

Functional Plasmonics with Energy Localization for Sensing, Optoelectronics and Nano Actuation



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Edwin Y.B. Pun (EE),

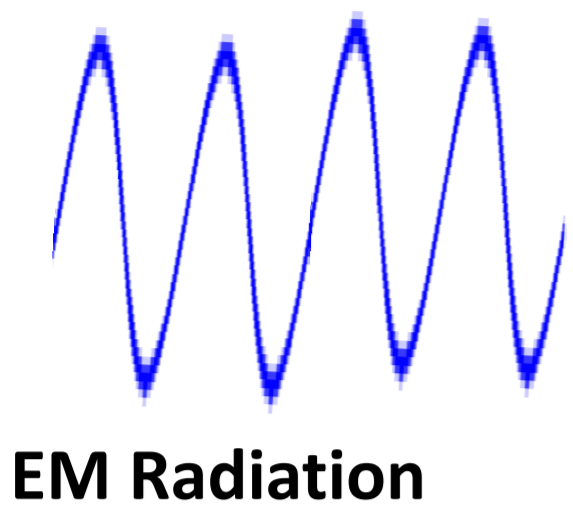


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K.S. Wong (Physics)

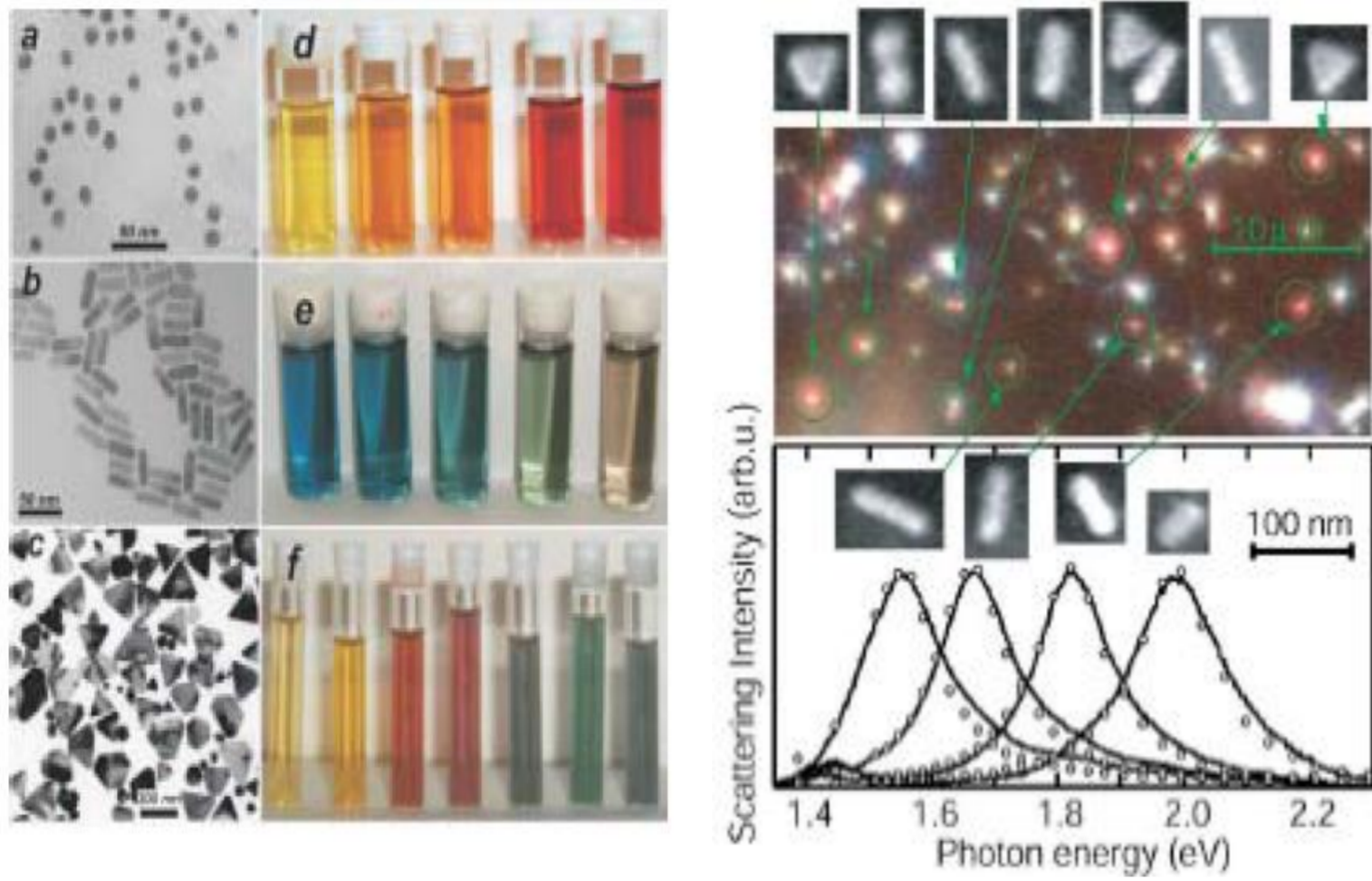
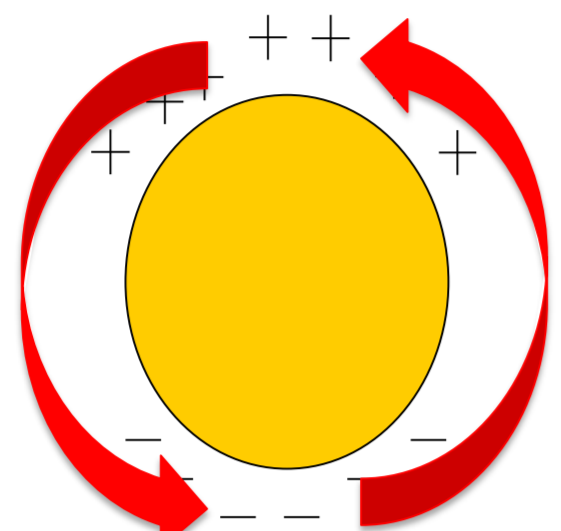


Charles Surya (EIE)

Surface Plasmons in Metallic Nano-sized Object

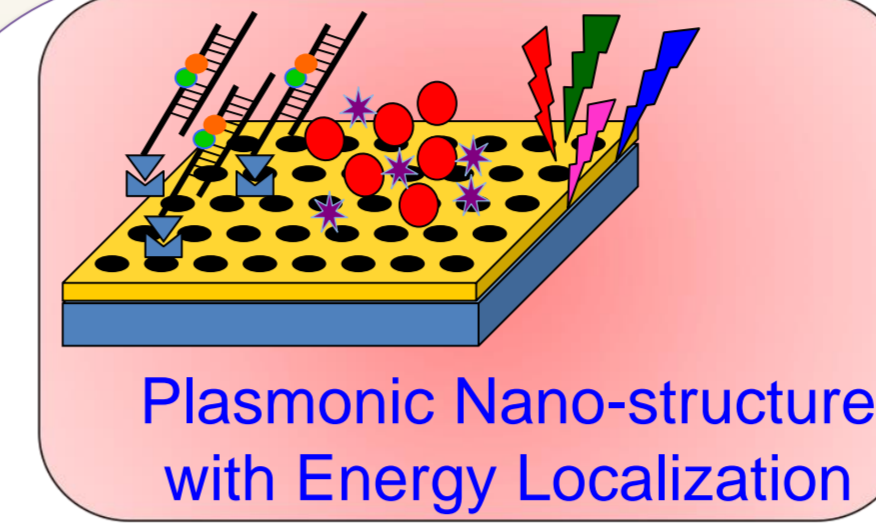


EM Radiation



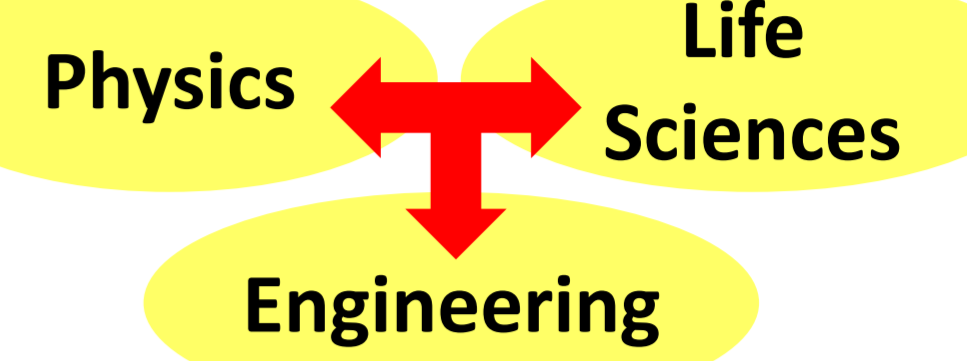
Useful Properties:

- Strong characteristic extinction
- Plasmons: $\sim 10^6$ of incident E-field
- Absorption & scattering coefficients $\sim 10^5$ of fluorescent dyes
- Size-, shape-, Environment-, dielectric constant-dependent resonance
- ⇒ tunable λ_{SPR} from visible to NIR



Plasmonic Nano-structure with Energy Localization

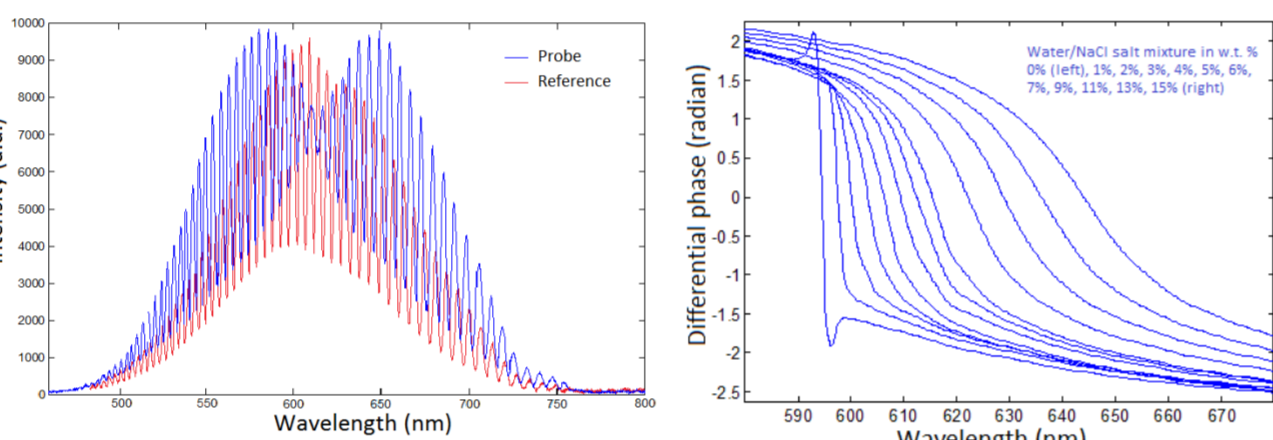
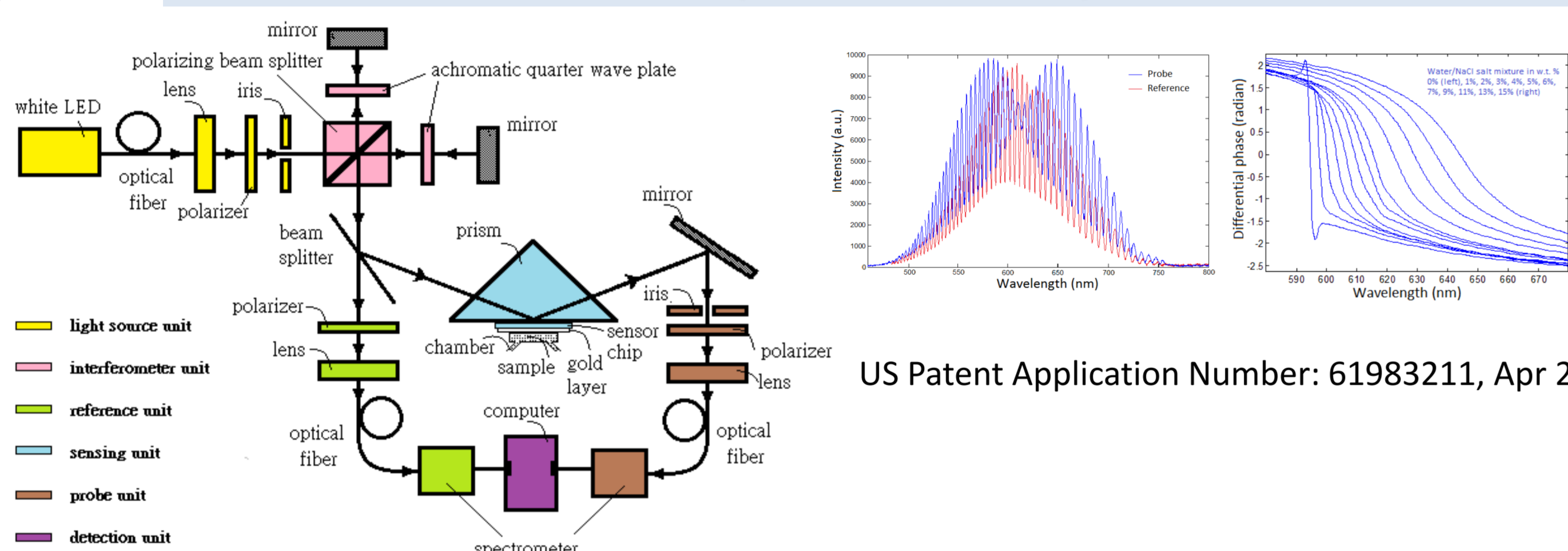
Objectives



1. Investigation of plasmon excitation in artificial metallic nanostructures and their variants through theoretical and experimental studies for generating energy localization and strong optical forces
2. Development of plasmonic device strategies for surface plasmon-mediated applications
3. Demonstration of a plasmonic biosensing platform with in-situ SERS detection capability
4. Establishment of a synergistic multidisciplinary research community for the advancement of plasmonics technology

