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Title: The localized surface plasmonic effects: from far-field to near-field optical measurements

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The localized surface plasmonic effects: from far-field to near-field optical measurements

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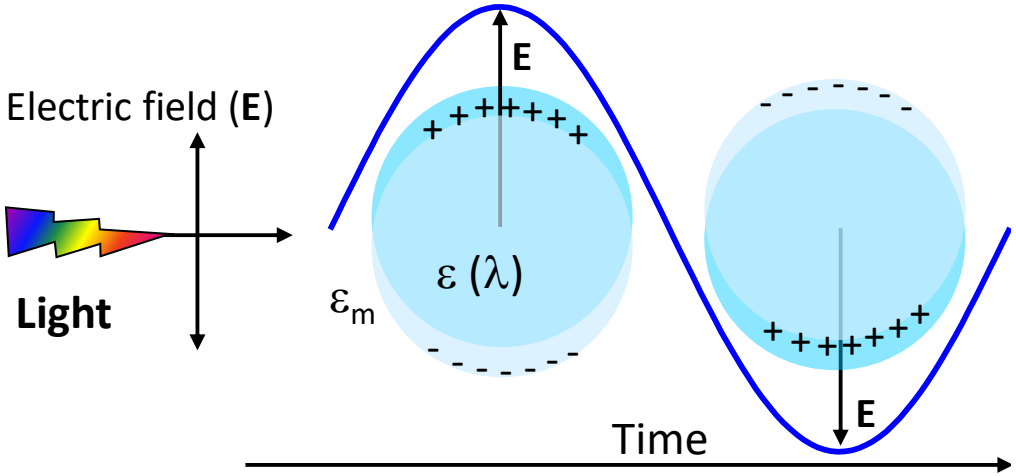
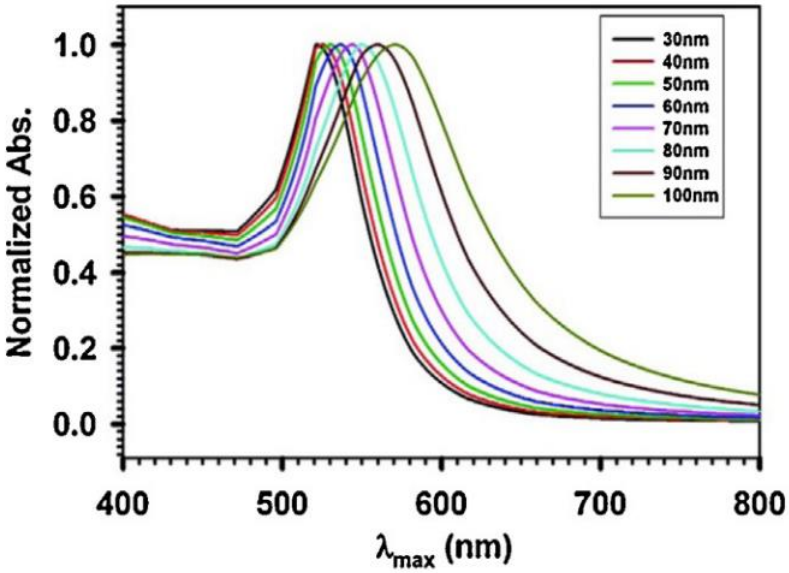
Outline

- Introduction
  - Localized surface plasmons
- Far-field observation
  - Experiment setup
  - Temperature-dependent plasmonic enhanced photoluminescence
  - Power-dependent PL
- Near-field observation
  - Scattering-type scanning near-field optical microscopy (sSNOM)
  - Nano Fourier-transform infrared spectroscopy (nano-FTIR)
  - Intersubband transition (ISBT)
- Future work

Localized Surface Plasmons



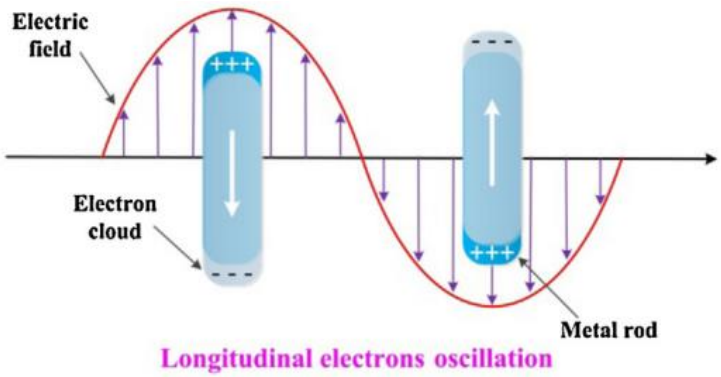
$$\text{Polarizability}: \quad \alpha = 4\pi r^3 \frac{\varepsilon(\lambda) - \varepsilon_m}{\varepsilon(\lambda) + 2\varepsilon_m}$$

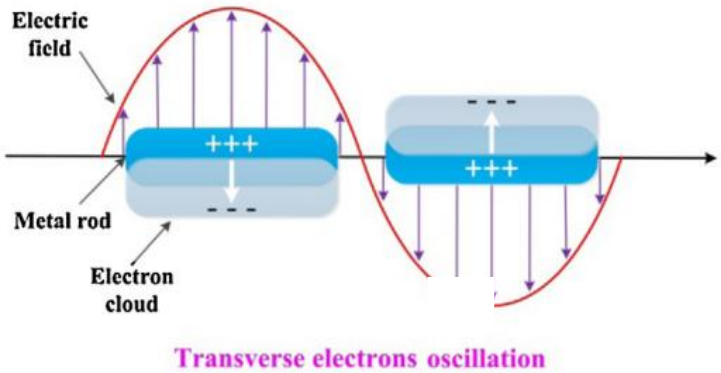


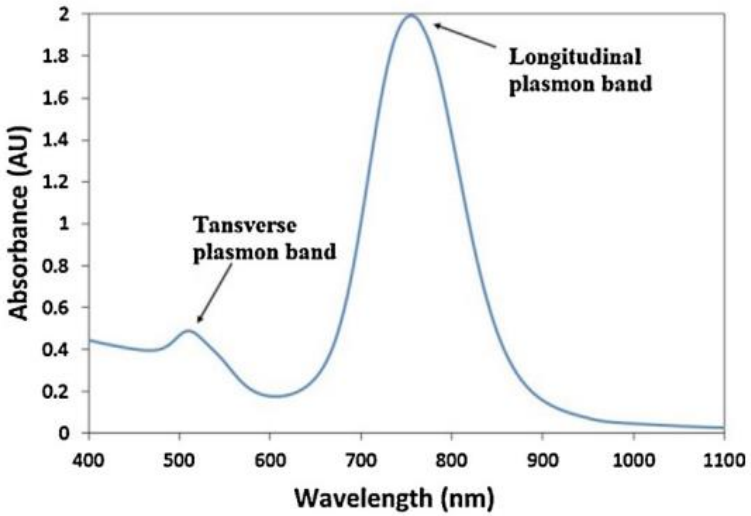
Willets, Katherine A., and Richard P. Van Duyne, *Annu. Rev. Phys. Chem.* 58 (2007): 267-297.

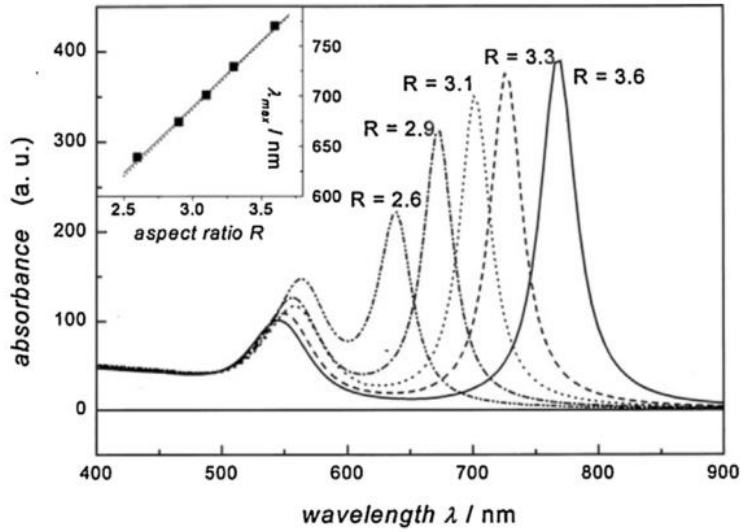
P.N. Njoki, et al, *J. Phys. Chem.* C 111 (2007) 14664–14669.

Plasmonic nanoparticles







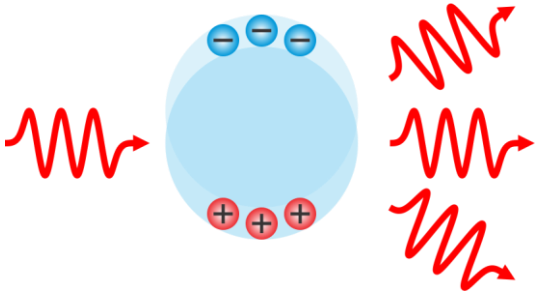


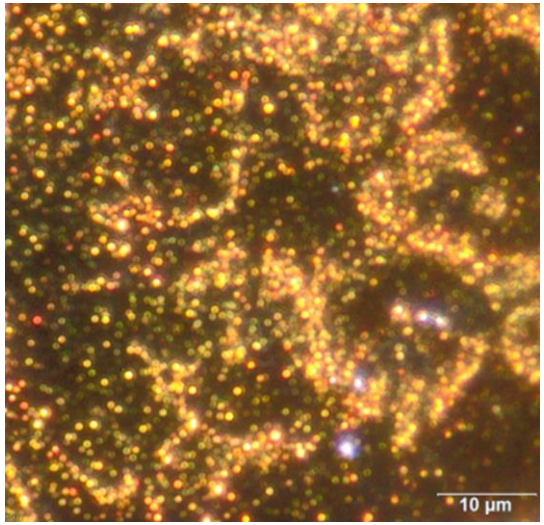
Jie Cao, et al, Sensors and Actuators B: Chemical, vol. 195, 2014, pp.

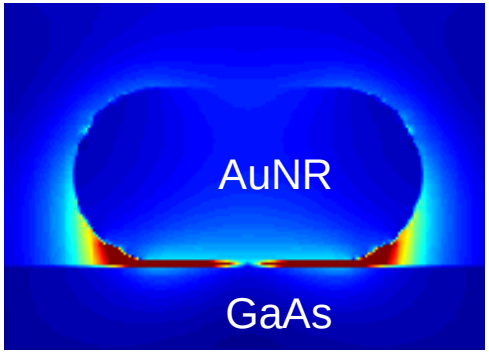
S. Link, et al, *J. Phys. Chem. B, 103, 1999, pp.3073-3077.*

Plasmonic effect in the far-field and near-field

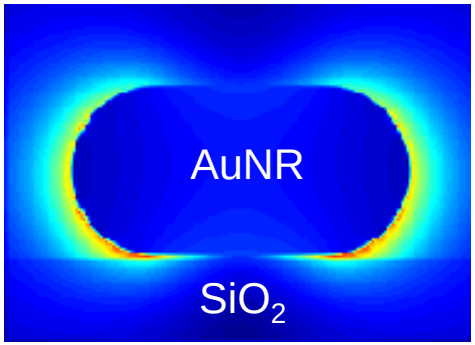
LSPR Excitation



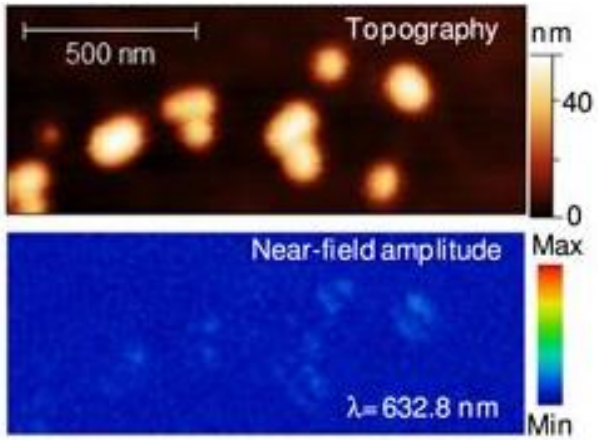


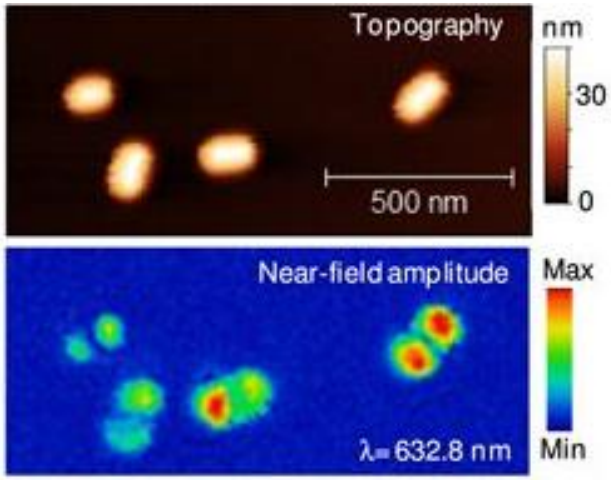


$\varepsilon_{GaAs} = 14.83 + i1.52$



$\varepsilon_{SiO_2} = 2.25$

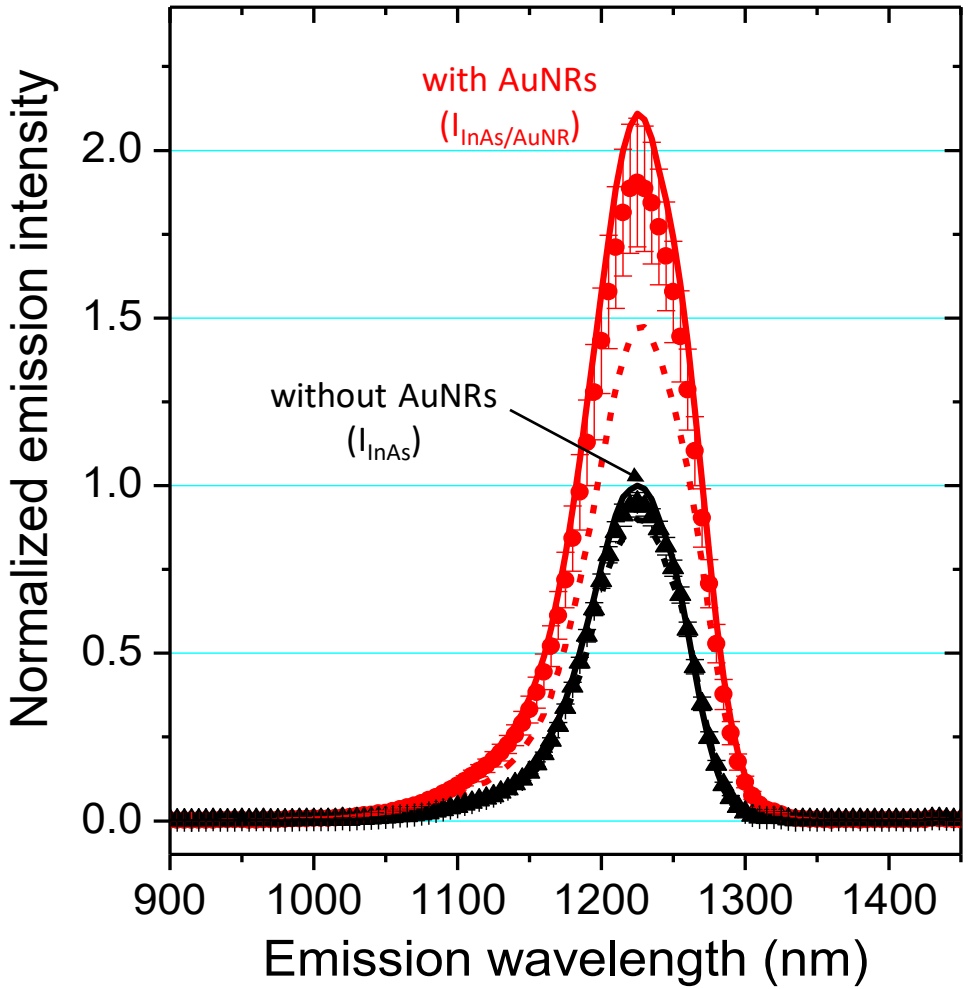


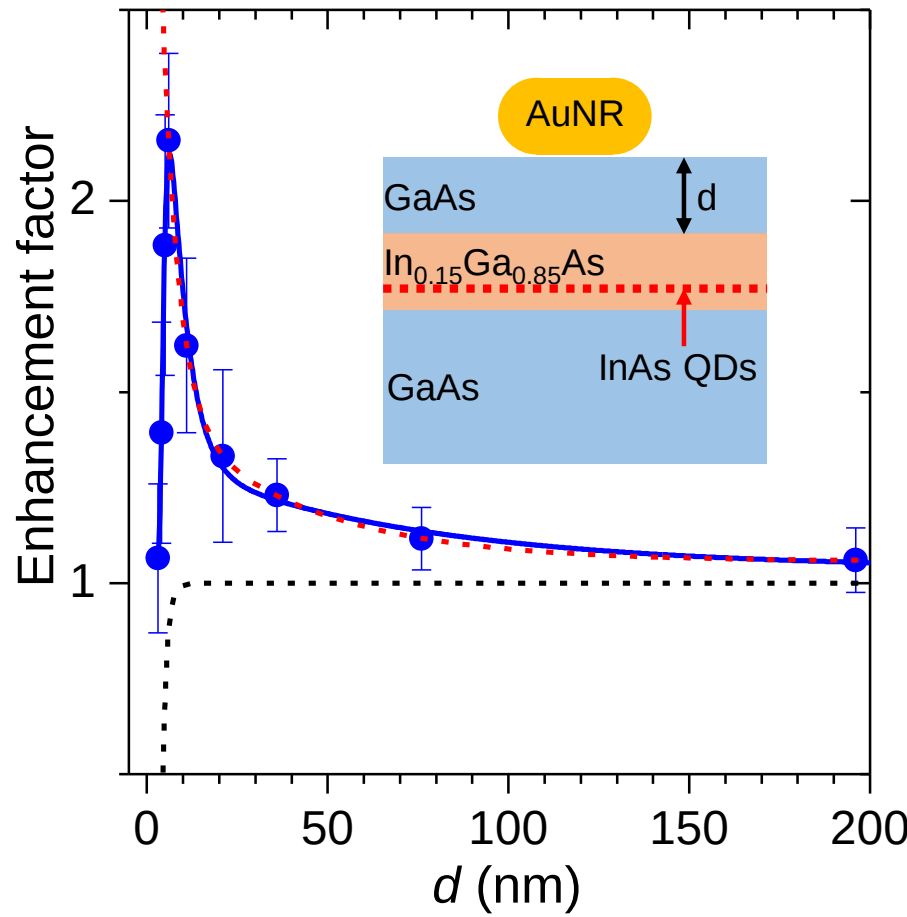


Sharmin Haq, et al, *Scientific Reports*, vol. 7, no. 1, 2017

LSP effect at far-field region

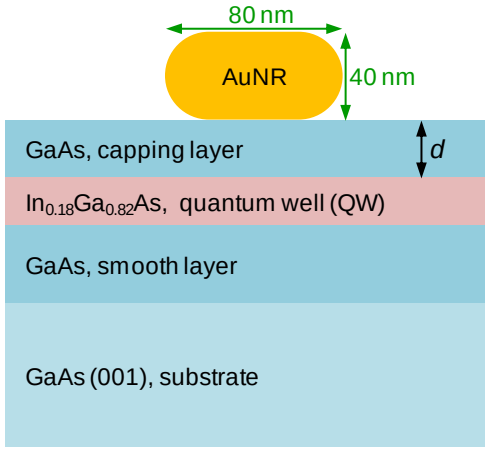
Thickness dependence of Quantum Dots PL emission

