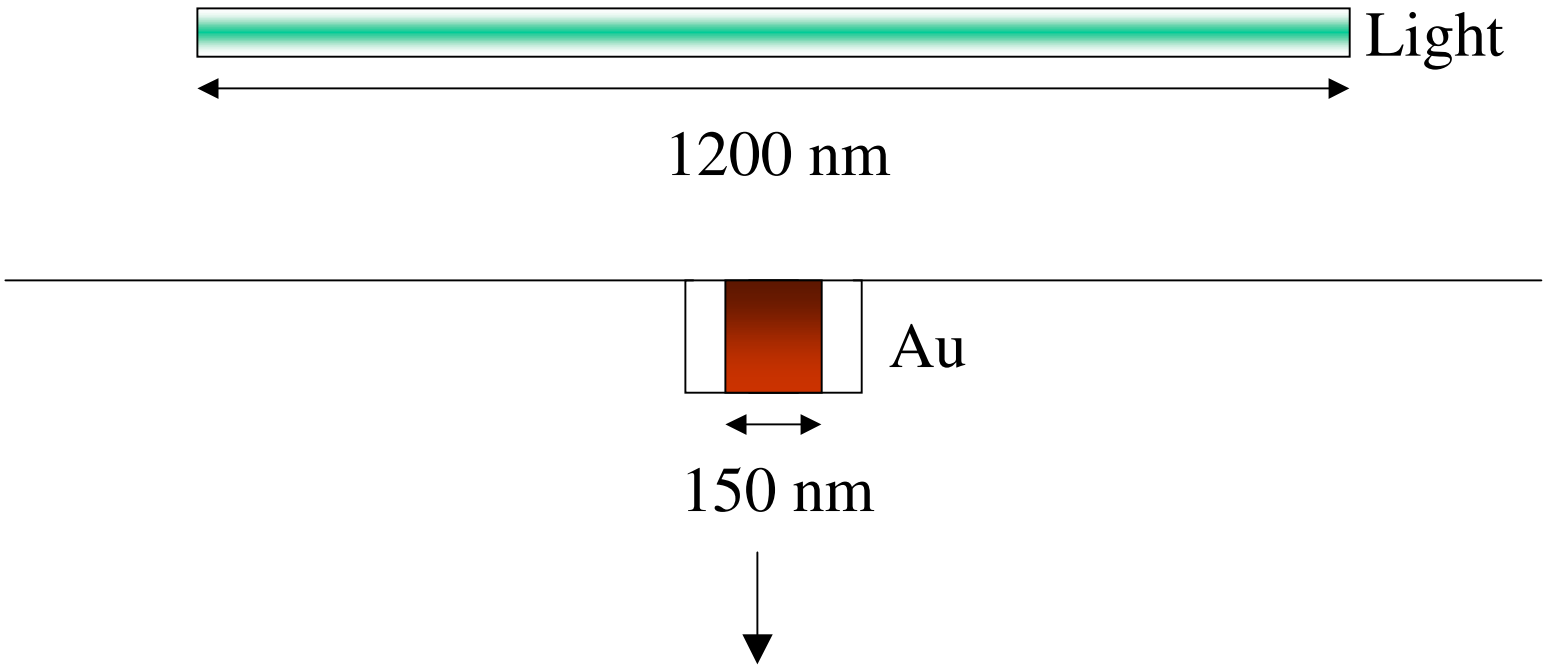
Question to Audience



What Portion of light will reach here?

Answer

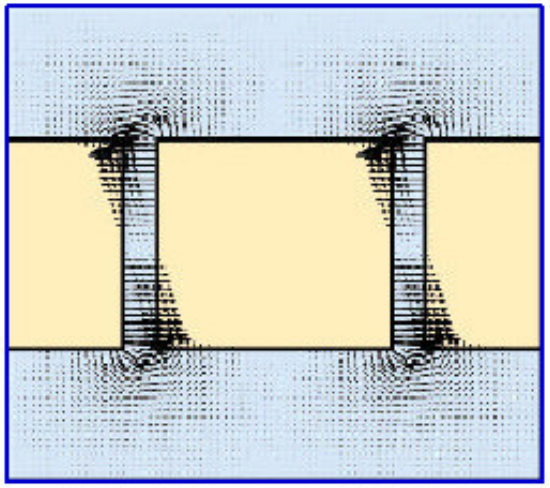
If you think it is 0.1 portion of light will squeeze through that hole,

You are WRONG!!

