CHARACTERIZATION OF GRAPHENE FILMS USING TERAHERTZ IMAGING AND SPECTROSCOPY

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Graphene has received significant attention due to its many unique properties, such as its two-dimensionality, zero-mass and zero-gap band structure, and unsurpassed strength. Additionally, its terahertz (THz) properties are being studied for future ultrafast electronics for information and communication, sensing and other applications. However, the basic properties of graphene in the presence of THz radiation are largely unexplored, although many theoretical studies exist. In this study, we explore the THz dynamics of graphene on indium phosphide (InP) and magnesium oxide (MgO) substrates, using THz time domain spectroscopy (THz-TDS) and laser terahertz emission microscopy (LTEM). Using LTEM, we compared the THz radiation from InP to the radiation through graphene on InP to find that graphene decreases the amplitude of THz. Furthermore, we investigated the effect of continuous wave (cw) lasers of different wavelengths on THz radiation and discovered that a 365 nm cw laser greatly decreased THz transmittance through graphene on InP, but an 800 nm cw laser had no effect, proving wavelength dependence of THz generation. We also studied the spatial variation of THz absorption of graphene on InP and MgO substrates using an LTEM system with THz-TDS, which allowed us to visualize the localized transmittance distribution of graphene. Both THz-TDS and LTEM results help us understand THz functionality in graphene on InP and MgO in order to develop future electronics.

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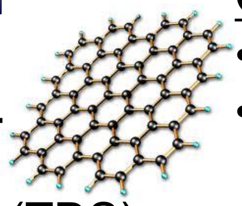
Purpose

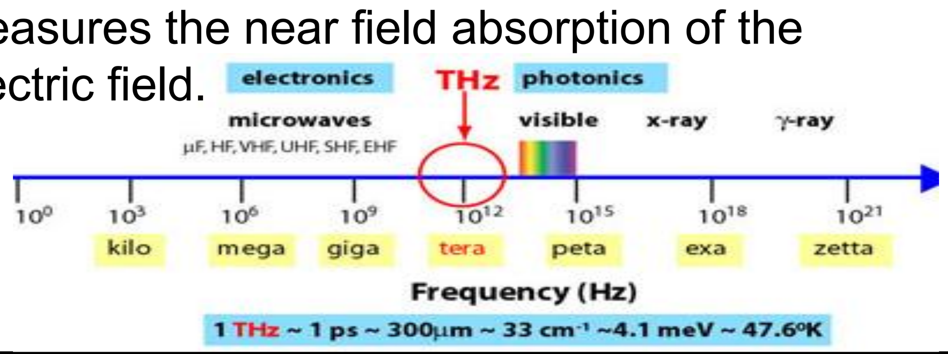
Motivation: Characterize and understand the terahertz (THz) dynamics of graphene for future applications. Graphene on InP is largely unexplored. InP has high e^- mobility (5400 $cm^2/(V{*}s)$ at 300 K) and a direct band gap.

Goals:
- Characterize graphene on InP
- Study the interface effects of graphene
- Look at the effect of continuous wave lasers

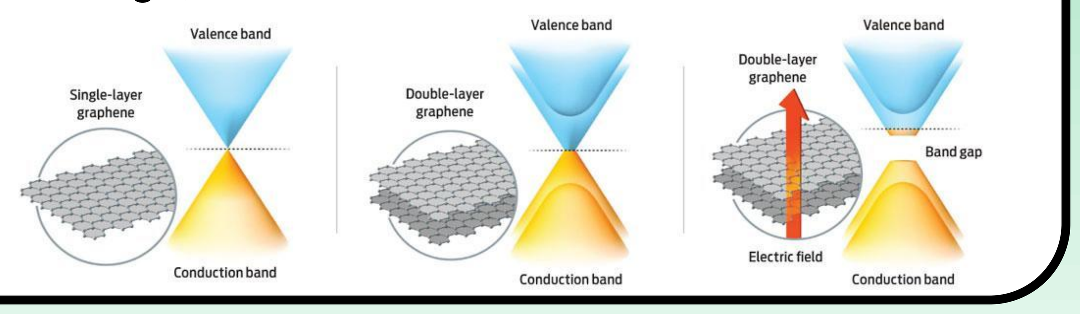
Background

Terahertz :
- Frequency range= 300GHz to 30 THz.
- Wavelength 1 mm to 10 micrometers
- Terahertz-Time Domain Spectroscopy (TDS) measures the transmitted electric field. Fourier transform gives frequency spectrum.
- Laser Terahertz Emission Microscopy (LTEM) measures the near field absorption of the electric field.

