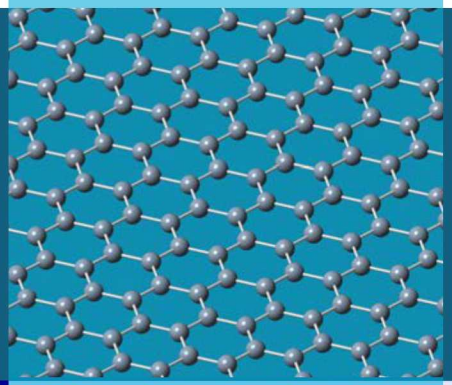
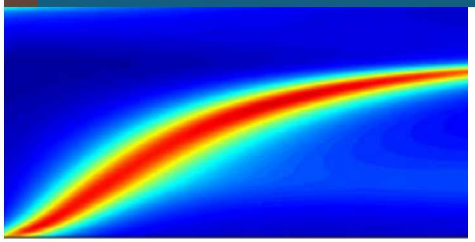
SAND2019-13303C

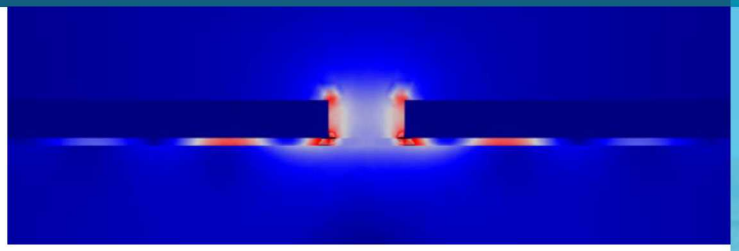
Sandia National Laboratories

Phonon Sculpting

Infrared Functionality via Vibration







Thomas Beechem

Team

SNL: A. Jarzembski, E. Paisley, C. Saltonstall, J. Shank, S. Smith

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PSU: JP Maria, R. Engel-Herbert

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PennState

VANDERBILT UNIVERSITY

UNIVERSITY of VIRGINIA

PIKE TECHNOLOGIES

U.S. NAVAL RESEARCH LABORATORY

U.S. DEPARTMENT OF ENERGY

NNSA

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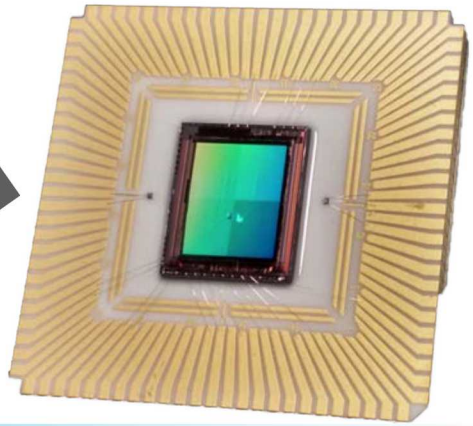
Vision: Dynamic Multi-Functional IR Sensing

Imagine



Right Now

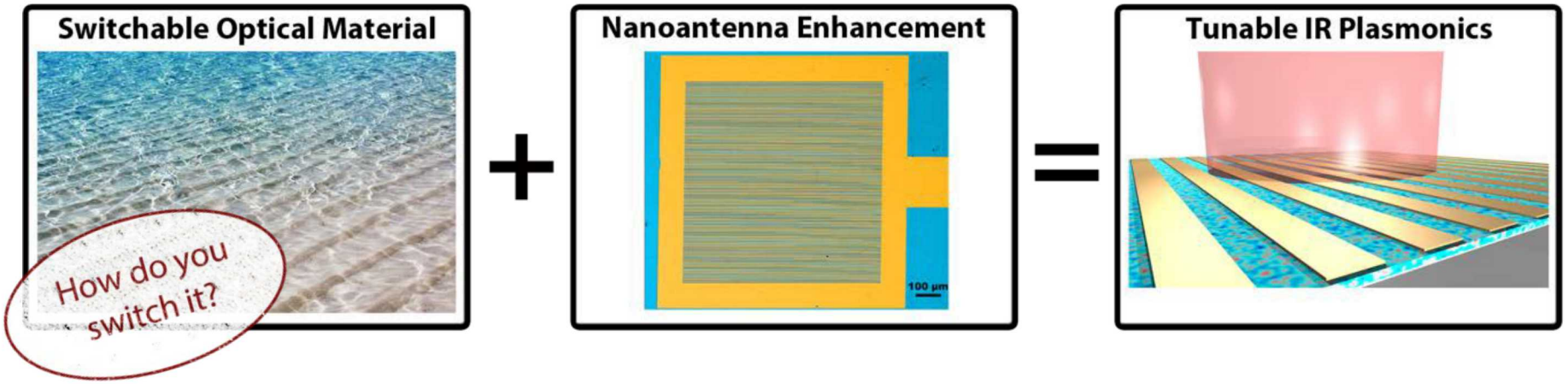
Problems:

1. One color for whole array
2. Moving Parts

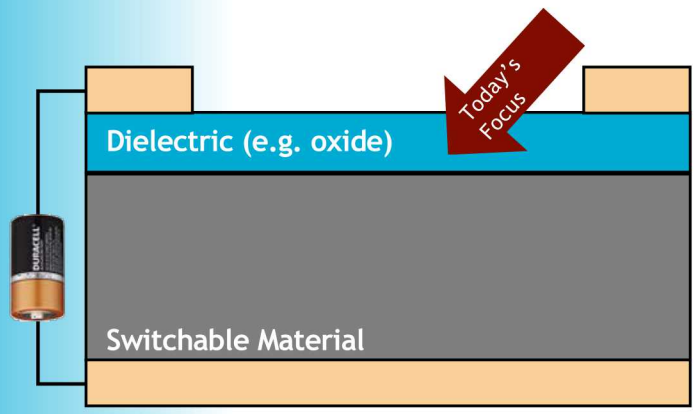
Images: Jasco & TelOps

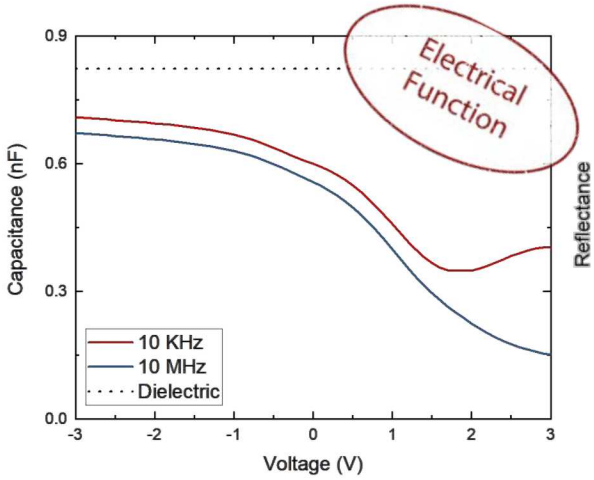
Always the Bridesmaid: Infrared Dielectrics

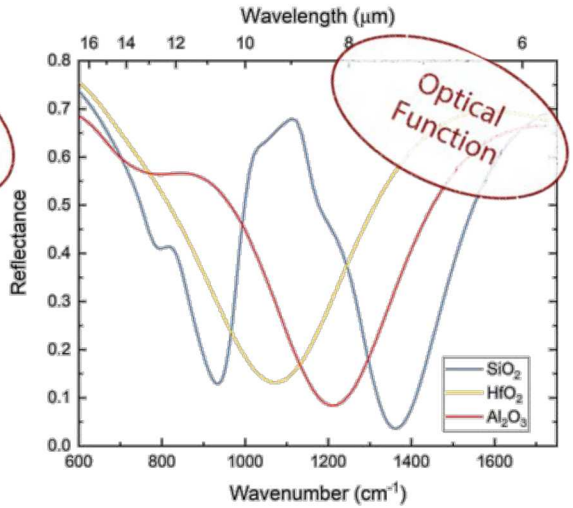
Need: Dynamic, Tunable, Infrared Devices



Indispensable Dielectric



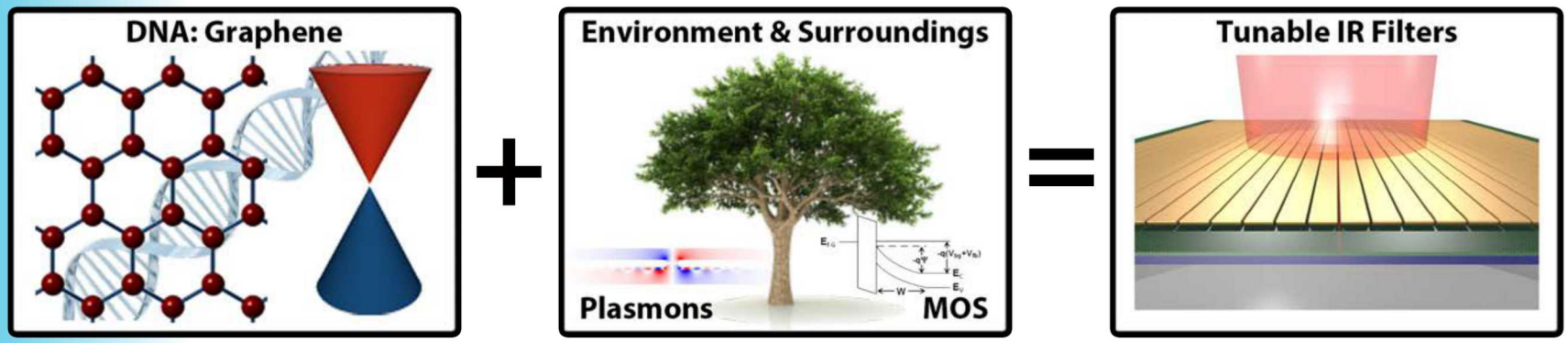




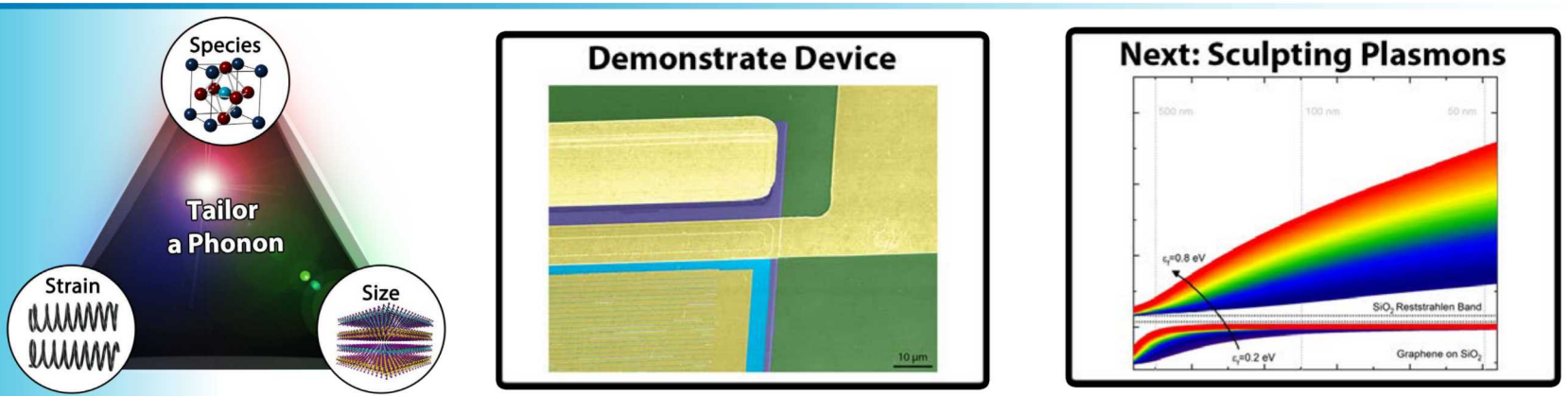
Perspective: Integrated Graphene Infrared Filters

