Simulation of plasma oscillation response to THz radiation applied upon high electron mobility transistors

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***Abstract*—By means of a numerical hydrodynamic (HD) model coupled with Poisson pseudo-2D equation , we simulate the drain current response of a high electron mobility transistor (HEMT) to a THz signal applied to its gate and/or to its drain contacts in order to obtain the optimal configuration in terms of detection.**

I. Introduction

Study of plasma oscillation in two dimensional electronic gas (2D) channel was initiated by Dyakonov and Shur [1], [2]. they showed that the nonlinear properties of the 2D plasma in the FET channel can be used for detection of the THz emission. The resonant detection of THz radiation by two-dimensional plasma waves was demonstrated using InAlAs/InGaAs High electron mobility transistor (HEMT) [4], and at room temperatures [3]. In this paper, by simulating the High Electron Mobility Transistor (HEMT) drain current response, we study the plasma wave oscillation and optimise the HEMT performances as THz detector.

II. Analytical model and discussion

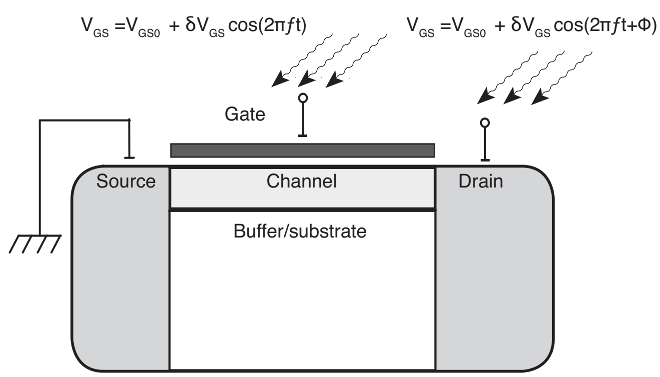

Fig. 1. *HEMT under THz electric signal detected by the gate and/or drain.*

The AC and DC drain current responses are simulated by the HD approach [5] coupled to a pseudo-2D Poisson equation [6].

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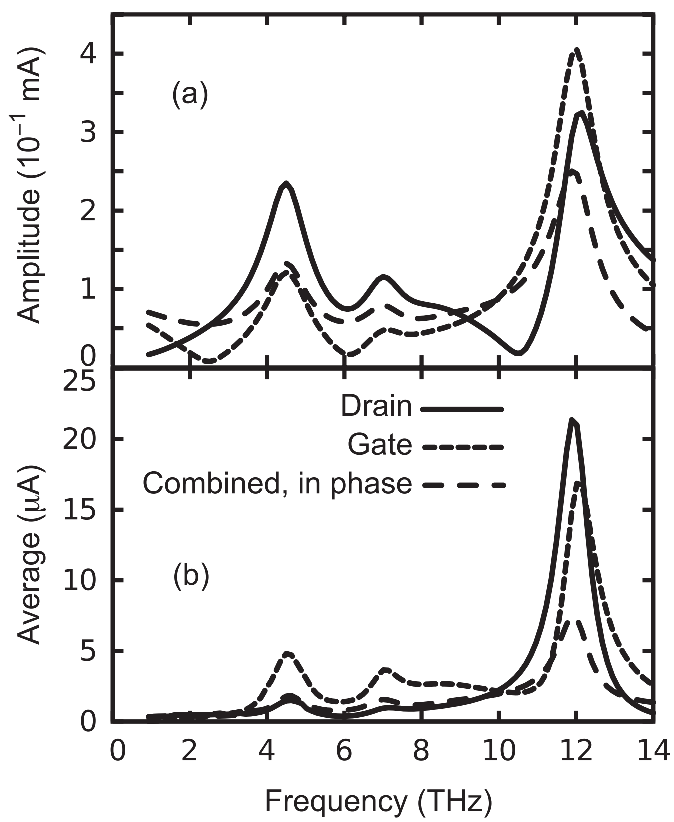

Fig. 2. Harmonic (a) and average (b) drain current response as functions of the radiation frequency for an excitation applied only to the drain (continuous line), only to the gate (dashed line) and combined in phase (dotted line).

Two kinds of THz excitations are considered (see figure1): (i) an excitation collected through the gate contact and described by the harmonic component of the gate potential, $\Delta V_{GS}(t) = \delta V_{GS}\cos(2\pi ft)$ (with f the frequency of the incoming THz radiation) ; (ii) an excitation collected through the drain contact and described by a component of the drain potential equal to $\Delta V_{DS}(t) = \delta V_{DS}\cos(2\pi ft + \varphi)$. We simulate an InGaAs HEMT identical to that reported in Ref. [7], [8].

