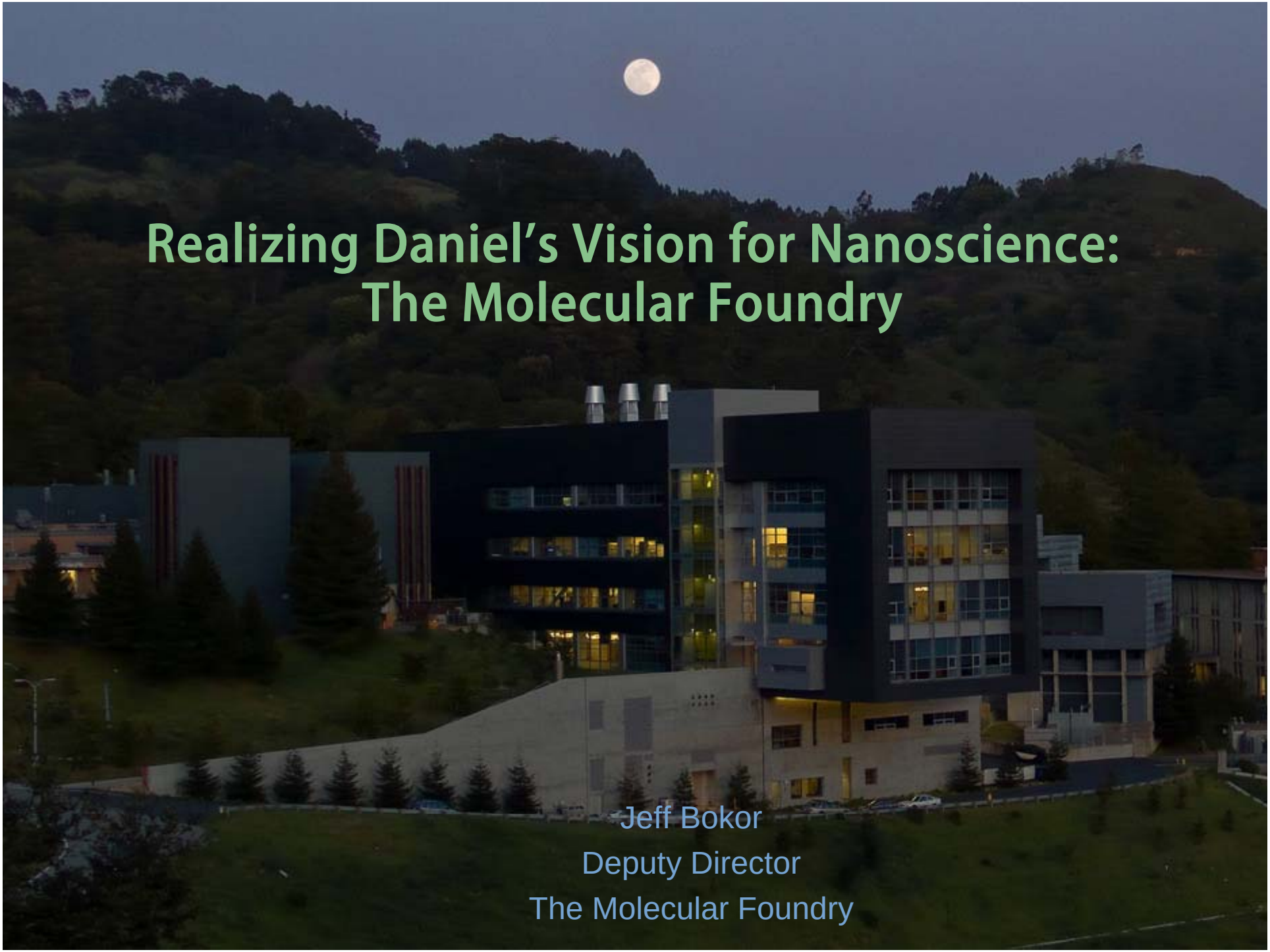
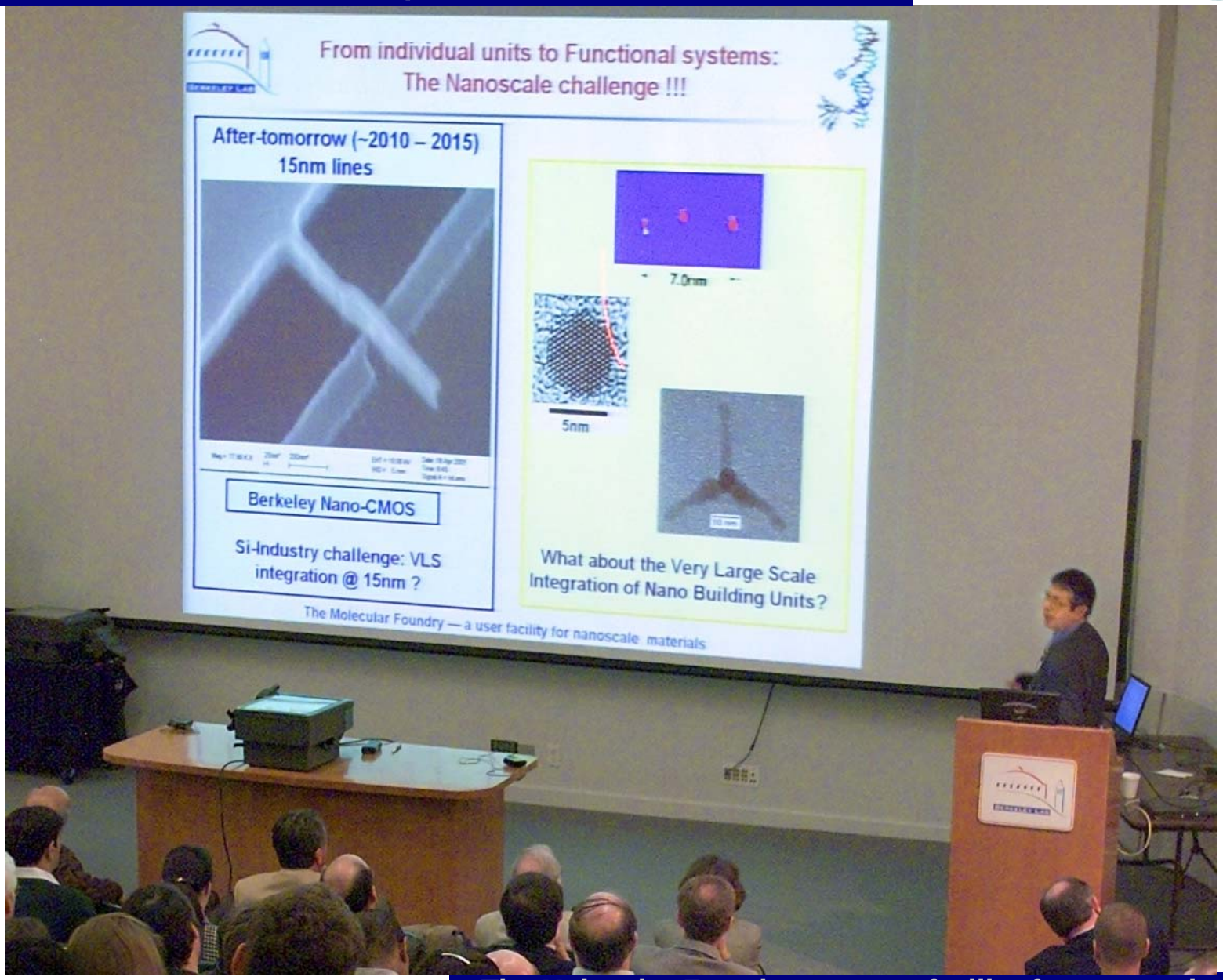


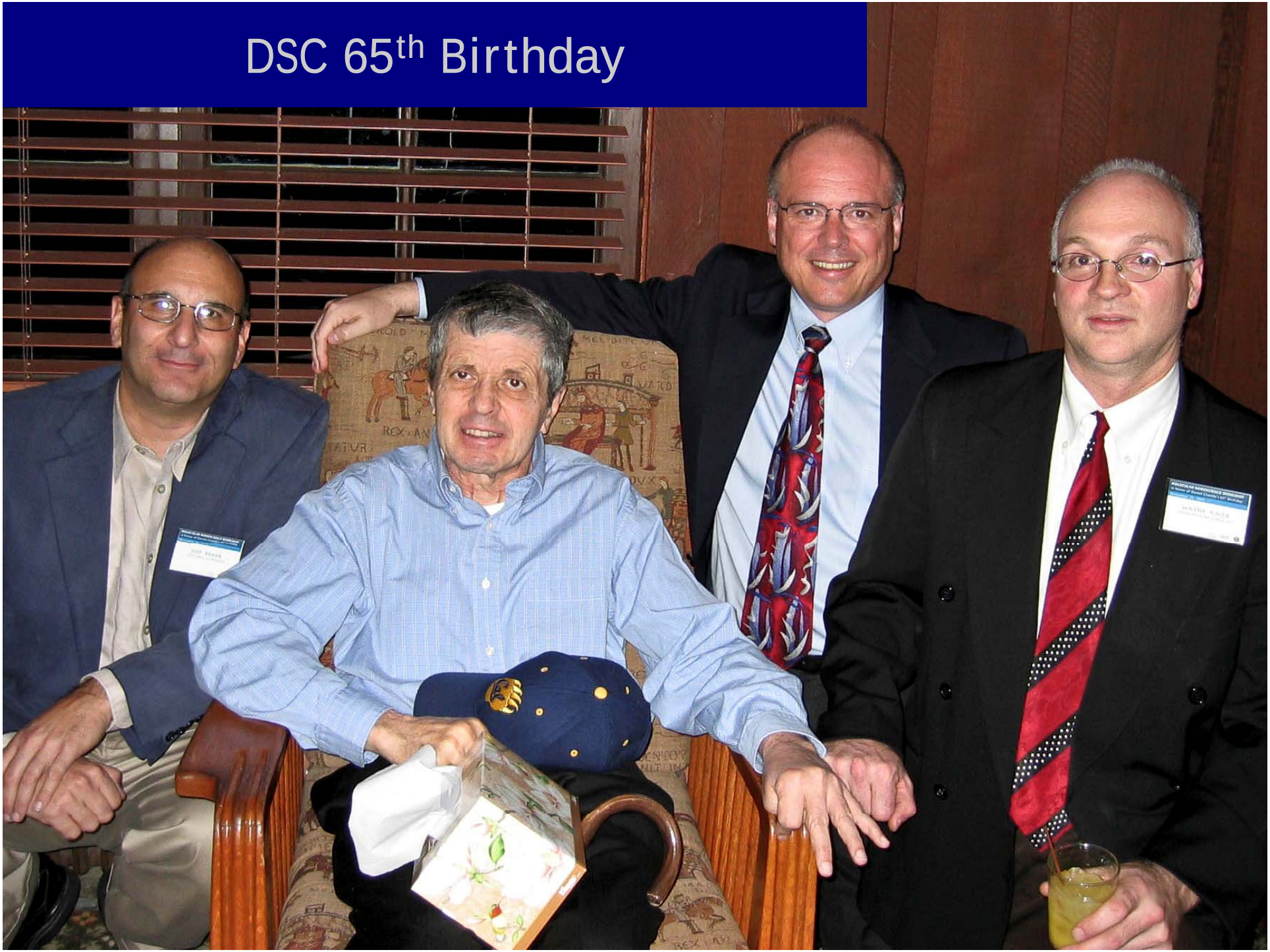
Realizing Daniel's Vision for Nanoscience: The Molecular Foundry