Goal: Spectrally tunable filters at single pixel level

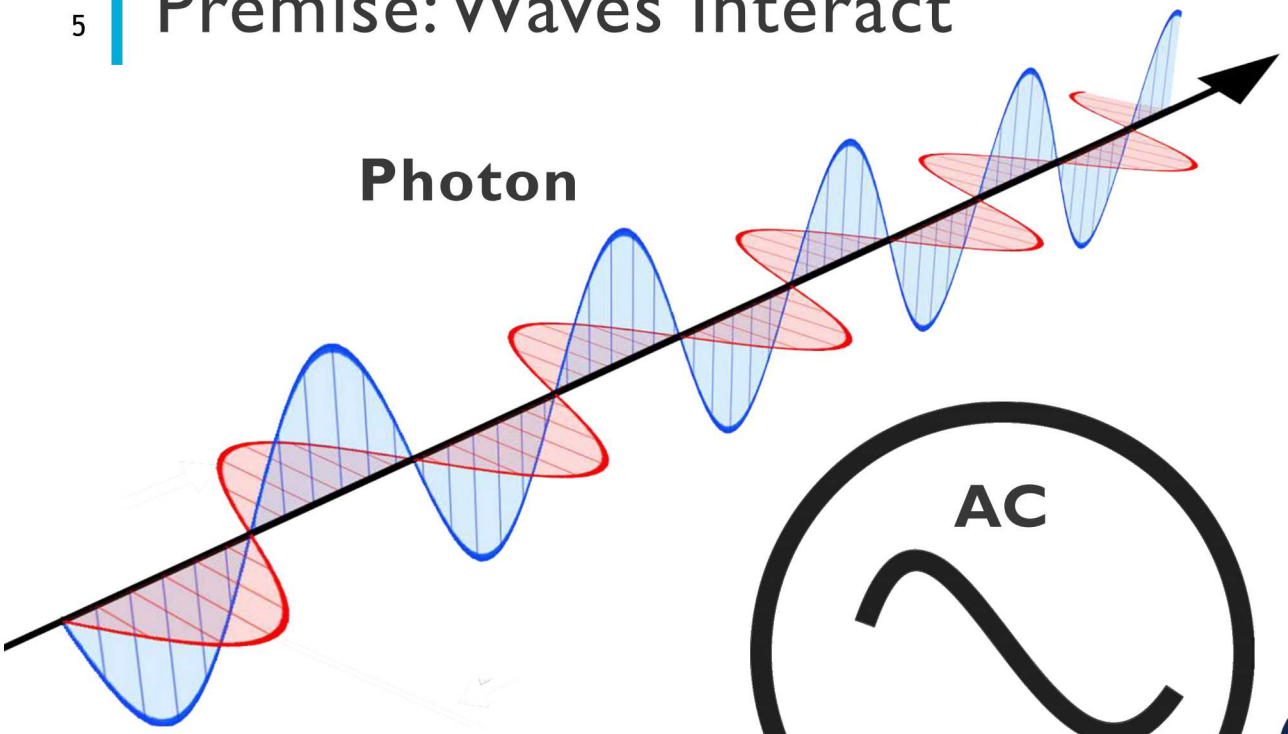
Premise



Path



Premise: Waves Interact



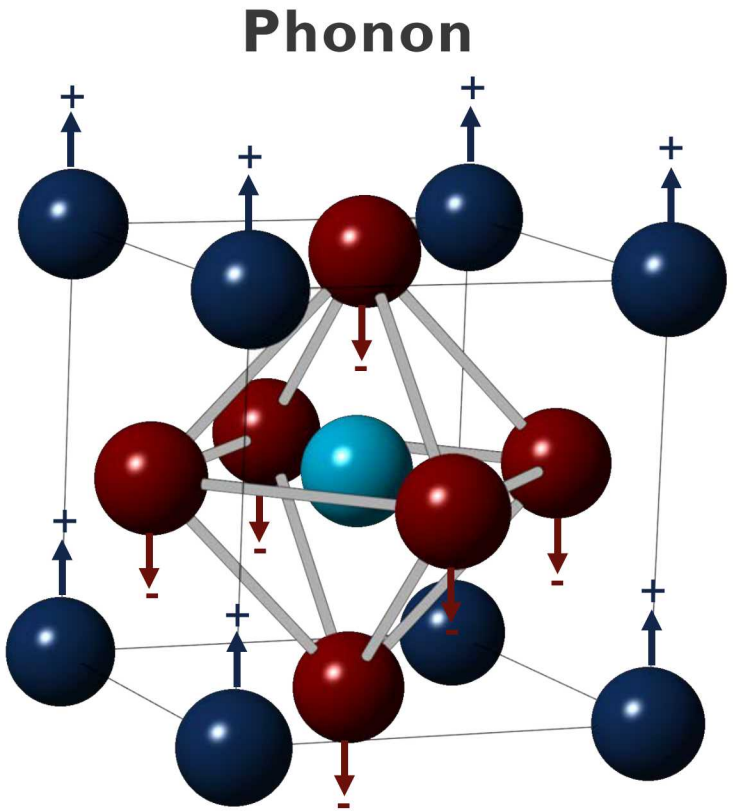
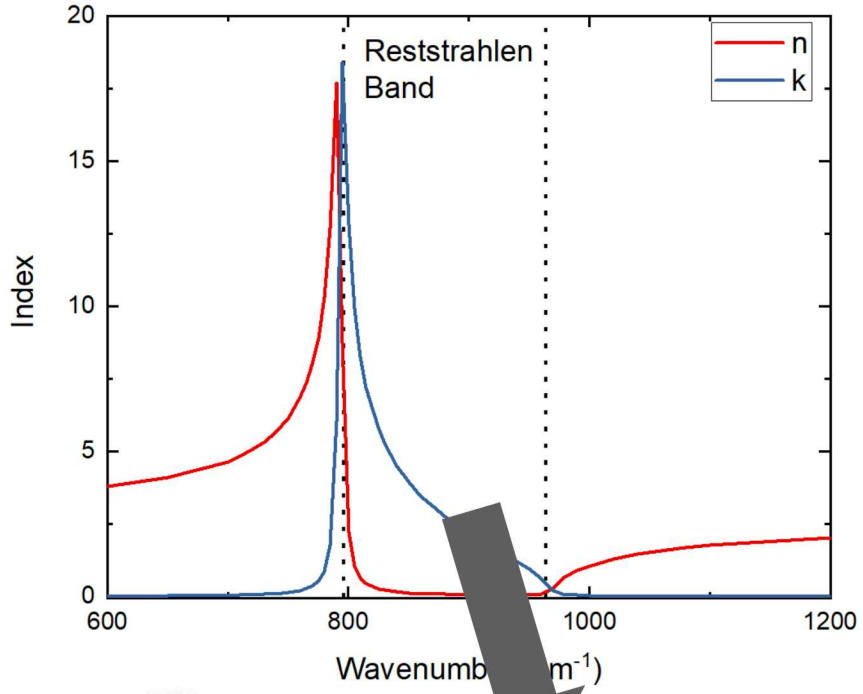
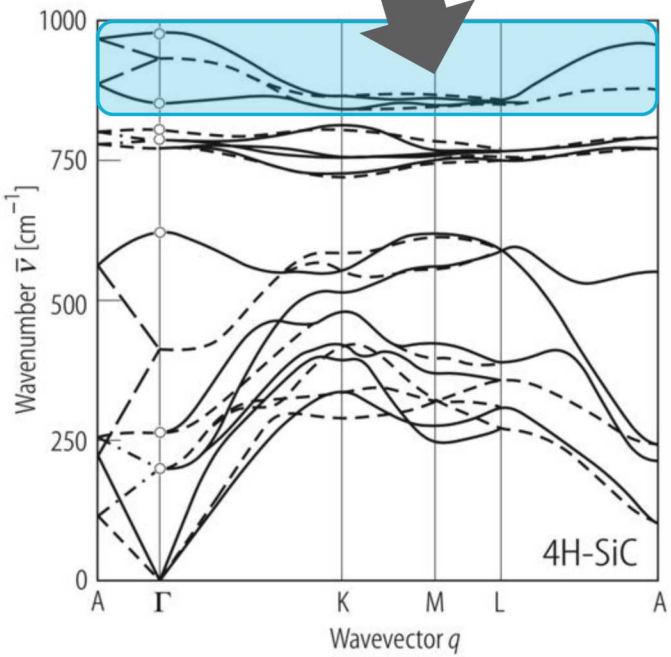
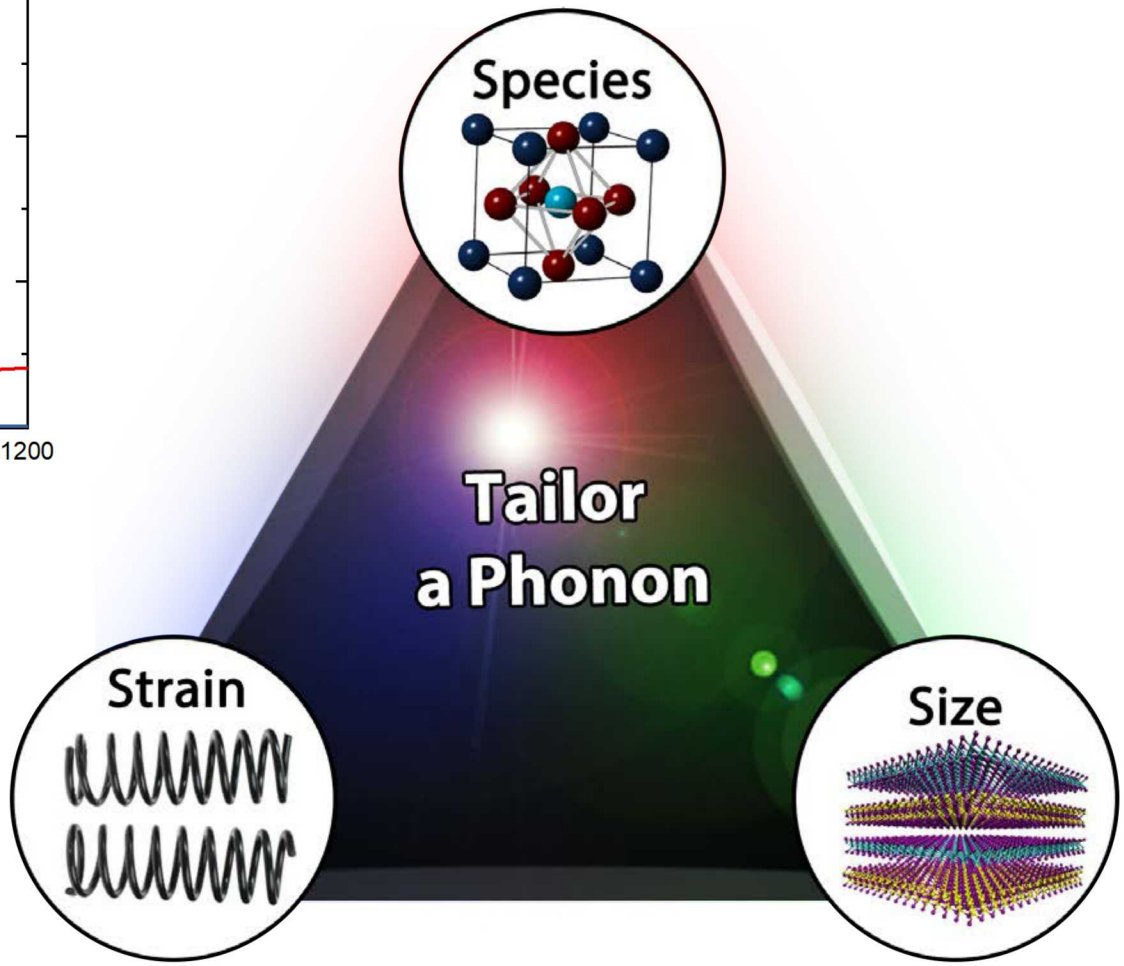


Image: EM-Wave. Toppr.com

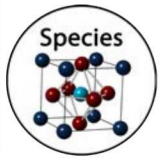
Idea: Designer Phonons for Infrared Optics