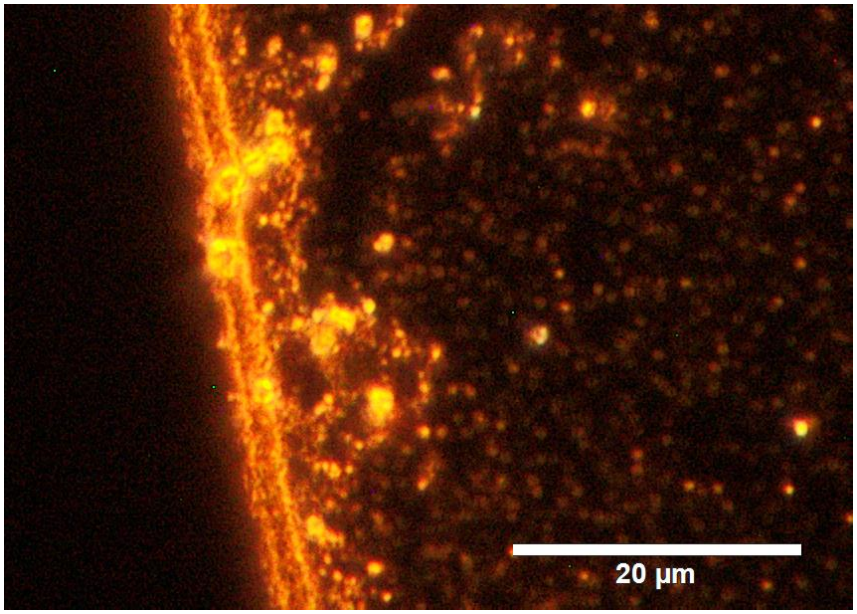


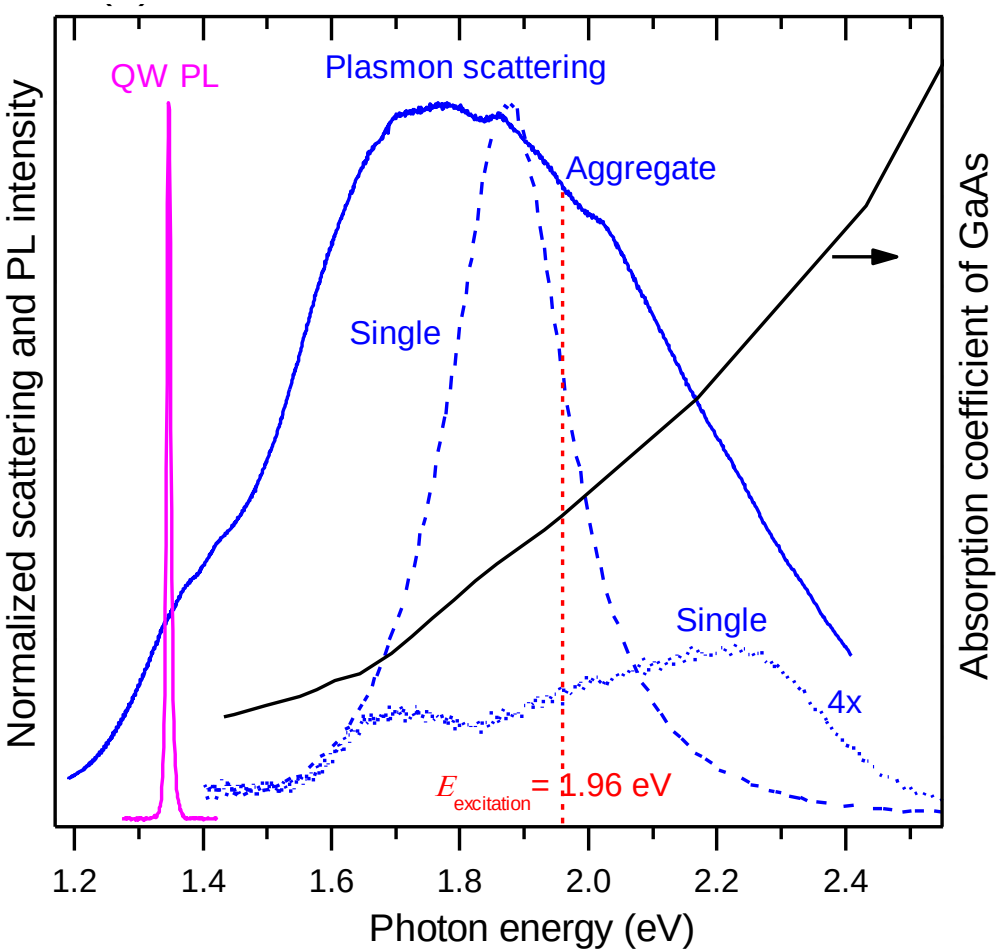


Sharmin Haq, et al, *Scientific Reports*, vol. 7, no. 1, 2017

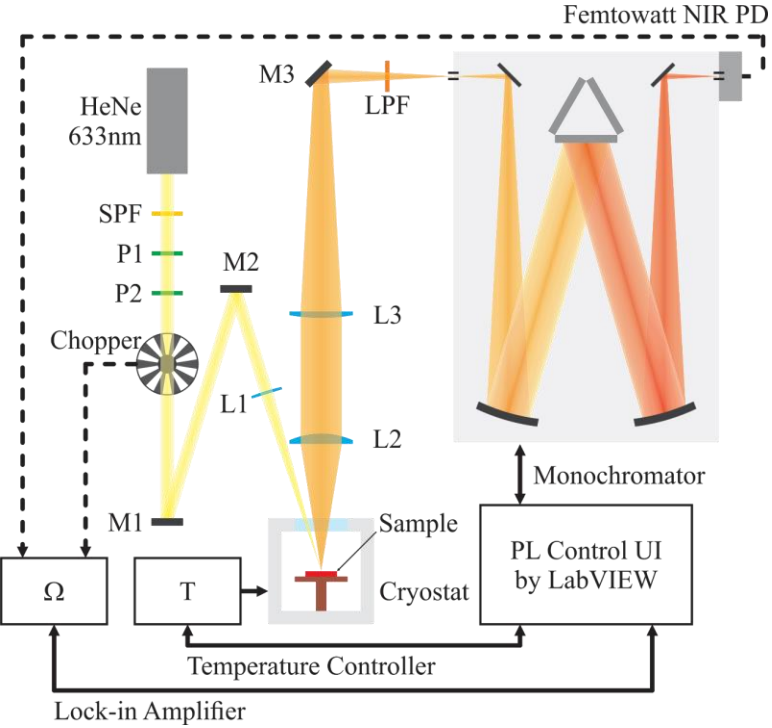
LSP coupled quantum well system

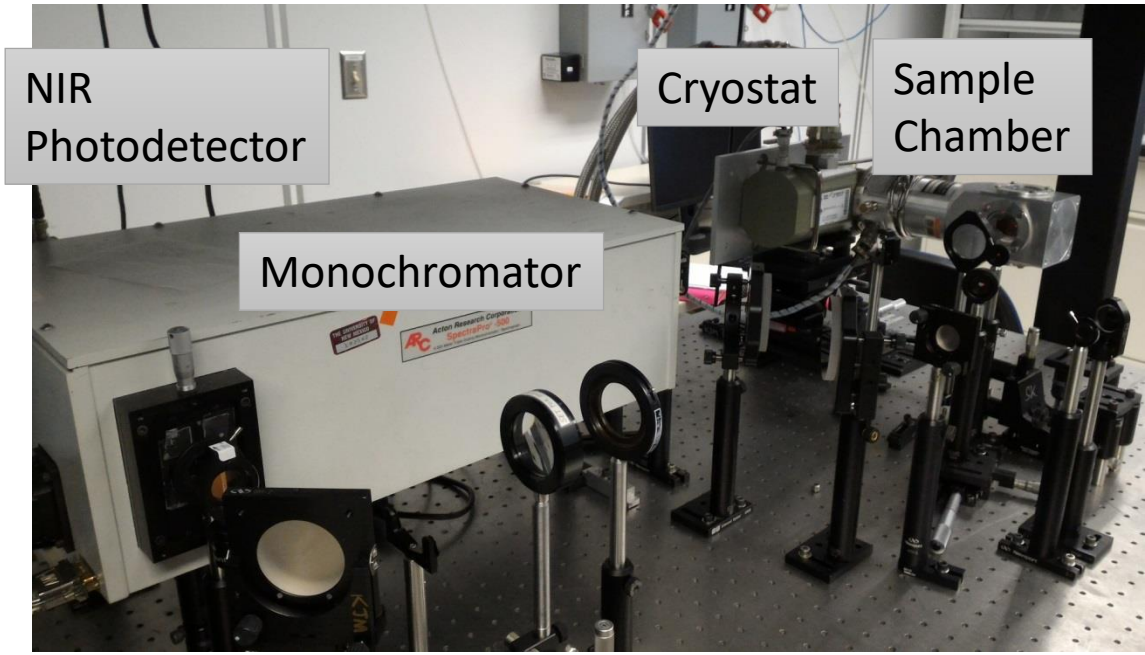




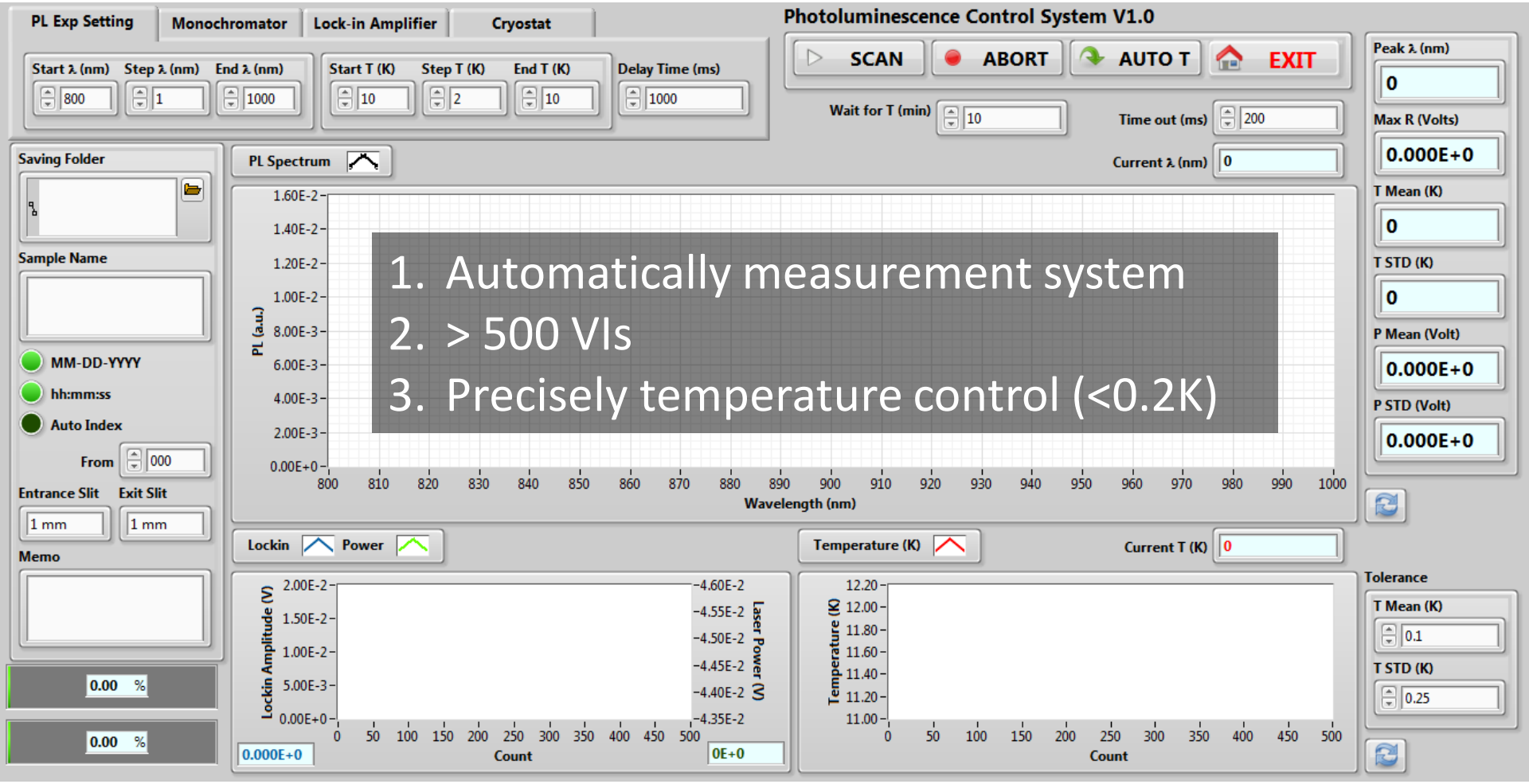


Home-built Cryo-Photoluminescence measurement system



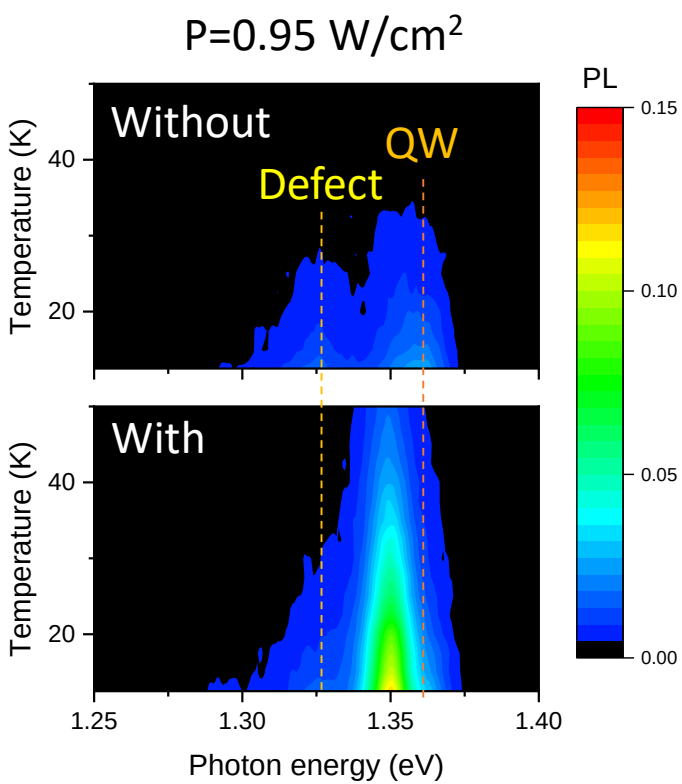


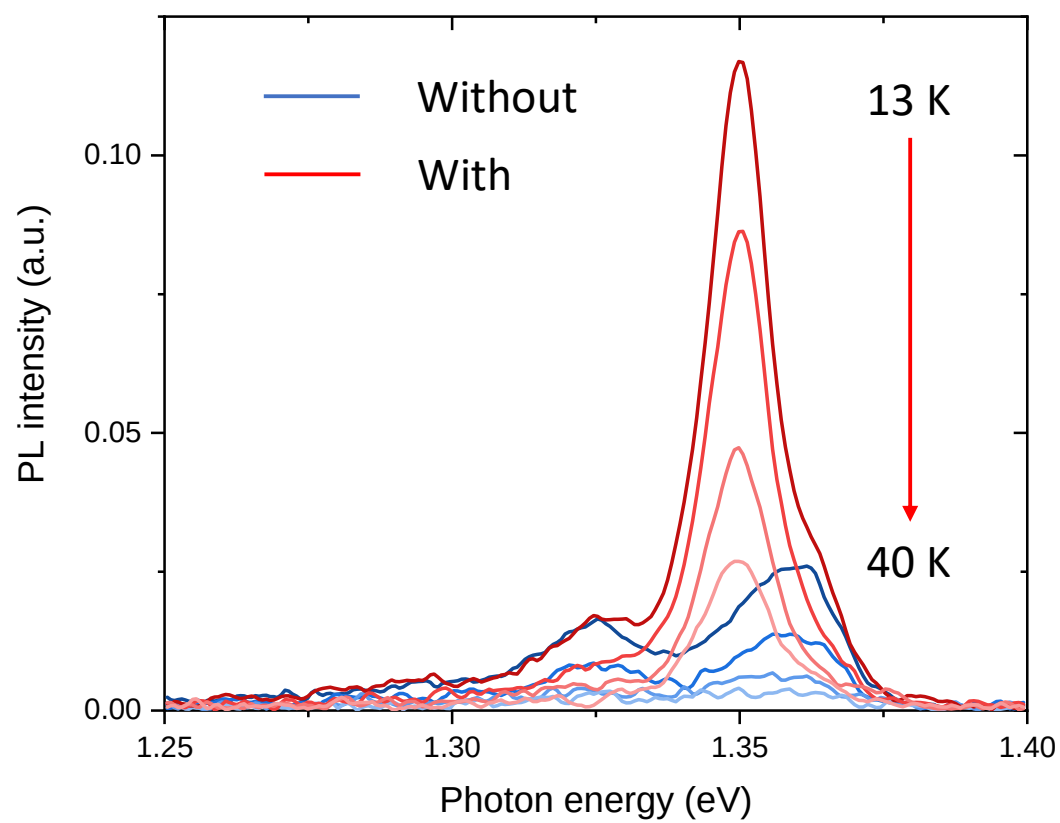
Home-built Cryo-PL Program (LabVIEW)