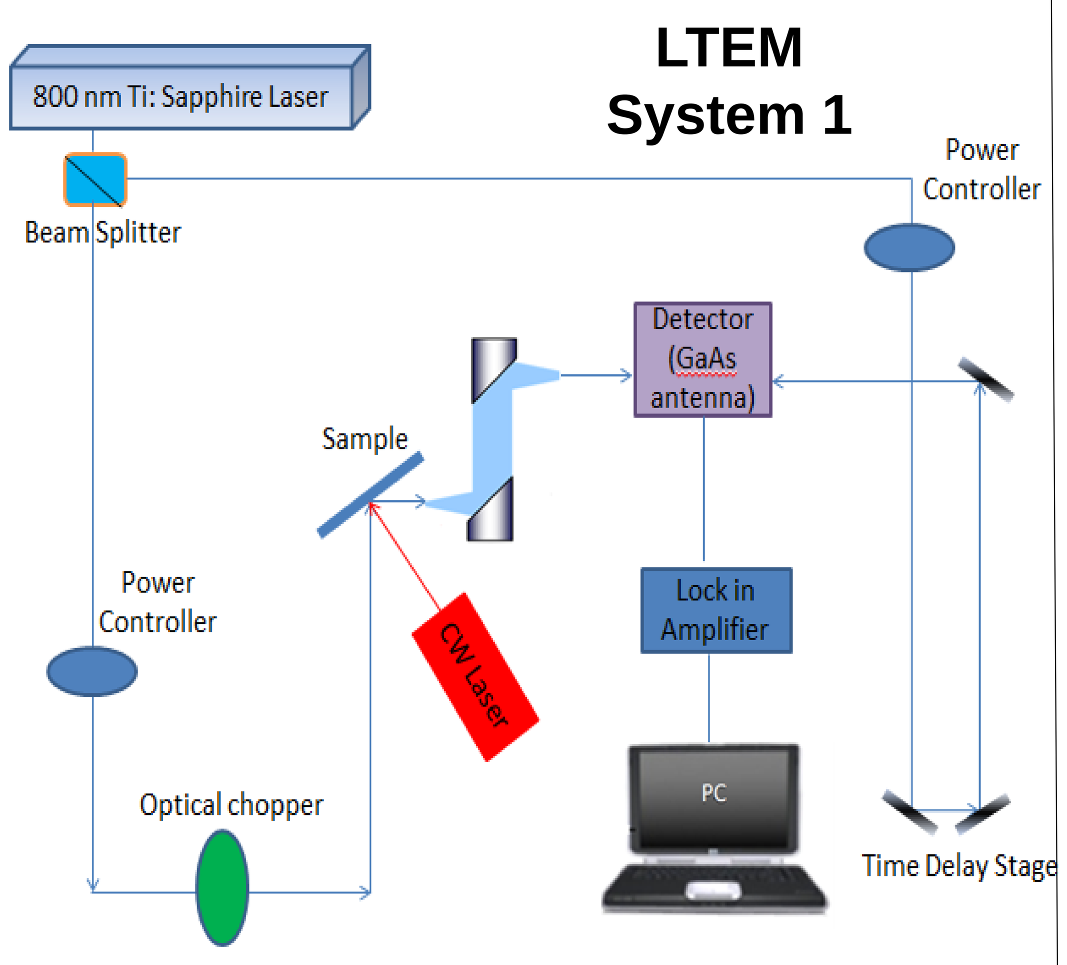




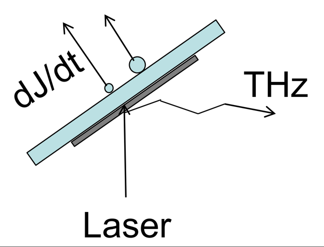
Graphene:
- Fabrication by chemical vapor deposition (CVD)
- Astounding properties: single layer semiconductor, zero bandgap, strongest and stiffest material, high mobility, lowest resistivity
- 2.3% interband absorbance
- Applications: information and communication, sensing, ultrafast electronics, transistors, inert coatings, biodevices