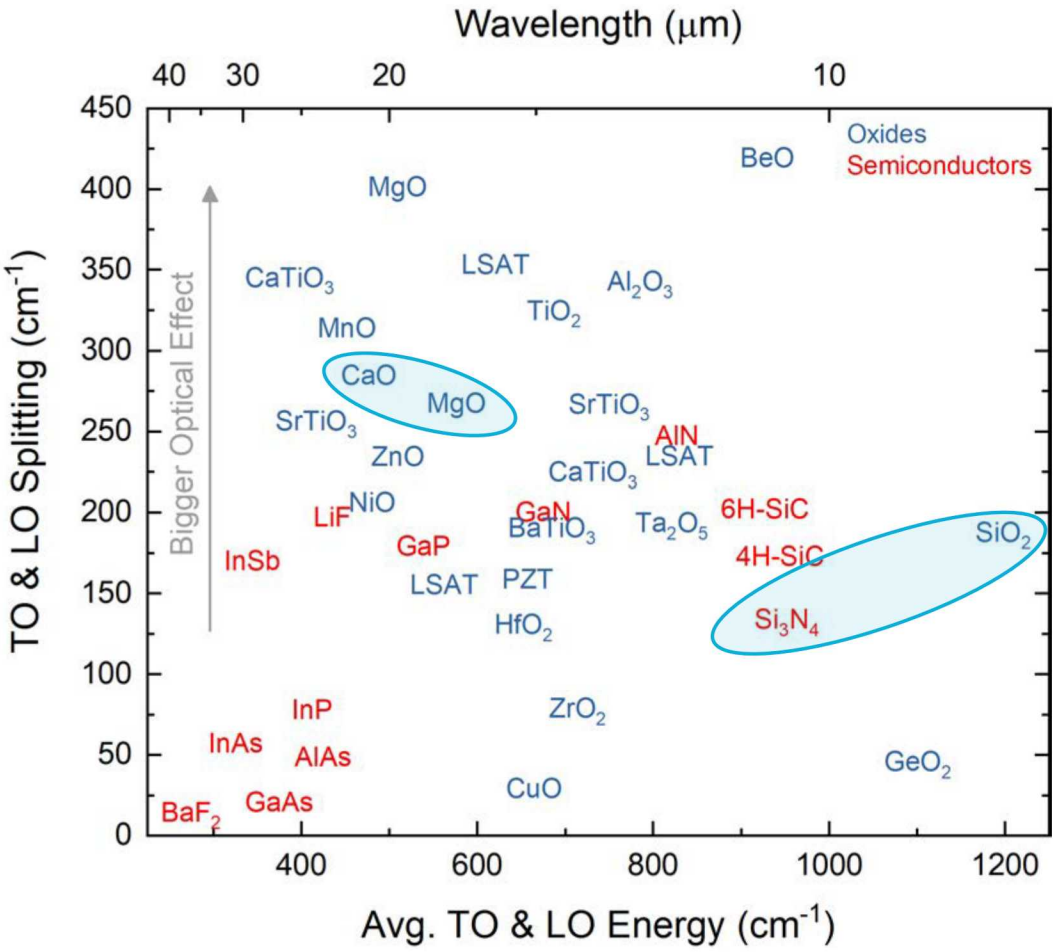


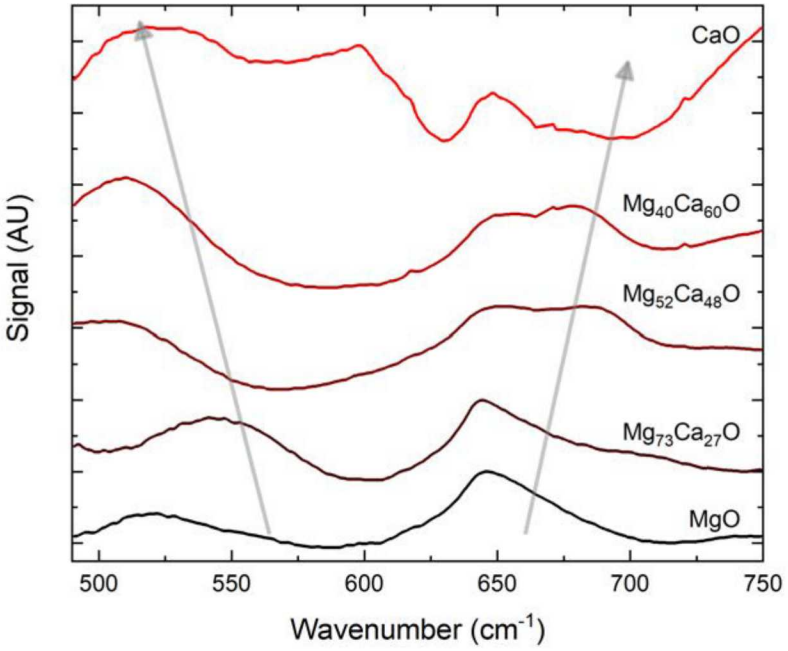


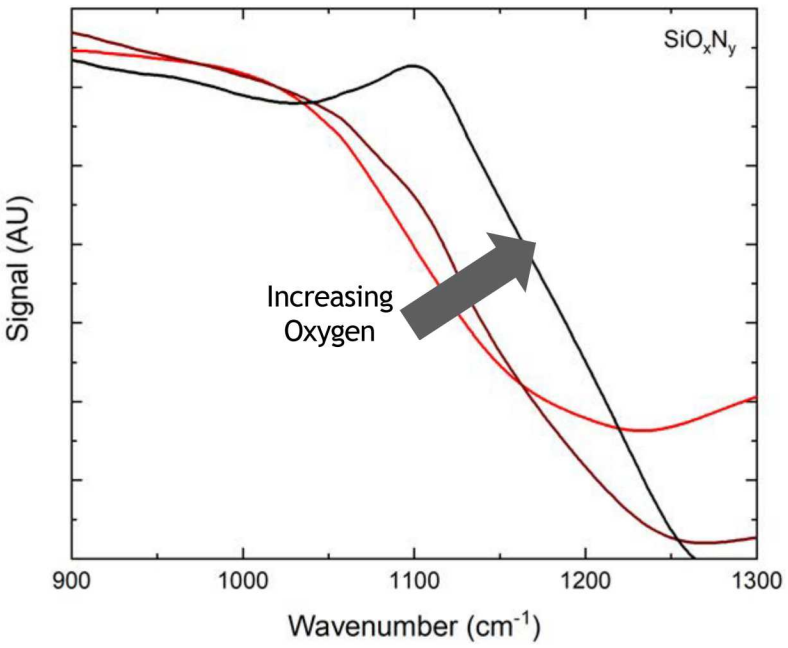
Dispersion: Springer "SiC phonon dispersion relations, density of states"



Designing Optical Response via Phonon Alloys



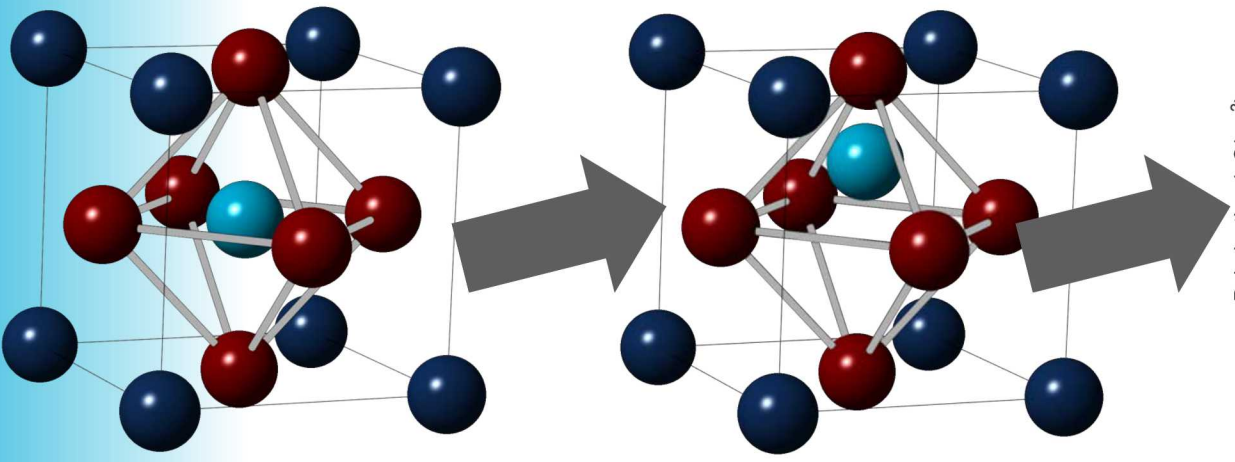


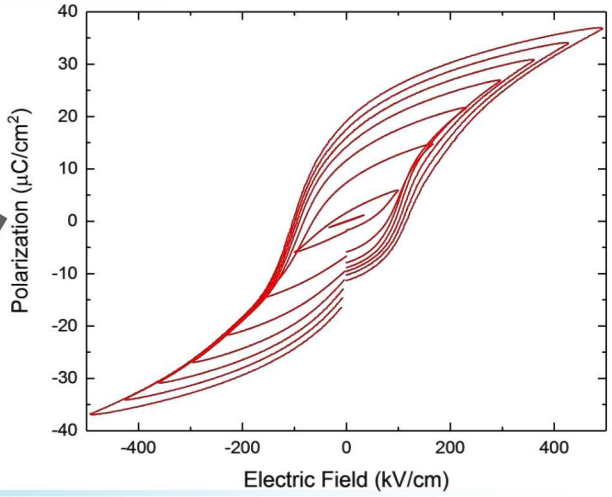


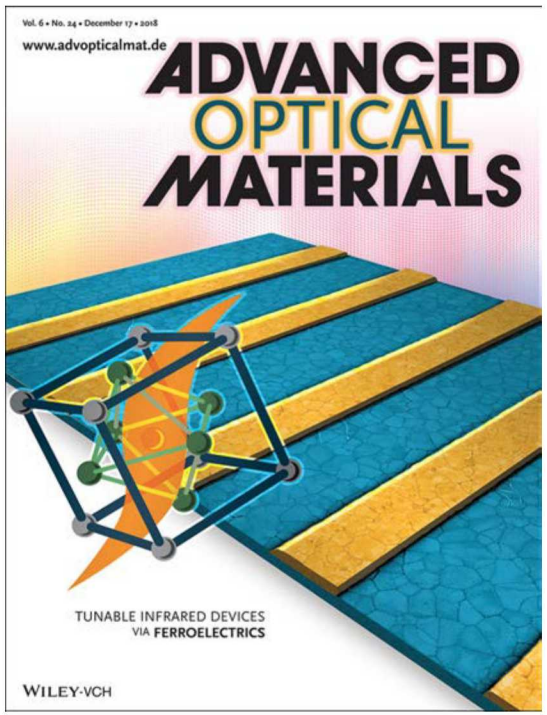
Strain

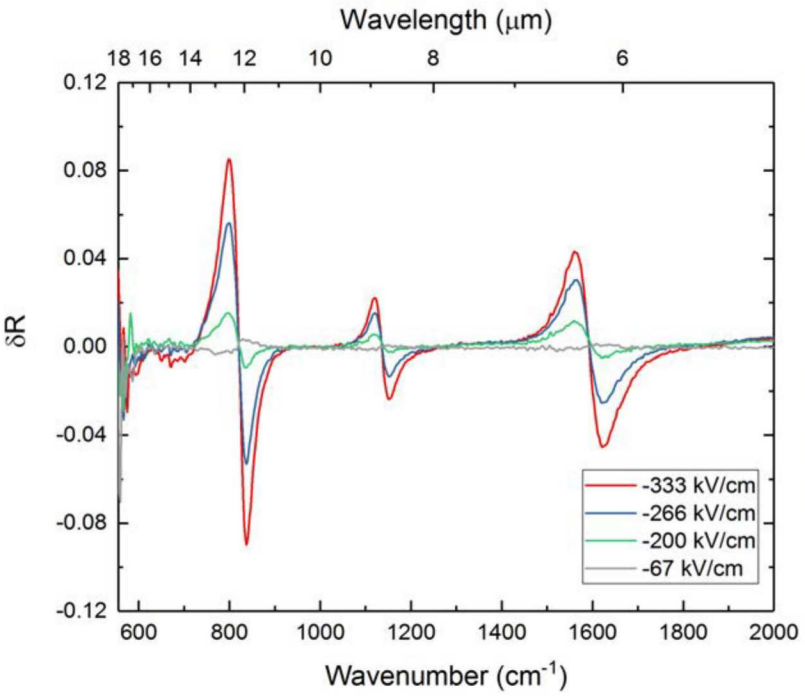
Tunable Plasmonics via Tunable Phonons

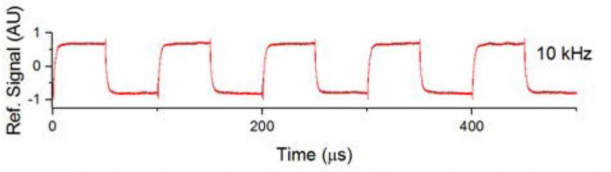
Affects Phonons?