1. Automatically measurement system
2. > 500 VIs
3. Precisely temperature control (<0.2K)

Brightening a defective photon emitter – 5nm QW

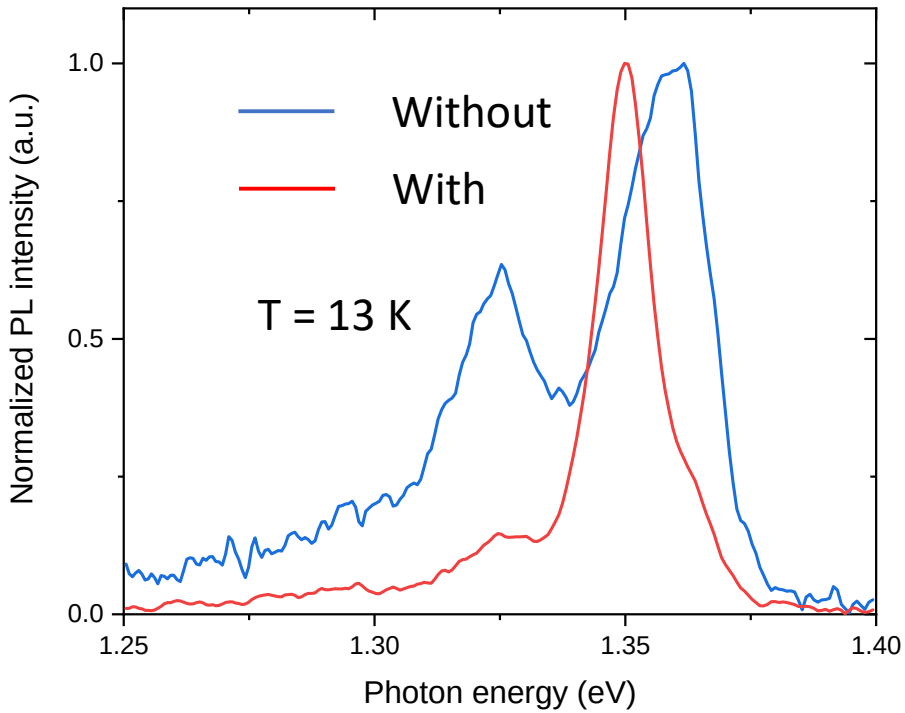


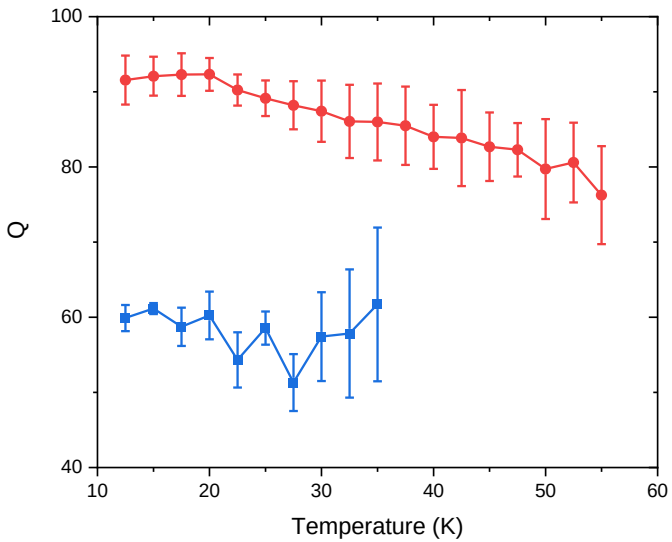


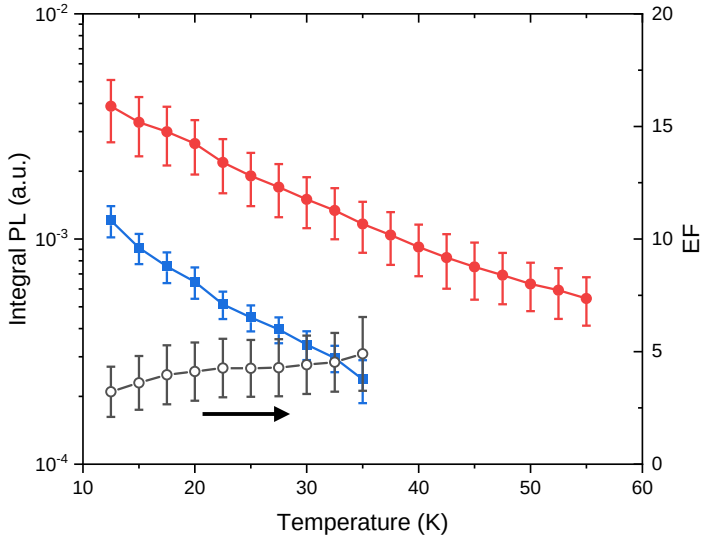
Low quality photon emitters can be brightened using plasmonic enhancement effect.

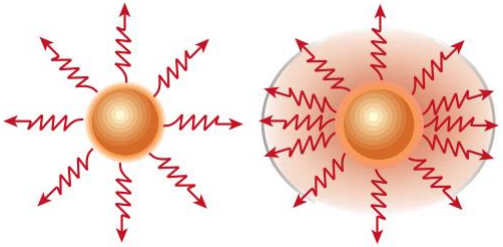
To be submitted

Plasmon enhanced PL of poor QW





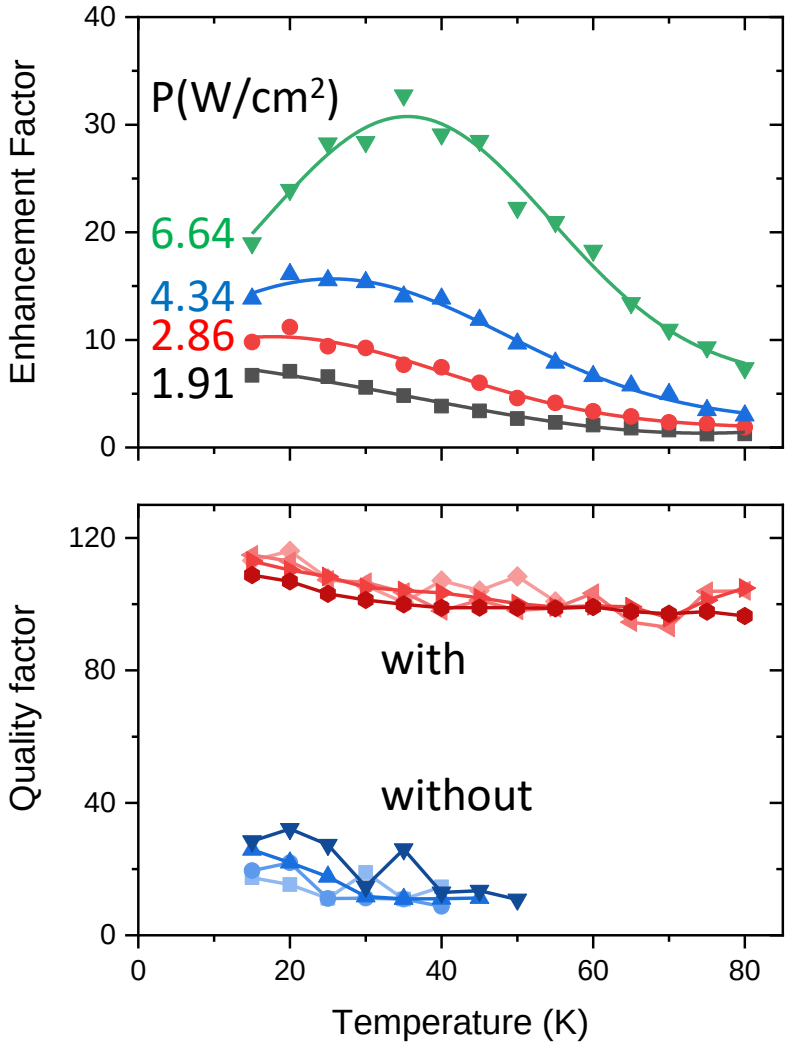


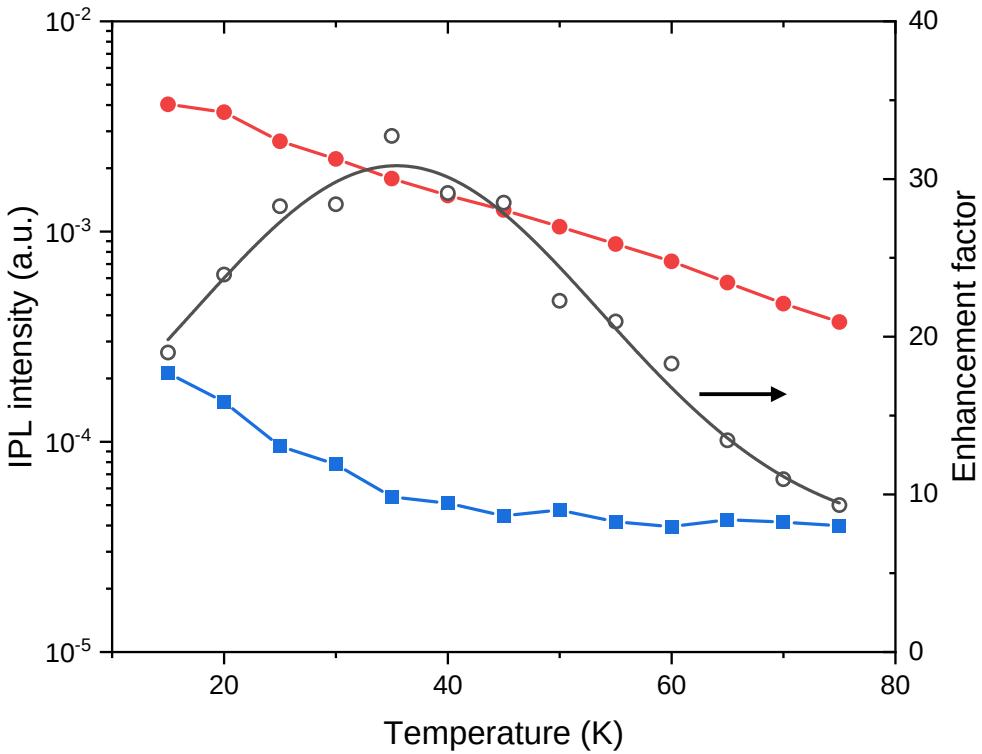


$$F_p = \frac{3}{4\pi^2}\left(\frac{\lambda}{n}\right)^3\left(\frac{Q}{V}\right)$$

Kerry J. Vahala, Nature 424, 839 (2003)

