



# Synthesis of Hexagonal Graphene Using Natural Graphite Crystals

Presented by Clarence King

Advisor: John Jaszczak

**Michigan Tech**

**Nanotech  
Innovations**

In Collaboration with Ethan Miltenberger

SPL

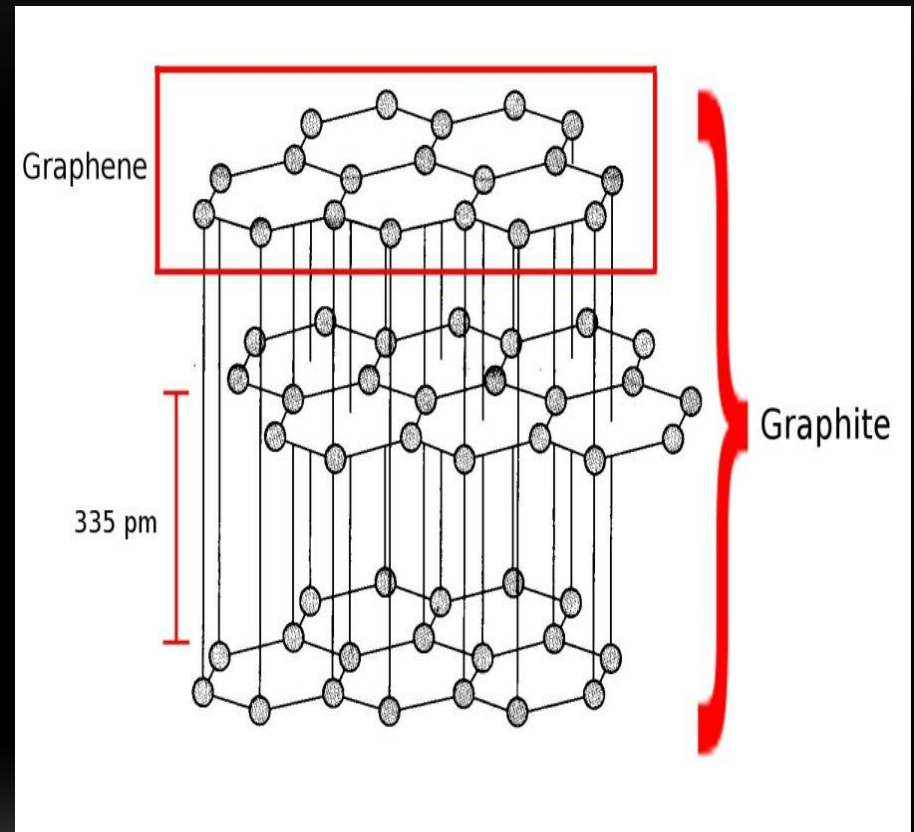
# WHAT IS GRAPHENE AND WHY SHOULD WE CARE?

Single layer of carbon atoms in a 2-dimensional hexagonal lattice

Over 100 times stronger than equally thick steel film

Has one of the highest thermal conductivity values for any known materials

Electrically classified as a zero-band gap semi-metal with very high electron mobility