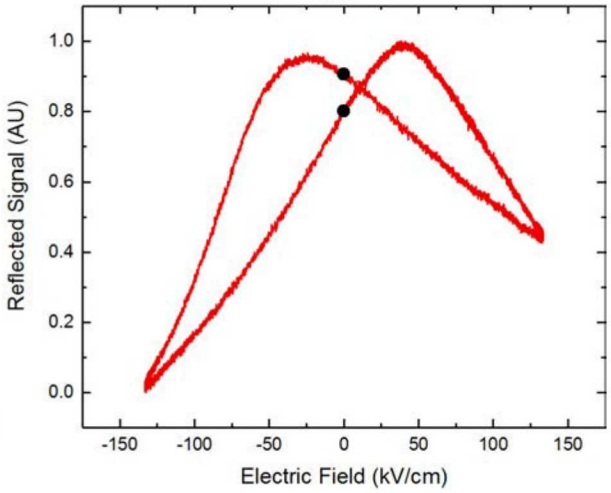




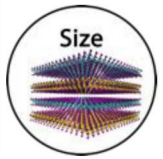








Details: Beechem et al. Adv. Opt. Mat. (6) 1800862. 2018



Coherency in Optical Response

PennState
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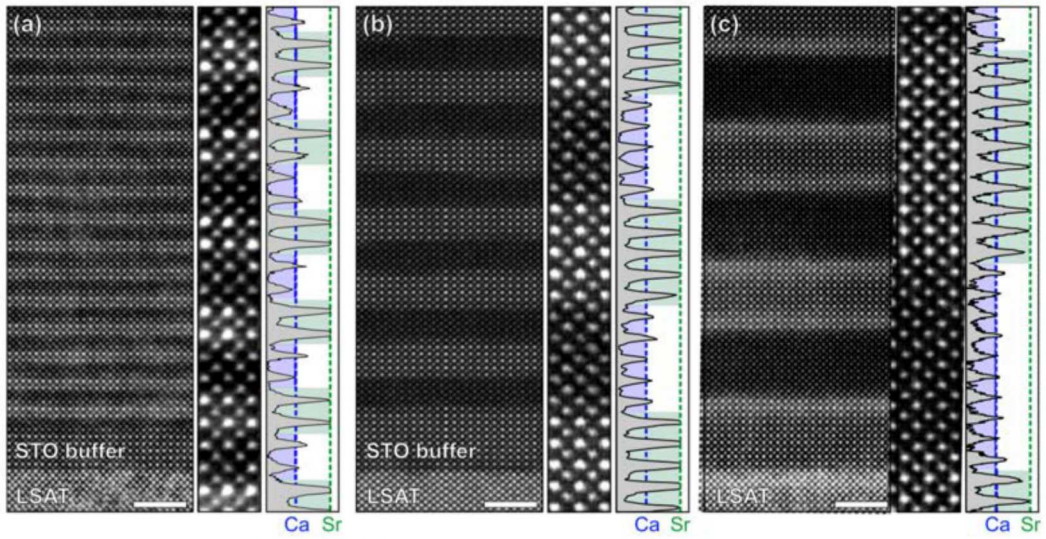
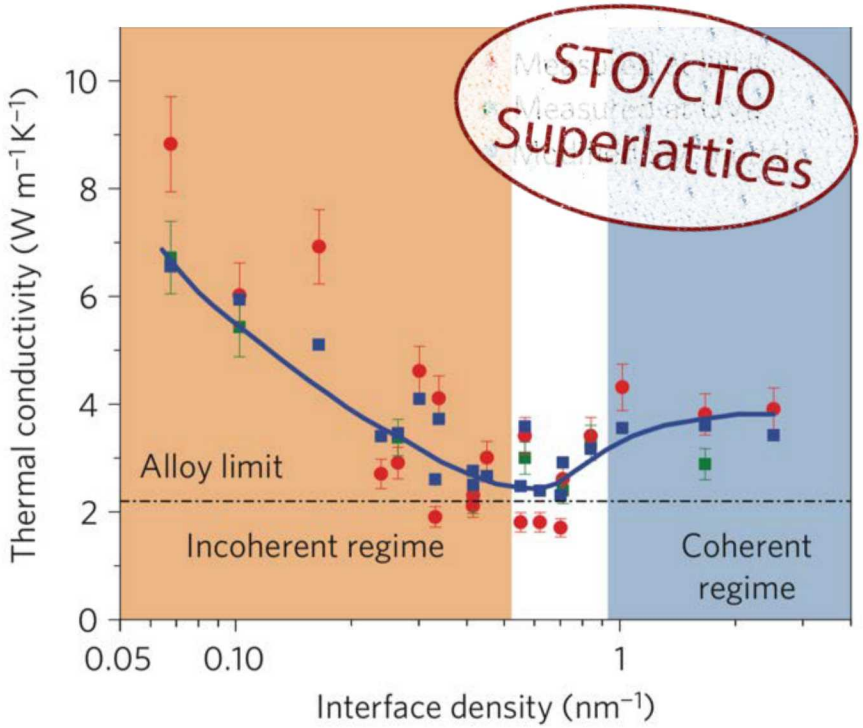
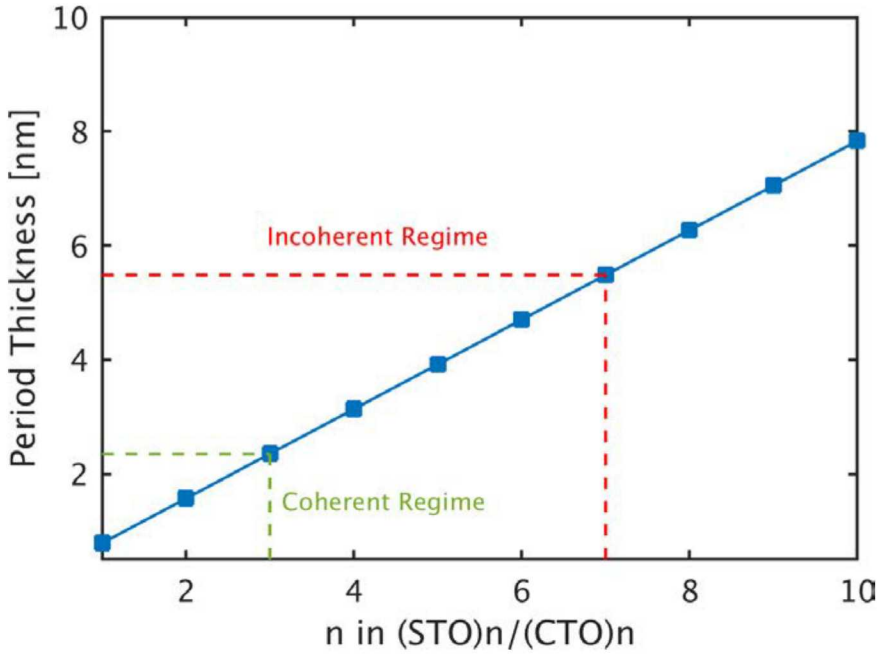
UNIVERSITY of VIRGINIA

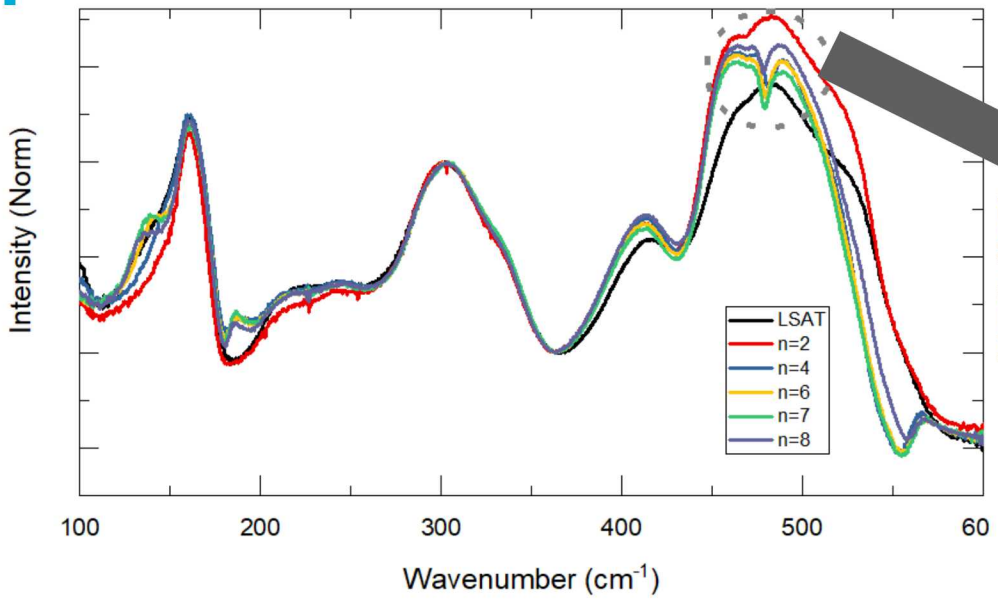


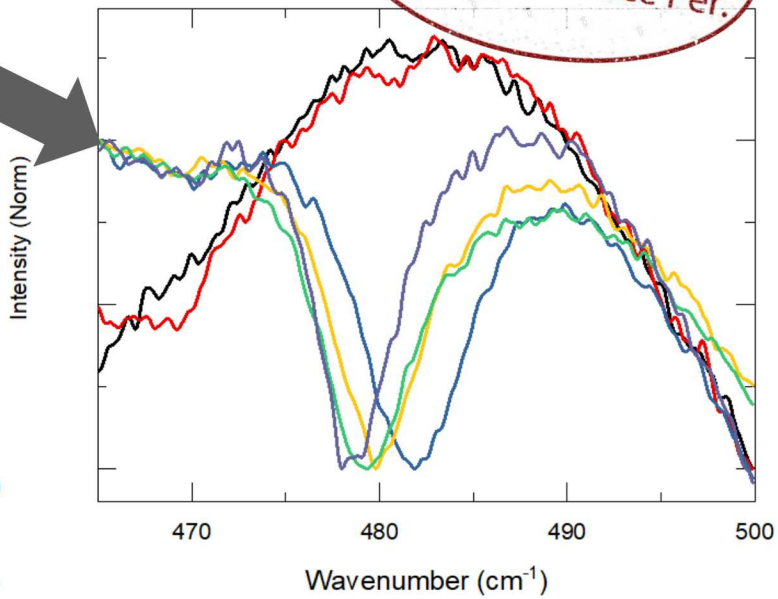




TEM Images: Haislmaier et al. APL Mater. (6) 111104. 2018, Therm. Cond.: Ravichandran et al. Nat. Mat. (13) 168 2014.

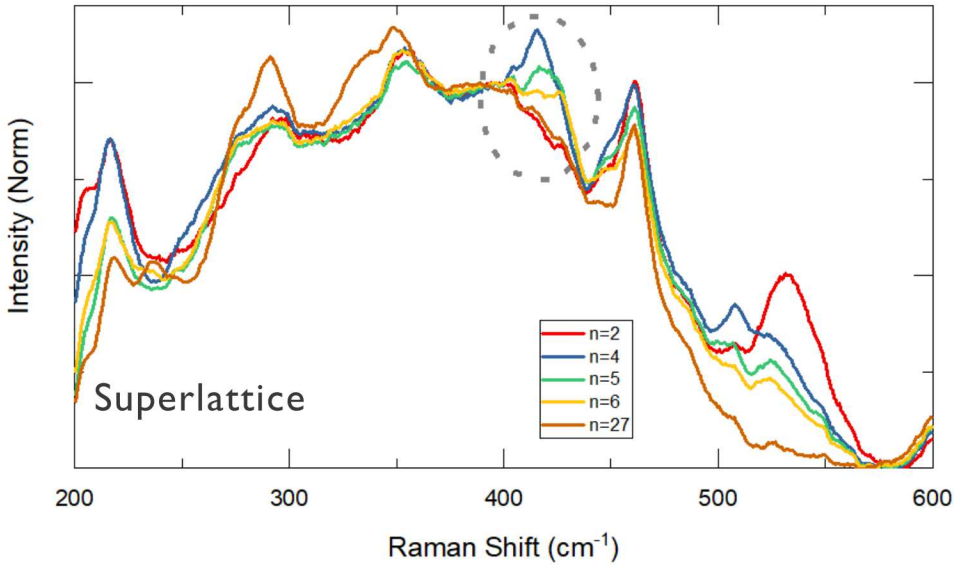
Epitaxial Superlattices: STO/CTO

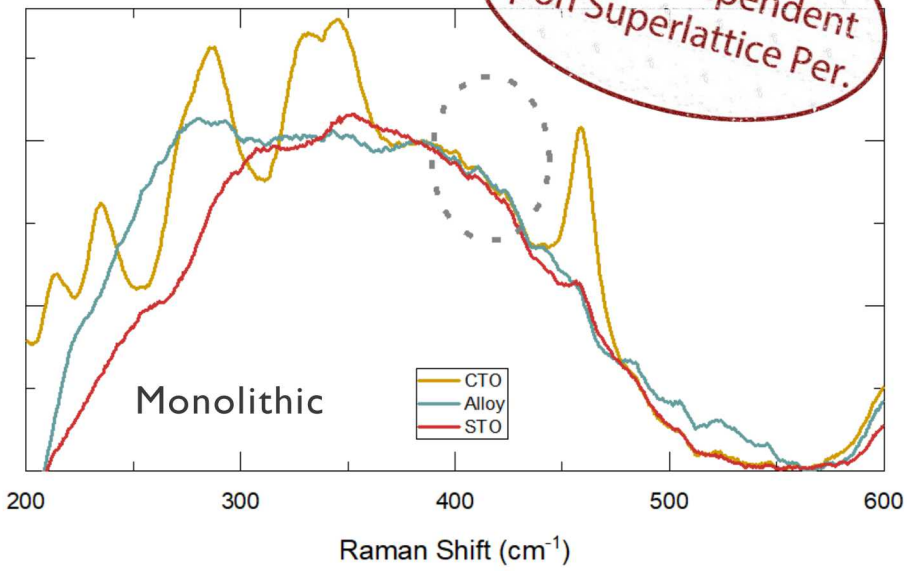




FTIR: Response dependent upon Superlattice Per.

Takeaway: Periodicity changing phonons

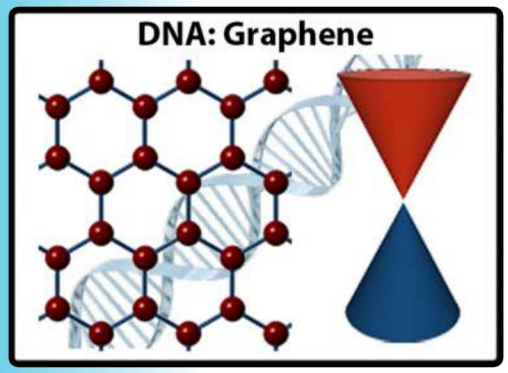




Raman: Response dependent upon Superlattice Per.

Phonon "Flavored" Graphene Infrared Filters

Premise



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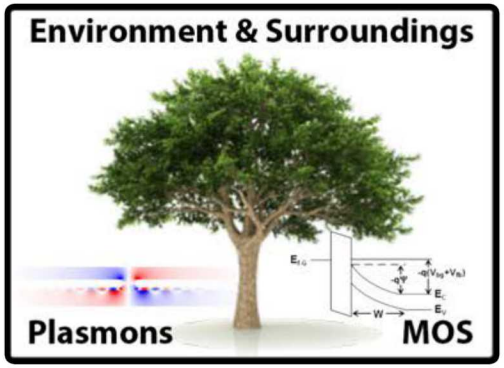

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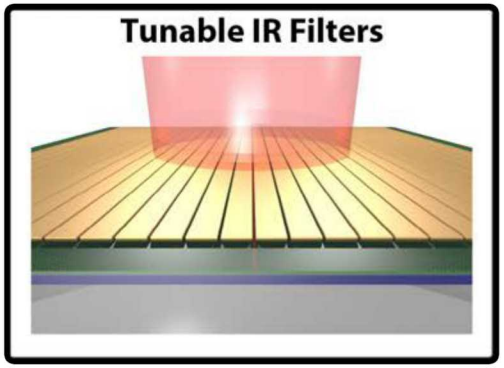
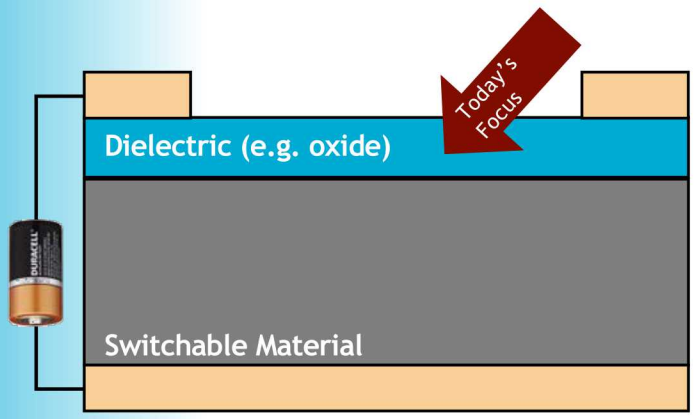
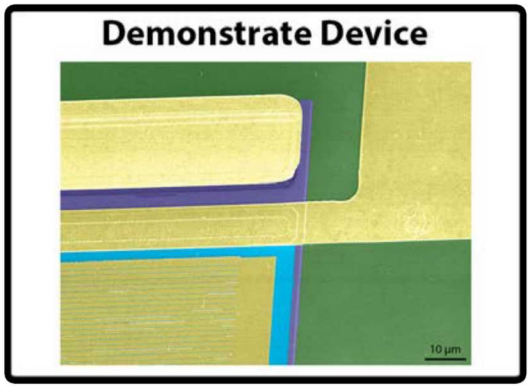
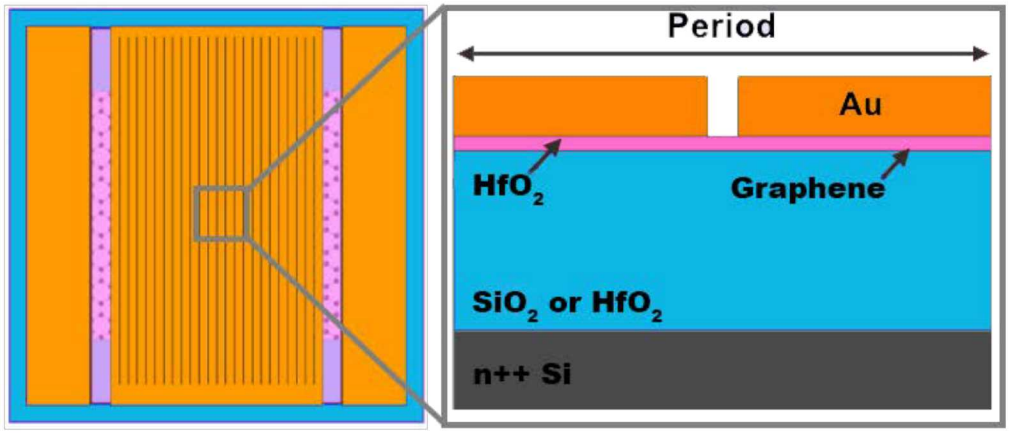


