Spacial confinement of the EM field for biosensing applications

Dr. Ron Gill

Nanobiophysics Group

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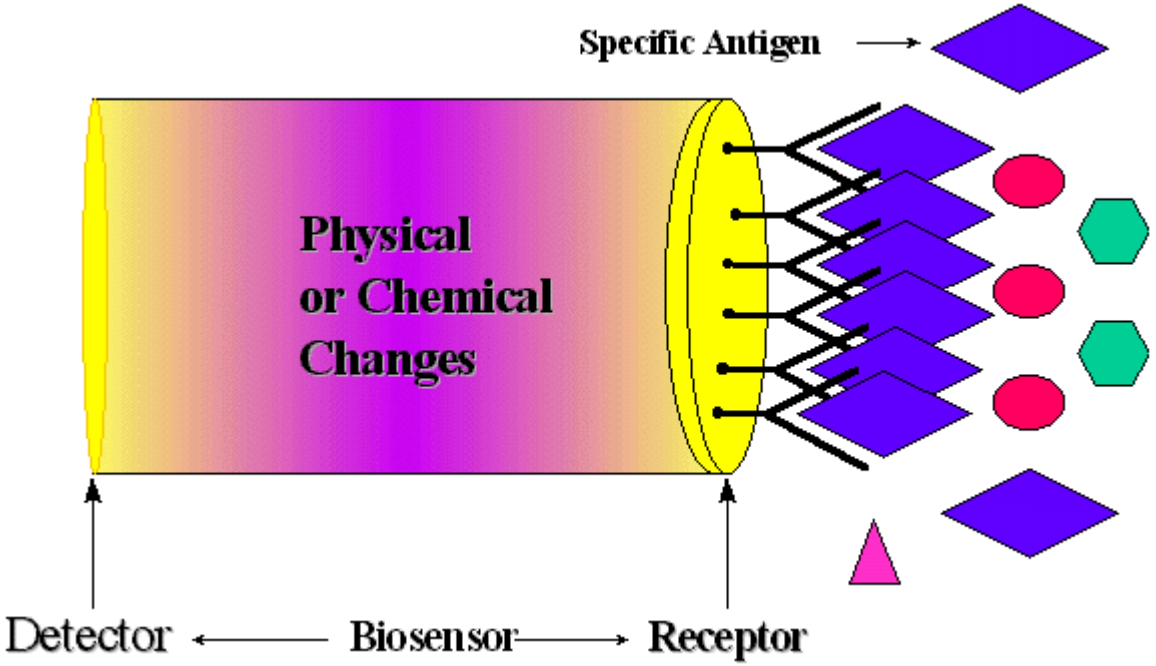
    - SEF

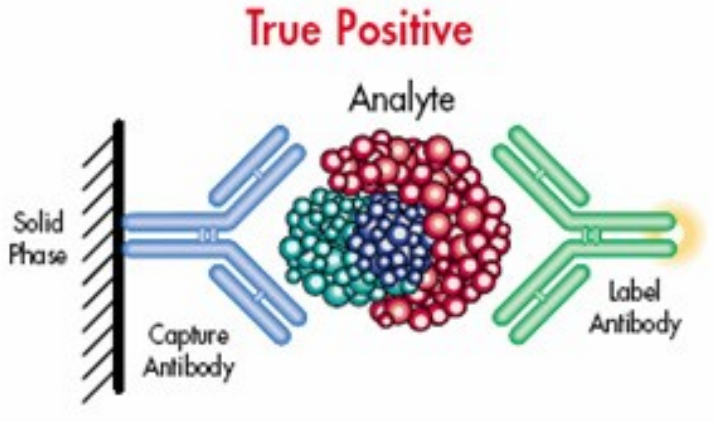
What are biosensors

- Using a biological element to recognize (detect + quantify) an analyte of interest.



Labelled vs. Label free assays

- The analyte binding can be detected without label by the change in mass, refractive index or native optical properties of the analyte
- In many cases a label is added to create higher chang
  property than the a
  itself



Why do we want to confine the EM field in optical detection?

- Confining the field to a surface, we can:
  - For label free detection – have a high sensitivity to the change in refractive index at the surface interface
  - For labelled detection - shorten analysis time by overcoming the need to wash off excess labels.
- Confining the field to a subwavelength volume we can benefit from stronger light-matter interactions that occur at high local EM fields.

