Photomixing Using Dual-Gate Graphene-Channel Field Effect Transistors

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Photomixing is a viable method for both converting between optical and electrical signals and generating electrical signals in frequency ranges such as the terahertz (THz) band that few devices can produce. If photomixing capabilities in the THz are demonstrated, it could be instrumental in future ultra-broadband communication technology. Here, we investigate the ability of dual-gate graphene-channel field effect transistors (G-FETs) to perform photomixing using a dual-frequency laser with a differential frequency of 12.5 GHz. The sample was fabricated using graphene grown by chemical vapor deposition on a SiO_2/heavily-doped Si substrate. To generate the infrared optical pump beam, a signal created by a 1.55-μm wavelength CW fiber laser was modulated by a frequency comb, generating sideband peaks spaced 12.5 GHz apart. The signal was then passed through amplifiers and arrayed waveguide gratings to extract two adjacent sideband components, eventually exciting the sample. The drain voltage was fixed at 0.5 V. The dual-gate voltages were adjusted to induce different doping profiles such as p-i-n or p-i-i, which allowed us to characterize the conversion efficiency as a function of operating mode. To measure the response of the sample, a microwave spectrum analyzer with a resolution bandwidth of 1 kHz was used. The results showed a typical response having the photomixed different frequency spectral component centered around 12.5 GHz. This demonstrates the photomixing capabilities of the device. Further research can compare the efficiency of graphene-based photomixers to existing devices. Graphene's special properties such as massless charge carriers and high carrier velocities could significantly improve photomixing technology.

EXPERIMENTAL STUDY ON CARRIER DYNAMICS AND RELATED PHOTONIC RESPONSES IN GRAPHENE

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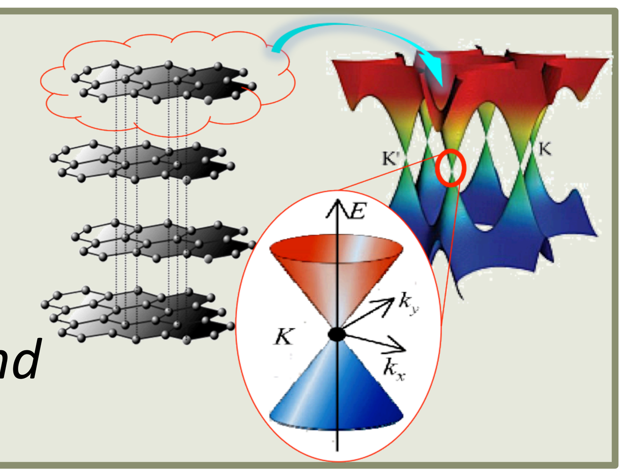
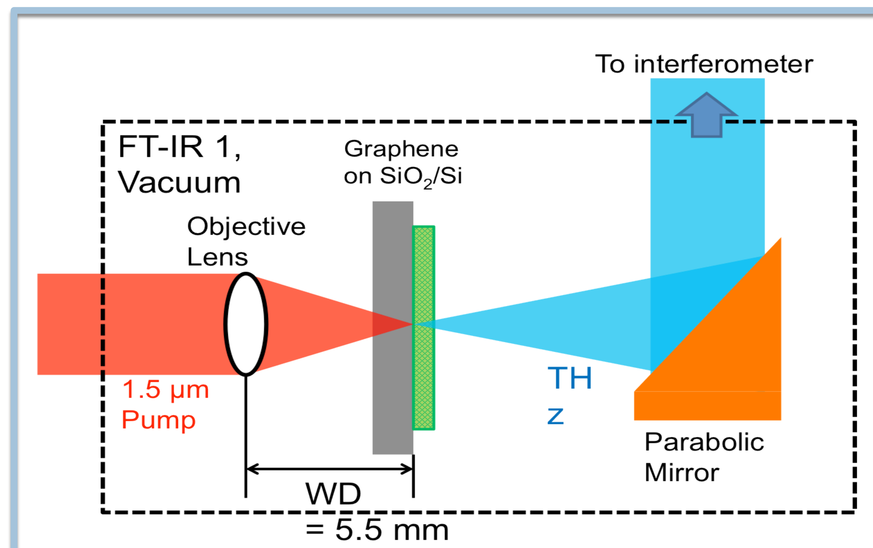
GRAPHENE

Mono- or few layers of sp^2 bonded carbon atoms in a honeycomb lattice.
Extraordinary properties: *Massless electrons and holes,*
Linear energy dispersion (no bandgap),
Ultrafast carrier relaxation and relatively slow recombination, and
High mobility



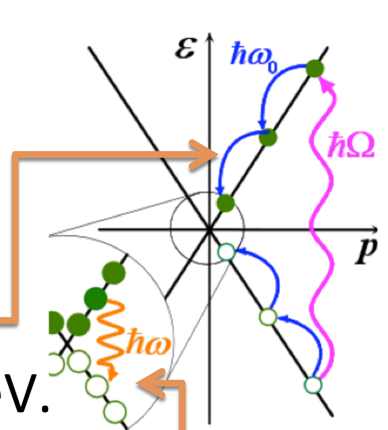
Observation of Spontaneous THz Photon Emission Using Fourier Transform-Infrared Spectroscopy

Introduction:



Goal: Observe spontaneous THz emissions after optically pumping graphene with a high powered laser.

