Terahertz Detection

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

NSF

Sandia National Laboratories

ITST

INSTITUTE FOR TERAHERTZ SCIENCE AND TECHNOLOGY

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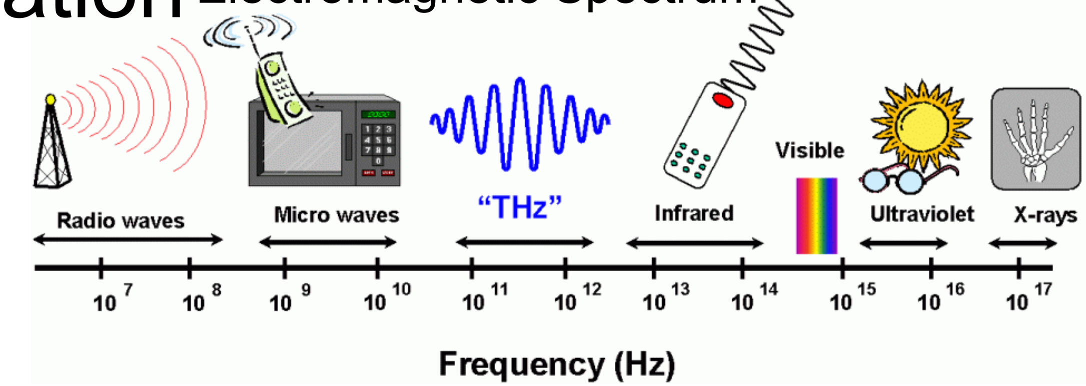
Why Terahertz?

Terahertz (THz) Radiation

- Electromagnetic Wave
- ≈ 100GHz – 10THz

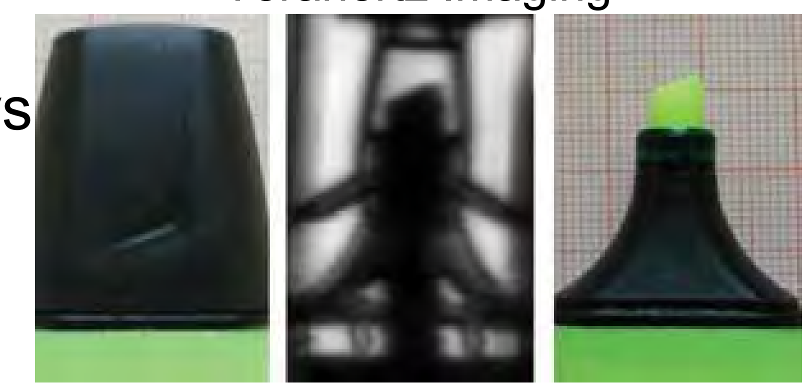
Electromagnetic Spectrum



Applications

- Imaging like X-rays
    - Medical and Security
  - >10,000x less energy than X-rays
- Communications
    - Fast, short range
    - Outer space