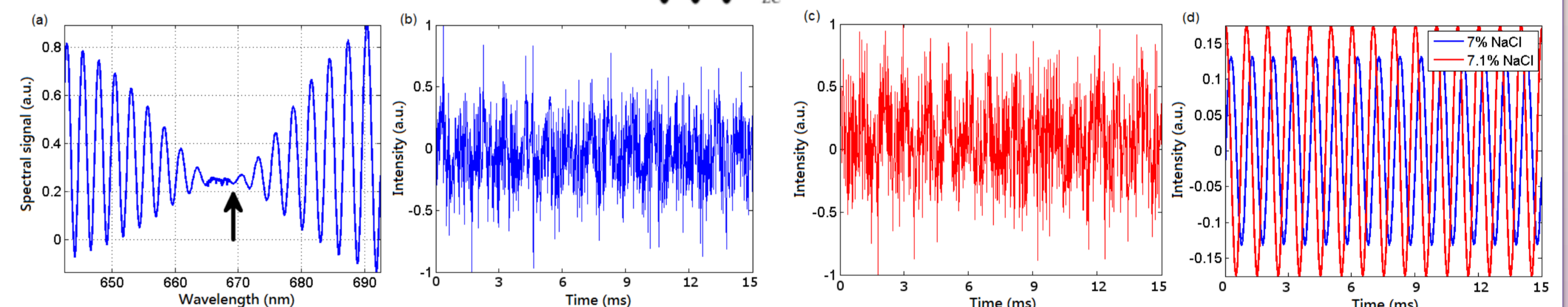
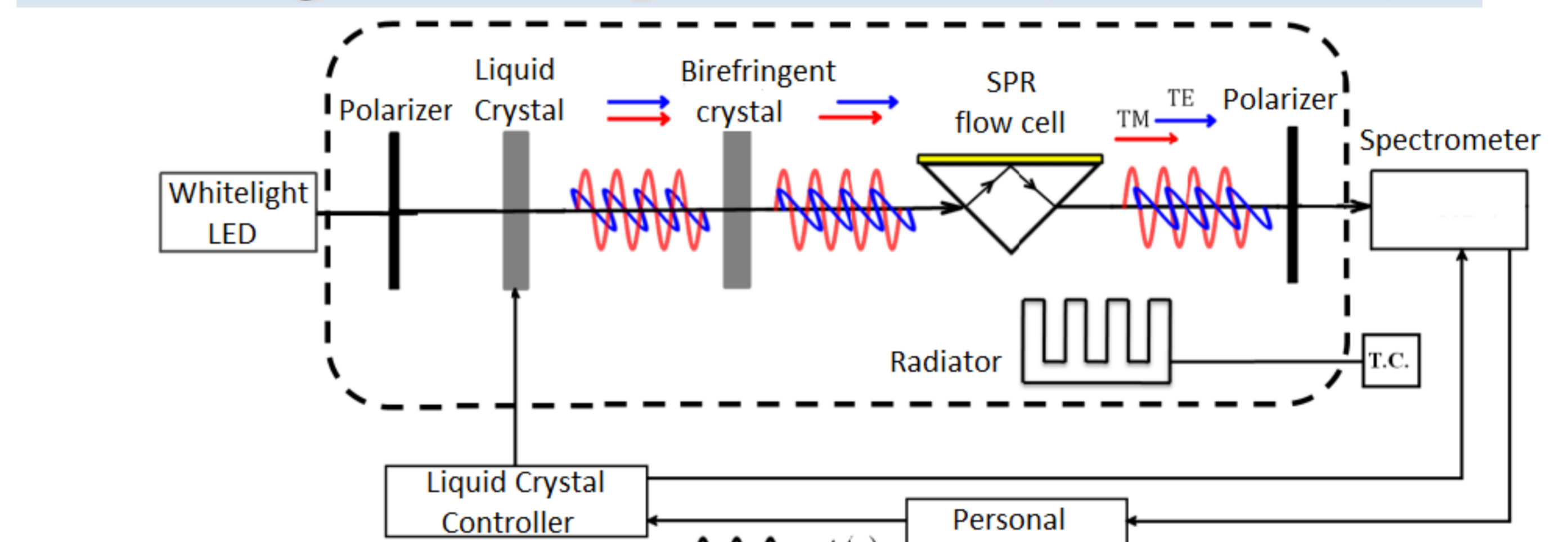
Phase-sensitive Surface Plasmon Resonance Sensing

White light spectral phase SPR biosensor (Ho, CUHK)



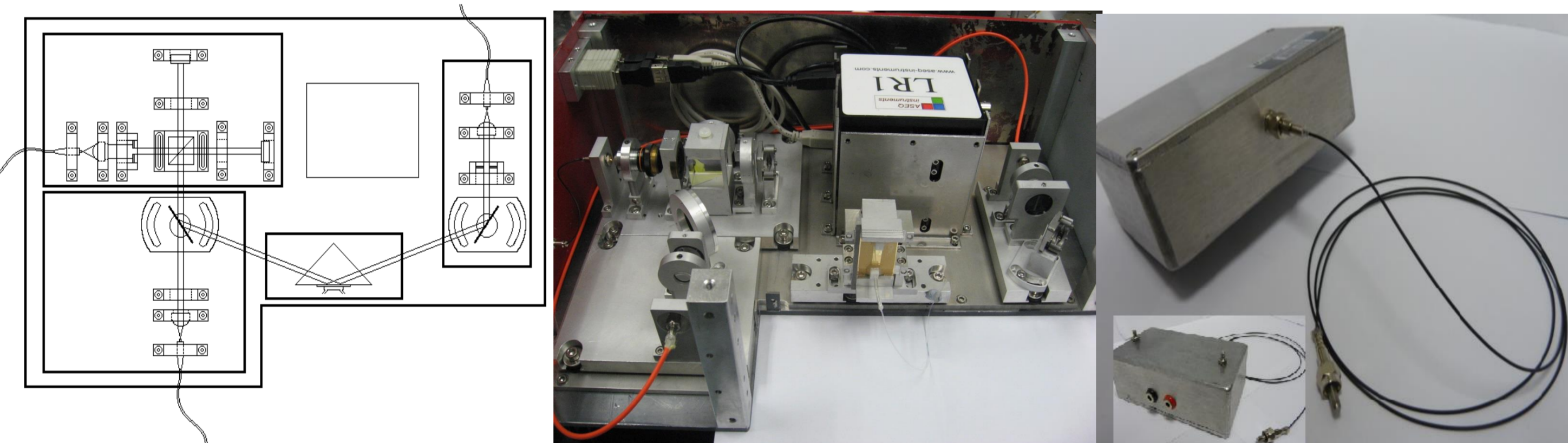
US Patent Application Number: 61983211, Apr 2014

Common-path spectral SPR interferometric sensing with temporal carrier (Ho, CUHK)



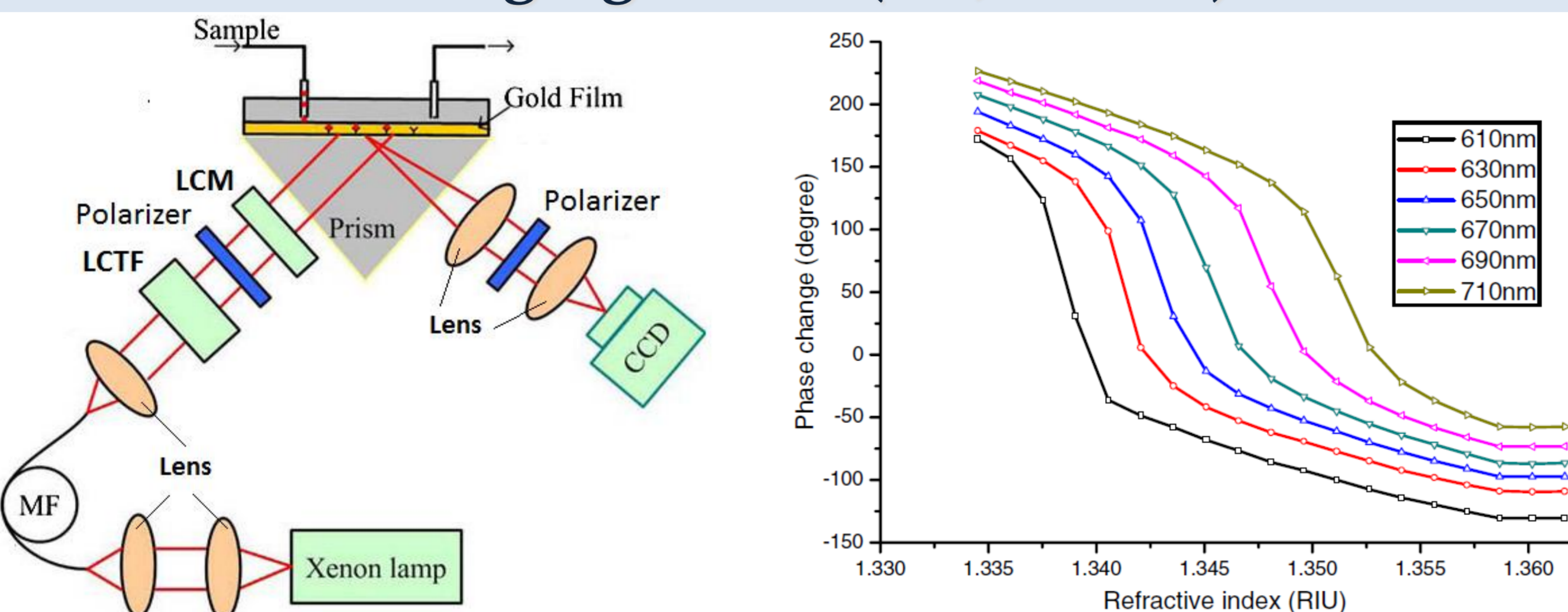
Ng et al, Opt. Exp. 21, 20268-20273 (2013)
US Patent US2013/0329230 A1 Pub date: Dec. 12, 2013

Spectral phase SPR biosensor prototype (Ho, CUHK)



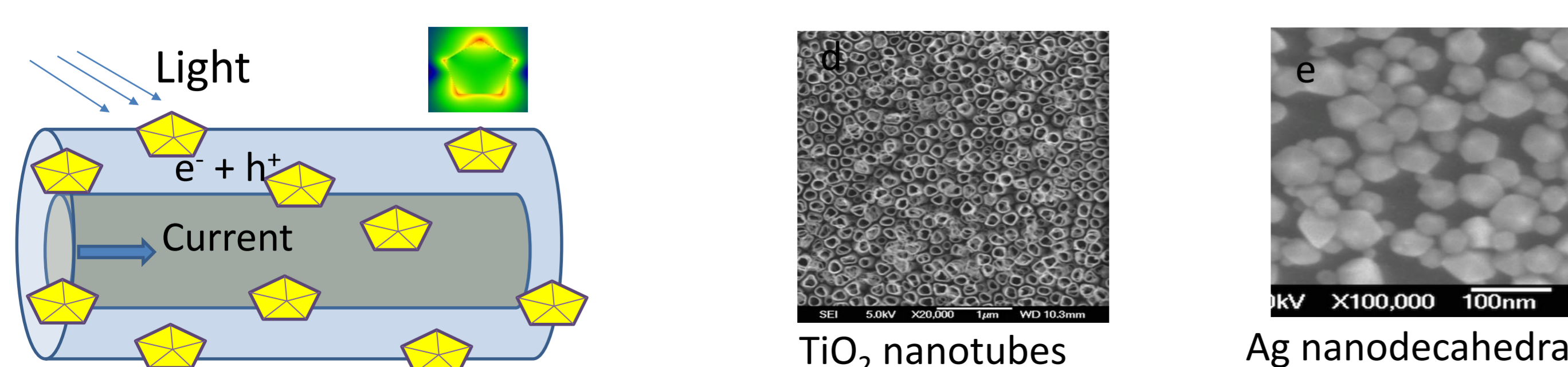
Start-up fund from Zhangjiagang (Jiangsu) (matching grant - RMB 2M)

Wavelength-multiplexing phase-sensitive SPR imaging sensor (Ho, CUHK)



Shao et al, Opt. Lett. 38, 1370-1372 (2013)

Plasmon-enhanced gas sensing (Ho, CUHK)

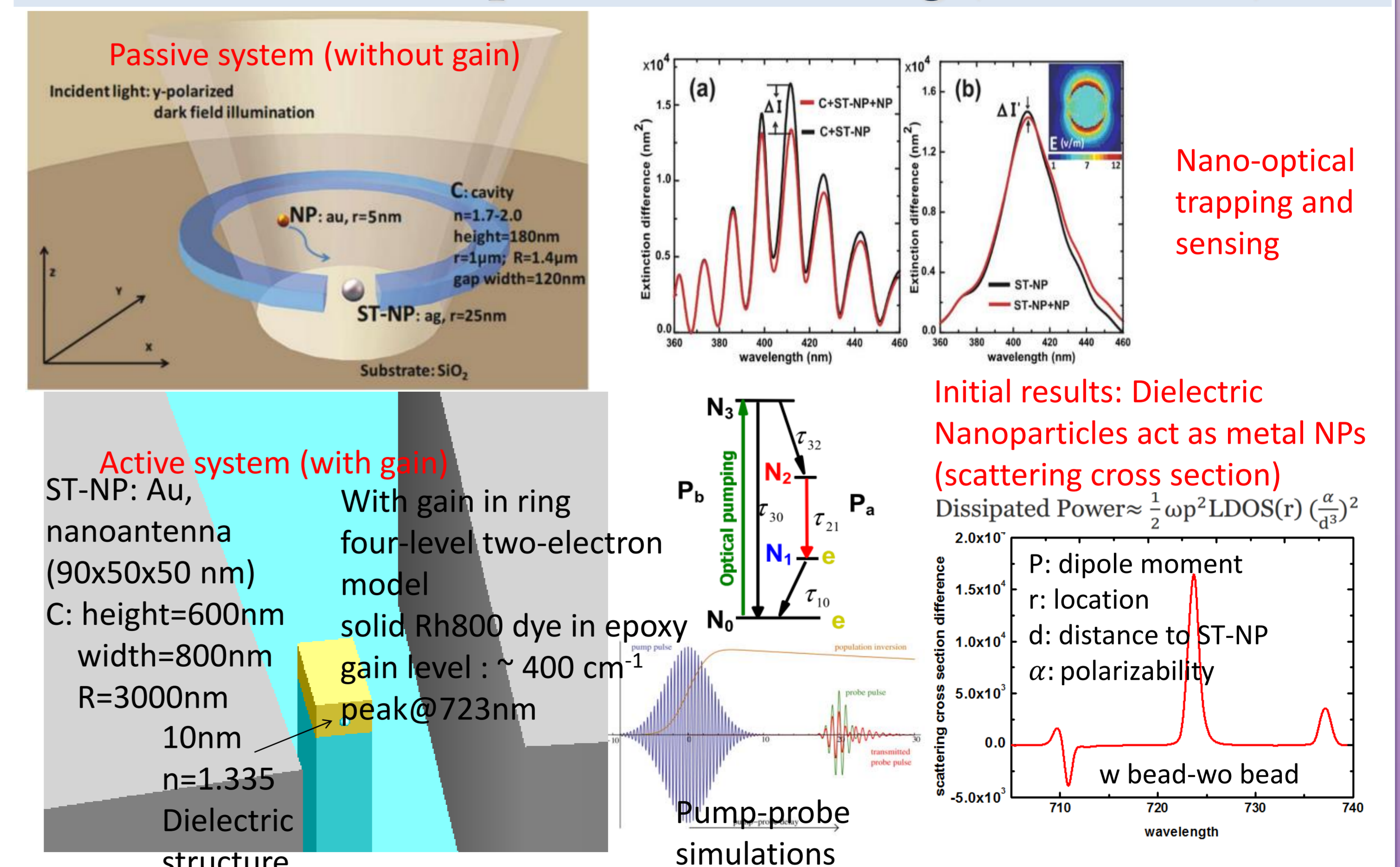


- ZnO tetrapods or TiO_2 as catalytic host
- Plasmonic nanocrystals (Ag decahedra) for energy harvesting

