Efficient Regime of Hybrid Surface-Radiating Waves in a THz Clinotron

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Abstract: *Peculiarities of a THz non-resonant clinotron in a regime of surface-radiating backward wave arising due to periodically modified grating have been presented. The simulation results demonstrate that the feedback and efficiency of the radiation output of the proposed regime is much higher in comparison with conventional surface wave clinotron in a THz range.*

Keywords: backward wave oscillator; clinotron; THz radiation; hybrid surface-radiating wave; Smith-Purcell radiation.

Introduction

Conventional Cherenkov non-relativistic BWO's and clinotrons operating in a surface wave regime produce radiation with mW output power level in THz range (0.3-1.2 THz) [1]. One reason of such low output power is due to strong attenuation of a surface wave and hence, decrease of the feedback and radiation output efficiencies. Based on our previous study on coupling between surface and radiating waves due to periodically modified grating [2] we show here that hybrid surface-radiating mode provides considerable increase of the efficiency of the radiation output and improves feedback, that enables Watt level of the output power in 0.5-0.7 THz range.

Results

When electron bunch moves above periodically modified grating (3- stage – every 3rd groove is of modified groove depth), a leaky wave is radiating into open space (Fig. 1) with intensity, which is much higher than that of conventional SPR [2]. Placing a reflecting wall above the grating provides a feedback by the radiating wave and in the case of resonance (closed waveguide radiating wave angle is close to the angle of a leaky wave) the hybrid surface-radiating modes appear [2]. In the waveguide dispersion such modes can be identified by the curves those are typical for intermode interaction. Additional analysis of the mode pattern should reveal both strong surface wave (near grating) and radiating wave (in the waveguide space between top and bottom walls). For the grating shown in Fig. 1 with the waveguide height D = 2 mm, areas of hybrid modes are indicated by circles for two cases of EB voltage in Fig. 2. Simulation results of a beam-wave interaction using MAGIC2D [3] are shown in Fig. 3 (U = 10.2 – 11.25 kV) and Fig. 4 (U = 17.2 – 19.5 kV) for two cases indicated in Fig. 2. The sweep of the accelerating voltage is implemented by an increase on

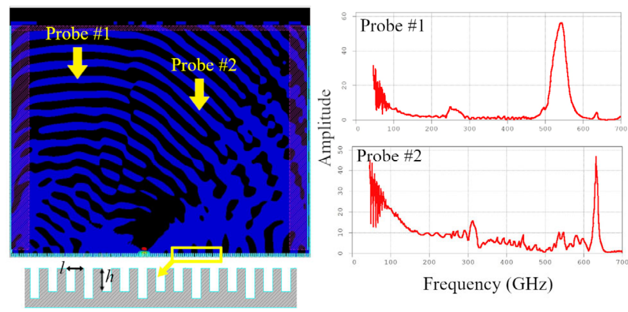

Figure 1. Simulation results of the radiation caused by an electron bunch moving above "3-stage" non-uniform grating. Period is l = 0.07 mm, regular groove depth h = 0.09 mm, increased groove depth 0.12 mm, U = 10 kV.

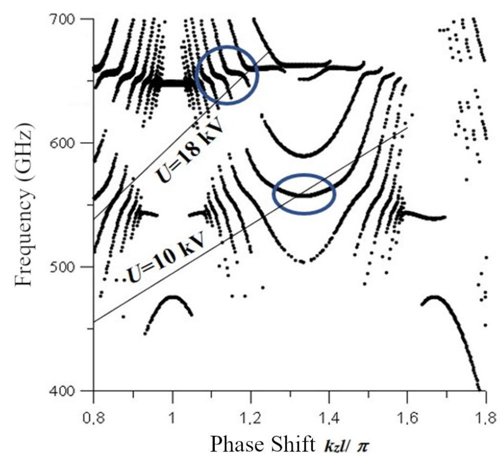

Figure 2. Dispersion of the waveguide of height D = 2 mm containing"3-stage" non-uniform grating.

75 V every 3 ns. Therefore, change of the interaction power occurs with interval of 3 ns and the width of the signal Fourier spectra approximately demonstrates frequency tuning due to voltage sweeping. For the case shown in Fig. 3, the radiating wave angle is almost normal to the grating and the field pattern is similar to this in DRO and orotron [4]. However, the presented case is with high coupling impedance due to the presence of the surface wave and is non-resonant one with no reflections at the waveguide ends. Hence, there is no need of use of complicated mirrors for the RF field focusing and the frequency tuning is almost continuous in the range of 545 – 552 GHz. Relatively wide radiation output can be placed either at the beginning, or at the middle of the top wall. Simulations show that this may provide ratio of the output power to the ohmic loss power within