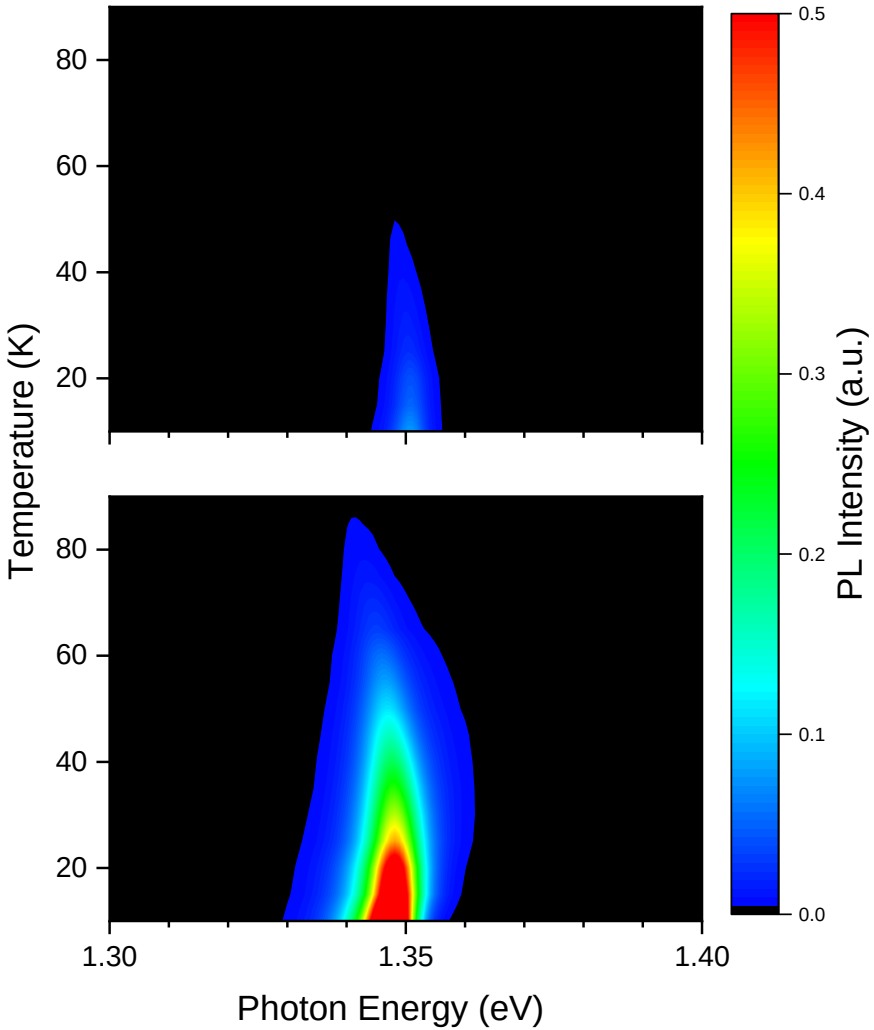
Power dependence of EF

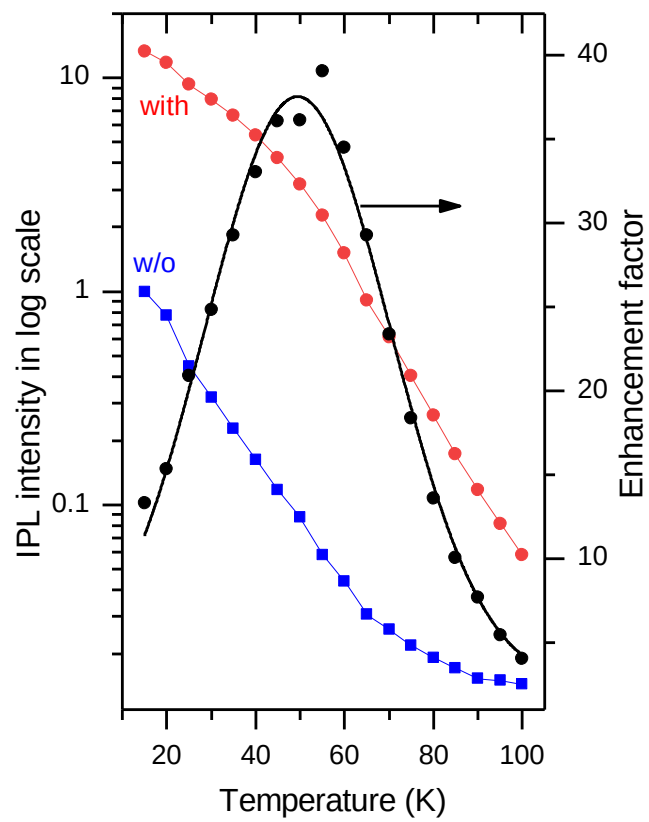




To be submitted

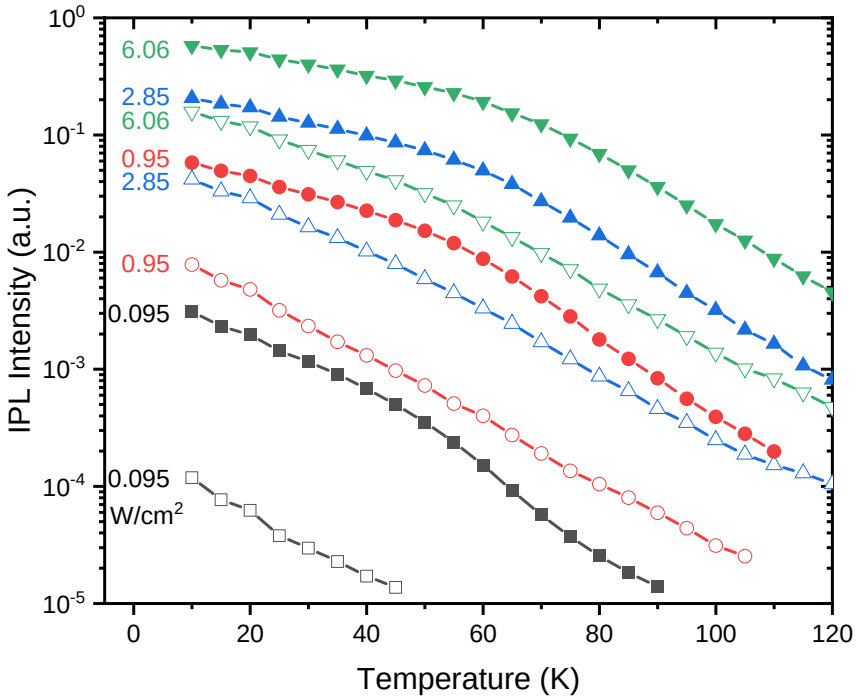
PL of QW with 10 nm cap layer

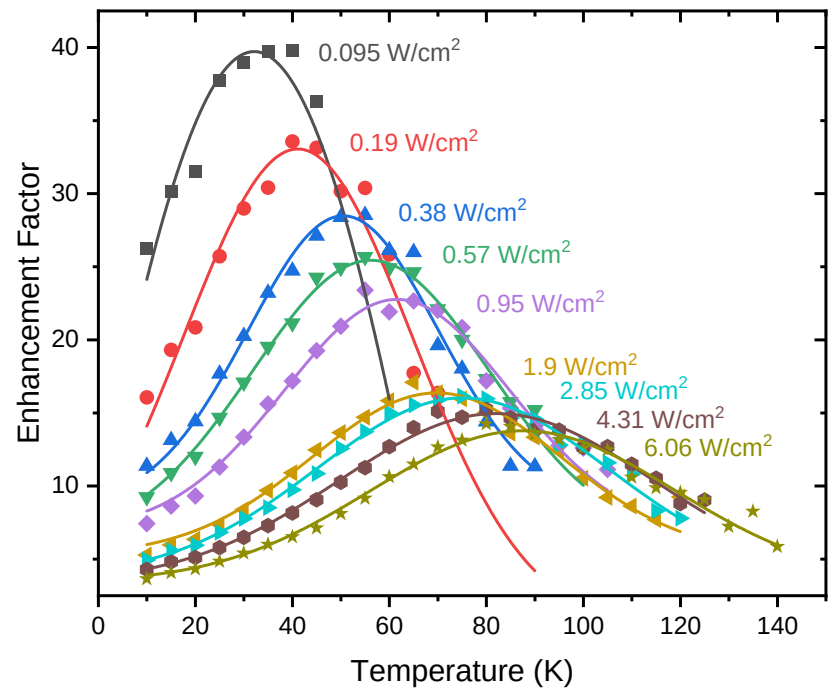


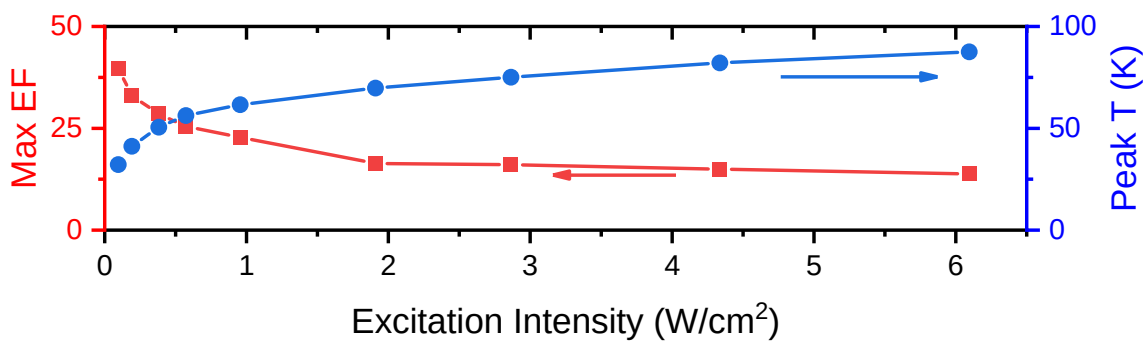


To be submitted

Power dependent in 10 nm cap QW

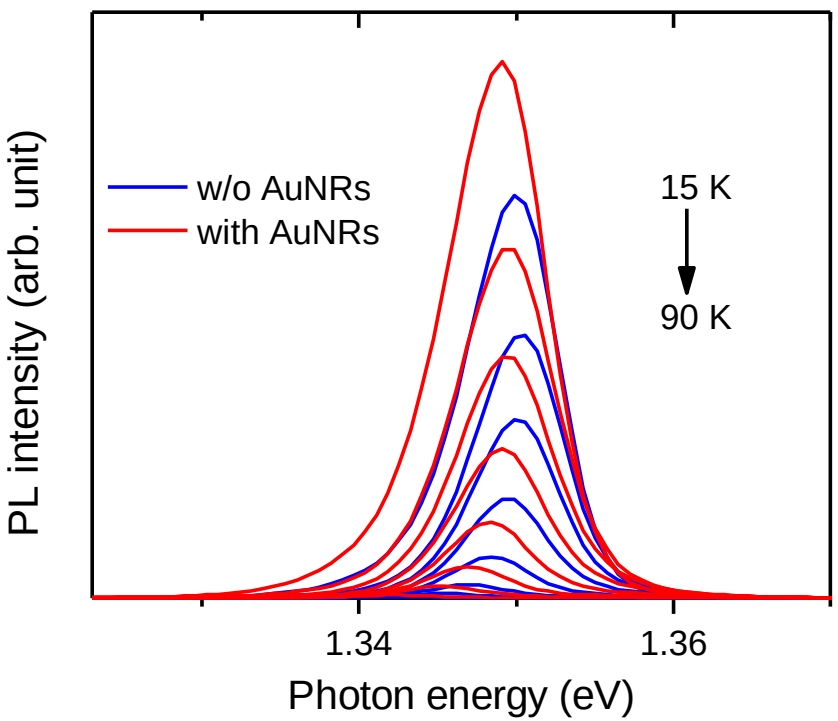


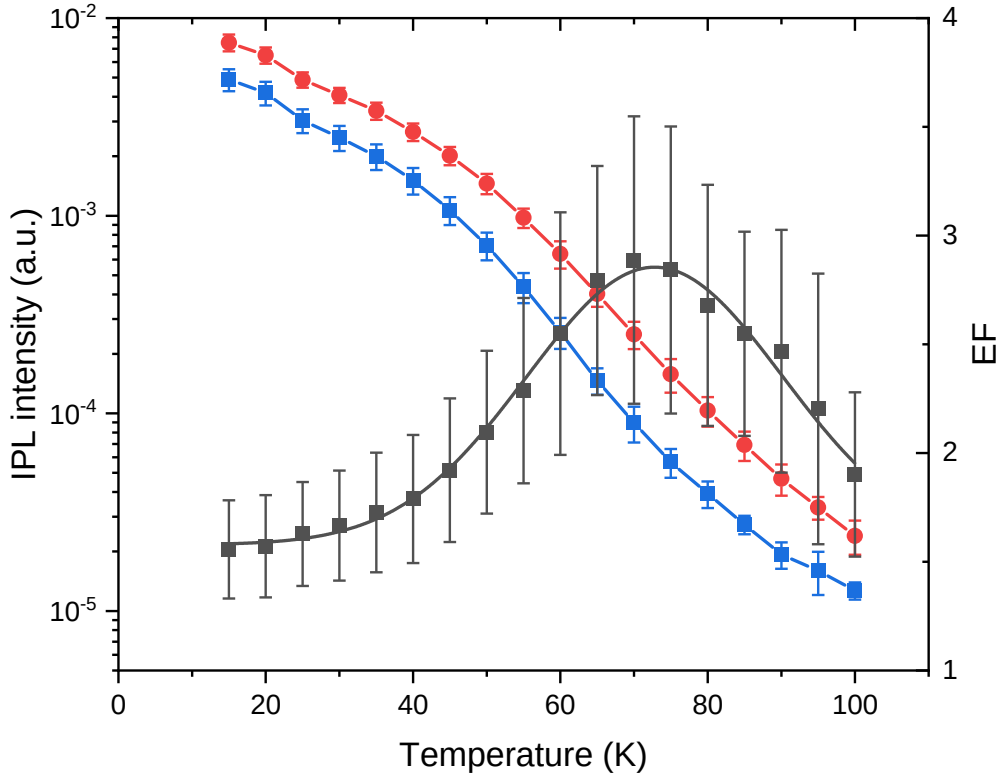




To be submitted

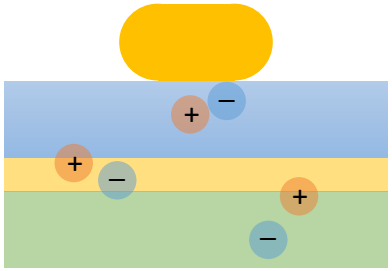
PL of QW with 15 nm cap layer





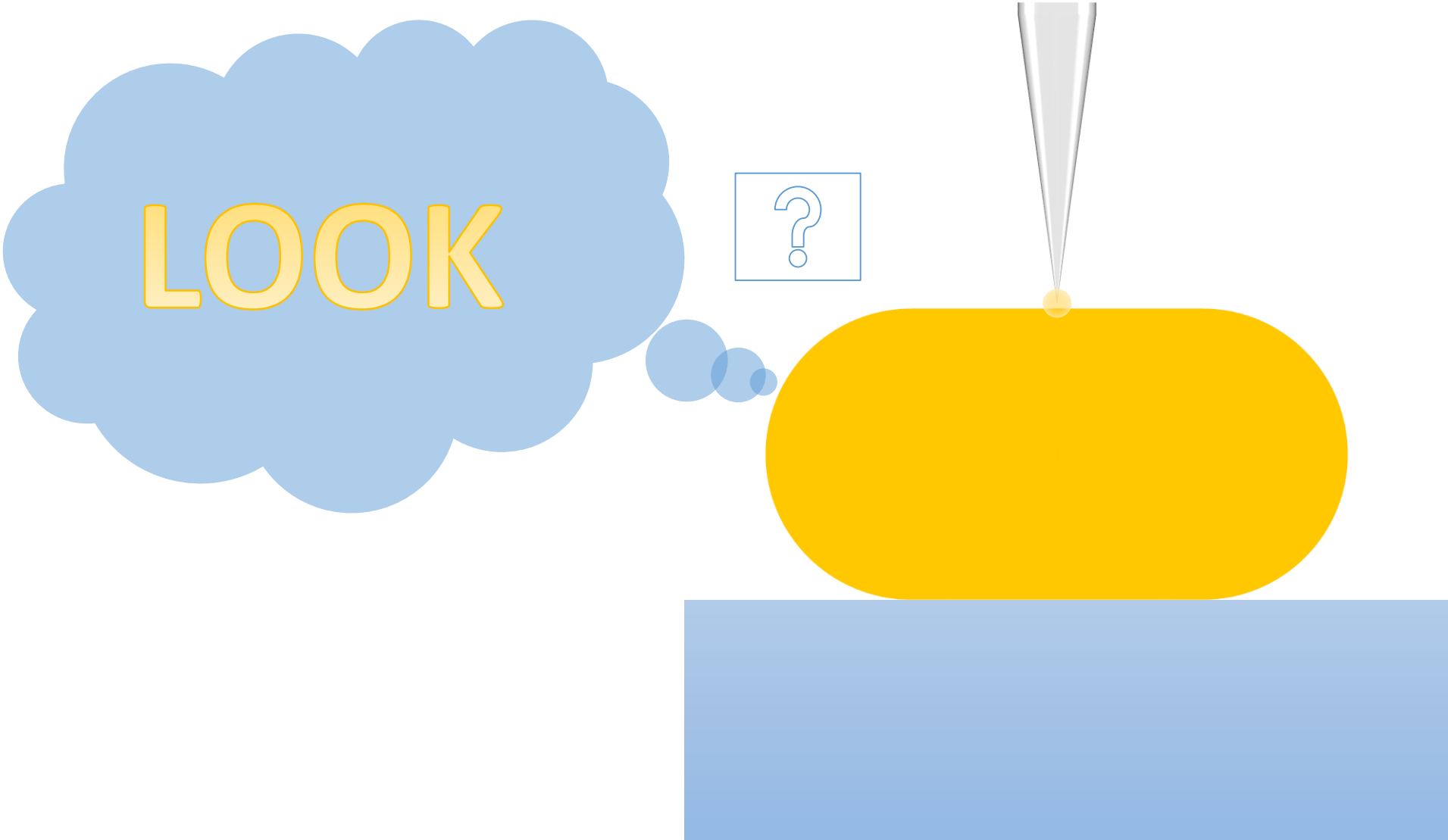
To be submitted

Summary of AuNRs probing



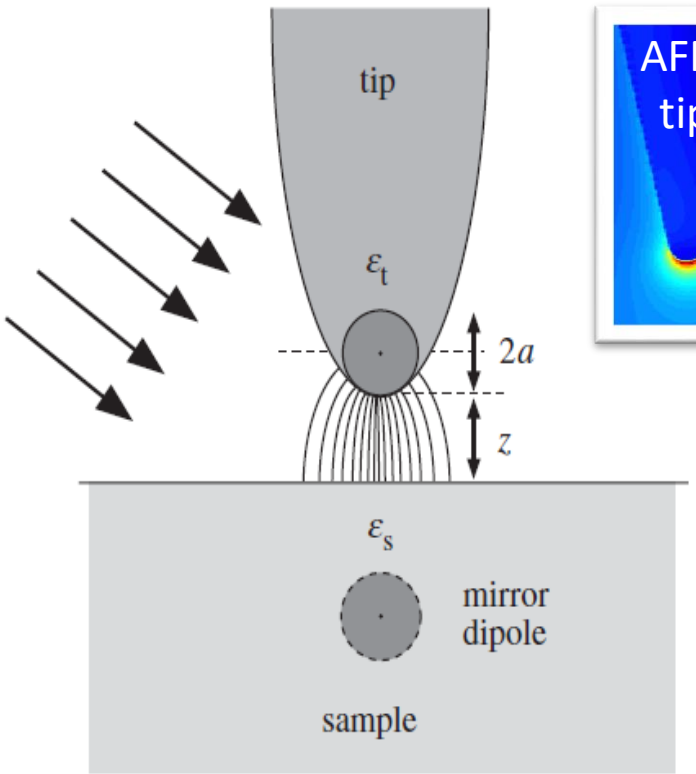
Colloidal plasmonic nanoparticle servers a simple probes for understanding carrier transfer across interfaces in semiconductor heterostructures

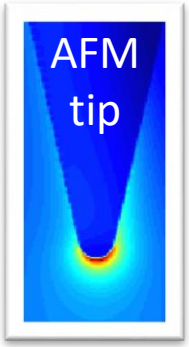
LSP effect at near-field region

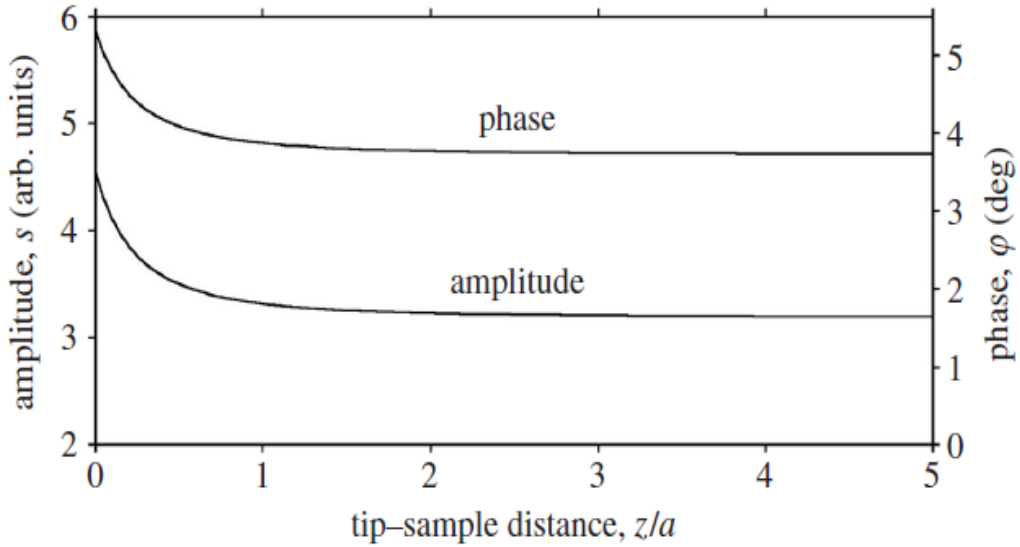


Introduction of sSNOM

Detection of near-field requires bringing a detector very close (1-10 nm) to the surface or a probe that can scatter the near-field to a detector mounted far away from the surface.



