

Dual-band Tunable Graphene-Based Filter

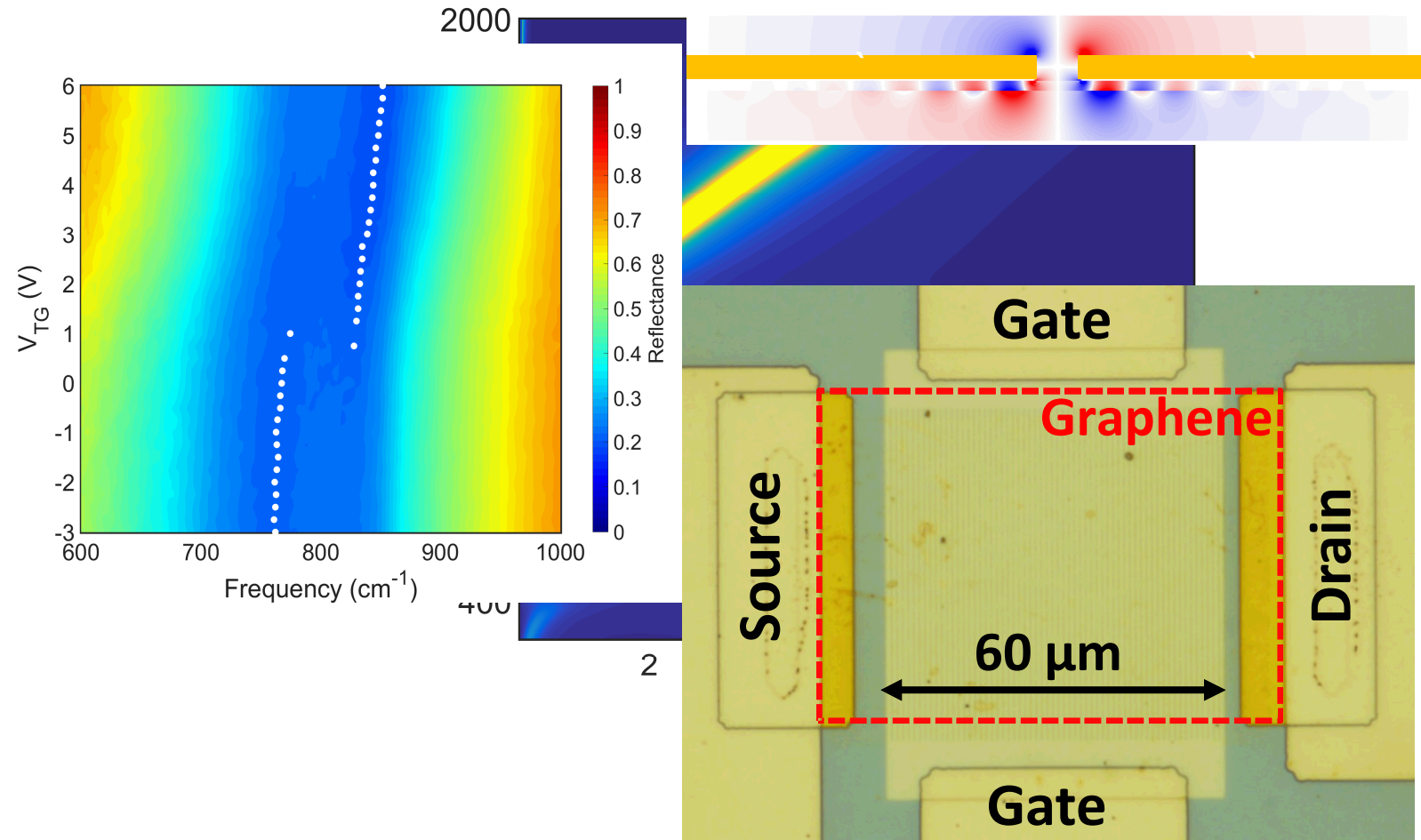
Michael Goldflam, Isaac Ruiz, Joel Wendt, Stephen Howell, Thomas Beechem



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

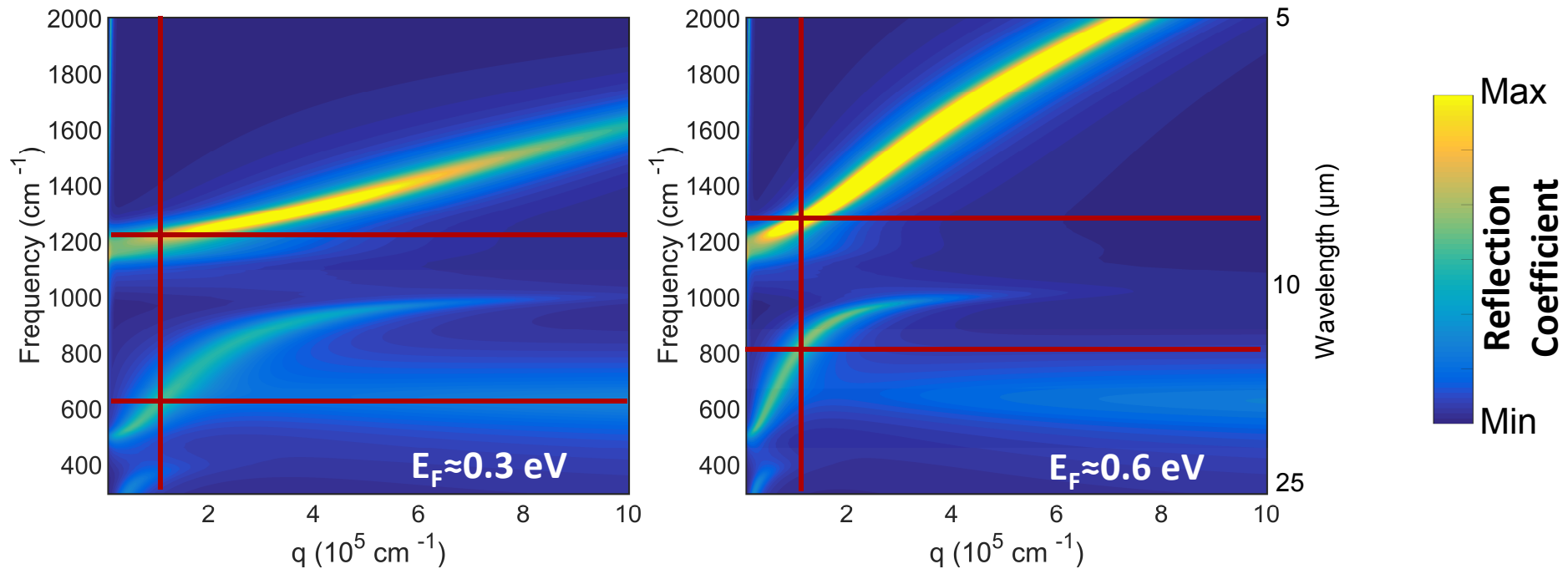
Outline

- Graphene
 - Tunable plasmonics
 - Limitations
- Tunable filter
 - Ensuring scalability
 - Multi-band tunability



