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Simulation of High-Power 8-mm Band Avalanche-Oscillator Diodes

P. P. Maksymov
Usikov Institute of Radiophysics and Electronics of the National Academy of Sciences of Ukraine, Kharkiv, Ukraine
e-mail: maksymov.pvl@ukr.net
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Abstract—The results of computer simulation of 8-mm band high-power avalanche-oscillator diodes (AOD) based on abrupt reverse biased *p–n* junctions with constant voltage have been presented. It is shown that AOD synchronously generate two oscillations in *p*- and *n*-regions of *p–n* junction, respectively. A technique is proposed for determining the parameters that ensure the diode operation in the mode of coherent oscillations. It is shown that the diode output power in this operation mode increases at the expense of summing-up the electron and hole components. The dynamic range of output power and the electronic efficiency are also determined.

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INTRODUCTION

Millimeter-band diode oscillators are in high demand in radiolocation and radio navigation systems, communication and telecommunication networks, and compact coherent transceivers [1–3]. The power of diode oscillators is determined by the power of active elements. Avalanche transit-time diodes (ATD) based on reverse biased abrupt *p–n* junctions are commonly used as active elements of microwave power oscillators. At present diode oscillators based on GaAs and Si ATD are the most powerful two-electrode devices over the whole millimeter wave range [3].

The ATD operation is based on dynamic negative differential conductivity that is determined by variable voltage $U_0 + U_\sim$ across *p–n* junction, where U_0 is the constant component of power supply and $U_\sim$ is the variable component of the oscillating loop of external circuit. Avalanche current in ATD is significantly less than the limiting current of reverse biased abrupt *p–n* junction, while the variable component of voltage $U_\sim$ is much less than the constant component U_0 that limits the diode output power [1–3].

As is shown numerically in [4–10], avalanche-oscillator diodes (AOD) based on reverse biased abrupt *p–n* junctions with high constant (dc) voltage are high-power diode generators. According to the AOD theory, the static volt-ampere characteristic includes a current instability section [9] that results in appearance of negative differential conductivity and synchronous generation of two self-excited oscillations in *p*- and *n*-regions of *p–n* junction, respectively. The presence of two oscillations automatically raises the problem of determining the possibility of enhancing the AOD output power by summing up the powers of these oscillations.

The purpose of this study is to simulate nonlinear processes occurring in silicon 8-mm AOD with external signal and to determine the dynamic range of output power and the electronic efficiency (EC).

PROBLEM STATEMENT

Reverse-biased abrupt Si *p–n* junctions with uniform doping of impurity atoms $N(x) = N_a(x) + N_d(x)$ and constant reverse bias voltage U_0 exceeding the static voltage of avalanche breakdown U_{av} (N_a is the acceptor concentration and N_d is the donor concentration) are the subject of numerical investigations.

The dynamic range determination of the output power of 8-mm Si AOD, while varying the reverse bias voltage from the minimum value causing the impact ionization of atoms to the voltage of impact ionization suppression is the subject of investigations [11].

The AOD simulation is based on the volt-ampere characteristic (VAC) that takes into account the compensation effect of the charge of mobile carriers. At high constant reverse bias voltage, this effect leads

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