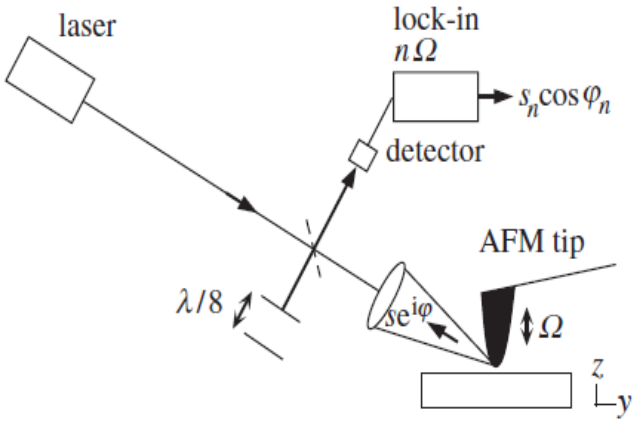




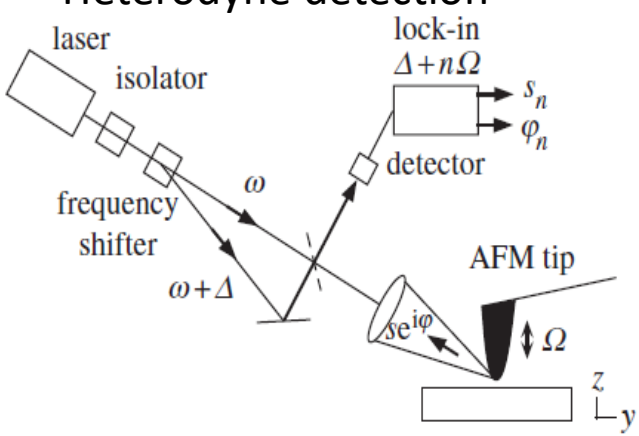
Fritz Keilmann, et al, *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 362.1817 (2004): 787-805.

Background free near-field detection

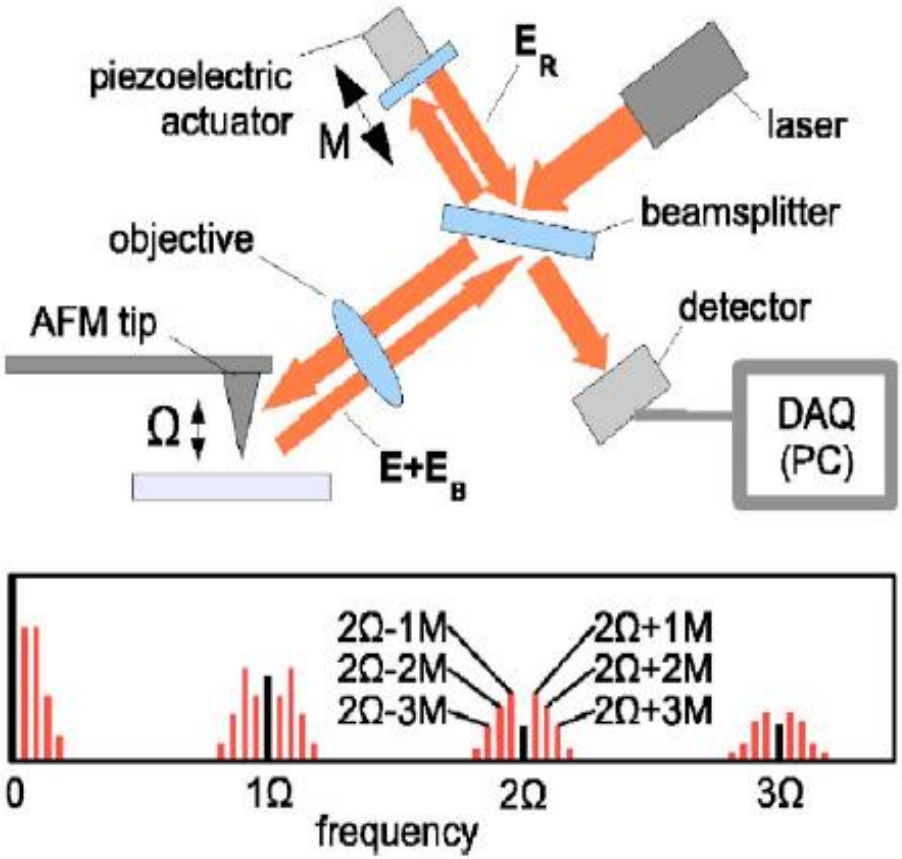
Homodyne detection



Heterodyne detection



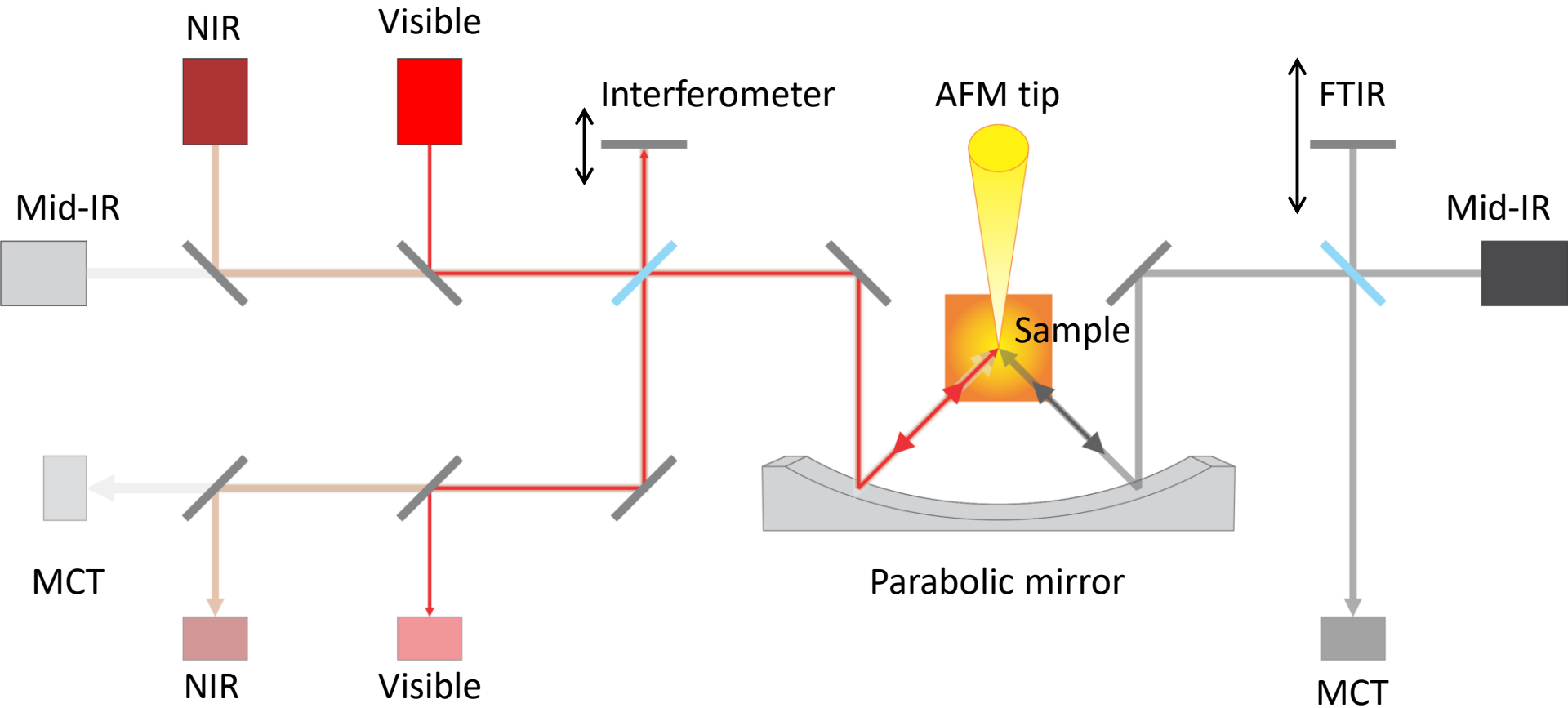
Pseudo-Heterodyne detection

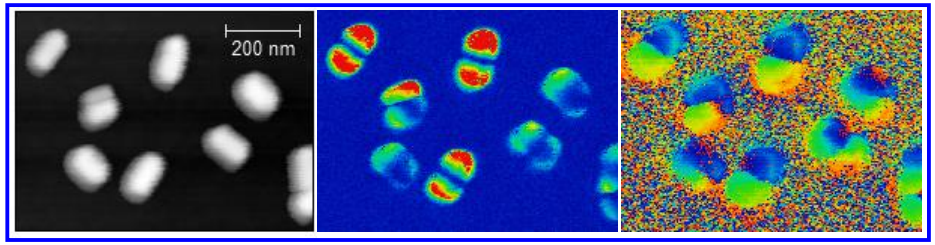


Fritz Keilmann, et al, *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 362.1817 (2004): 787-805.

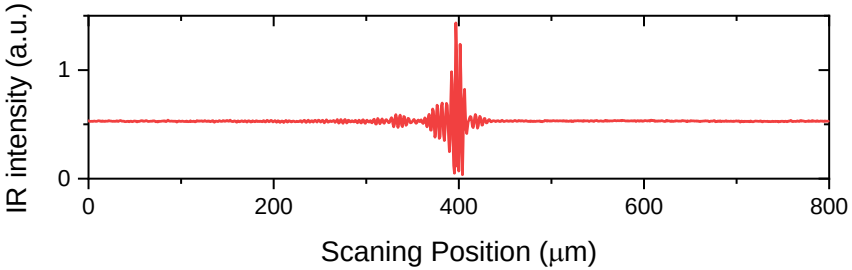
Nenad Ocelic, et al, *Appl. Phys. Lett.* 89.10 (2006): 101124.