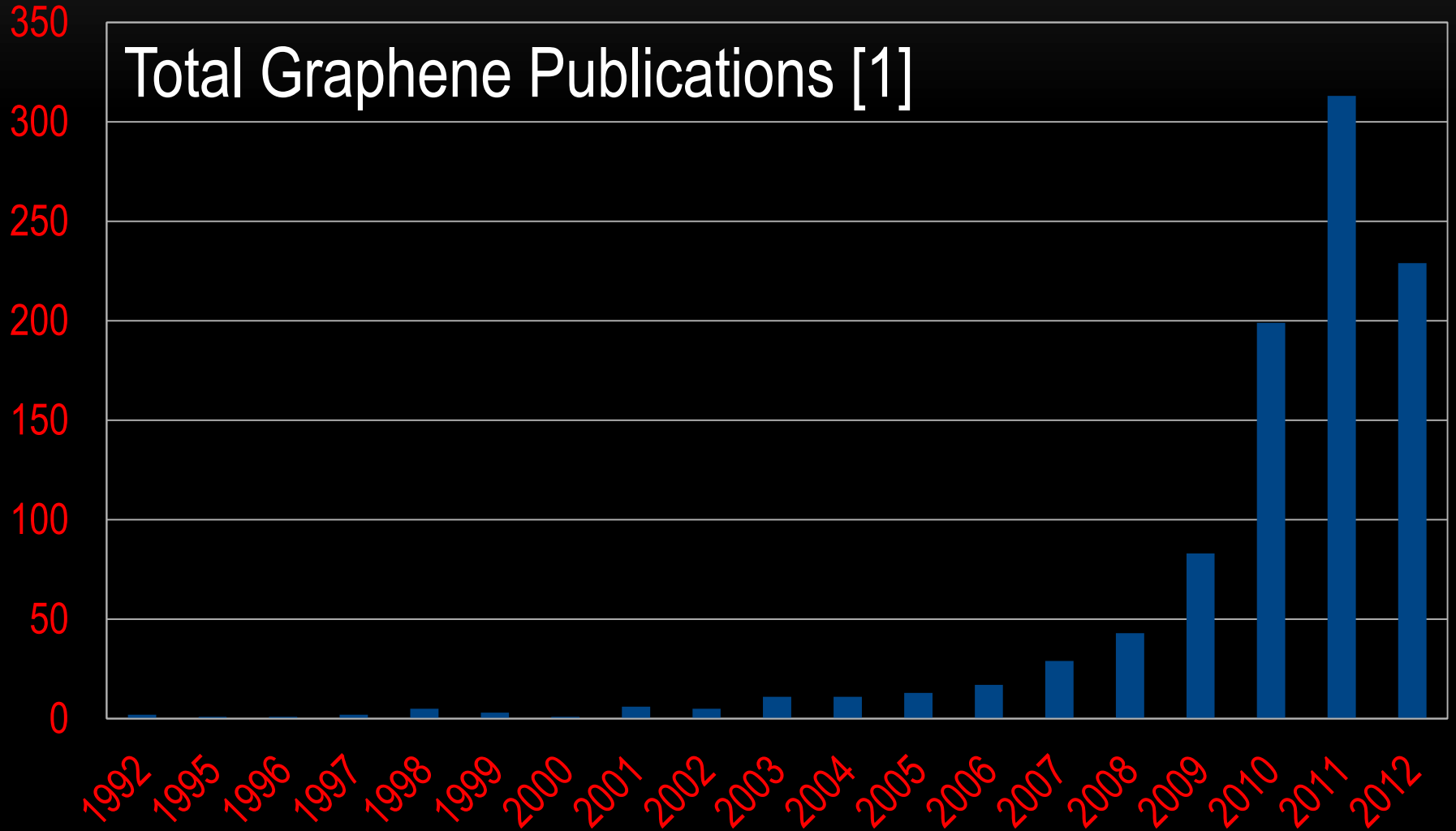
# RESEARCH OBJECTIVES

Synthesis of graphene using mechanical exfoliation

Synthesize hexagonal shaped graphene flakes using naturally occurring graphite hillocks.

Characterization of graphene using optical microscopy and Raman spectroscopy

# MOTIVATION FOR STUDY



# OPTICAL IMAGING OF GRAPHENE



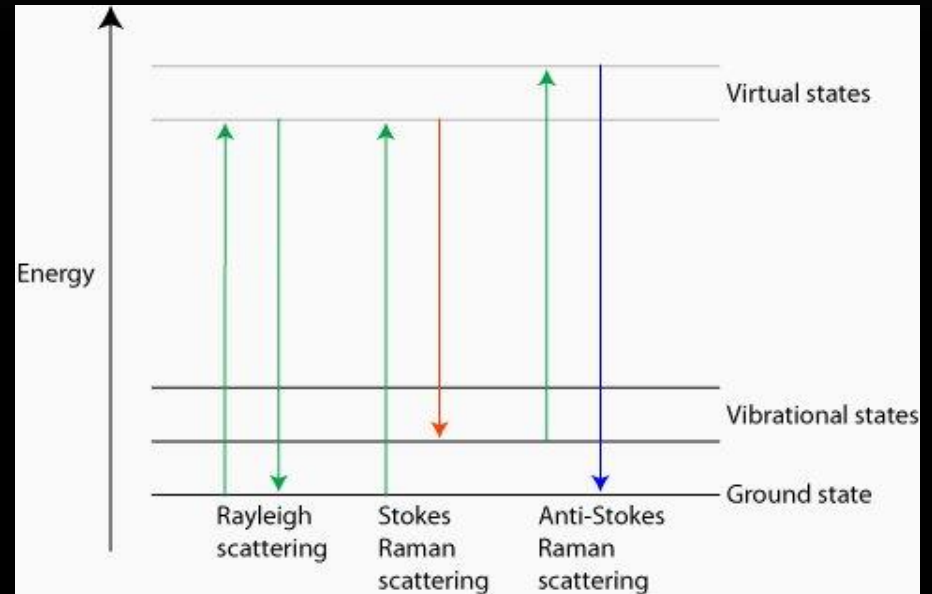
Peres et al. 2009 [2]

