Analysis on Resonant Cavities of 231GHz EIA with Trapezoid Subwavelength Holes

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Abstract: *A novel resonant cavity of extended interaction amplifier (EIA) is designed, combined with a double-grating structure and trapezoid subwavelength holes array structure. The resonant cavity is analyzed when operating at the* TM_{31}*-*2π *mode in millimeter-wave band. The electric field distributions, dispersion, Q, and R/Q characteristics are simulated with the different parameter trapezoid subwavelength holes. Compared to the EIA which adopts the resonant cavity with rectangular holes, the one with trapezoid-hole resonant cavity may have a higher gain and wider bandwidth.*

Keywords: trapezoid subwavelength holes, EIA, resonant cavities, millimeter wave

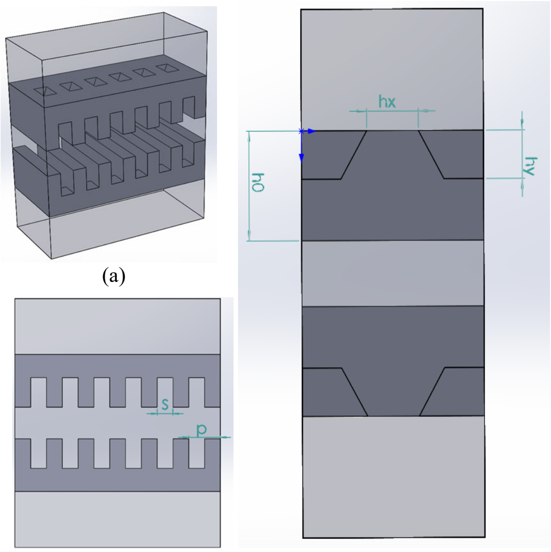
Introduction

The extended interaction klystron (EIK), combined with characteristics of Klystrons and traveling-wave tubes, is a compact vacuum electron device. Each individual cavity of the EIK is essentially a shorted section of a coupled-cavity traveling-wave circuit, which supports efficient modulation and energy exchange between the high frequency field and the electron beam [1-2]. Therefore, the EIK has high gain per unit length, simple topology, and capacity for relatively high power[3]. Due to the series of perfect performances, the EIK is utilized as a high-power radiation source amplifier for a long time[4-7]. This type of amplifier is called EIA. To realize high gain and high efficiency of the EIA in mm-Wave band, it is important to design a kind of high frequency structure of EIA with a good performance. For EIA here, the high frequency structure refers to resonant cavities.

In this paper, we propose resonant cavities with double gratings and trapezoid subwavelength holes array structure, and analyze their electric field distributions, dispersion and characteristic impedances.

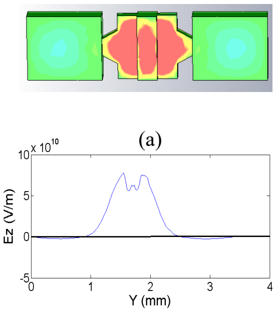
Design and Results

The high frequency structure consists of double gratings, an array of trapezoid subwavelength holes and external metal walls, whose geometry is shown in Fig.1. As can be seen from the figure, firstly, the space between the grating and the metal wall is regarded as a coupled cavity through the subwavelength holes. Secondly, each hole is located in the center of each gap of the grating, which is the same to the symmetrical grating. In x-y plane, the hole is shaped as a trapezoid, and its ratio of the short side's length to the long side's is 0.5. In addition, the sheet beam can pass through the channel, the center of two gratings.



(a)
(b) (c)

Fig. 1. The physical model of the resonant cavity.(a) The 3D geometry of the structure, (b) y -z-cut of the figure 1(a),(c) x -y-cut of the Figure 1(a)



(b)

Fig. 2. Electric field distributions.(a) Ez in 3D version, (b) Ez along Y direction

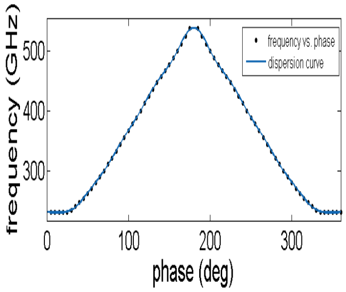


Fig. 3. Dispersion curve

In order to obtain a better performance, the TM_{31}-2π mode is chosen as the operating mode, as the electric field at this mode is centralized in the beam channel. Based on the fact that the cavity is required to operate at 231 GHz, the structural

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dimensions are listed as follows: p=0.28 mm, s=0.14 mm, h_x=0.24 mm, h_y=0.22 mm, h_0=0.28 mm. For a single gap, the result is that the resonant cavity operates at 230.96 GHz and its R/Q is 131.1 Ω. Moreover, the electric field distribution and the dispersion curve are respectively shown in Fig.2 and Fig.3.

Considering the further performance of the EIA, we adopt the resonant cavity with 3 gaps as the intermediate cavity operating at 231.01 GHz, and its R/Q is 373.34 Ω. In order to analyze the effects of different parameters, we define their ratio of the short side's length to the long side's as 'a_0' and study the influence of changing a_0. During the process, we only change the sizes of the holes by tuning the values of a_0 and h_x, while keeping that the resonant frequencies of these different cavities are the same. As a_0 grows, the shape of the subwavelength hole is more similar to rectangular. When a_0 increases to 1, the shape becomes totally rectangular. The simulation results of the Q and R/Q are shown in TABLE I and Fig.4.

TABLE I. Q AND R/Q VARING WITH A_0

a₀	0.25	0.5	0.75	1
Q	903.52	939.13	959.18	980.55
R/Q (Ω)	385.74	373.34	365.71	358.92

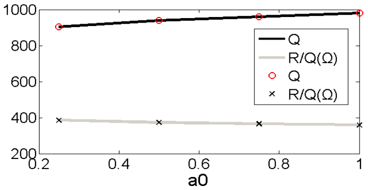

Fig. 4. Q and R/Q varing with a_0

According to the graph, it can be seen that Q increases, with a_0 increasing, while R/Q decreases. As far as it is known, to some extent, the higher R/Q may predict stronger beam-wave interaction, which also means higher gain, and lower Q predicts wider bandwidth of EIA. In other words, lower a_0 may predict both higher gain and wider bandwidth of EIA.

Summary

Compared to the resonant cavity with rectangular subwavelength holes, the one with trapezoid subwavelength holes may have better performance at 231 GHz. Operating on the proper parameters, the higher gain and wider bandwidth may have been obtained for the EIA.

Acknowledgment

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