PHYSICAL DESIGN OF A RECTANGULAR RF-DEFLECTOR FOR ULTRA-SHORT BUNCH LENGTH MEASUREMENT

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Abstract:
Cylindrical deflectors which are now widely used for bunch length measurement suffer from the degeneration of polarization, while rectangular deflectors can separate polarization mode easily. This paper is focused on the study of a one-cell rectangular deflector, which is considerably different from cylindrical structure or multi-cell structure. A one-cell structure is free of π mode restriction and can achieve higher deflection efficiency per unit length. The proposed scheme is expected to achieve time resolution better than 200fs with the driving power less than 1MW. Cavity optimization and beam dynamic simulation are introduced in this paper.

Introduction:
We propose to use a rectangular structure with an aspect ratio not equal to 1. For 10 MeV electron beams and 1 MW driving power, the rectangular RF deflector system is targeted to be shorter than 1 m and is supposed to achieve time resolution better than 200 fs.

Optimization of the Cell Geometry:
The deflecting voltage can be expressed by the function of a ,b and h.

$$V_d = \sqrt{\frac{2PQ\omega\varepsilon}{a^3bh}\frac{8\pi\mu_0 c}{k_c^3}}\sin\left(\frac{\omega h}{2v_z}\right)$$

This equation is assumed as the basis for optimizing the cavity in this paper. We conclude that for an ideal and closed rectangular cavity operated in TM_{120} mode, the optimal dimension to generate maximum deflecting efficiency is 120.59 mm × 106.64 mm × 46.96 mm (*x*×*y*×*z*).

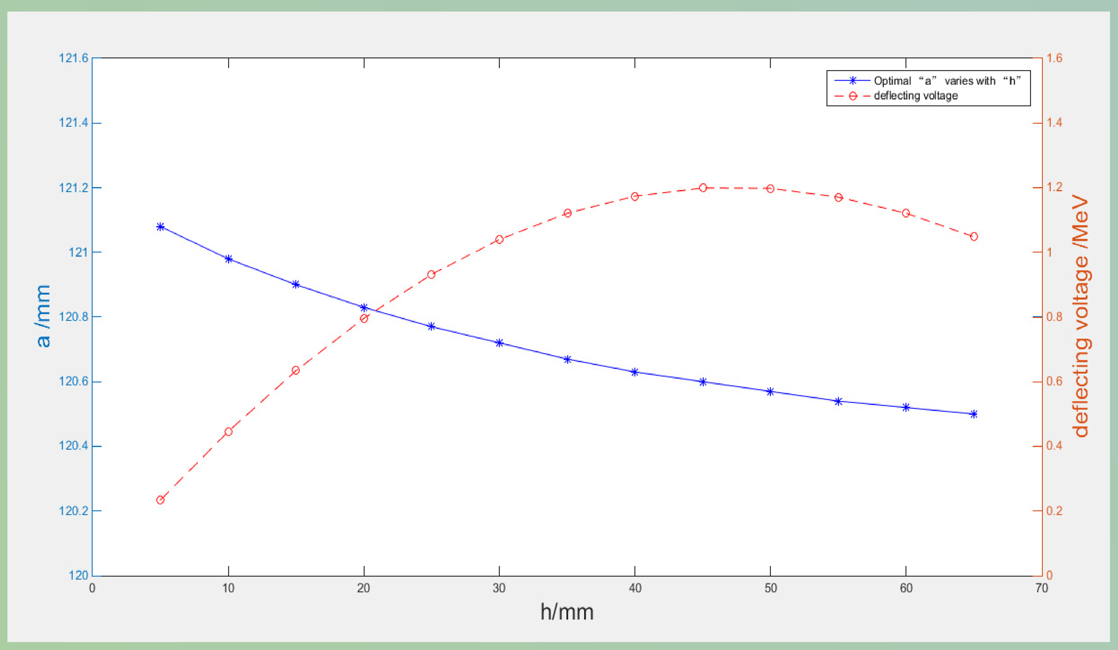

Figure 1: Optimal *a* and the deflecting voltage as a function of *h*, the power loss *P* is assumed as 1 MW.

CST SIMULATION:
In this section, the 3-D simulation software CST is used to adjust the parameters of the RF-deflector cavity and calculate the distribution of electromagnetic field and S-parameter.
Finally, we simulated a practical open cavity operated in TM_{120} mode, the optimal dimension to generate maximum deflecting efficiency is 120.80 mm × 104.20 mm × 46.96 mm (*x*×*y*×*z*).

