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Department of Physics

Terahertz Detection

with 2D Plasmons in a Grating Gated High Electron Mobility Transistor

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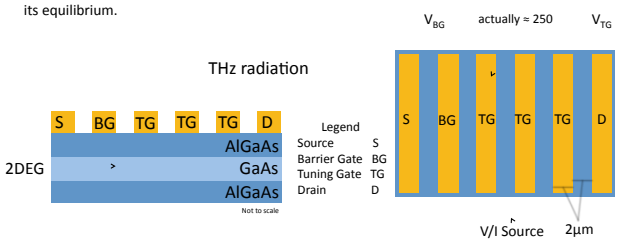
The terahertz band of the electromagnetic spectrum has many promising applications such as imaging for security or medical purposes, far infrared spectroscopy, and the study of protein dynamics. However, the terahertz part of the electromagnetic spectrum is not being used to its full advantage due to the technological difficulties in developing tunable coherent sources and sensitive tunable narrowband detectors. This project explores a special grating gated, GaAs/AlGaAs, high electron mobility transistor (HEMT) as tunable terahertz detectors.

Terahertz Imaging

2D Plasmon

The two dimensional electron gas (2DEG) is displaced by the oscillating electric field of the terahertz radiation. The resultant electric field acts as a restoring force. This oscillating motion has a resonant frequency that if matched with the terahertz source you get a 2 dimension plasmon or an oscillating plasma, that will result in a high amplitude signal. This can be compared to the idea of a mass on a spring that if you displace the mass from equilibrium the restoring force of the spring pulls the mass back and the mass begins to oscillate. And with well timed pulls, which match the resonant frequency, you can get it to oscillate very far from its equilibrium.



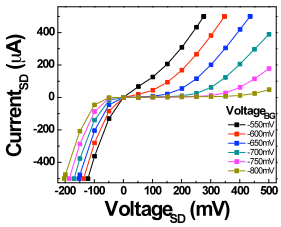
The fingers of the grating gate tune the electron density in the channel. The first finger or barrier gate as a bolometric sensor. The other 250 or so fingers make up the tuning gate which tunes the 2D plasmon's resonant frequency.

$f_{plasmon} \propto \sqrt{n_{2D} k_j}$

- n_{2D} Electron Density controlled by the tuning gate voltage
- k_j Wavevector created by period of the grading

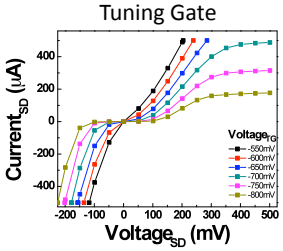
The two dimensional electron gas (2DEG) is created from the layering of the device. Aluminum Gallium Arsenide (AlGaAs) has a larger band gap than Gallium Arsenide (GaAs), this creates a quantum well and thus our 2DEG.

Barrier Gate



- Higher gate voltage means bigger barrier

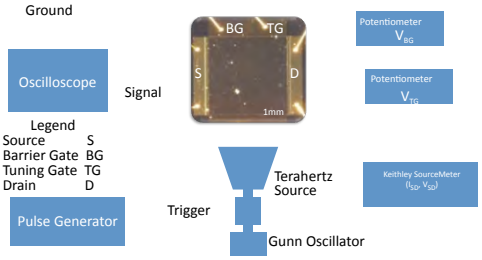
Tuning Gate



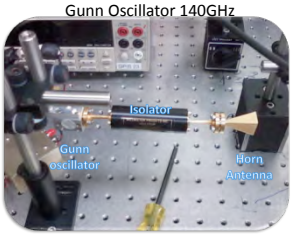
- 250 fingers act as a continuous gate giving rise to saturation current

These two graphs are initial tests without radiation shining on the device. Each color represents a different voltage applied to the one of the gates, a voltage is applied across the device and a current is measured.

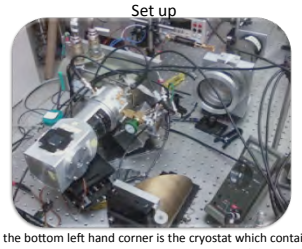
Experimental Set-up



Gunn Oscillator 140GHz

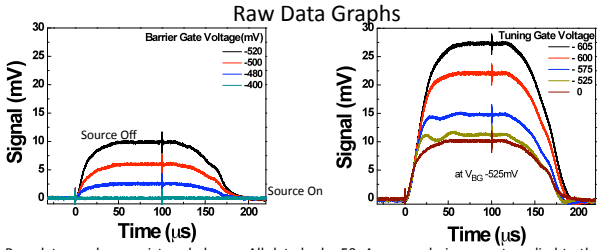


Set up



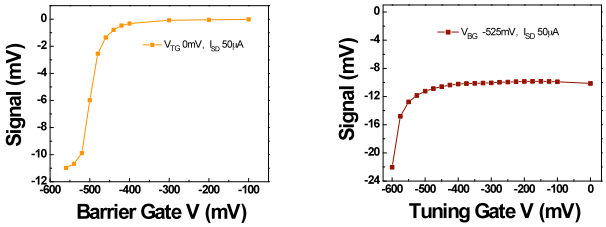
In the bottom left hand corner is the cryostat which contains the sample and is connected to a closed cycle refrigerator.

Raw Data Graphs



Raw data graphs are pictured above. All data had a 50μA source-drain current applied to the device. The vertical lines at 0 and 100μs are noise from the pulse generator which switches the Gunn oscillator on and off. The base line of these graphs is actually the on state but this does not affect the magnitude of the signal only the sign and this is represented in the analyzed signal graph.

Analyzed Signal



- No signal until pinch off of channel or activation of bolometric senor
- No clear evidence of plasmon resonance

These two graphs are summaries of the complete set of raw data pictured above. The average of the flat range between 50μs and 100μs was taken and plotted against the gate voltage. The sign of the signal has been corrected as mentioned above.

Conclusions

The device that we were working with was working correctly in that the gating action works as expected. However, we have yet to see any plasmon resonance. Nonetheless, the terahertz source that we were working with is at a low frequency and this could mean that any plasmon resonance would be happening near pinch off. This could make it difficult to distinguish the plasma resonance from the pinch off response.

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