Particle-In-Cell Simulation of 100 GHz Reentrant Linear Magnetron

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***Abstract*—100 GHz linear magnetron employing the ten-vane reentrant resonator is investigated by using a two-dimensional particle-in-cell simulation. The dynamics of electron beam, the time variation of electric energy in each vane, and the generated power density are examined when the injected current density is varied. The maximum power density is 180 mW/mm^2 at 100 GHz when the current density of 80 A/cm^2 is used.**

I. INTRODUCTION

THE terahertz (THz) region of the electromagnetic spectrum between 0.1 and 10 THz exhibits unique physical properties in various applications [1]. Although the progress in the development of electronic and photonic THz radiation sources, high power, low-cost, and compact radiation sources are demanded for the practical applications. Recently, the vacuum electron devices based on the bunched electrons in a vacuum have received much attention for their efficient interaction mechanism [2,3]. Despite of its outstanding merits, the several crucial issues such as the generation and the focusing of the high current density electron beam through the beam tunnel and the circuit with the micro-electro-mechanical system (MEMS) compatible structure are remained [4,5]. In this study, the 100 GHz reentrant linear magnetron for the THz radiation source is investigated by using a two-dimensional (2D) particle-in-cell (PIC) simulation MAGIC code.

II. SIMULATION MODEL

A schematic of the 100 GHz reentrant linear magnetron modeled by the 2D MAGIC code in the *x-y* plane is shown in the Fig. 1 where the emission area is indicated at the cathode.

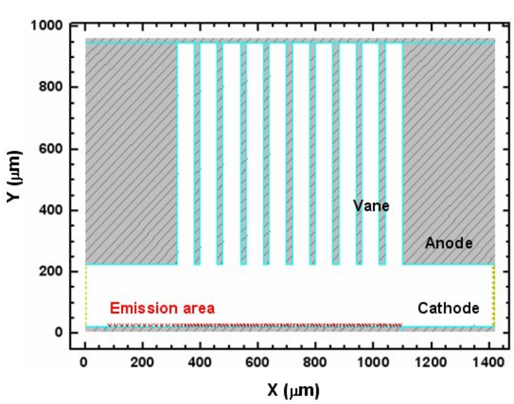

Fig. 1. Schematic of the 100 GHz reentrant linear magnetron modeled by the 2D MAGIC PIC code in the *x-y* plane.

In the simulation, the Cartesian-coordinate system is used, the length of the coordinate *z* is considered as 1 m to calculate the current density and power density, and the conductivity of conducting materials is assumed to be 5.8 x 10^7 S/m. The geometrical parameters of the ten-vane reentrant resonator are calculated by using a theoretical calculation and a finite-difference-time-domain (FDTD) simulation for the π-mode resonance at 100 GHz. The distance between the cathode and the anode is 200 um, the depth of vane is 720 um, and the thickness of vane and anode are 60 um and 20 um, respectively. The π-mode resonant frequency at a mode number of ten is separated by about 0.2 % with the adjacent π-1 mode. For the synchronism between the resonant mode and the electron beam, the drift velocity of an electron is equal to the phase velocity of the wanted resonant mode in the reentrant resonator. When the electrons emitted from the cathode moving into the *x*-axis interact with the resonant mode, the electrons are developed into bunched electron beams enforcing the oscillation in the reentrant linear magnetron. The operating condition examined from the synchronism condition results in the beam voltage of 2 kV and an external magnetic field of about 0.78 T for the oscillation frequency of 100 GHz.

III. SIMULATION RESULTS

The effect of injected current density and the external magnetic field on the distribution of electron beam, time evolved electric energy, and the generated power densities are analyzed. The spatial distribution of electrons normalized by the peak value is measured along the *x*-axis to compare the density modulation of the electron beam at the simulation time of 22 ns after the oscillation is saturated.

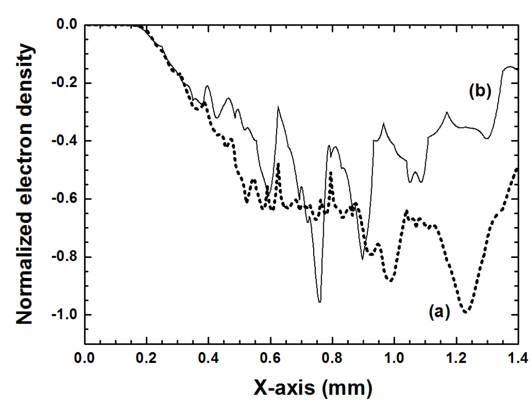

Fig. 2. Normalized electron density with the injected current density of (a) 60 A/cm^2 and (b) 320 A/cm^2 along the *x*-axis.

As shown in Fig. 2, the two bunches of electrons denoted by the dotted line are made in the end region of the reentrant resonator when a 60 A/cm^2 is used. In case of 320 A/cm^2, the five bunches of electron are fully developed, and reveal that the

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maximum bunch of electron is formed in the central region of the reentrant resonator. The simulated time variation of electric energy in each vane with the injected current density of 60 A/cm^2 and 320 A/cm^2 is shown in the Fig. 3. Based on the electron bunches formed in the interaction space, the electric energy in each vane is mature.

