Room temperature generation of terahertz radiation from dual grating gate HEMT's

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Abstract— we report on room temperature generation of the terahertz radiation from dual grating gate high electron mobility transistor. The emission spectra were measured using Fast Fourier Spectroscopy. Both coherent and incoherent excitation of the plasmons can give rise to the broadband emission in the present device.

***Index Terms*— Emission of terahertz radiations, HEMT, grating gates device, plasma waves.**

I. INTRODUCTION

THE plasma wave mechanism in two dimensional system has been investigated because of its potential to propose new room temperature solid state sources of terahertz radiation [1-5]. The resonant frequency can reach terahertz range for nanometer size systems and can be tuned by the electron density (i.e. the gate bias) [3]. The excitation of the plasma waves can be either coherent or incoherent. For the latter one, the mechanism is related to the thermal excitation of the plasmons by mean of injection of hot electrons in the channel. Both theoretical and experimental investigations have been done on terahertz emission from 2D plasmons in grating structures of Si FET's [1] and in $Al_{0.3}Ga_{0.7}As/GaAs$ heterostructures [2]. All reported up to now results were obtained at cryogenic temperatures. On the other hand, the coherent excitation is related to Dyakonov-Shur instability or Ryzhii-Sato-Shur relaxation time effect [3,6]. Experimental investigations by using different architectures (GaInAs based HEMT, GaAs FET, GaN based HEMT) have shown the possibility to emit terahertz radiation even at room temperature [7,8].

In the present work, we report on the first observation of room temperature emission from grating-gate GaAs-based high electron mobility transistor (HEMT) devices. A broadband spectrum with maximum intensity around 2.4THz was observed. The experiment was performed using standard infrared spectroscopy (FTIR) system coupled with a Silicon bolometer.

II. DEVICE STRUCTURE

The structure is based on a HEMT incorporating doubly interdigitated grating gates that can periodically confine the 2D electrons to form a 2D-plasmon grating and can extensively convert the non-radiative longitudinal plasma waves to radiative transverse electromagnetic waves. The devices are fabricated using InGaP/InGaAs/GaAs material systems as shown on figure 1-(a). The 2D plasmon layer is formed with a quantum well in the InGaAs channel layer. The grating gate was formed with 65-nm thick Ti/Au/Ti by a standard lift-off process. The lengths of the gates G1/G2 are 100/300 nm respectively. The numbers of fingers for G1/G2 are 60/61 respectively and the length of the ungated regions is 100 nm. The total length/width of the active region is 30/75µm. Top view of the device with parametrical geometry is shown in Fig.1-(b). More details about the samples can be found in [9].

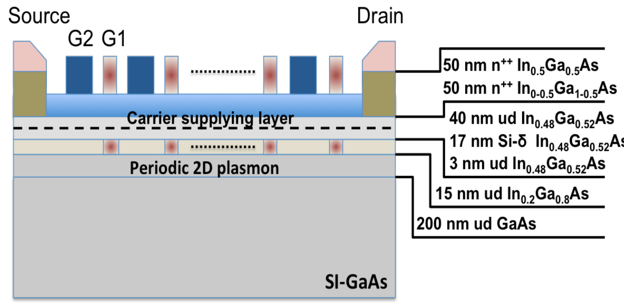

Fig.1-(a): Cross section of the HEMT device with the layers structures.

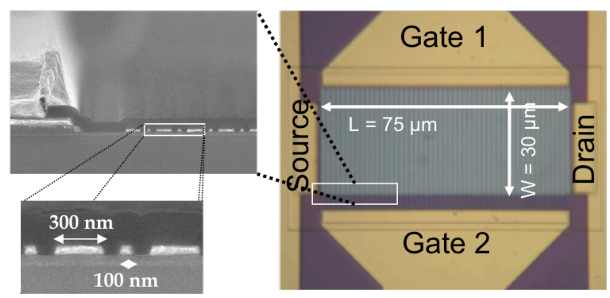

Fig.1-(b): Top view and SEM image of the device with geometrical parameters

III. EMISSION OF THZ RADIATIONS

The monochromatic source of the FTIR was replaced by a new under vacuum chamber that contain the device. The detection of the radiation was performed using highly sensitive Silicon bolometer. All Experiments were performed