Jeff Bokor
Deputy Director
The Molecular Foundry

Daniel Speaking at First Molecular Foundry Workshop - 2002



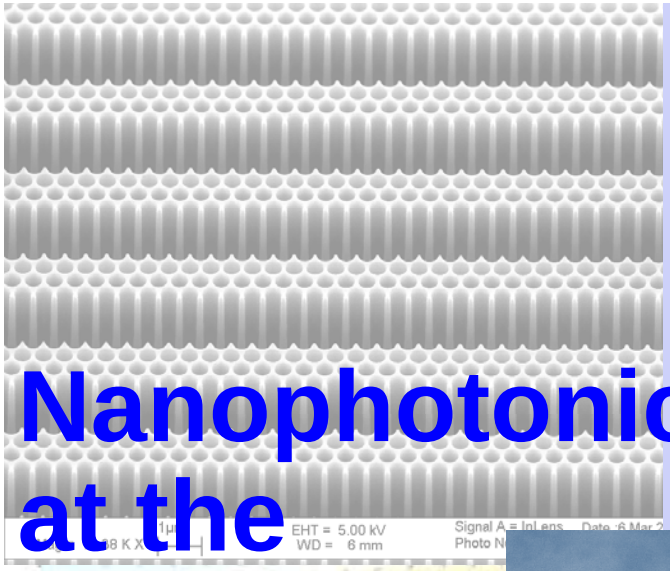
DSC 65th Birthday

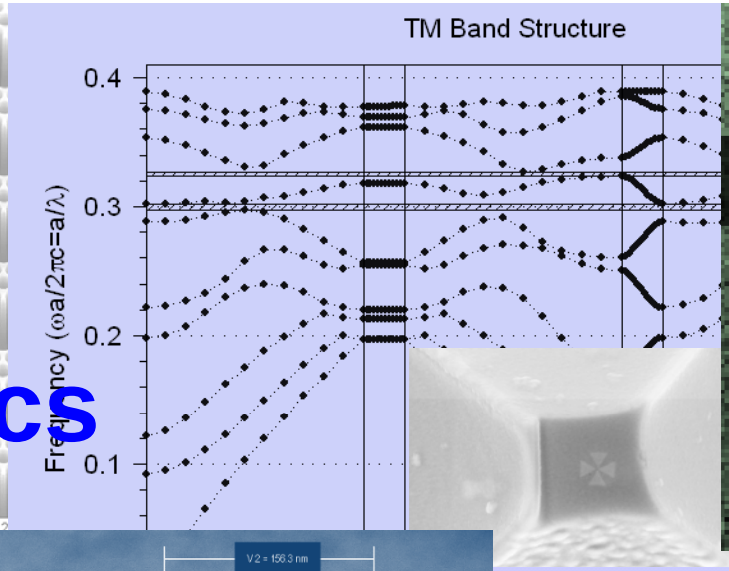


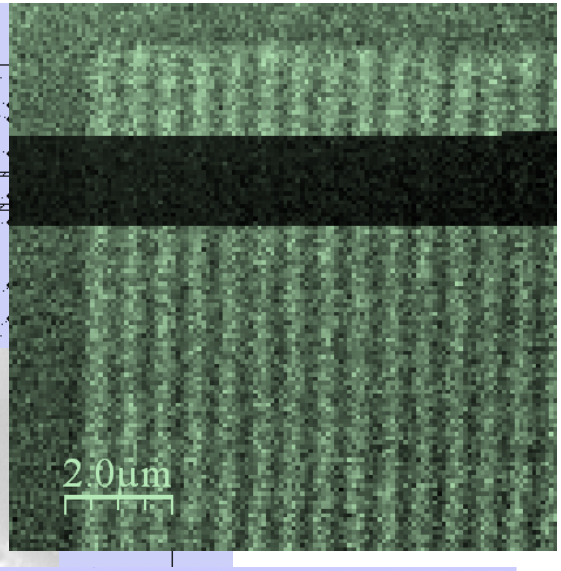

WAYNE KNOX
JEFF BOKOR

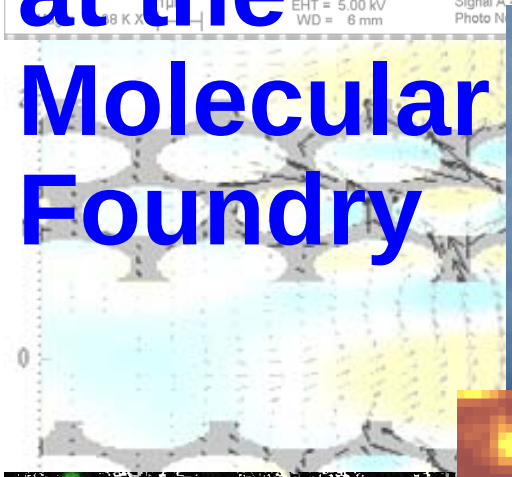

Cal

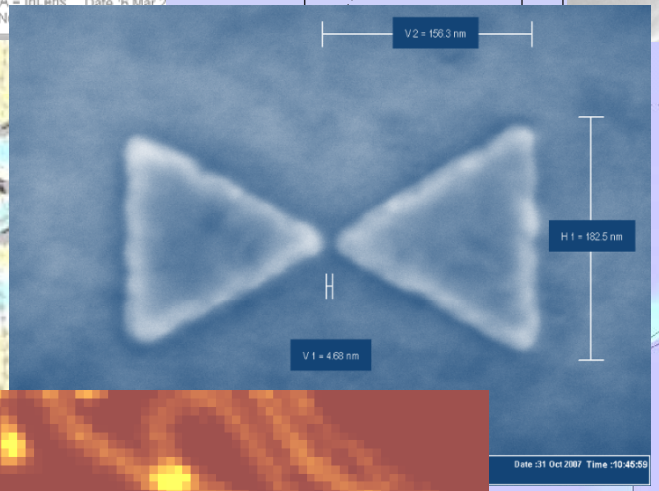
Nanophotonics at the Molecular Foundry

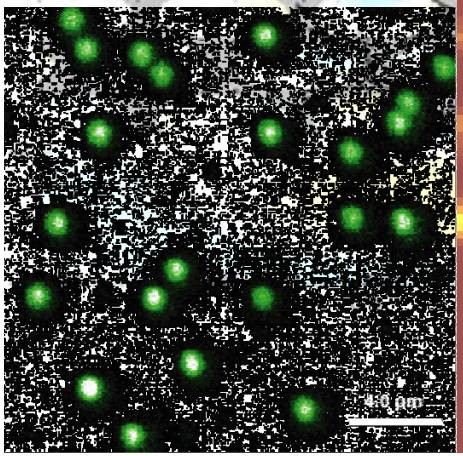


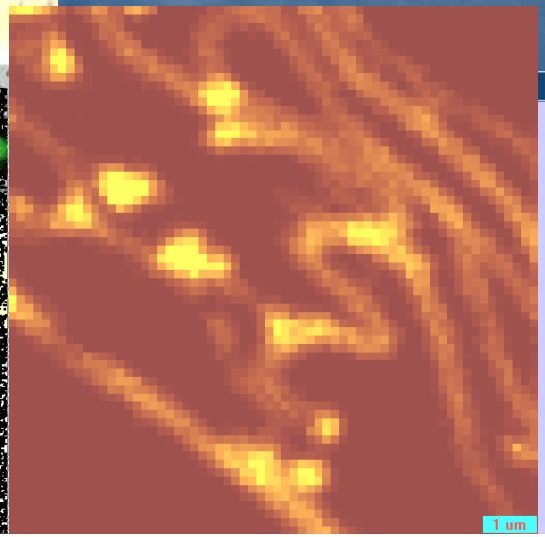




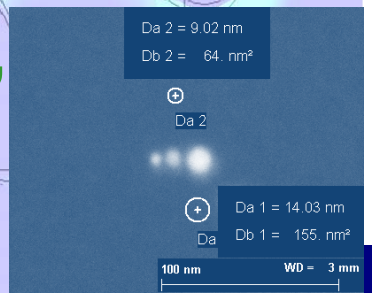








P. J. Schuck, S. Cabrini, A. Weber, A. Chang, B. Ding, B. Harteneck, S. Dhuey, H. Choo, S. Wu, B. Cohen, D. Milliron, G. Han



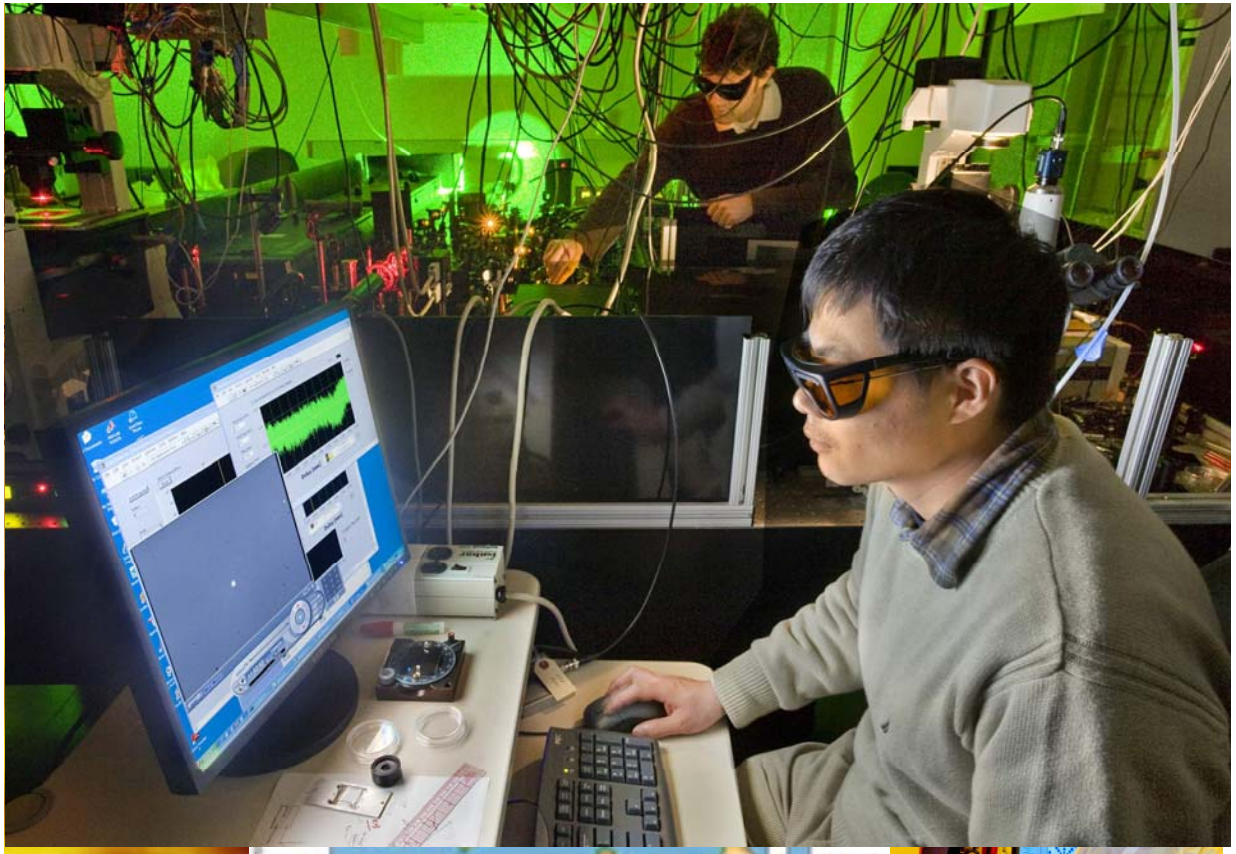
Come here and enjoy…

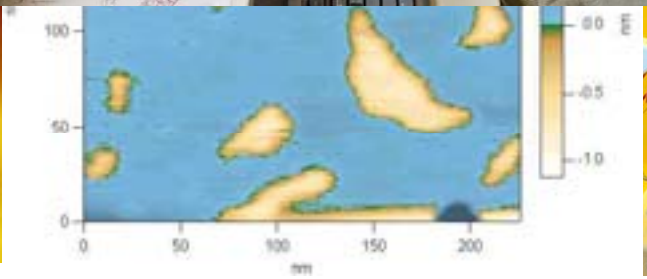
Coffee…

The view…

www.foundry.lbl.gov

Research!!!