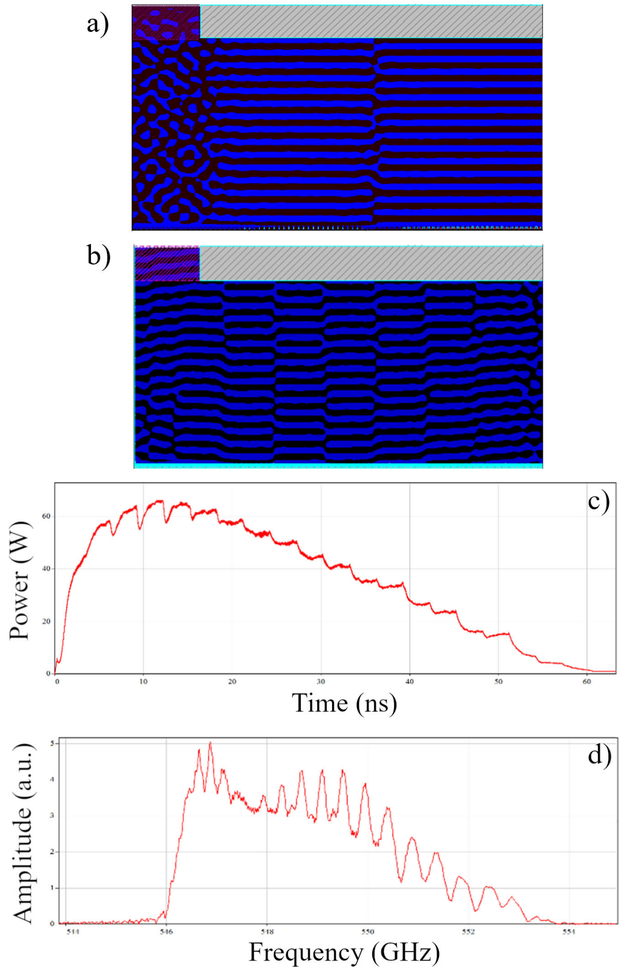

Figure 3. Simulation results of the radiation excitation by the EB inclined to the grating by 0.4° of 0.1 mm thickness with current of 0.3 A and initial voltage of $U = 10.2$ kV increasing on 0.075 kV every 3 ns. a), b) field pattern at $U = 10.2$ kV and $U = 10.95$ kV; c) power of ohmic loss vs. time; d) FT spectra.

$P_{out} / P_{loss} < 1/4$ (σ was 1.75×10^7 S/m). This ratio is quite high for slow wave THz oscillators, especially for these operating in a surface wave mode and may provide output power level up to 10 W or 0.5 % efficiency for the given parameters.

The second oscillation case shown in Fig. 4 corresponds to hybrid modes with some angle to the grating (30-60°). Number of radiating wave reflections from the top wall depends on the waveguide height D that determines length of a feedback by the radiating wave as well as the radiation output efficiency. The frequency tuning range is about 630 – 635 GHz due to sweep of voltage with similar to the previous case output parameters ($P_{out} / P_{loss} < 1/3$, $P_{out} < 25$ W, $\eta \leq 0.5$ %).

Summary

Simulation of the clinotron operation by backward hybrid surface-radiating waves demonstrated advantages of such regime for the efficient radiation output and strong feedback. The simulated output radiation was about 25 W and 1 % frequency tuning band at 0.6 THz range.

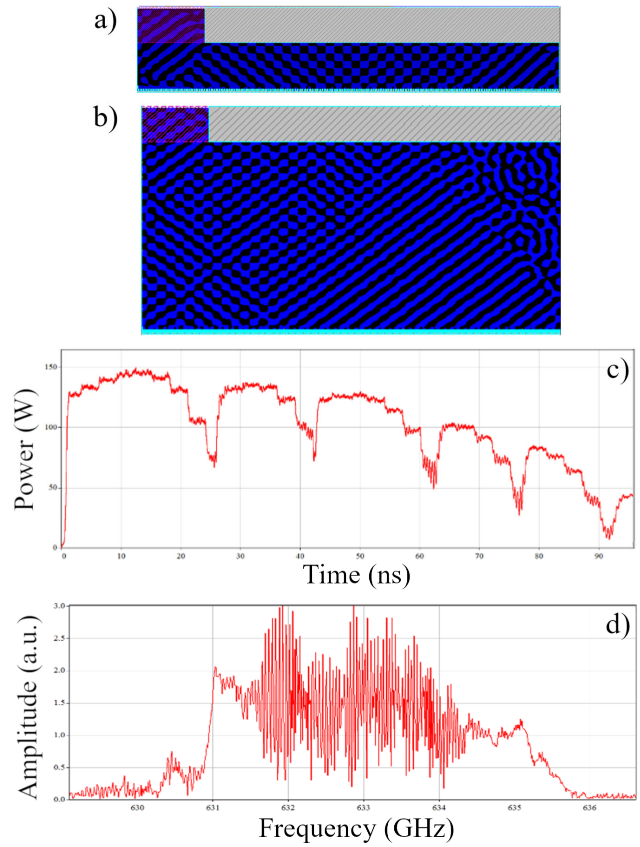

Figure 4. Simulation results of the radiation excitation by the EB with current of 0.3 A and initial voltage of $U = 17.2$ kV increasing on 0.075 kV every 3 ns. a), b) field pattern at $U = 17.2$ kV for $D = 2$ mm and $D = 8$ mm; c) power of ohmic loss vs. time; d) FT spectra.

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