TRANSVERSE RADIATION INPUT AND OUTPUT FOR PLANAR RELATIVISTIC SURFACE-WAVE OSCILLATORS AND AMPLIFIERS*

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The output power of relativistic high-current microwave sources decreases when operating frequency increases and transverse dimensions of the slow-wave structure (SWS) shrinks. To mitigate this power decline, the oversized slow-wave structures are needed so the problem of mode competition arises. Relativistic surface-wave oscillators are attractive devices for generation of multi-megawatt power at sub-terahertz waves, since a usage of evanescent operating mode provides ultimate mode selection at least in one transverse direction. However, evanescent nature of the operating wave brings a number of difficulties such as a scattering of the wave at the edges of the grating, a power leakage to the cathode, and high ohmic losses. All these issues hamper utilizing of the generated microwave radiation for the applications.

To organize the effective and practical radiation output in the relativistic high-power surface-wave oscillator, we recently proposed [1] to apply an additional diffraction grating with a period twice larger than the period of the main corrugation (Fig. 1). The similar method was studied earlier for low-voltage clinotron devices [2-4]. The main corrugation and the additional corrugation form the bi-periodic grating with the odd grooves being deeper than the even grooves. The auxiliary grating scatters the evanescent operating waves into the gaussian beam leaking in perpendicular direction to slow-wave structure. Produced gaussian output beam is suitable for applications. Besides, at sub-terahertz frequencies, the transverse energy extraction reduces the Ohmic losses drastically thus increasing the device efficiency. According to simulations, 150-GHz surface-wave oscillator based on sheet electron beam with voltage of 600 kV and current of 600 A can provide 90 MW of output power with 25 % efficiency.

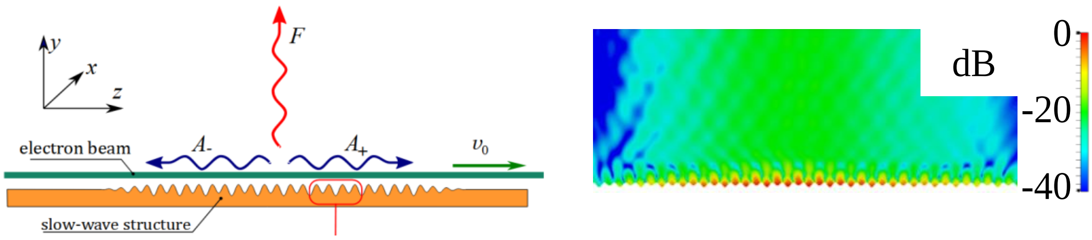

Fig.1. (Left panel) Surface-wave oscillator with transverse energy output (not in scale). Bi-periodic slow-wave structure driven by sheet electron beam provides coupling of surface wavebeams A_+ and A_- with transverse output wavebeam F. The odd grooves of the bi-periodic grating are deeper than the even grooves. (Right panel) PIC-code simulated pattern of the microwave magnetic field. Both the evanescent operating mode and the output gaussian beam are seen.

The same method could be used for power input in surface-wave amplifier as well [5]. In high-power extended interaction klystron exploiting open gratings as surface-wave cavities driven by a high-current sheet electron beam, additional corrugation provides in- and out-coupling of the radiation. Simulations based on both averaged quasi-optical model and PIC code demonstrate the feasibility of the 150 GHz amplifier with 20-40 MW output power in gaussian beam and 20-30 dB linear gain in 1% bandwidth.

REFERENCES

[1] A.M. Malkin, A.E. Fedotov, V.Yu. Zaslavsky, A.S. Sergeev, S.E. Fil'chenkov, E.D. Egorova, and N.S. Ginzburg, “Relativistic sub-terahertz surface-wave oscillators with transverse Gaussian-like radiation output.” // *IEEE Electron Device Letters*, vol. 42, No. 5, pp. 751-754, 2021.

[2] E.M. Khutoryan, A.N. Kuleshov, S.S. Ponomarenko, K.A. Lukin, Y. Tatematsu, M. Tani, “Efficient Excitation of Hybrid Modes in a THz Clinotron.” // *J. Infrared, Millimeter, and THz Waves*, vol. 42, pp. 671–683, 2021.

[3] E.M. Khutoryan, Yu.S. Kovshov, A.S. Likhachev, S.S. Ponomarenko, S.A. Kishko, K.A. Lukin, V.V. Zavertanniy, T.V. Kudinova, S.A. Vlasenko, A.N. Kuleshov, T. Idehara, “Excitation of Hybrid Space-Surface Waves in Clinotrons with Non-uniform Grating.” // *J. Infrared, Millimeter, and THz Waves*, vol.39, no.3, pp.236-249, 2018.

[4] S.S. Ponomarenko, A.A. Likhachev, S.A. Vlasenko, Y.S. Kovshov, V.V. Stoyanova, S.A. Kishko, E.M. Khutoryan, A.N. Kuleshov, K.A. Lukin, Y. Tatematsu, and M. Tani, “Traveling-Wave Amplification in a Circuit With Nonuniform Grating.” // *IEEE Transactions on Electron Devices*, vol. 68, no. 10, pp.5232-5237, 2021.

[5] N.S. Ginzburg, A.M. Malkin, V.Yu. Zaslavsky, A.E. Fedotov, and A.S. Sergeev, “Relativistic sub-THz surface-wave sheet-beam amplifier with transverse energy input and output.” // *IEEE Transactions on Electron Devices* , vol. 69, No. 2, pp. 759-762, 2022.

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