ZnO tetrapods with uniform size distribution; length $\sim 700\text{nm}$ and diameter $\sim 100\text{nm}$

Unpublished data

Squeezing the local density of state (LDOS) for ultrasensitive plasmonic sensing (Ho, CUHK)



H. Zhang et al, Opt. Lett. 39, 873 (2014)

Acknowledgement:

Collaborative Research Fund (CRF), Research Grants Council (RGC), Project # CUHK1/CRF/12G

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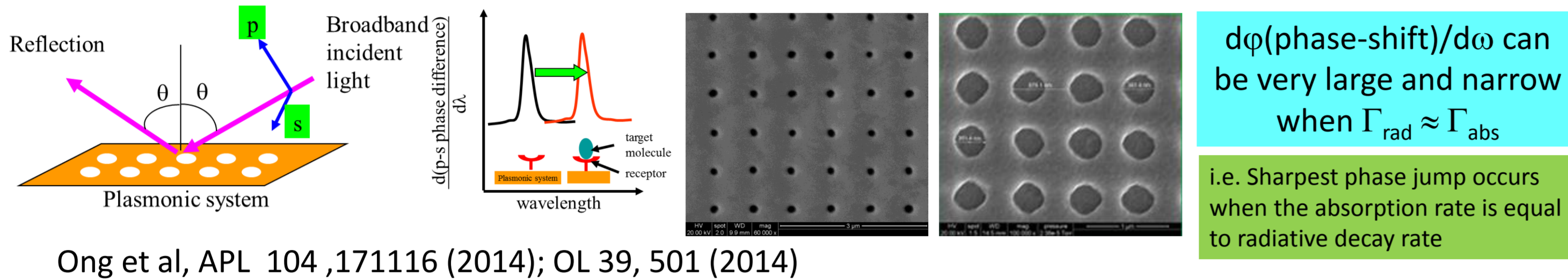
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K.S. Wong (Physics)



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Phase-sensitive Surface Plasmon Resonance Sensing (Cont.)

Sensing with phase-based SPR spectroscopy (Ong, CUHK)

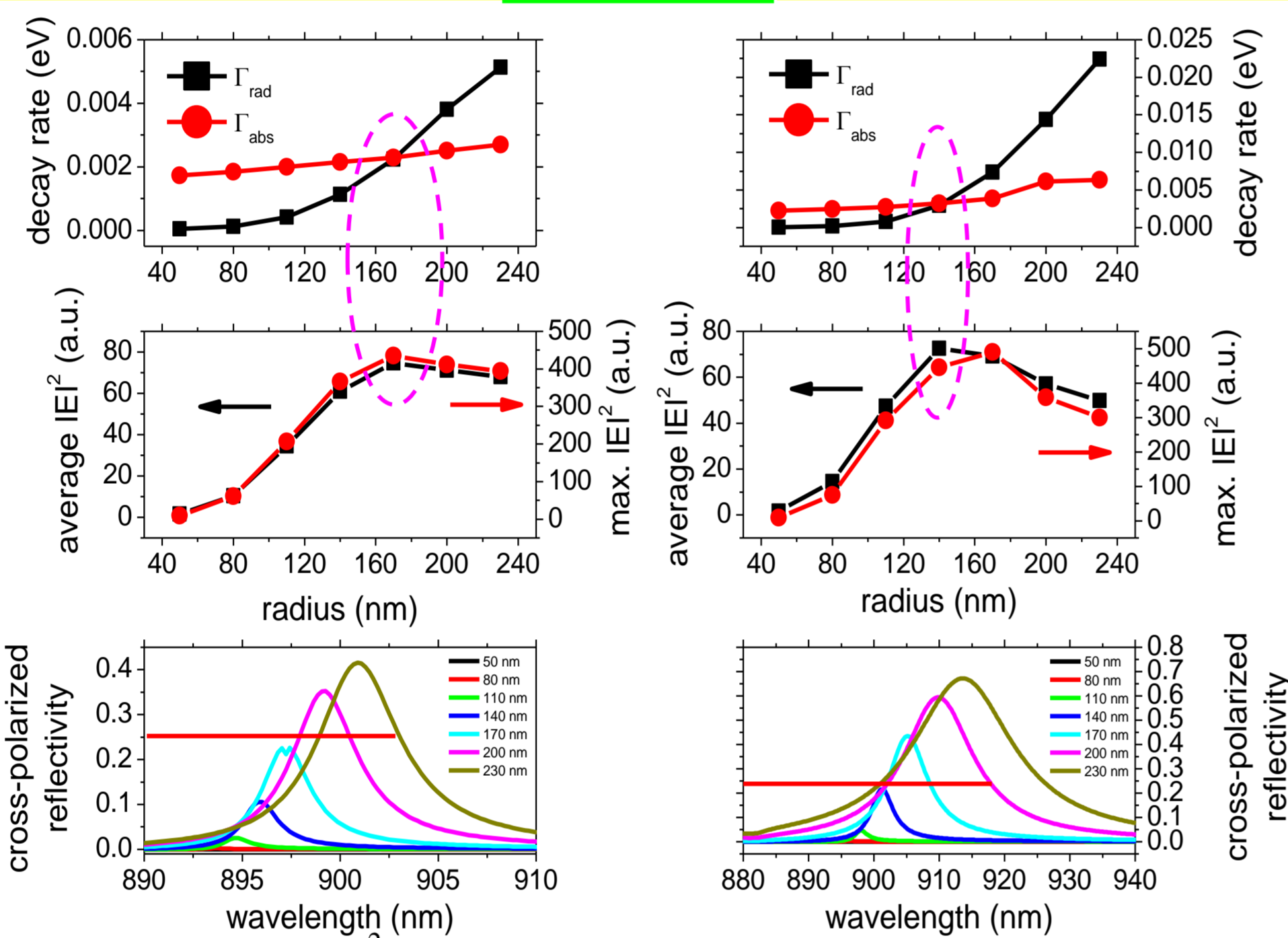


Key contribution

Field enhancement is strongest occurs at critical coupling: $\Gamma_{\text{abs}} = \Gamma_{\text{rad}}$
(absorption rate = radiative decay rate)

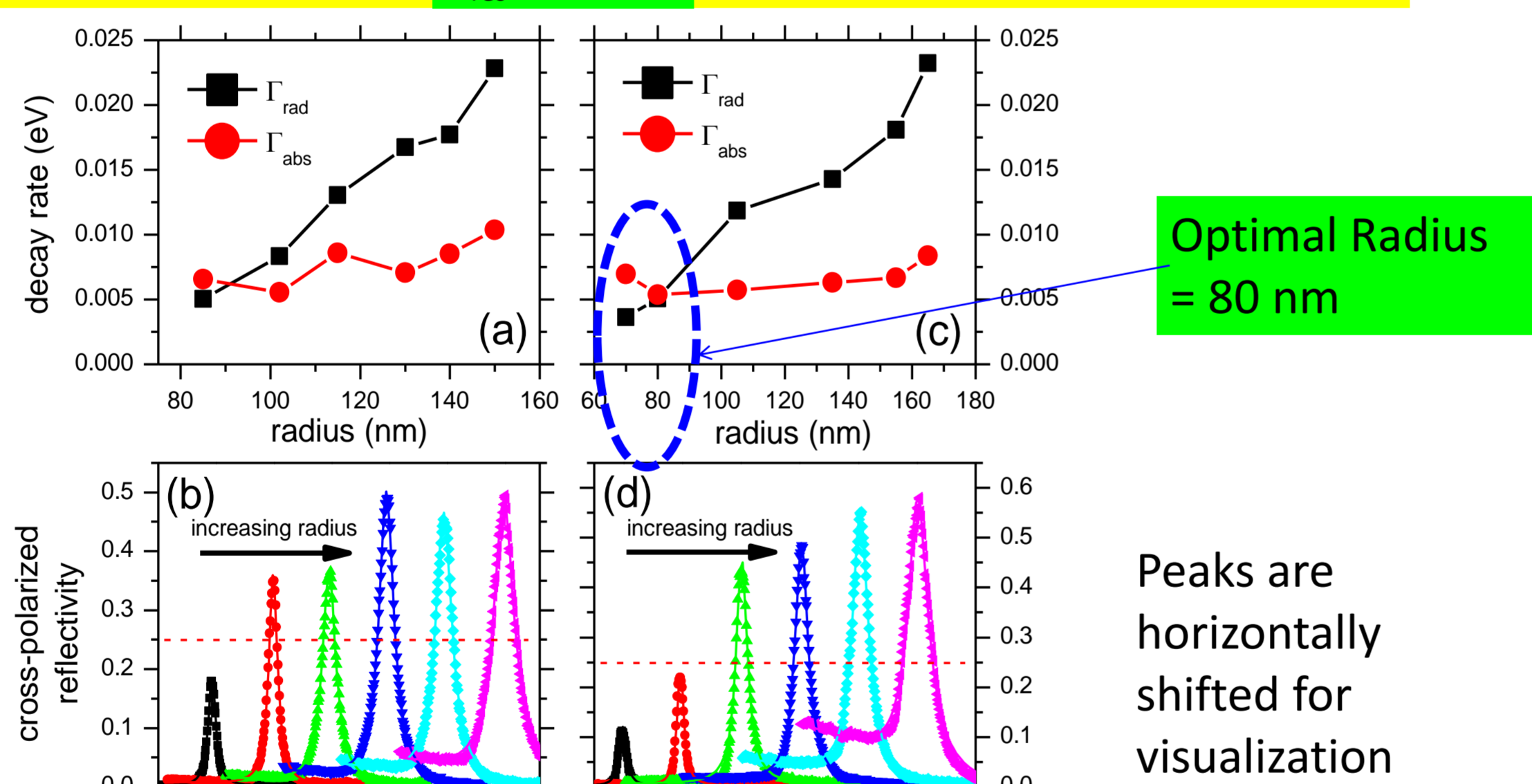
FDTD results 2D periodic arrays (-1,0) SPP

Ag: period = 670 nm, height = 60 nm $\lambda_{\text{res}} \sim 900$ nm Au: period = 670 nm, height = 120 nm



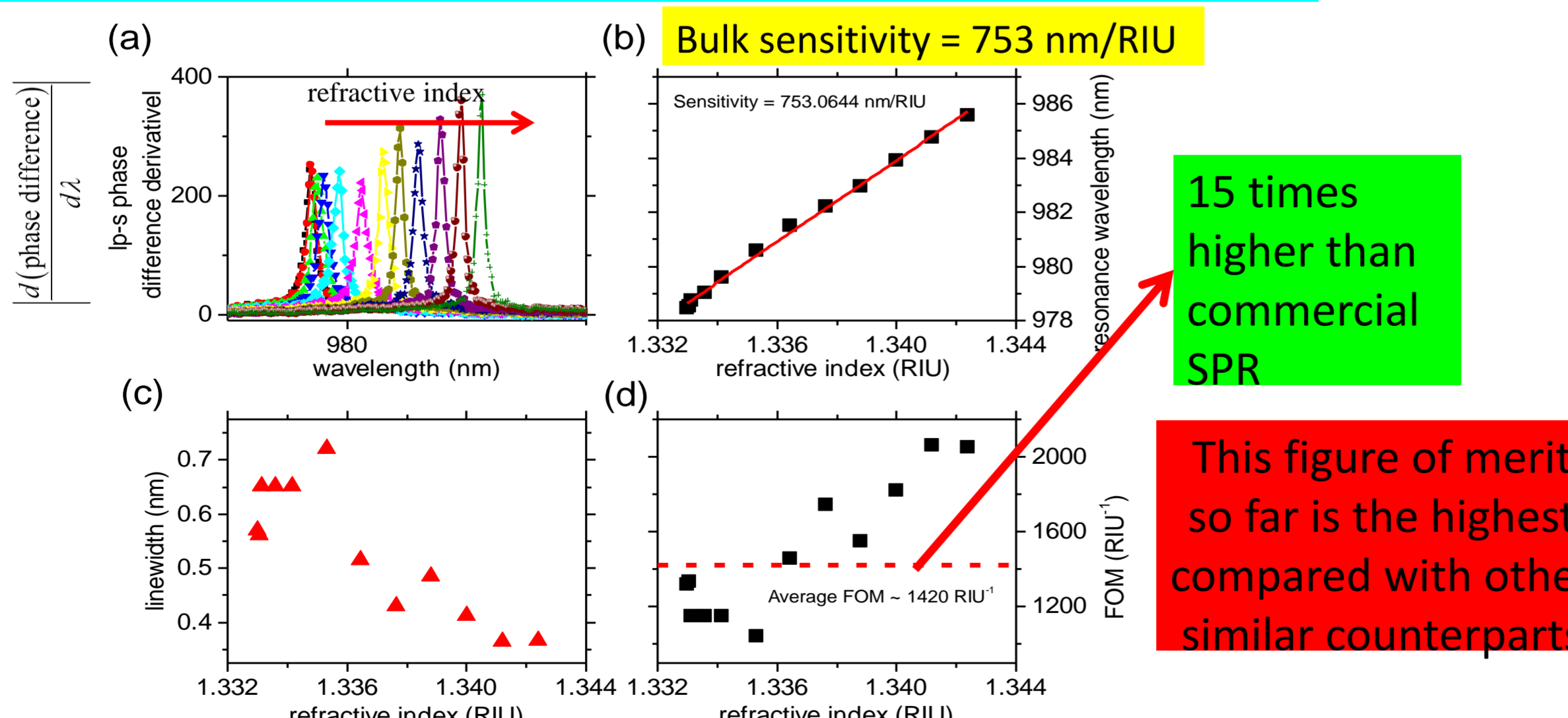
Experimental verification

Ag: period = 670 nm, height = 140 nm $\lambda_{\text{res}} \sim 900$ nm Au: period = 650 nm, height = 270 nm

