Radial Multigap Resonant Cavity for W-Band High Power EIK

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Abstract: *A novel angular radial multigap resonant cavity (ARMRC) is proposed for W-band high power extended interaction klystron (EIK). The proposed cavity can operate with an angular radial sheet electron beam (ARSEB), which has larger space-charge limited current than conventional sheet electron beam. As a result, the angular radial EIK based on the proposed ARMRC is expected to provide higher output power than the corresponding conventional sheet beam EIK. High frequency characteristics of the proposed ARMRC are investigated here by using simulations. The 2π-mode resonant frequencies of the ARMRC have been obtained for different radii, angular spread, and cavity heights. The study provides guidelines for the design of a high power angular radial EIK at W-band.*

Keywords*:* Angular radial, multigap resonant cavity, high frequency characteristics, EIK

Introduction

Sheet electron beam (SEB) EIK has attracted wide interest in the past years for its significantly improved performance over the conventional klystrons. A multigap resonant cavity (MRC) is the core component of an EIK; the dimensions of the MRC determine the gain and bandwidth of the EIK directly. EIKs have been developed at Ka, W, and G bands exhibiting high reliability. In 2014, J. Pasour et al demonstrated a W-band EIK which gave an output power of 7.7 kW at 94 GHz; a 19.5 kV, 3.6 A SEB was employed and the electronic efficiency was as high as 8.6% [1].

The concept of angular radial SEB (ARSEB) has been proposed by Wang et al for a Ka band TWT [2]. One of the key points of the ARSEB is that the electron beam diverges azimuthally when moving towards the collector, resulting in a decreasing current density. Thus, the ARSEB has larger space-charge limited current than conventional SEB with the same initial cross sectional area and voltage. The combination of ARSEB and EIK is expected to produce a significant improvement. Therefore ARMRC is proposed and investigated here through simulation.

Model of the ARMRC

Fig. 1 shows the perspective views of the proposed ARMRC as well as the conventional MRC. Different from the conventional MRC, the ARMRC has concentric arc-shaped gaps which are periodically arranged along the radial direction and are connected at both ends. The cavity gaps have the same angular spread as that of the ARSEB. The interaction area between the ARMRC and the ARSEB increases gradually towards the collector. It is expected that beam-wave

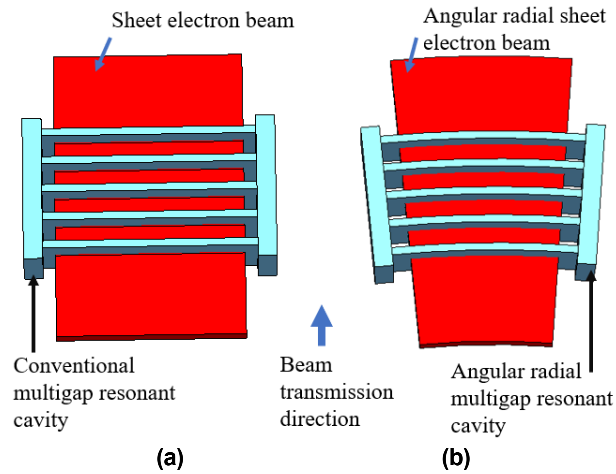


Figure 1. Compasion between the 3D models of (a) conventional sheet beam five-gap resonant cavity and (b) proposed ARMRC.

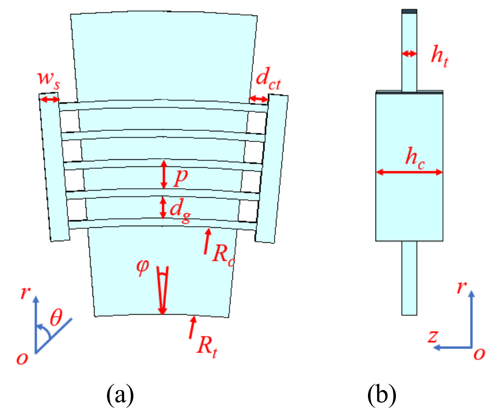


Figure 2. Structure parameters of the proposed ARMRC on (a) *rθ* plane and (b) *rz* plane.

interaction in this case will be more efficient as compared to the conventional EIK, providing higher gain and electron efficiency.

Fig. 2 shows the dimensional parameters of the ARMRC. The angular (azimuthal) spread of the electron beam tunnel and the cavity is φ. The separation between the cavity and the beam edges is dct. The radial period of the gaps is p and the separation between adjacent gaps is dg. The radii of curvature of the first gap and the beam tunnel are Rc and Rt, respectively. The heights of the beam tunnel and cavity are ht and hc, respectively.

High frequency charateristics of the ARMRC

The electric field distribution for different modes of the ARMRC has been investigated by using Eigenmode Solver of CST Microwave Studio [3]. The initial dimensional parameters are listed in Table I, where *n* denotes the number of gaps.

Table I. Dimensional parameters of the ARMRC.