It is proved that 100 times of intensity is transmitted!!!

Why?

Surface Plasmon Resonance



Houdini.

Surface Plasmon Resonance

Ashok Rangaswamy

Surface Plasmon Resonance (SPR) is a powerful technique to measure biomolecular interactions in real-time in a label free environment. While one of the interactants is immobilized to the sensor surface, the other are free in solution and passed over the surface. Association and dissociation is measured and kinetic rate constants can be measured. This technique is not limited to protein-protein interactions but all kind of interactions between molecules can be measured. Examples are DNA-protein, lipid - protein and protein - plastic surfaces.

Surface plasmons

♣ **Plasmon** is a quantized collective oscillation of electrons in the bulk or surface of the material.

♣ To excite the plasmon,it is necessary to produce fluctuation in charge density.

♣ The simplest way to do this is with a beam of electrons or other charged particles.

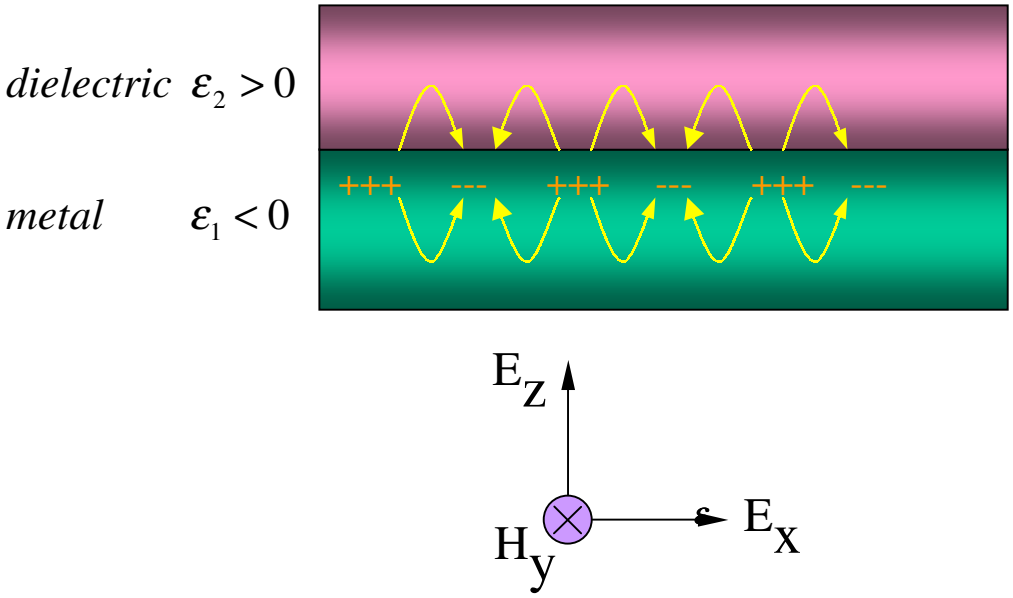
♣ Such a Beam can excite collective modes of oscillations by means of long range coulomb forces.

♣ At surface of solids, an oscillation of surface charge density fluctuations is possible

♣ These Surface plasmons exist in a number of modes.Some of these modes can radiate and hence can also be excited by light.

