Tunable InGaAs/InAlAs/InP Far-IR Detector Based On Plasmon Resonance

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***Abstract*—An InGaAs/InP based HEMT with grating gate is investigated as a THz detector. Resonant THz absorption by two-dimensional plasmons is tunable with a gate bias.**

I. INTRODUCTION AND BACKGROUND

PLASMON resonances in the two dimensional electron gas (2DEG) of a high electron mobility transistor (HEMT) cause measureable effects in device transport, which can be the basis for a THz detector. The resonance frequency depends on the gate-tuned sheet charge density of the 2DEG and on the characteristic length of the gate metallization by which free space THz radiation couples to the plasmon. Thus, this type of device can be used as a *tunable* detector. This work presents an experimental investigation of such a device fabricated from the InGaAs/InP material system. Using e-beam lithography to fabricate a gate in the form of a grating with sub-micron period, sensitivity of the conductance to incident THz fields is reported. Direct absorption of THz, temperature effects, and the effects of source to drain current on system performance are also investigated. It is expected that this class of device will find use in spaceborne remote sensing and situational awareness applications.

An epitaxial HEMT structure based on InGaAs/InAlAs/InP is chosen because the high sheet charge densities in this materials system lead to the shortest possible resonance wavelengths. The gate metallization in the form of metal stripes serves several functions. The electric field of the incident THz radiation polarizes the stripes, and the resulting local periodic dipole field excites plasmons in the underlying 2DEG. The grating period defines the wavevector of the two dimensional plasmon, whose dispersion relation then defines the resonance frequency. Because the dispersion relation is a function of the 2DEG sheet charge density, the resonance frequency can be tuned by applying a bias to the gate.

II. RESULTS

The resonance wavelength at the maximum expected density of 3 x 10^{12} cm^{-2} and the minimum practical grating period of 0.5 μm is calculated to be 26 μm (Fig. 1). Fig. 2 presents the calculated temperature-dependent transmittance spectrum, according to the theory of Ref. 1, for density 2.4 x 10^{12} cm^{-2}, which suggests distinct absorption resonances even above liquid nitrogen temperature. This resonance is in the range of commercial p-type germanium lasers (50 – 140 cm^{-1}) [2] and THz quantum cascade lasers (117 and 136 cm^{-1}) [3], which are used in this work to excite and study the resonance.

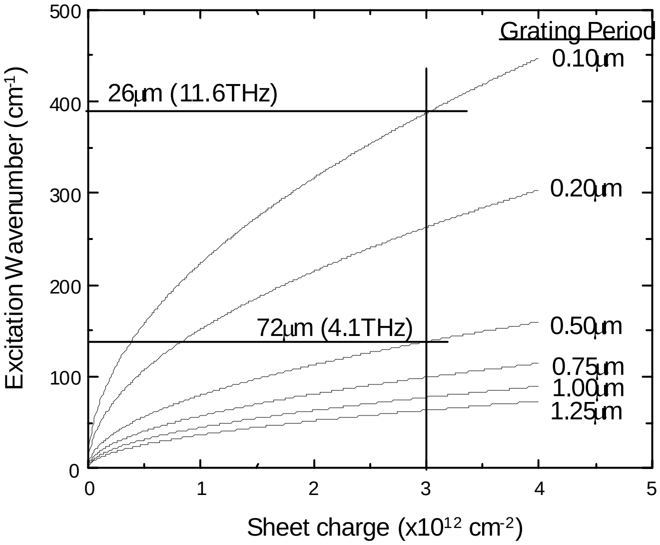

Fig. 1. Calculated plasmon resonance wavenumber vs. sheet charge density in InGaAs 2DEG for different grating gate periods.