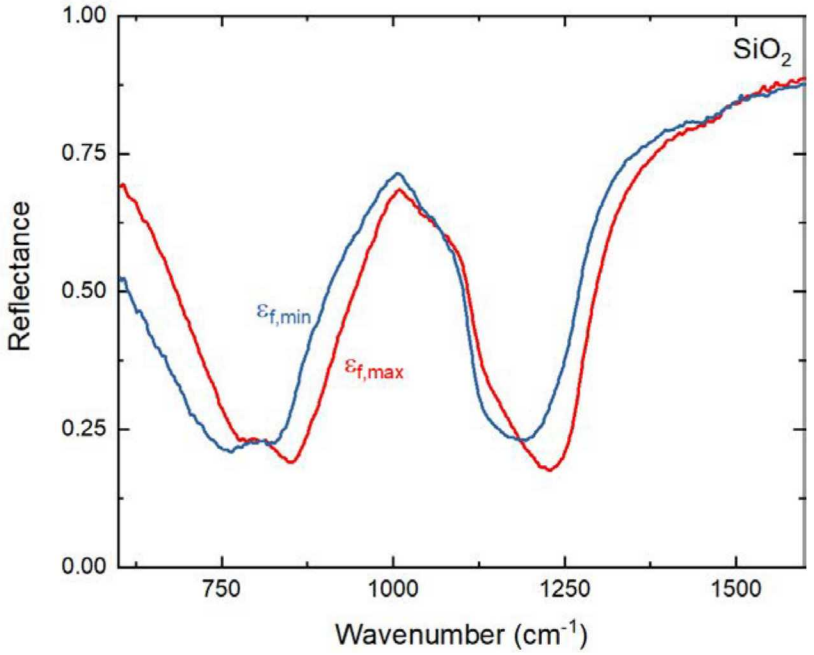
Dielectric Dictation

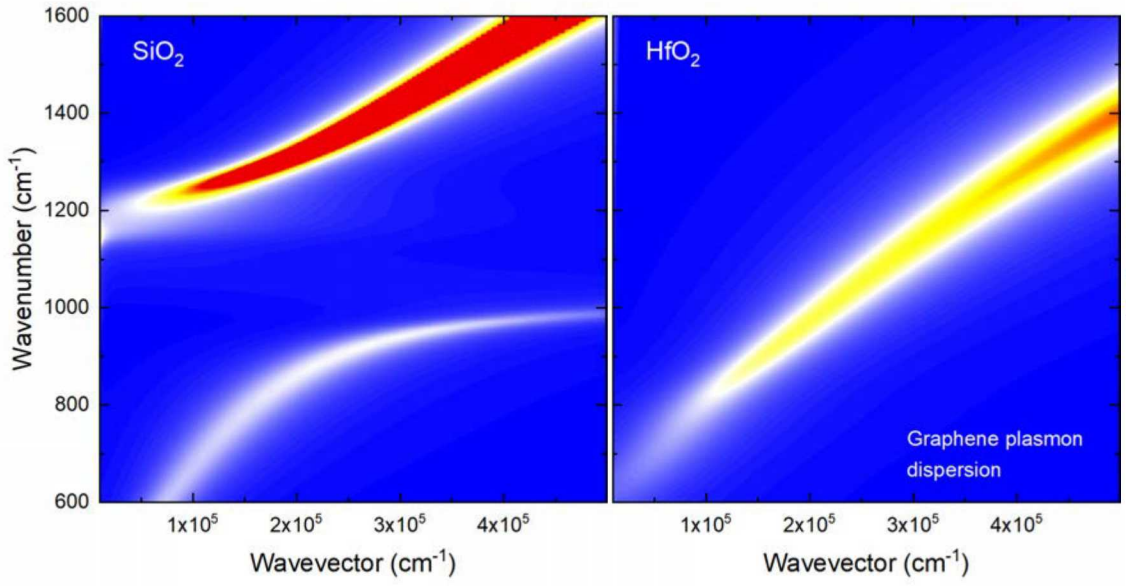


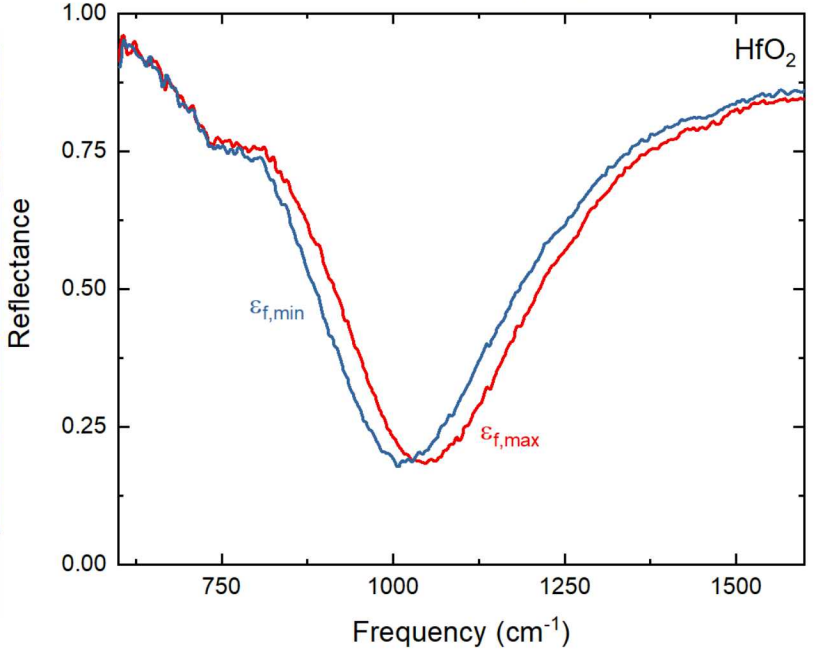


Reflection: Leveraging Dielectrics



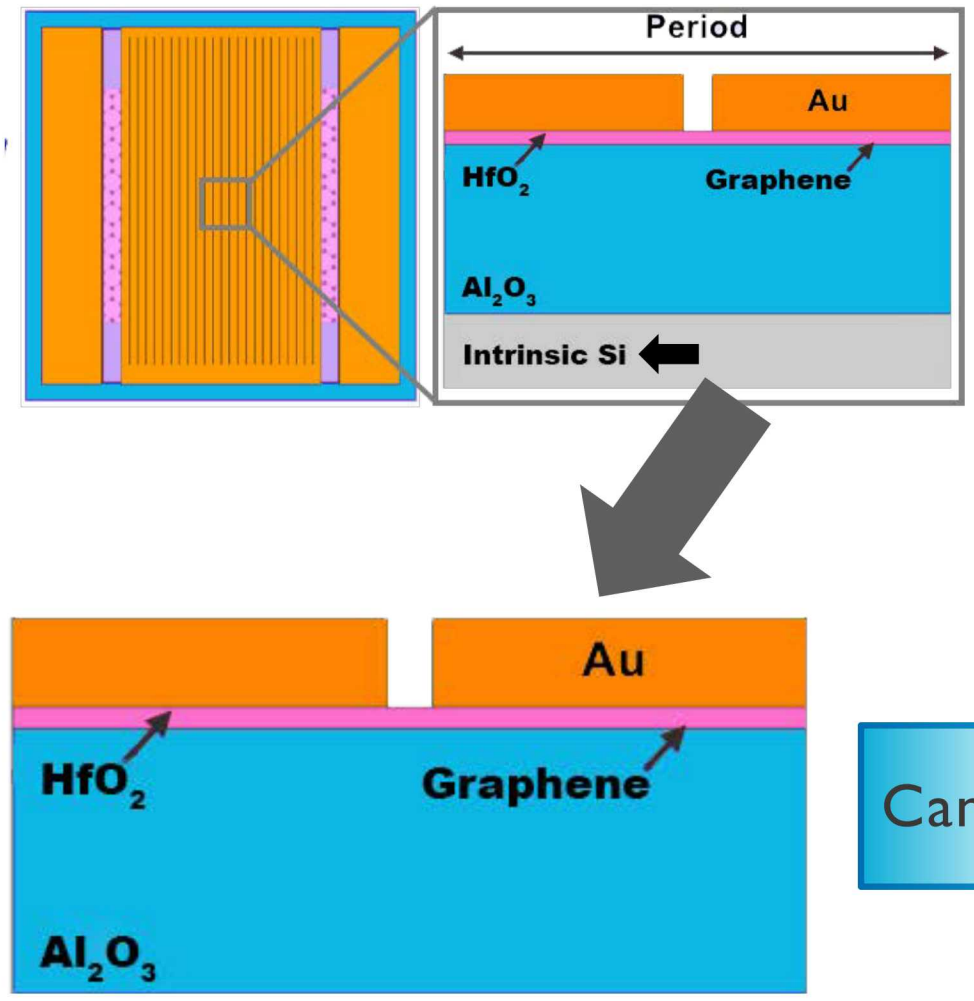


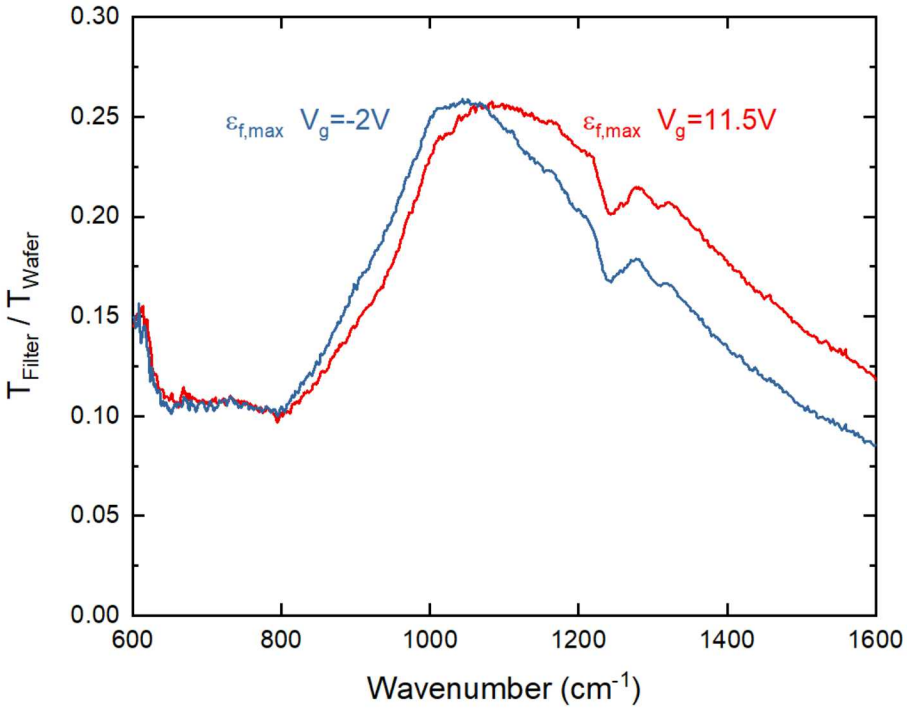




Details: Goldflam et al. Opt. Exp. (7) 8532. 2018, Goldflam et al. Opt. Expt. (25) 12400. 2017