Parameters	Values (mm)	Parameters	Values (mm)
R_c	30.00	h_t	0.40
R_t	24.26	h_c	1.75
w_s	0.5	d_{ct}	0.5
p	0.78	φ	10 deg
d_g	0.58	n	5

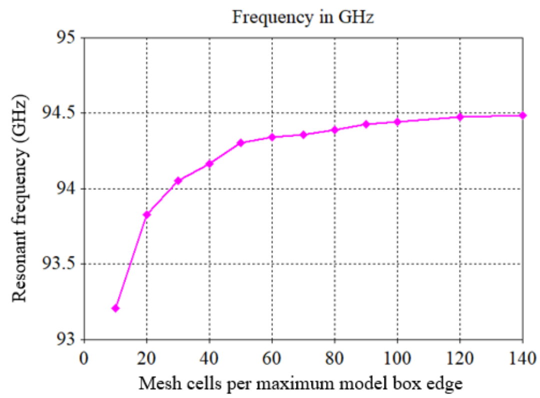
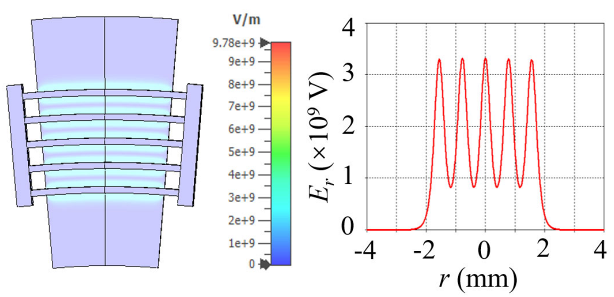


Figure 3. Resonant frequency of the ARMRC vs. number of mesh cells per maximum model box edge (2π-mode).



(a) (b)

Figure 4. (a) Electric field distribution and (b) radial electric field of the ARMRC (2π-mode, 94.5 GHz).

Fig. 3 shows the 2π-mode resonant frequency of the ARMRC for varying number of mesh cells per maximum model box edge, where the Tetrahedral mesh is used. It can be seen that the resonant frequency of the 2π-mode converges to 94.5 GHz when the mesh cells per maximum model box edge approaches 140.

Fig. 4 (a) shows the magnitude of the 2π-mode electric field of the ARMRC. The electric field is concentrated near the gaps and the strength is quite uniform along the azimuthal direction. Fig. 4 (b) shows the radial component of the electric field strength along the center of the beam tunnel, as marked in Fig. 4 (a). The electric field is periodically distributed along the radial direction. Thus the 2π-mode electric field of the ARMRC meets the requirement for an efficient beam-wave interaction with an angular radial SEB.

Among the dimensional parameters of the ARMRC, R_c, h_c, and φ play more important roles. Variation in anyone of these causes significant change of the azimuthal length of the ARMRC. The gap parameters dg and p are important as well but these should be fixed once the operation voltage is

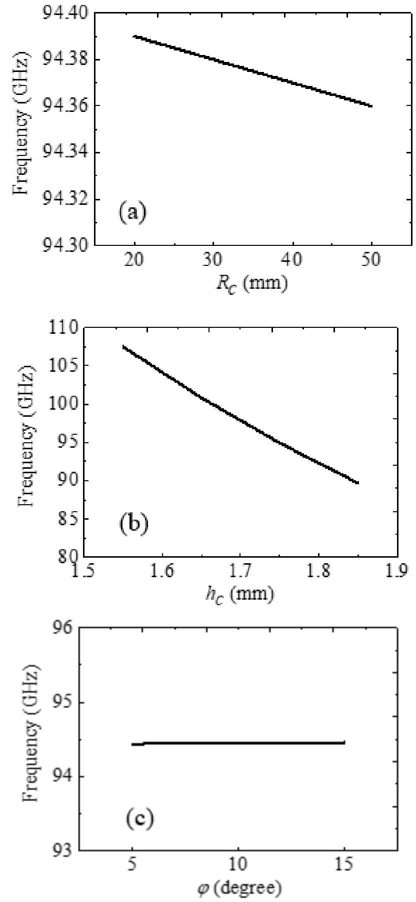


Figure 5. Resonant frequencies of the 2π mode with different (a) R_c, (b) h_c and (c) φ.

determined. As a result, only R_c, h_c, and φ are available to tune the resonant frequency of the ARMRC.

Figures 5 (a), (b), and (c) respectively show the effect of Rc, hc, and φ on the resonant frequency of the 2π-mode, with the other dimensions kept the same as those listed in Table I. As can be seen, increasing R_c causes a slight frequency drop while increasing the cavity height hc causes a significant drop in frequency. The angle of the ARMRC has little impact on the resonant frequency.

Discussion

A novel ARMRC has been proposed and investigated for application in high power W-band angular radial EIK. The simulated electric field distribution has been shown to be suitable for an ARSEB. The effects of the main dimensional parameters on the resonant frequency have been studied for guiding the design of W-band ARSEB EIK.

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