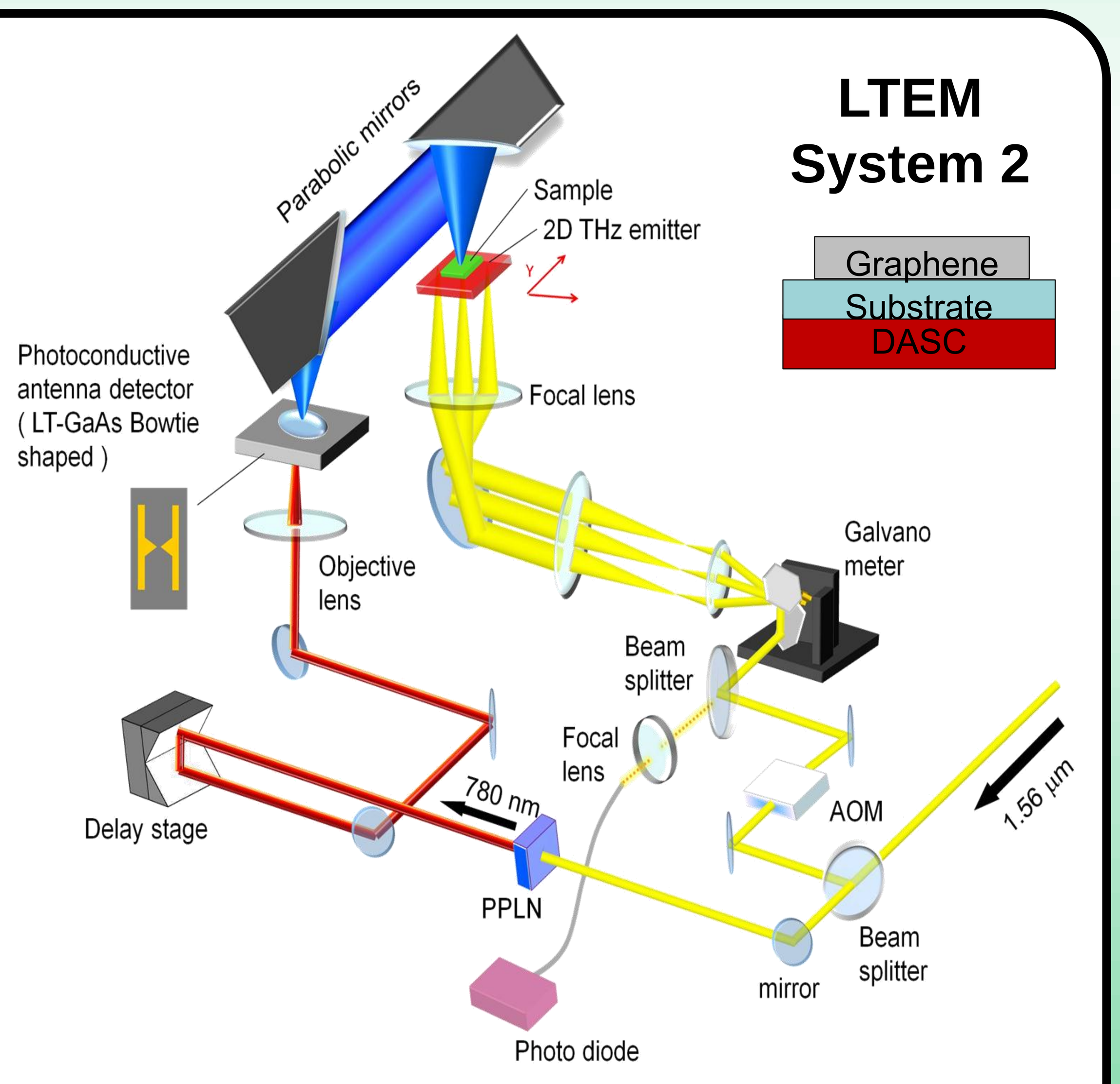


Methods



- Obtained waveforms and images of graphene on InP with and without 365 nm cw laser and 800 nm cw laser
- Reflection type setup: **Emission**
- THz generated by InP substrate
- Surge current/ surface field effect