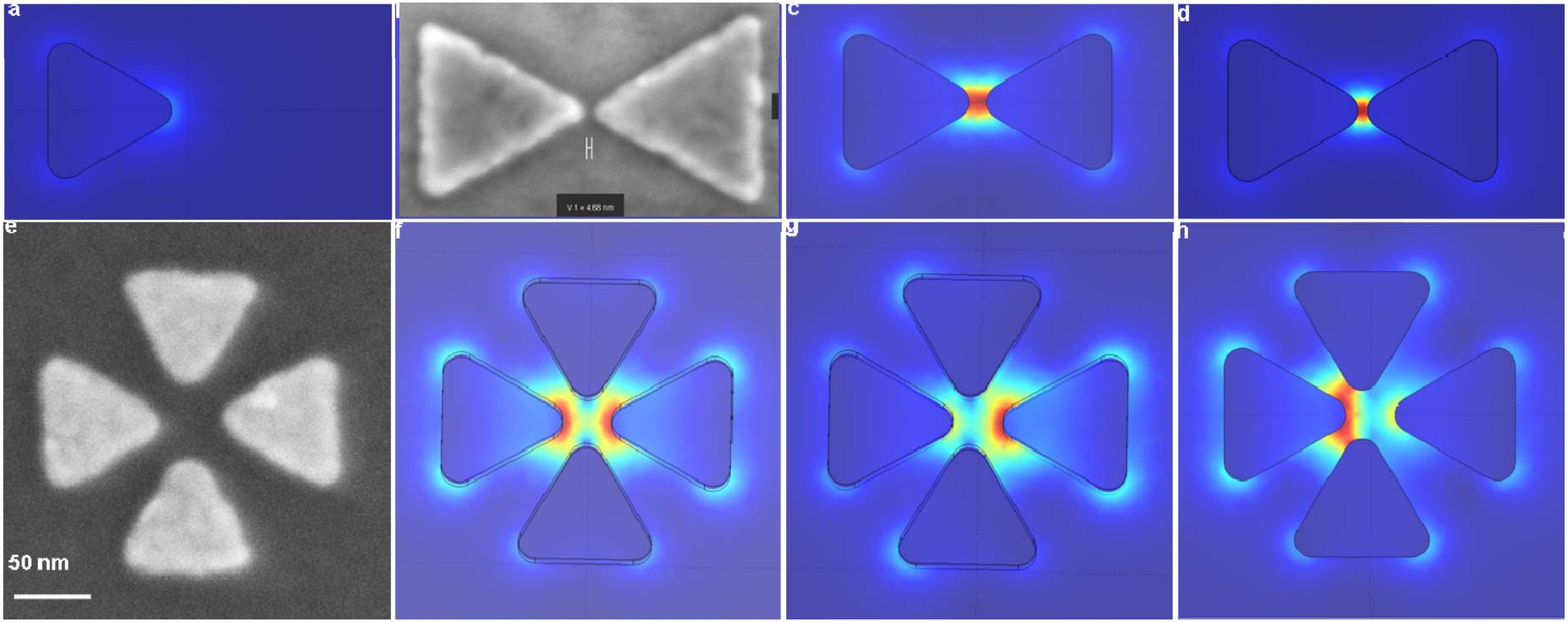




The Molecular Foundry – a user facility for nanoscale materials

Plasmonic Nanoantennas

Control and Manipulation of Optical Fields at the Nanoscale

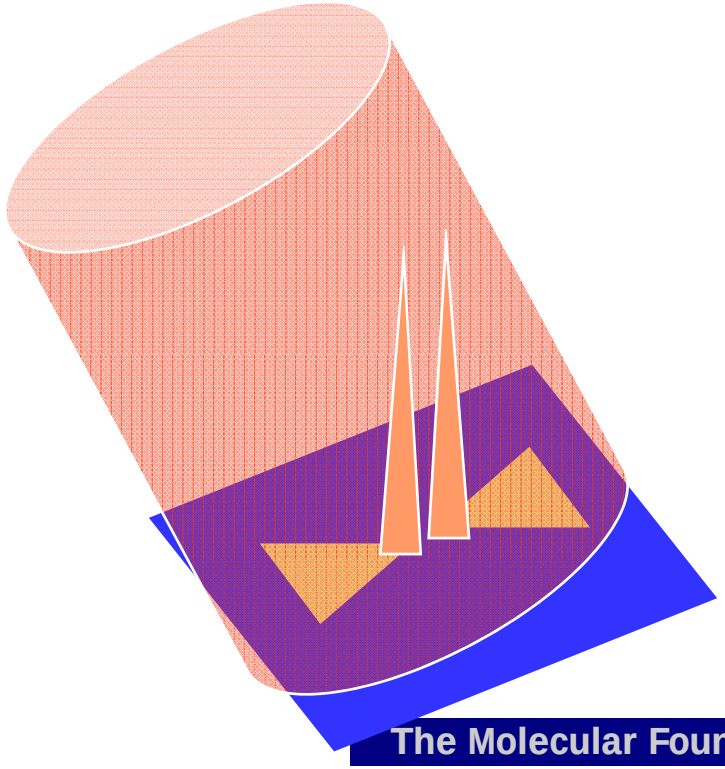


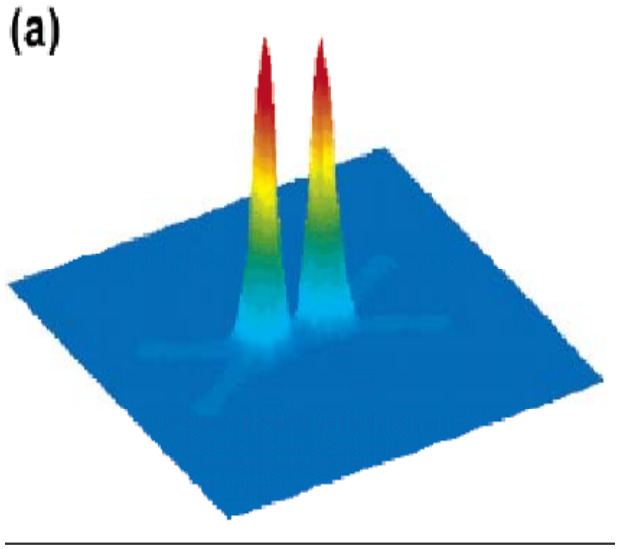
Nanopatterning for plasmonic antennas

- Bowtie antennas, two metallic triangles facing tip to tip with small gap.
- High local field in sub-wavelength volume

External illumination

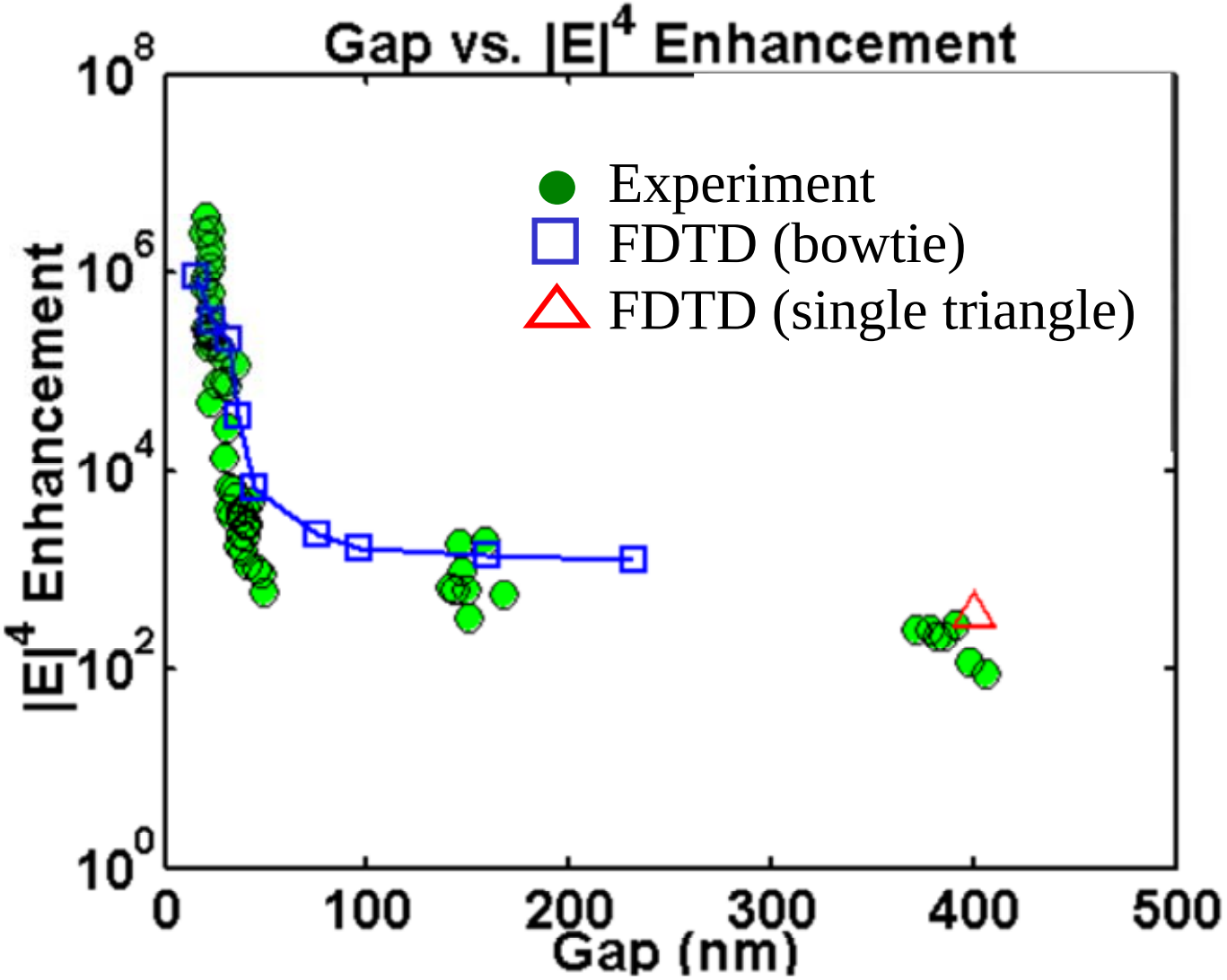
signal





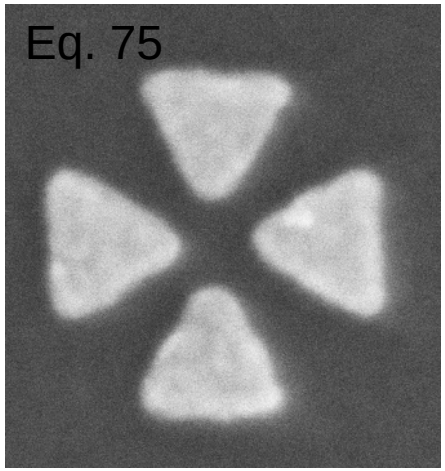
S. Cabrini. Collaboration with J. Schuck Imaging and Manipulation Group

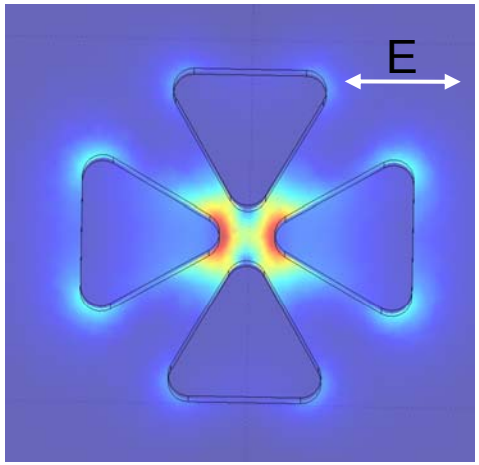
Need for Smallest Gap



Resonance of “Cross” Nanoantennas

- Optimize interaction with all polarizations

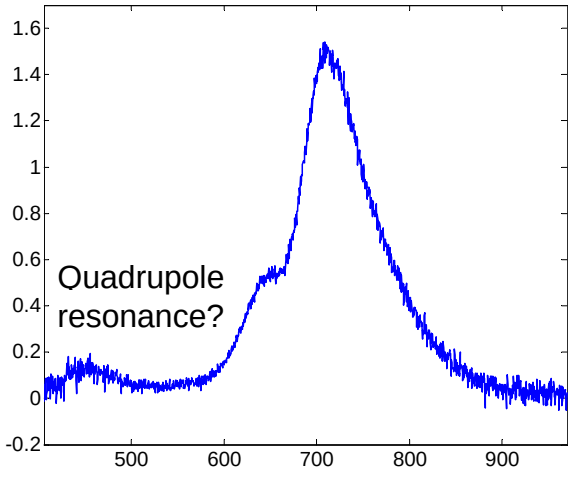




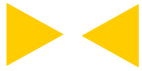
COMSOL simulation of normalized E-field at resonant wavelength

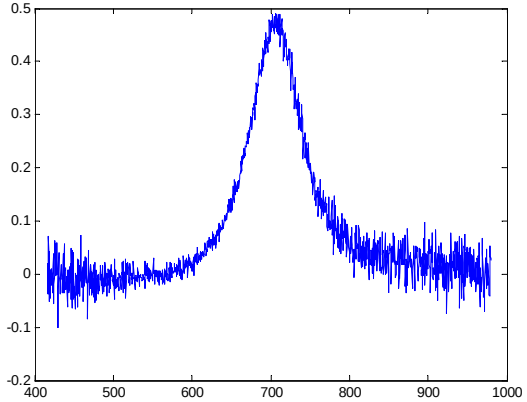
Scattering spectrum for a Eq. 75 Cross = Parallel Polarization + Perpendicular Polarization