# RAMAN SPECTROSCOPY BASICS

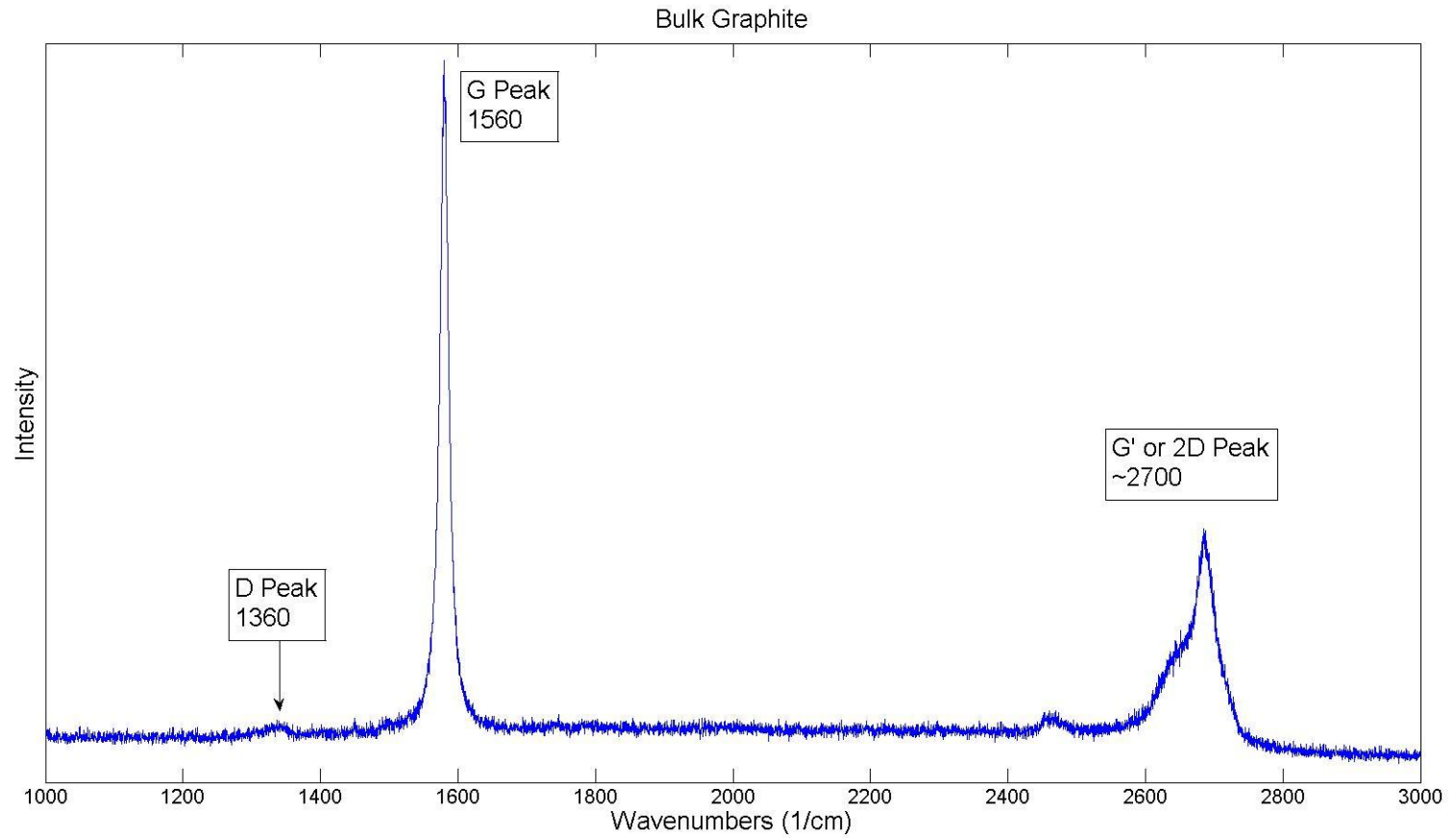
Incident light on a molecule will be scattered either elastically (Rayleigh) or inelastically (Raman)

In Raman scattering, energy is transferred into mechanical vibrations (phonons)