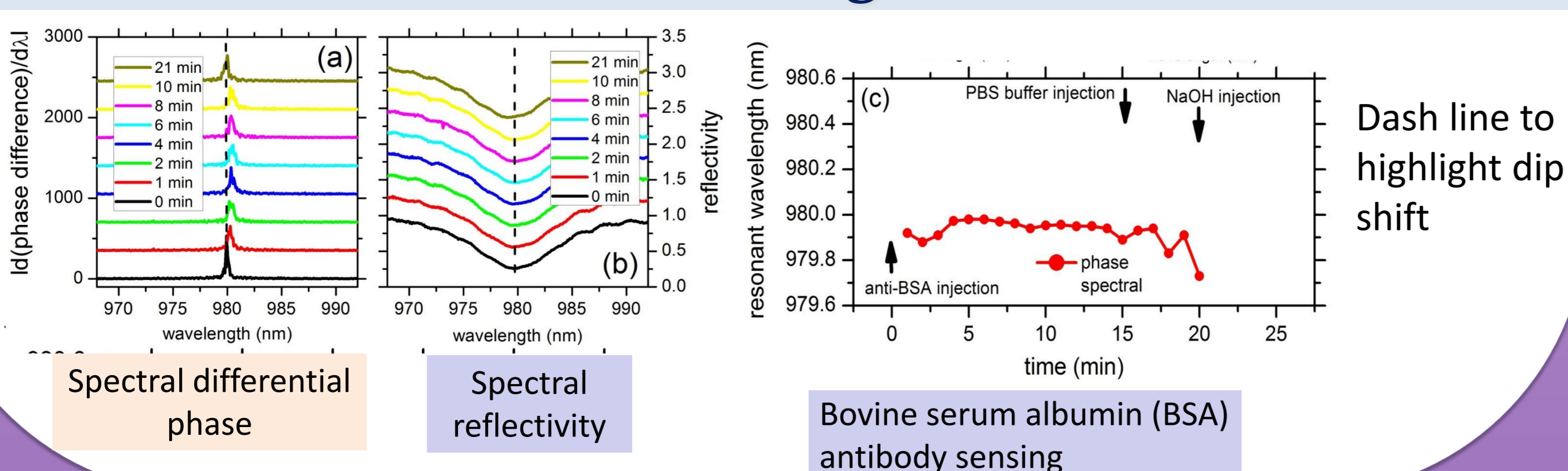


Experimental results

2-D Au array with period = 750 nm, hole depth = 100 nm and radius = 80 nm

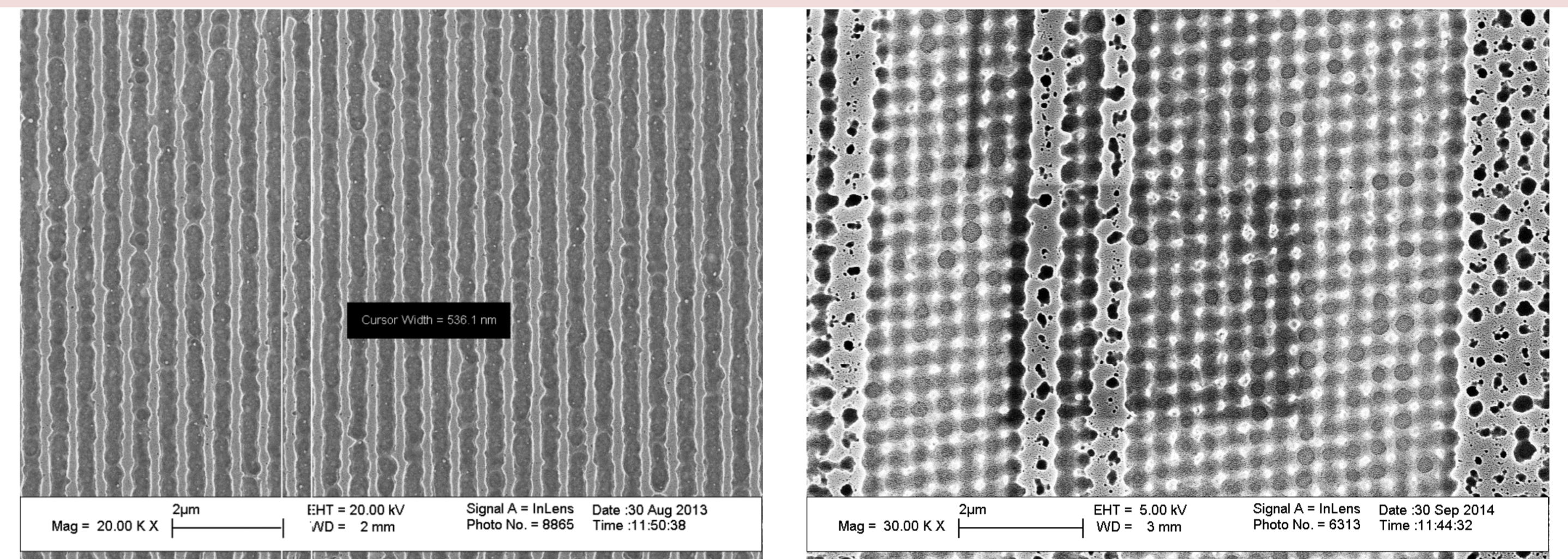


Protein sensing results

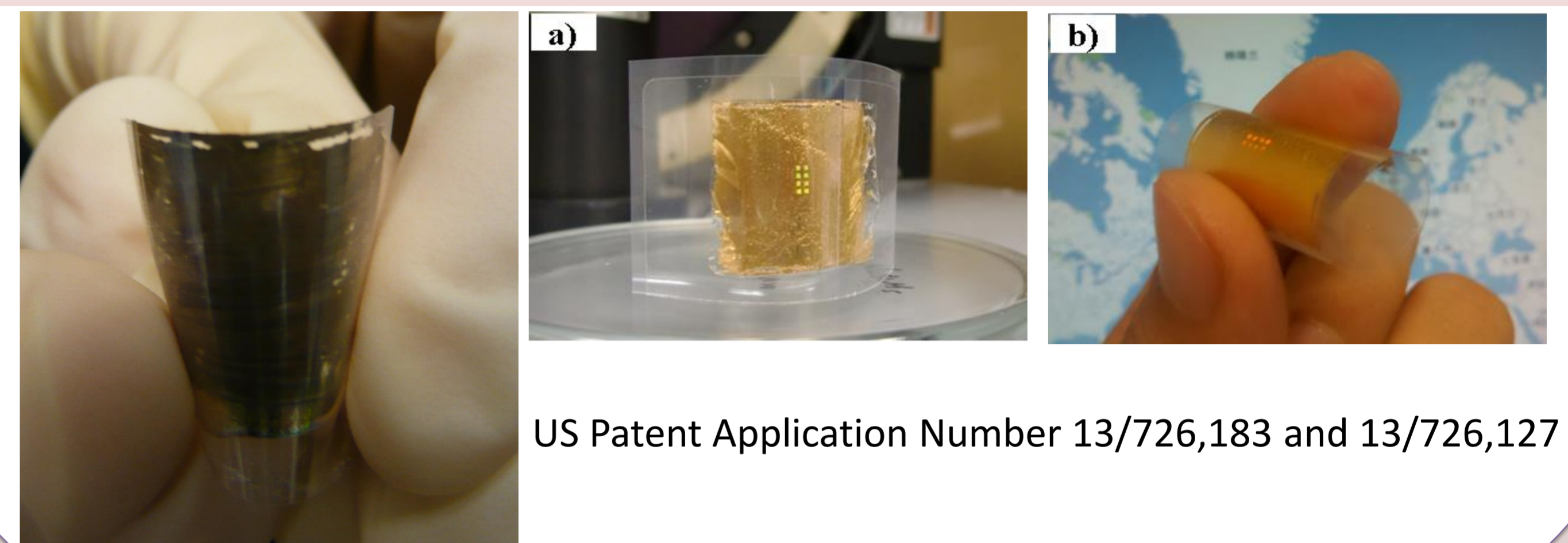


Plasmonic Substrate Fabrication

Direct transfer of nano-patterned metallic film to flexible substrates (Cheah, HKBU)

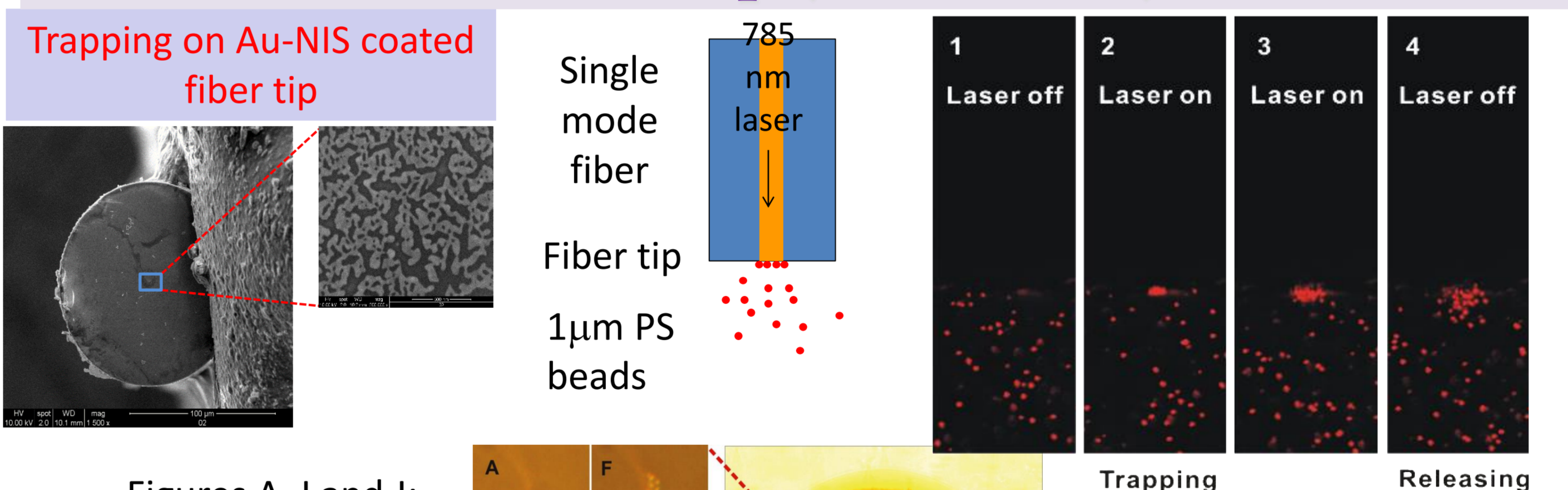


Plasmonic structures on flexible substrates (Cheah, HKBU)



Plasmonic Nanotrapping

Optical tweezers with random plasmonic structures on fiber tip (Ho, CUHK)