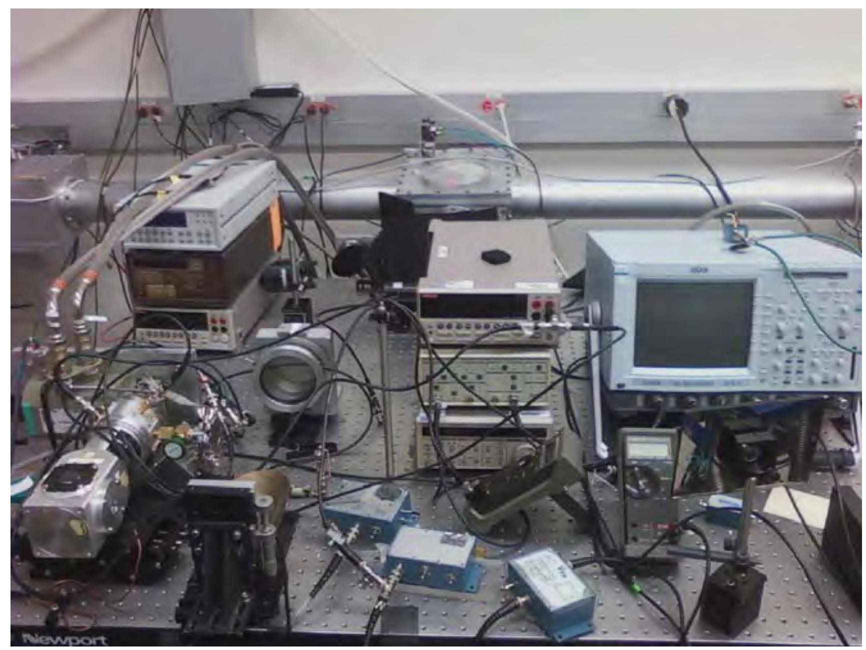
Terahertz Imaging



Picture (bottom) from http://optics.org/cws/article/research/9937/1/oleima3_99-02
Picture (top) from http://www.sp.phy.cam.ac.uk/SPWeb/research/thzcamera/WhatIsTHzImaging.htm

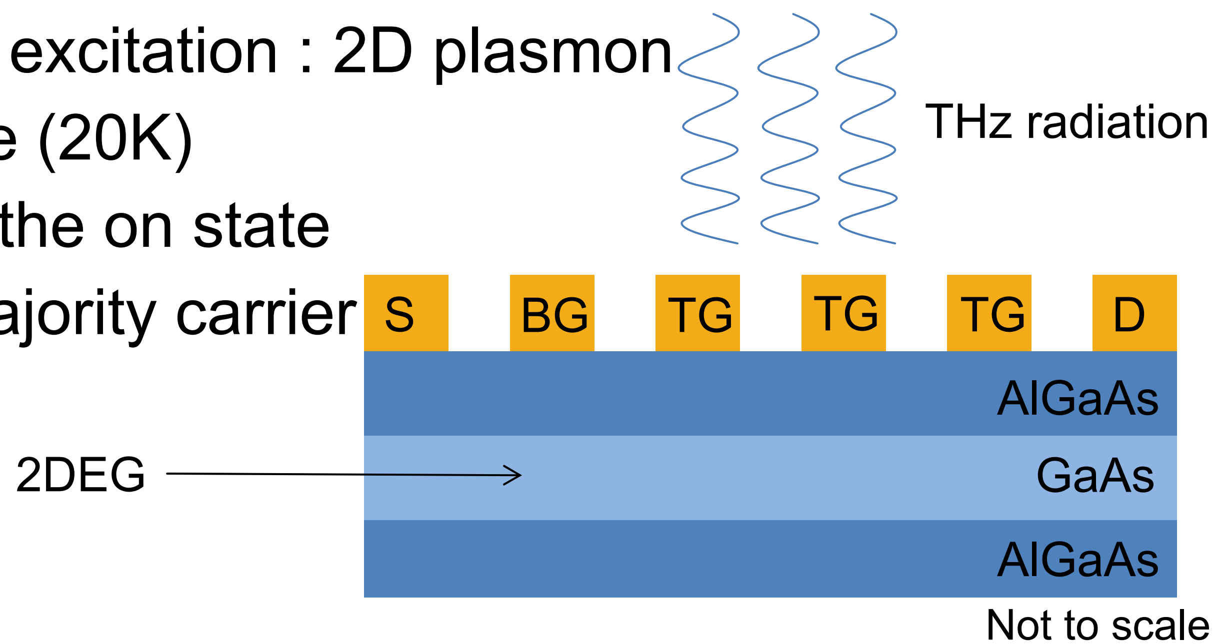
Research Objectives

- Ultimate goal
  - Narrow band tunable terahertz detector
- Bias a Transistor using LabVIEW
- Recreate code with new equipment
- Measure detector response
  - Bias a THz detector (without radiation)
  - Bias the detector with THz radiation (~140GHz)



