-5} + 2.003i \cdot 10^{-5}$$

$$v_y = -2.282 \cdot 10^{-4} + 1.133i \cdot 10^{-4} \quad (3)$$

RESULTS

In order to estimate the increase of the transverse emittance we calculate the bunch parameters by means of the tracking code ASTRA . For the undisturbed RF field of the gun cavity and for the bunch charges 80pC and 1nC the results are given in Tab. 1

Table 1: Results of the tracking calculation

Q[pC]	80	1000
φ [grad]	57.3	57.3
σ_i [mm]	0.23	0.51
σ_z [mm]	0.97	3.36
ε [mm mrad]	0.69	3.84
E_0 [MeV]	9.5	9.5

Now from eqs.(1) we calculate the growth of the transverse emittance and obtain:

Table 2: The growth of the transverse emittance

Q[pC]	80	1000
$\delta\varepsilon_x$ [mm mrad]	0.00633	0.048
$\delta\varepsilon_y$ [mm mrad]	0.025	0.113

This result shows, that for an average power of 10 kW the emittance growth, connected with the asymmetry of the RF field in the coupler plane is smaller than 5% and nearly independent of the bunch charge.

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