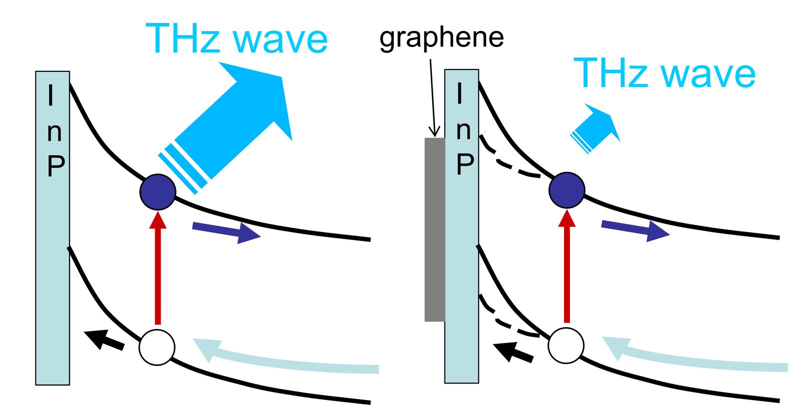


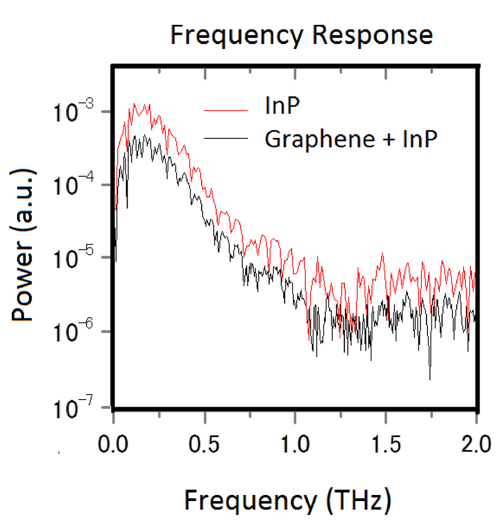


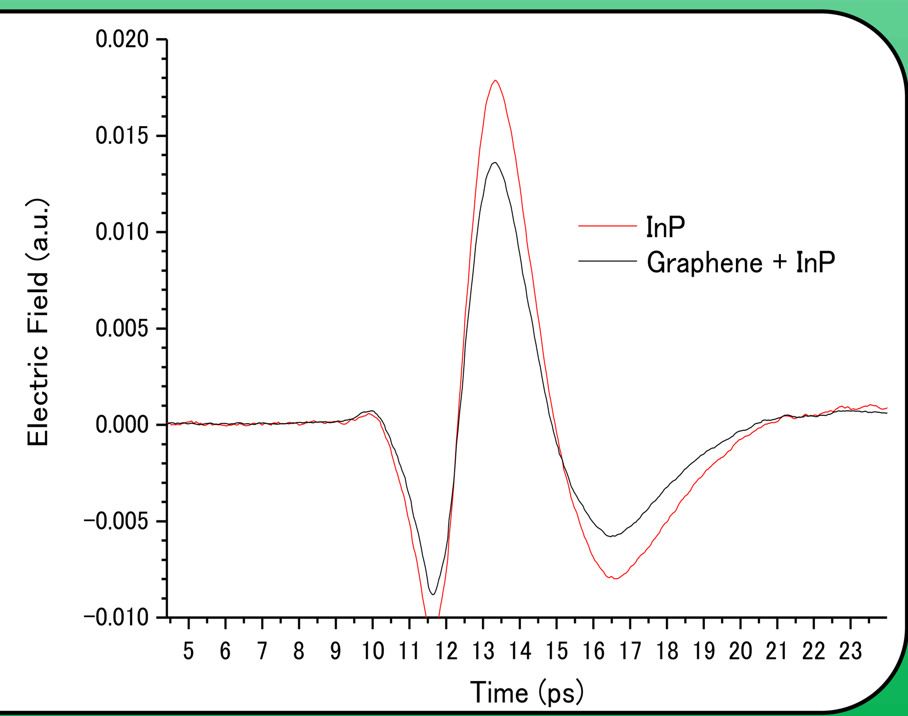
- Galvano meter for raster scanning
- DASC crystal instead of substrate emitter
- Transmission type– measured **transmittance** of graphene on MgO and InP
- Optical rectification, 1.56 micron laser
- Peak amplitude monitored over time with cw laser

Results A (System 1)