Terahertz Detector

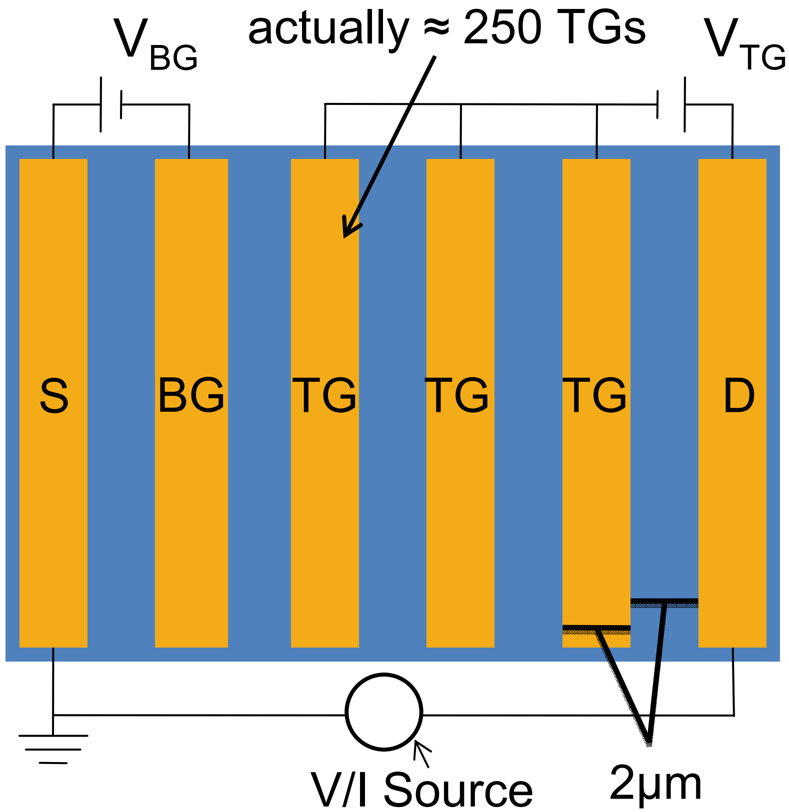
- High Electron Mobility Transistor (HEMT)
  - Type of Field Effect Transistor (FET)
  - Control conductivity with electric field
  - Chemical make up (Epitaxial growth)
    - Quantum Well
      - creates 2 Dimensional Electron Gas (2DEG)
        - resonant excitation : 2D plasmon
  - Low temperature (20K)
  - Our device is in the on state
  - Electrons are majority carrier