E



E





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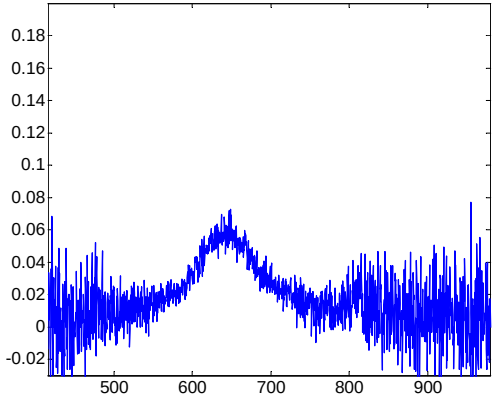
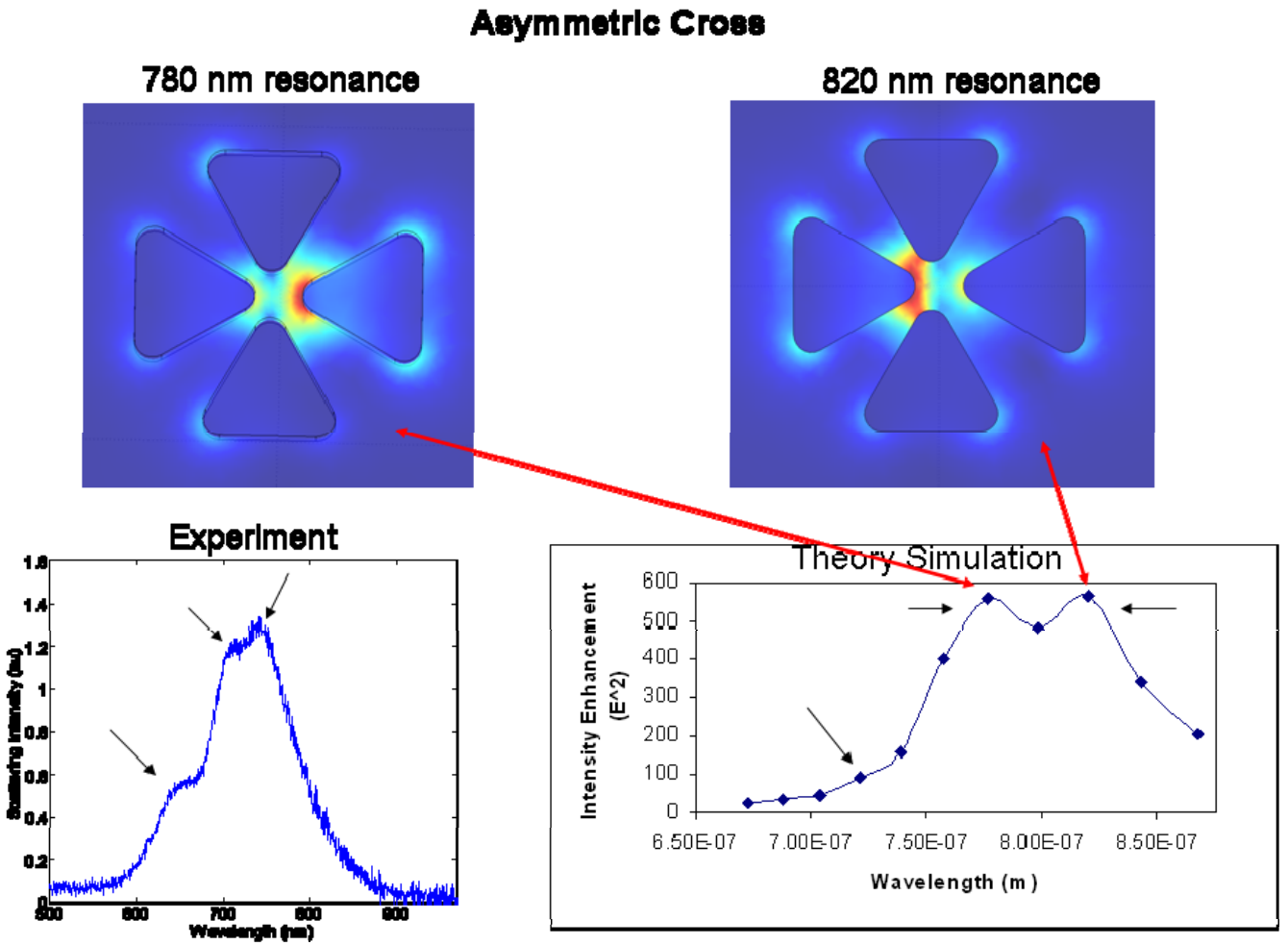


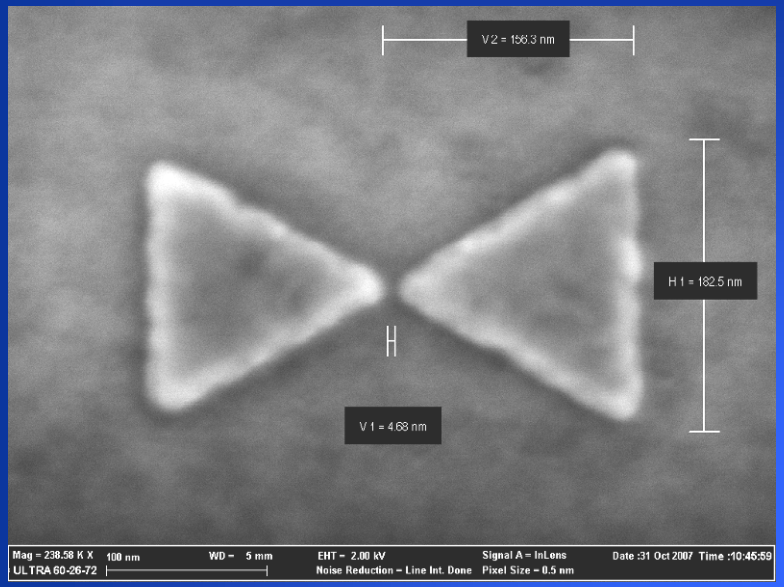
Plasmonic Nanoantennas

Plasmonic Color Nano-sorter

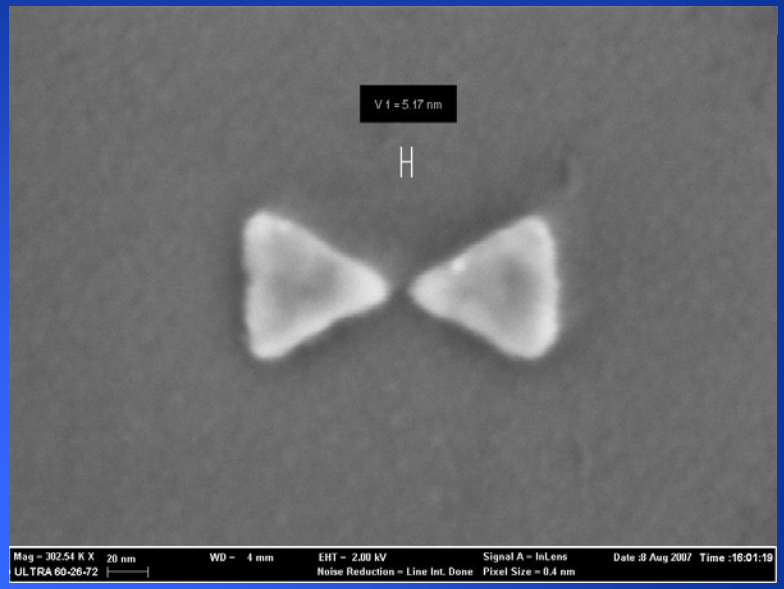


Bowtie Nanoantennas: E-beam Fabrication

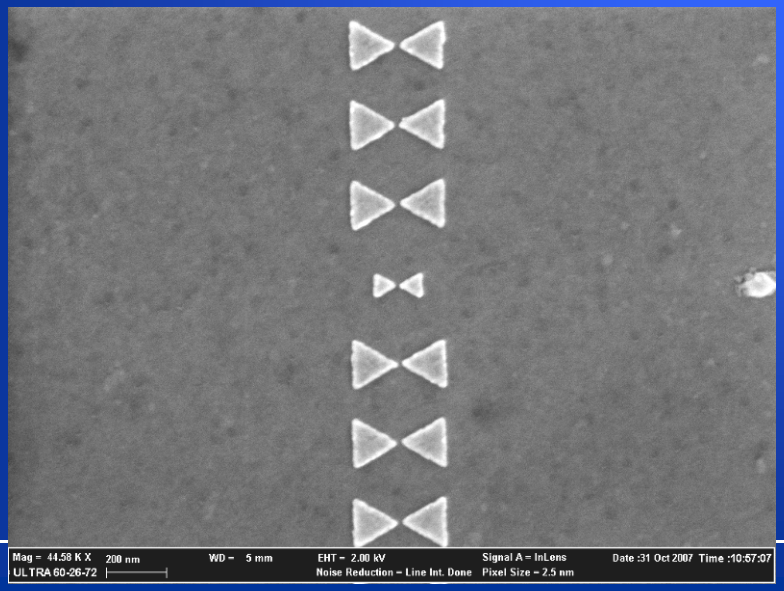
150nm bowtie, 4nm gap.



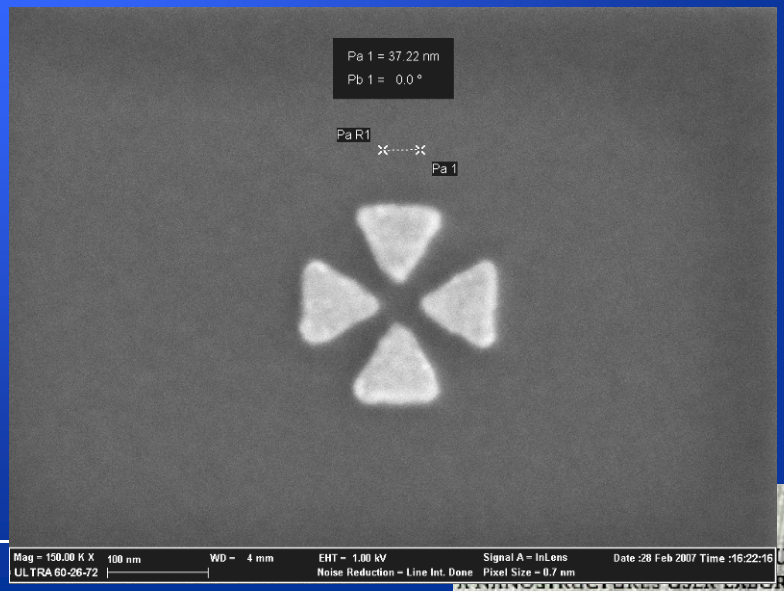
Gold liftoff of bowtie, 5nm gap.



Bowtie chains.

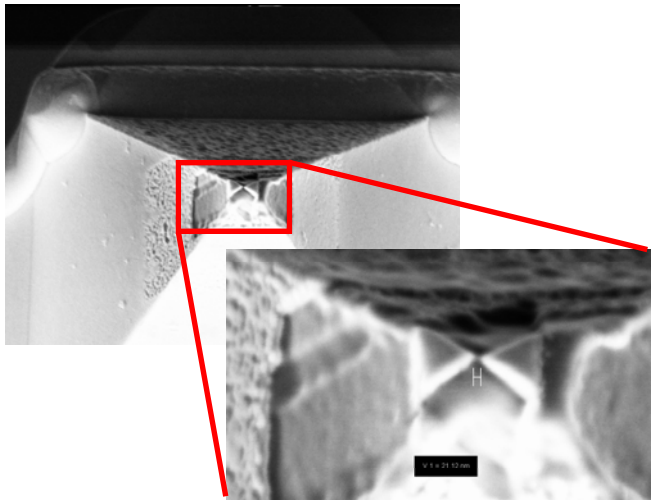


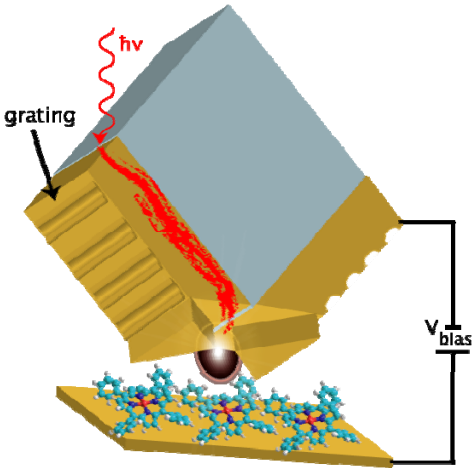
Gold liftoff of e-beam exposed bowtie cross.