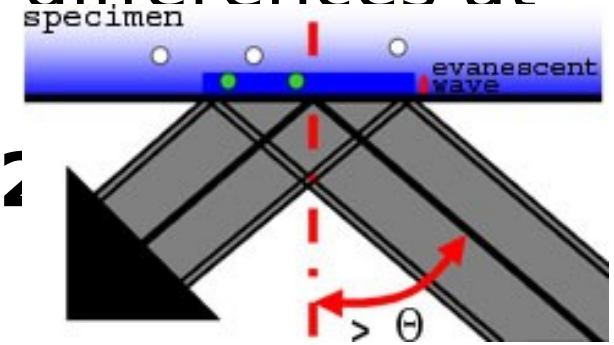
Confining the field to a plane

- TIRF

- Waveguide + interferometry
- Photonic Crystals
- SPR

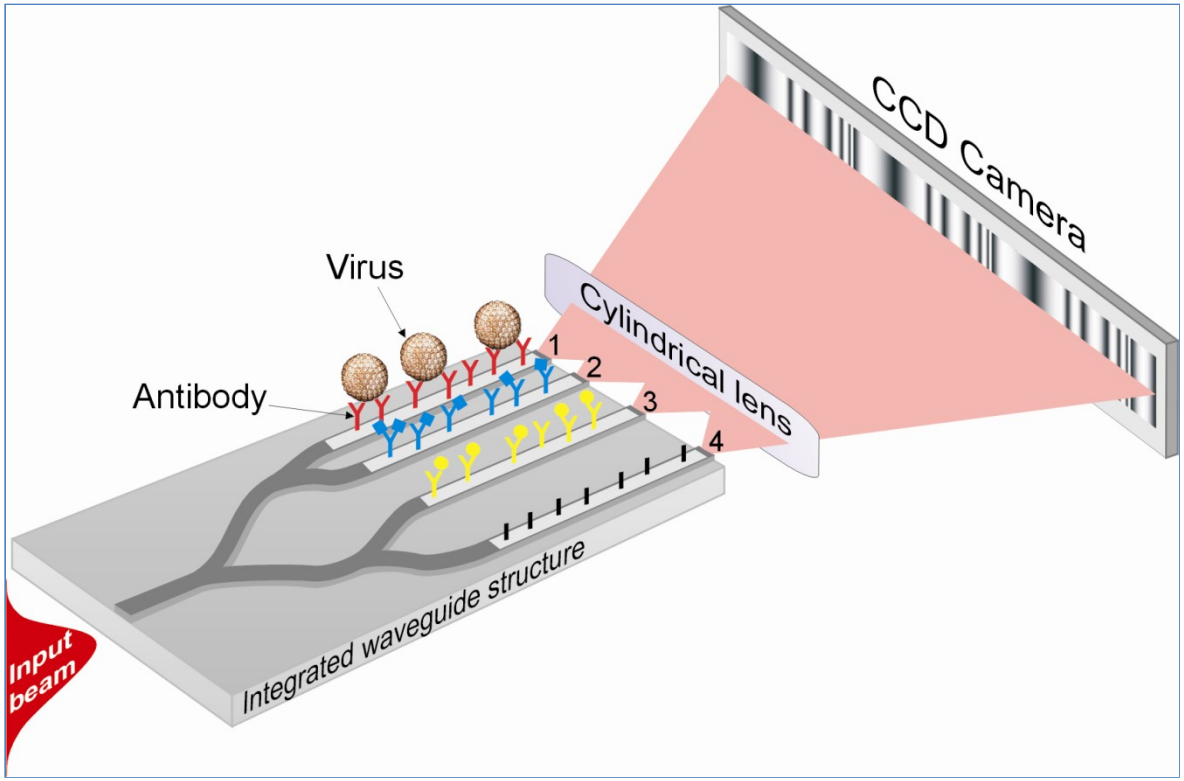
Total Internal Reflection (TIR)

- TIR creates an evanescent field of about 100nm.
- Only fluorophores in this short distance from the surface can be excited.
- Penetration depth depends on wavelength, angle, and refractive index differences at the interface.
- **$d = \lambda(o)/4\pi(n(1)^2\sin^2 - n(2$**
- **$I(z) = I(o)e^{-z/d}$**