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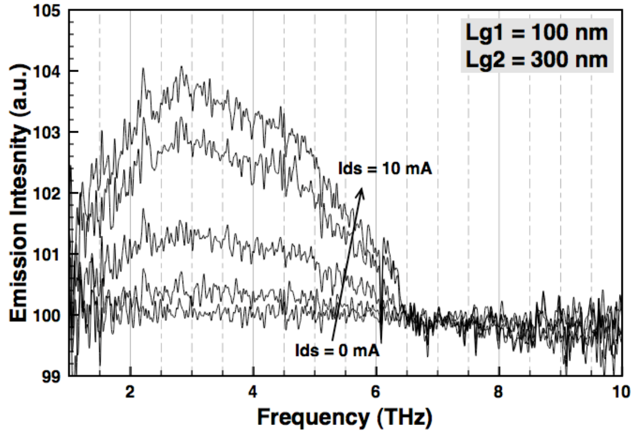

Fig.2: Spectral emission from the sample as a function of the frequency at different values of the drain-to-source voltage.

at room temperature. The signal was obtained as following: first we measure the reference signal (Black body radiation, beamspliter, transistor turned off,…). Then the transistor is switched on and we measure again the signal. The relative intensity is obtained as a ratio of these two signals. Figure 2 shows the obtained spectra from the sample, demonstrating the broadband emission ranging from 0.5 to 6.5 THz. The abrupt cutoff at 6.5 THz is due to the Reststrahlen band of optical phonon modes of the GaAs-based materials [8]. The simulations based on a first principles electromagnetic approach shows that the main part of the emission can be interpreted as due to the thermally excited incoherent plasmons resulting in broadband signal. It shows the overall shape of the experimental observation [8].

However, it can be also understood as superposition of emissions due to coherent plasma excitations under the cavities along the channel. Due to the slope along the channel (caused by drain-to-source bias) the effective applied gate bias inside the cavities is not equal. The electron density is then not uniform from the source to the channel resulting in different resonant frequency inside each cavity. The superposition of those spectrums can result in broadband emission. Near-field emission spectra at each section of the grating finger were simulated using a dedicated finite-differential time-domain simulator, in which the 2D plasmon dispersive/instability effects are modeled. Since the 2DEG densities in the plasmon cavities are dispersed from the source to drain due to applied *V*ds the peak emission frequency corresponding to the plasmon resonant frequency shifts from the source to drain. Such spatial distributions on the near-field spectra are superposed at the far field, resulting in a spectral broadening (see Fig. 3). The estimated power of the emission is within 0.1 μW from a single device. More investigations are undergoing to explain the exact origin of the emission.

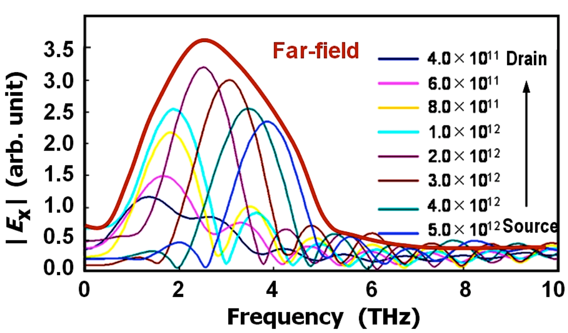

Fig.3: FDTD simulation for near-field and far-field emission spectra from a dual-grating gate HEMT.

As far as we know, this is the first clear observation of room temperature terahertz emission from solid-state devices. This can open the way for new electronic devices within terahertz range.

IV. Conclusion

In conclusion we experimentally observed the generation of the terahertz radiation at room temperature from our original double grating gate HEMT. Two mechanisms are considered to explain the results: i) incoherent hot plasmons excitation and ii) coherent plasma waves instability related THz emission.

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