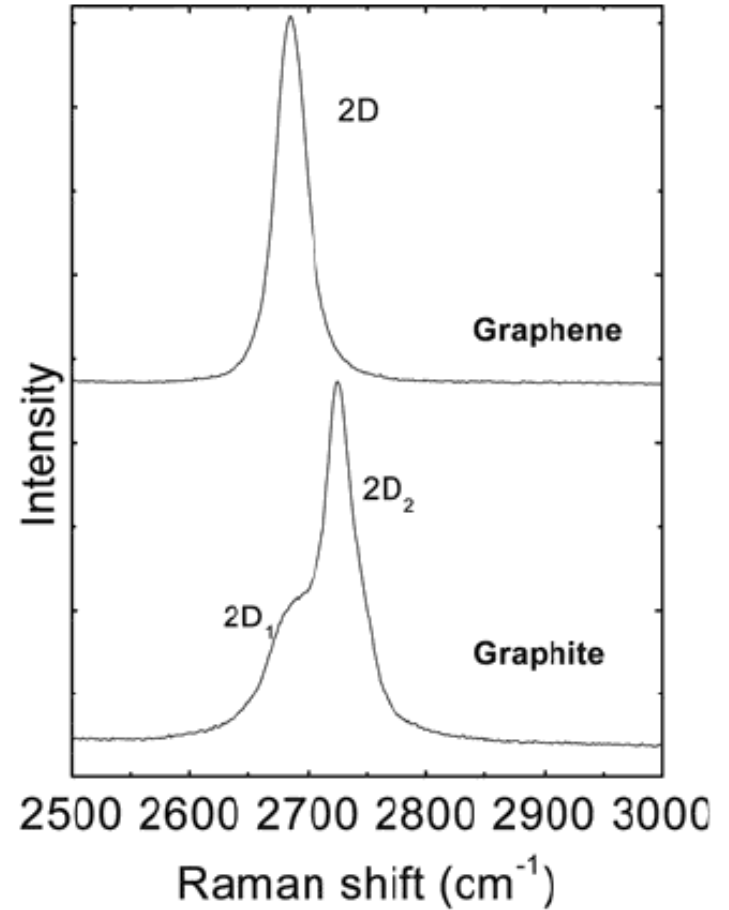
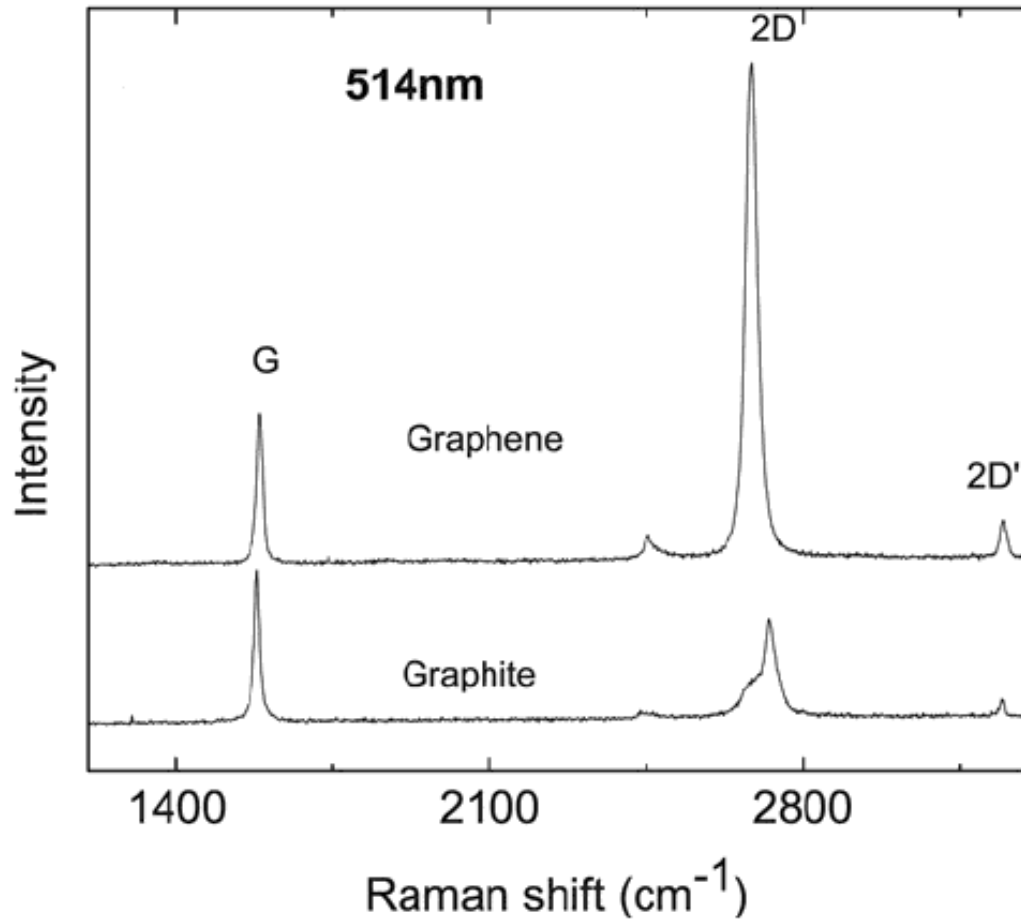
This energy shift corresponds to a shift in photon frequency which can be measured



