PHYSICS DESIGN AND DYNAMIC SIMULATION OF A C-BAND PHOTOCATHODE ELECTRON GUN FOR UEM*

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Abstract- **For discovering structure with atomic scale and studying more details of chemical material and biological tissue, ultrafast electron microscopy (UEM) has been developed and applied in plenty of subjects and studies. A C-band photocathode electron gun working at 5712MHz is designed to produce ultrashort electron beams with better dynamic parameters, which is using coaxial coupler to decrease the size of the model and keep better symmetry of the field in the photocathode gun. Using CST MWS and superfish to simulate the field in the photocathode and calculate physics parameters to confirm the properties of the cavity. A solenoid magnet is designed to compensate the emittance and focus electron beams to keep from bunch expansion. Dynamic process has been simulated and parameters are calculated, including normalized rms emittance and rms size of electron bunches, and the initial phase degree and the magnetic field strength is optimized by parmela.**

Introduction

- ◆Ultrafast electron microscope uses electron beams with higher energy as the probe to discover minute structure, and could also be used to observe dynamic process.
- ◆A C-band coaxial coupled photocathode gun working at 5712MHz is designed and physical parameters are calculated.
- ◆A solenoid magnet is used at the downstream of accelerating cavity to focus the electron beams, in order to prevent the space charge force inside the beams which makes size expansion and forces the electron beams defocused. In this paper, shape and magnetic field strength of the solenoid are mainly optimized.
- ◆In this research, CST Microwave Studio is used to simulate the 1.6-cell C-band gun cavity and optimize the structure of coaxial coupler. The magnetic field of solenoid is simulated and optimized to keep the dimension of electron beams and compensate emittance by using parmela. To find out the range of initial phase degree of captured electron bunches, dynamic process of electron bunches emitting from the photocathode is simulated and different values of initial phase degree are scanned. The dynamic parameters after optimization are calculated at the exit of the photocathode gun.

Physics Design of the Coaxial Coupled Photocathode

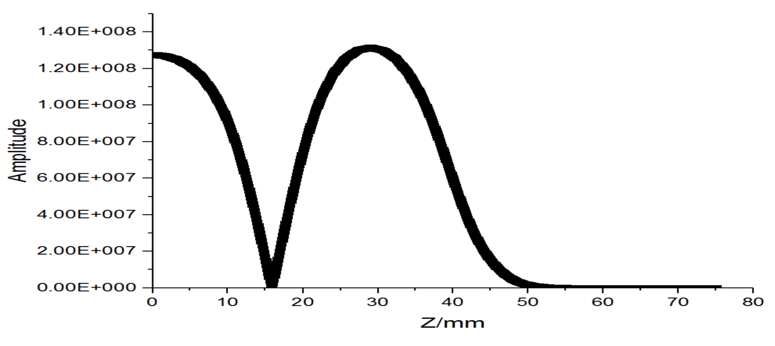

Figure 1: Ez of pi-mode along axis

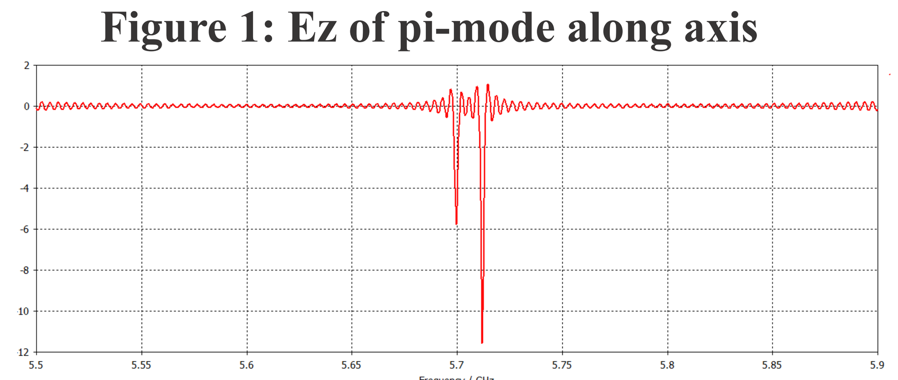

Figure 2: S11 curve of full model

Table 1: Main microwave parameters

Pi-mode frequency	5712.02MHz
0-mode frequency	5699.82MHz
Mode separation	12.22MHz
Shunt impedance per meter	143.879 $M\Omega/m$
Q factor	12084.4

- ☐ The 2D pi-mode field result is calculated by superfish and the electric field along z-axis is used to accelerate particles and result is showed in Fig.1.
- ☐ Main microwave parameters are listed in Table 1 and parameter positions are showed in Table 1.
- ☐ The full model is built and simulated using time domain solver in CST. The pi-mode electric field has been simulated and S11 curve is calculated and showed in Fig.2. This curve has two resonance peaks at 5700MHz and 5712MHz, which represents the 0-mode and the pi-mode.

