Terahertz Plasma-Wave Excitation in 80-nm Gate-Length GaAs MESFET by Photomixing Long-Wavelength CW Laser Sources

Taiichi Otsuji, Yoshihiro Kanamaru, Hajime Kitamura, and Shin Nakae

Department of Control Science and Engineering, Kyushu Institute of Technology, Iizuka, Fukuoka, 820-8502, Japan
Phone: +81-948-29-7722, Fax: +81-948-29-7709, E-mail: otsuji@ces.kyutech.ac.jp

Emerging information technologies necessitate further extension of operating frequency bands in electronic systems to beyond terahertz (THz). Conventional semiconductor device technologies, which rely upon real-carrier transport, however, face to the substantial limit of operation in the THz region. New operating principles should be appreciated to establish novel THz device technology for the real applications.

Two-dimensional electron plasma in the electron channel of submicron FET's can make resonant oscillation in the THz range. Dyakonov and Shur formulated the 2-dimensional plasma dynamics as a function of device parameters and applied gate bias voltages V_{gs} (offset from the threshold) [1]. The THz radiation can be coherently absorbed via inter-subband transitions of conduction electrons if the electrons are transversely well confined in the channel. The resonant intensity increases with the plasma coherency, or equivalently with $v_p\tau/L$, where v_p the plasma-wave velocity, τ the plasma relaxation time, L the gate length. The resonance frequency is given by the standing-wave condition, proportional to v_p/L. The resonance frequency can be externally controlled by V_{gs}, since v_p is a function of V_{gs}, which offers the tunability of oscillation. The THz plasma resonant phenomena, however, has only been measured by illuminating a AlGaAs/GaAs HEMT with a single 2.5-THz gas laser source [2], and there has been no experimental reports on the resonance frequency dependence on V_{gs}. This paper demonstrates the first experiment on it.

Experimental setup is shown in Fig. 1. A pair of wavelength-tunable CW laser sources having a 100-nm band around 1550 nm was prepared for. The terahertz excitation was performed by photomixing the two sources in a manner of difference-frequency generation. The plasma resonance effects modulate the DC drain-source potential, which is originated from even-mode harmonic resonance components. Thus, the modulated DC drain-source components (O[100 μV]) were precisely measured by using a lock-in amplifier. An 80-nm gate-length GaAs MESFET [3] was selected as a sample. The gate width is 100 μm (12.5 μm x 8 sections). The photomixed laser beam was lineally polarized along the channel axis and illuminated onto one section of the channel as shown in Fig. 2. The difference frequencies were set at 0.96, 1.55, and 2.55 THz.

In general, the semi-insulating GaAs material is transparent to the photon in the 1550-nm range. However, because of the deep trap centers produced by Cr and O doping for defect compensation, significant photocurrent was generated under both single-laser and photomixed-laser illuminations (see Fig. 3). In order to discriminate the effect of the plasma resonance from the background, the measured DC drain-source voltages (initially biased at +0.2 V) under single-laser illumination were subtracted from those under photomixed-laser illumination, which is hereafter denoted as DC drain-source modulation component ΔV_{ds}. V_{gs} dependence of ΔV_{ds} was measured under each difference-frequency condition. Figs. 4 (a) and (b) plots the measured and simulated results. The vertical axis $\Delta V_{ds} \cdot V_{gs}$ corresponds to the plasma resonance intensity. The results clearly indicate the occurrence of plasma resonance at the peak points of $\Delta V_{ds} \cdot V_{gs}$. In the simulation, the plasma-wave velocity v_p was accurately calculated taking the V_{gs} dependence of the density of electrons in the MESFET channel into account. Compared the measured results to the simulated ones, as shown in Fig. 5, the V_{gs} dependence of the resonance frequency well coincides with the simulated results. In summary, although the measurement is an indirect observation, it was verified for the first time that the plasma resonance frequency is controlled externally by V_{gs} in a wide terahertz range.