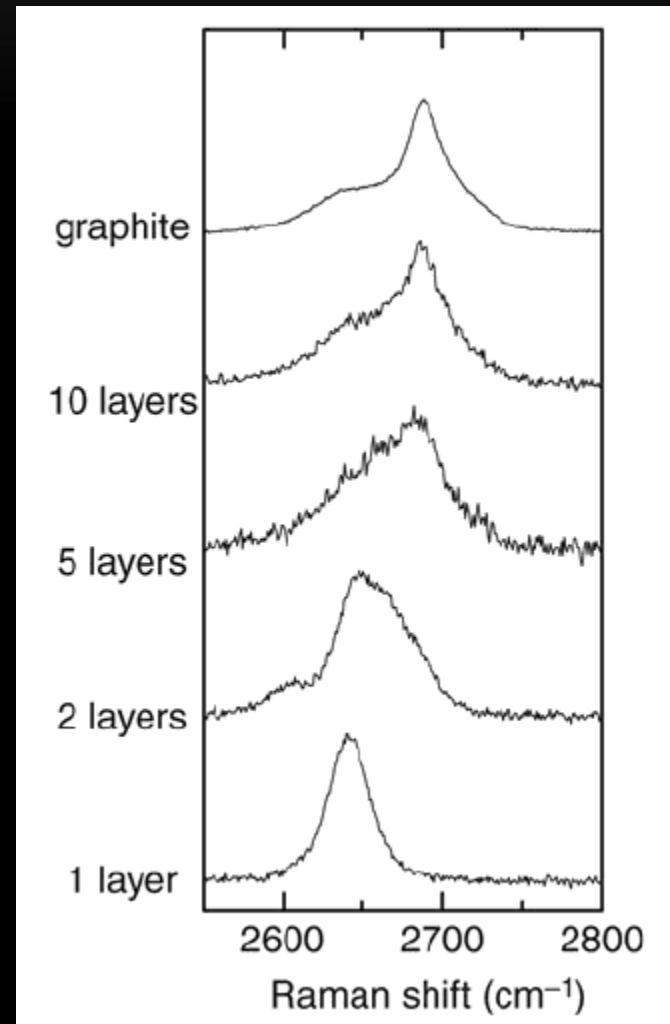
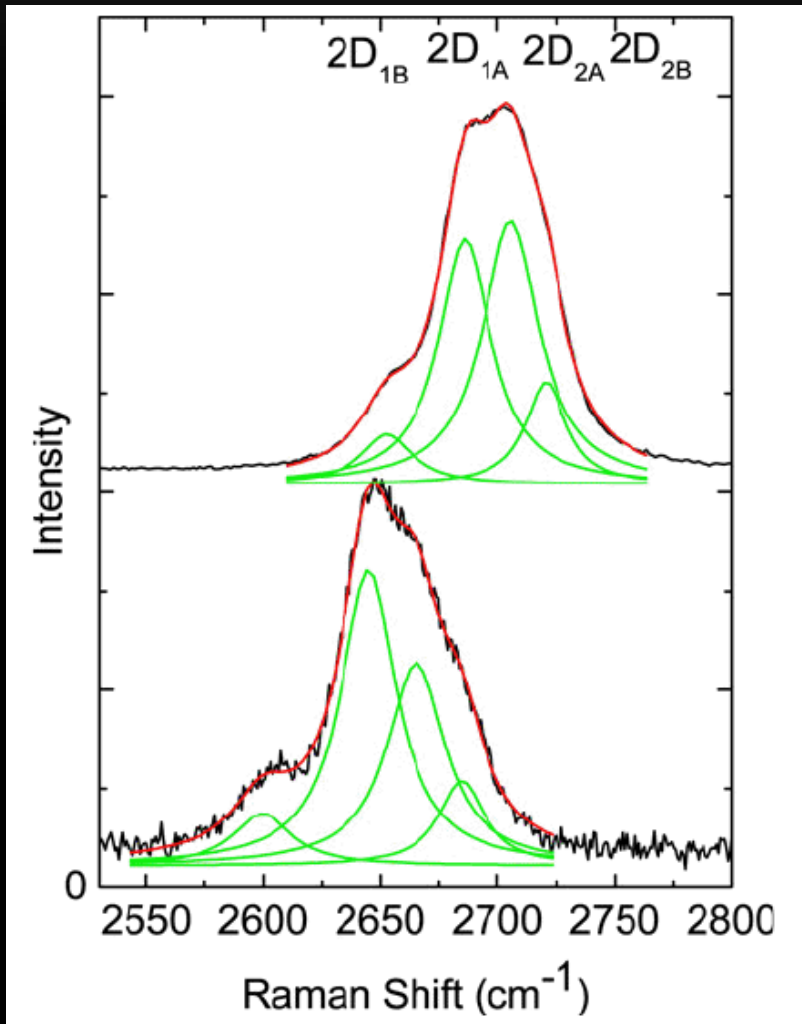
# RAMAN SPECTRUM OF GRAPHITE