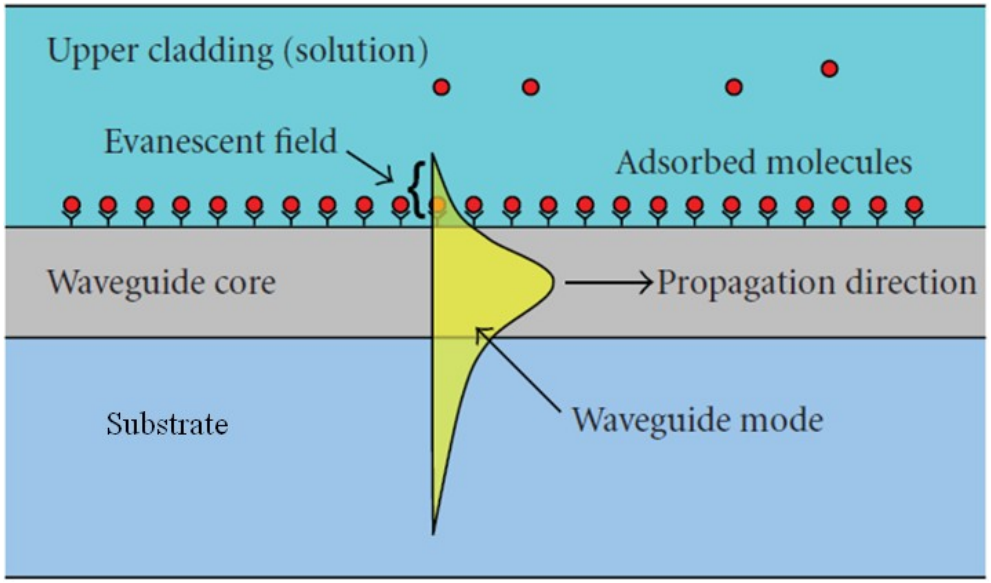


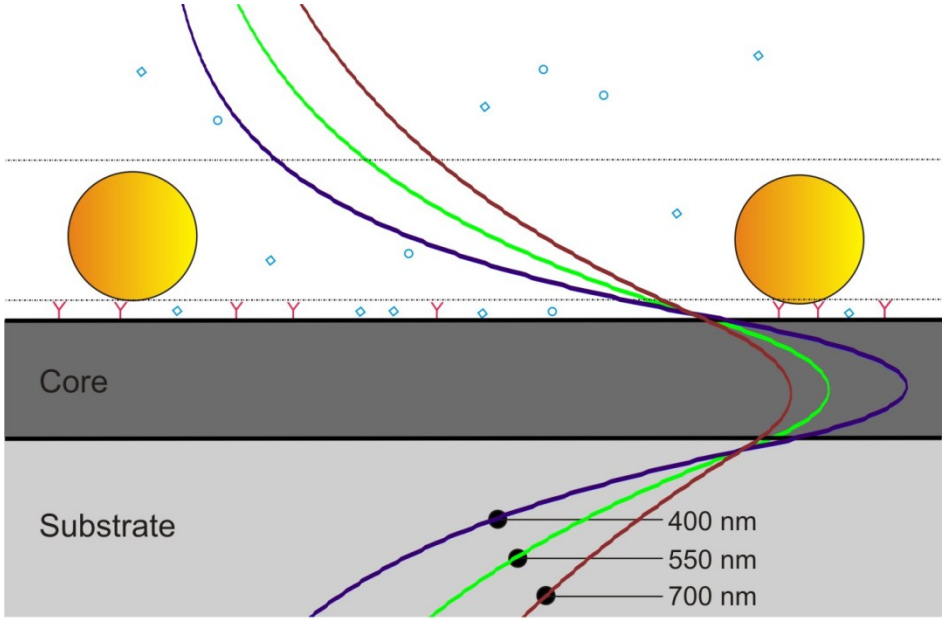
(http://www.lambert-instruments.com)

Waveguide+Interferometer



- Refractive index at waveguide interface determines the speed of light. Interferometer gives a readout for the phase difference between different paths.

