Room Temperature Terahertz Imaging by a GaAs-HEMT Transistor Associated with a THz Time Domain Spectrometer

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***Abstract*—We demonstrated a room-temperature detection of terahertz radiation with a plasma wave nanometric transistor. The detection is resonant and can be efficient for terahertz time-resolved imaging.**

I. Introduction And Background

SINCE the first demonstrations of all-optoelectronic terahertz imaging in 1995 with a pulsed time-domain setup [1], various all-optoelectronic systems have been developed, either based on pulsed [2], continuous-wave cw [3], or quasi-cw [4] near-infrared laser sources. Because none of these approaches achieved real -time imaging capabilities, a number of researchers have recently begun to focus on the development of faster cw imaging systems, which are based on purely passive detection [5]. In this work we present the approach which combines a pulsed time-domain setup with the resonant detection by plasma waves. The presented system could preserve the pulsed spectroscopic imaging information, enables the acquisition of a wide range of information including the absorption spectral characteristics, the depth and the nature of the objects.

Nonlinearities related to plasma wave excitations in two dimensional electron gas in a nanometer-size high electron mobility transistor HEMT were first studied by Dyakonov and Shur [6] as a way to realize selective resonant and voltage tunable THz detectors. Recently, the tunable resonant detection of THz radiation by two-dimensional plasma waves was demonstrated using HEMTs at cryogenic [7,8] and room temperatures [9]. In addition, room temperature plasma wave THz emission was reported from InGaAs/GaAs and GaN/AlGaN HEMT [10,11].

II. Results

Using a room temperature GaAs HEMT plasma wave detector we detected pulsed terahertz radiation from time domain THz source. Applications of a constant drain bias, allowed us driving the transistor closer to the plasma wave instability region, and increase the device sensitivity by more than two orders of magnitude.

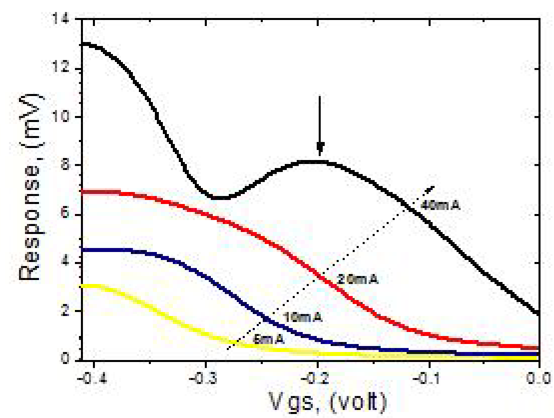

Fig.1: Drain response to the femtosecond pulsed terahertz radiation as a function of gate voltage for different values of current from 5 to 40 mA. arrow: position of resonance maxima as a function of gate voltage (After [13])

The response to the THz radiation is shown in figure 1 as a function of gate voltage for different values of the drain source current (from 5 to 40 mA). One can see that the detection is strongly increased by increasing the drain current and driving the transistor into the current saturation region. Below 20 mA only nonresonant detection is observed as a broadband peak around -0.41 V. With the increase of drain current, above 40 mA, the additional peak appears as a shoulder on the independent background of the nonresonant detection around -0.2 V. We attribute this behavior to the resonant detection of THz radiation by plasma waves.

The idea of using THz radiation for imaging and sensing has been already reported by many authors. Here, we extend this approach by associating a surface field emission source gated with a Ti:Sapphire femtosecond oscillator laser and a tuneable HEMT detector. An example of direct application of the system in terahertz imaging field is presented in figure 2. We used a fast terahertz pulse imaging system based on femtosecond Ti:Sa laser oscillator. The system is relatively compact and simple since it does not require a pump probe time delay stage. Consequently, the usual complexity of the optics involved can be greatly reduced.

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Fig.2: Raster-scan imaging in transmission mode of a metallic paper clip: (Top) without envelope, (Bottom) in envelope. Terahertz image with a numerical aperture of 0.5; 0.3mm pixel size, 20mmx10mm,Vgs=-0.2V, Ids=40mA. (After [13])

The image in the figure 2, revealing the envelope contents, were taken for V_{gs} = -0.2 V and $I_{d\ s}$= 40 mA. The estimated corresponding plasma frequency is around 0.5 THz. We can easily distinguish the metal part of the object under investigation even if it inserted in a paper envelope.

III. CONCLUSION

The results clearly illustrate that plasma wave nanometer transistors can be efficient future detectors for terahertz imaging applications based on a femtosecond pulsed terahertz source once integrated in detector arrays. Future work has to show which type of the FET system is most suitable for sensitive resonant terahertz source detection.

Acknowledgement: This work is supported by the "Conseil Régional d'Aquitaine, in collaboration with the Labri UMR 5800, and Innovative Imaging Solutions corporation: www.i2s-corp.com I2S. This work is also partially supported by JSPS International Fellowship Program for Research in Japan. The authors from Montpellier University acknowledge the CNRS and GDR-E project *Semiconductor sources and detectors of THz frequencies* and Region of Languedoc-Roussillon through the "Terahertz Platform" project.

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