RF DESIGN OF A HIGH AVERAGE BEAM-POWER SRF ELECTRON SOURCE

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Abstract

There is a significant interest in developing high-average power electron sources, particularly in the area of electron sources integrated with Superconducting Radio Frequency (SRF) systems. For these systems, the electron gun and cathode parts are critical components for stable intensity and high-average powers. In this initial design study, we will present the design of a 9-cell accelerator cavity having a frequency of 1.3 GHz and the corresponding field optimization studies.

INTRODUCTION

There is a growing need for higher-brightness and higher-average current electron sources for a myriad of applications [1]. Electron beams of high-bunch charge and repetition rates are required for activities such as:

- testing for beam instabilities in future high-energy physics machines [2];
- light sources being planned for higher repetition rates to serve many users [3];
- electron machines being used for waste treatment [4];
- several security applications [5];
- radio-isotope production [6];
- or in industry in a similarly configured accelerator driving a free-electron laser with an output beam tailored and ideal for next-generation lithographic techniques [7].

Despite the fact that there is a significant interest in achieving these higher-average power electron sources, there has been limited progress in the field, particularly in the area of electron sources integrated with Superconducting Radio Frequency (SRF) systems. Many challenges must be overcome for such integration, as incorporating a robust, efficient high-current cathode system into the SC environment has historically proven very difficult, and the basic complexity of the SRF system with the associated cryo-module and 2 K liquid helium needs makes such systems daunting [8].

GENERAL CONCEPT

The use of Superconducting Radio-Frequency (SRF) cavities may allow linear accelerators (linacs) that are less than 1.5 meters in length to create electron beams above 10 MeV with average beam powers measured in 10's of kW. Such compact SRF accelerators can have high wall-plug power efficiencies and, for example, may be compact enough to be readily transported and operated at local sites [9].

Design of a 1.3-GHz Gun Structure

In our design, the gun cavity is integrated into the first cell of the 9-cell standard ILC/XFEL (International Linear Collider/European X-Ray Free Electron Laser) cavity [10], resulting in a 8.4-cell accelerating structure. The first cell (a fractional length of 0.4 compared to the other cells) includes the cathode system. The remaining eight cells are standard. This design feature is also key to a compact design. The first cell is designed on the basis of RF field calculations.

In this study, the 8 cells of the standard ILC/XFEL cavity parameters are used and the 1st cell of this structure is redesigned to match the desired parameters.

The detail of the design parameters are shown in Figure 1 and Table 1 gives the design parameters for the modified 1st cell of 9-cell cavity.

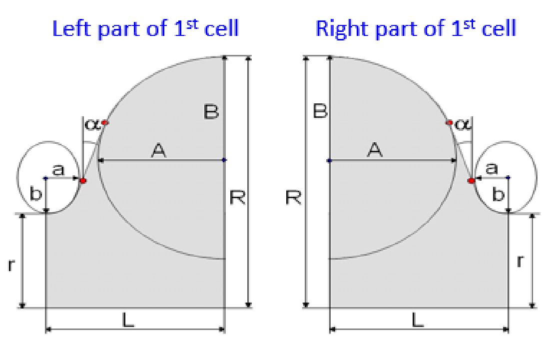

Figure 1: The elliptical cavity geometry design parameters. The values of parameters are given in Table 1.

Table 1: The Design Parameters of the Modified 1st Cell

Design Parameters	Left part [mm]	Right part [mm]
Iris Radius, r	3.5	35
Cavity Radius, R	99.056	99.056
Length, L	12.93	34.59
External Radius, A	11.53	24
External Radius B	11.53	24
Horizontal Half Axis, a	1.4	9.2
Vertical Half Axis, b	1.4	12

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Figure 2 shows a frequency scan of the modified 9-cell structure performed with the code SUPERFISH [11]. As seen, there are two frequencies near the desired 1.3-GHz operating point; however, only one frequency, that at 1300.92 MHz, gives the desired TM_{01} field map. This is the π-mode frequency of the standard ILC/XFEL geometry design.

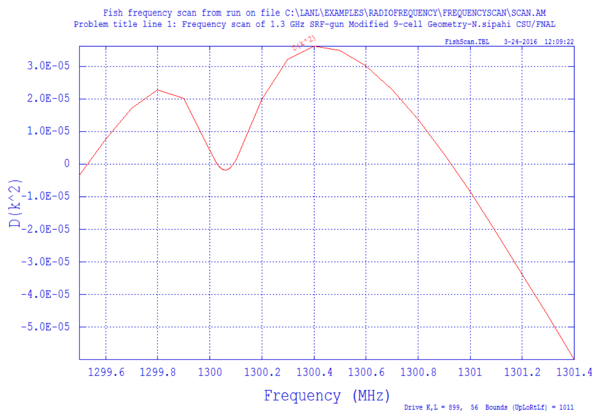

Figure 2: The frequency scan results of the modified 9-cell structure's design.

Figure 3a shows the modified 9-cell structure and field map. Figure 3b is a magnified view of Figure 3a around the 1st 1.4 cells to clearly show the field map of the designed structure.