Plasmonic Tuning in Graphene

Reflection Coefficient



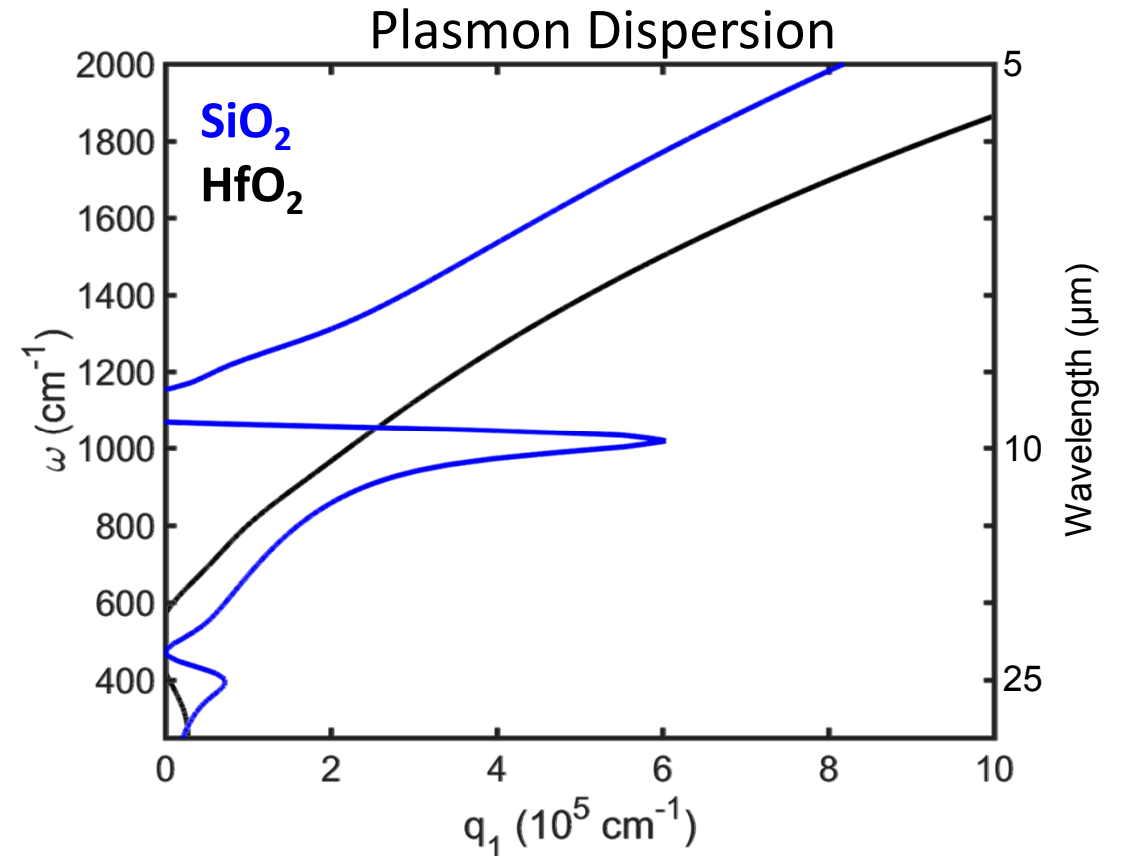
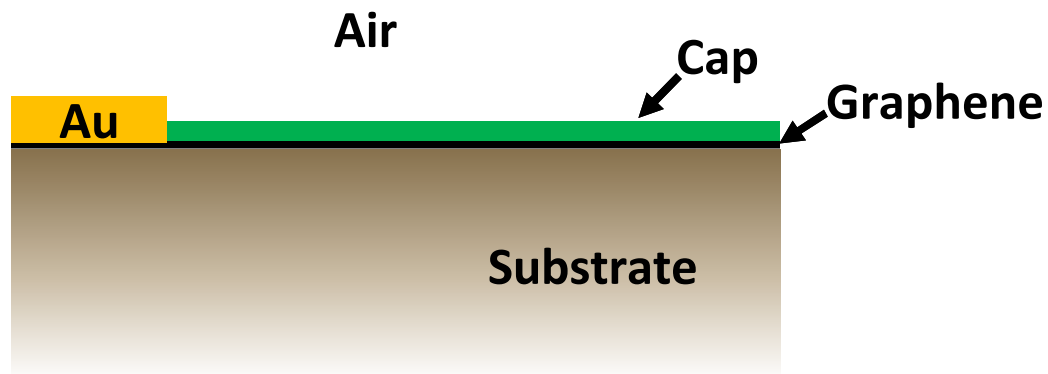
Plasmonic response easily tuned through carrier injection

Z. Fei, et al, *Nano Lett.* **2011**, **11**, (11), 4701-5.
J. Chen, et al, *Nature* **487** (7405), 77-81 (2012).

Limitations of Graphene

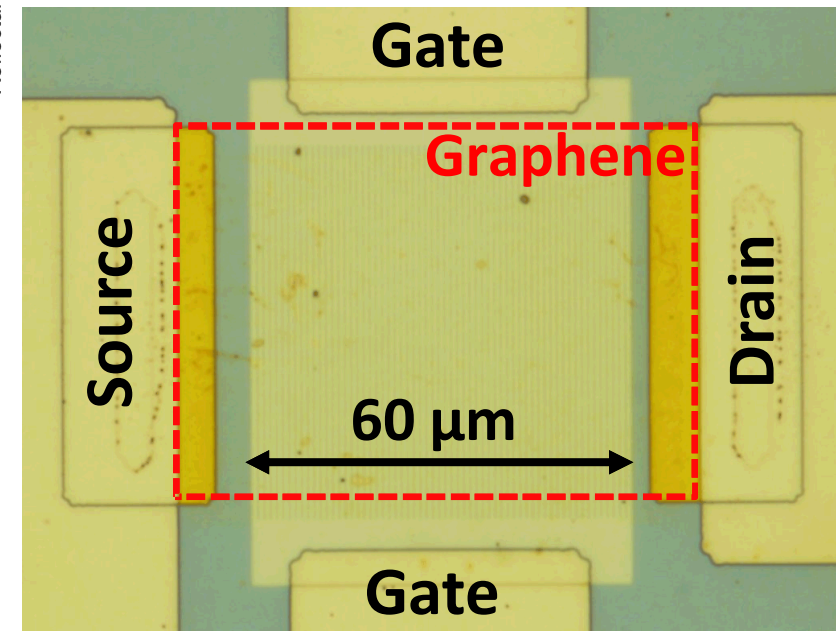
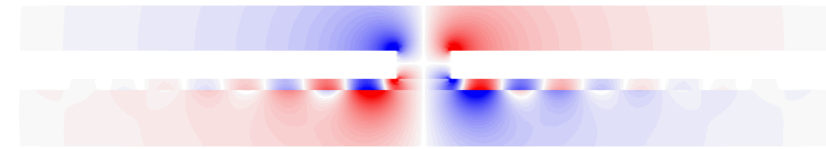
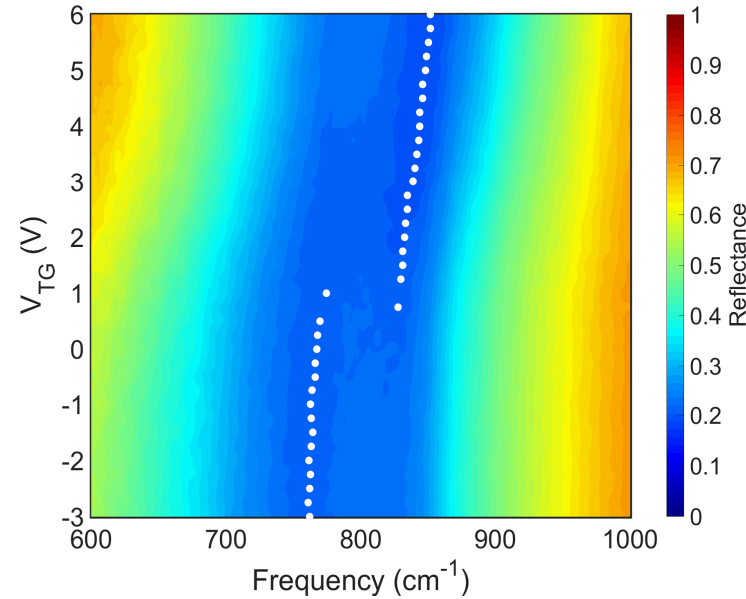
Graphene changed by environment and fabrication methods