Legend

Source	S
Barrier Gate	BG
Tuning Gate	TG
Drain	D

Terahertz Detector



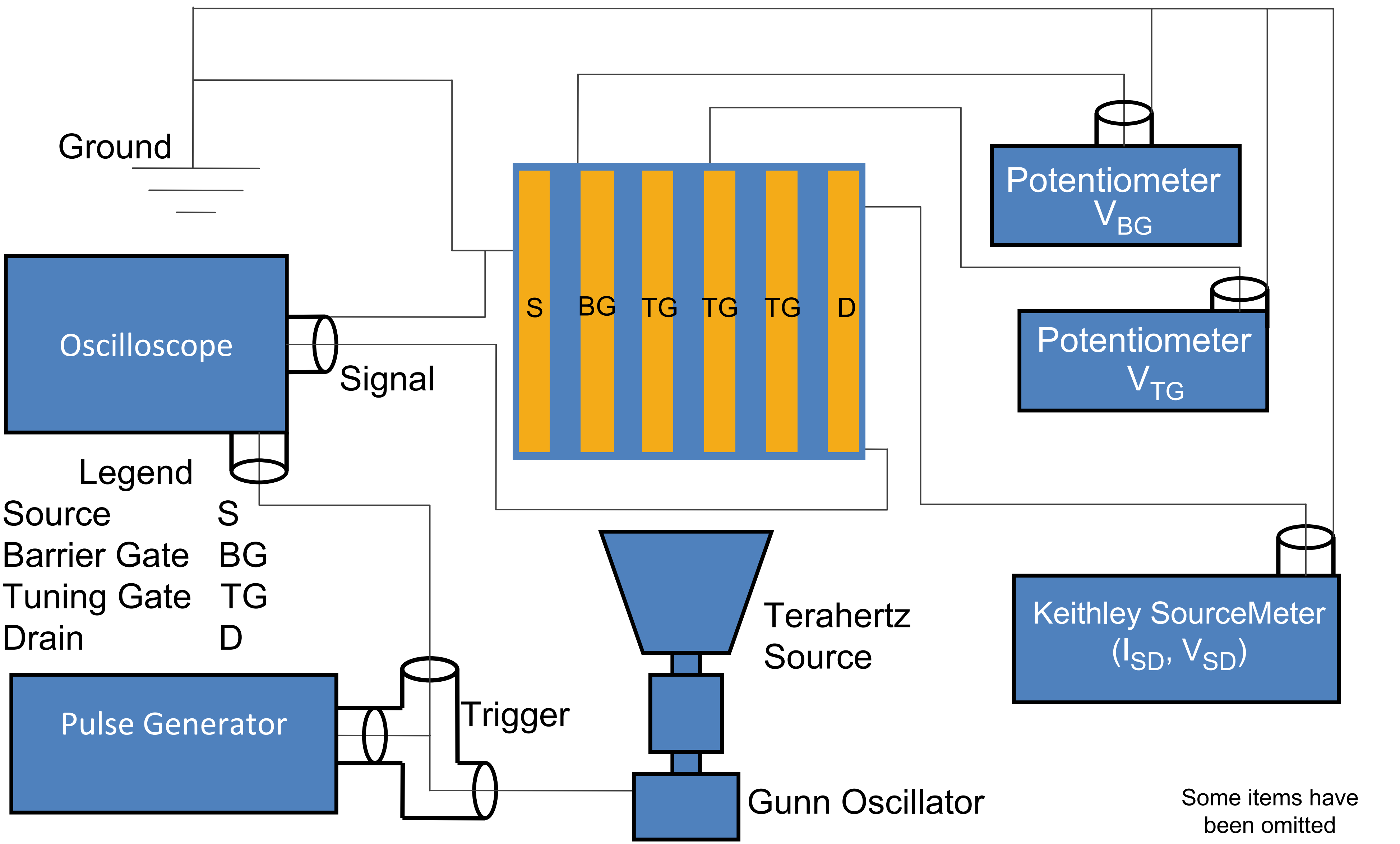
Legend

Source	S
Barrier Gate	BG
Tuning Gate	TG
Drain	D

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

- 1x1mm Dimensions
- BG controls conductivity
  - Bolometric Response
- TG tunes resonance of 2D plasmon
  - Electron density (n)
  - Wave vector (k)
- Under constant current
  - Plasmon should cause a change in voltage