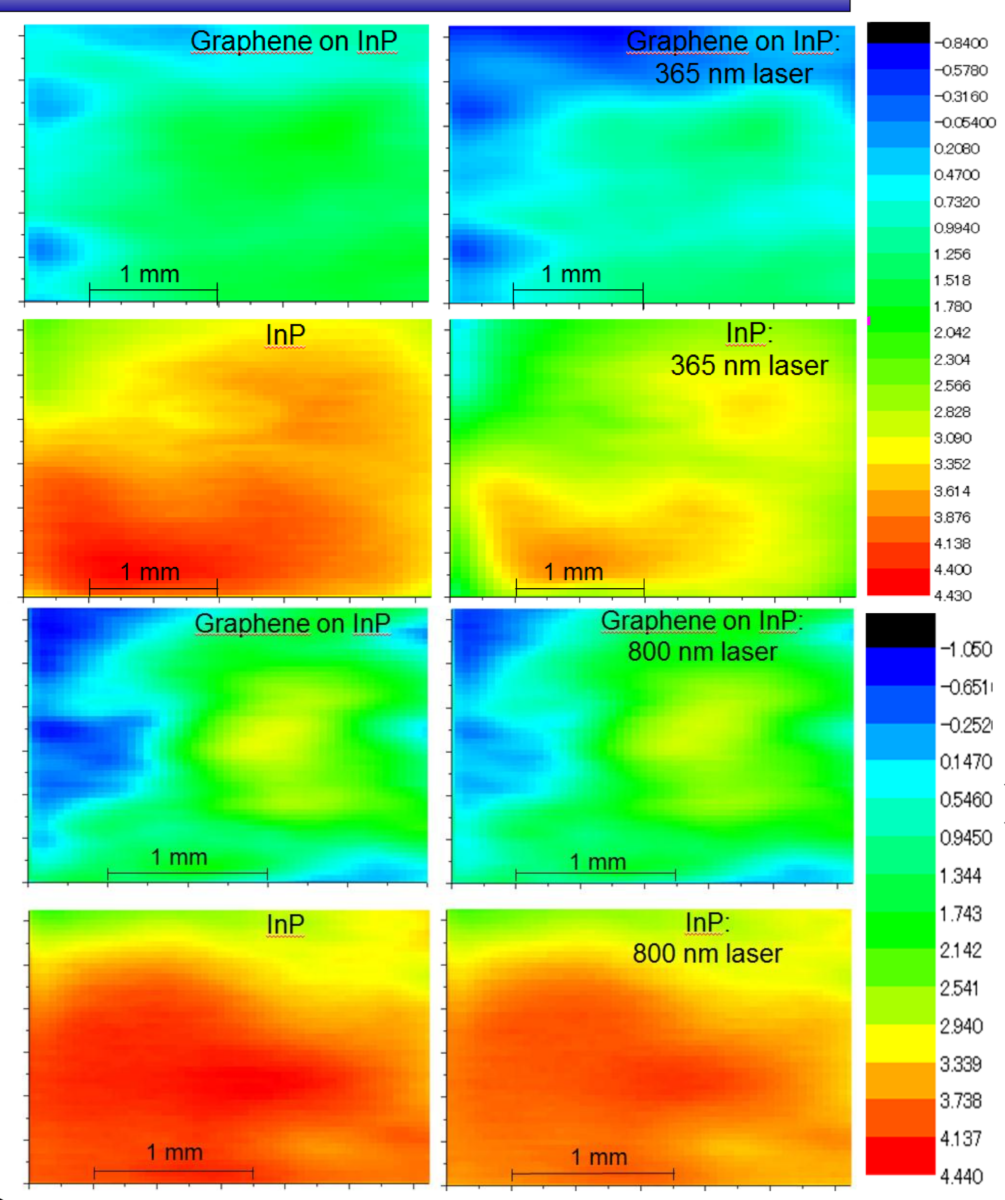
1. THz emission decreases more than expected in the presence of graphene on InP.