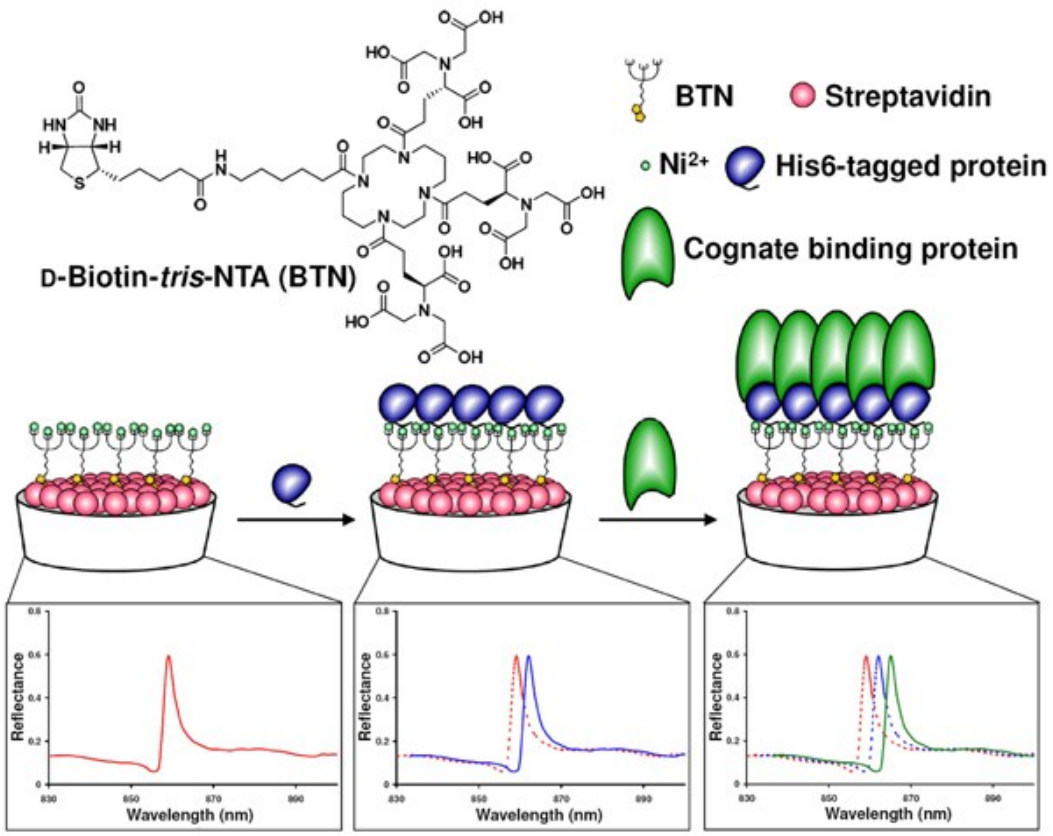

Upper cladding (solution)
Evanescent field
Adsorbed molecules
Waveguide core
Propagation direction
Substrate
Waveguide mode


Core
Substrate
400 nm
550 nm
700 nm

Photonic Crystals

- Photonic crystals are composed of periodic dielectric or metallo-dielectric nanostructures leading to a band-gap structure

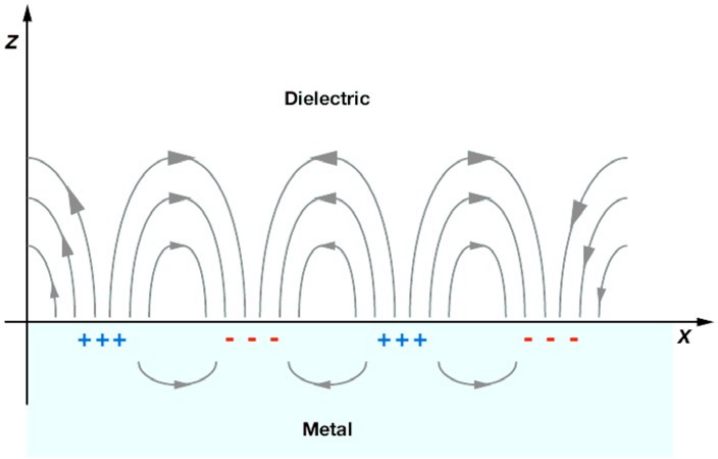
- Reflectance wavelength depend on the periodicity of the low and high refractive index materials and on the refractive index difference.