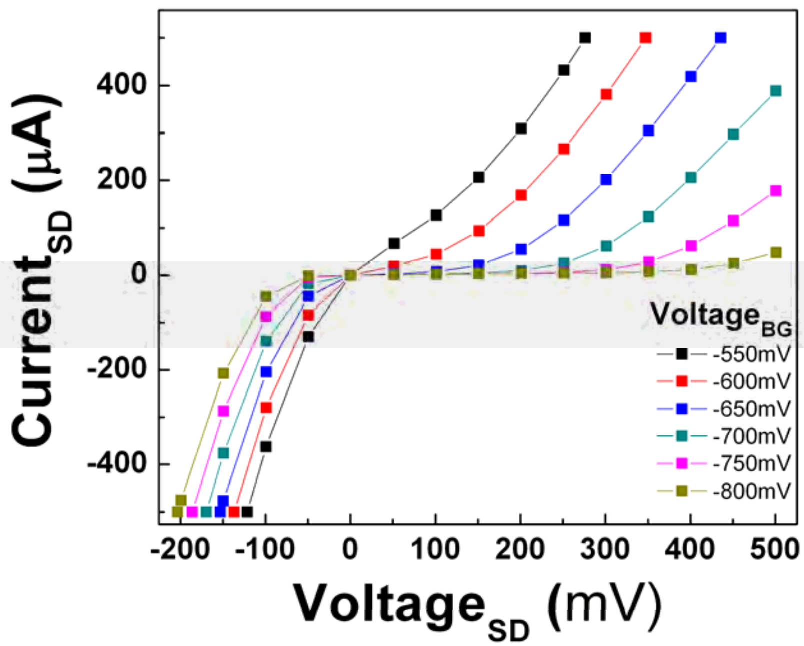
Experimental Set-up



Some items have been omitted

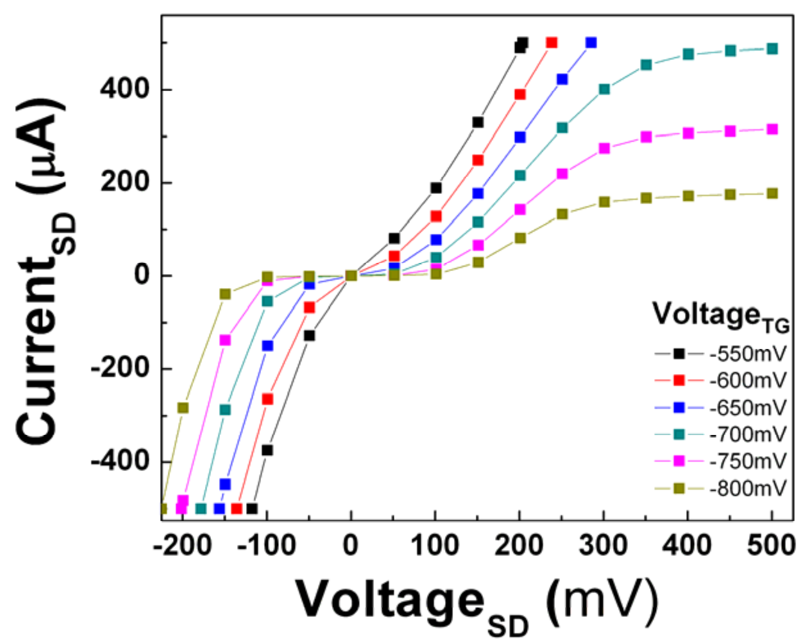
Gate Bias without Radiation

Barrier Gate



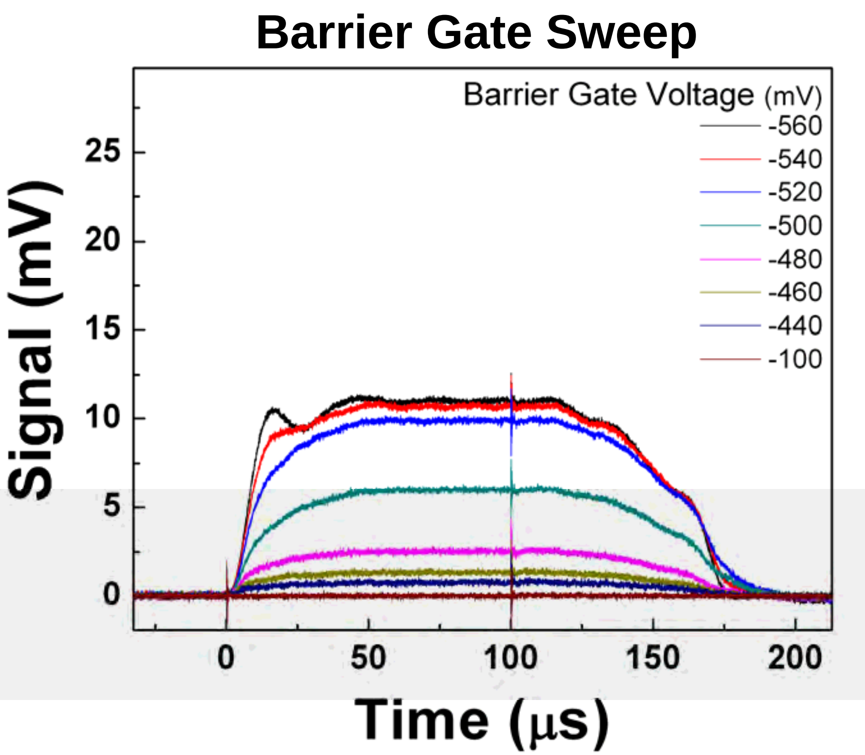
- Higher V_{BG} limits current
- Higher V_{BG} means more voltage to achieve same current
- Creates energy barrier that electrons must cross