- Fermi level pinning
- Plasmon dispersion modification
- Environmental degradation

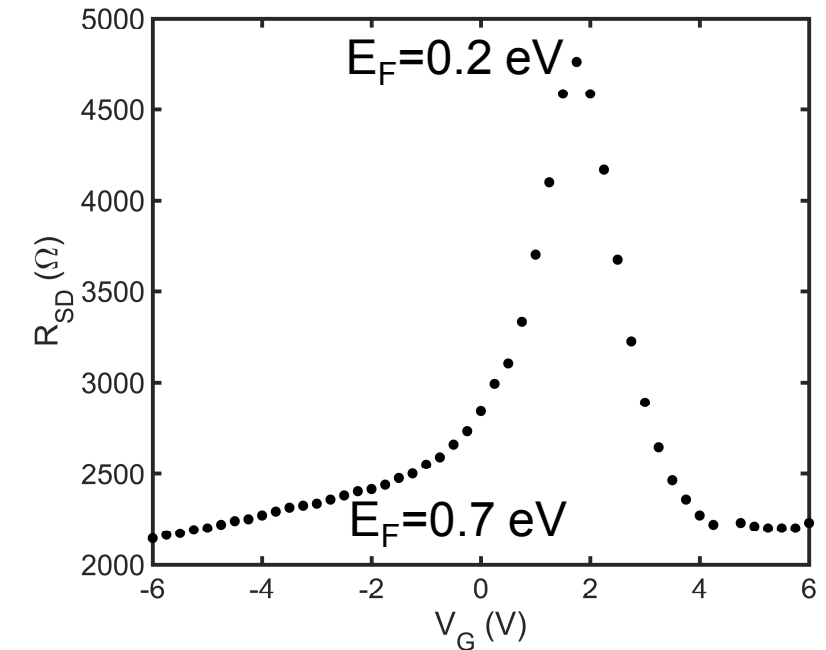
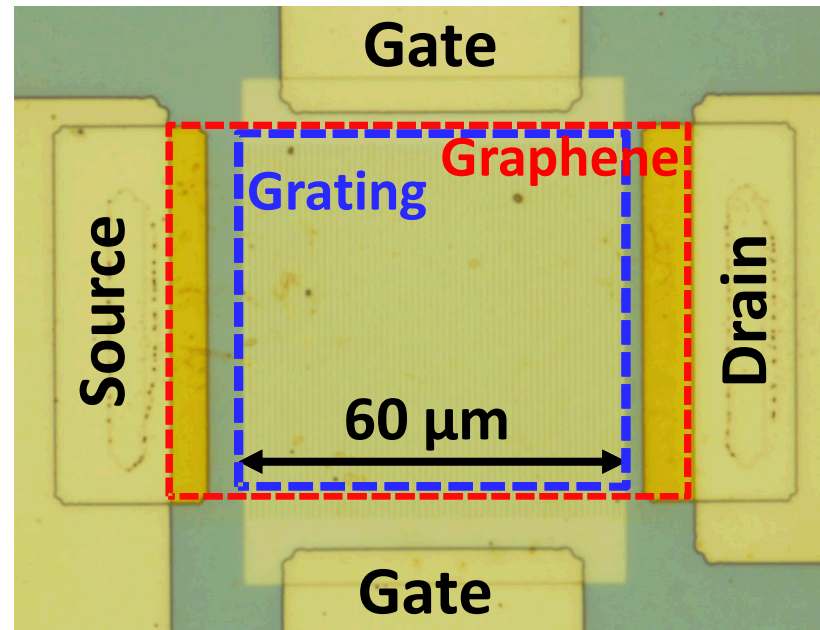
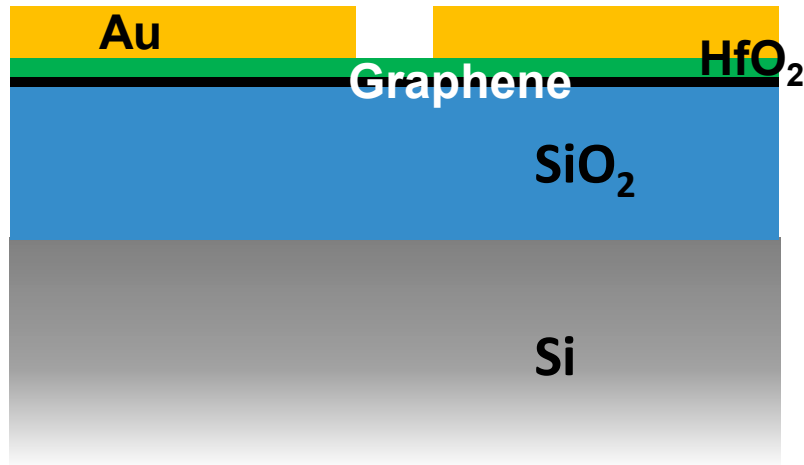


Outline

- Graphene
 - Tunable plasmonics
 - Limitations
- Tunable filter
 - Ensuring scalability
 - Multi-band tunability