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References

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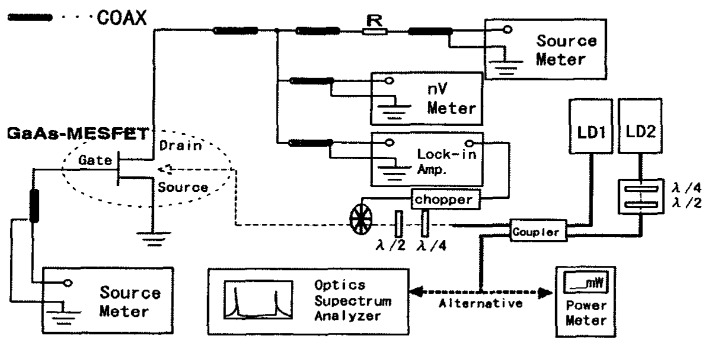
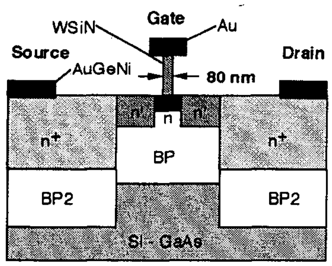
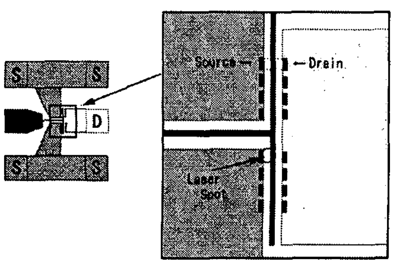


Fig. 1 Experimental setup.



(a) Cross sectional view.



(b) Pad layout and illumination point.

Fig. 2 80-nm gate-length GaAs MESFET.

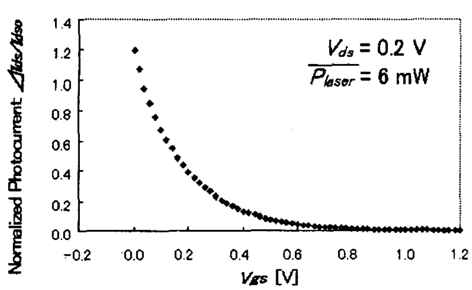


Fig. 3 Measured photocerrent ΔI_{ds} vs. V_{gs}. The vertical axis is normalized by original drain current I_{dso}.

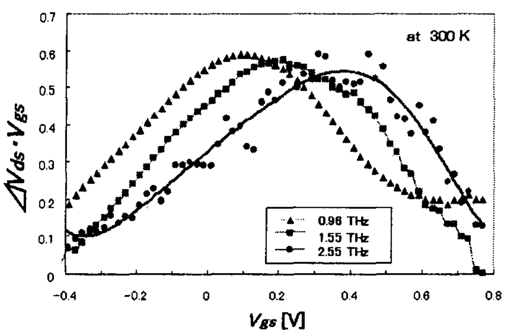


Fig. 4(a) Measured resonance intensity vs. V_{gs}.

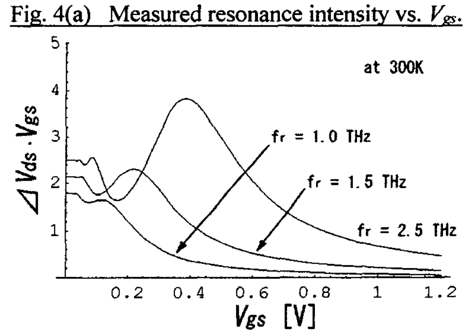


Fig. 4(b) Simulated resonance intensity vs. V_{gs}.

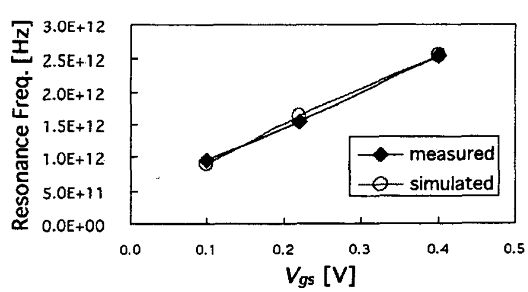


Fig. 5 Resonance frequency vs. V_{gs}.