Simulation of Dynamic Process

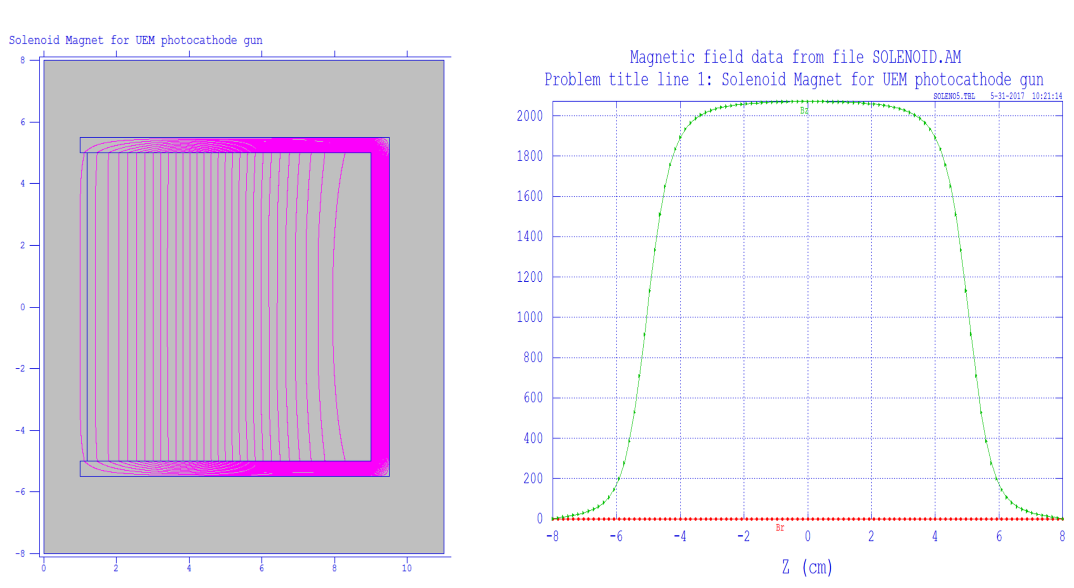

Figure 3: initial solenoid shape and magnetic field

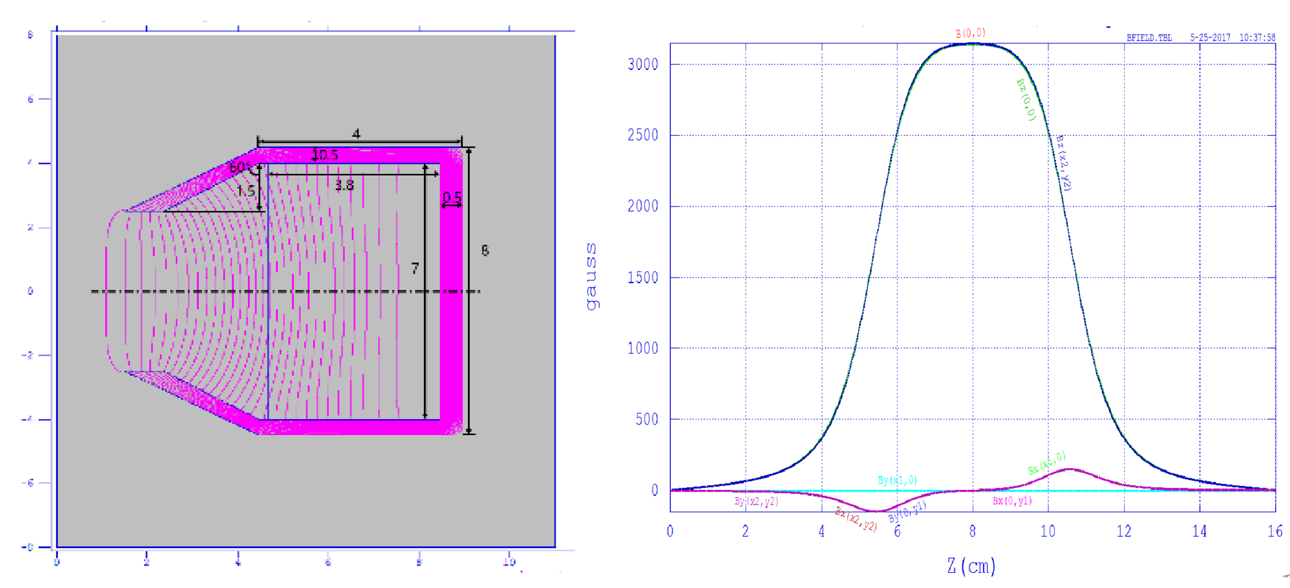

Figure 4: optimized solenoid shape and magnetic field

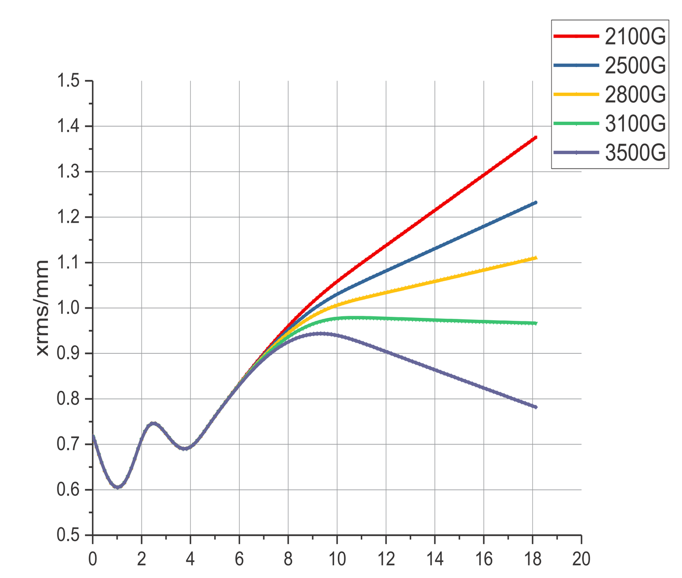