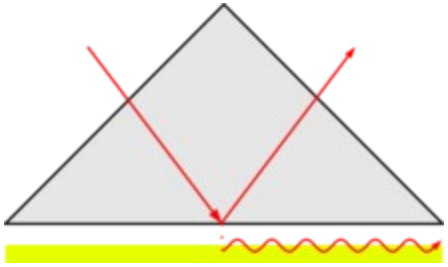


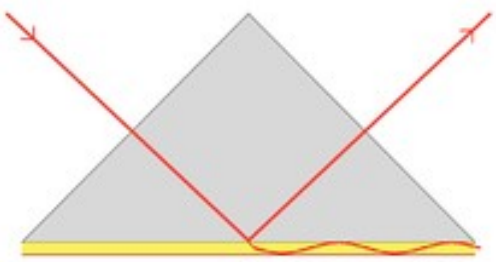
http://www.scs.illinois.edu/~phgroup

Surface plasmon resonance (SPR)

- Surface Plasmons are collective charge density oscillations of the nearly free electron gas in a metal.
- To match both energy and momentum of the photon and the plasmon, a high refractive index glass prism is used for SPR in either the otto or the Kretschmann configuration.

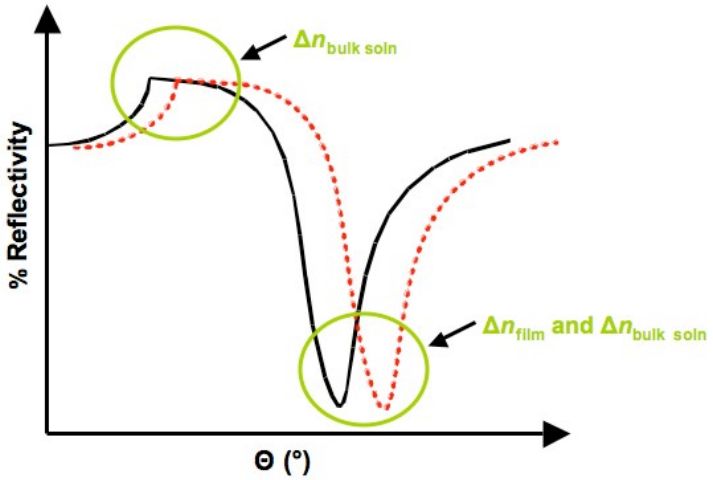






Surface plasmon resonance (SPR)

- The dispertion (relationship between momentum and frequency (energy)) is dependant on the dielectric constant of both the metal and the dielectric at the interface.



A sensogram gives the reflectance as a function of angle of incidence or wavelength

$$k'_x \approx \sqrt{\frac{\varepsilon'_1 \varepsilon_2}{\varepsilon'_1 + \varepsilon_2}} \frac{\omega}{c}$$

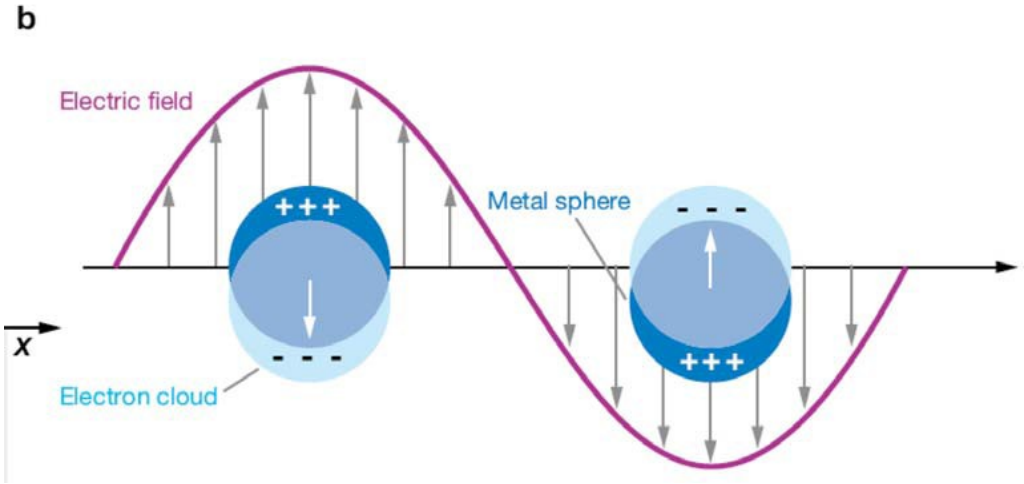
Confining the field to a small volume

- LSPR (Localized surface plasmon resonance)
- enhanced-LSPR

- Using the EM field enhancement
  - Raman scaterring enhancement
  - Fluorescence enhancement