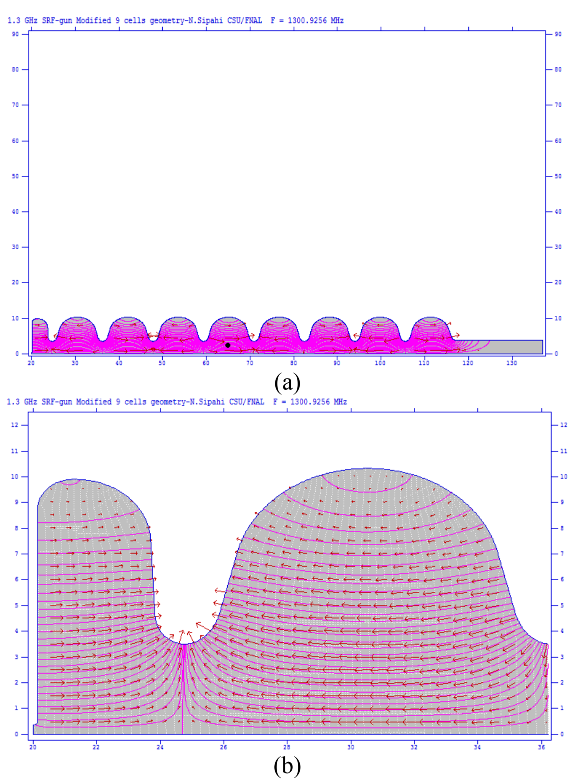

Figure 3: a) The modified 9-cell geometry design matched to the frequency of 1.3 GHz and its field map in SUPERFISH. b) The magnified view of first 2 cells in Figure 3a.

Figure 4 shows the on-axis field distribution of the modified 9-cell accelerating cavity. The field in the 0.4 cell has been maximized based on the design conditions.

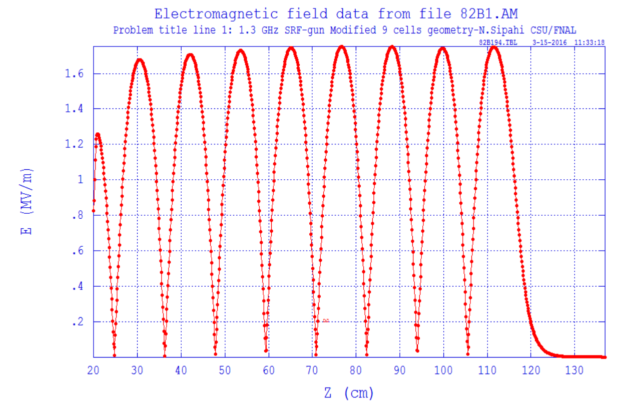

Figure 4: The on-axis electromagnetic field distribution of the modified 9-cell structure.

The 3D code, CST Microwave Studio (CST MWS) [12] was used to compare and validate the simulation results generated with SUPERFISH. Figures 5 and 6 show the output of this work.

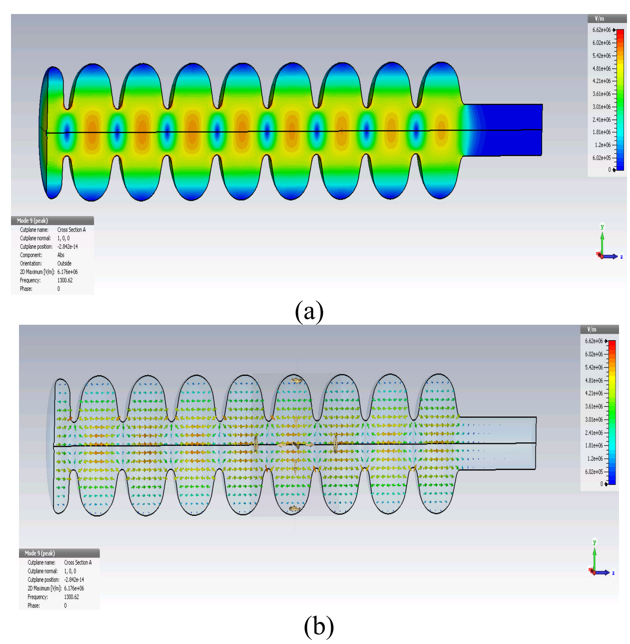

Figure 5: a) The Modified 9-cell geometry design with the frequency matched to 1.3 GHz and the contour plot of the fields using CST MWS. b) The modified 9-cell geometry with the view of field arrows in the π-mode using CST MWS.

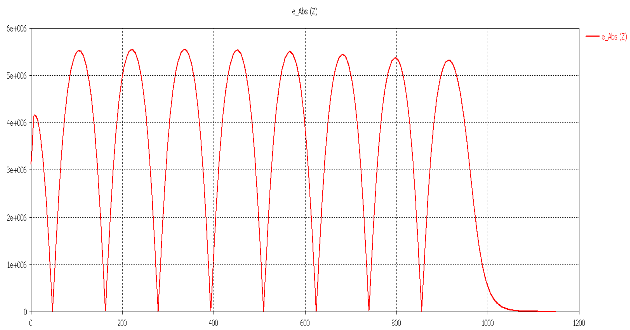

Figure 6: The on-axis electromagnetic field distribution of the modified 9-cell accelerating section geometry design in CST MWS.

We summarize in Table 2 the results obtained from the two different simulation codes.

Table 2. The Results of SUPERFISH and CST MWS (peak fields are calculated for 10 MeV output energy)

Parameters	SUPERFISH	CST MWS
Frequency [MHz]	1300.92	1300.64
E_{peak} [MV/m]	18.7	22.5
B_{peak} [mT]	38.5	44.6
B_{peak}/E_{peak} [mT/ (MV/m)]	2.06	1.98
R/Q [Ω]	934	936

Even though meshing refinement method is different between SUPERFISH and CST MWS, the results in Table 3 are quite similar.

CONCLUSION

We have performed the initial simulations to design a modified 9-cell accelerator structure via use of both SUPERFISH and CST MWS. Further iteration of the geometry will be considered following the optimization of the particle tracking.

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