# RAMAN SPECTRUM OF GRAPHENE

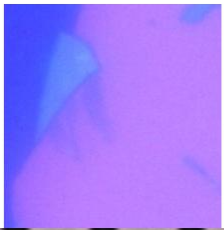


# RAMAN SPECTRUM OF GRAPHENE



# RESULTS: GRAPHENE FLAKES

Single Layer



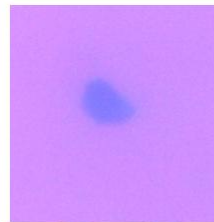
Bi-Layer



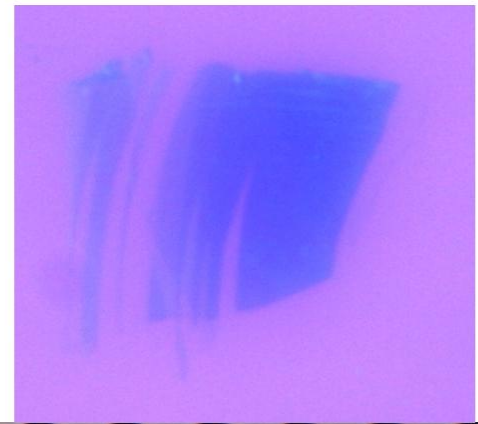
3-Layer



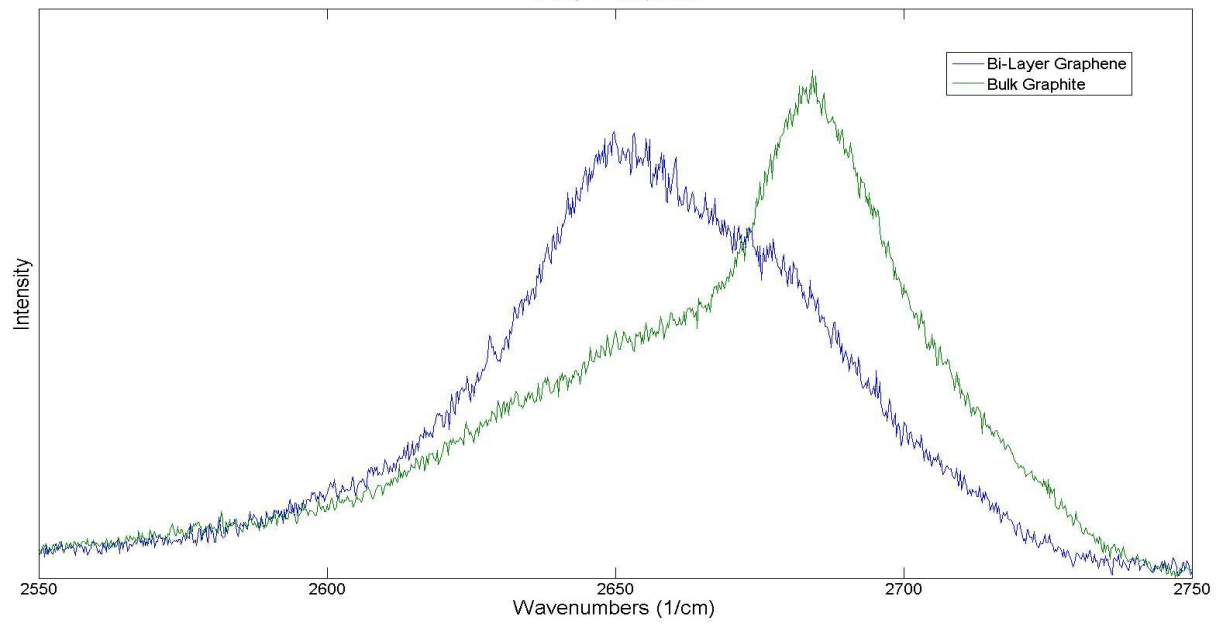
5-Layer



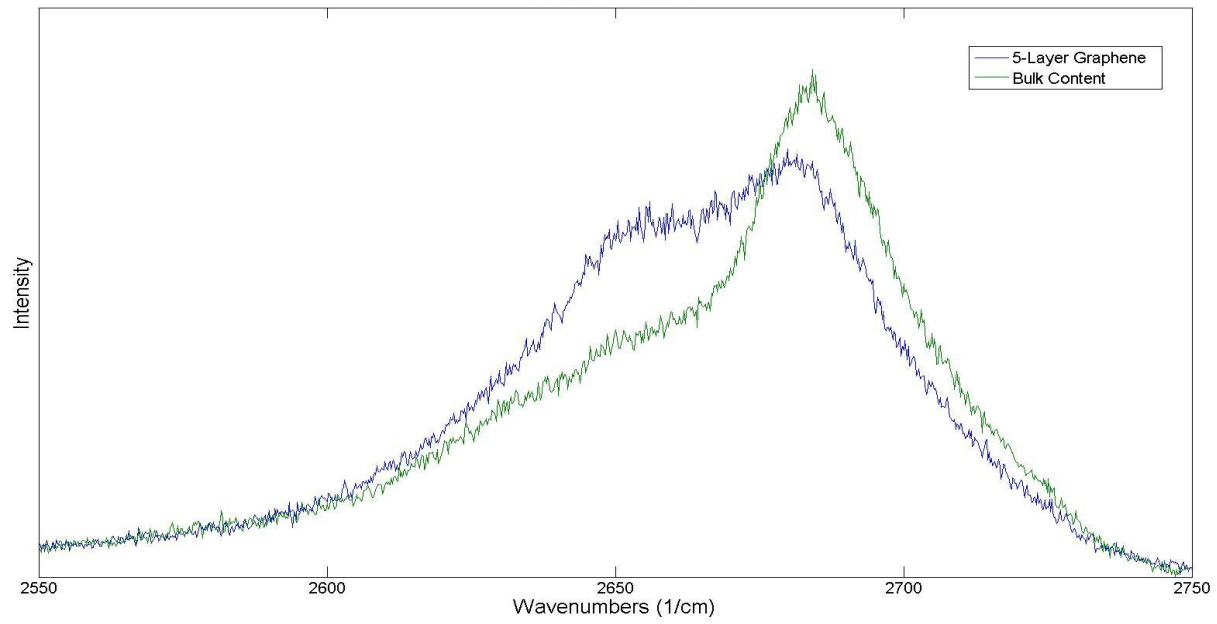
Multi Layer



Bi-Layer Graphene