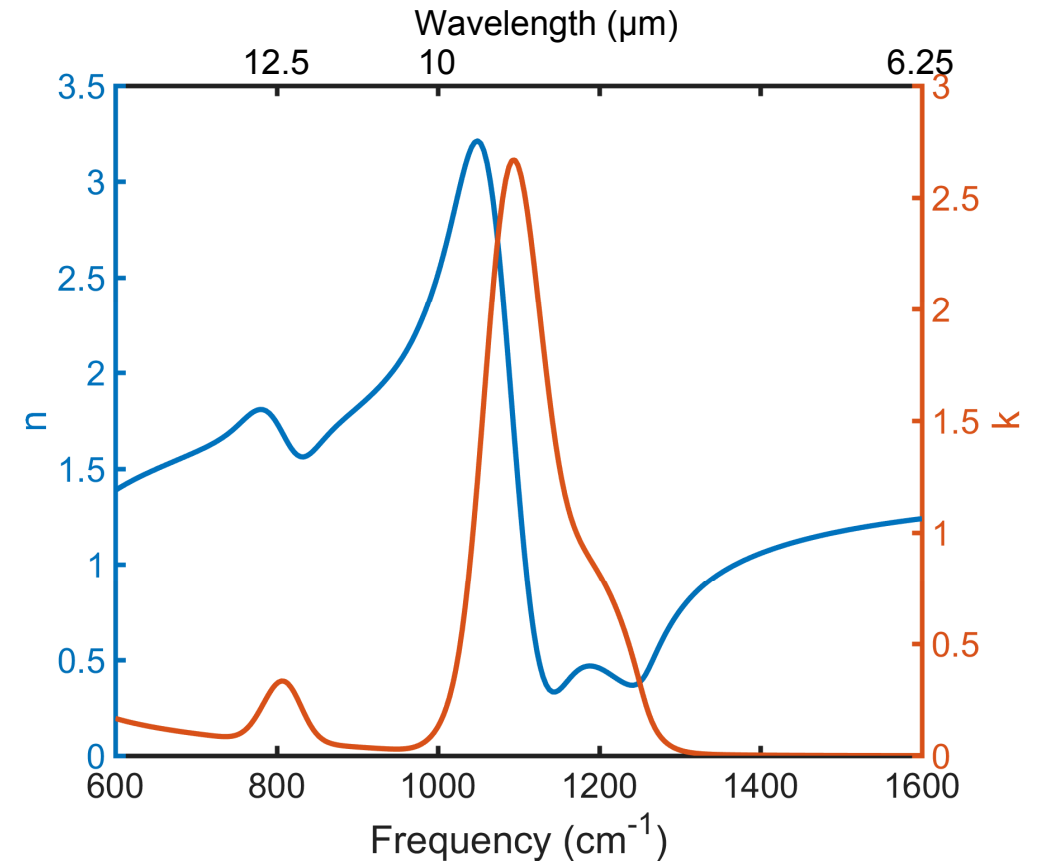
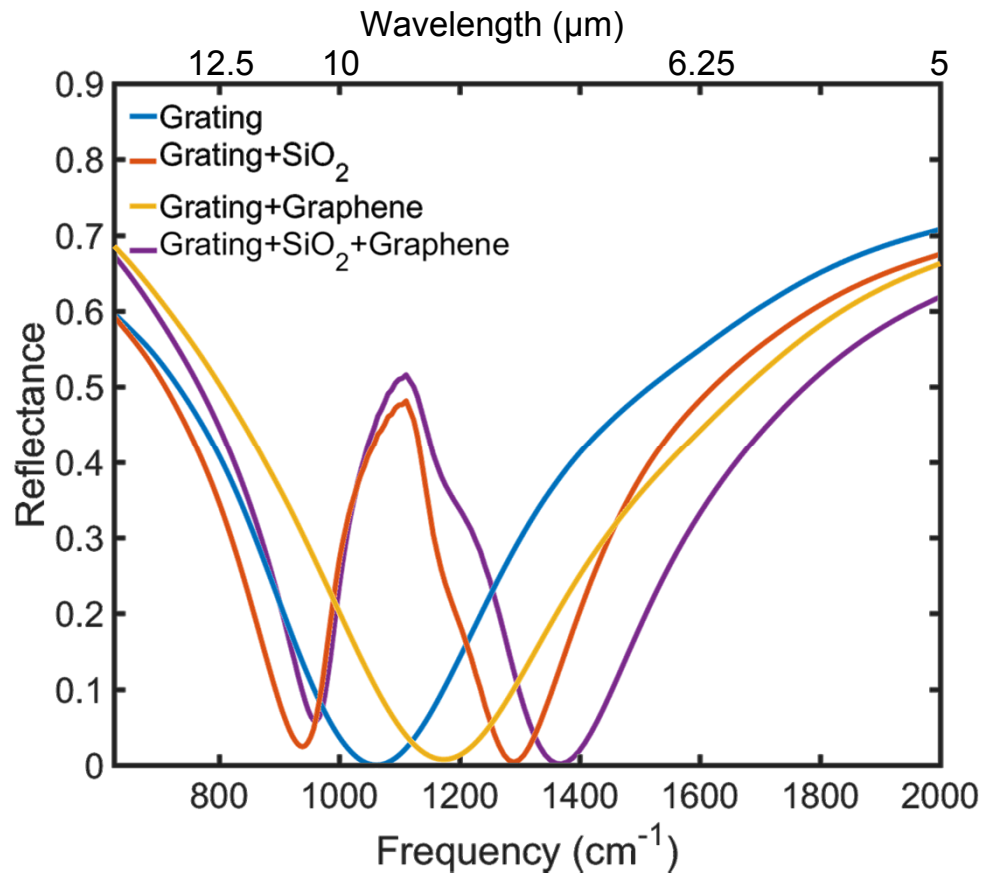


Device Design



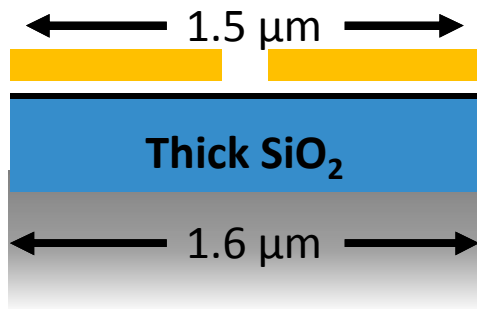
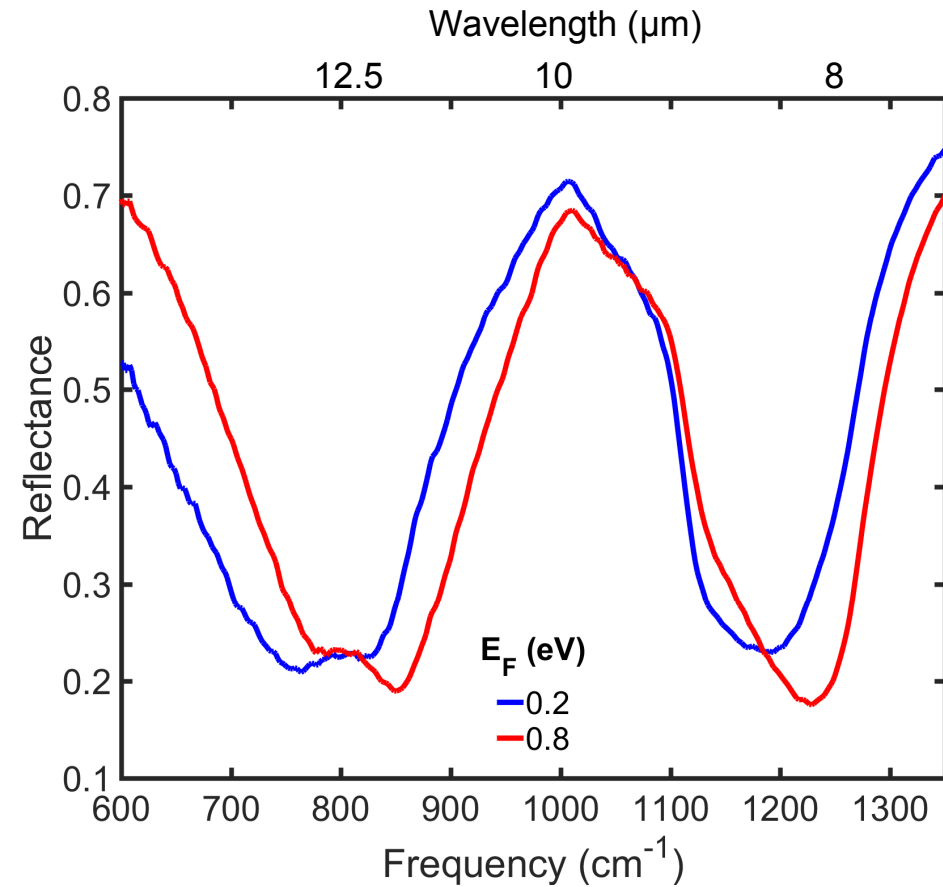
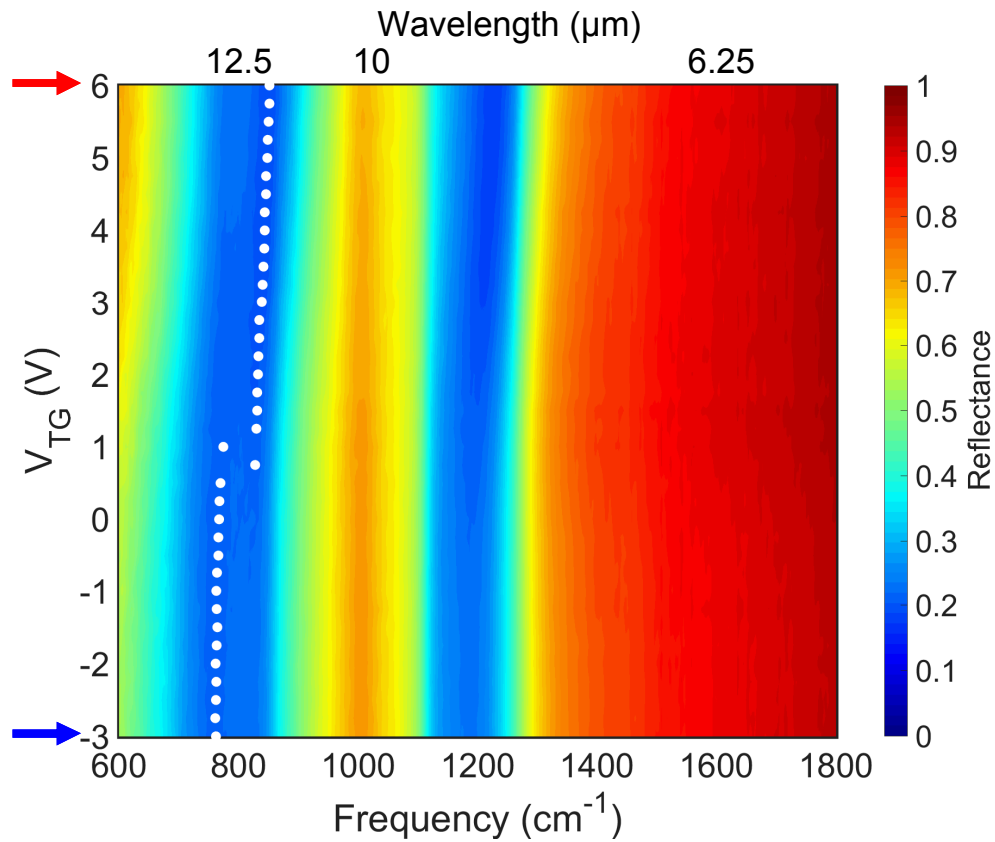
- Scalable (continuous and unpatterned large-area CVD graphene)
- Protected graphene (capping layer)
- Avoid metal-graphene contact