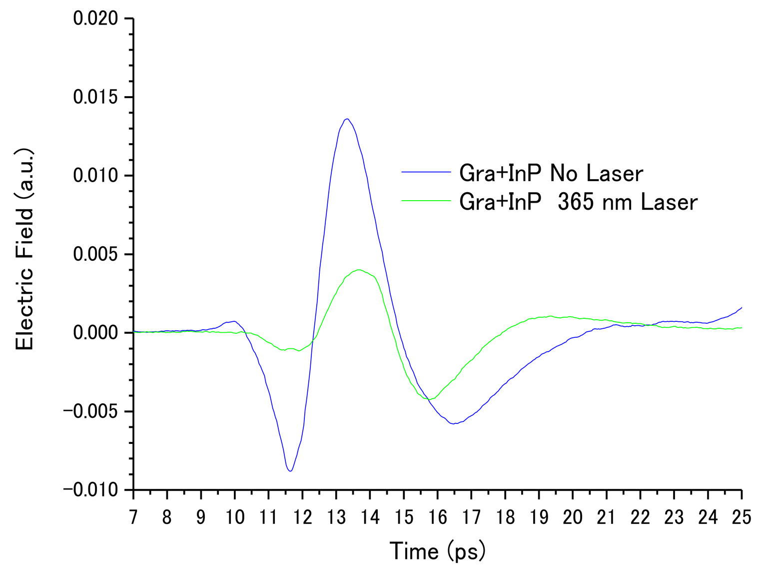


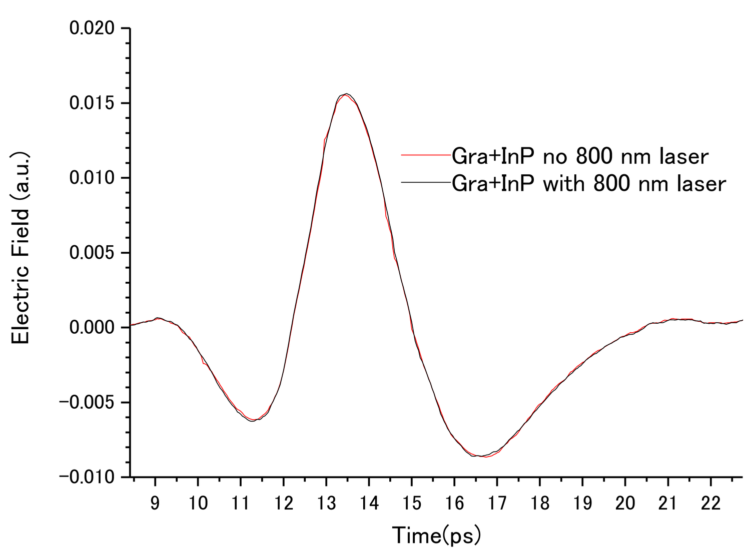




Results B (System 1)