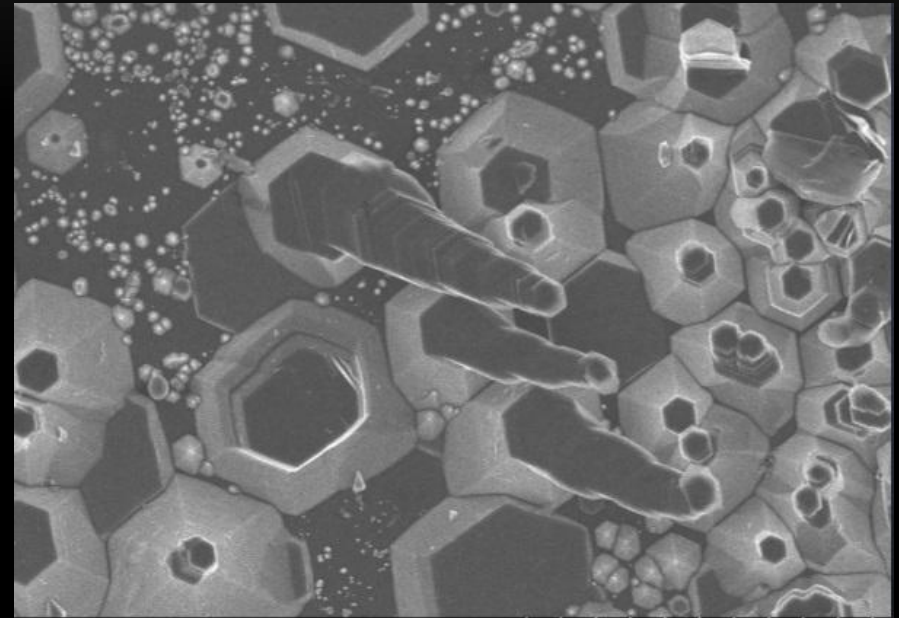
5-Layer Graphene



# GRAPHITE HILLOCKS

Natural graphite formations  
with very little to no structural  
defects

Easily cleave into hexagonal  
graphite flakes

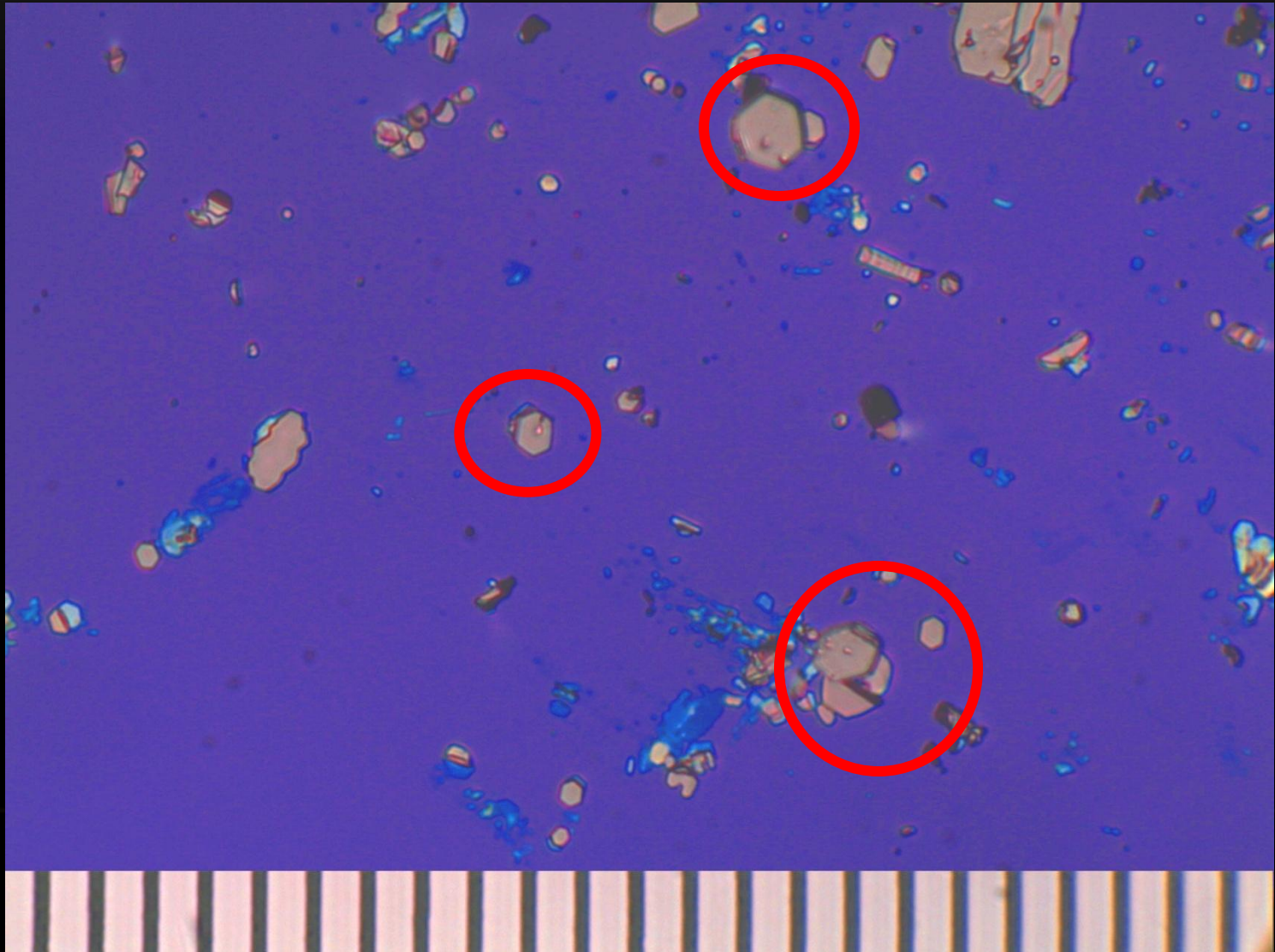


S4700 5.0kV 6.6mm x2.50k SE(U)

20.0um

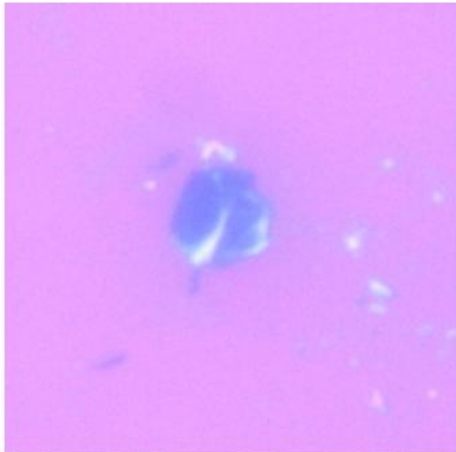
SEM image of Graphite Hillocks courtesy of Ethan Miltenberger