Tuning Gate

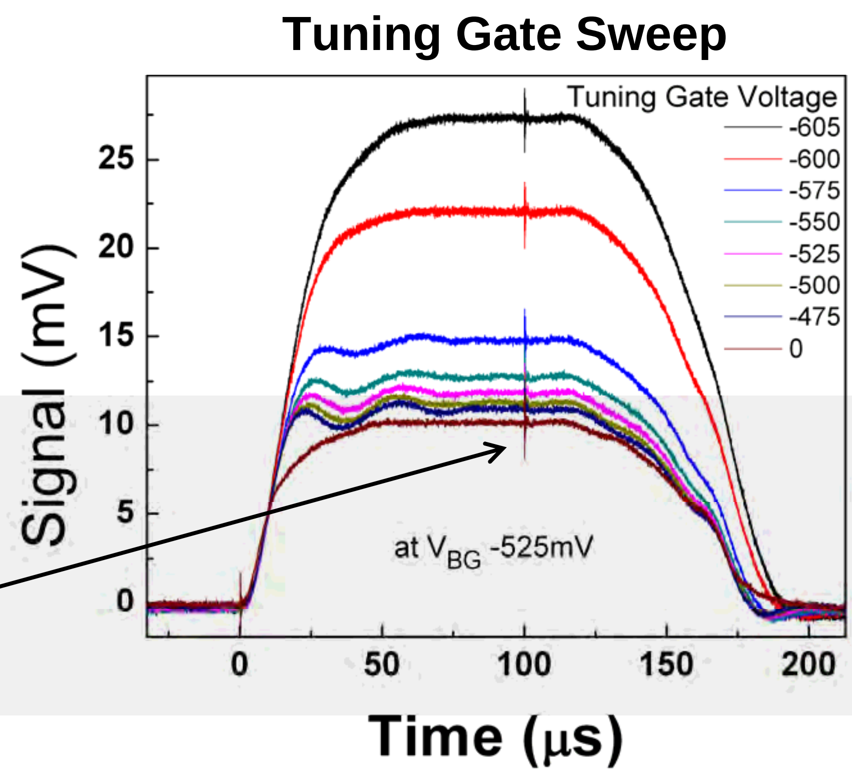


- Verification of working gate
- ~ 250 tuning gates act like a continuous gate

Raw Signal Data



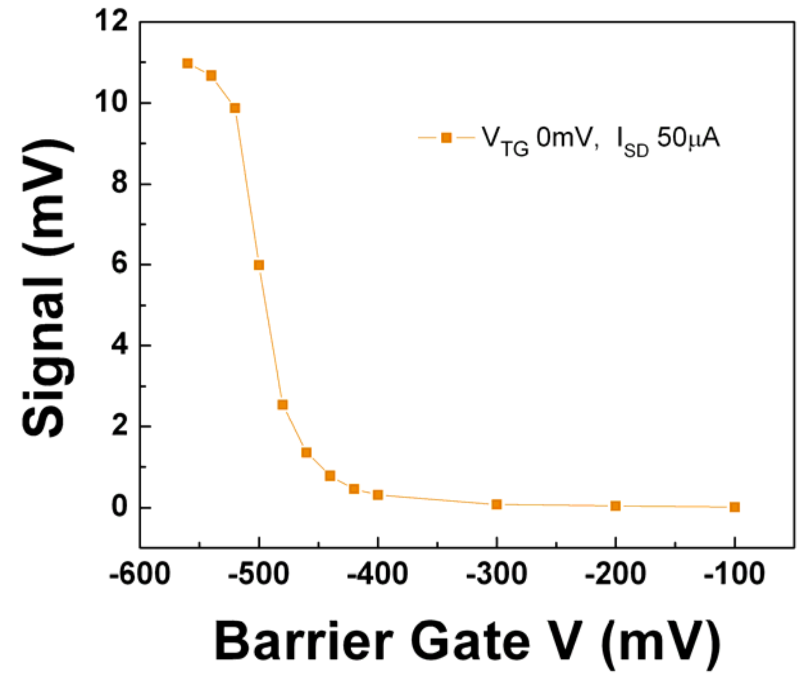
- We convinced we are seeing a bolometric response because of signal after pinch off