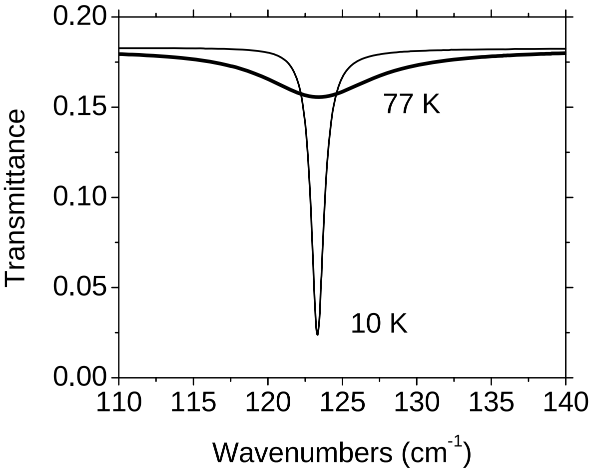

Fig. 2. Calculated resonance line shape for THz transmittance at two different sample temperatures.

Fig. 2 presents an electron micrograph of the device. The metallization is such that the THz radiation can pass only through the 360 μm x 280 μm gate region for transmittance measurements using a close-coupled Ge:Ga photoconductor. Device conductance is monitored synchronously with the THz laser pulse. Fig. 4 presents an image of the gold grating gate formed by e-beam lithography, demonstrating the 0.5 μm period. Fig. 5 presents a photograph of the device mounted in a TO-39 package for testing. The device is mounted in a liquid helium cryostat, and a hole in the base of the TO-39 package allows transmittance of THz radiation from a p-Ge or

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QCL, which is detected by a Ge:Ga photoconductor. Simultaneously, the source-drain current is monitored as a function of gate bias.

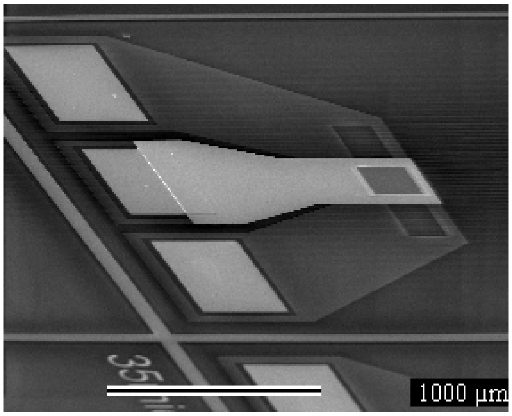

Fig. 3. Electron micrograph of InGaAs HEMT with grating gate.

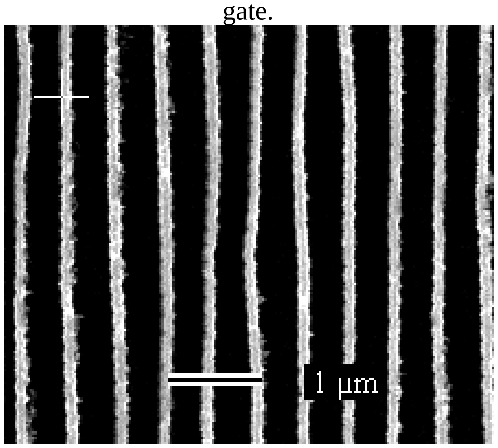

Fig. 4. Electron micrograph of gold grating gate of 0.5 µm period.

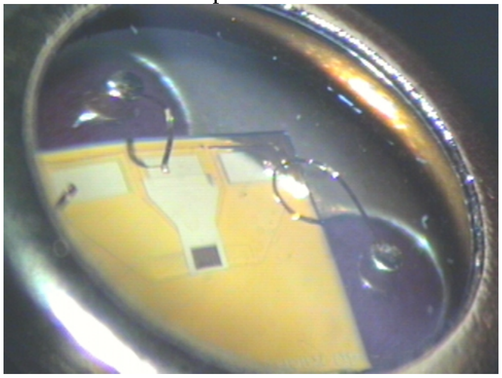

Fig. 5. Device mounted in TO-39 package.

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