Building the Filter Response



- Presence of SiO₂ increases resonance Q-factors
- Dielectrics can modify resonance location.

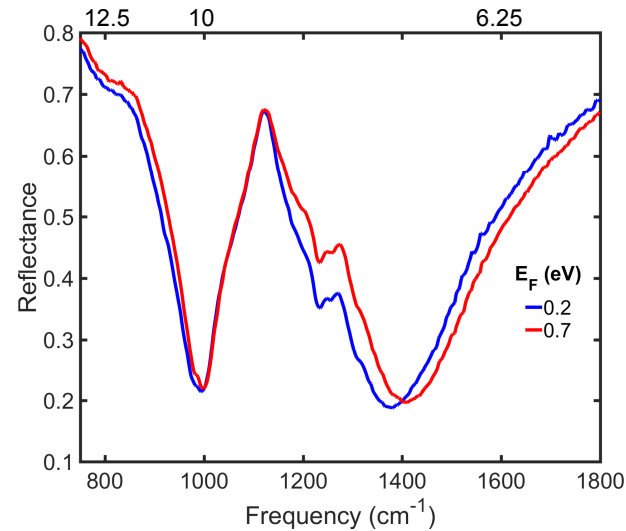
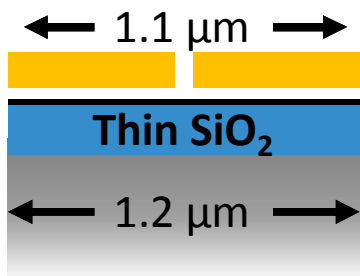
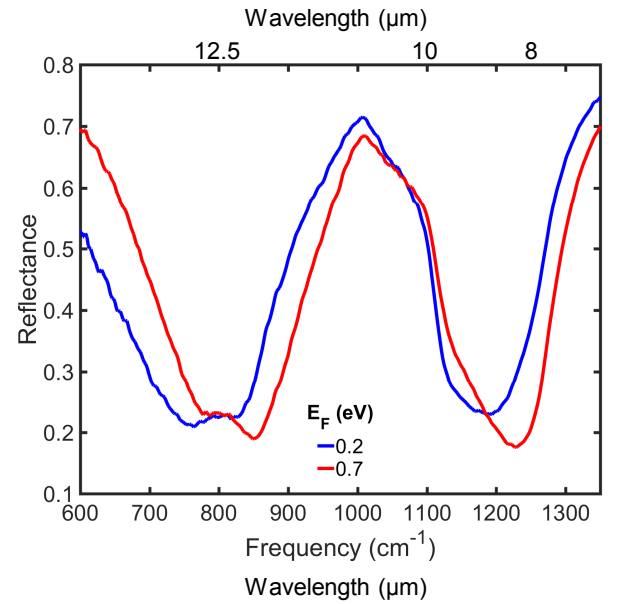
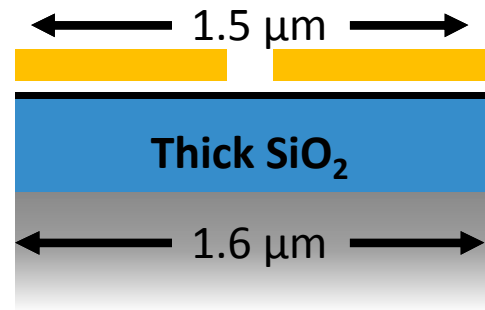
Measured Reflectance



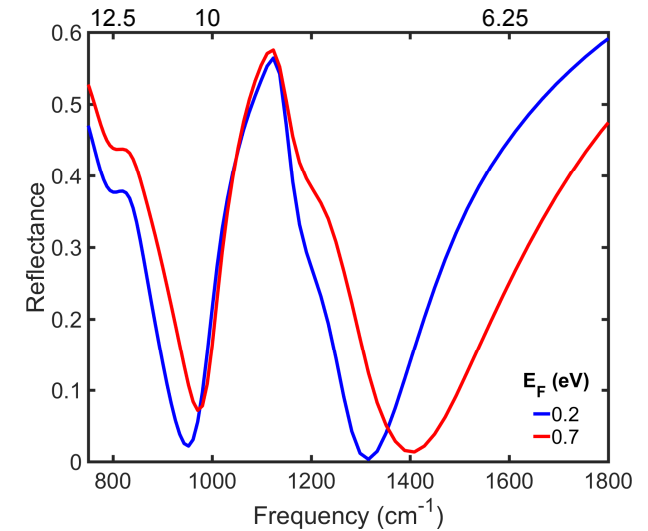
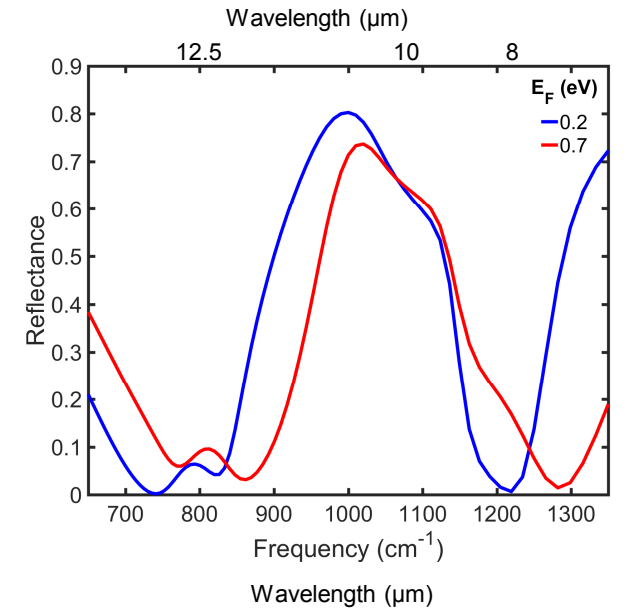
- Shift in position of two resonances simultaneously.
- Larger shifts are lower frequencies.
- Spectral shift depends on both grating design and SiO₂ thickness.