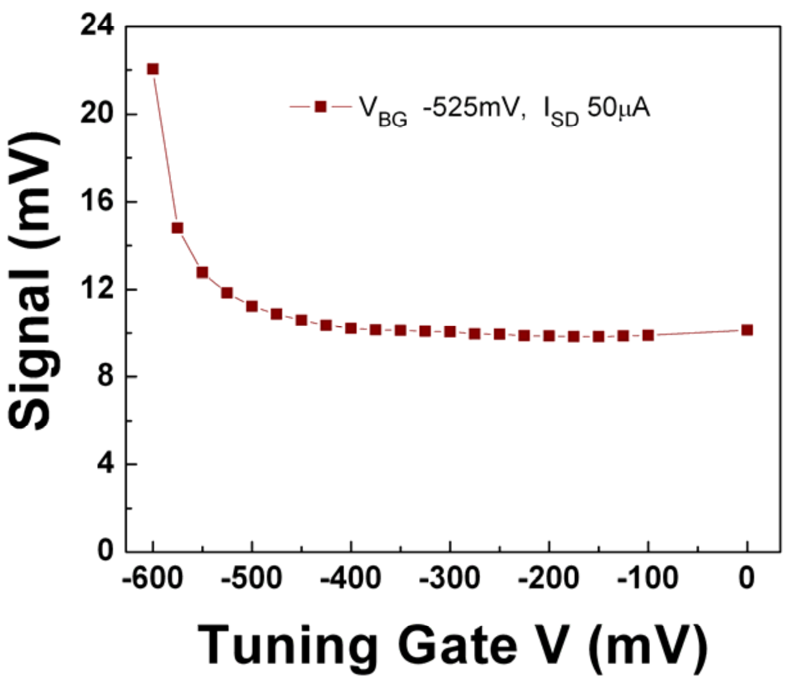


- Electronic noise from the pulse generator

Initial Response Data

- No Signal until reaching pinch-off
- Ideal barrier gate voltage around -500mV





- No visible plasmon resonance
  - Polarity of the current
  - Built in values for device
- Pinch-off and resonance may be hard to differentiate

Summary

- Learned how to code in LabVIEW
- Integrated different instruments into experiment
- Learned to bias a transistor
- Saw terahertz detector working
- Have yet to see plasmon resonance