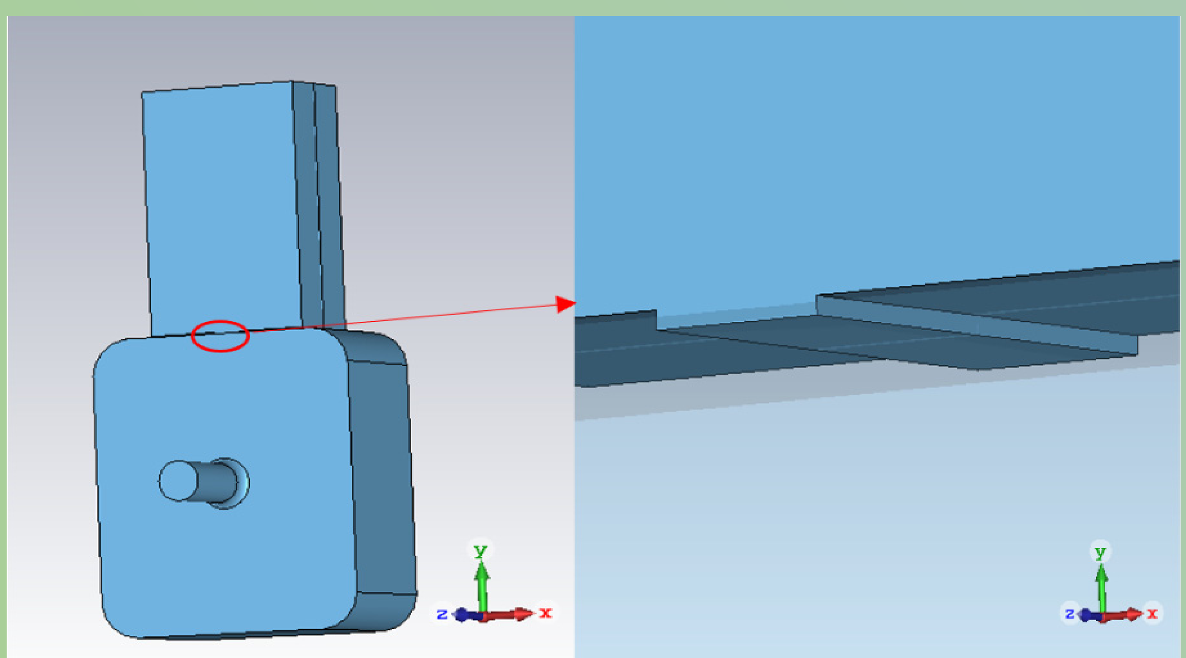

Figure 2: Structure of the RF-deflector cavity

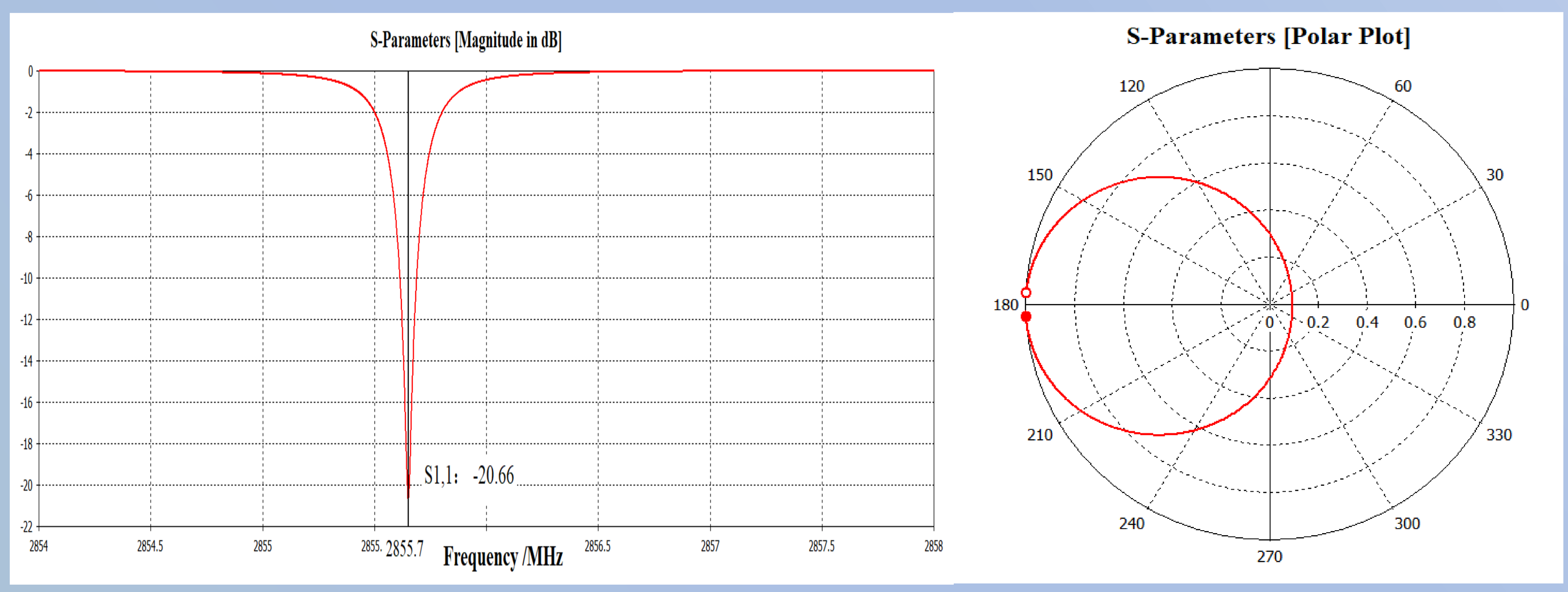

Figure 5: The magnitude and polar plot of S-parameter of rf-deflector

BEAM DYNAMICS SIMULATION AND ANALYSI
We used Parmela for particle tracking and for evaluation of the performance of the cavity. the calculated time resolution is 174.15 fs and meets our requirements. This electron beam is focused to a vertical beam size of 0.3 mm (RMS), and it will enlarge to 0.884 mm (RMS) when the RF-deflector is on. the RMS bunch length is about 482.70 fs. There is a 0.70% deviation between our calculations and theoretical results (486.11 fs). Overall the RF-deflector system in principle meets the design requirements.