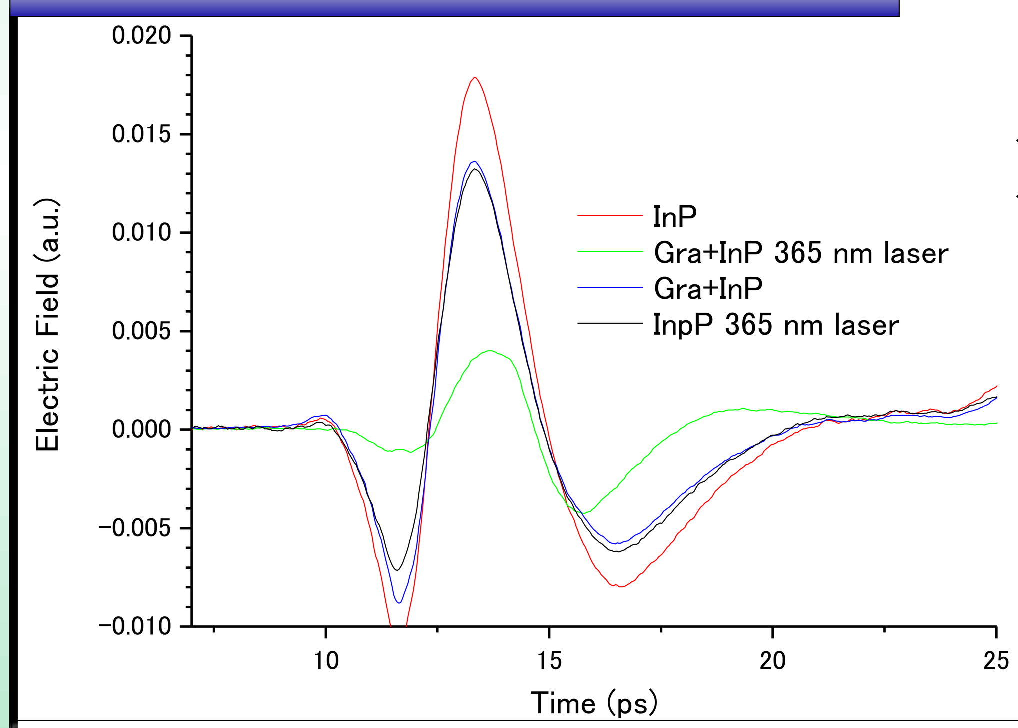


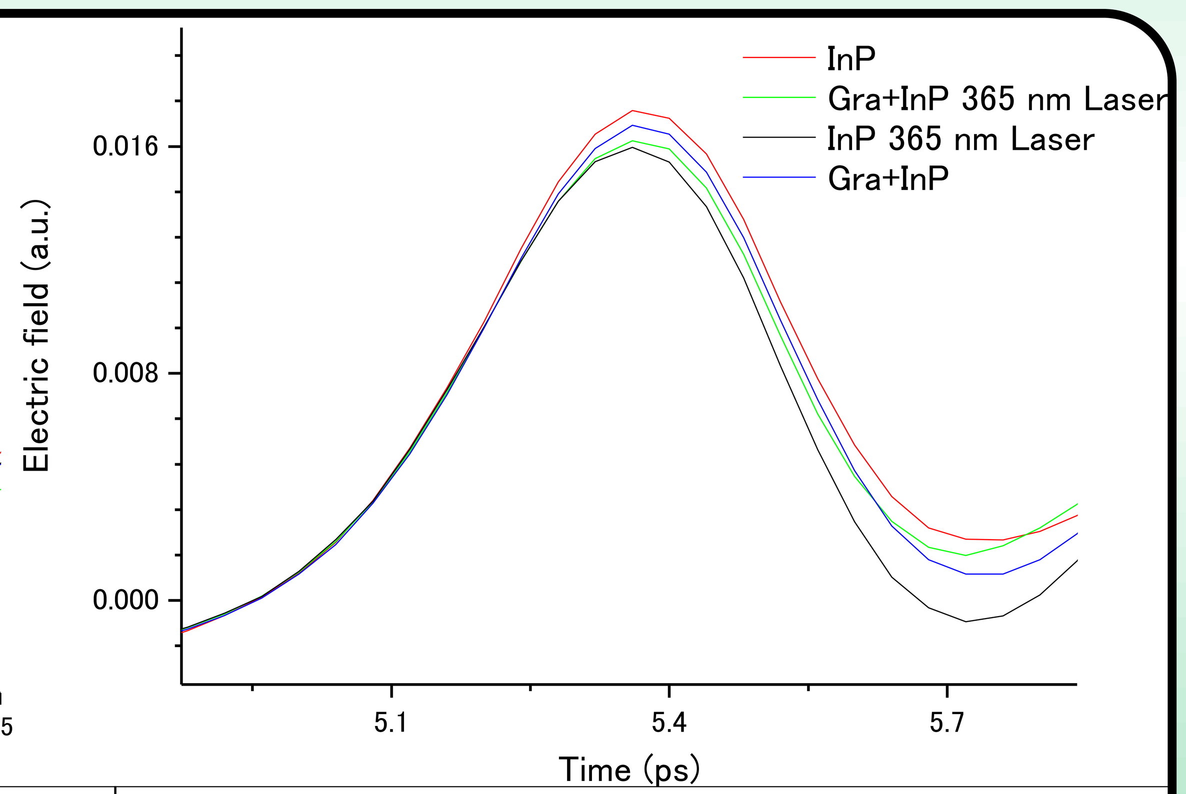
The left images are 2.5x2.5 mm images from system 1. System 1 waveforms on the right agree with image data.

2. We see inhomogeneity on the surface of graphene, while the substrate is uniform.

3. A 365 nm cw laser decreases the THz emission, but an 800 nm cw laser has no effect.

Future Work





System 1/Emission: Greater decrease on graphene	System 2/Transmission: Greater decrease on InP

1. Although the 365 nm laser clearly effects the THz emission and transmittance, we cannot determine if this effect is from graphene or InP because emission (system 1) and transmission (system 2) results are contraversial.
2. Continue experiments with cw laser on InP only and graphene on InP to understand the strange cw laser effects and its effect on transmission vs emission.

Conclusions

1. Graphene effects surge current mechanism on InP, decreasing THz emission.
2. We can see the local distribution of the surface of CVD graphene using an LTEM system.
3. A 365 nm laser clearly affects THz emission mechanism.

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Acknowledgements

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