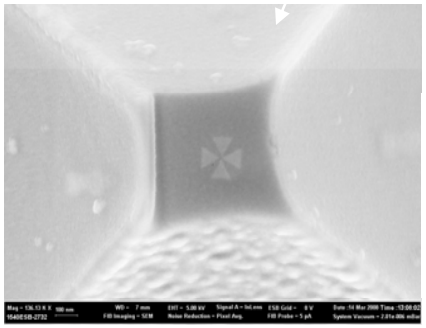


Scanning Nanoantenna Micro(Nano)scope

Optical Imaging Spectroscopy
+ 10nm resolution
+ high lateral control



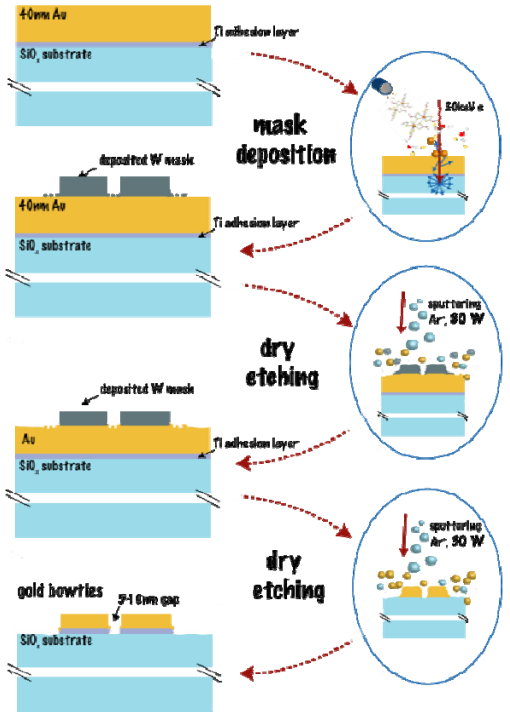




Raman, nanoCARS, photoluminescence, etc.
- **~ 10^5 times more efficient than NSOM**
- **5-10 times better spatial resolution**
- **> 10 times larger enhancement than ANSOM**

Novel nanofabrication techniques essential for these length scales and "substrates"

Electron-beam Induced Deposition and differential dry etching to build plasmonic nanostructures

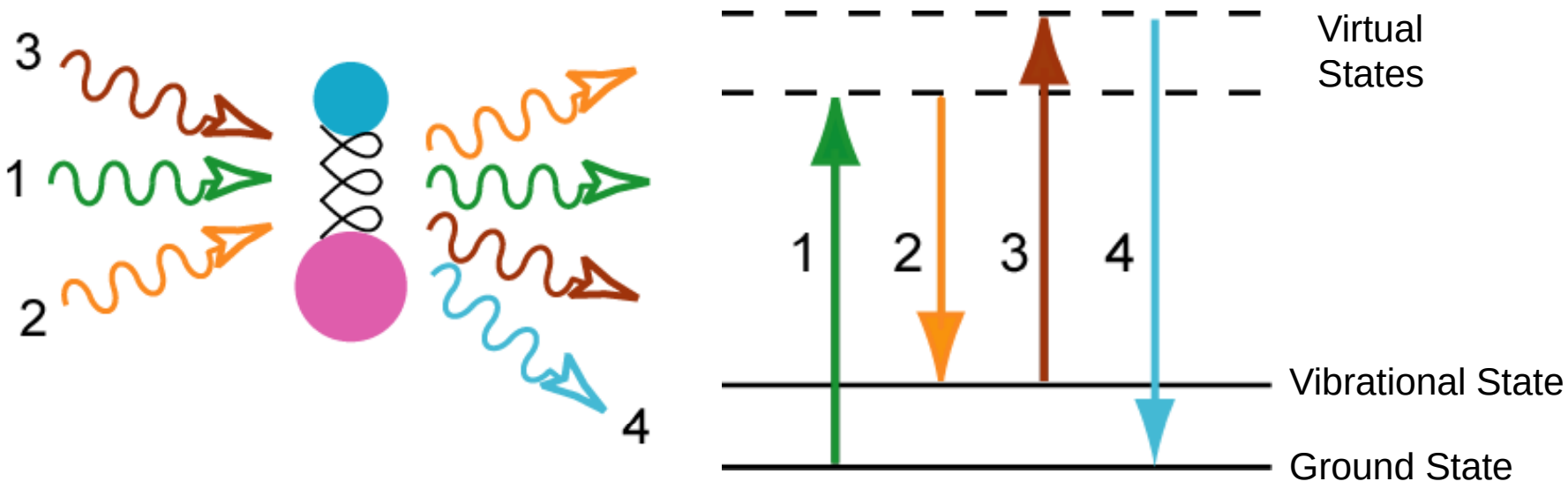


Stefano Cabrini, Alex Weber, Jim Schuck

CARS: Better Sensitivity

What is CARS?

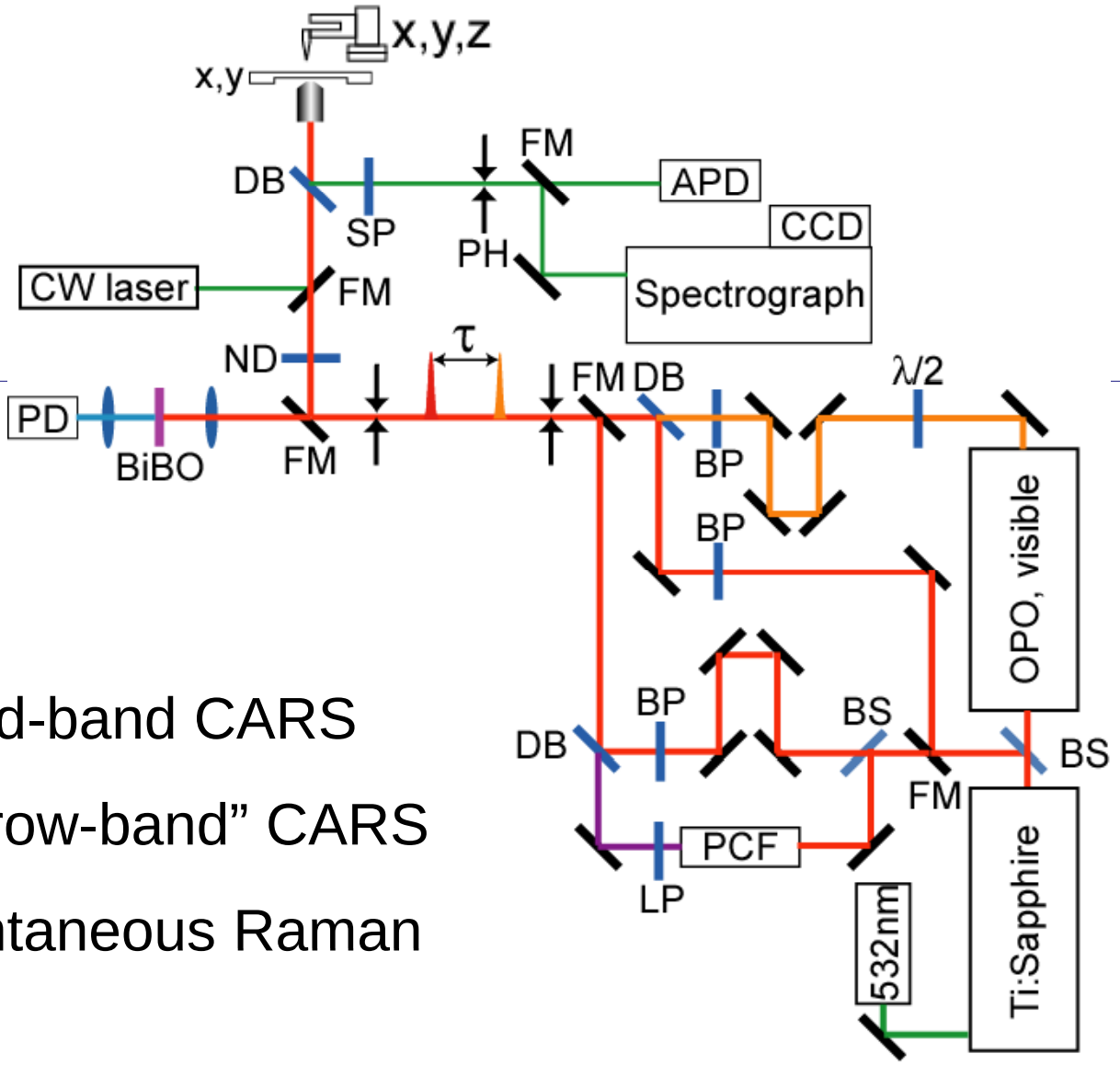
CARS: Coherent Antistokes Raman Scattering



ω_p Pump/Probe beam ω_S Stokes beam ω_{aS} Anti-Stokes beam

Better signal-to-noise for nanoscale structures

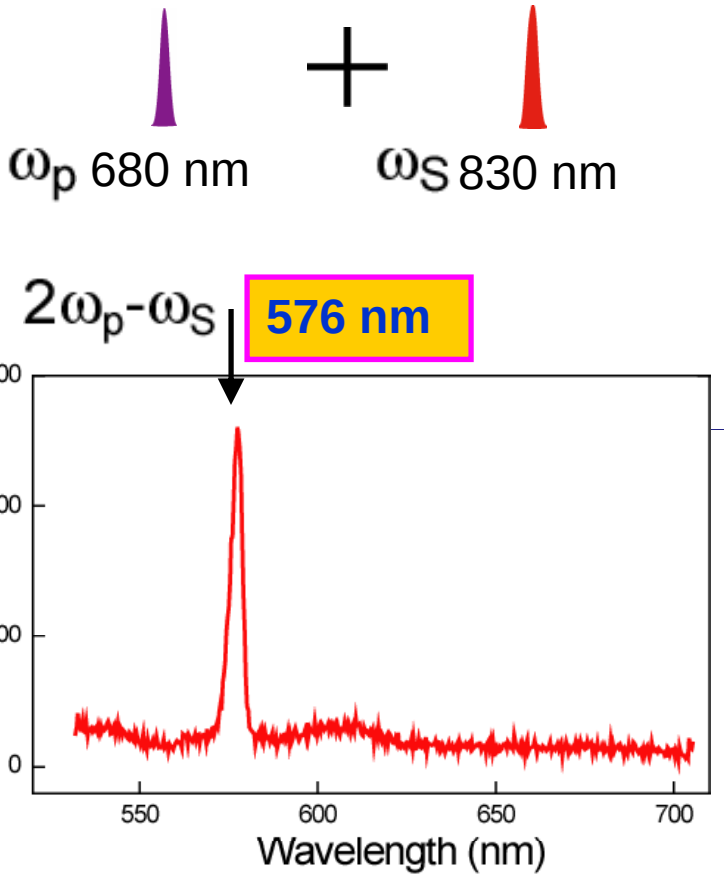
Three Raman setups on one Microscope

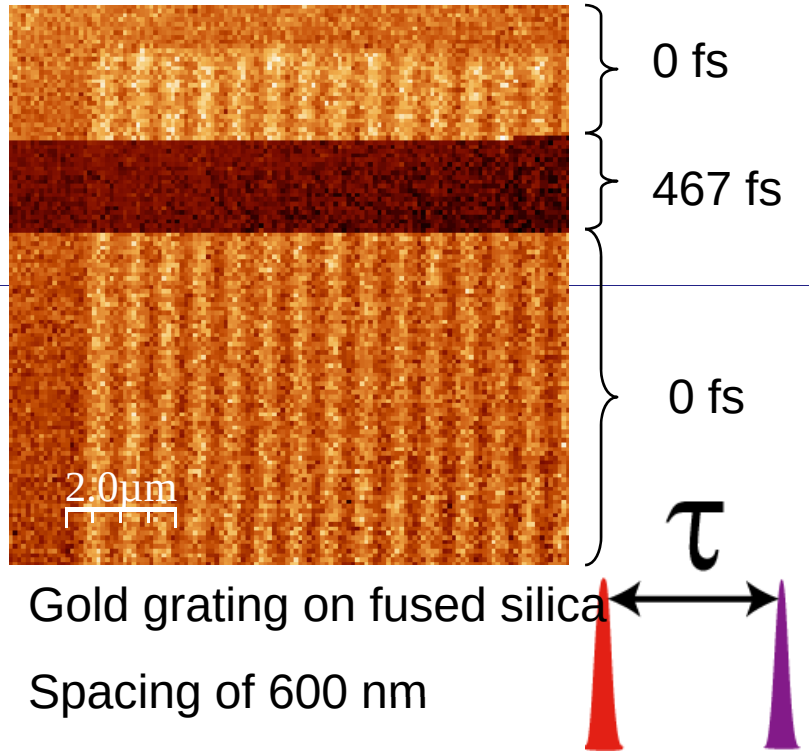


1. Broad-band CARS
2. “Narrow-band” CARS
3. Spontaneous Raman

CARS IMAGING:

Four-Wave Mixing (FWM), non-resonant $\chi^{(3)}$



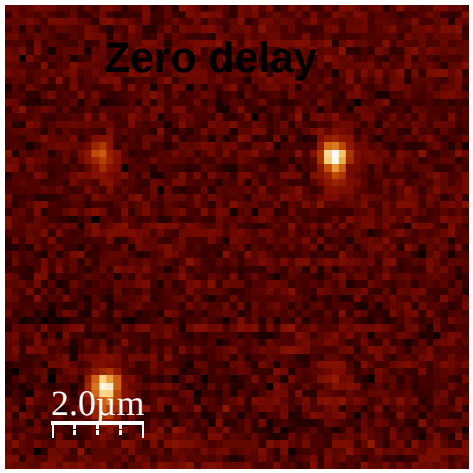


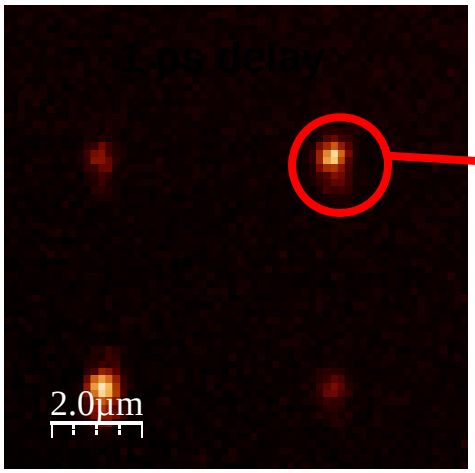
Gold grating on fused silica

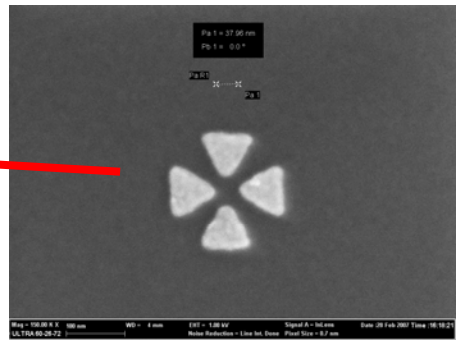
Spacing of 600 nm

- **Imaging based on nonlinear optics (FWM) renders higher spatial resolution**
- **ITO under ebeam exposure has large FWM signal**