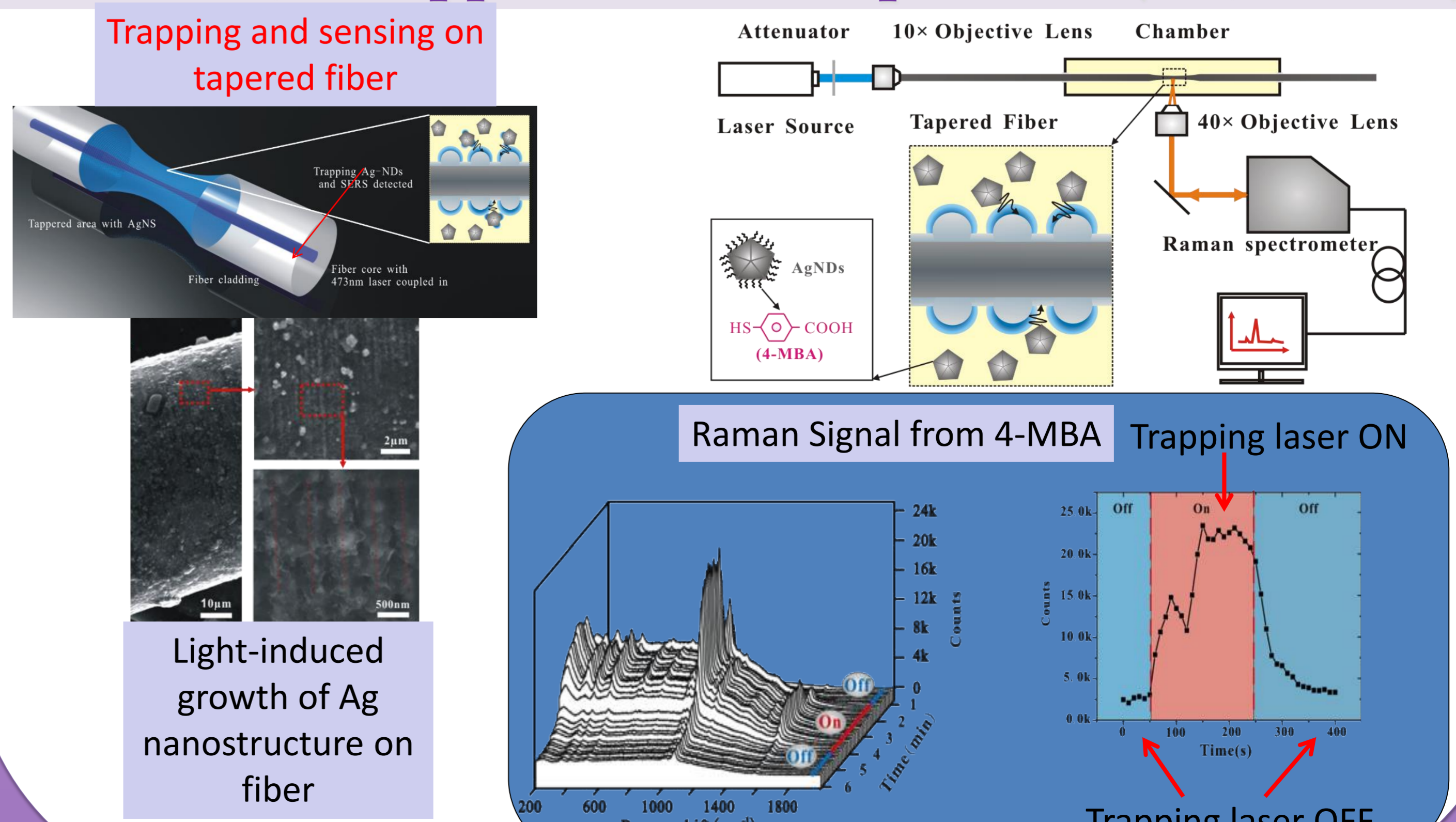


Figures A, I and J: 785 nm Laser OFF

Figures B - H: 785 nm laser ON

Time evolution of PS trapping when 785 nm laser went through OFF-ON-OFF cycle

Fiber based plasmonic optical tweezers with Raman detection, "Trapp-and-sense" operation (Ho, CUHK)



Acknowledgement:

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Lu et al, Plasmonics 7, 167-173 (2012)

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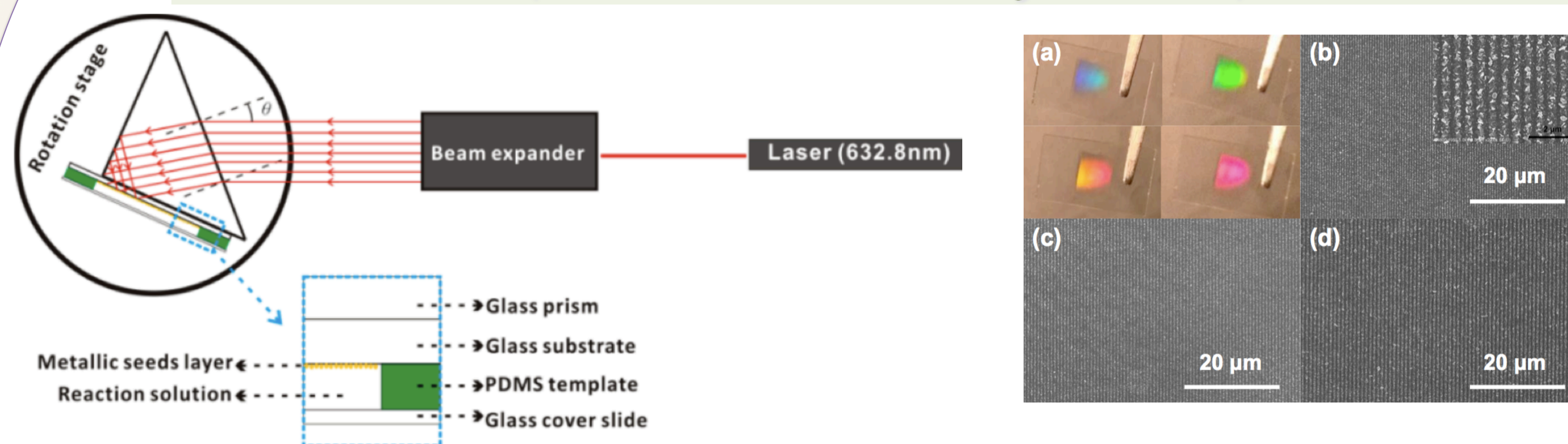
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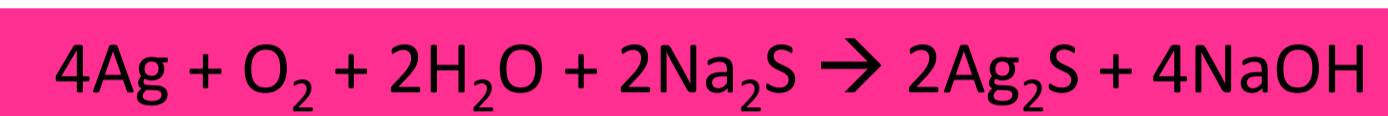
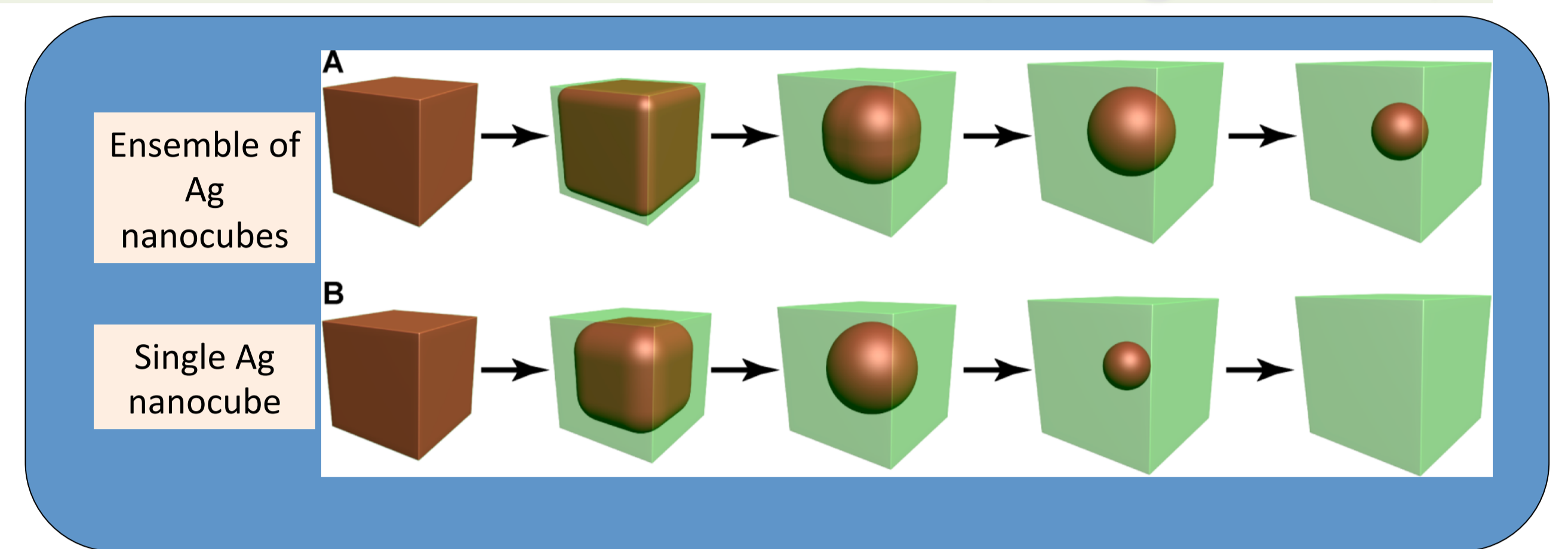
Charles Surya (EIE)

Plasmonic Nanoparticles

Nanostructured Ag gratings (Ho, CUHK; Choy, HKU)



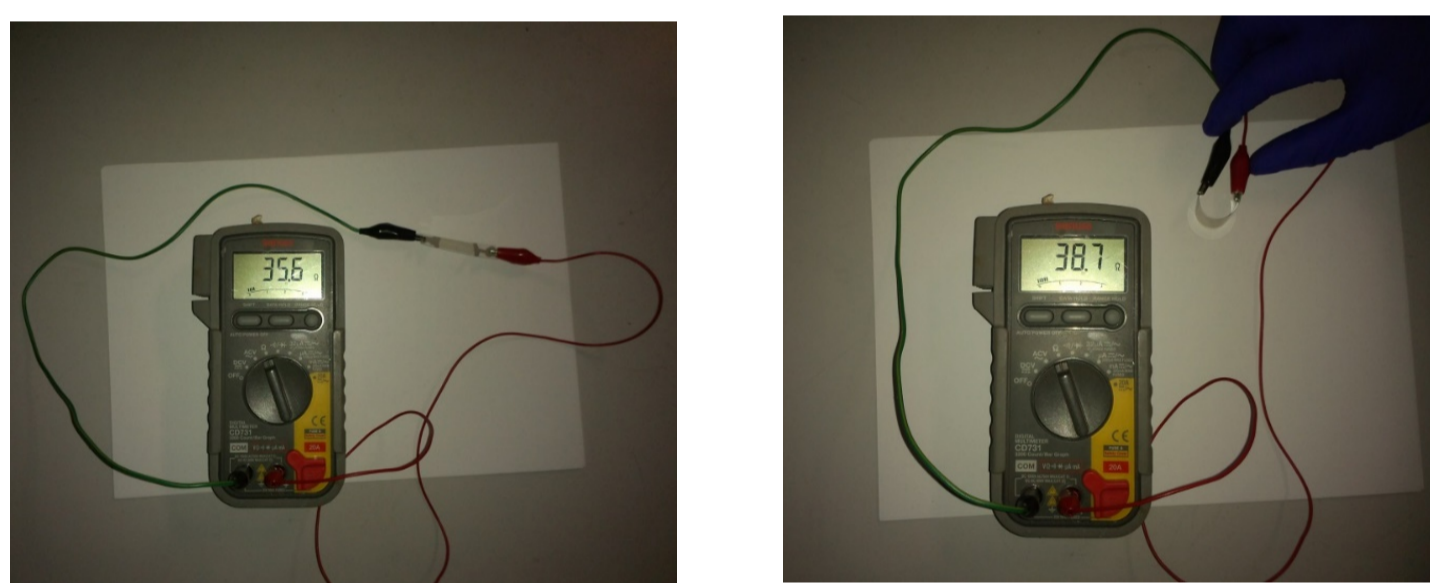
Plasmonic and structural evolutions during the sulfidation of silver nanocubes (Wang, CUHK)



New class of room-temperature solution-process nano-metal flexible electrode (Choy, HKU)

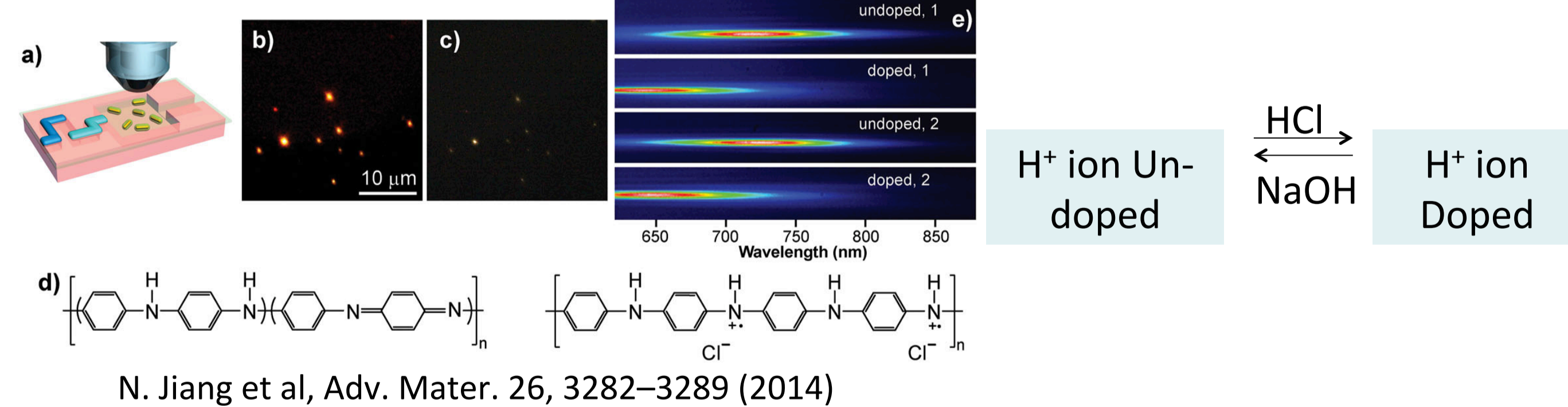
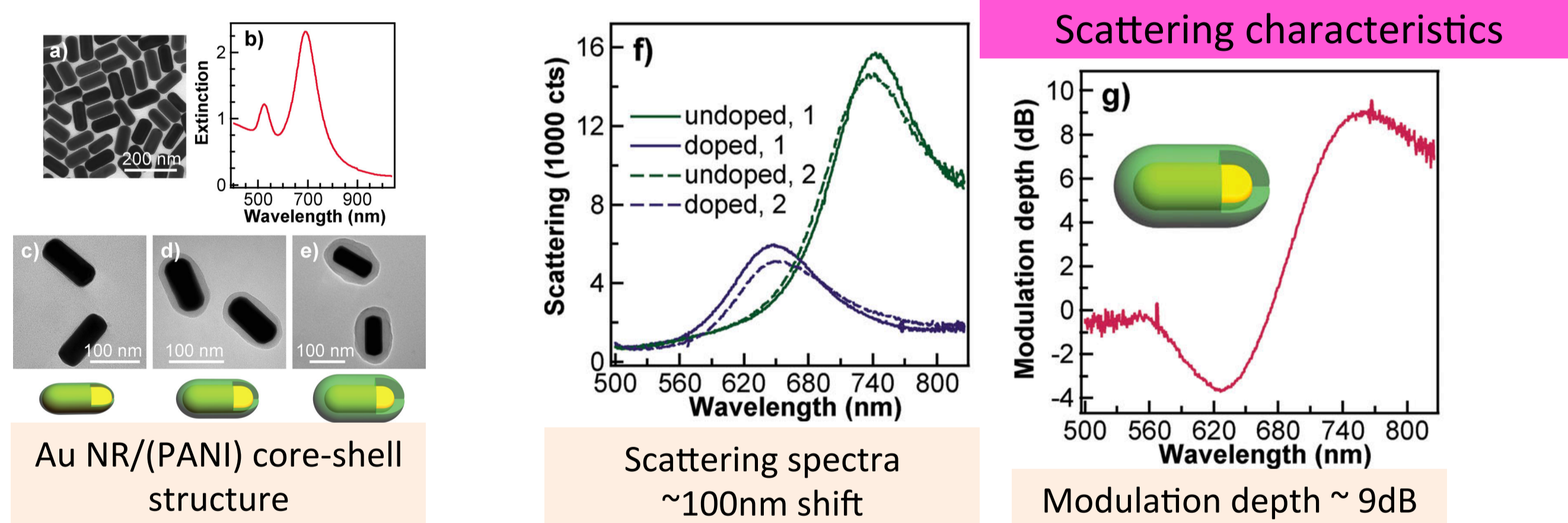