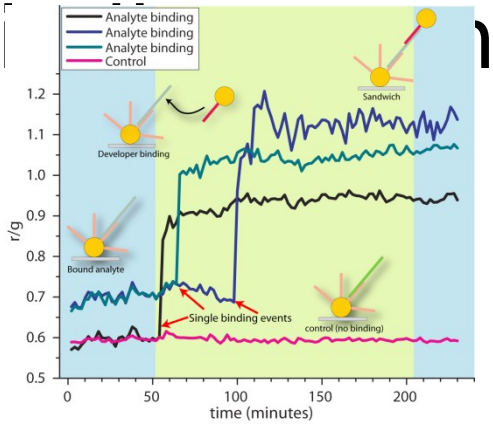
Localized Surface plasmon resonance (LSPR)

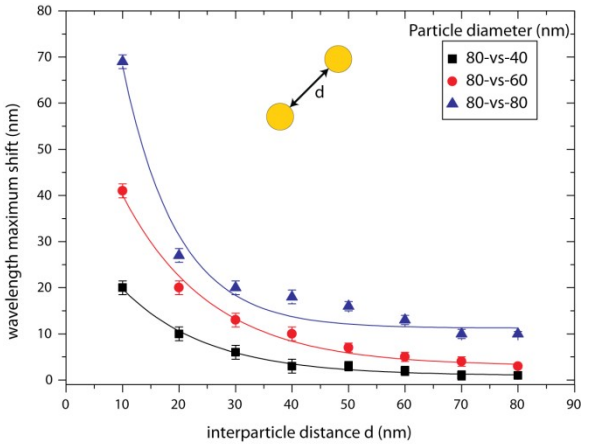
- Only ω has to match, since there is no propogation.
- The plasmon resonance frequency is still dependent on the dielectric constant of the environment.



Enhanced LSPR by coupling

- Plasmonic nanoparticle can be used as tag also.
- Plasmon-plasmon interactions shift the plasmon wavelength significantly – can be used to detect single b[illegible]nt.

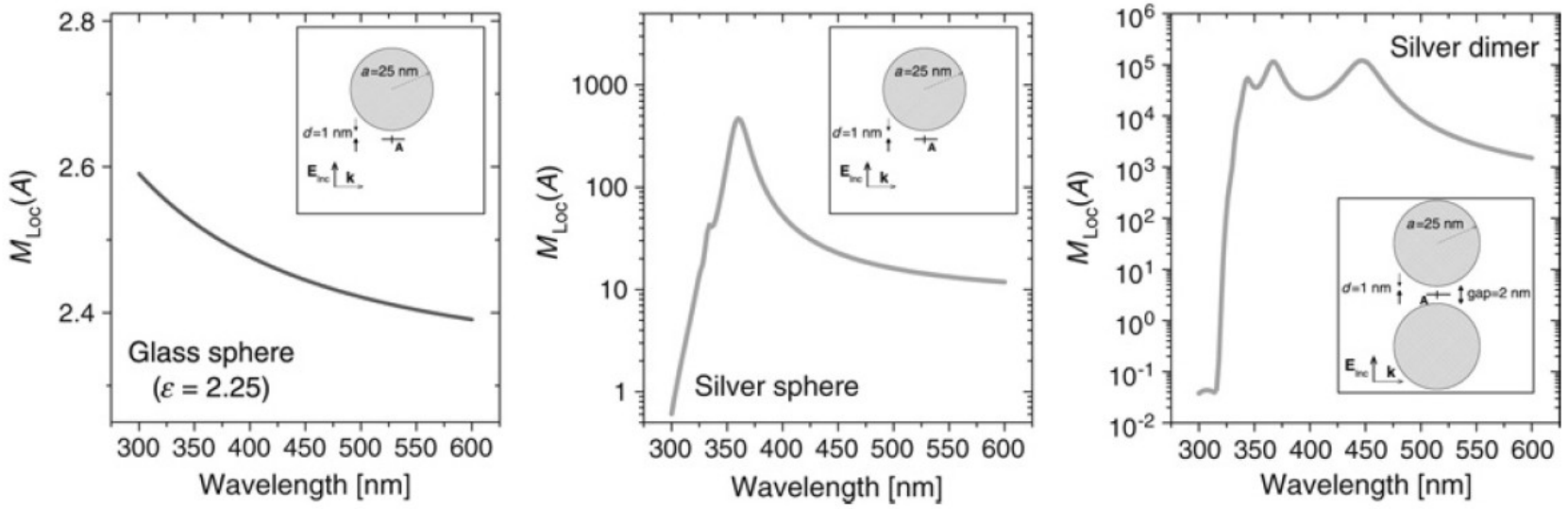




Enhancement of EM field by plasmonic resonant nanoparticles

- Near metal particles that support plasmon resonance, one gets local field enhancement especially at the resonance peak.