Fig. 2 shows both average (DC) and amplitude (AC) current responses as functions of the THz excitation frequency, for a signal applied to the drain, to the gate and combined (THz signal applied on the drain and gate). Each spectrum exhibits three resonance peaks which can be identified as plasma resonances corresponding to two first modes of 2D plasma resonances (at 4.7 THz and 7.1 THz) and the 3D plasma resonance (at 12 THz).

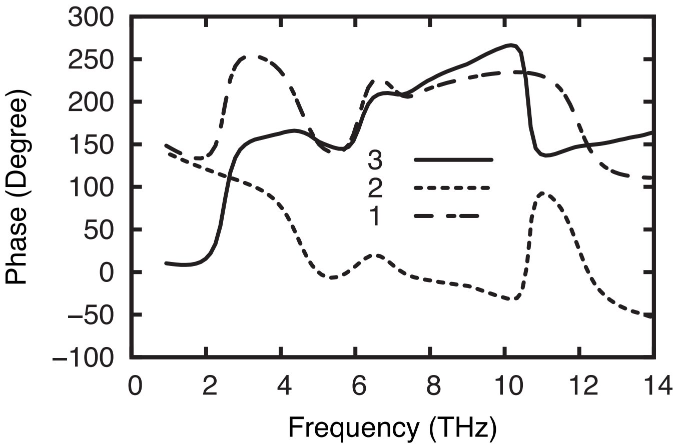

Fig. 3. Phase angle between the harmonic drain current and the excitation as a function of the radiation frequency for (1) an excitation to the drain, (2) an excitation to the gate. (3) represents the difference between these two quantities.

We remark that the domain of 2D plasma resonances (that is from 3 THz to 10 THz) of the current response (Fig. 2) is more sensitive to the gate excitation mode while the region of the 3D resonance peak is more sensitive to the drain excitation mode.

The phase angle between the harmonic current and each voltage excitation is reported in Fig. 3: it is evident that the current responses corresponding to the combined excitation are almost in phase opposition. Fig. 4 presents the average and harmonic current responses for the combined excitation mode as functions of the excitation frequency with different phase angles between the excitation signal upon the gate and drain. The spectra corresponding to a phase angle equal to $3\pi/4$ give a better result with respect to the pure drain excitation mode and gate excitation mode shown in Fig. 2.

III. Conclusion

We have shown that the domain of 2D plasma resonance is more excited by the gate excitation mode and the 3D plasma resonance is better excited by the drain excitation mode. We demonstrate that the THz detection performances can be significantly improved when the drain and the gate excitations are nearly in opposite phase.

Acknowledgment

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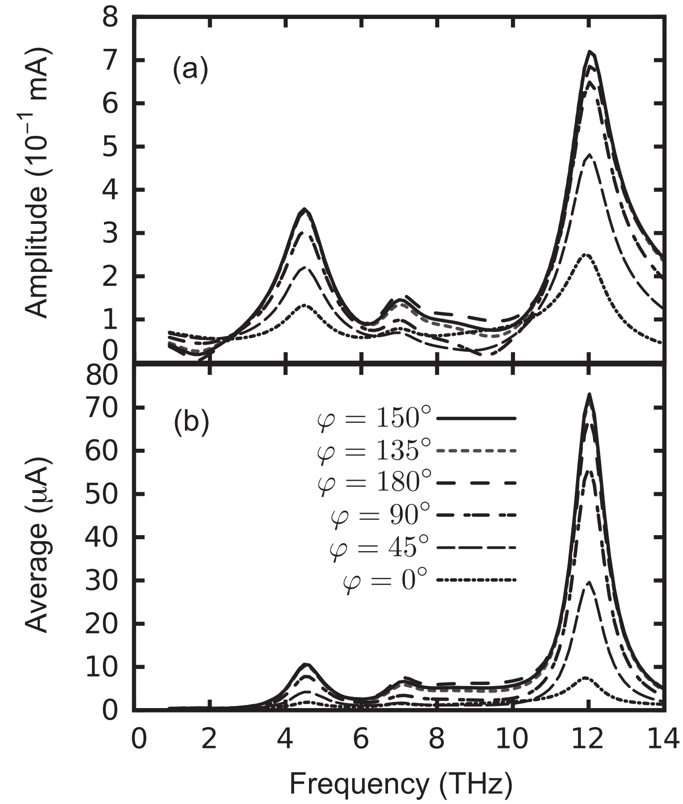

Fig. 4. Harmonic (a) and average (b) drain current responses as functions of the excitation frequency for different values of the phase-shift φ between drain and gate excitations.

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