Figure 5: rms size in x-plane of the electron bunches in scanning different values of maximum of magnetic field

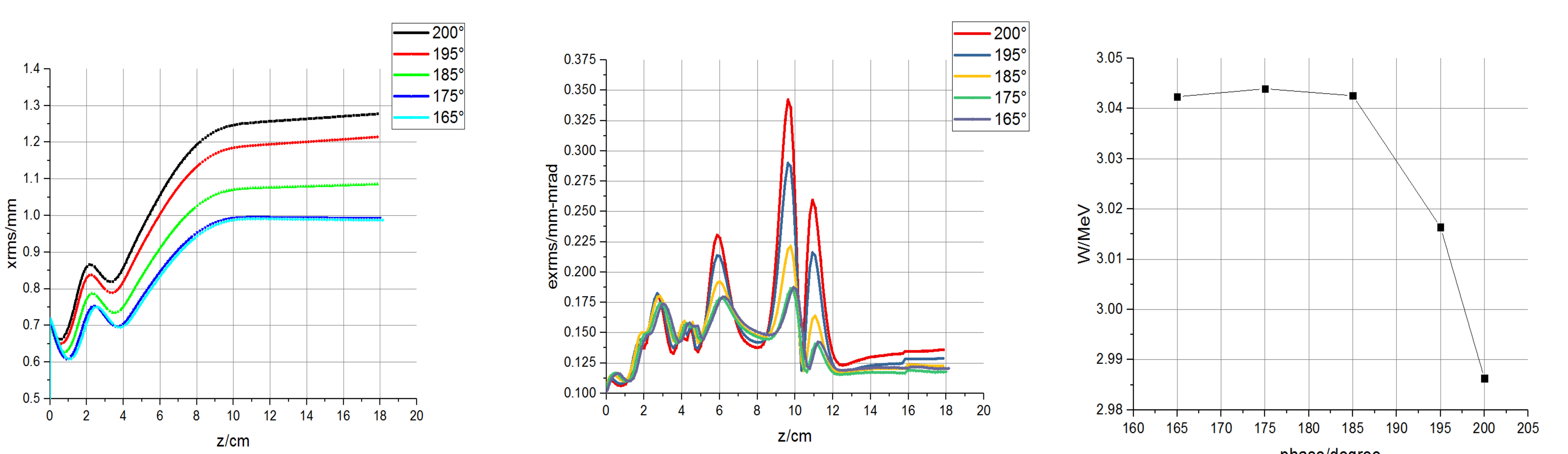

Figure 6: the change of rms size, emittance and beam energy of different phase degree