- Even higher enhancements are achievable with nanoparticle pairs because of the field confinement to the gap area



Principles-of-SurfaceEnhanced-Raman-Spectroscopy / Le Ru & Etchegoin

Enhanced Raman Scattering

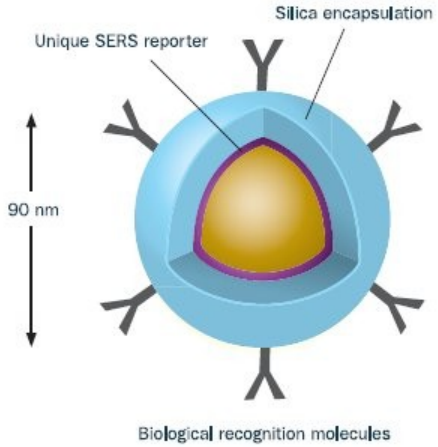
- The Raman signal of molecules includes many peaks thus enhabeling high multiplexing
- As a scattering signal it does not suffer from quenching and doesn’t tend to bleach.

However:

- Normal Raman scattering cross section is about 14 orders of magnitude smaller than fluorescence cross section

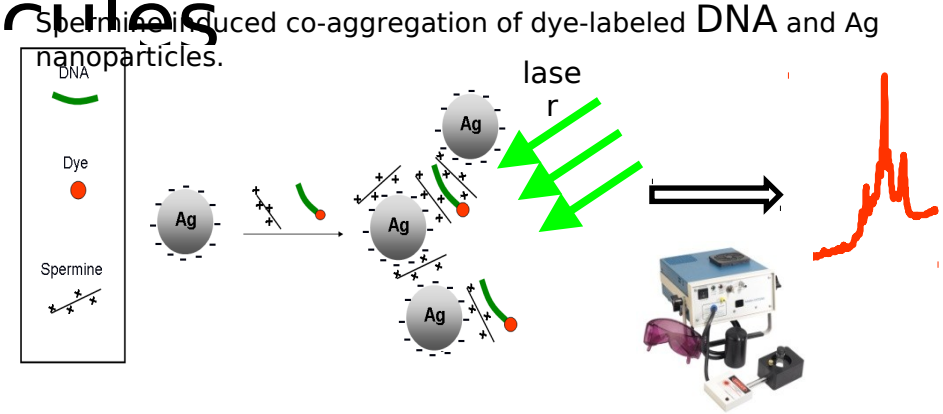
Enhanced Raman Scattering

