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OPTICALLY CONTROLLED GaAs DUAL-GATE MESFET AND PERMEABLE BASE TRANSISTORS

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SUMMARY

Direct optical control of microwave/millimeter wave devices can provide faster switching, gain and phase adjustability in amplifiers, and frequency tuning or locking in oscillators (ref. 1). Furthermore, it can reduce the complexity of fiber optic signal distribution networks for Gallium-Arsenide (GaAs) Monolithic Microwave Integrated Circuit (MMIC) based phased-array antennas for future space communication system.

Several authors have investigated the photovoltaic and photoconductive effect of light on the dc characteristics and the equivalent circuit parameters of GaAs single-gate Metal Semiconductor Field Effect Transistors (MESFETs) (refs. 1 and 2). However, the single-gate MESFET has several limitations.

This paper presents computed results on light induced voltage, V_{lit}, and its effect on the dc characteristics of both the GaAs dual-gate MESFET and the GaAs Permeable Base Transistor (PBT). The dual-gate MESFET when compared with the single gate MESFET has found a wide variety of applications. This is so because of the presence of two independent control gates together with excellent isolation characteristics. The PBT on the other hand has a much higher figure of merit, that is, the maximum frequency of oscillation. Typically, the figure of merit of a PBT is 150 GHz as compared to 60 GHz for GaAs MESFET. Hence, PBTs can operate at a much higher speed than MESFETs.

Figure 1 is a schematic diagram illustrating the coupling of light from a laser to the active region, of a dual-gate MESFET and of a PBT, through an integrated optical waveguide and an optical fiber respectively. Light is responsible for the generation of excess electron-hole pairs in the active region; which in turn increases the minority carrier concentration, that is, holes in a n-type channel. An expression for the light induced voltage V_{lit} as a function of the minority carrier concentration and other physical properties of GaAs is given in reference 3.

An expression relating drain current, I_{ds}, to the applied gate terminal voltages, V_{gs1} and V_{g2}, and the drain to source voltage, V_{ds}, for a depletion-mode (normally-ON) dual-gate MESFET is given in reference 4. Illuminating either of the two gates of a dual-gate MESFET is equivalent to forward biasing that gate by a voltage source equal to V_{lit}. The net voltage at that gate is therefore a superposition of the gate terminal voltage and V_{lit}. An expression relating drain current density J to the applied gate bias V_{gs}, and V_{ds} for a permeable-base transistor is given in reference 5. The net voltage at the gate is a superposition of V_{gs} and V_{lit}.

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The dual-gate MESFET active layer thickness, the PBT active layer thickness and their respective doping densities are indicated in figure 1. The intrinsic carrier concentration and the minority carrier life time are 1.79×10^6 cm^3 and 10^{-8} sec respectively. The wavelength of the incident light and the optical absorption coefficient in GaAs are normally 0.87 μm and 10^4 cm^{-1} respectively.

Using these equations light induced voltages are computed for the dual-gate MESFET and the PBT as a function of the incident optical power density. This is shown in the inset in figure 2. The light induced voltage is observed to increase linearly with the incident optical power density. Besides, the two devices are almost equally sensitive to light.

The computed I_{ds} of the dual-gate MESFET as a function of V_{ds}, with gate 2 optically illuminated, is shown in figure 2. Further, I_{ds} increases by 16 mA with gate 1 optically illuminated (1 μW/cm^2) and $V_{gs1} = -1.5$ V and $V_{g2} = 0V$. The computed drain current density J as a function of V_{ds} for a PBT when the gate grating is illuminated is shown in figure 3. The dual gate MESFET provides additional control due to the presence of two independent control gates while the PBT can handle a much higher current density.

