Nanotransistors — for Terahertz detection and emission

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A field effect transistor (FET) can act as a resonator for plasma waves propagating in the channel. The plasma frequency of this resonator depends on its dimensions and for gate lengths of a nanometer size can reach the Terahertz (THz) range. The interest in the applications of FETs for THz spectroscopy started at the beginning of 90s with the pioneering theoretical work of Dyakonov and Shur [1] who predicted that a steady current flow in a FET channel can become unstable against generation of the plasma waves. These waves can, in turn, lead to the emission of the electromagnetic radiation at the plasma wave frequency. This work was followed by another one where the same authors have shown that the nonlinear properties of the 2D plasma in the transistor channel can be used for detection of THz radiation [2]. THz emission in the nW power range from submicron GaAs and GaN FETs has been observed both at cryogenic as well as at room temperatures [3-5]. At the moment, however, FET based THz microsources can not compete with existing Quantum Cascade Lasers (QCL) or Time Domain Spectroscopy (TDS) sources. It appeared, nevertheless, that THz detection by FETs can be very promising and close to practical applications. Recently, non-resonant plasma properties were successfully used for the room temperature broadband THz detection and imaging.

The possibility of the detection is due to nonlinear properties of the transistor, which lead to the rectification of the ac current induced by the incoming radiation. As a result, a photoresponse appears in the form of a dc voltage between source and drain which is proportional to the radiation intensity (photovoltaic effect). The more information on the state of the art of the FETs as the emitters and detectors can be found in review papers [6, 7]. Here we present an overview of the main results stressing the most recent concerning THz detection by FETs. We show that FETs are sensisitive and fast enough to be used to construct focal plane arrays of new type of THz cameras. We describe possibility of imaging up to 1.6 THz with room temperature FETs [8] and influence of magnetic field on THz detection by FETs [10].

We present also recent results on THz emission obtained in different types of GaN/AlGaN nanometric high electron mobility transistors. We show that depending on the transistor geometry different THz emission mechanisms play role. In most of the investigated HEMTs 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 — instability threshold. First results have been obtained at cryogenic temperatures, however recently it was shown that from the field plate geometry 150nm and 250nm gate length GaN/AlGaN HEMTs one can obtain an efficient room temperature THz emission [10]. The results presented in this lecture were obtained in collaboration with F. Teppe, D. Coquillat, and N. Dyakonova.

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