Bowtie Cross CARS

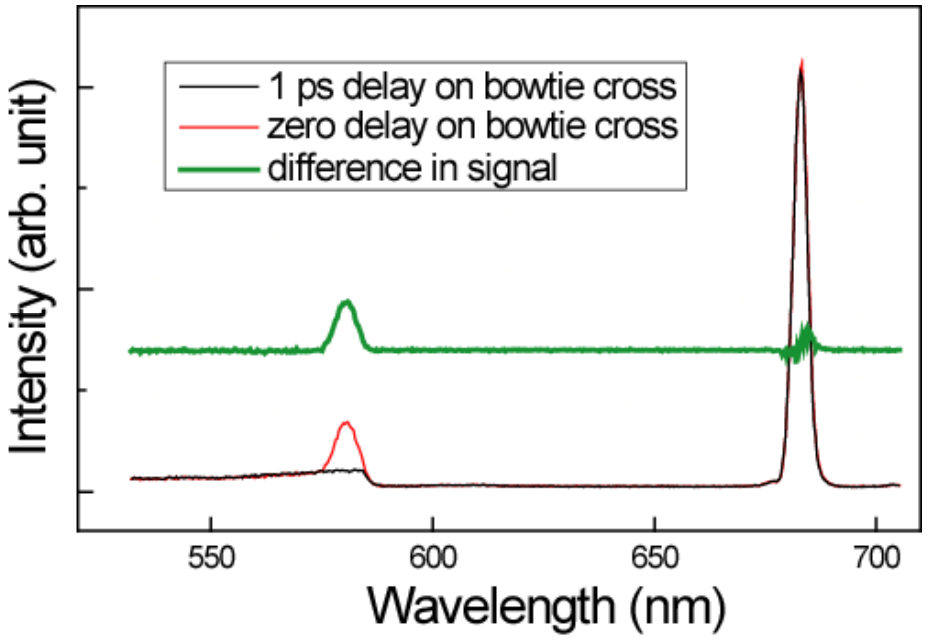




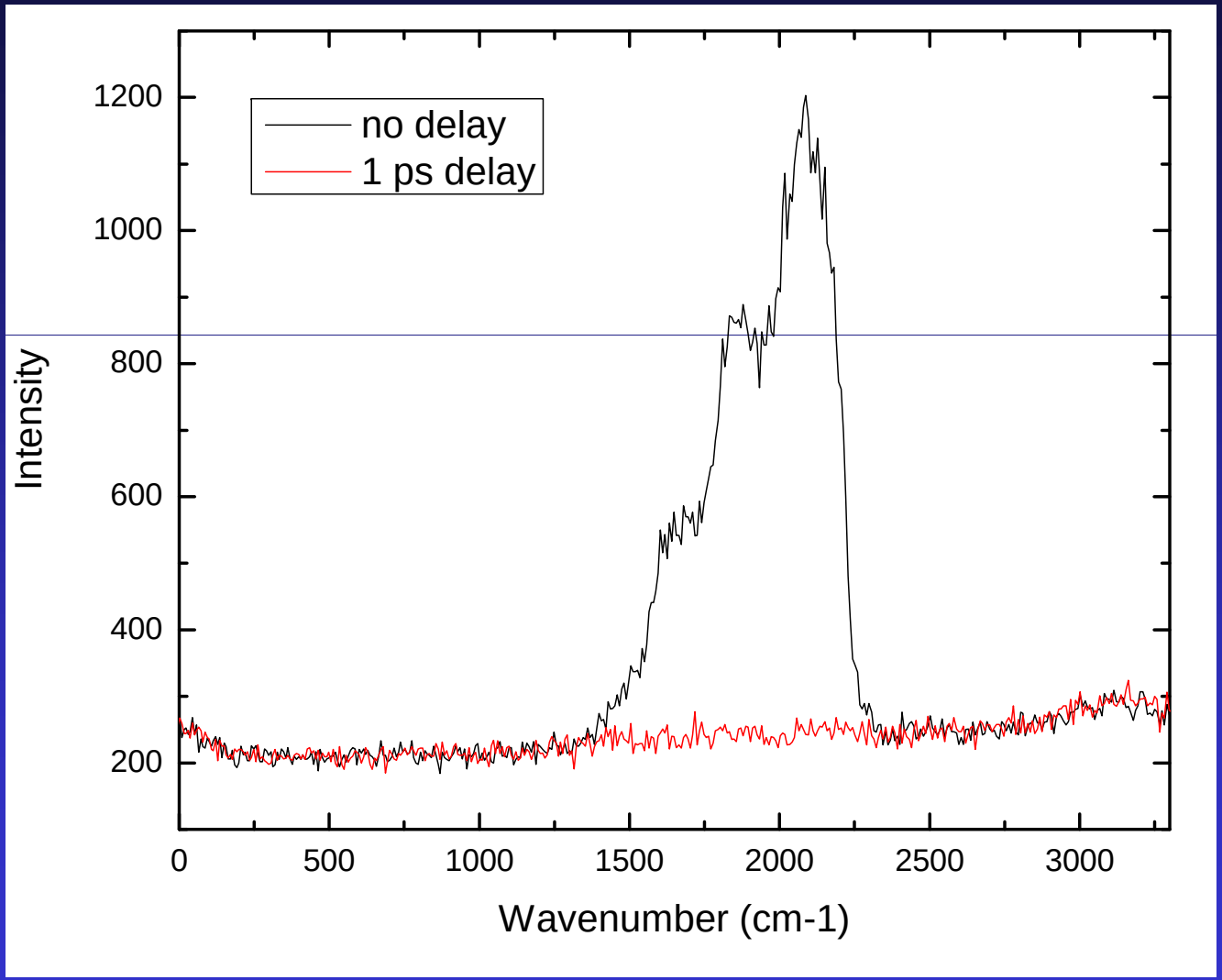


Double Bowtie "cross"

- **TPPL competes with FWM**
- **But TPPL can be subtracted by using the signal with long delay**



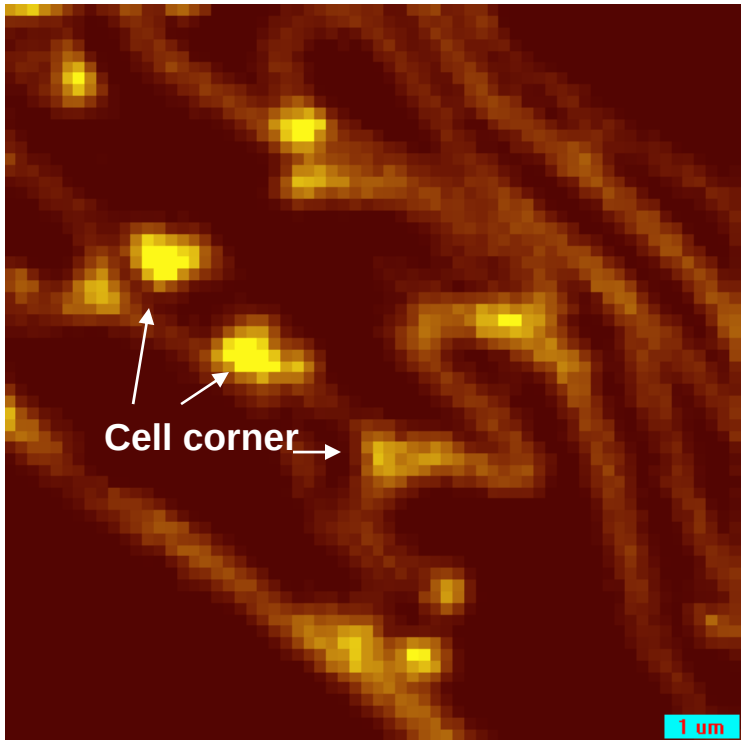
Broadband CARS spectra from HSQ on Si



Plant Cell Wall *CARS* Imaging

P. Adams, P. J. Schuck, M. Schmidt
Energy Biosciences Institute and Molecular Foundry

- **CARS image of Lignan concentration in dry arabidopsis leaf section**
  ~ 1600 cm^{-1} band



BioFuels Goals:

- **Visualize the chemical and physical obstacles to biomass breakdown.**
- **Develop better pretreatment procedures**
- **Identify suitable plant materials**

Self-Similar Au Nanoparticle Chains

VOLUME 91, NUMBER 22 PHYSICAL REVIEW LETTERS week ending 28 NOVEMBER 2003

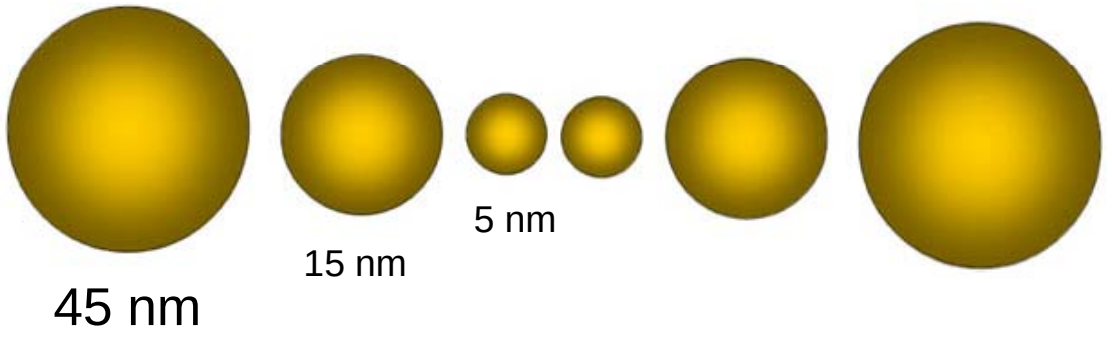
Self-Similar Chain of Metal Nanospheres as an Efficient Nanolens

Kuiru Li,[1,*] Mark I. Stockman,[1,†] and David J. Bergman[2,‡]

[1]*Department of Physics and Astronomy, Georgia State University, Atlanta, Georgia 30303, USA*

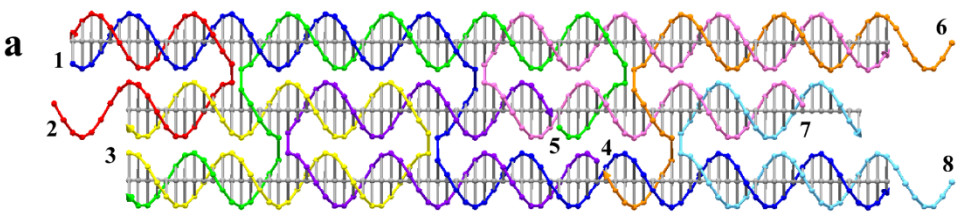
[2]*School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, 69978, Israel*

(Received 17 June 2003; published 26 November 2003)