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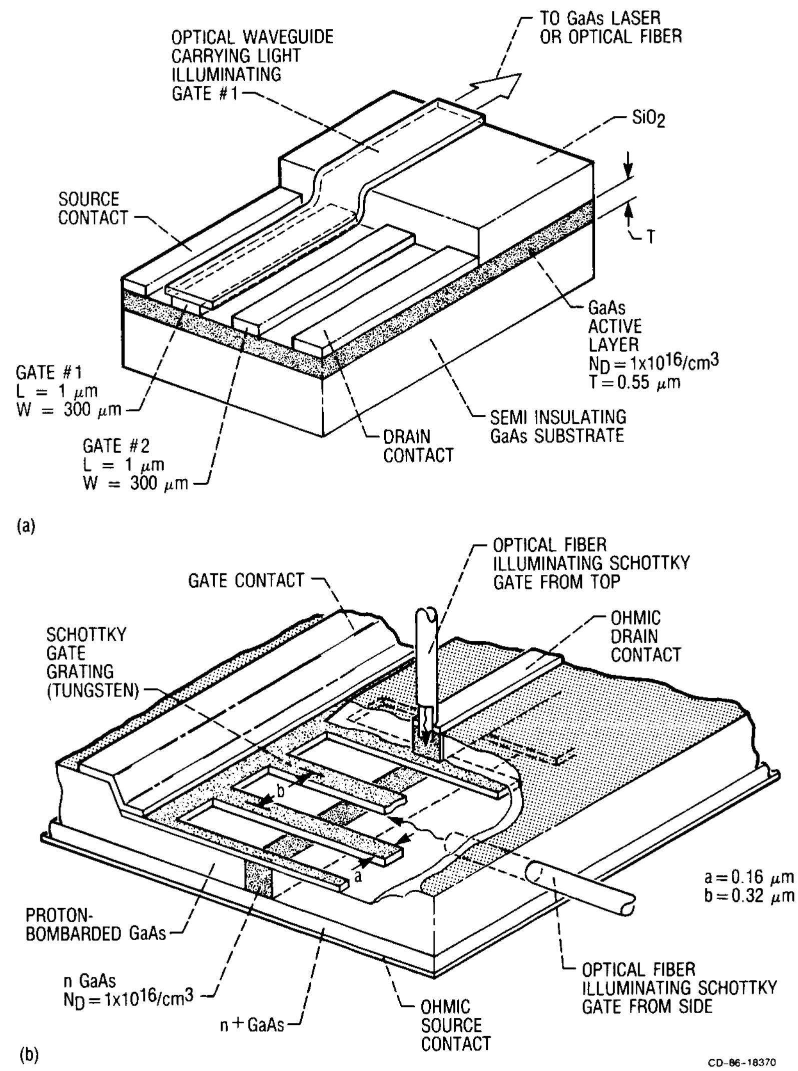

Figure 1. - Schematic diagram illustrating (a) an optical waveguide illuminating a dual-gate MESFET. (b) an optical fiber illuminating a permeable base transistor at two possible locations.