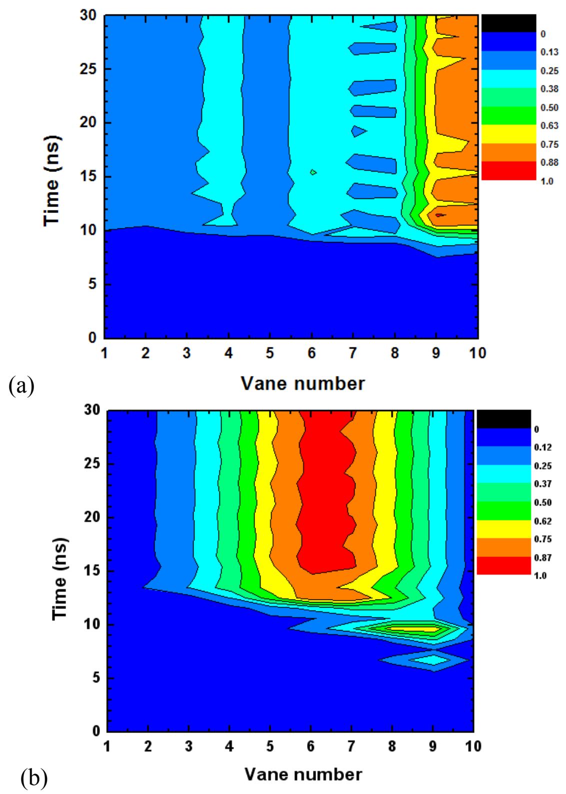

Fig. 3. Simulated time variation of electric energy in each vane of the reentrant resonator with an injected current density of (a) 60 A/cm^2 and (b) 320 A/cm^2.

When the injected current density of 60 A/cm^2 is imposed from the cathode, the maximum electric energy is built up near the end region of resonator indicating the enforcement of π-1 mode oscillation by the two bunches of electron. However, in case of 320 A/cm^2, the electric energy has a peak value in the central region showing π-mode oscillation. The time variation of electric energy also shows that the π-1 mode is excited near 6 ns, and then the π-mode dominantly oscillates after 12 ns suffering from mode competition. The generated power density and the corresponding oscillation frequency are shown in Fig. 4 when the external magnetic field is varied from 0.75 T to 0.87 T with the different injected current density from 40 A/cm^2 to 80 A/cm^2. As the injected current density is increased, the range of the external magnetic field for the oscillation is extended and the external magnetic field for the maximum power density is shifted from 0.77 T to 0.81 T. When 60 A/cm^2 and 80 A/cm^2 are used, the maximum power densities are 120 mW/cm^2 and 180 mW/cm^2, respectively. As the injected current density is increased, the oscillation frequency is decreased from 100.3 to 100.1 GHz due to the filling of the electron beam in the interaction space.

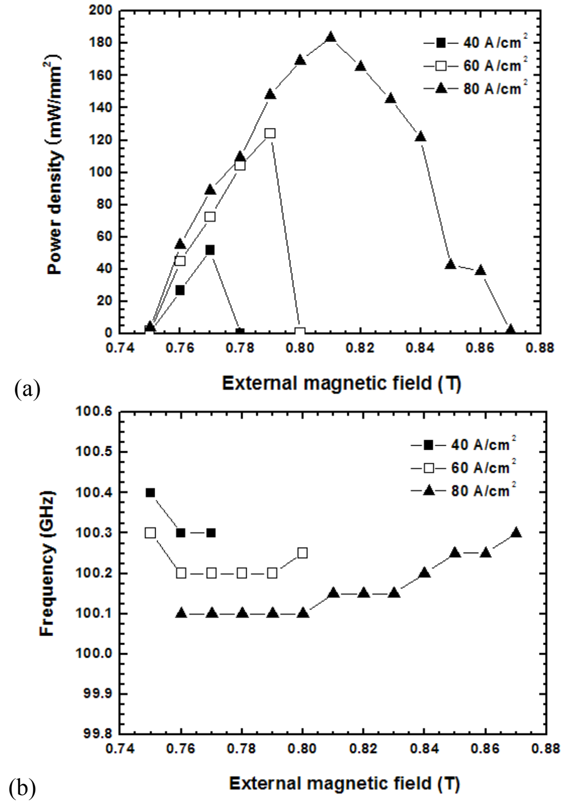

Fig. 4. (a) The generated power density, and (b) the corresponding oscillation frequency when the external magnetic field is varied from 0.75 T to 0.87 T.

IV. CONCLUSIONS

Simulated behaviors of 100 GHz linear magnetron employing the ten-vane reentrant resonator is investigated by using a two-dimensional particle-in-cell simulation. The geometrical parameters are selected to give a π-mode resonance at 100 GHz. The electron distribution in the interaction space and time variation of electric energy reveal that the π-mode oscillation with 320 A/cm^2 is dominant, although the π-1 mode with 60 A/cm^2 is excited. When the current density of 80 A/cm^2 is used, the maximum power density is 180 mW/mm^2 at the oscillation frequency of 100.1 GHz.

REFERENCES

[1] P. H. Siegel, “Terahertz technology,” IEEE Trans. Microwave Theory Tech. 50, 2002, pp. 910-928.

[2] S. Bhattacharjee et al., “Folded waveguide traveling-wave tube sources for terahertz radiation,” IEEE Trans. Plasma Sci. 32, 2004, pp. 1002-1014.

[3] S. G. Jeon et al., “Three-dimensional particle-in-cell simulations of 300 GHz reflex klystrons,” J. Appl. Phys. 101, 2007, pp. 054519 1-5.

[4] R. L. Ives, “Microfabrication of high-frequency vacuum electron devices,” IEEE Trans. Plasma Sci. 32, 2004, pp. 1277-1291.

[5] John H. Booske, “Plasma physics and related challenges of millimeter-wave-to-terahertz and high power microwave generation,” Phys. Plasma 15, 2008, pp. 055502 1-16.

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