Acknowledgements

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- CNSI
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- Faculty Advisor: Jim Allen
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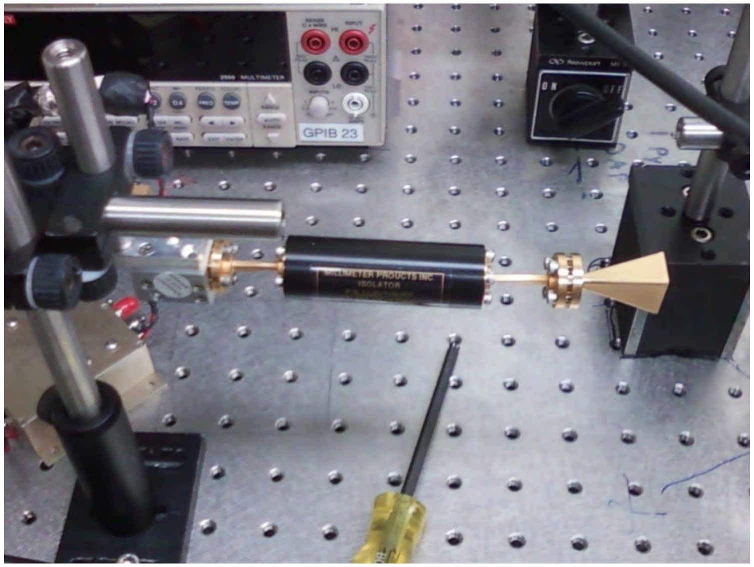
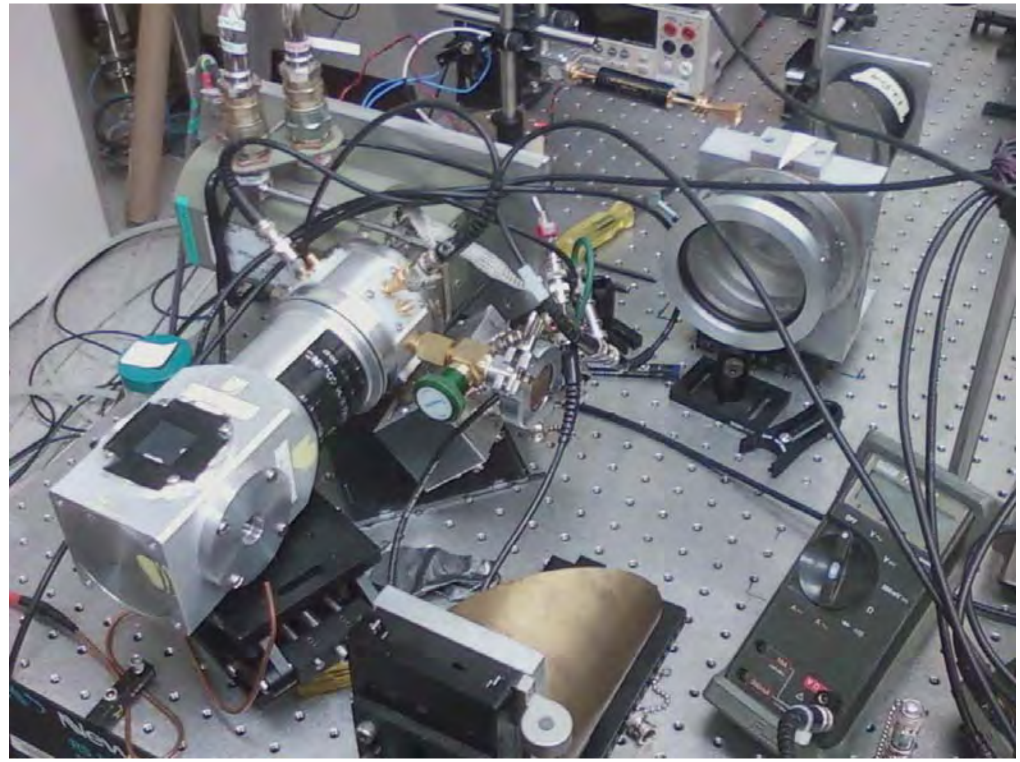
- Sandia National Laboratories
- Institute of Terahertz Science and Technology(ITST)

Additional Info

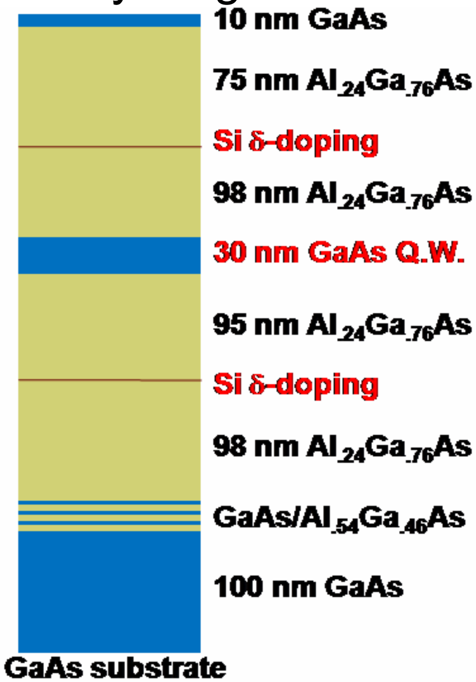
Gunn Oscillator



Experimental Setup



Layering



Additional Terahertz Imaging