Schematic of sSNOM system

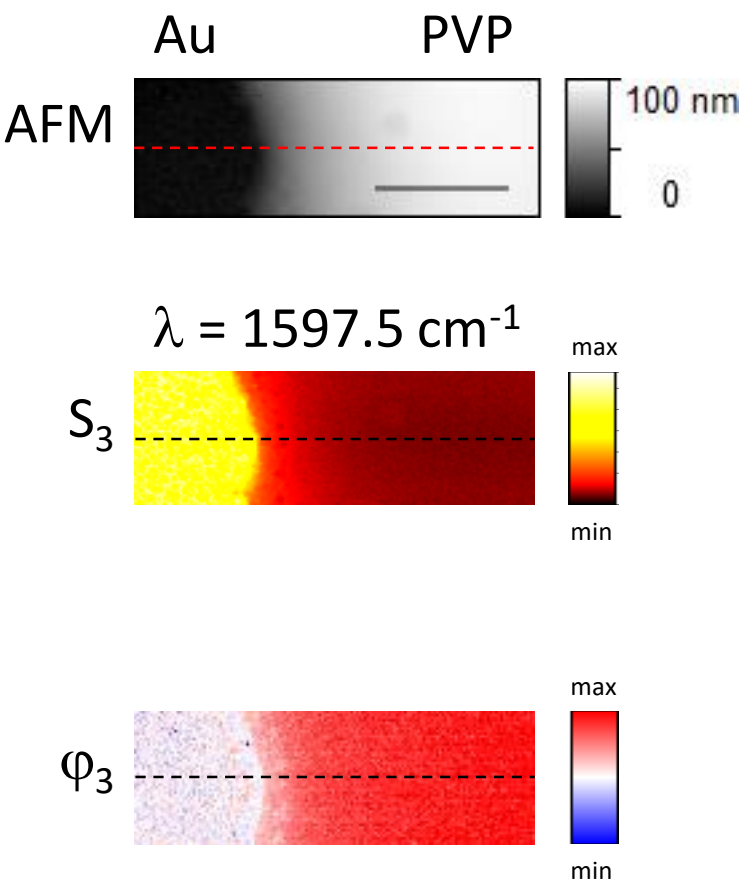


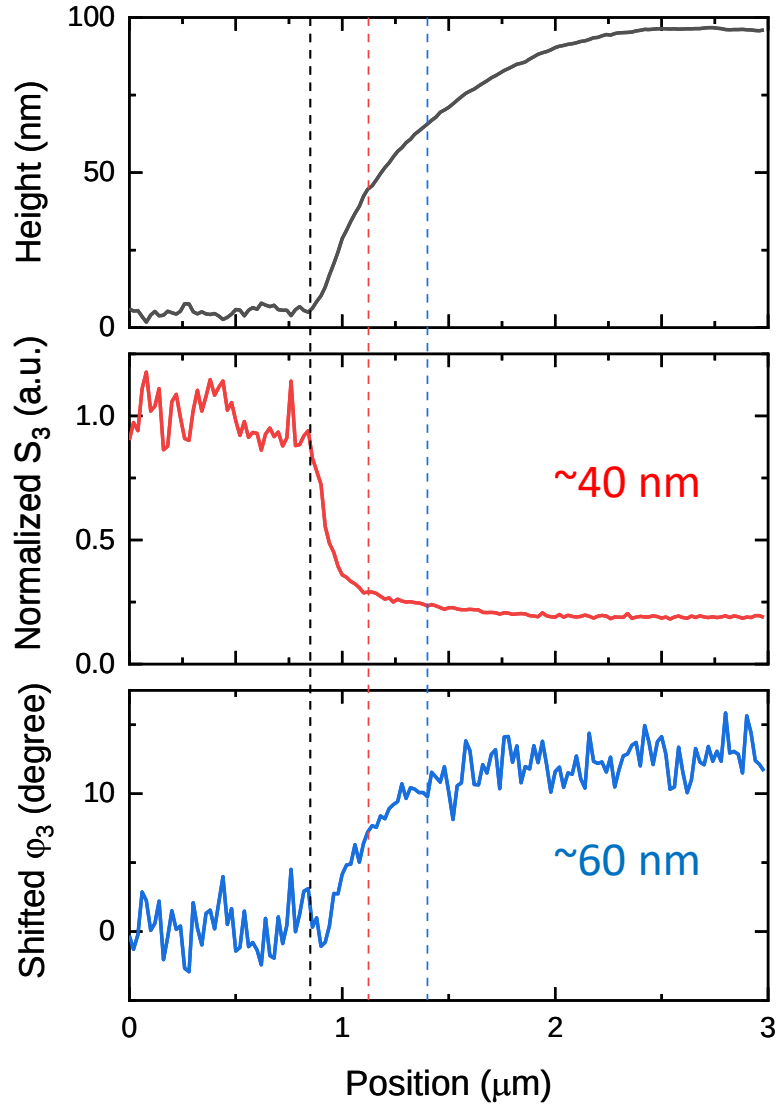


Topography Optical amplitude Optical phase

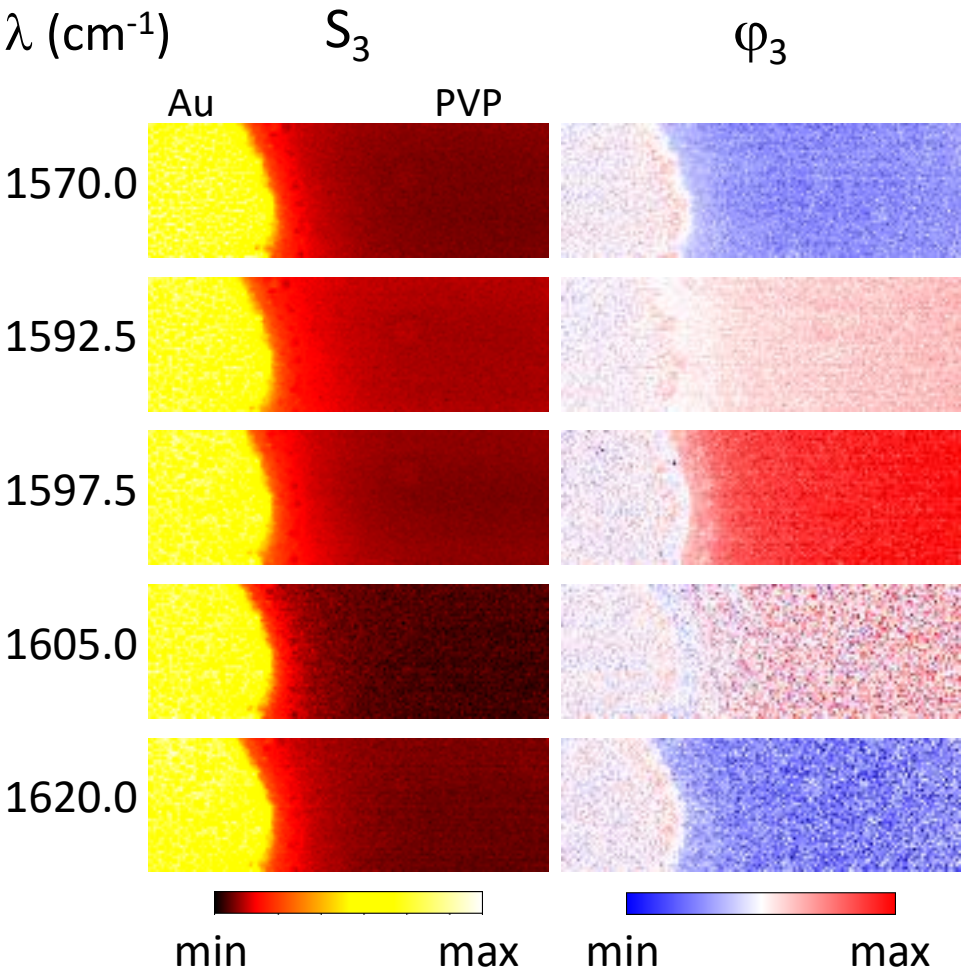


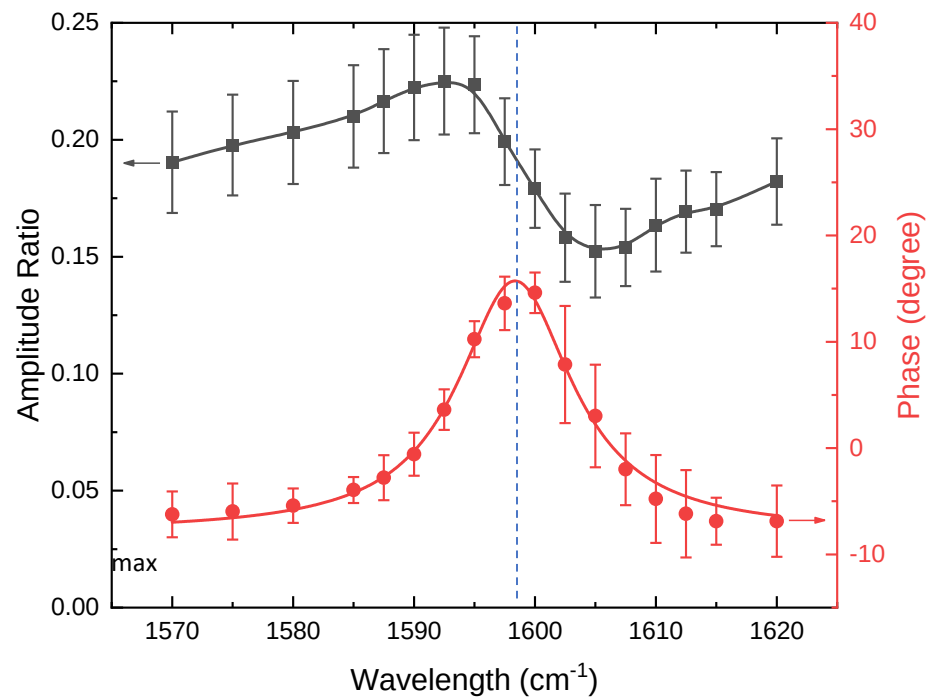
Near-field spectroscopy - poly(4-vinylpyridine) PVP thin film





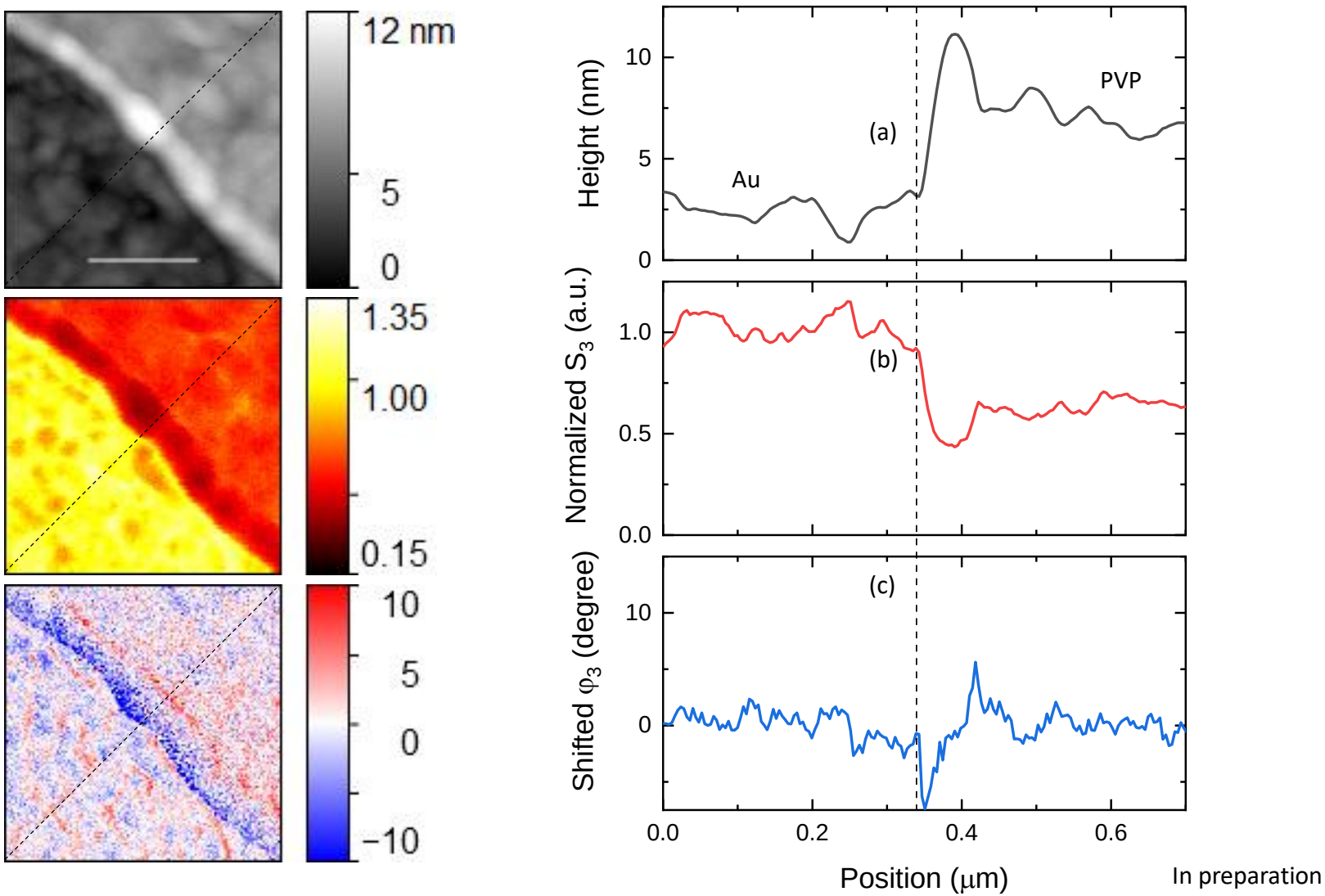
Near-field spectroscopy - PVP film





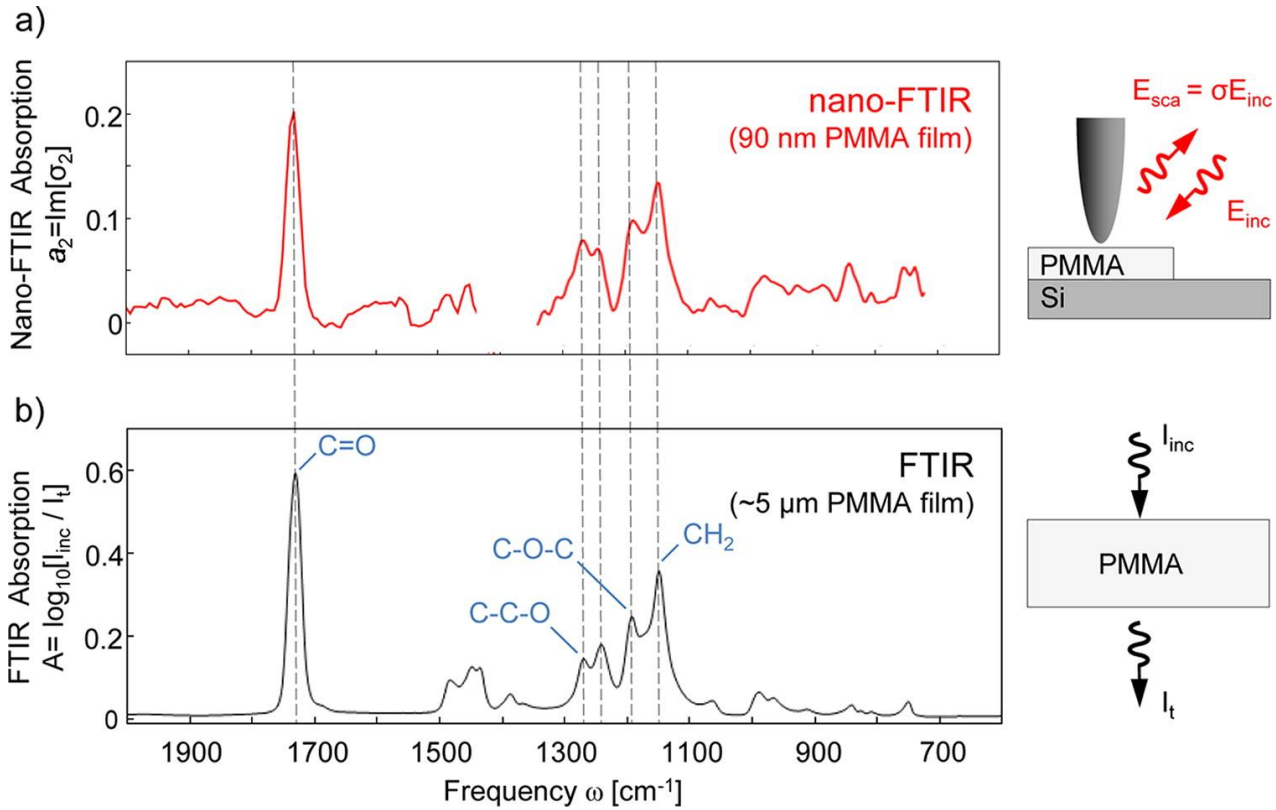
In preparation

Near-field spectroscopy limitation



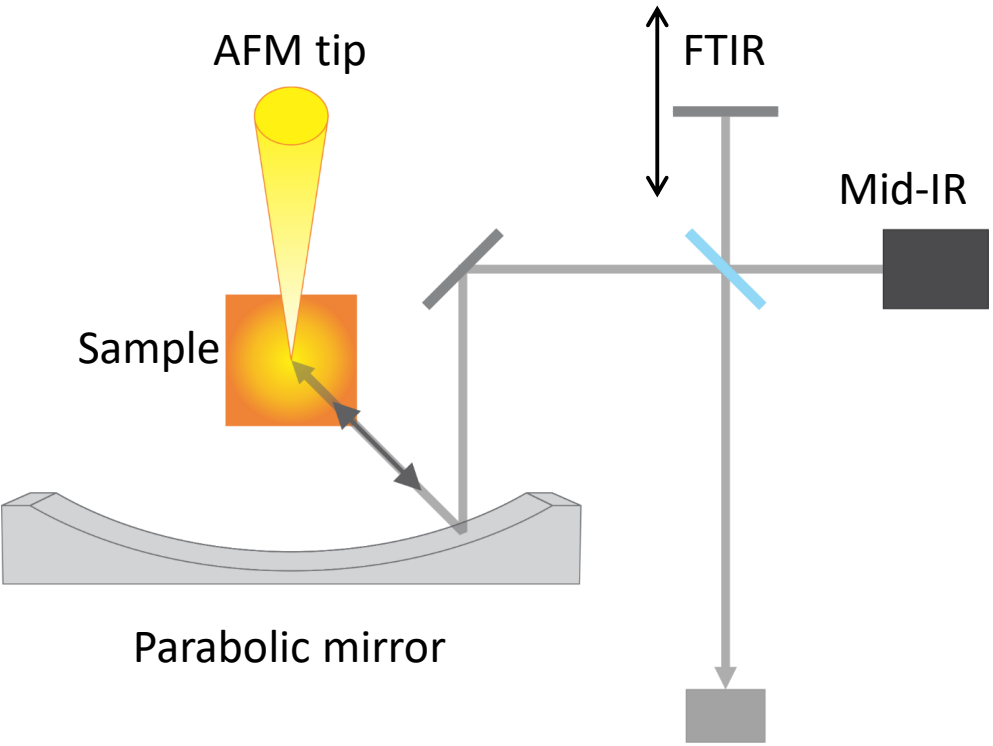
In preparation

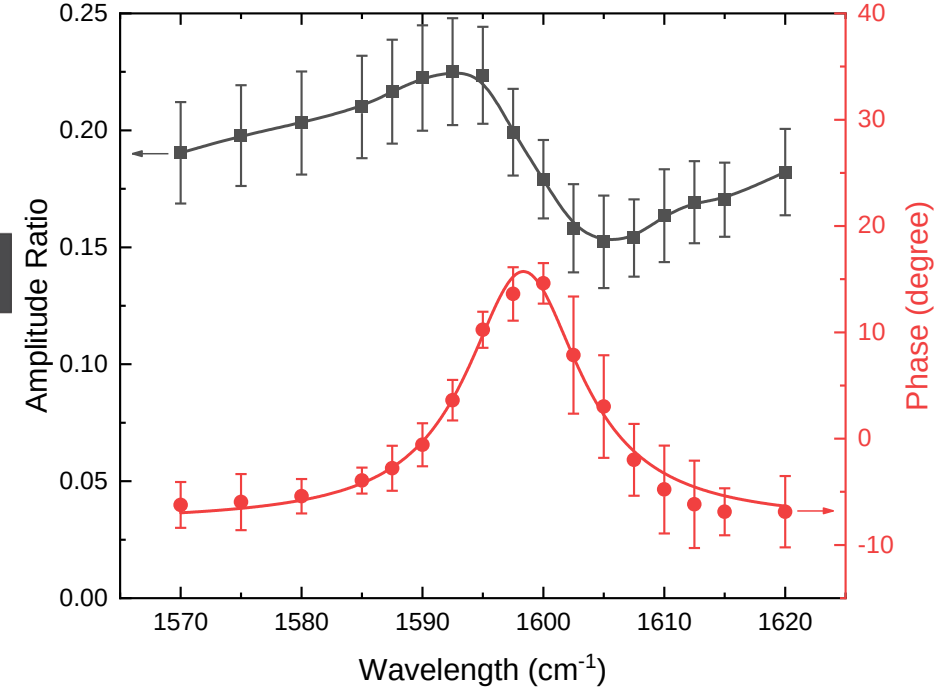
nano-FTIR vs. conventional FTIR

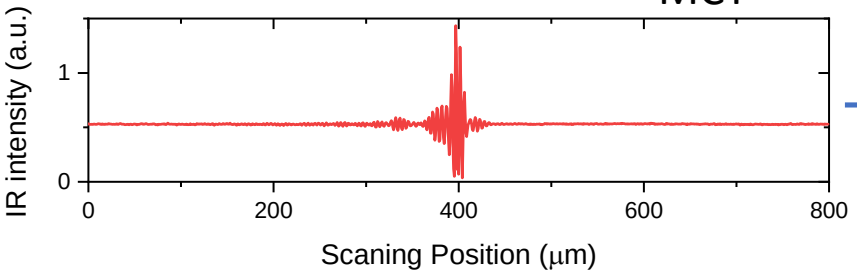


Huth, Florian, et al. *Nano letters* 12.8 (2012): 3973-3978.

