Terahertz Detectors and Emitters Based on Plasma Wave Oscillations in Nanometer Gate Length Transistors

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Abstract: The channel of High Electron Mobility Transistor can act as a resonator for the plasma waves propagating in 2D electron gas. The plasma frequency increases with reduction of the channel length and can reach the Terahertz range for nanometre size transistors. This work presents an overview of the experimental results on THz detection and emission by nanometre size transistors and multi-grating structures with nanometre size gates.

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1. Introduction

The channel of High Electron Mobility Transistor can act as a resonator for the plasma waves propagating in 2D electron gas. The plasma frequency increases with reduction of the channel length and can reach the Terahertz range for nanometre size transistors. As it was predicted by Dyakonov and Shur[1], when a current flows through a field effect transistor, the steady state can become unstable against generation of plasma waves leading to the emission of an electromagnetic radiation at the plasma wave frequencies. It was also predicted [2] that nonlinear properties of the 2D plasma in the transistor channel can be used for resonant and voltage tuneable detection of THz radiation.

2. Results

We present an overview of results on THz emission and detection obtained in different types of InGaAs/GaAs , InGaAs/InP and GaN/AlGaN nanometre high electron mobility transistors [3-10]. We show that in agreement with the theoretical predictions i) the emission frequencies correspond to the estimated characteristic plasma wave frequencies and ii) the emission appears once the drain current exceeds a certain well defined threshold value[3-5]. We present also the results on the plasma wave related THz detection [6-10] and show that processing of the gate lengths below 100nm in InGaAs/InP systems allows for a resonant voltage tuneable detection at frequencies up to 3THz .

Most of the results have been obtained at cryogenic temperatures, however very recently it was shown that by increasing the drain current in 200nm GaAs/AlGaAs and InGaAs/InP transistors one can obtain room temperature resonant detection in sub- THz range [7,9]. Also first room temperature THz emission from 150nm gate length GaN/AlGaN transistors [5] was observed.
Si metal oxide semiconductor field effect transistors _MOSFETs_ with the gate lengths of 120–300 nm have been studied as room temperature plasma wave detectors of 0.7 THz electromagnetic radiation. The obtained values of responsivity and noise equivalent power demonstrated the potential of Si MOSFETs as sensitive detectors of terahertz radiation [10].

The emission experiments reported in this work were motivated by the prediction of a current-induced instability in a gated 2D electron gas resulting in plasma wave generation in the THz range[1]. The experimental results indeed demonstrate THz emission appearing when the drain current exceeds a certain threshold value with the emission frequencies which are in a reasonable agreement with the estimates for fundamental plasma modes. However, other features predicted in Ref. 1 (such as the efficient

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tunability of the emitted radiation frequency by the gate bias) are not observed. This and other still unexplained features of THz emission and detection by nanometre size field effect transistors are discussed.

We also report on THz emission from multi-grating structures [10-14]. These structures have a specific geometry and can be considered as many inter-connected field effect transistors. They are very interesting from the point of view of potential applications as they allow increasing the dimension of active emitting/detecting region from nanometer size –for single transistor- up to sizes comparable with THz radiation wavelengths. These structures have shown for example an efficient room temperature THz emission [15].

2. References

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