Optical Properties of Solids,
Fredrick Wooten,1972 Academic Press

Surface plasmons



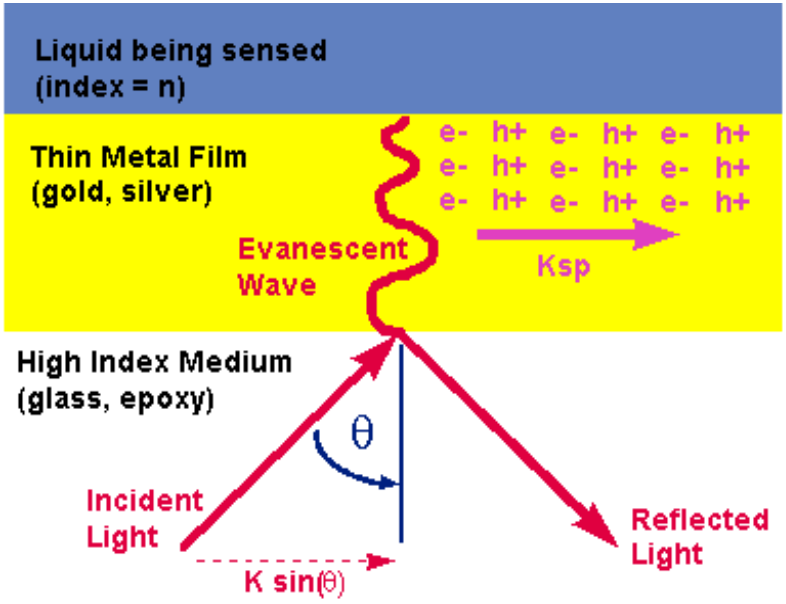
Electromagnetic waves which exist at the interface between two media with dielectric constants having different signs are called Surface Plasmons

Surface plasma oscillations: fluctuations of the charge on the metal boundary followed by SP mode

Surface plasmons

One mechanism that leads to surface plasmon absorption is coupling of a surface plasmon to light by means of surface roughness.

Surface plasmon resonance occurs when the component of the light wave-vector matches the wave-vector of the surface plasmon



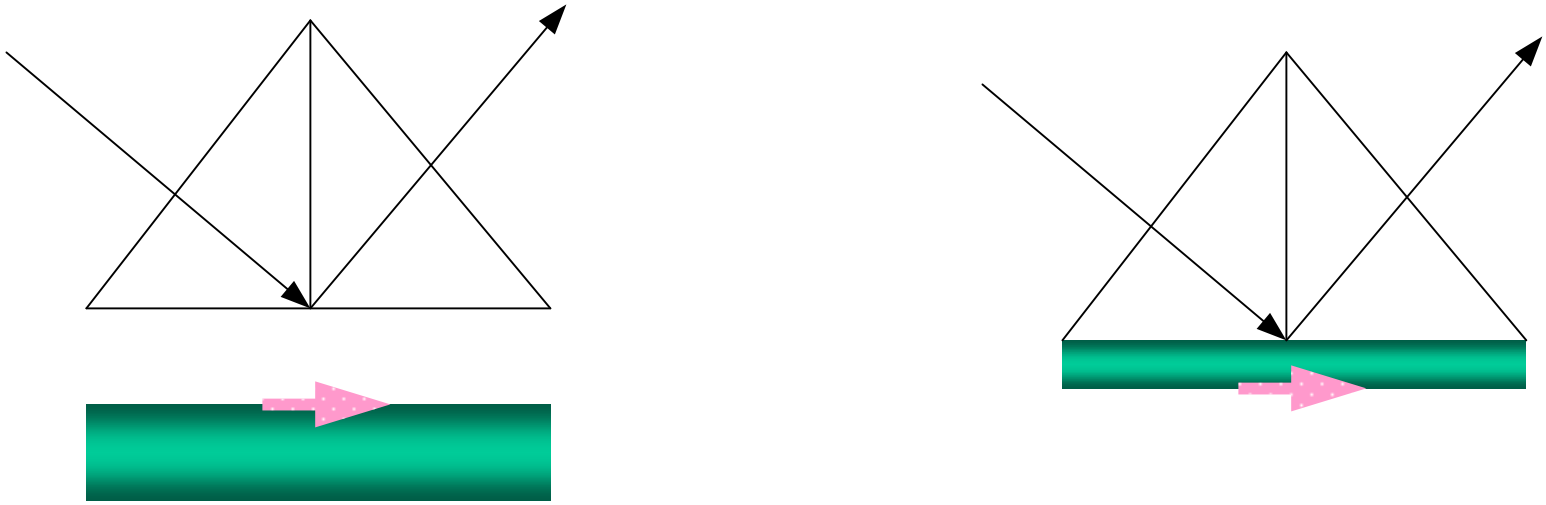
$$K_{light} = K_{sp}$$

$$\frac{\omega}{c} n_p \sin\Theta \cong \frac{\omega_p}{c} \sqrt{\frac{\varepsilon_m + n_l^2}{\varepsilon_m + n_l^2}}$$

