Investigation on the High Gain Sheet Beam Extended Interaction Klystron with Strong-coupling Multiple-gap Cavities in W-band

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***Abstract*— A strong-coupling five-gap barbell output cavity is investigated combined with the design of W-band sheet beam extended interaction klystron (SBEIK), which may have many advantages of resonant mode separation, gap fields coupling and RF energy exporting with high efficiency. Then the output cavity is used to construct a high gain W-band SBEIK with eight multiple-gap cavities. With the sheet beam voltage of 75kV, and the current of 4A, the output power can attain to 32kW with the gain high than 50dB. The result agrees very well with the one-dimensional calculation program.**

I. INTRODUCTION

THE sheet beam electron devices with the 2-dimensional plan structures have become the important directions to promote the vacuum electronics to the millimeter-wave and terahertz band with high power output radiation. Also it is with the potential technologies to develop the integrated vacuum electronics. The sheet beam extended interaction klystron (SBEIK) has the typical and attractive characteristics with the plan structural multiple gap cavity and extended beam wave interaction system. Recently, a few research works have been carried out for the development of the SBEIK in W-band and G-band, and some important progress has been obtained [1-3]. In this paper, we focus our research on the W-band SBEIK to find the right way to get higher gain per unit length with higher peak power for the whole tube.

II. DESIGN OF STRONG-COUPLING FIVE-GAP CAVITY

In our previous research works [4], an equivalent circuit method with its theories has been derived to simplify the physical model for the five-gap extended interaction output structure to analyze the cavity mode, resonant frequency, gap impedance and the bandwidth etc. The related theories has also been used to the W-band SBEIK to analyze the degenerate five resonance mode, and the 2π mode is selected as the available working mode. For the comparison, the traditional weak-coupling and strong couple five-gap output cavity with the same resonant structure is simulated and analyzed respectively. And the two types of five-gap cavities structures with its electric field distribution for 2π mode along z axis are given in Fig.1. Then for the further comparison, the electric fields amplitude distribution in the center line of the cavity is plotting in the Fig. 2, and the corresponding RF parameters for the two types of five-gap cavity are calculated thoroughly with the results given in the Table1. From that we know the strong-coupling output cavity can have characteristics for the good electric field coupling in the output gap than the weak-coupling one, and with the resonant mode separation is of about 640MHz for our strong-coupling five-gap cavity. Also the much low Q_L and Q_e for the strong-coupling five-gap cavity can make the multi-gap cavity SBEIK easily export the RF energy to the output waveguide with high efficiency more stability.

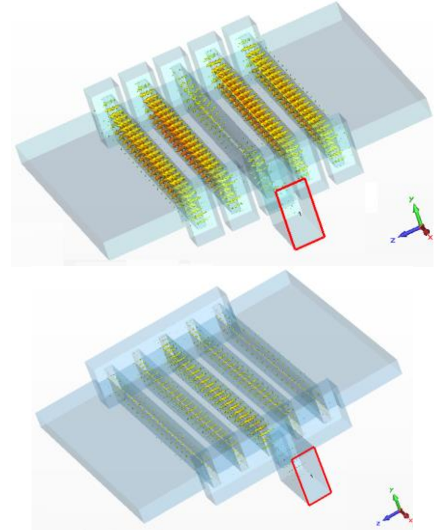

Fig. 1. The electric fields distribution of the 2π mode for the weak-couple (top) and strong-couple (bottom) five-gap output cavity

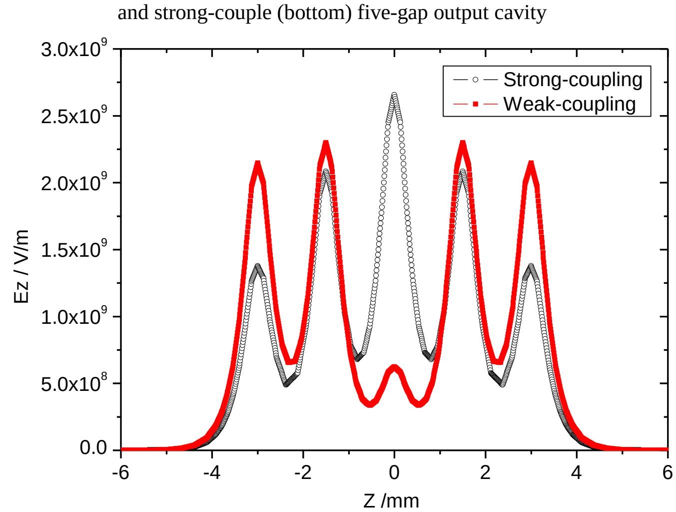

Fig. 2. Comparison of electric fields distribution along Z axis for the weak-couple and strong-couple five-gap output cavity