- Transparent electrode on glass substrate made with new concept/approach
- Preliminary results:
 - S1: transmission (T) = 83% (at 550nm), sheet resistance (R) = 140 ohm/sq
 - S2: T = 75% (at 550nm), R = 18 ohm/sq
- Bare glass shown for reference



Lu et al, ACS Nano, 8, 10980, 2014;
Lu et al, Patent Application No. 14/455,584, 2014

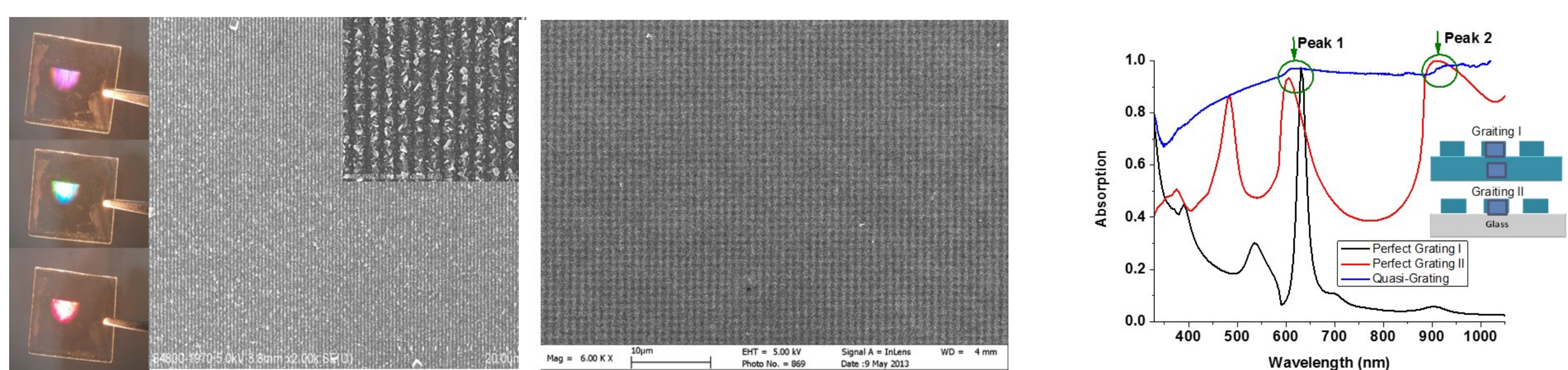
(Gold nanorod core)/(polyaniline shell) plasmonic switches with large plasmon shifts and modulation depths (Wang, CUHK)



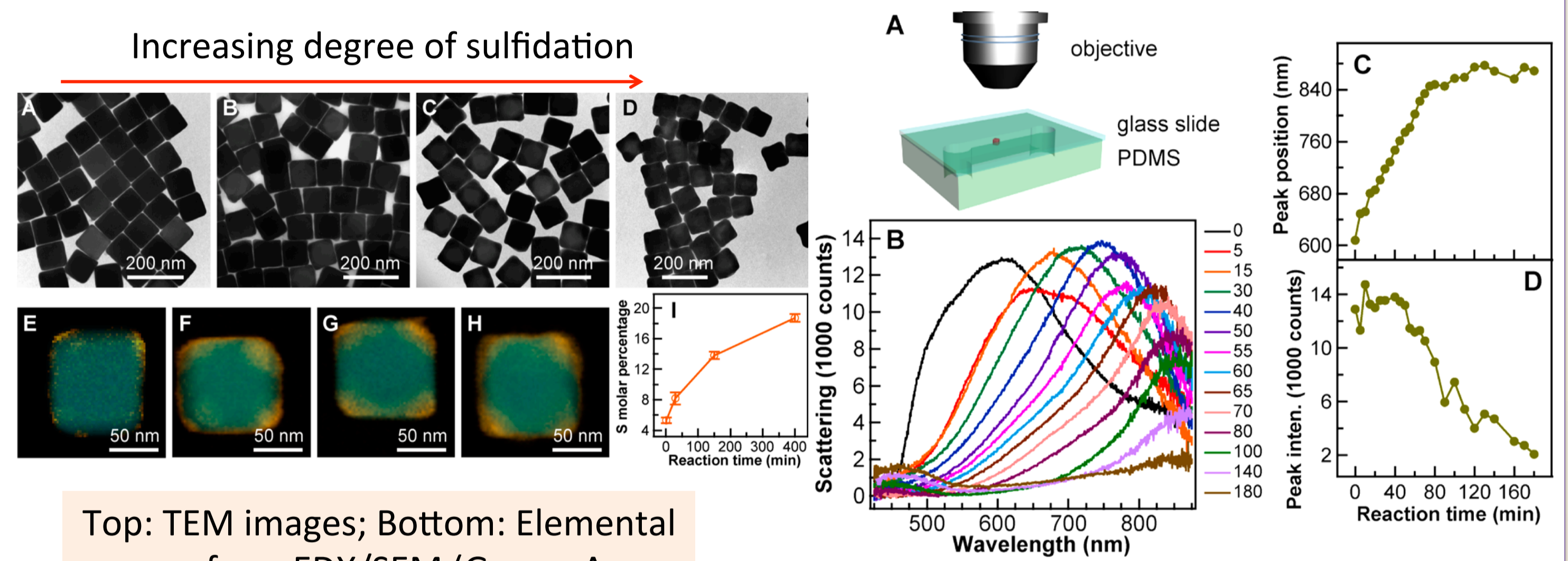
N. Jiang et al, Adv. Mater. 26, 3282-3289 (2014)

New plasmonic gratings from random nanoparticles (Choy, HKU)

New Physics: Maintenance of diffraction effect from a new Class of Macro-Periodic and Micro-Random Plasmonic nanostructures with simultaneous spatial translational symmetry and long-range order breaking
Potential application: Wideband and polarization independent electrodes



H. Lu et al, Scientific Reports, submitted



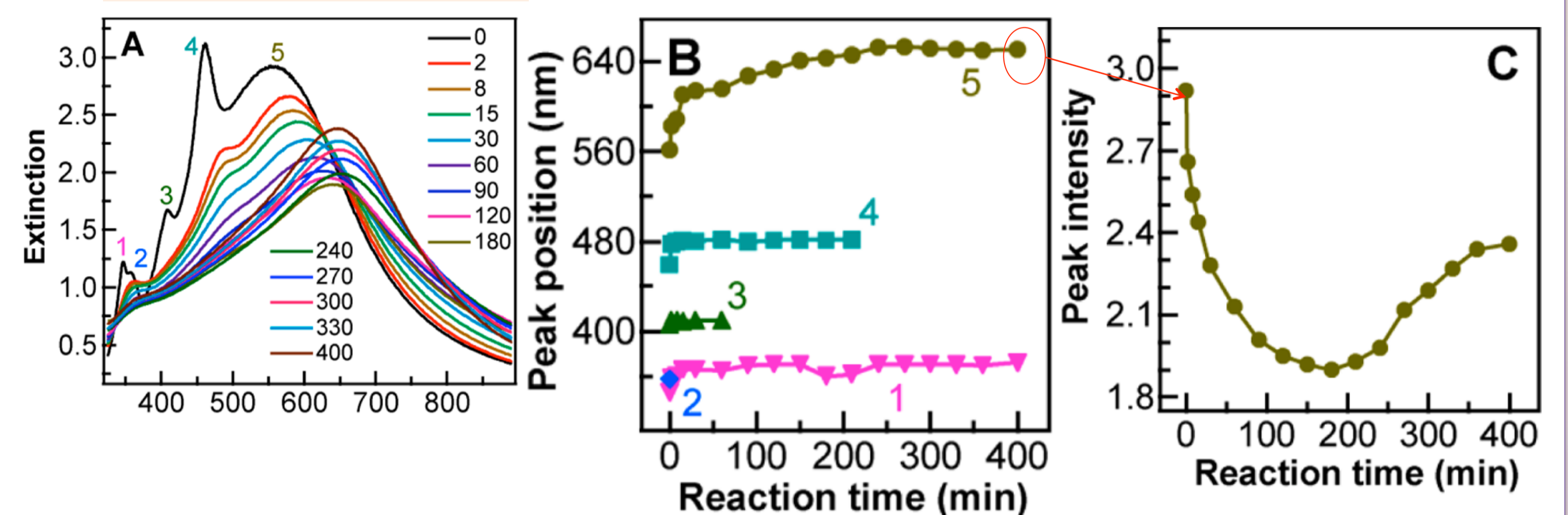
Top: TEM images; Bottom: Elemental map from EDX/SEM (Green: Ag, Brown: S)