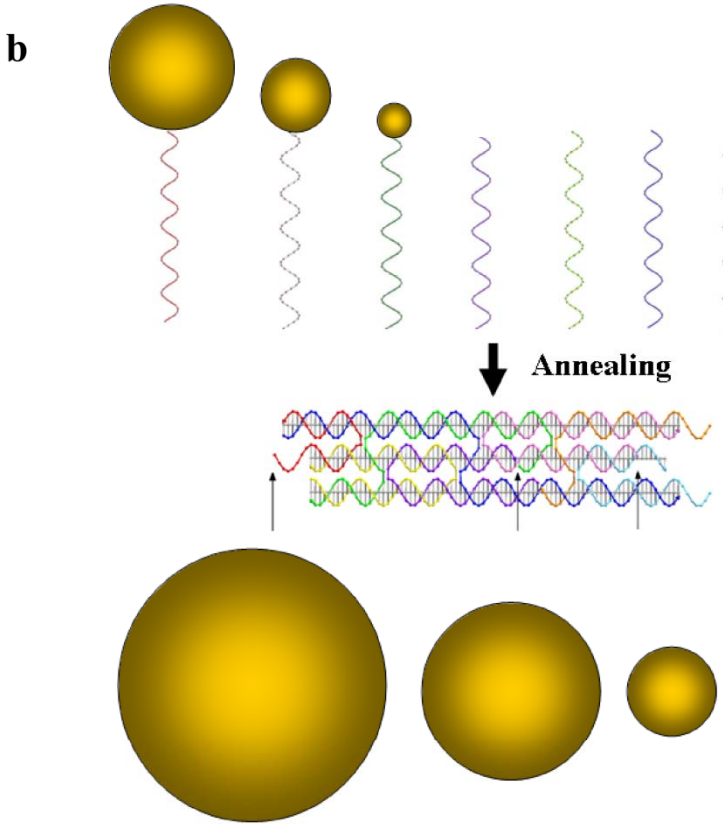


Field gain > 1000
Raman enhancement > 10^{13}

Fabrication by DNA Self-Assembly



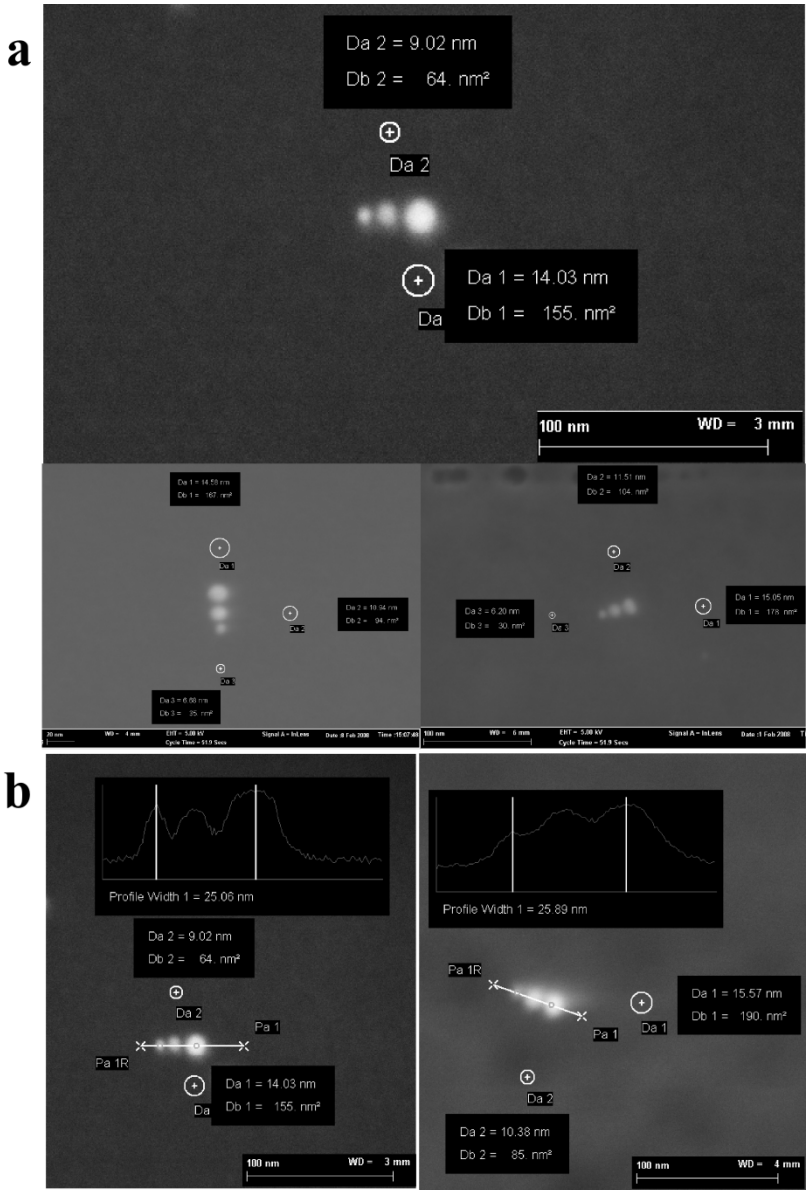
DNA “triple crossover molecule



Baoquan Ding, Stefano Cabrini, Ronald N. Zuckermann and Jeffrey Bokor

Molecular Foundry

Results: 3 particle ‘half-chains’



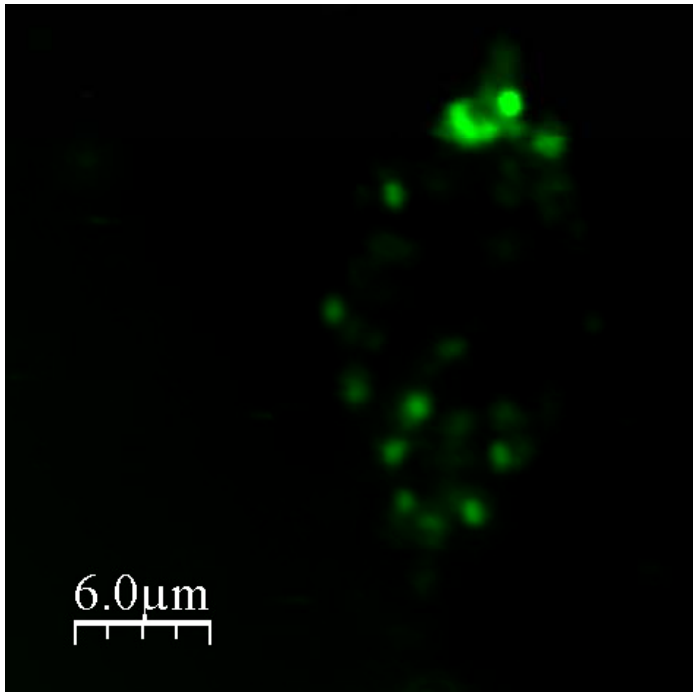
- DNA triple-crossover molecules used for self-assembly of 3-particle gold chains
- Particle spacing ~2.5 nm with tight control (±0.8 nm)
- Yield is low, but improving
- Optical characterization in progress

Ideal “Single-molecule” Probes: Upconverting Lanthanide-doped Nanocrystals

Shiwei Wu*†, Gang Han*†, Delia J. Milliron*, Shaul Aloni*, Virginia Altoe*, Dmitri V. Talapin‡, Bruce E. Cohen*§, and P. James Schuck*§

*Molecular Foundry, Lawrence Berkeley National Lab

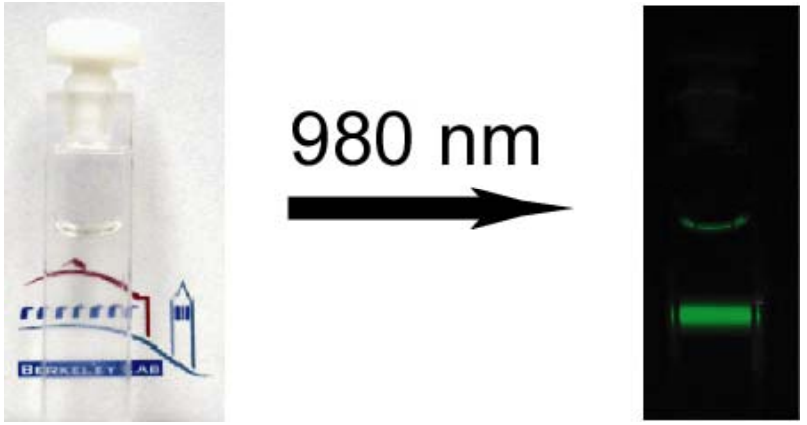
Luminescence image of Upconverting Nanoparticles (UNCPs) in a cell



Why do we study the UCNPs?

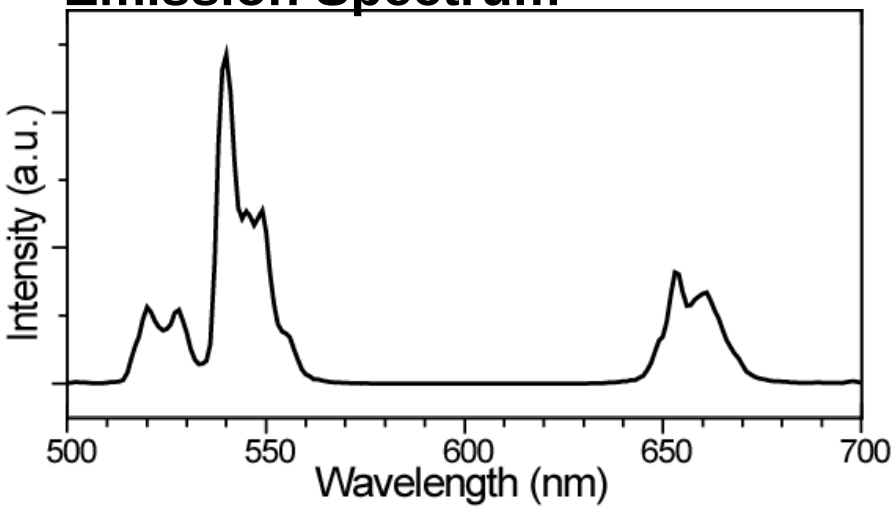
Ideal single-molecule probe

- ✓ Good brightness
- ✓ Uninterrupted emission (no blinking
- ✓ No photobleaching
- ✓ Near-zero overlap with background autofluorescence (anti-Stokes, two-photon, etc)
- ✓ Bio-compatibility (water-soluble, non-toxic)
- ✓ Deep penetration (NIR)