Scanning of different parameters

- ☐ The initial shape and optimized shape of the solenoid are presented in Fig.4 and Fig.5. Different values of maximum magnetic field have been simulated to determine the most suitable value of the magnet and the results are showed in Fig.6 and the value of 3100G is enough to prevent the electron bunches from expansion.
- ☐ To find out the range of initial phase degree of captured electron bunches, dynamic process of electron bunches emitting from the photocathode is simulated and different values of initial phase degree are scanned. The result that electron bunches with initial phase degree from 165 degree to 200 degree could be captured and accelerated in the C-band photocathode gun is presented in Fig.6.
- ☐ The main dynamic parameters of electron bunches at the downstream of the coaxial photocathode gun are listed in the Table 2 and change of beam size and emittance is presented in Fig.7.

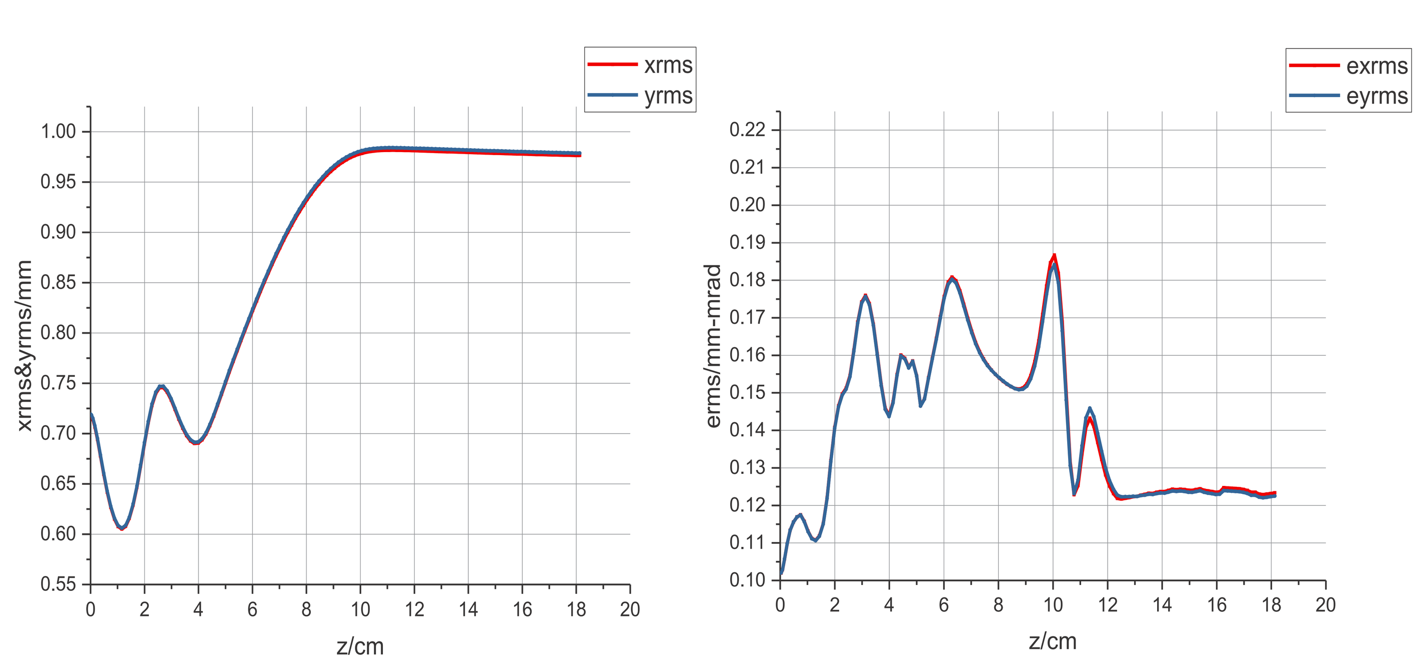

Figure 7: rms size and emittance in x-plane and y-plane of electron bunches

Table 2: Main dynamic parameters at the exit of gun

Rms size in x-plane	0.9874mm
Rms size in y-plane	0.9897mm
Emittance size in x-plane	0.1205mm-mrad
Emittance size in y-plane	0.1203mm-mrad
Energy gain	3.0423MeV
Energy spread	5.84e-04

SUMMARY

In this paper, we design a 1.6-cell C-band photocathode electron gun with coaxial coupler. After finishing the physical design, the solenoid magnet has been designed and dynamic process has been simulated using Parmela and dynamic parameters are calculated. Furthermore, after fabricating the model of gun, the electric field and shunt impedance would be measured.