Sulfidation of single Ag nanocube

Evolution of extinction with increasing degree of sulfidation

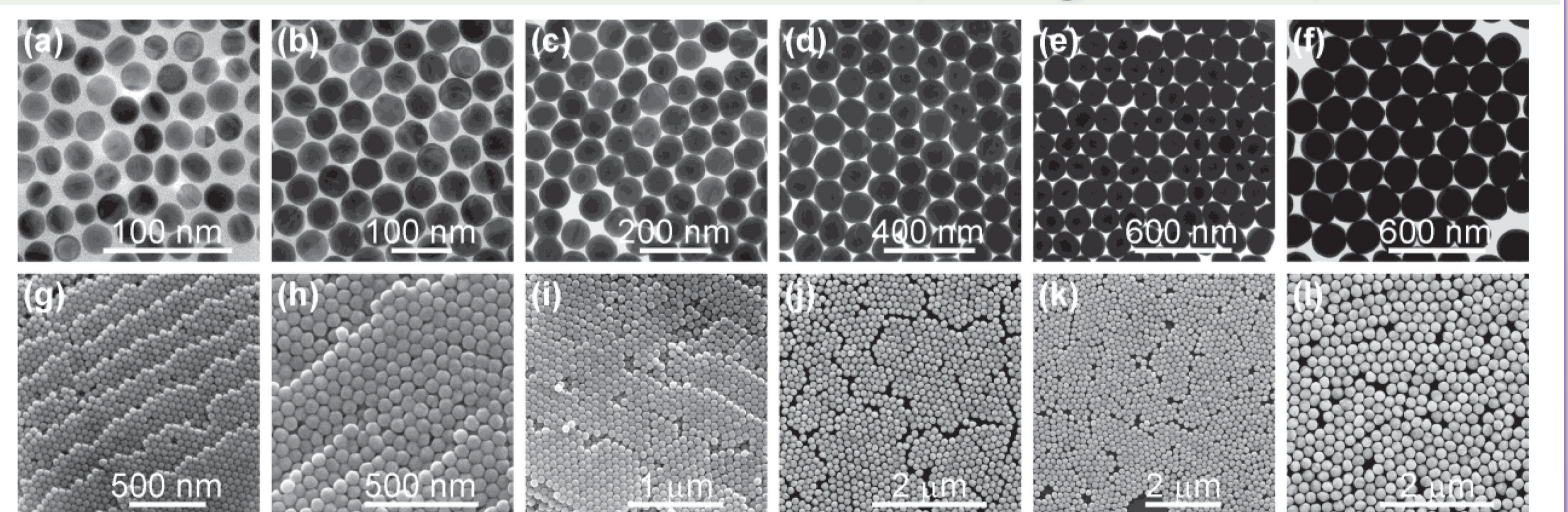
Spectral shift of resonance peaks

Shift of Peak 5 associated with a transverse dipole mode

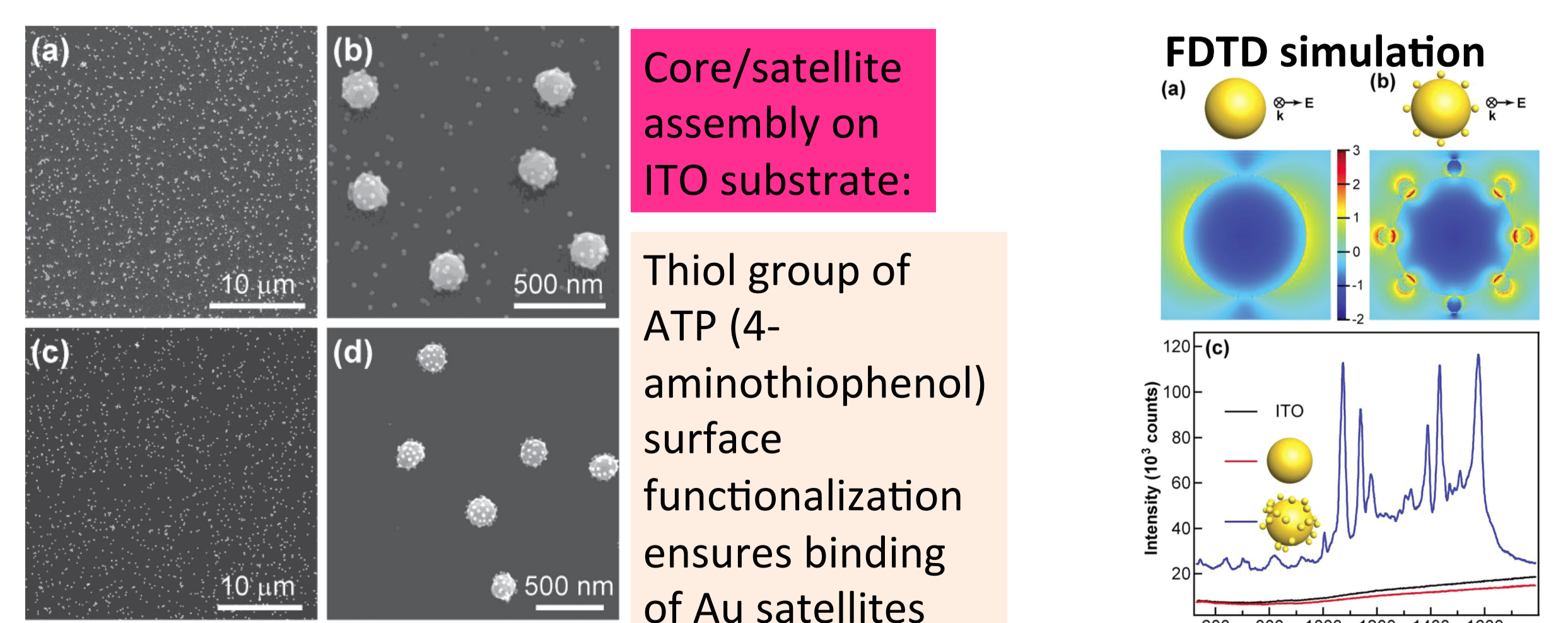


C. Fang et al, ACS Nano 7, 9354-9365 (2013)

Monodisperse gold nanospheres and their core/satellite nanostructures (Wang, CUHK)



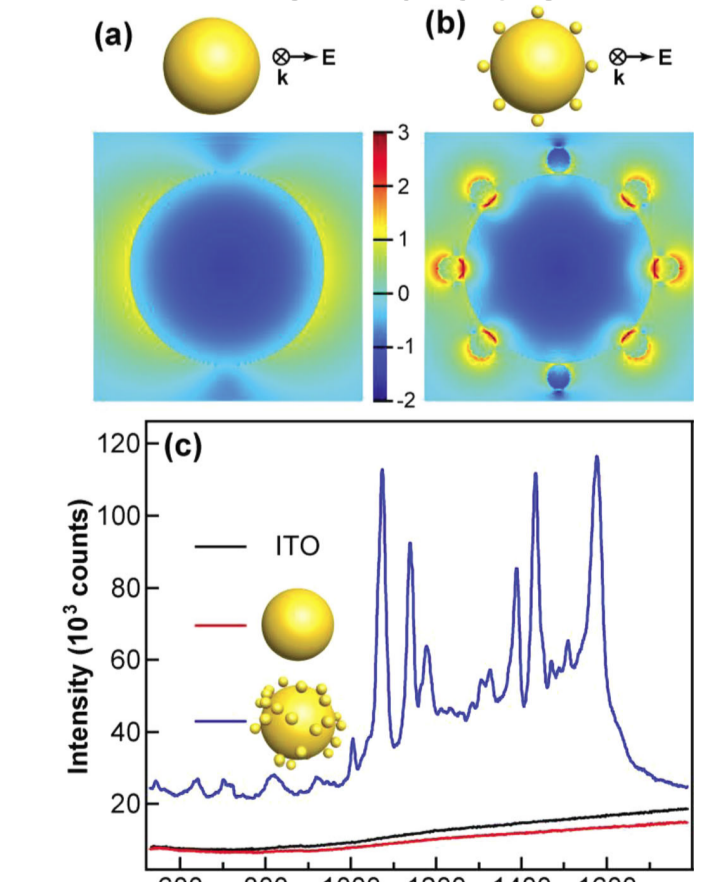
20 – 220nm AuNS (Top: TEM, Bottom: SEM images)



Core/satellite assembly on ITO substrate:

Thiol group of ATP (4-aminothiophenol) surface functionalization ensures binding of Au satellites

FDTD simulation



SERS signal from ATP-assembled core/satellite nanostructures

Q. Ruan et al, Adv. Optical Mater. 2, 65-73 (2014)

Acknowledgement:

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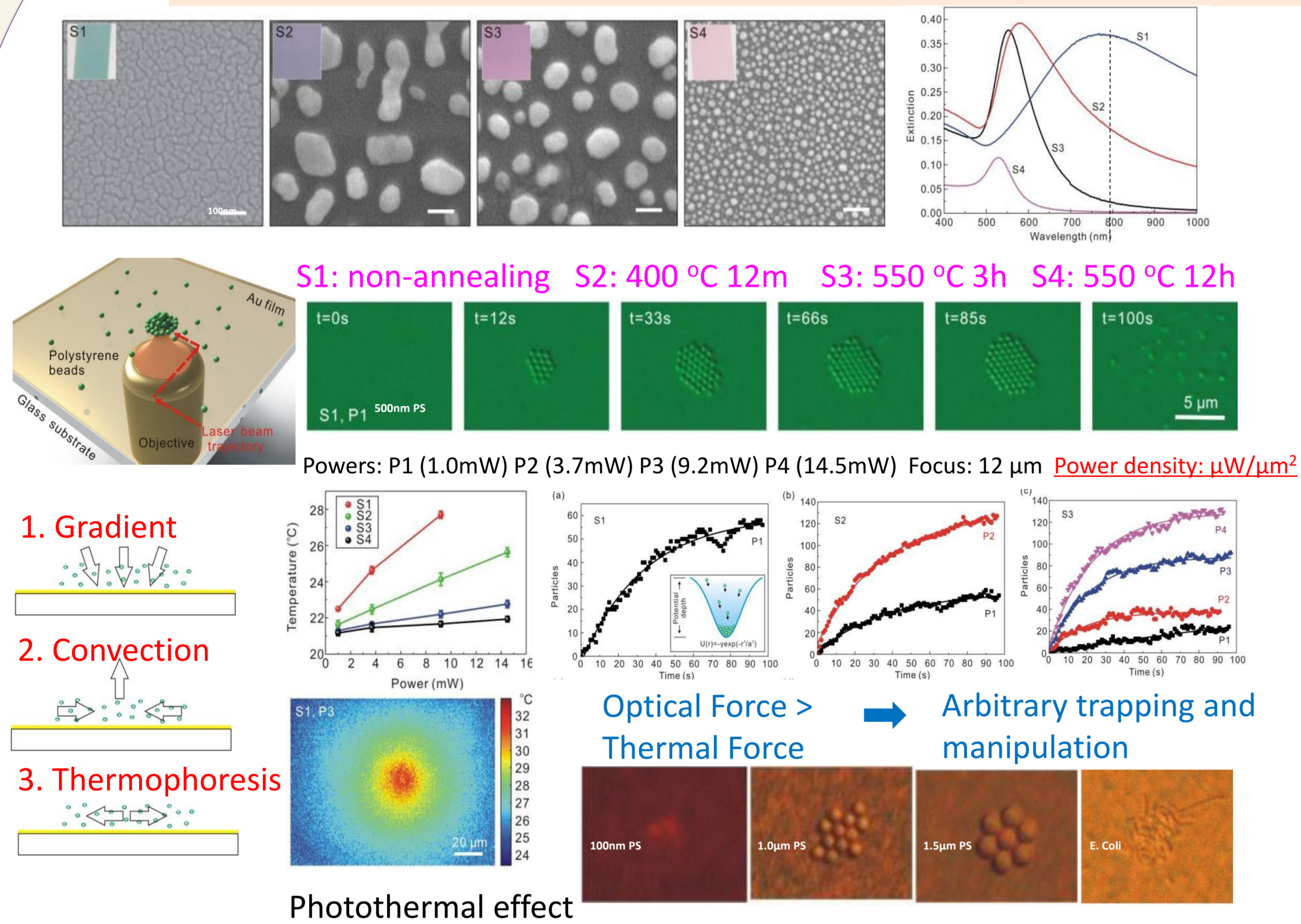
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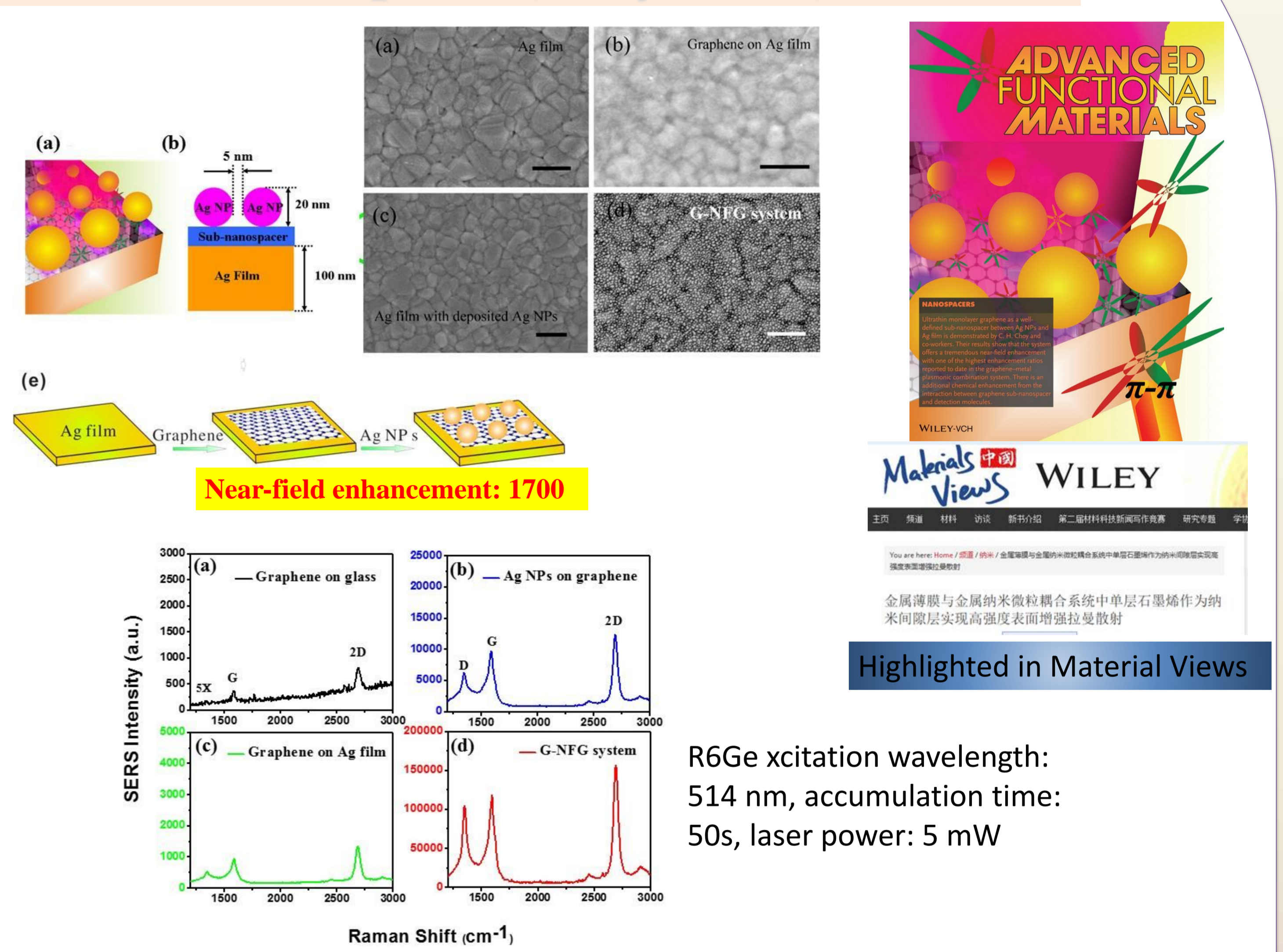
Charles Surya (EIE)