# INITIAL RESULTS: GRAPHITE HEXAGONS

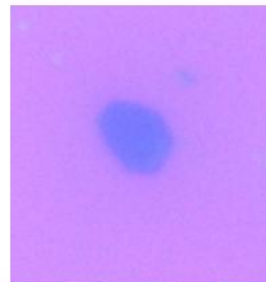


# FINAL RESULTS: GRAPHENE HEXAGONS

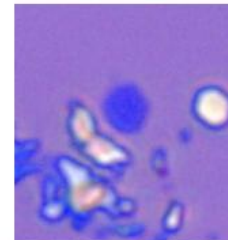
4-Layer



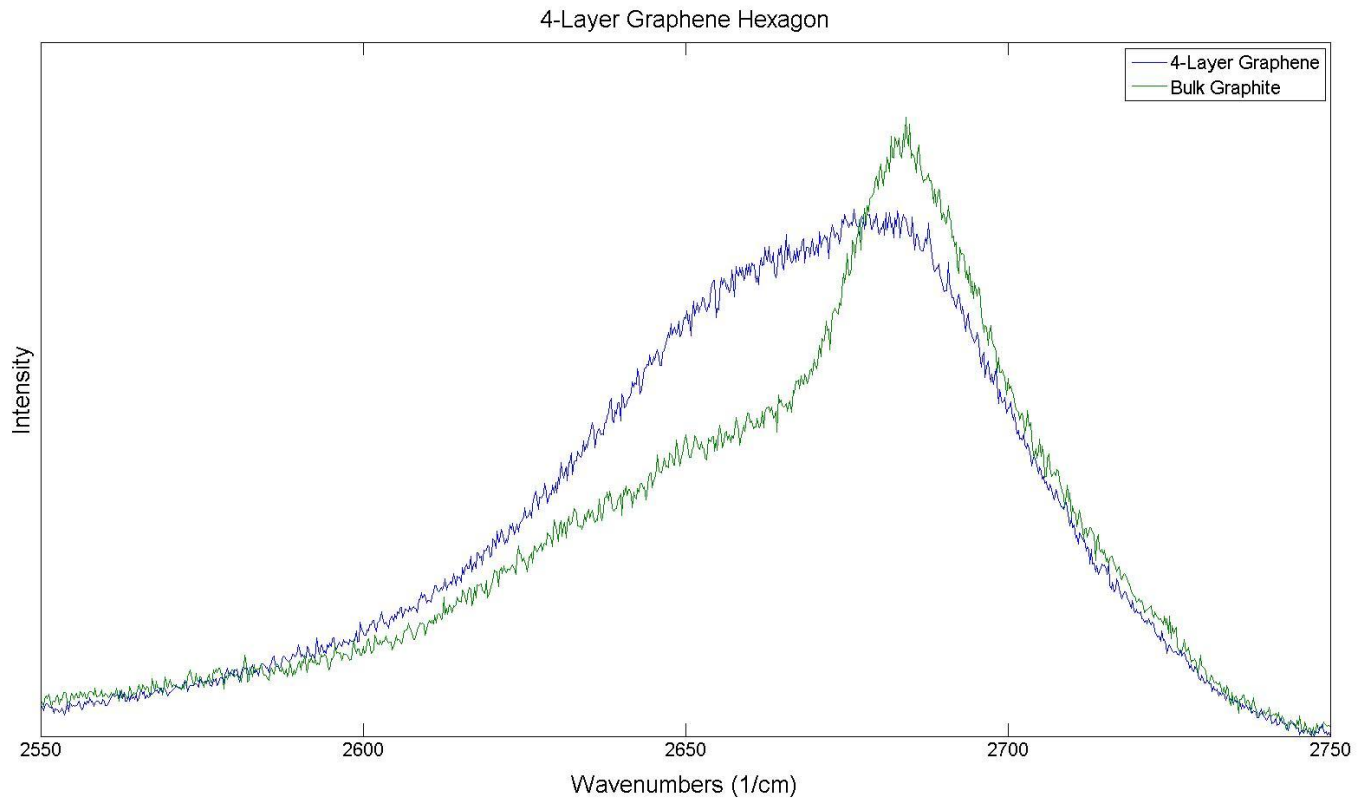
5-Layer



Multi Layer



# FINAL RESULTS: GRAPHENE HEXAGONS



# FUTURE RESEARCH

Refine technique to possibly get single layer graphene hexagons and larger flakes in general

Detailed Fourier analysis of 2D Raman peak of graphene

# REFERENCES

1. Raw data from Sciverse Scopus database Summer 2012
2. Peres, N. M. R and Ricardo M Ribeiro. "Focus on Graphene." *New Journal of Physics*: Volume 11, Number 9. September 2009. Image.
3. Ferrari, Andrea C. "Raman Spectroscopy of Graphene and Graphite: Disorder, Electron–Phonon Coupling, and Nonadiabatic Effects" *Solid State Communications*: Volume 143, Number 1-2. 2007.

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