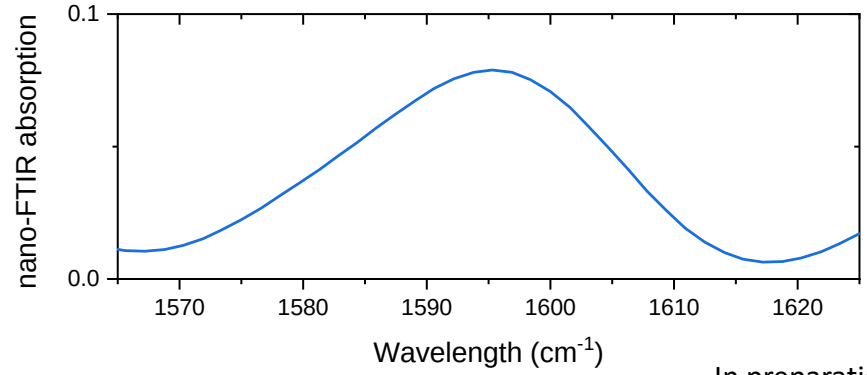
Nano-FTIR Spectroscopy





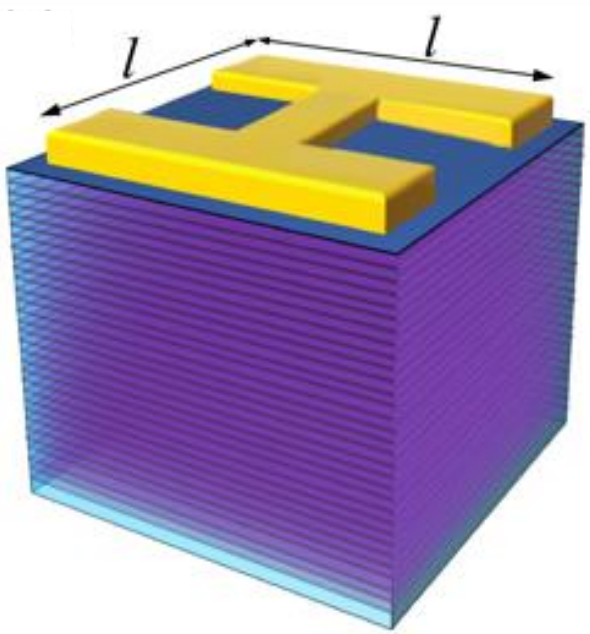


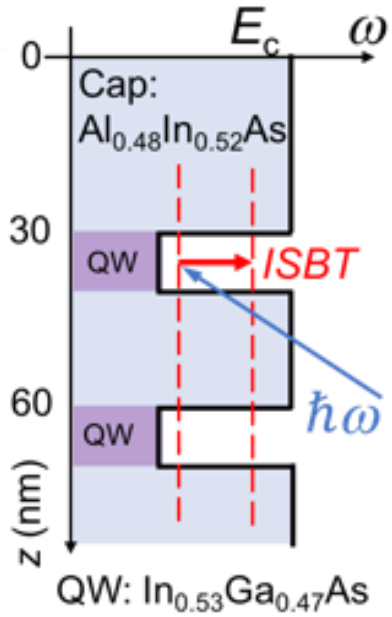
FFT

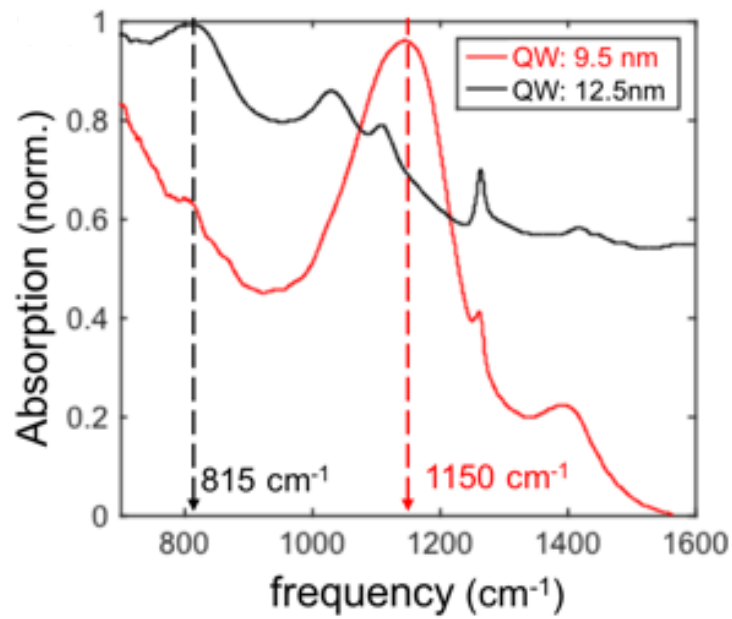


In preparation

sSNOM probing ISBT

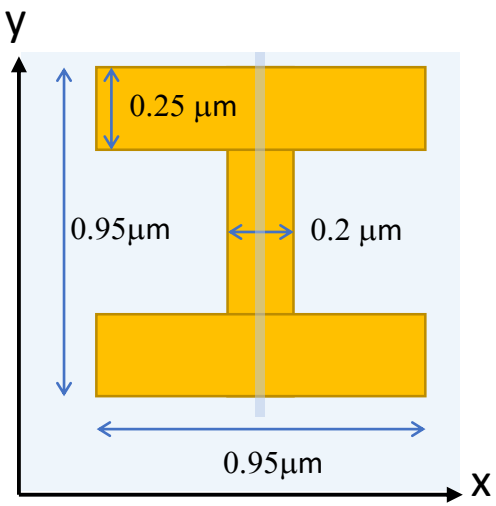


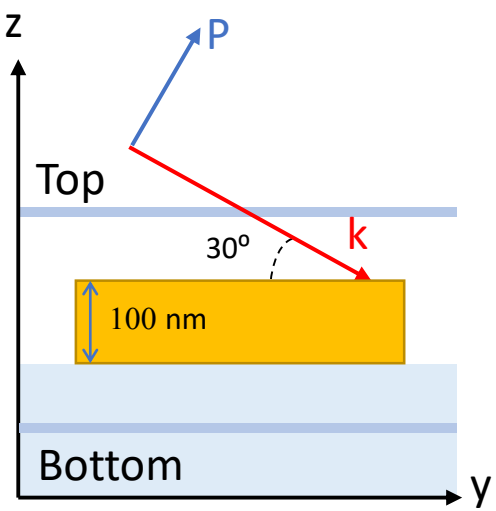


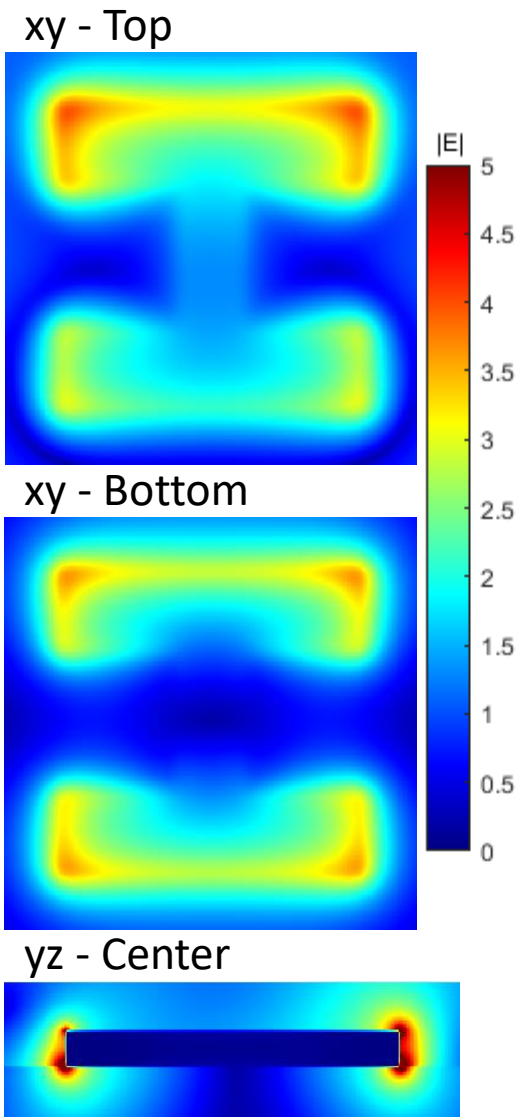


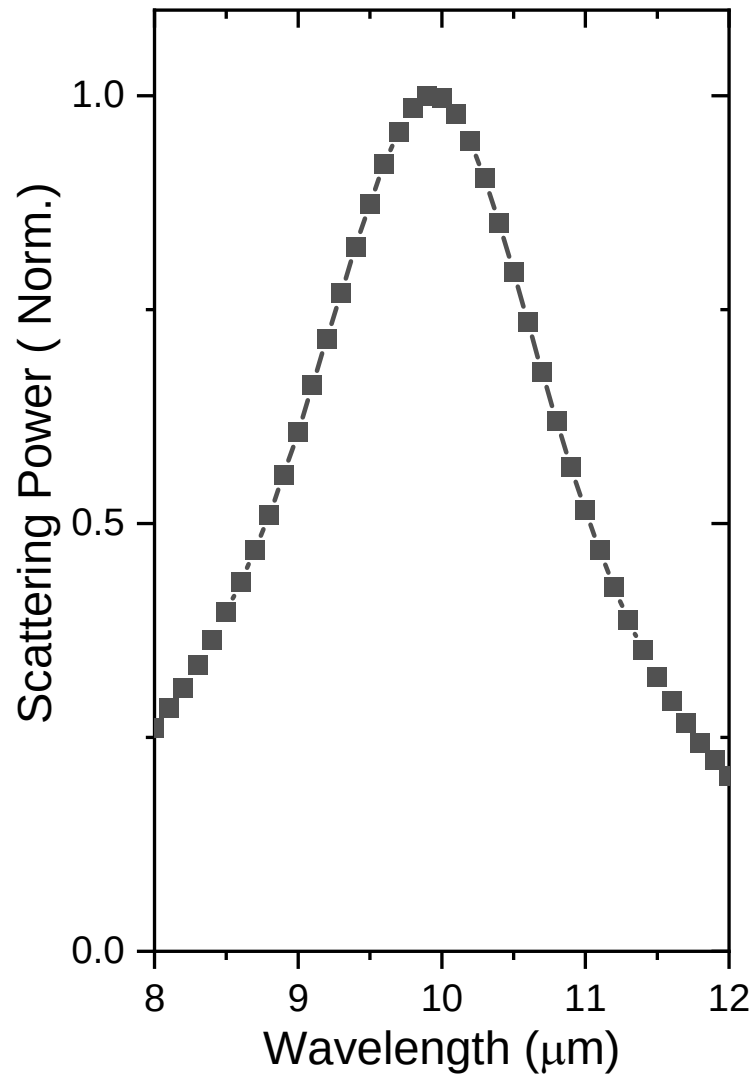
To be submitted.

FDTD simulation of resonators





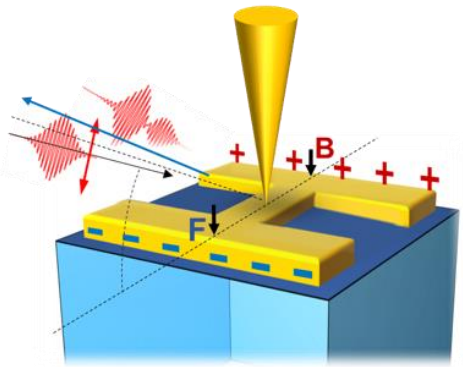


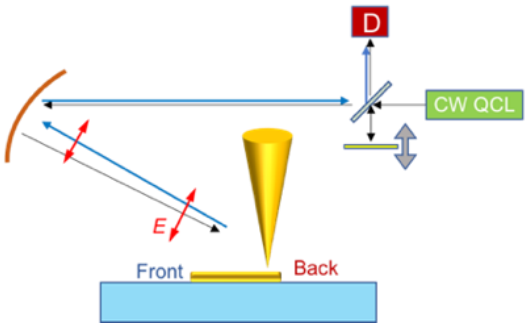


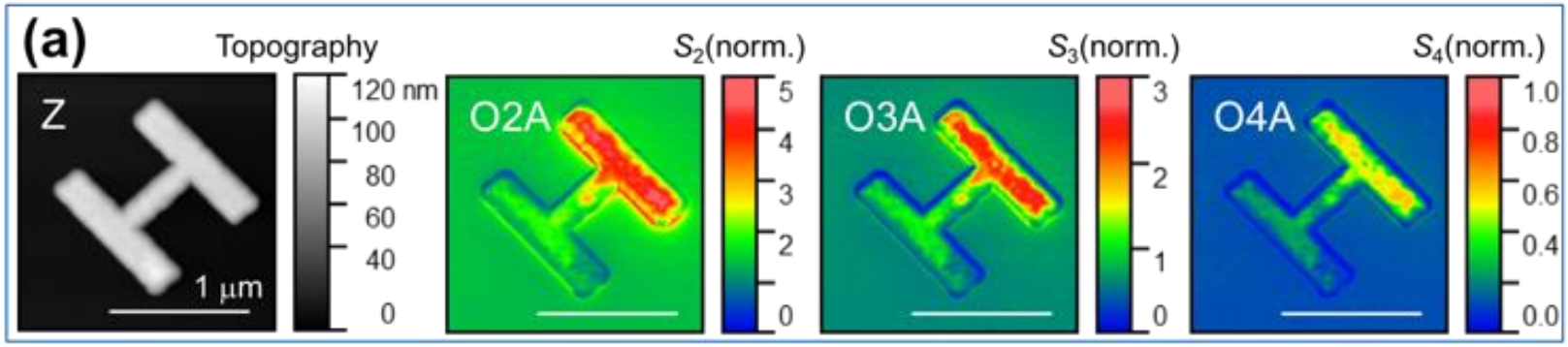
To be submitted.

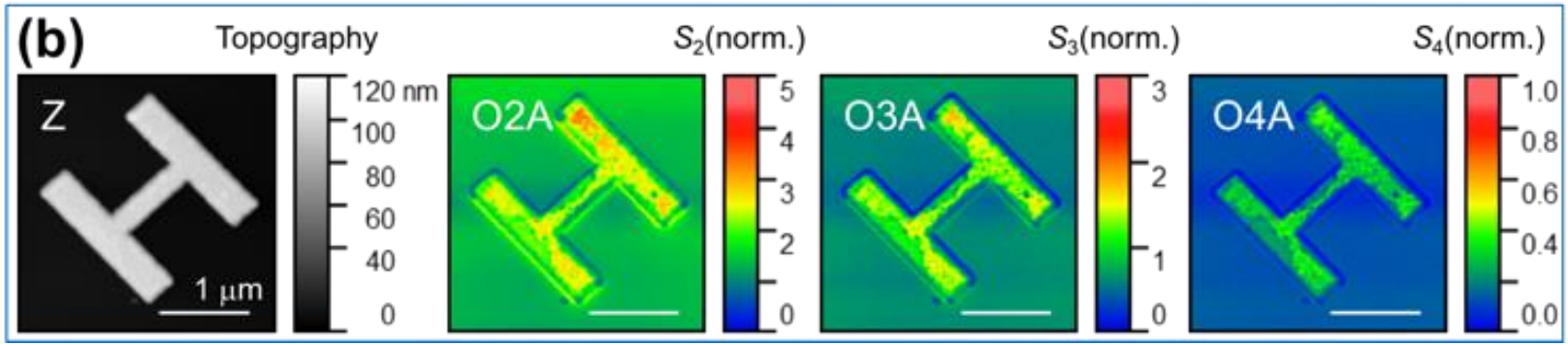
Near-field images of resonators

λ = 10 μm



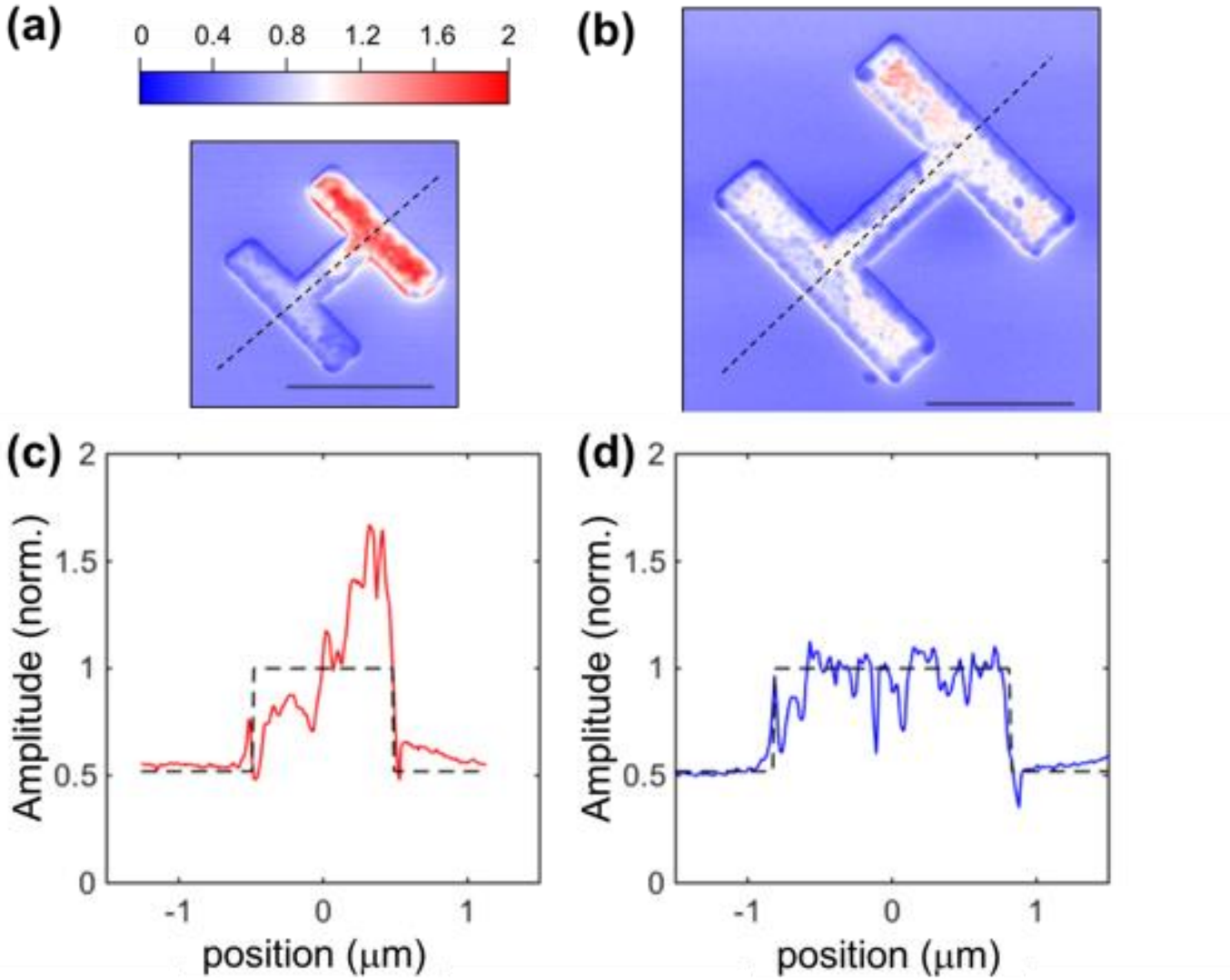






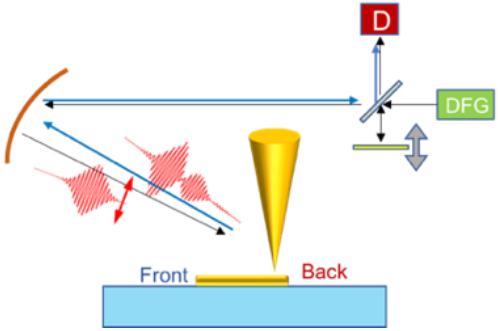
To be submitted.