Table 1. Comparison of RF parameters for the weak-coupling and strong-coupling five-gap output cavity

Parameters	F(GHz)	R/Q	Q_0	Q_e	Q_L
Weak-coupling	94.60	70.43	1358.2	4530.8	1045.0
Strong-coupling	94.50	71.68	1343.5	694.9	460.4

III. Beam-wave interaction Calculation and analyses for the High gain W-Band SBEIK

The above strong-coupling five-gap output cavity is then used to construct our high power W-band SBEIK with eight multiple-gap cavities to obtain the high gain with only small input signal. The simulation physical mode of SBEIK is given in Fig.3. The whole beam-wave interaction is consisted with the single-gap input cavity, and six intermediate cavities with each of them strong-coupling three-gap. Then the strong-coupling five-gap structure is used as the output cavity for high power generating and coupling in our SBEIK.

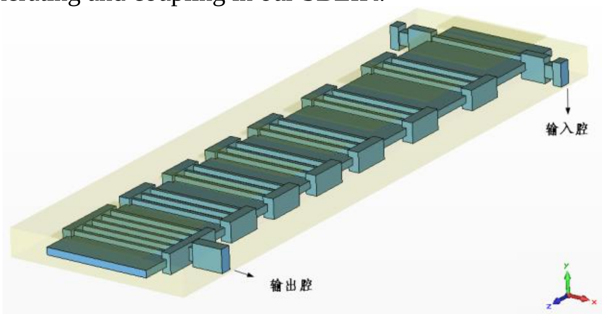

Fig. 3. The physical mode of the whole W-band SBEIK using 3D PIC software

Then the 3D PIC software is used to simulate the beam wave interaction process for our eight-cavity high gain SBEIK. With the sheet beam voltage of 75kV and the current of 4A, the typical magnify processes of the high frequency electric fields during the beam-wave interaction is given in Fig.4, and we can know from the results that the high output power of our SBEIK amplifier can be obtained with our strong-coupling five-gap cavity. In Fig.5, the variation of output power and gain corresponding with the input power is calculated and plotted with several calculating points. We can know that when the input power is 0.32W, the maximum output power can attain to 32kW with the gain high than 50dB. However, with the increase of the input power more than 0.32W, the saturated output power becomes smaller. Then, for the comparisons, the one dimensional non-linear program is used to calculate the same physical model of our SBEIK with the above parameters, and the results are also given in Fig.5. It is obvious that the tendency of the gain and output power for the one-dimensional program is in good consistent with the 3D-PIC program, but he maximum output power is a little low that the 3D PIC. The more detail analyses and calculation will be introduced in detail later. Also, this strong coupling five-gap output cavity with our eight cavity SBEIK physical model will be used to develop the high gain amplifier in the millimeter-wave and terahertz band with high power output radiation later.

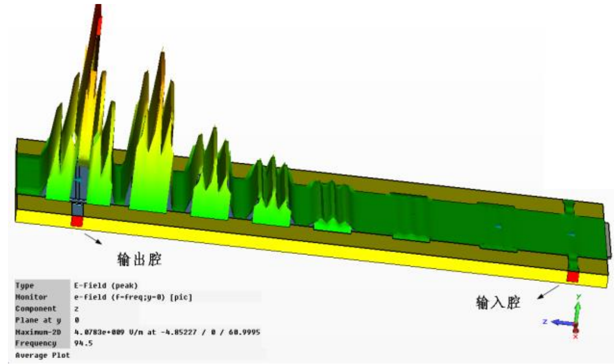

Fig. 4. Typical magnify processes of the high frequency electric fields after beam-wave interaction with 3D PIC calculation

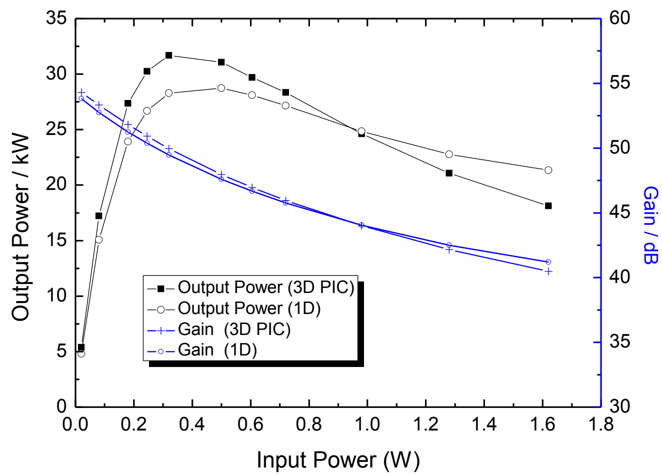

Fig.5. Variation of output power and gain corresponding with the input power

IV. Acknowledgements

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