Vertical Diodes Response to Optical and Electrical THz Excitations

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Abstract

We use a hydrodynamic model self-consistently coupled to a 1D Poisson solver, to simulate the excitation by optical beating as well as by electrical perturbation of plasma waves in n^+nn^+ InGaAs diodes at room temperature. We calculate the electric field response and the velocity response of the carriers in the middle of the diode regions. Our results show clearly the presence of three-dimensional plasma resonances in the terahertz frequency domain for the two region types (n and n^+). The investigation is completed by introducing stochastic perturbations according to the Langevin equation.

Introduction

Two-dimensional plasma waves in transistors are considered a very promising physical phenomenon for the detection and generation of terahertz radiation[1]. Additionally, the possibility to use three-dimensional (3D) plasma waves in a terahertz radiations detector based on bulk GaAs has been proposed [2],. However this possibility has received much less attention in the literature. In this context, we have performed a systematic study of n^+nn^+ InGaAs diodes to investigate the plasma collective oscillation phenomenon taking place in the mentioned device.

Model

We use a numerical approach based on three hydrodynamic equations related to carrier concentration, velocity and energy conservation, coupled to a one-dimensional Poisson solver. The optical excitation is included in the equations through the term[3]

$$G(t) = G_0[1 + cos(2\pi ft)] \tag{1}$$

where f is the frequency of the beating and G_0 describes the photogeneration efficiency. The electrical excitation is taken into account by controlling the applied voltage in the Poisson equation.

Results and Discussions

The I-U characteristics is presented in fig. 1. It is evident that the response of the internal electric field (as well as the carrier velocity) must be related to the choice of the generation rate G_0 (see fig. 2), since these quantities depend directly on the power of the incident beam. In fig. 3, We observe an excellent agreement between the calculated resonance frequencies and the corresponding analytical 3D plasma frequencies expression[1]

$$f^{3D} = \frac{1}{2\pi}\sqrt{\frac{e^2 n}{m_{eff}\epsilon}} \tag{2}$$

We remark that the diode exhibits similar behavior when submitted to stochastic perturbations.

Conclusion

The I-U characteristics of the diode validates the proposed model, while the frequency results show clearly that the resonances associated with 3D plasma waves in InGaAs diodes lie in the THz domain, thus opening new possibilities to exploit diodes as solid-state terahertz devices operating at room temperature.

References

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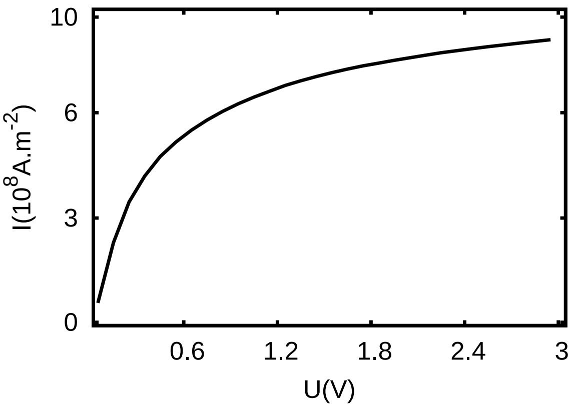

Fig. 1. The I-U characteristic curve for n^+nn^+ InGaAs diode of active region 500 nm length.

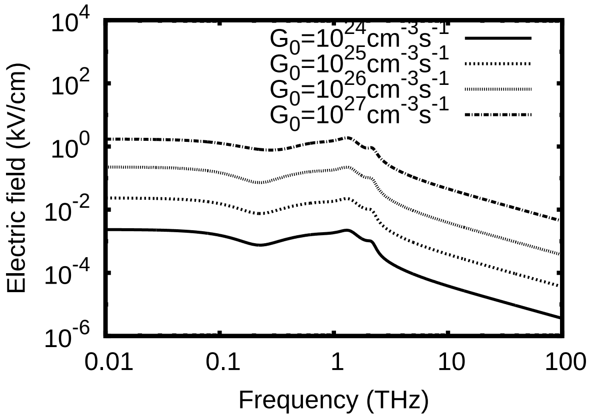

Fig. 2. Oscillation amplitudes of the electric field as a function of optical photoexcitation frequency for different G_0 amplitudes in the center of the diode

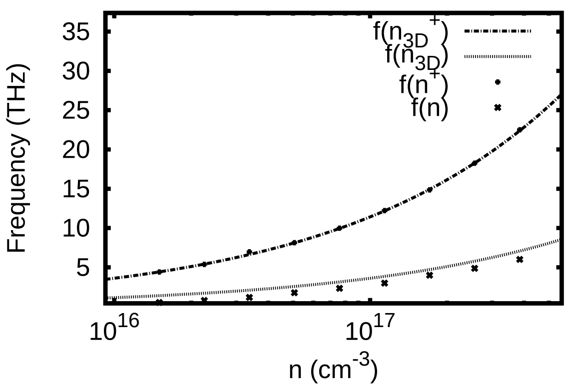

Fig. 3. Resonance frequencies due to the response of the optical beating impulse taken at the center of n and n+ regions, depending on the concentration n for a constant ratio n+/n equal to 10. The symbols refer to our hydrodynamic calculations and the dashed lines to the analytical formula(2).