Novel Applications of Plasmonics

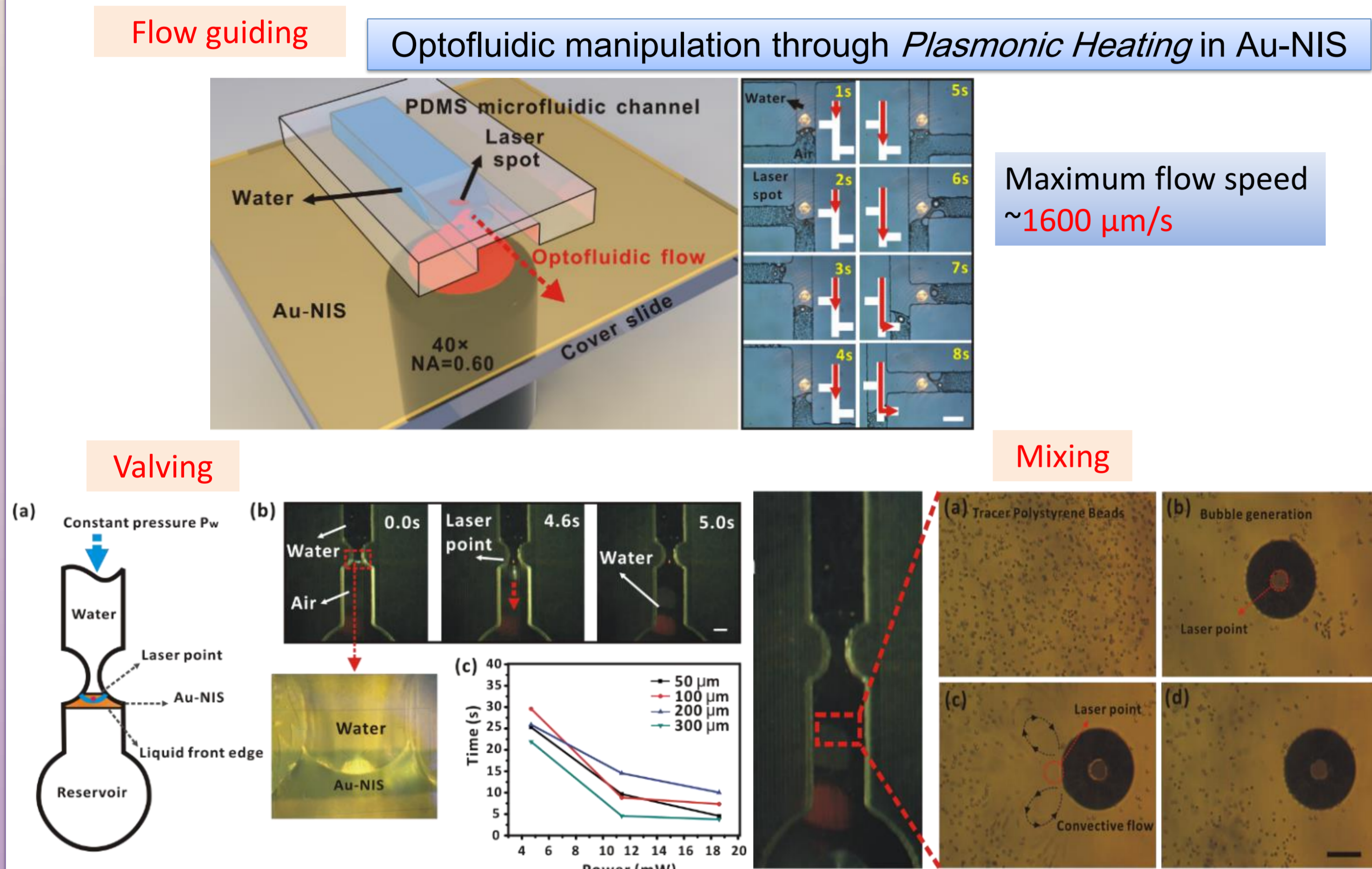
Plasmonic tweezers on gold nanoisland substrate (Ho, CUHK)



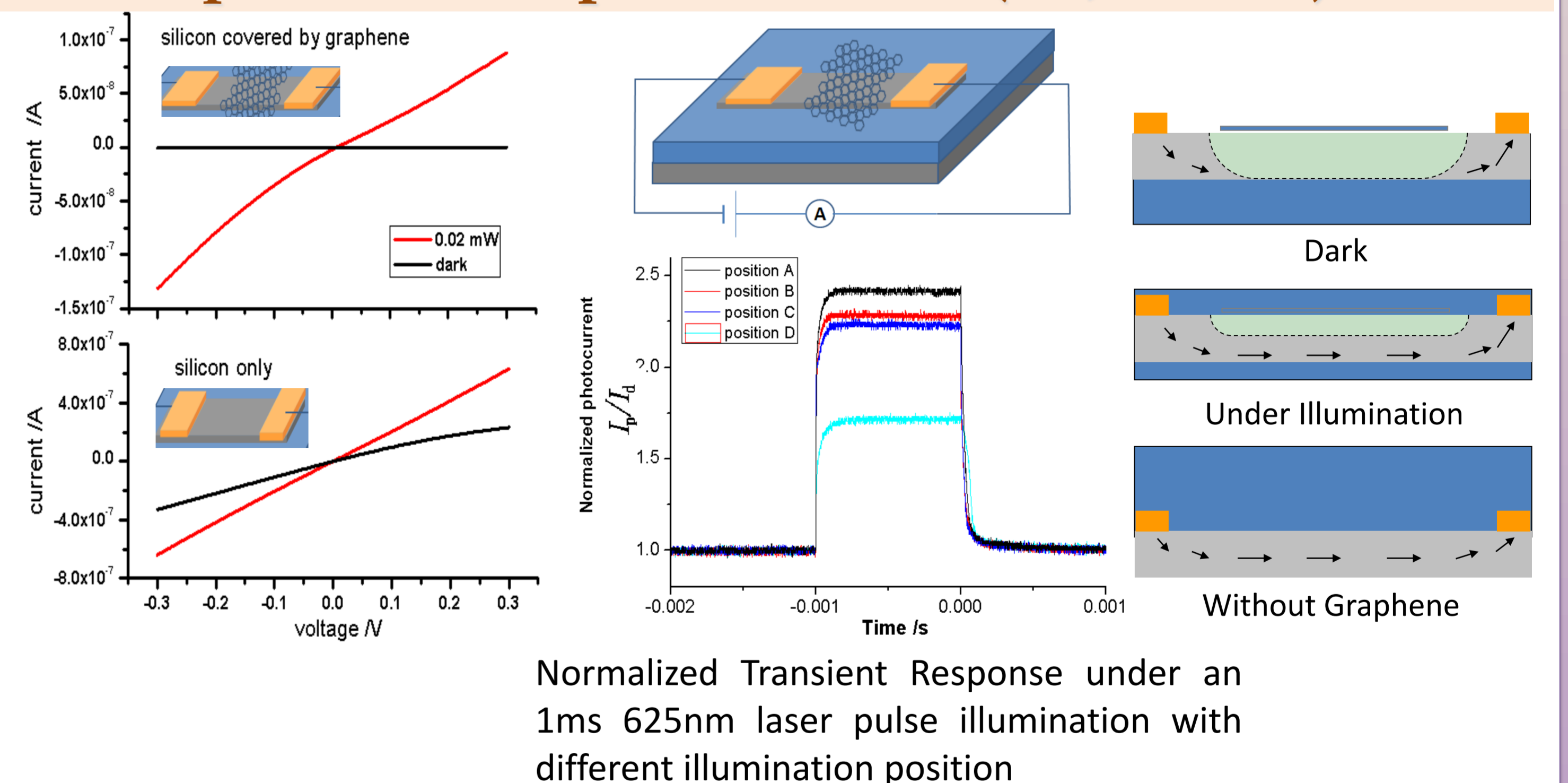
SERS using metal NPs - ML graphene nanospacer (Choy, HKU)



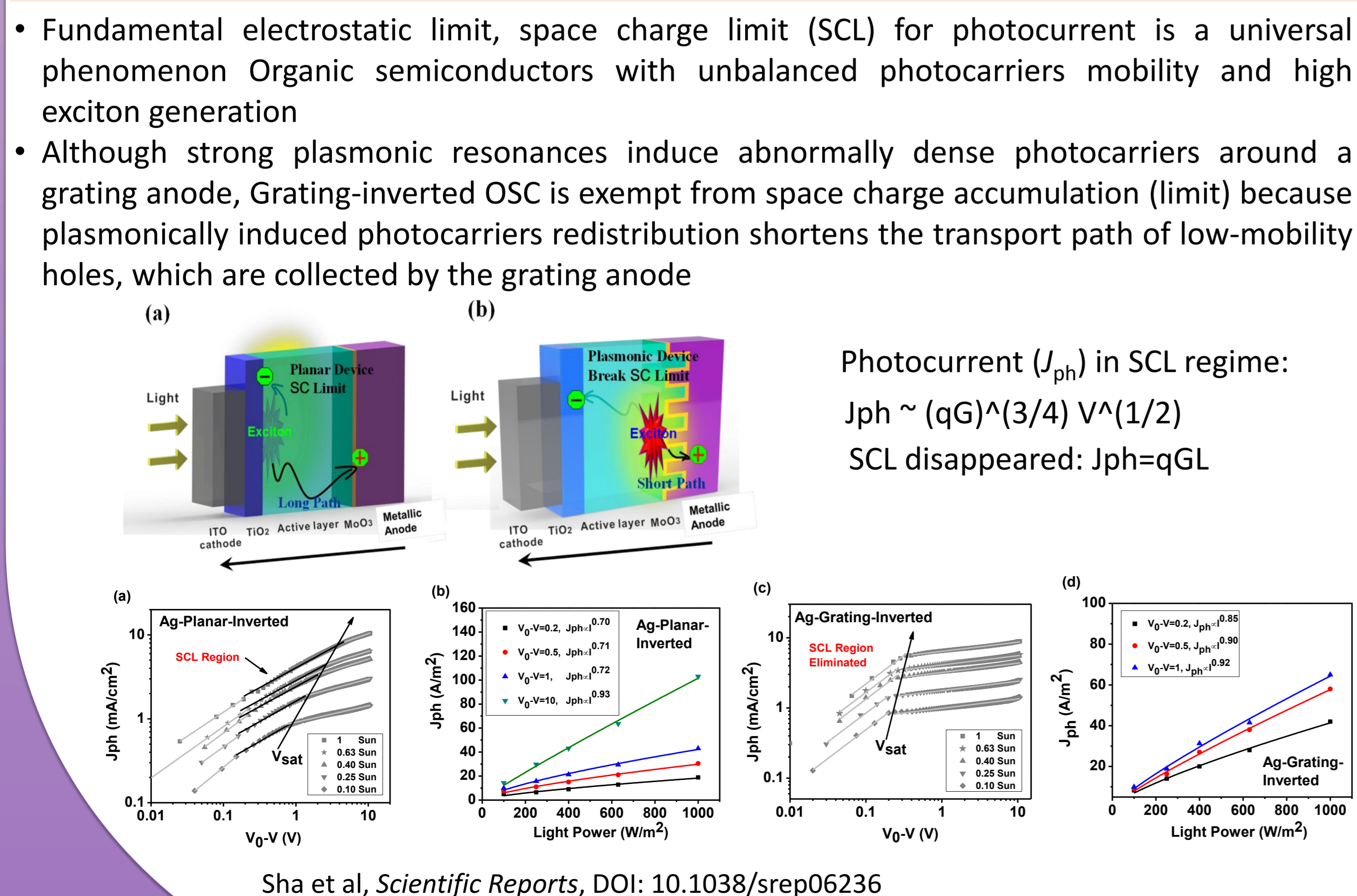
Optofluidic manipulation and optical tweezers on random plasmonic structures (Ho, CUHK)



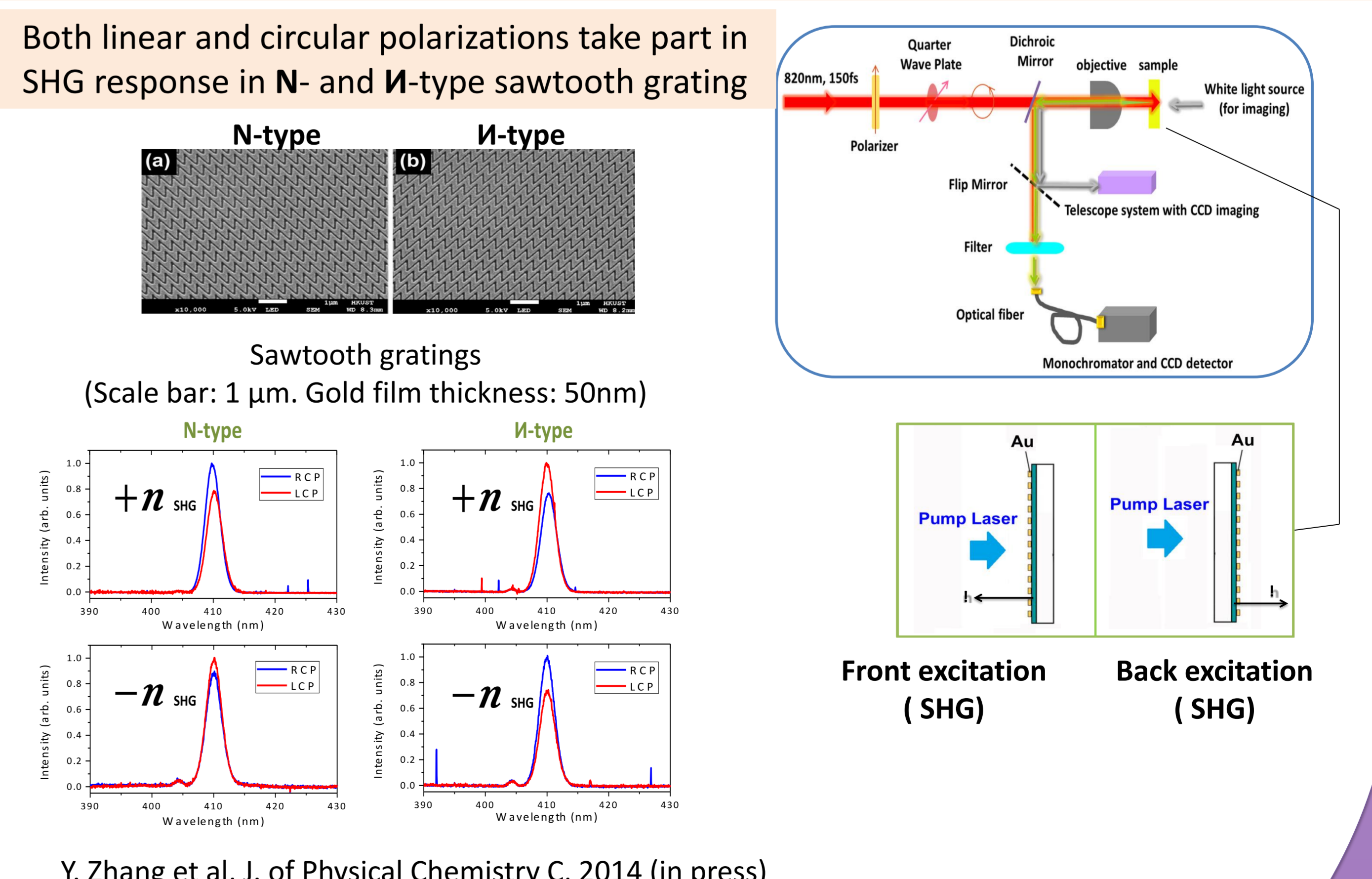
Graphene/Silicon heterojunction based high performance photodetector (Xu, CUHK)



Breaking the space charge limit in OSCs by a novel plasmonic-electrical concept (Choy, HKU)



Circular polarized SHG in single-layered gold sawtooth structures (Chan and Wong, HKUST)



Acknowledgement:

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