Transmission: Low-Voltage Tuning

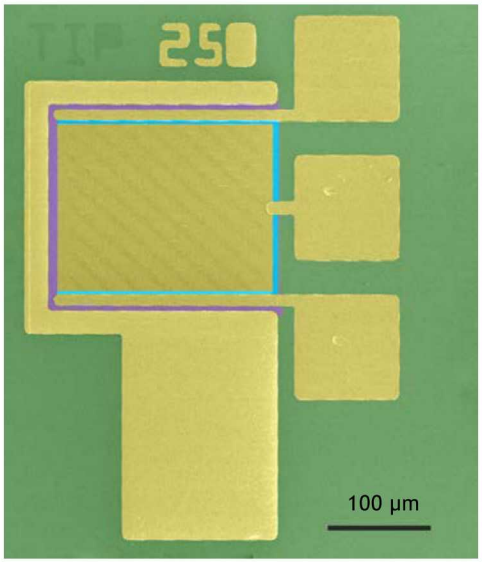


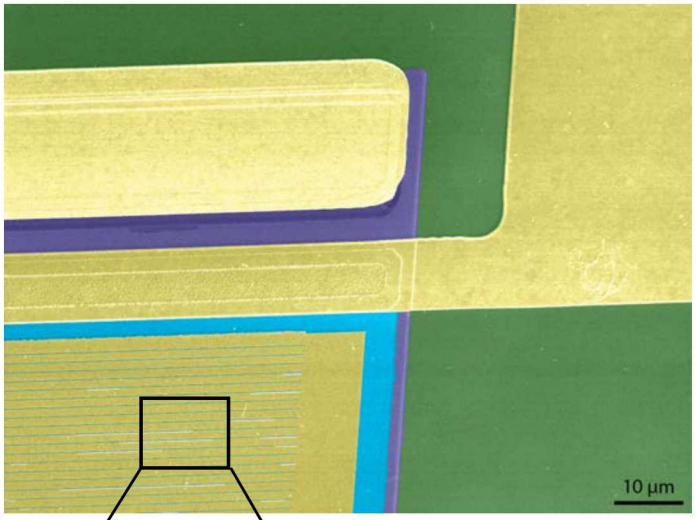


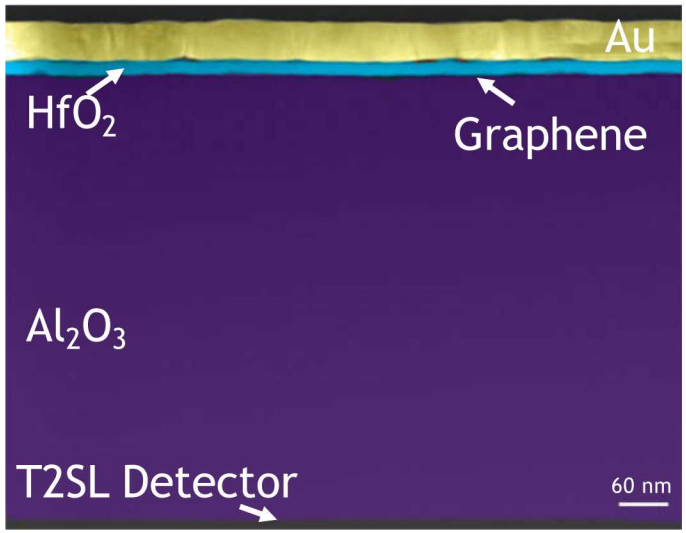
Can we build it directly on detector?

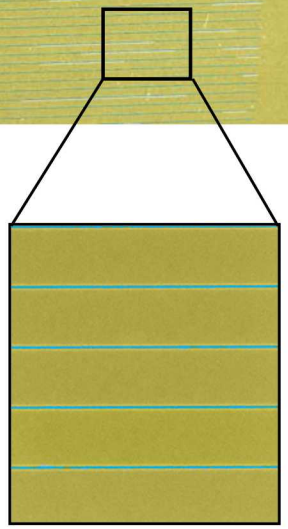
Tunable Integrated Pixel (TIP)

Goal: Detector and tunable filter all in one









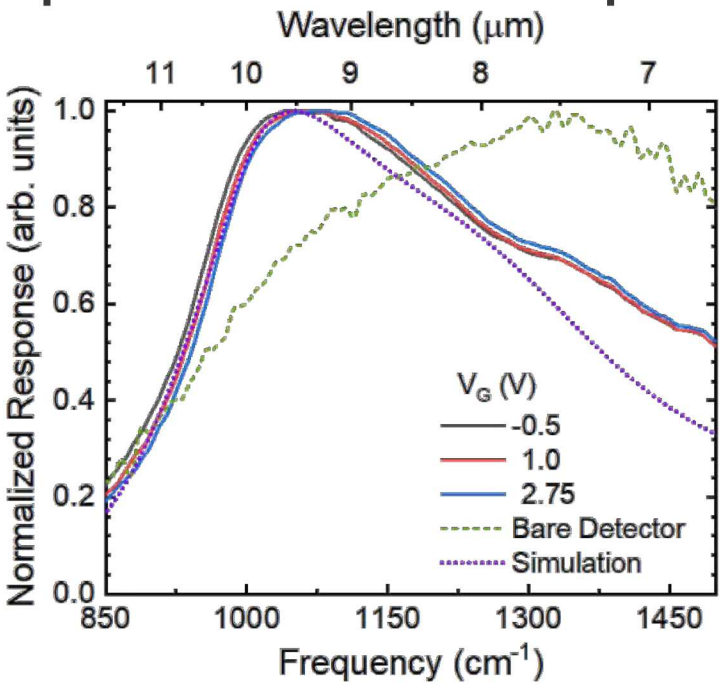
No Moving Parts

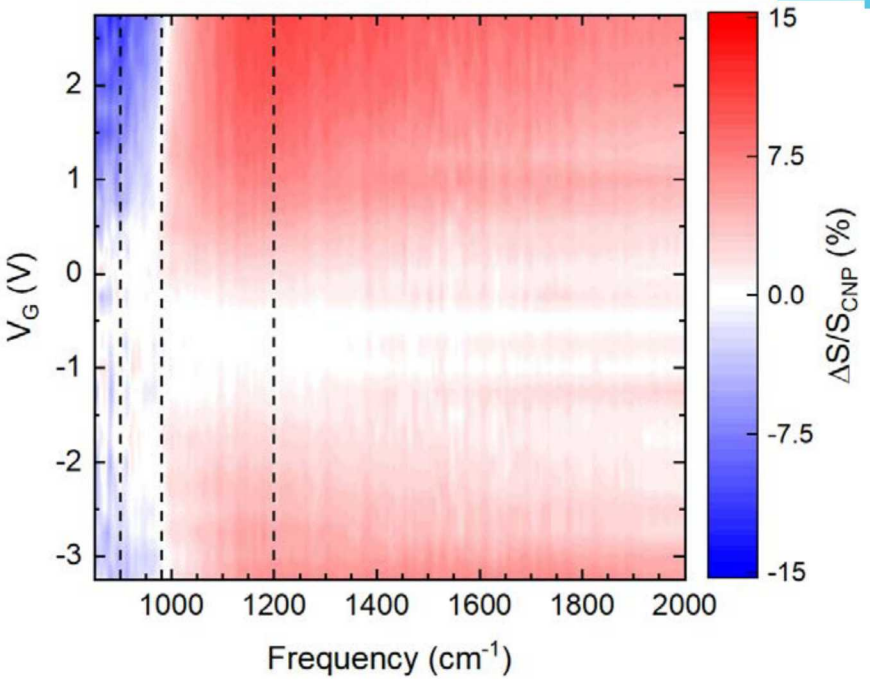
Intrinsic Alignment

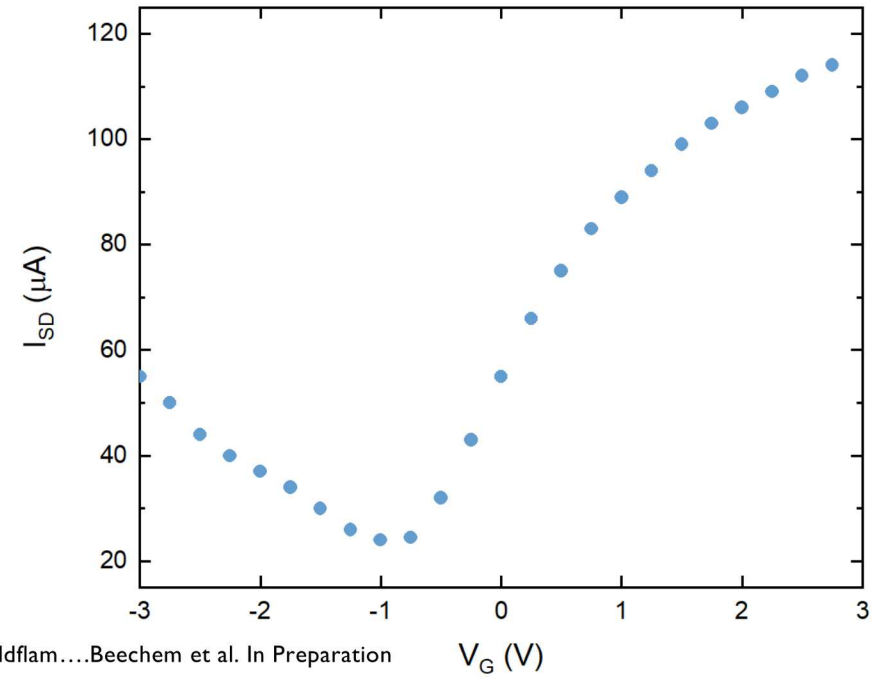
Standard Fab Processing

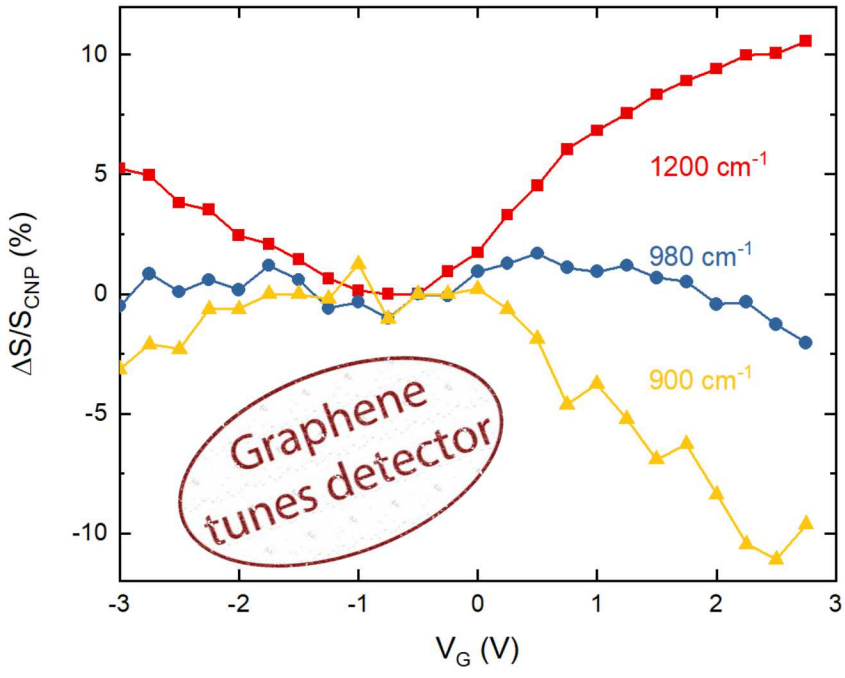
Details: Goldflam….Beechem et al. In Preparation

TIP Spectral Photoresponse



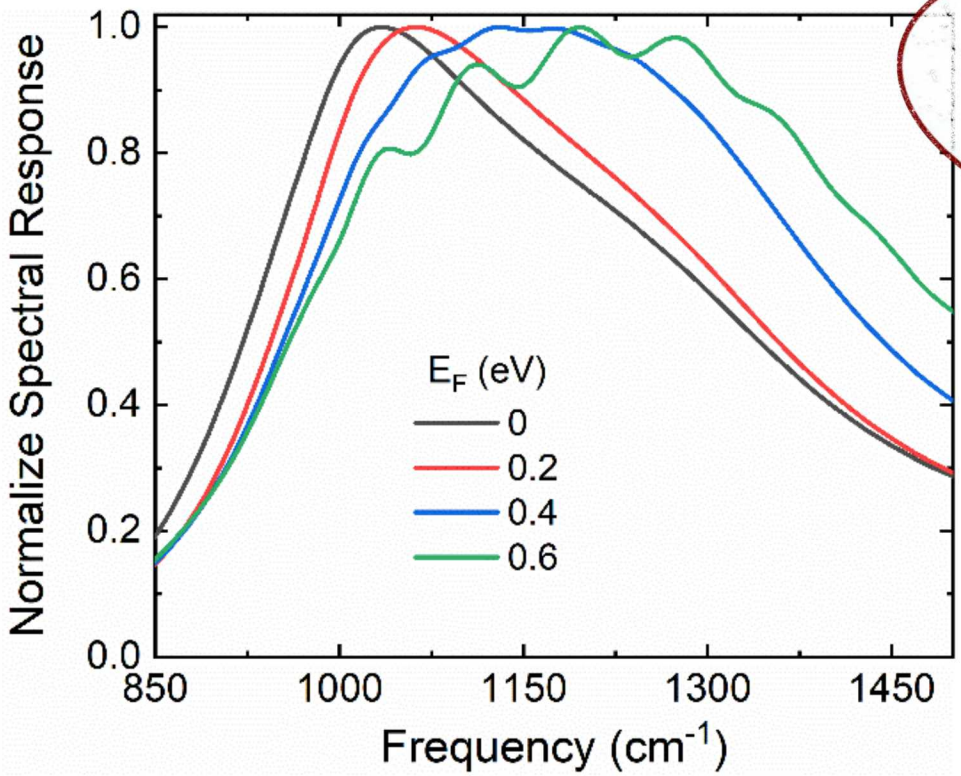






Details: Goldflam….Beechem et al. In Preparation

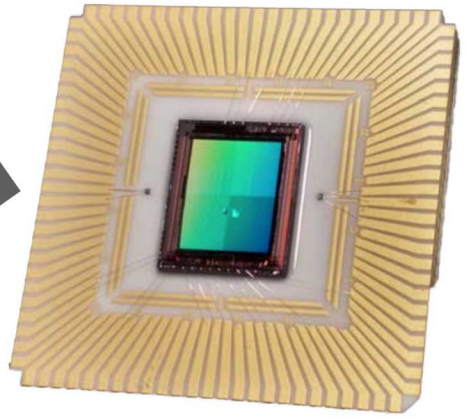
Where's the ceiling?