- Raman tags

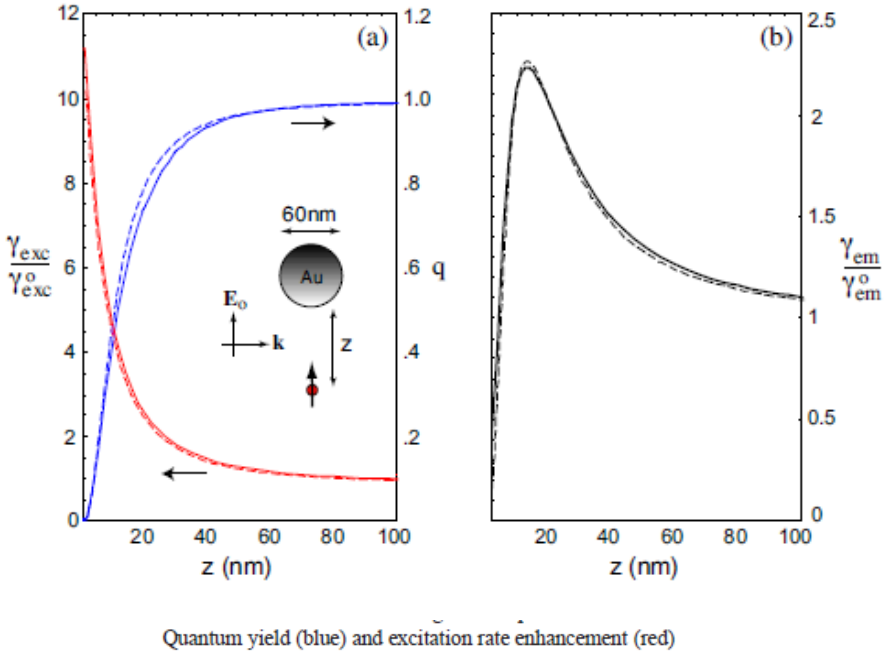


http://www.oxonica.com/diagnostics/

- Raman spectra of dye-labeled molecules

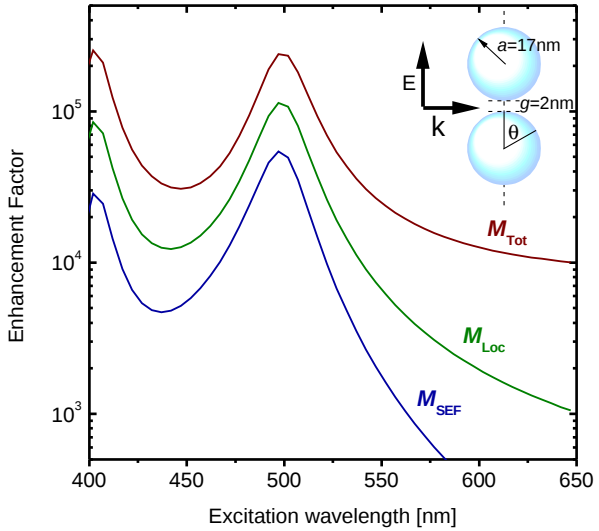


Enhanced fluorescence



Quantum yield (blue) and excitation rate enhancement (red)

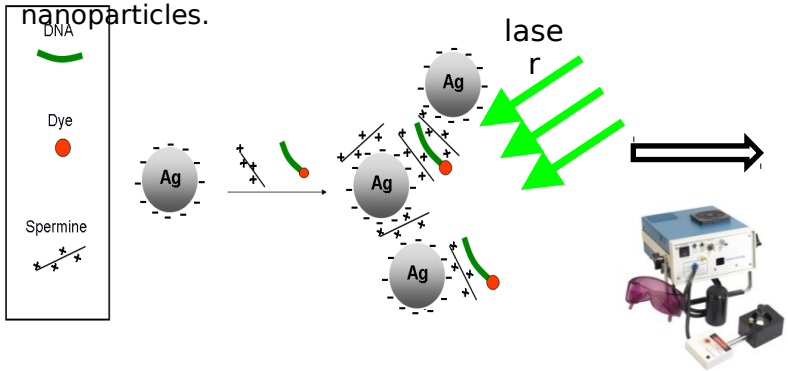
Bharadwaj and Novotny, Optics Express 15, 21, 14266 (2007)

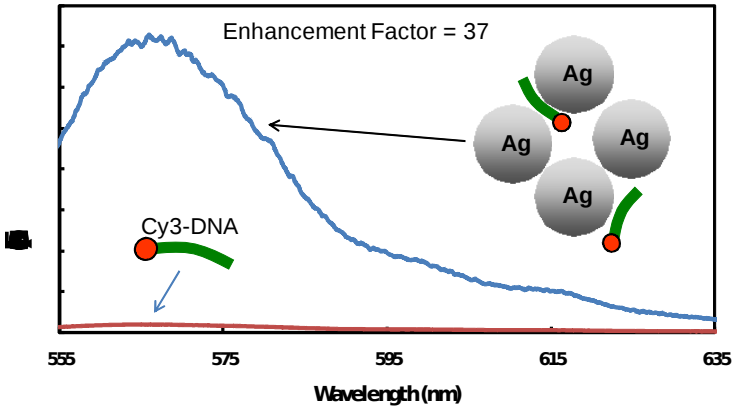


Gill and Le Ru, PCCP (2011)

Enhanced fluorescence

Spermine induced co-aggregation of dye-labeled DNA and Ag nanoparticles.





Gill and Le Ru, PCCP (2011)

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