ε_m	dielectric constant of metal
n_p, n_l	Refractive indices of glass, liquid
ω_p	Plasmon frequency

Optical Properties of Solids,Fredrick Wooten,1972 Academic Press
http://www.ti.com/sc/docs/products/msp/control/spreeta/refract.htm

Surface plasmon Resonance

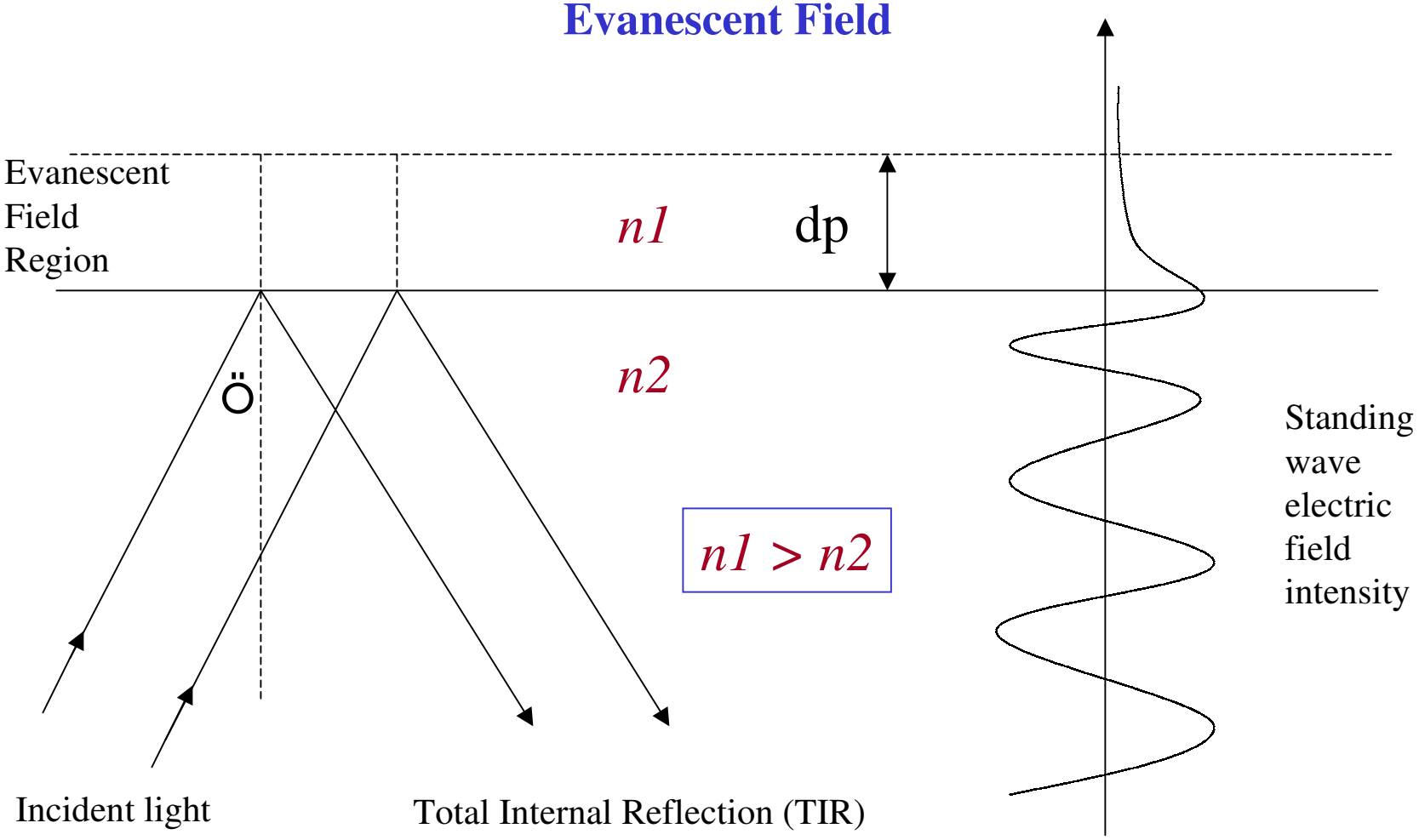


optically dense medium and either a less dense dielectric (Otto configuration) or metallic layer (Kretchmann-Raether configuration)