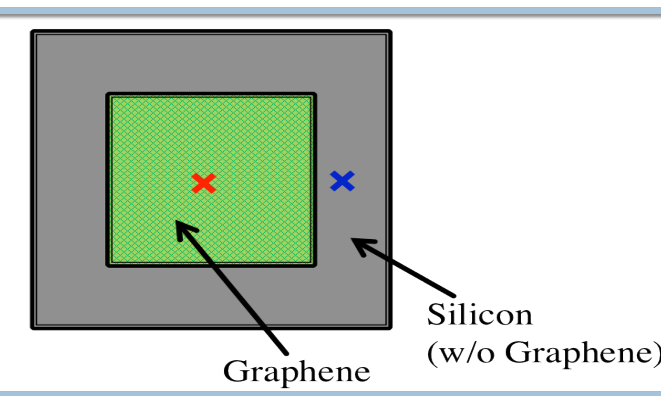
Theory: Photo-carriers in graphene first emit optical phonons in increments of 198 meV. Then THz photons are emitted.



*V. Ryzhii, M. Ryzhii & T. Otsuji, **JAP 101**, 083114 (2007).*

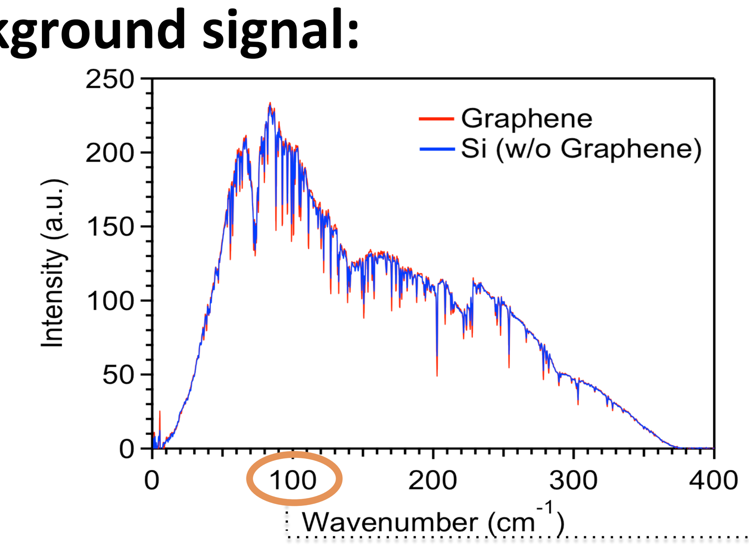
Methods:

1. Measure background emissions of graphene and silicon regions of sample.
2. Excite graphene and silicon regions by a high-powered infrared fiber laser and measure emissions.
3. Normalize data with background emissions and compare.



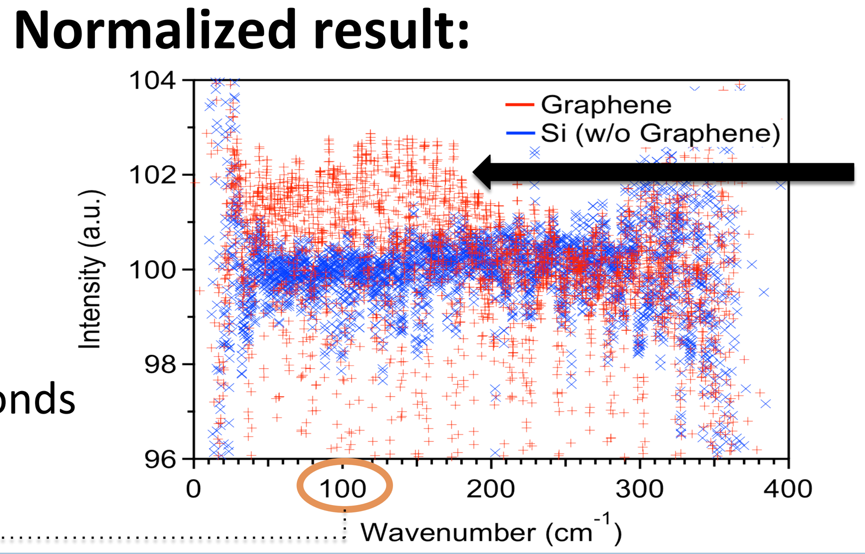
Results:

Background signal:



Corresponds to 3 THz

Normalized result:



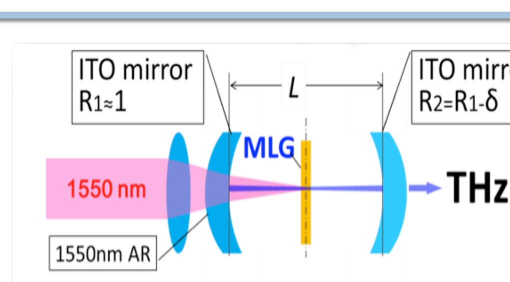
Possible spontaneous THz emissions

Discussion:

Observed signs of possible spontaneous THz emission

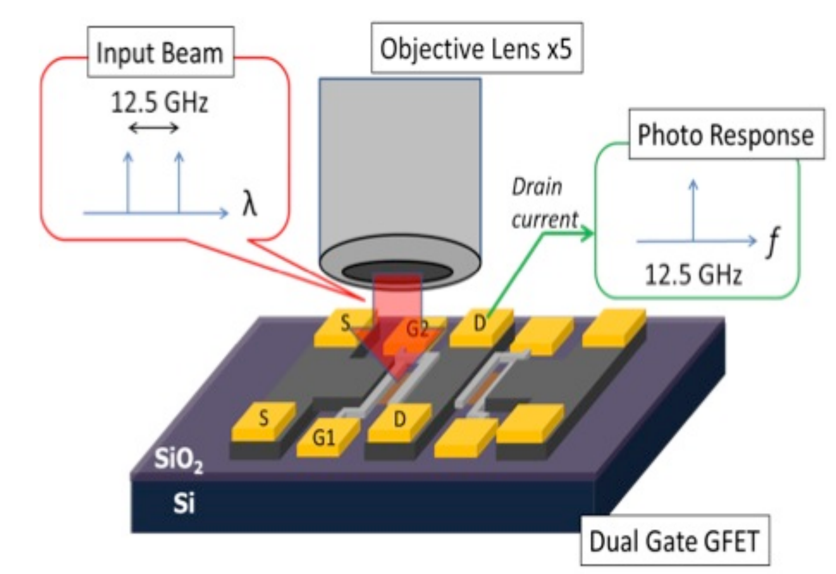
Future research:

To observe spectrum using Fabry-Perot cavity (stimulated emissions).
To measure the dependence of emission spectra on pumping power.



Photomixing Using Dual-Gate Graphene-Channel Field Effect Transistors

Introduction:



Photomixing: Generation of continuous wave (usually THz) radiation from two optical input frequencies.

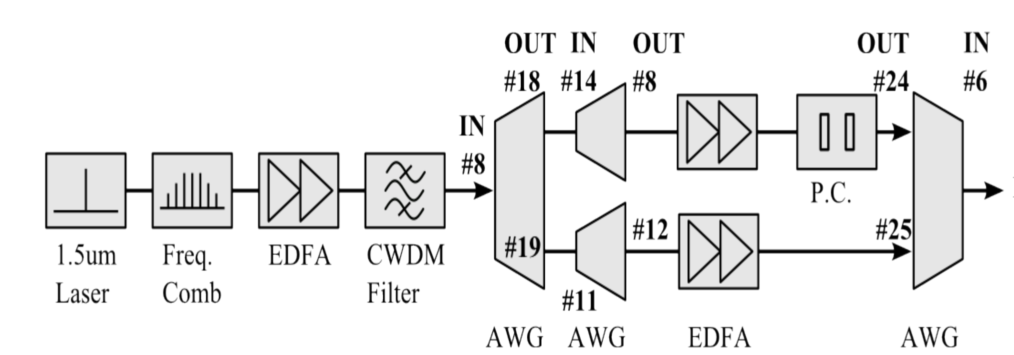
Goal: Shine an optical signal with two spectral peaks spaced 12.5 GHz apart to generate a beat-note in a G-FET, stimulating a photocurrent with a frequency of 12.5 GHz.

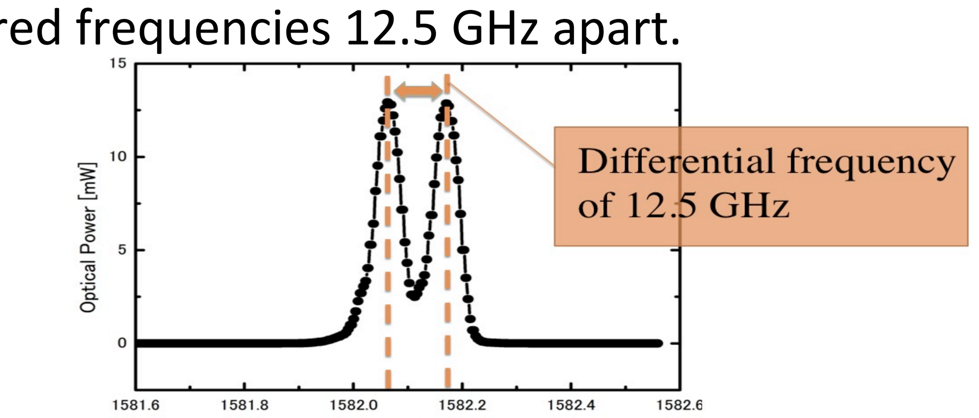
Applications: Convert optical → electrical signals, generating THz waves (few existing sources), THz detector.