Measured Reflectance

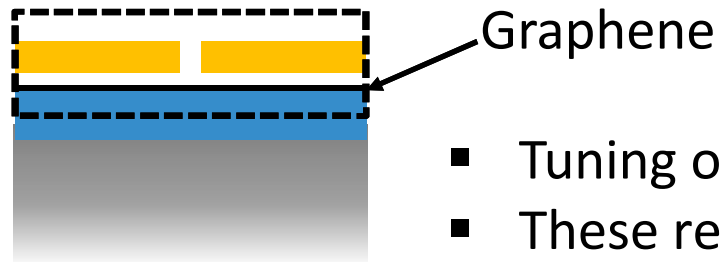
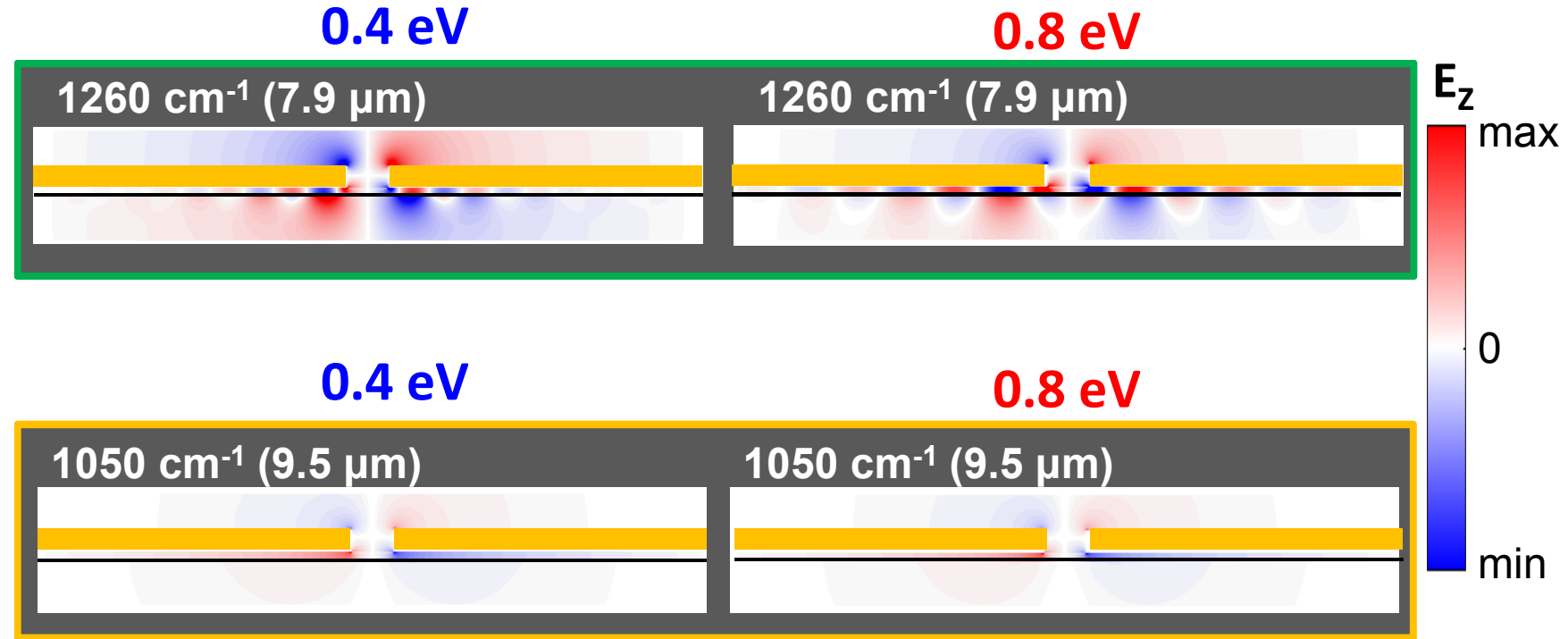
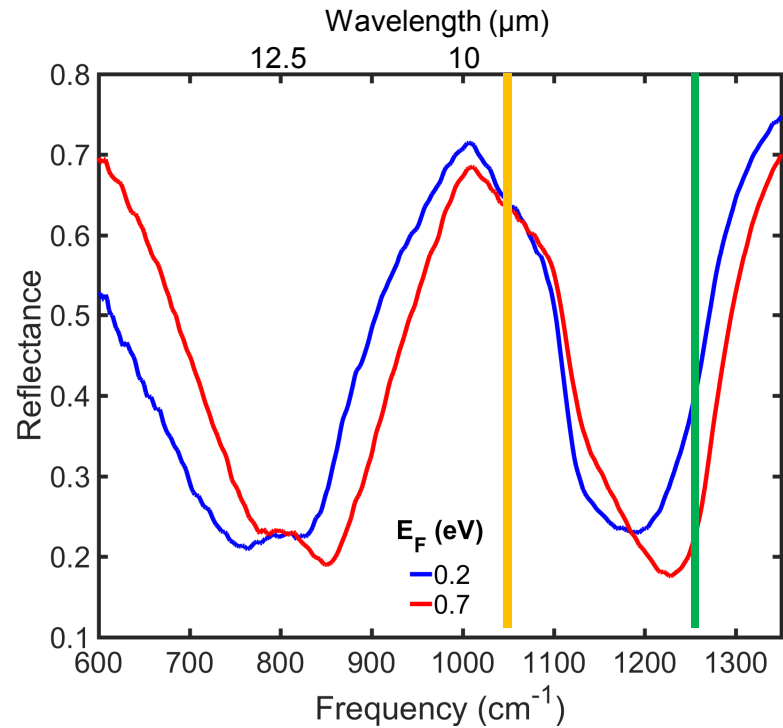
Measurement