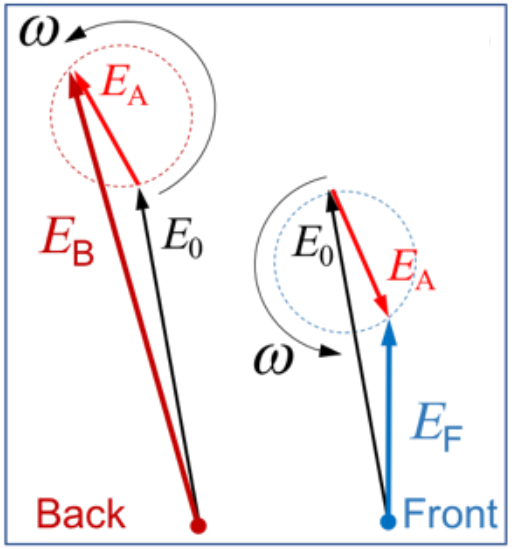
Weak coupling of tip-resonators



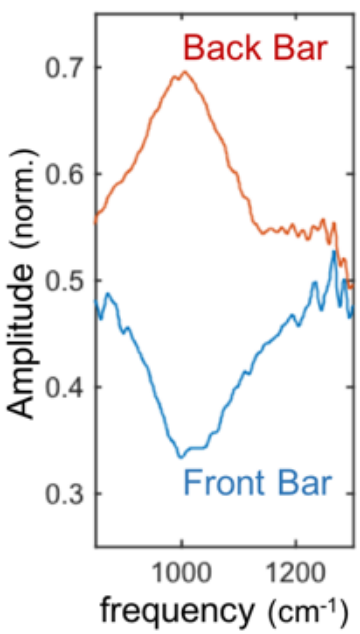
To be submitted.

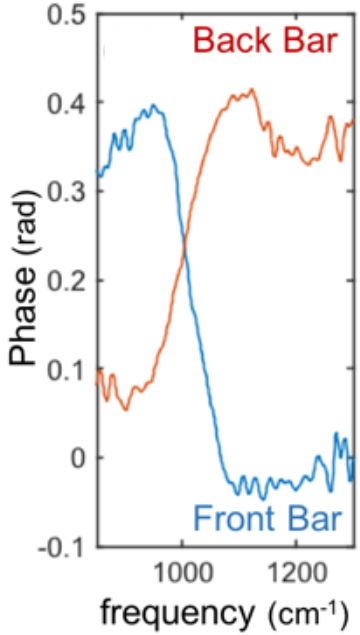
Nano-FTIR on resonators

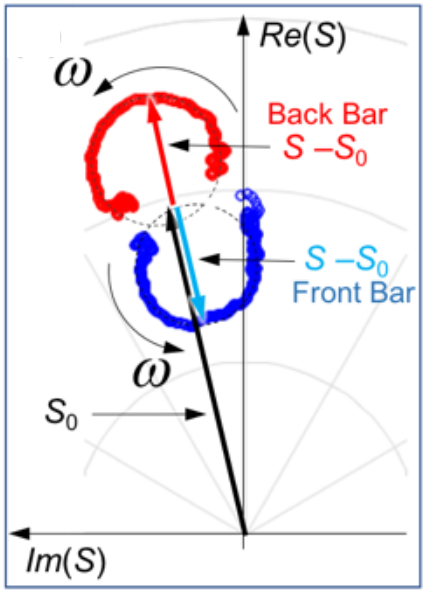


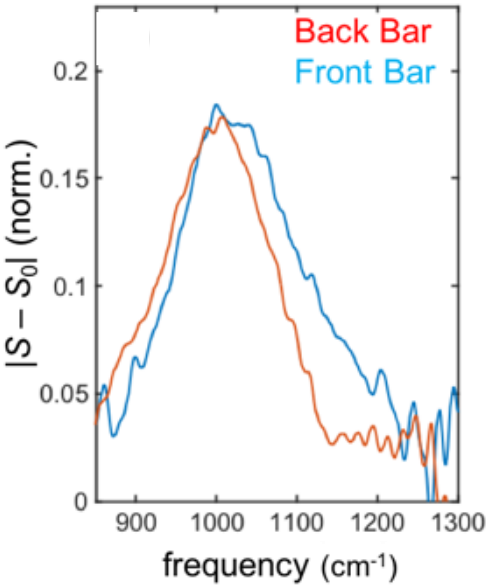


$$E(\omega) = E_0 + E_A(\omega)$$



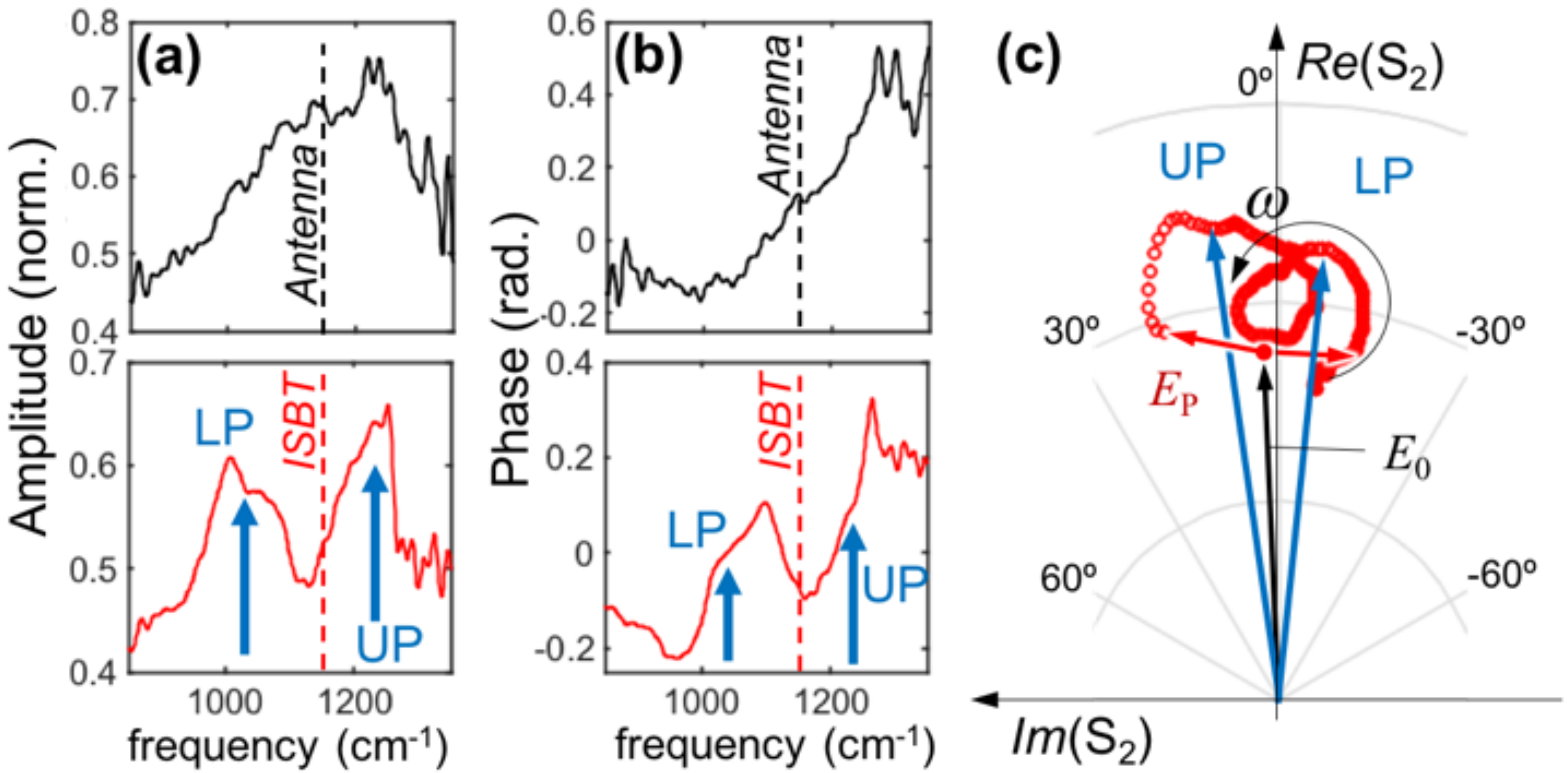






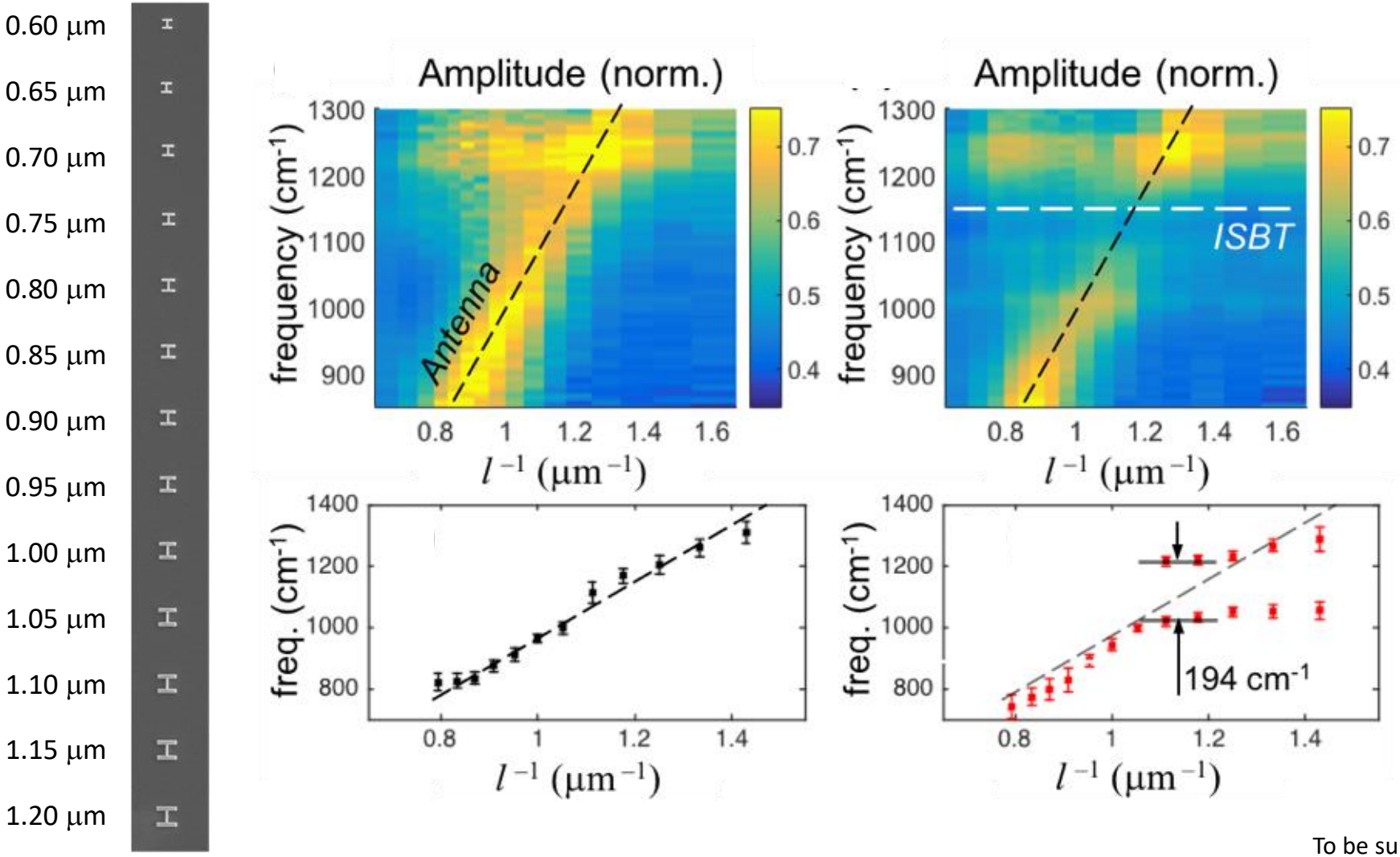
To be submitted.

ISBT measurement by nano-FTIR



To be submitted.

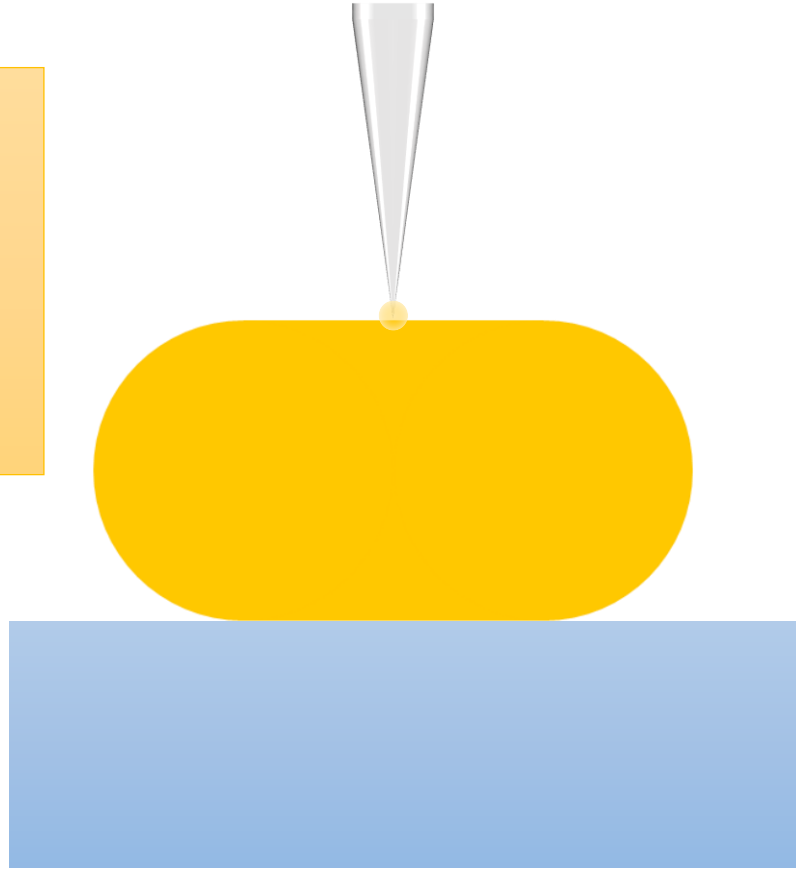
ISBT mapping



To be submitted.

Summary of sSNOM

sSNOM provide an new capability to investigate the fundamental properties of nano-materials with high spatial resolution < 20 nm as well as temporal and spectral solutions.

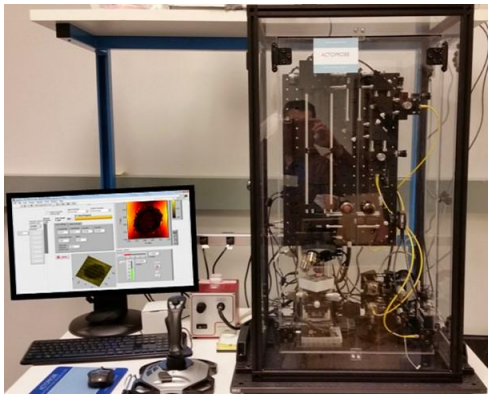


Future work: Explore the nanoworld

sSNOM

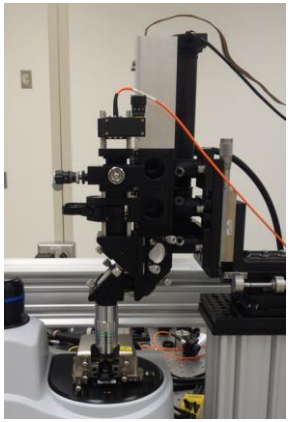
neaspec.com

SCM



actoprobe.com

TERS



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- Short-term goal: pump-probe measurement in THz region with fs temporal resolution.
- Long-term goal: innovate novel microscope to explore the world of nanoscales.
  - Spatial
  - Temporal
  - Spectral
  - Temperature

THz → X-ray

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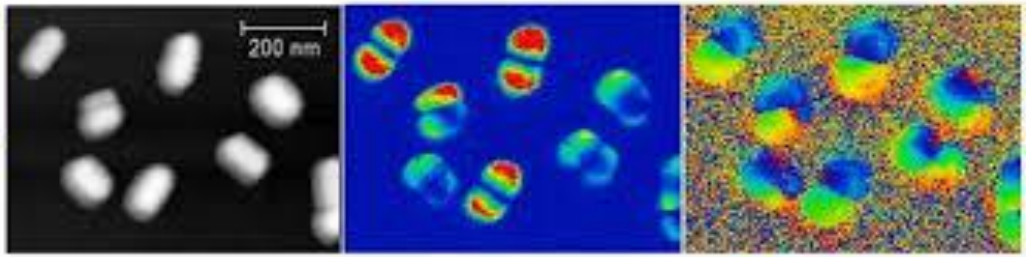
UNM

Habteyes Group



Thank you.

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University of New Mexico