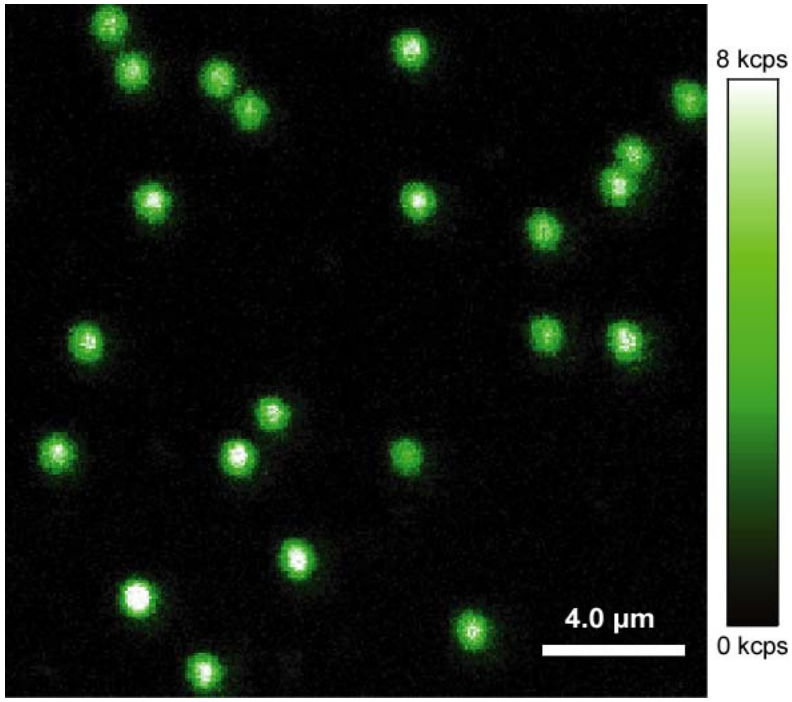


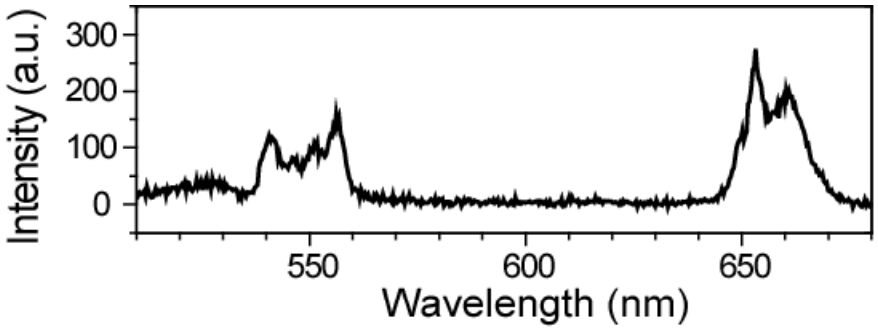
Transparent in visible

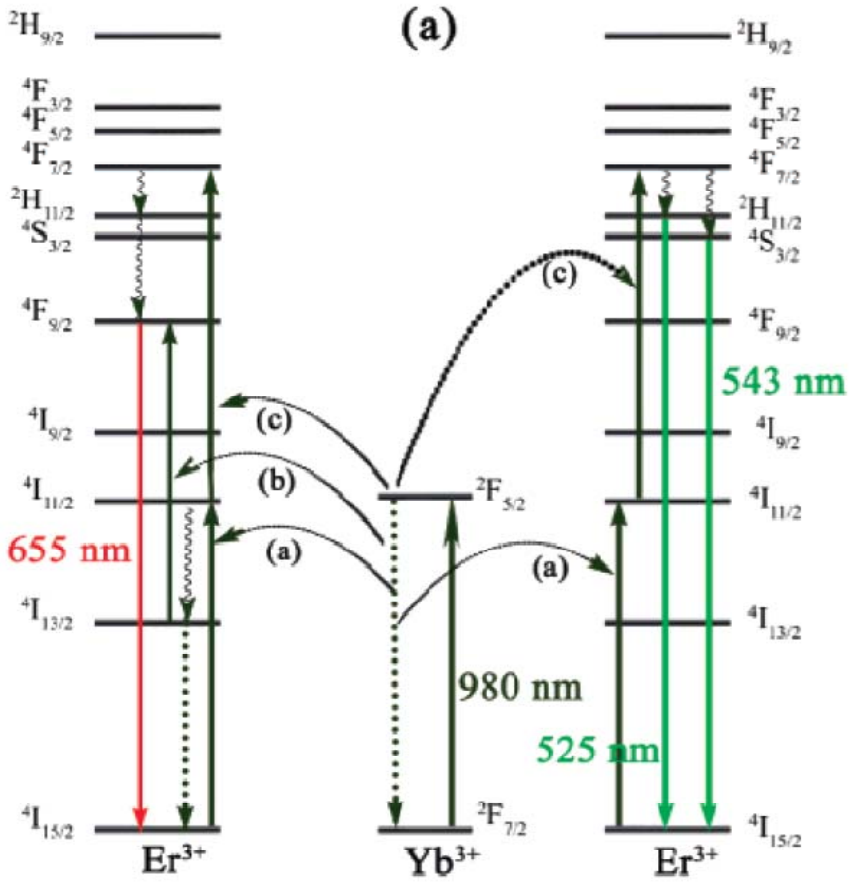
Emission Spectrum



Er,Yb:NaYF Single-particle upconverting luminescence

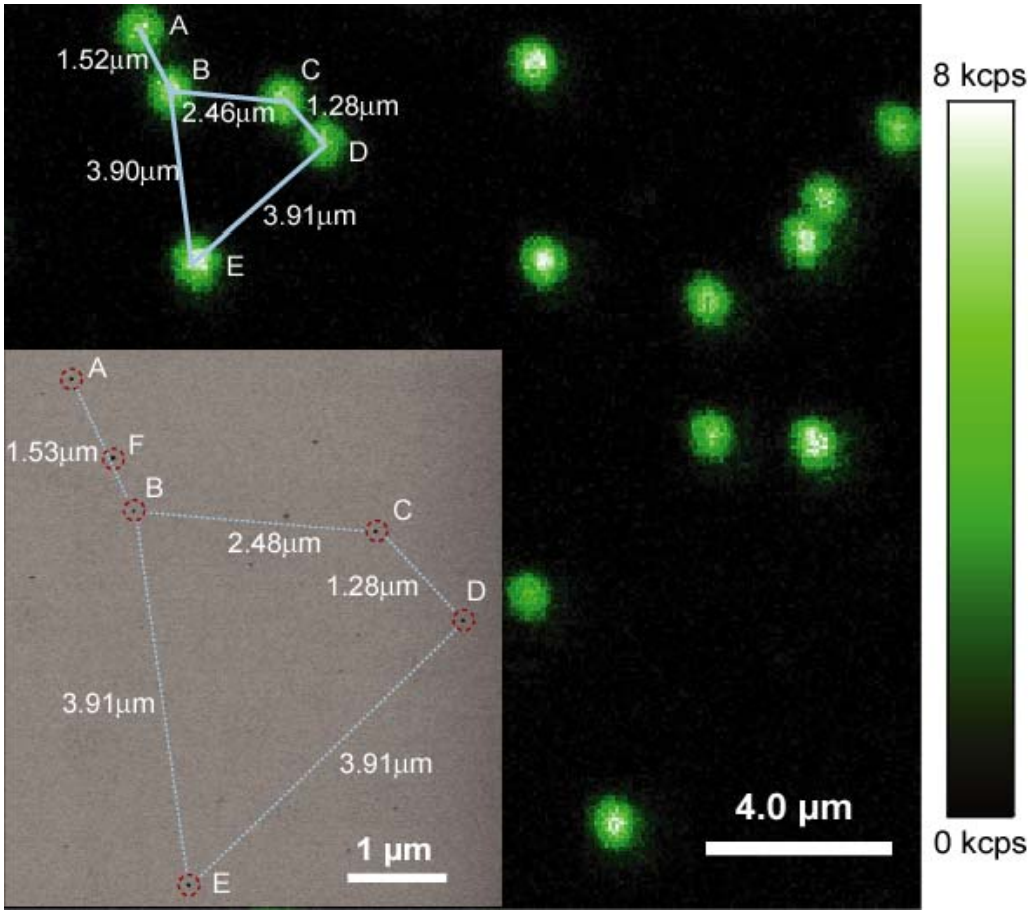






Mai et al., JPC C, 111, 13721 (2007)

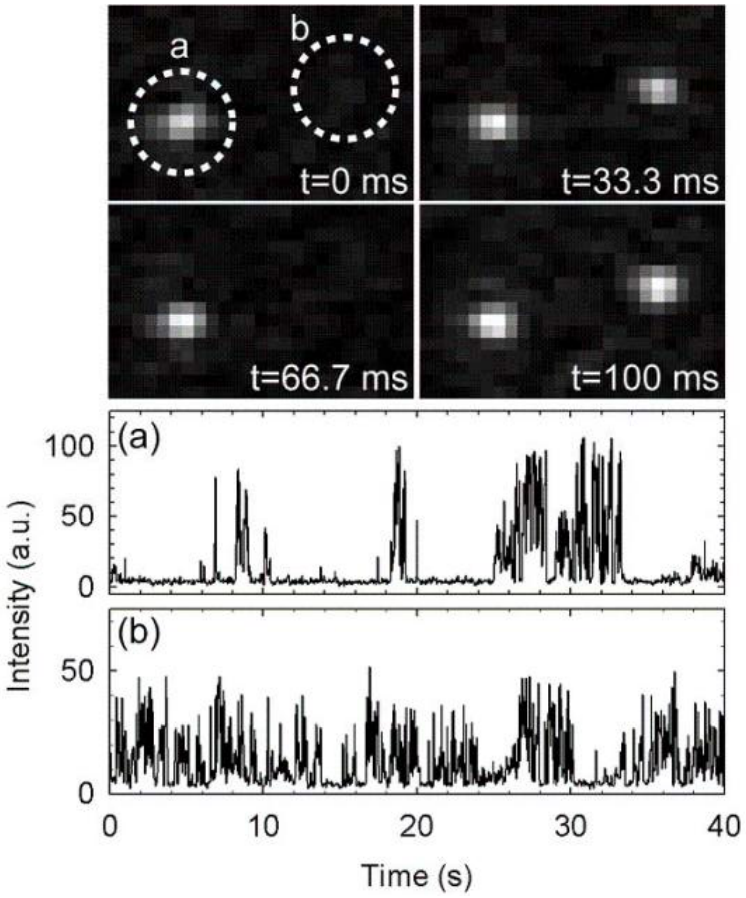
Confirmation of “single particle”



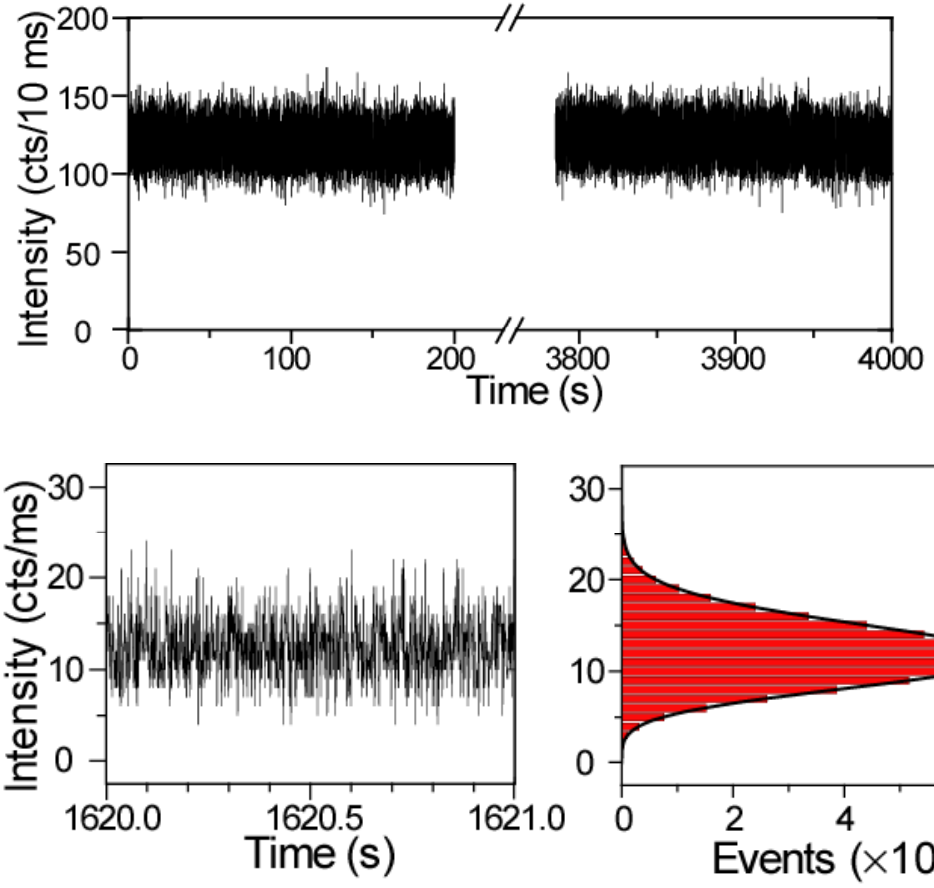
- All particles emit; i.e. – no “dark” particles

Photostability and Non-blinking

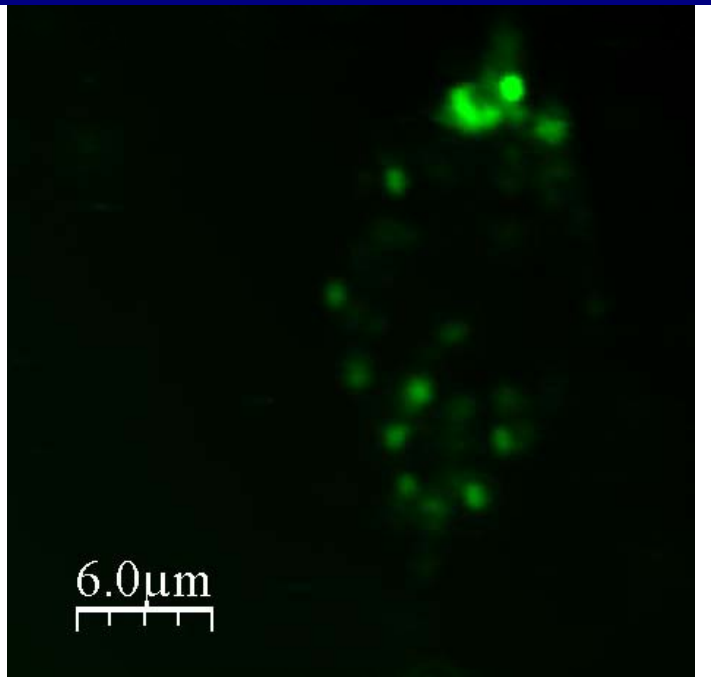
Qdots



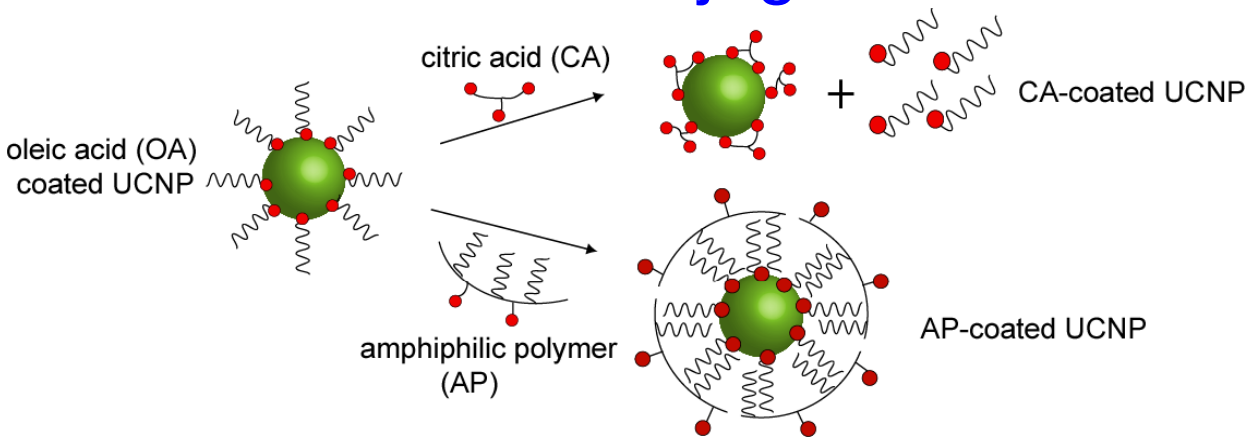
UCNPs



UCNPs as imaging probes in the cell



Surface conjugation



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Combinatorial Nanoscience

Single-Digit Nanofabrication

Synthesis and Characterization of Nanointerfaces

Next Proposal Submission Deadlines: Oct. 13, 2008