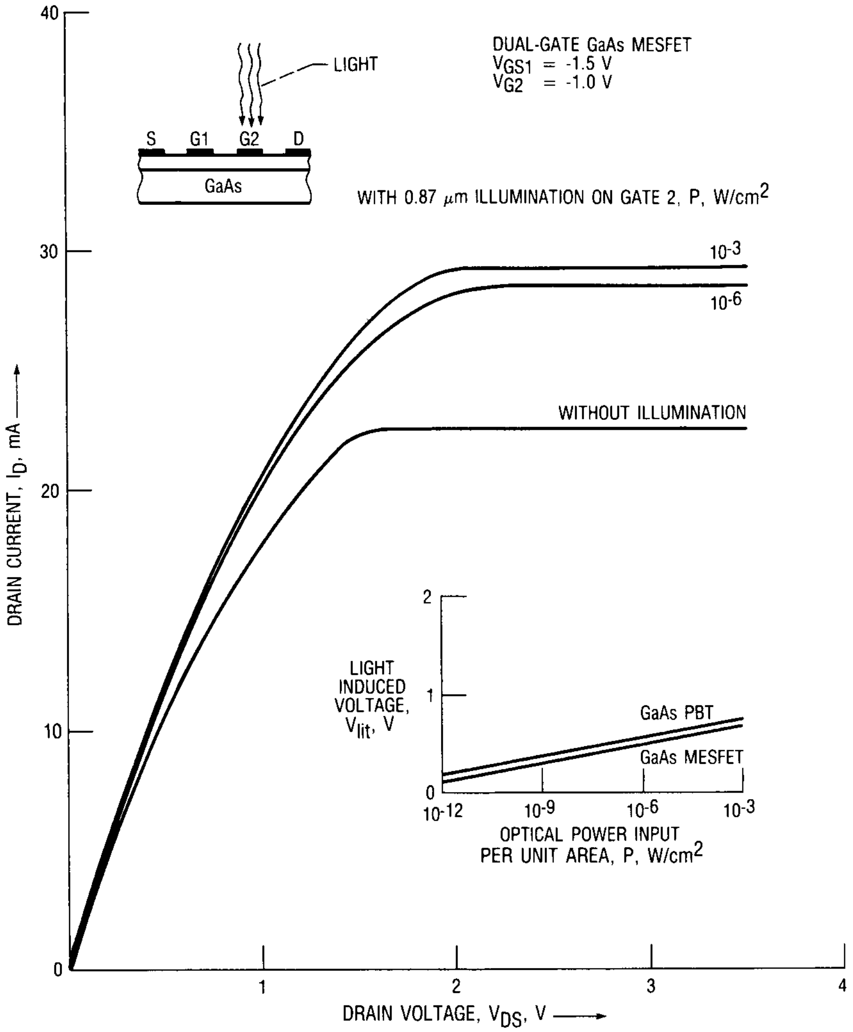

Figure 2. - Drain current versus drain to source voltage with gate 2 illuminated for a dual-gate MESFET. Also shown in inset is the light induced voltage as a function of the incident optical power.

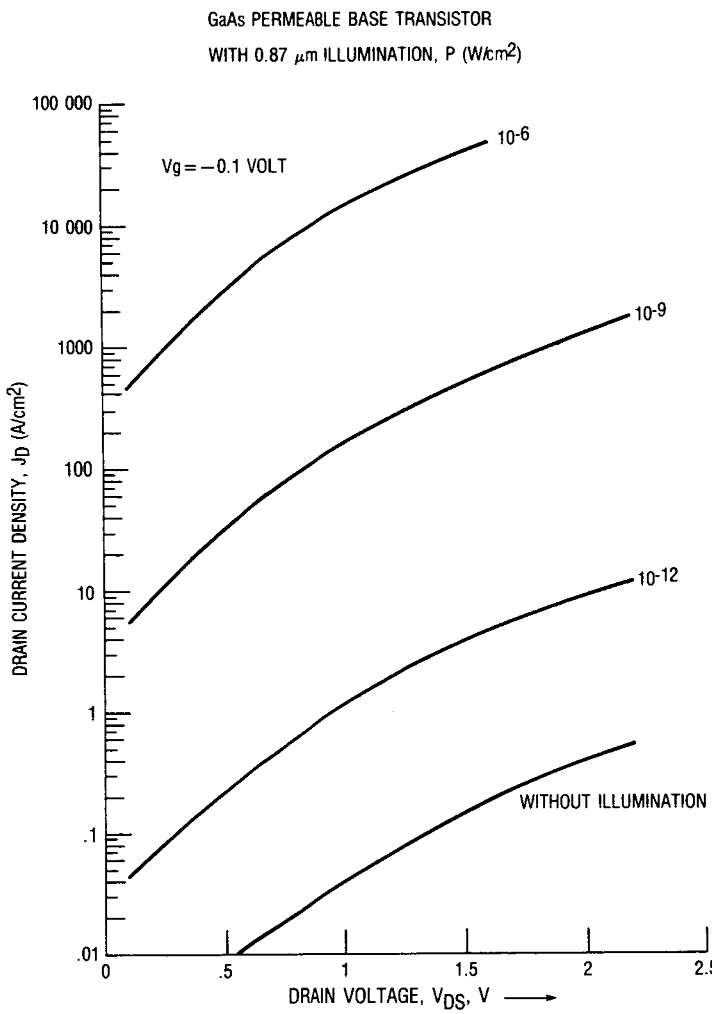

Figure 3. - Drain current density versus drain to source voltage with gate illumination for a permeable base transistor.

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15. Supplementary Notes

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16. Abstract

Optically induced voltage and dc characteristics of the GaAs Dual-gate MESFET and the Permeable Base Transistor (PBT) with optical illumination at wavelength below 0.87 μm were obtained and compared with GaAs MESFET. It was observed that PBT can handle higher current density when illuminated.

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