Simulation with "better" graphene

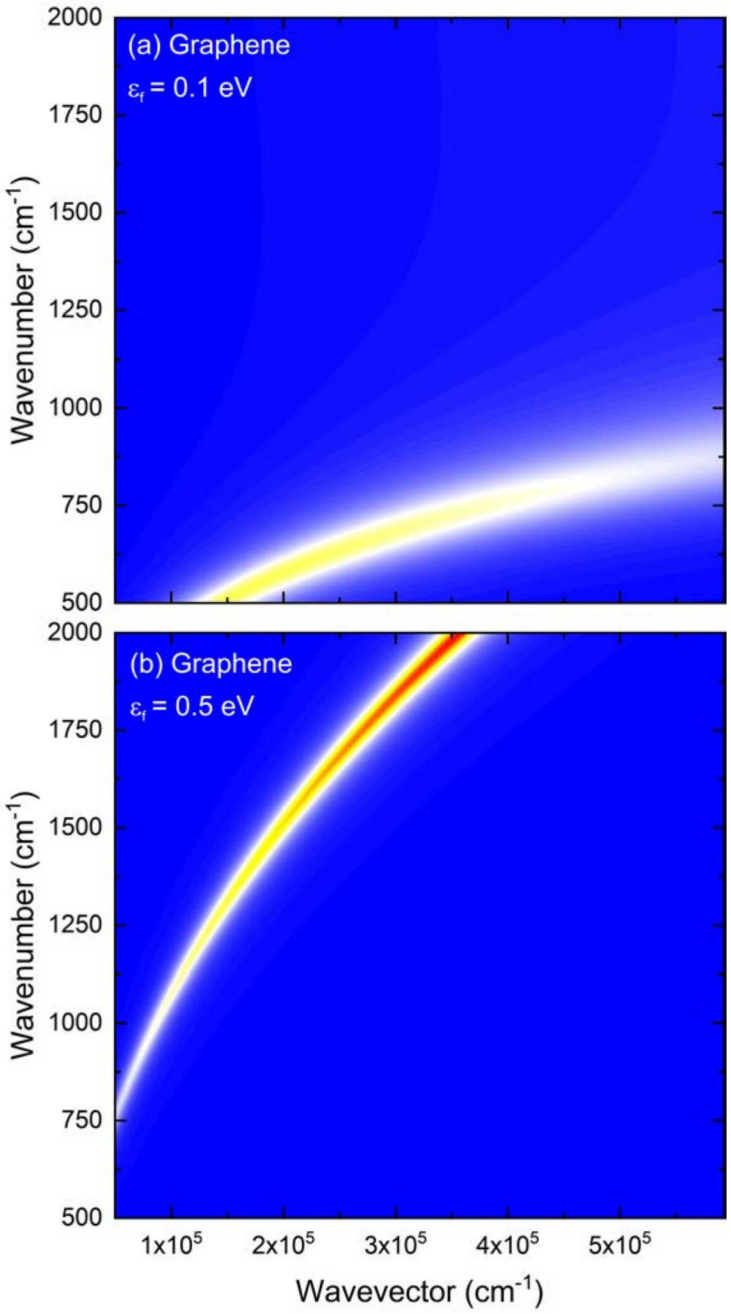
Improvement

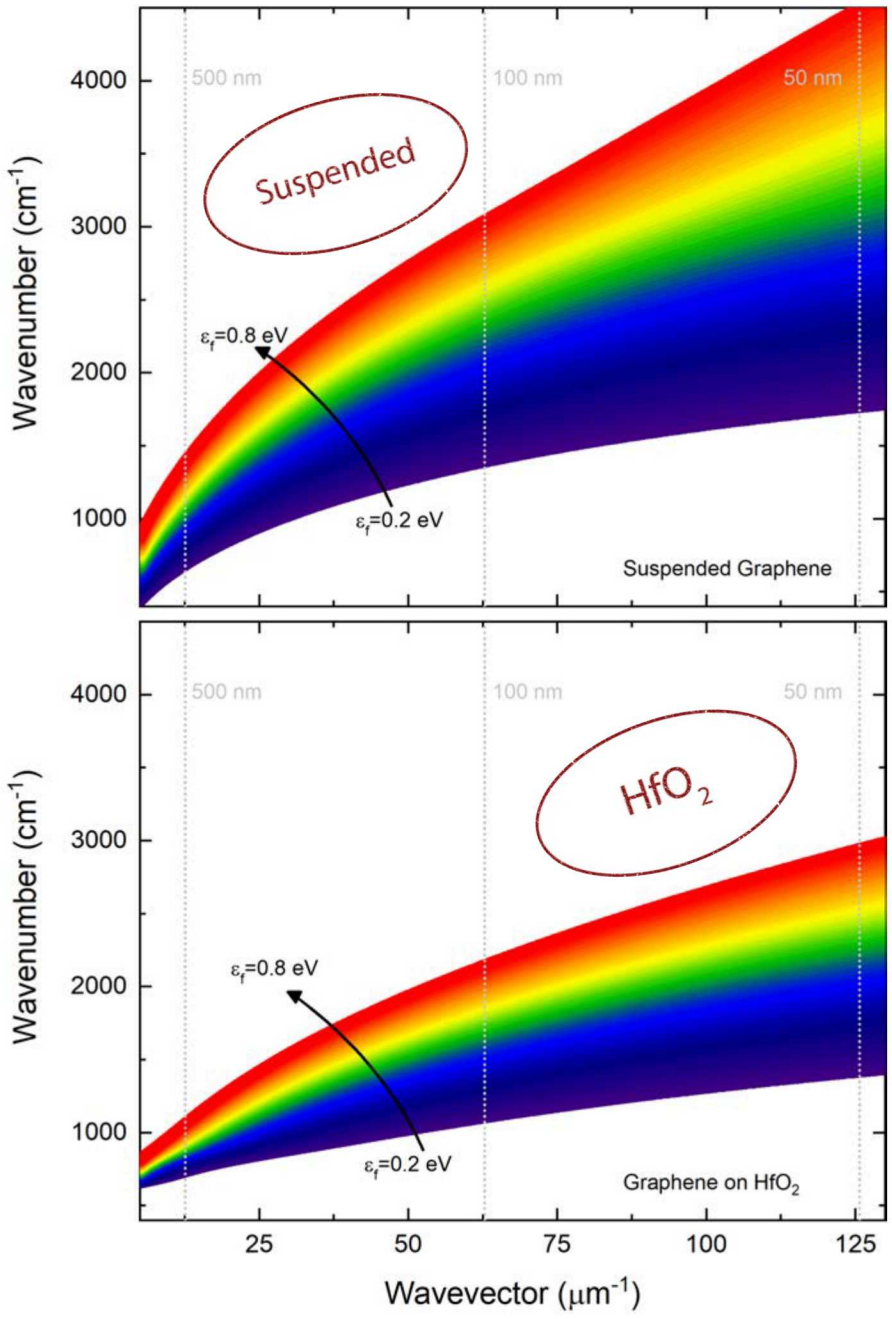
1. Improved graphene
2. "Smarter" metasurface tuning
3. **Tailored Dielectric**



Details: Goldflam….Beechem et al. In Preparation

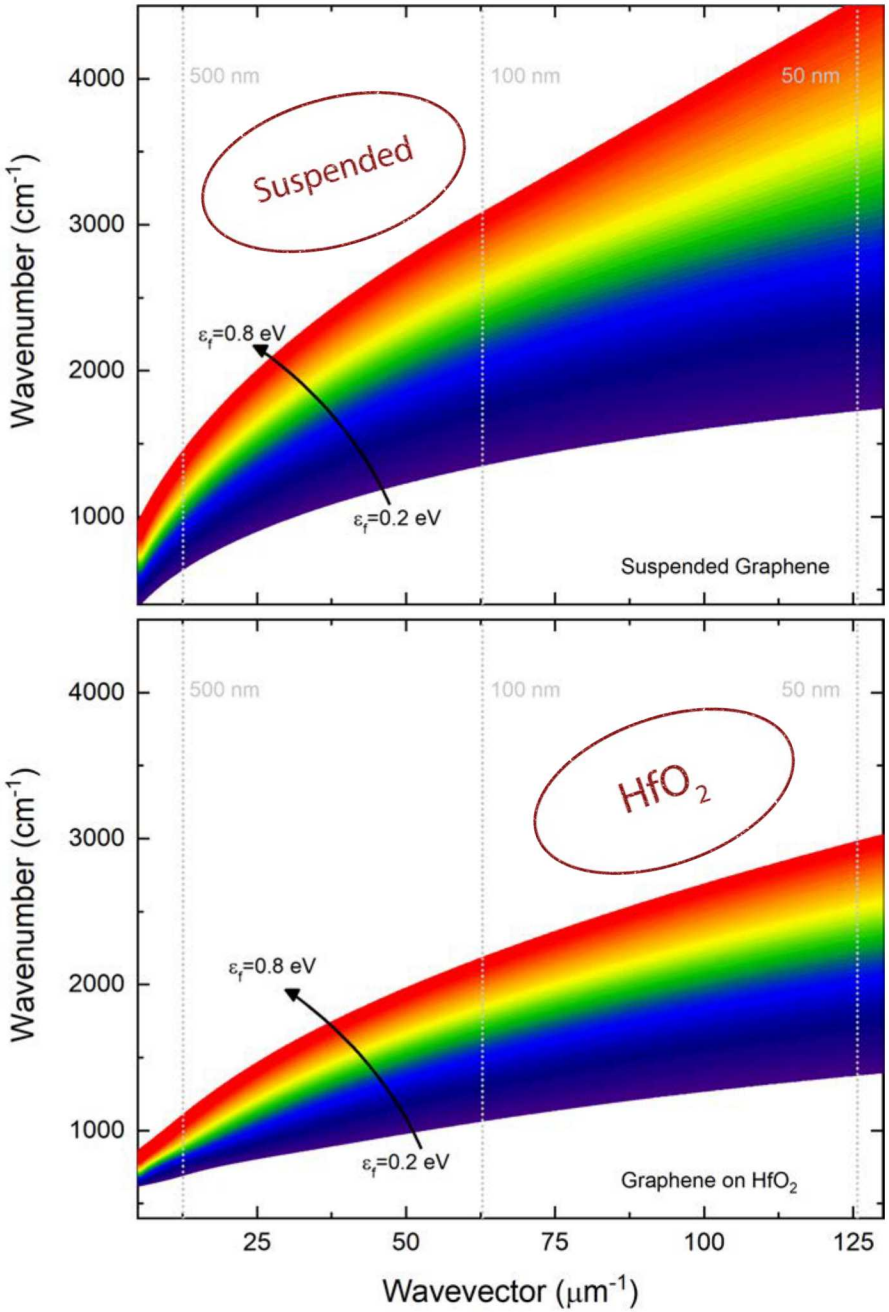
Tailoring Tuning with Dielectrics

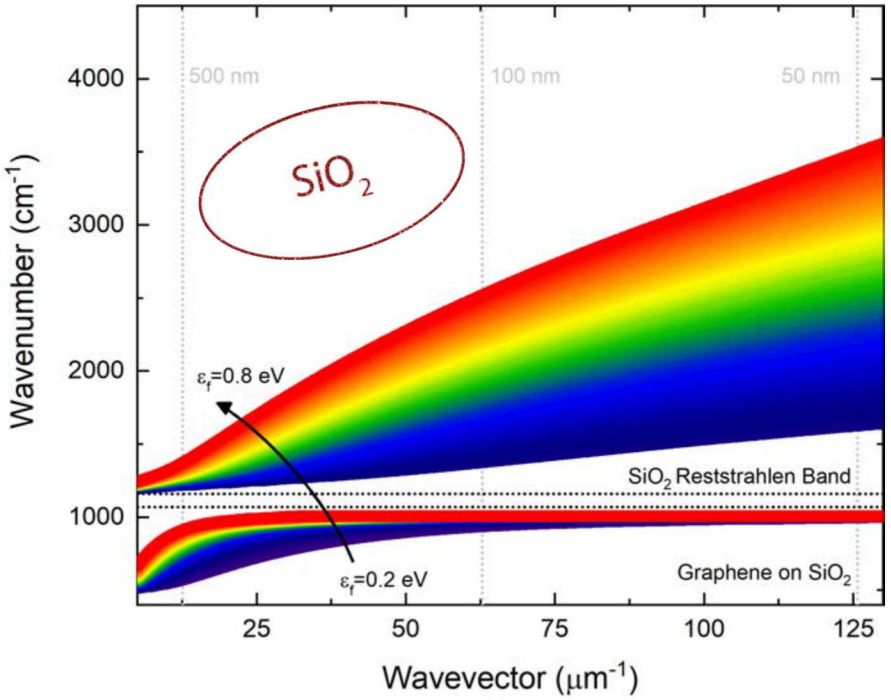




Details: Jarzembski, Goldflam….Beechem et al. In Preparation

Tailoring Tuning with Dielectrics





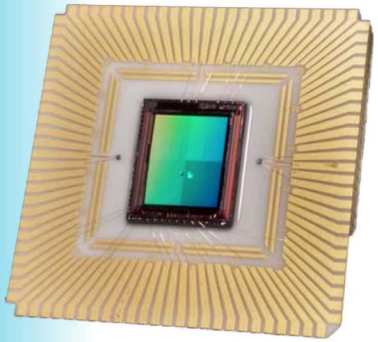
Takeaway

Dielectric determines **where** & **how much** graphene tunes.