Simulation



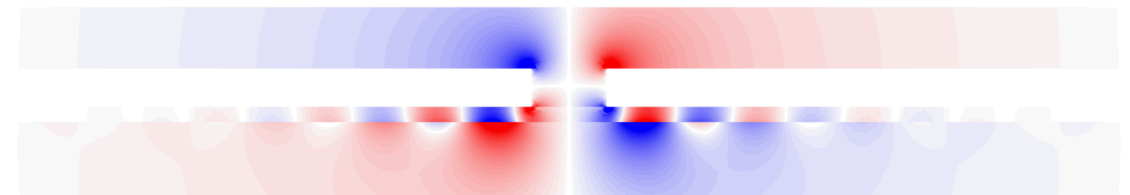
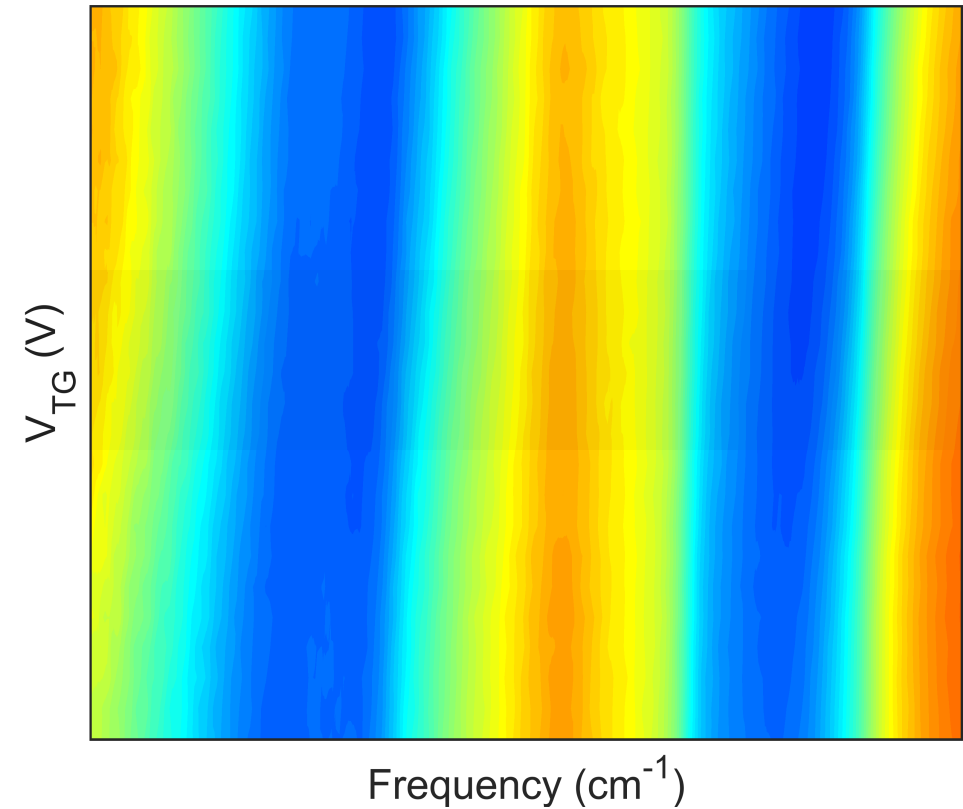
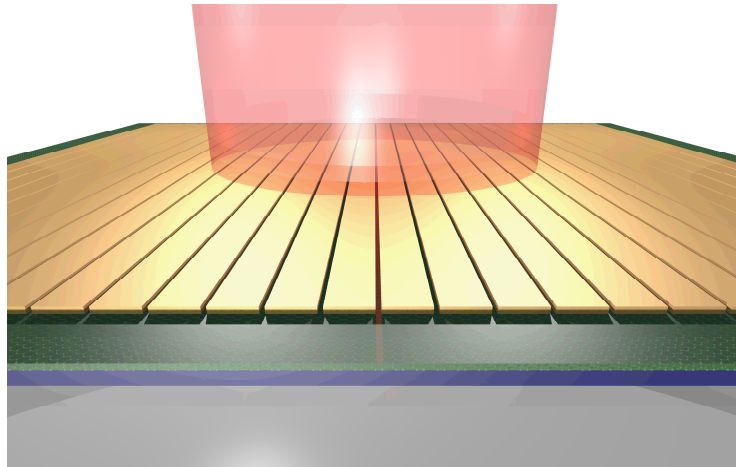
Origin of Tuning

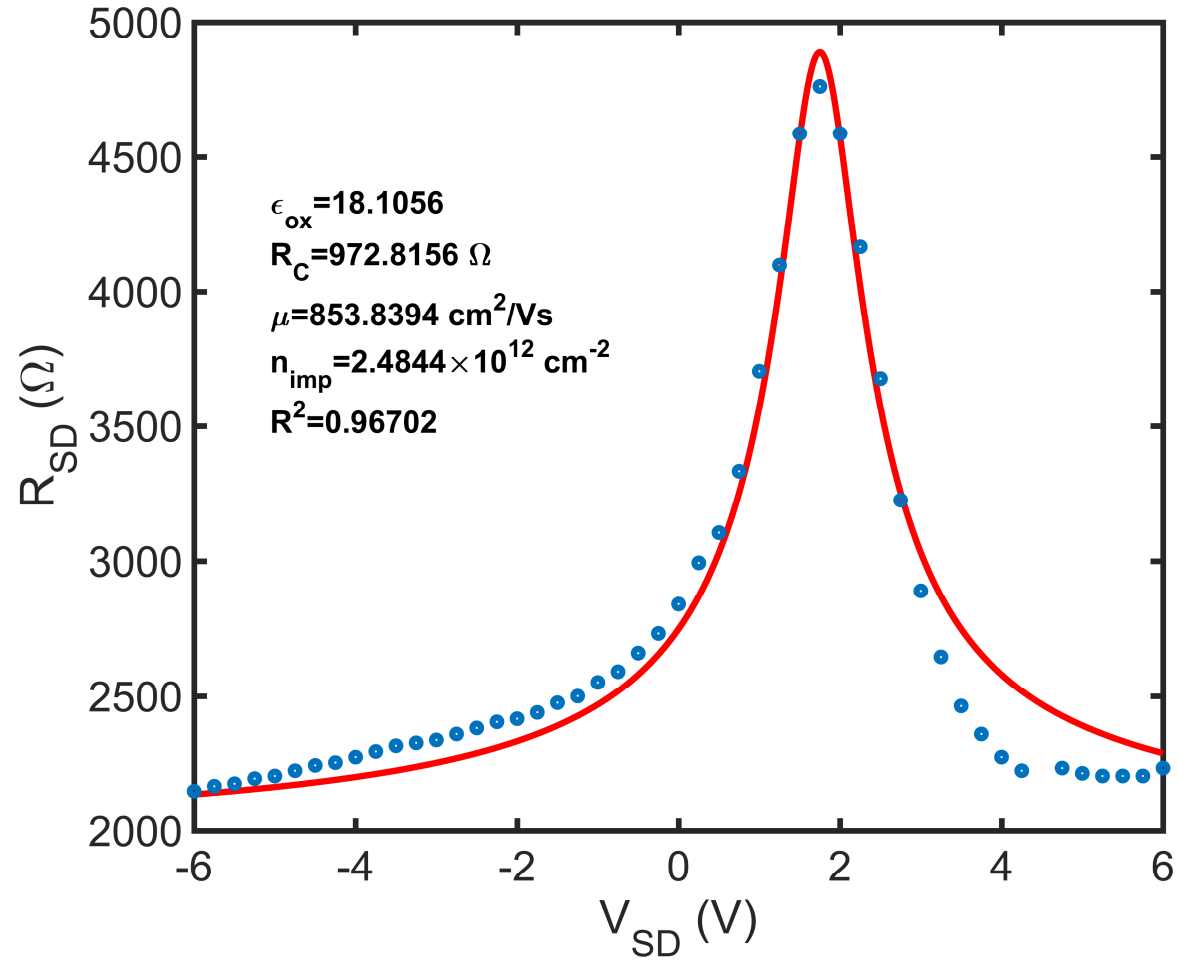


- Tuning occurs only where plasmon is excited and modified with Fermi energy.
- These regions are determined by dielectric cladding layers making them selectable.

