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Bandwidth Extension of an *S*-band, Fundamental-Mode Eight-Beam Klystron

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Abstract: *We present the design of a five-cavity, broadband, high-power multiple-beam klystron (MBK) operating in S-band. The MBK uses a 32 A, 45 kV eight-beam electron gun [1] whose design has been successfully tested in a previous narrowband MBK circuit [2, 3]. The circuit was optimized using the 3D particle-in-cell code MAGIC; the predicted performance includes a 3-dB bandwidth of 6.7%, peak power of ~600 kW and a gain of 33 dB. This circuit performance represents a three-fold increase in the bandwidth-power product relative to our previous circuit.*

Keywords: Multiple-beam klystron; MBK; bandwidth extension; broadband cavity.

Design of a Broadband Multiple-Beam Circuit

To achieve broad bandwidth operation, the circuit employs three two-gap cavities (the input cavity, second cavity, and output cavity) and two single-gap cavities (third cavity and pen-ultimate cavity). The purpose of the two-gap cavities is to increase the *R/Q* to enable broader bandwidth operation while maintaining the desired saturated power and gain within the constraints of a short overall interaction length. In the two-gap cavities, four rectangular slots couple two separate but dimensionally-identical cavities via their common endwalls. As expected for a system of two coupled individual cavities, there are two eigenmodes with distinct frequencies: the $m = 0$ (2π-mode) and the $m = 1$ (π-mode). The coupling slot dimensions control the mode frequency separation and also the coupling strength between the two gaps. For stability reasons and because of geometric constraints, the π-mode was selected as the operating mode for all of the two-gap cavities.

The first four cavities comprise the bunching circuit (Fig. 1a) which produces a highly bunched beam over the frequency band of interest at the axial location of the output cavity with reasonable gain. The evolution of the bunching currents for several frequencies as a function of axial position at 300 W of input power is shown in Fig. 1b. The magnitudes of these currents peak at an axial location approximately 18 cm downstream from the center of the first gap – the logical position to place the output cavity. In Fig. 2, the bunching current at this axial location is plotted as a function of frequency for different input drive power levels. Note that the beam modulation is relatively flat with frequency and linear with input power.

The predicted MBK output power as a function of frequency is shown in Fig. 3 (using a broadband, two-gap output cavity and a constant 300 W RF input drive). As seen in the figure, the circuit generates >550 kW across the band with a peak power of more than 600 kW at ~3.27 GHz. The 1-dB bandwidth is 5.2% (3-dB bandwidth of 6.7%) with a maximum gain of 33 dB and corresponding efficiency of 42%. This performance has been achieved with an overall circuit length of ~22 cm. Table I summarizes the operating characteristics of the five individual cavities (the 2π-mode frequencies of the three two-gap cavities have been tuned well outside the operating band).

Acknowledgement

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References

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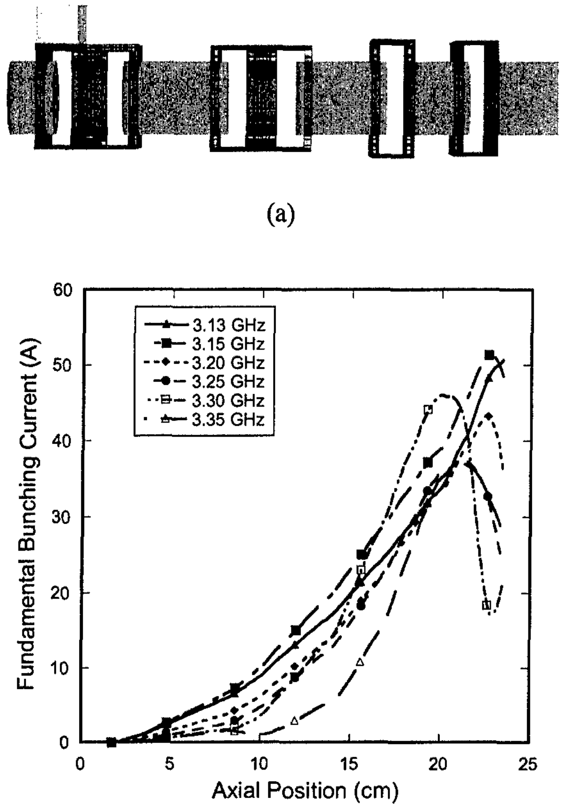

(a)

(b)

Figure 1. (a) MAGIC-3D solid model of the bunching circuit; (b) the computed fundamental bunching current as a function of axial position for a variety of driving frequencies (constant 300 W RF input drive).

Table 1: Individual characteristics of the five cavities comprising the broadband MBK circuit.

Cavity	# of Gaps	f_0 (GHz)	Q
Input	2 (π-mode)	3.160	54
Idler 1	2 (π-mode)	3.328	65
Idler 2	1	3.384	63
Idler 3	1	3.456	--
Output	2 (π-mode)	3.213	19

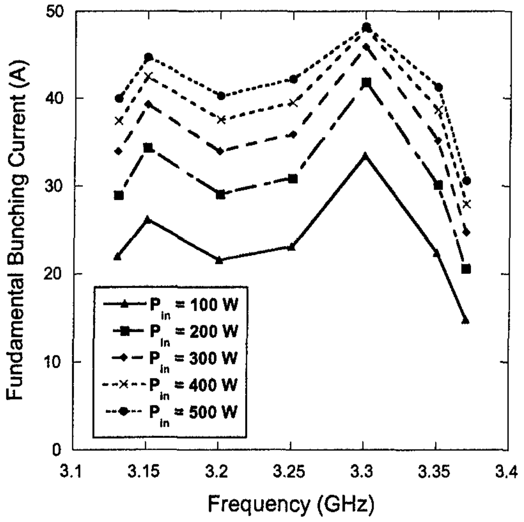

FIGURE 2. Computed (MAGIC-3D) fundamental bunching current as function of frequency at an axial location of ~18 cm downstream from the center of the first gap for a variety of input drive power levels.

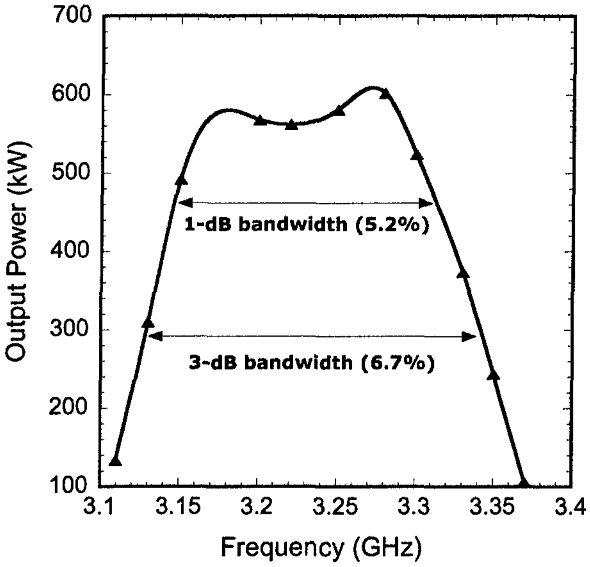

FIGURE 3. Computed (MAGIC-3D) frequency response of the eight-beam, five-cavity MBK circuit for a constant drive power of 300 W.