Details: Jarzembski, Goldflam….Beechem et al. In Preparation

Take Home Message

Vision



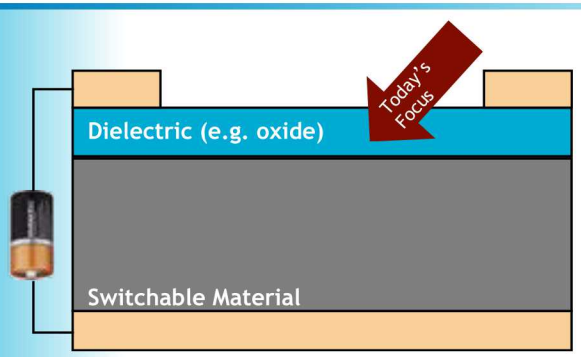
Dynamic, tunable, infrared sensing at pixel level

Path

Graphene allows integration directly atop detector (mat'l agnostic)

Design the Dielectric

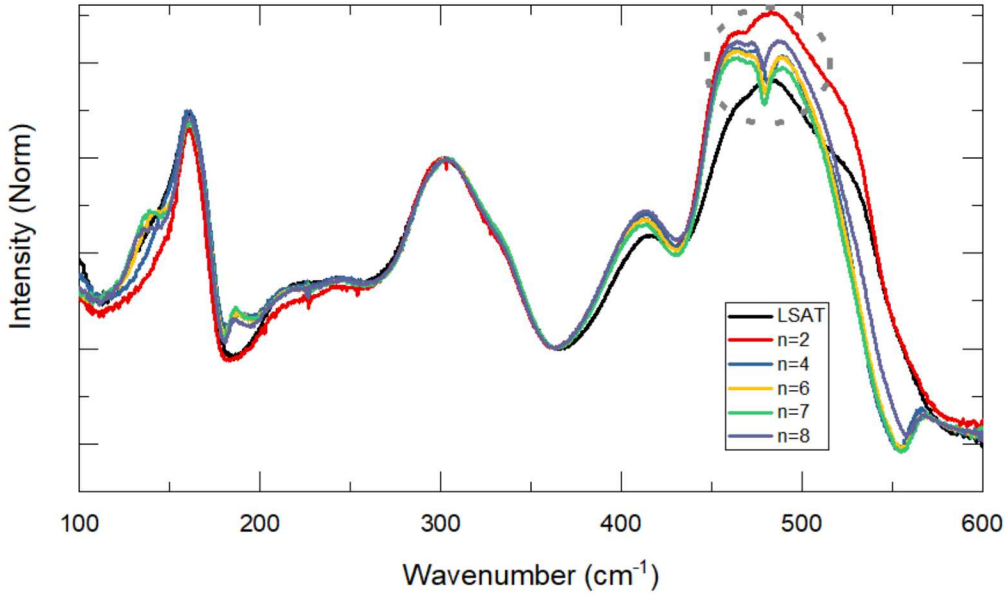
Outcome

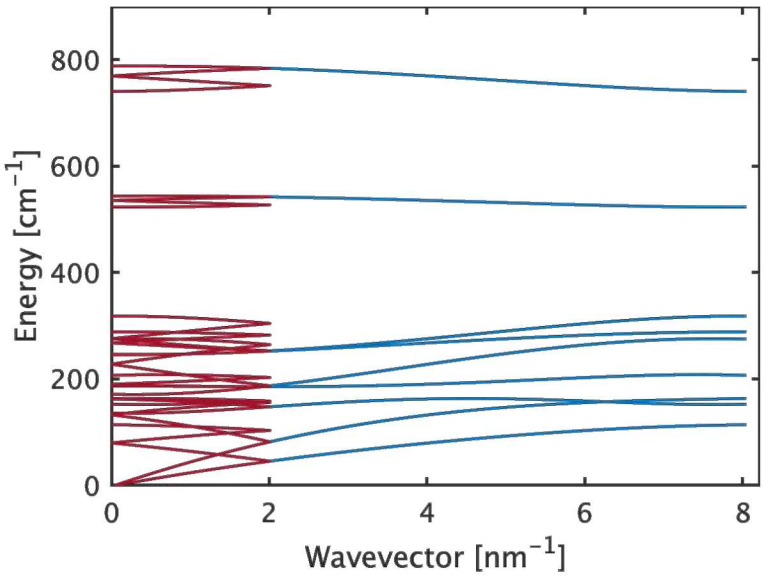


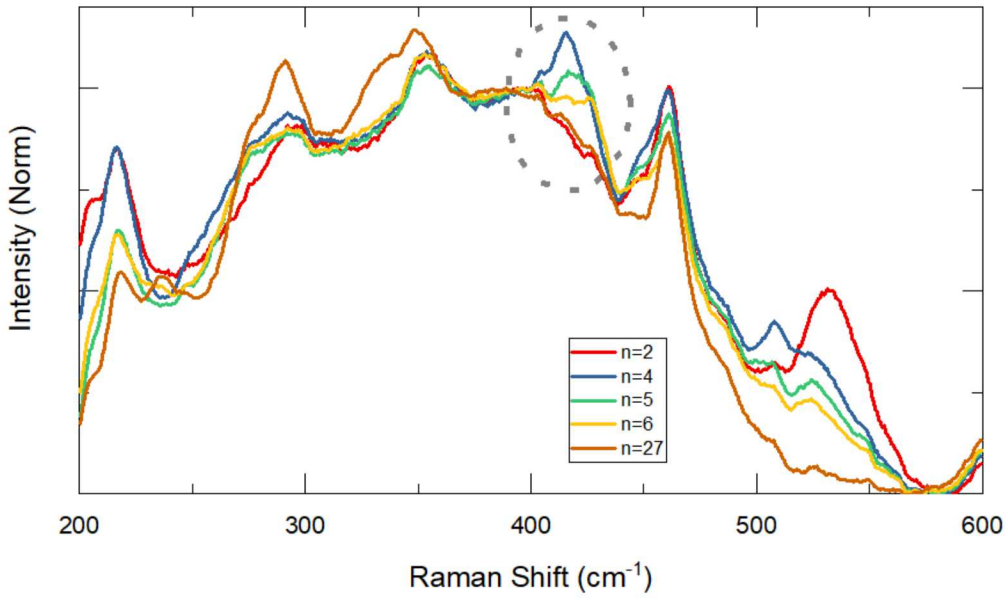
Dielectric determines tunability.

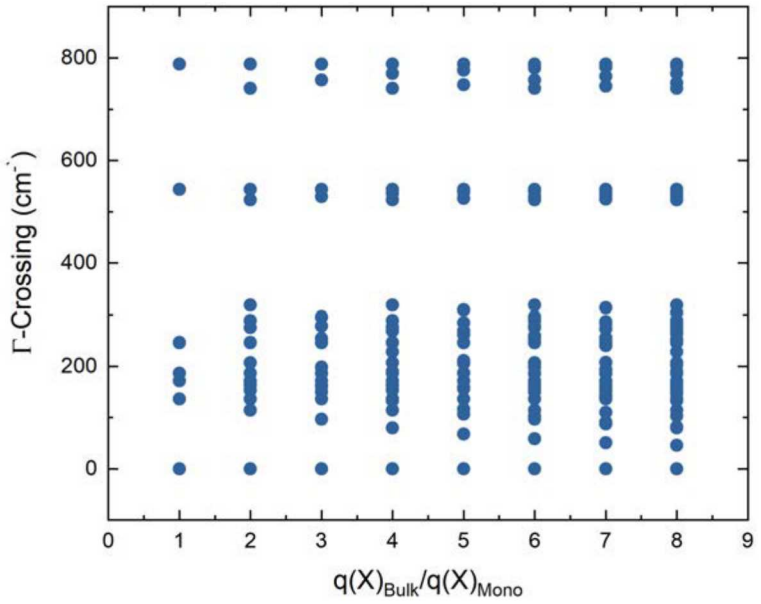
Possibilities…Coherence & Localization

Hypothesis 1: Formation of "coherent" superlattice phonon modes



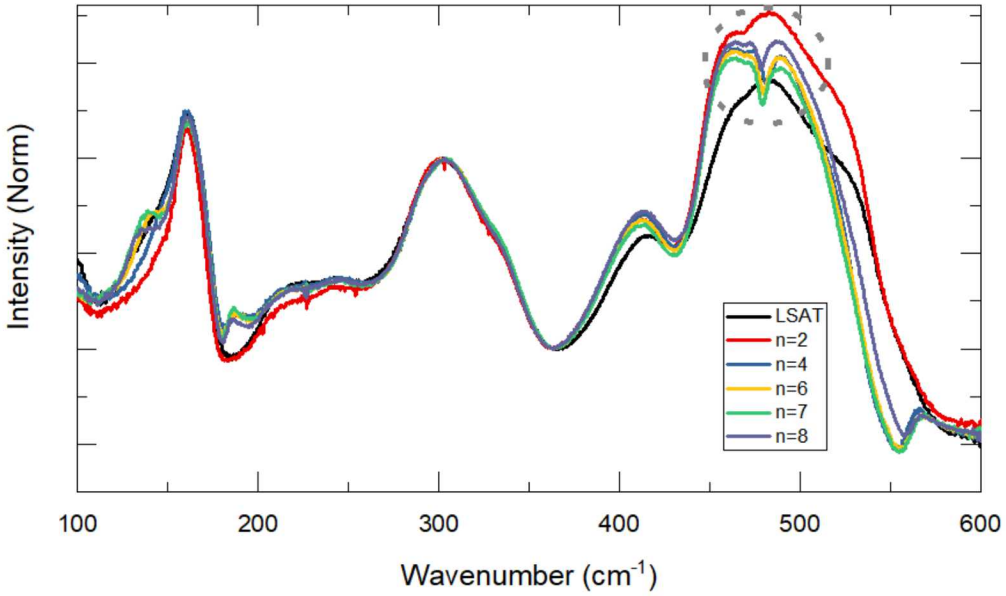


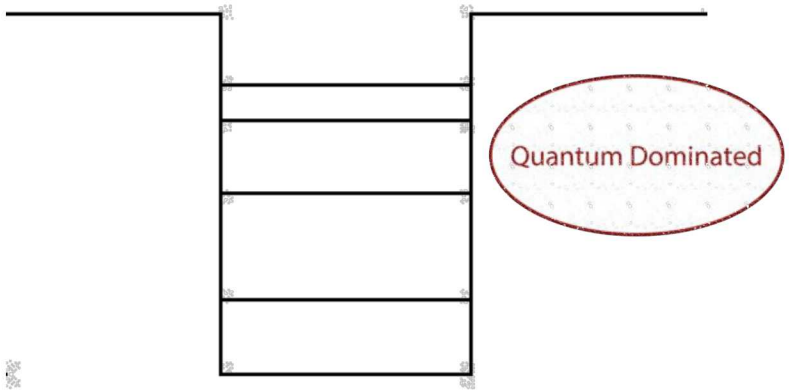


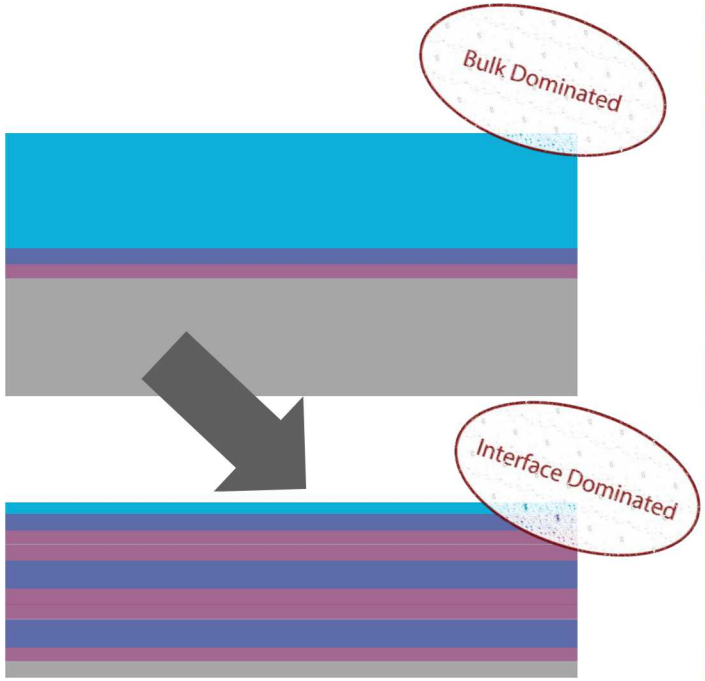


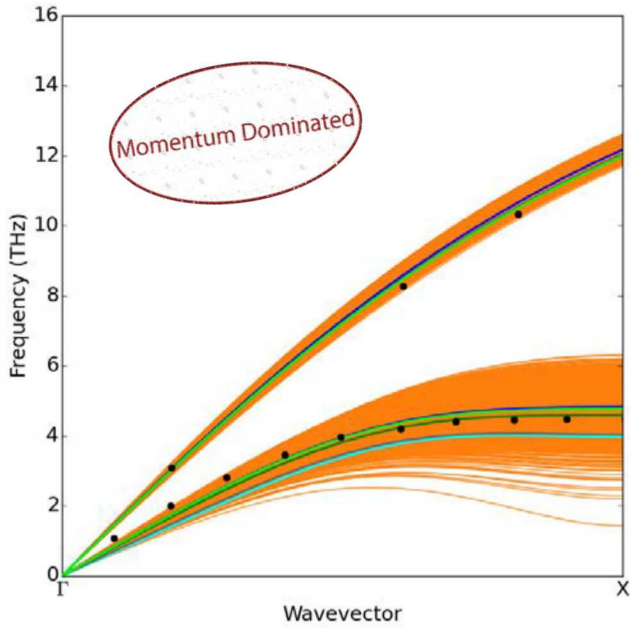
Possibilities…Coherence & Localization

Hypothesis 2: Localization in 3 flavors









Dispersion: A. McGaughey Research Group (Nanoscale Transport Phenomena Laboratory).