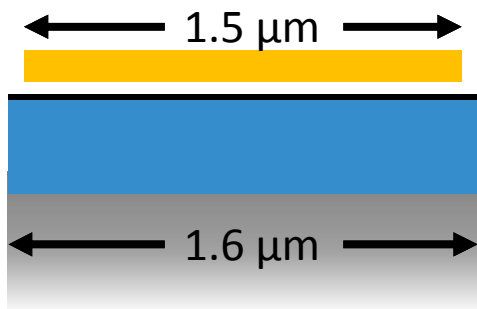
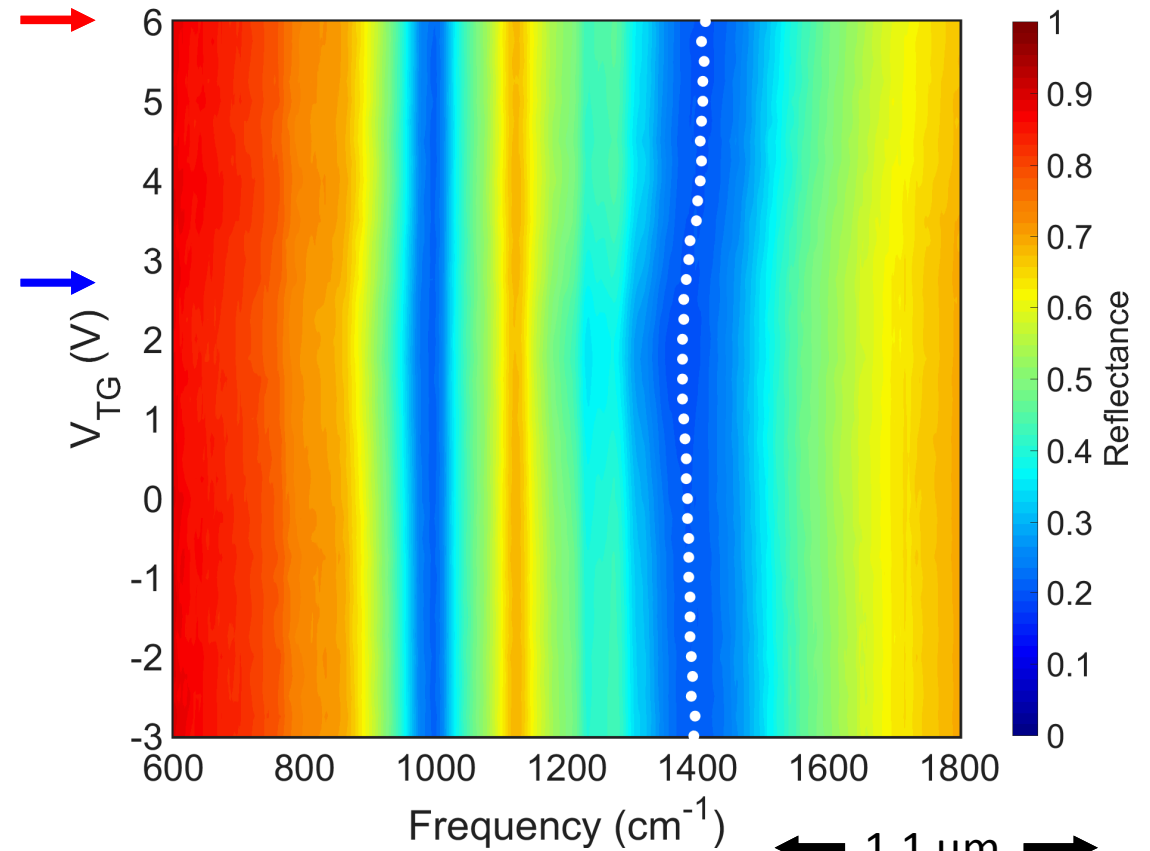
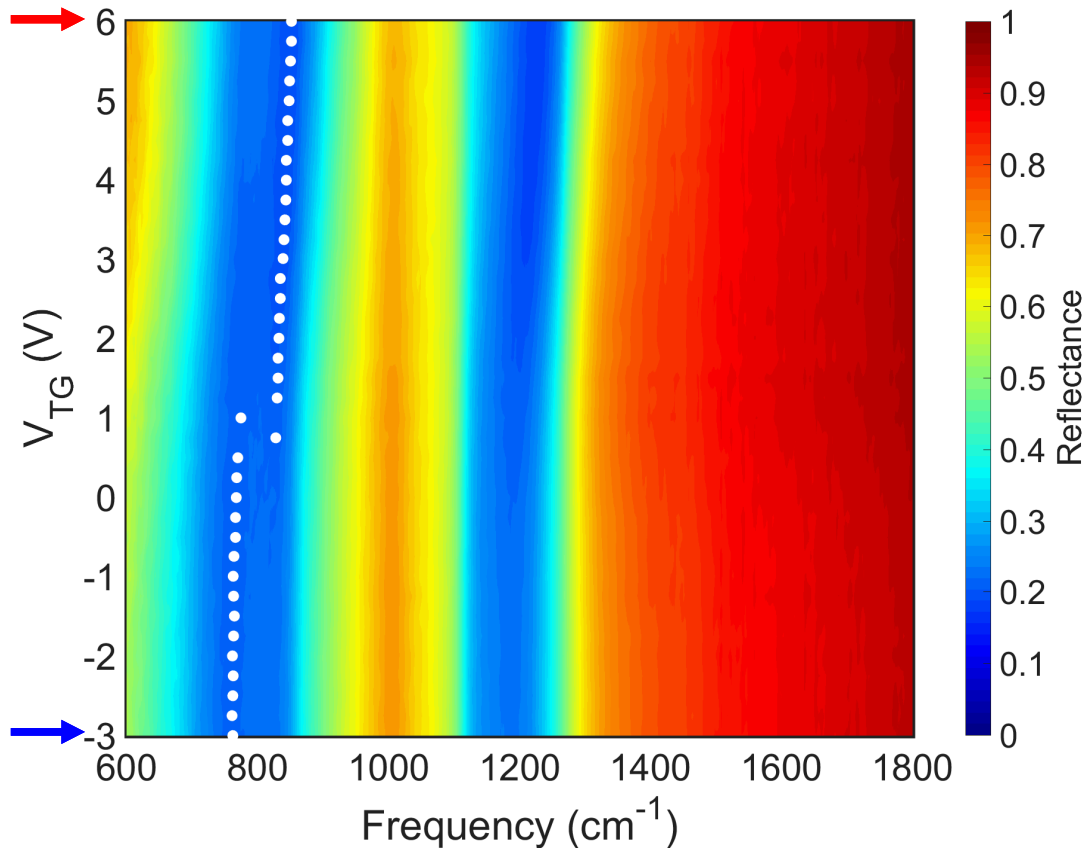
Conclusion

- Demonstrated scalable and tunable graphene-based IR filter.
- Enables modification of response in two bands simultaneously.
- Graphene is continuous and protected for device longevity.





Measured Reflectance



- Spectral shift depends on both grating design and SiO₂ thickness.
- Shift in position of two resonances simultaneously.
- Larger shifts are lower frequencies.