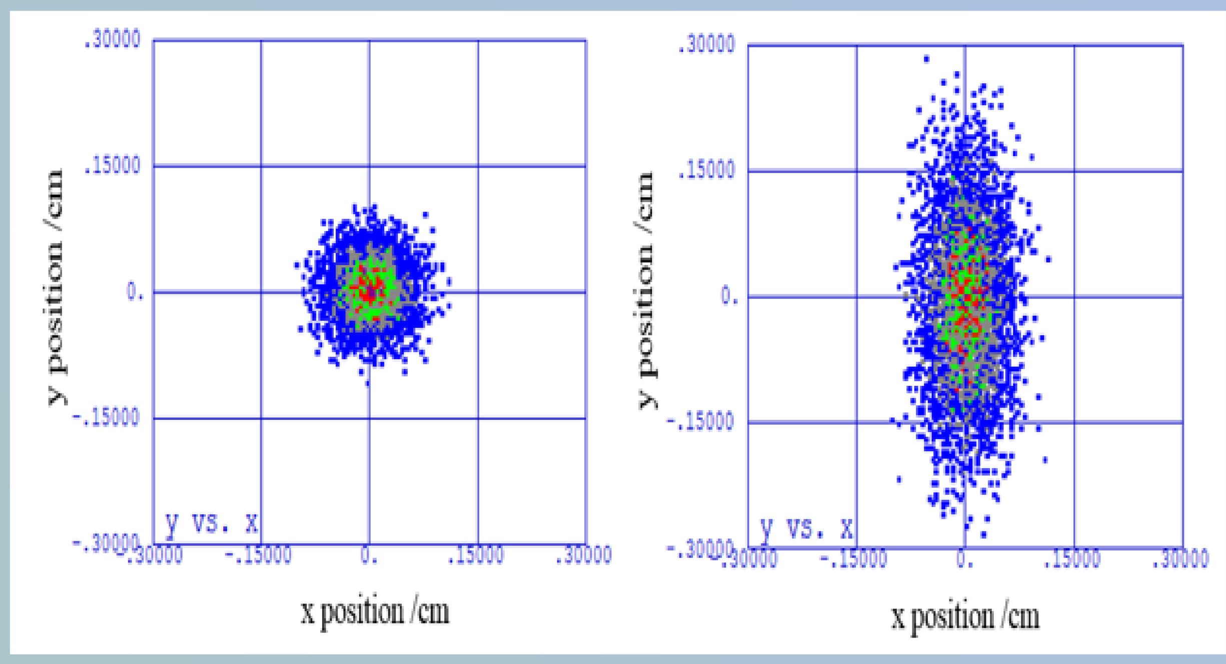

Figure 4: Transverse profile of the electron beam with the RF-deflector off (left) and RF-deflector on (right).

Conclusion:
In this paper, we introduced the basics of RF-deflector for sub-picosecond bunch measurement and obtained an optimal solution for the cavity size. We built a model of this cavity by 3-D simulation software CST, and calculated the distribution of electromagnetic field. For 10 MeV electron beams, the designed RF-deflector system, which is shorter than 1 m, achieves the time resolution better than 200 fs. Theoretical calculations have been verified by Parmela.

Reference:
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