*V. Ryzhii, M. Ryzhii , V. Mitin , M.S. Shur , A. Satou & T. Otsuji, **JAP 113**, 174506 (2013).*
*V. Ryzhii, M. Ryzhii, V. Mitin & T. Otsuji, **JAP 107**, 054512 (2010).*

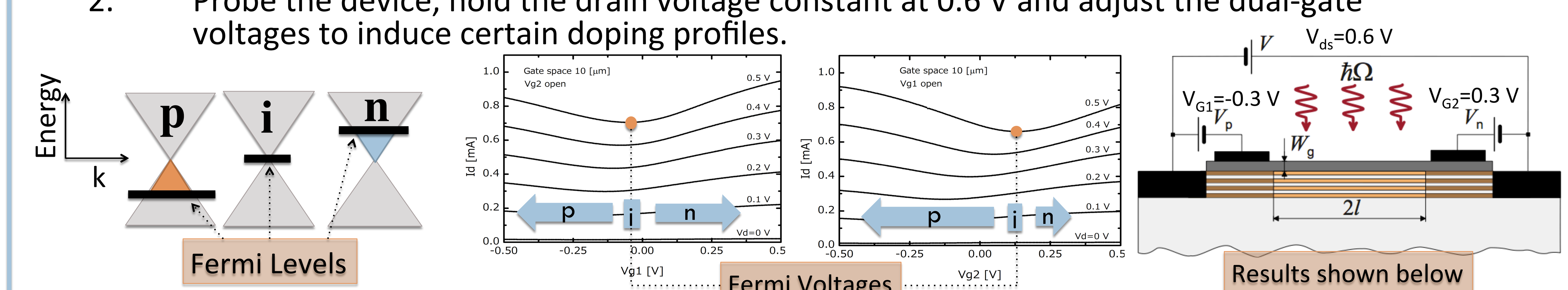
Methods:

1. Generate optical signal with two coherent infrared frequencies 12.5 GHz apart.





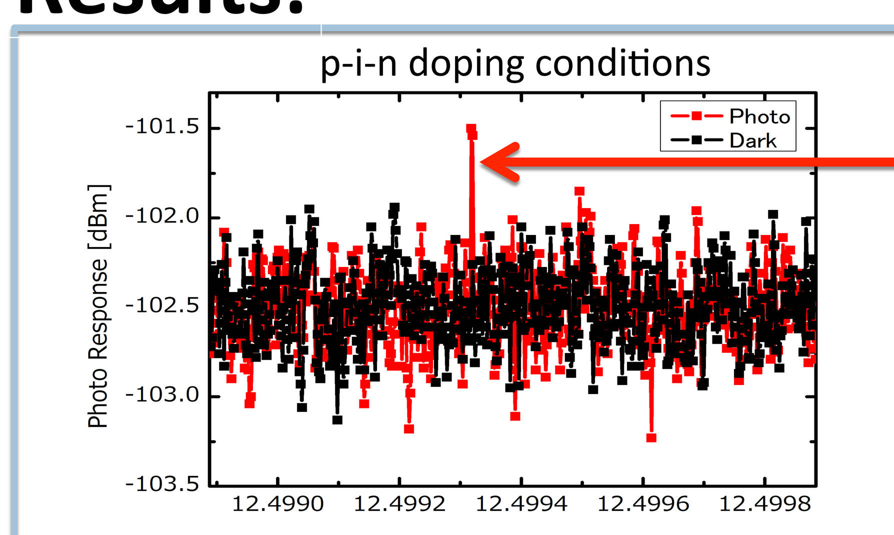
2. Probe the device, hold the drain voltage constant at 0.6 V and adjust the dual-gate voltages to induce certain doping profiles.



3. Illuminate the device from above with generated pump beam and measure the electrical response of the device using a spectrum analyzer.

*V. Ryzhii, M. Ryzhii, V. Mitin & T. Otsuji, **JAP 107**, 054512 (2010).*

Results:



Discussion:

Successfully observed 12.5 GHz electrical response.

Future Research:

To upgrade differential frequency.
To compare with plasmonic detection in a n-i-i mode.
To compare photomixing abilities of G-FET with other available photomixing devices.

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