An evanescent field extends from this interface to ***drive*** the electrons on the dielectric metal interface producing a Surface Plasmon

http://www.qub.ac.uk/mp/con/plasmon/sp1.html

Evanescent Field



Optical fiber sensors:principles and components,edited by John Darkin & Brian Culshaw,Artech House,1988

Evanescent Field

In TIR, the incident light and reflected light interact and result is a standing wave disturbance close to the interface.

Detailed analysis of Maxwell's equations shows that this standing wave decays exponentially away from the interface into lower refractive index material.
Depth of penetration of exponentially decaying evanescent field is given by

$$Dp = \frac{\lambda}{2\Pi\sqrt{n_1^{\,2}\sin^2\theta - n_2^{\,2}}} \qquad Dp = \frac{\lambda}{2\Pi\sqrt{\sin^2\theta - \sin^2\theta_c}}$$

This is the distance from the surface over which the electric field of the standing wave disturbance decays to 1/e of its value at the interface.

λ is the free wavelength of the light. For typical optical fiber sensor arrangement n_1 is around 1.5 and if the medium of investigation is aqueous, n_2 is about 1.33.
Depth of penetration has the minimum value of $\lambda/5$ and to about one wavelength for angles about 1deg greater than the critical angle.

Optical fiber sensors:principles and components,
edited by John Darkin & Brian Culshaw,Artech House,1988

Evanescent Field

Theoretically dp goes to infinity at critical angle and,but in practical, there is always light leakage and scattering at near critical angles as a result of surface roughness.
So in approximate, material located within one wavelength of an interface between two transparent materials can interact with evanescent field.

More substantial penetration will not occur unless highly collimated beams incident at angles very close to critical angle are used.

The simplest form of interaction with the evanescent field is **ABSORPTION**.
If a light absorbing material is brought within the field region,there is attenuation is reflected energy.This phenomenon is used in SPR sensors.

The Evanescent field intensity at the interface between two transparent materials is relatively weak, since energy stored in the standing wave disturbance is only of similar magnitude to the instantaneous maximum value of energy flux of the electric field of incident light exciting the disturbance.

Optical fiber sensors:principles and components,
edited by John Darkin & Brian Culshaw,Artech House,1988

Surface plasmon and Evanescent Field

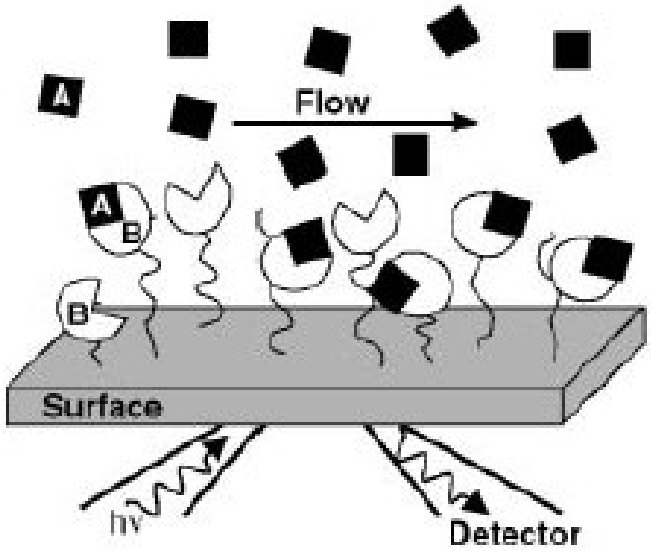
The interface between the two transparent media is coated with a thin layer of metal (50 nm) such as gold or sliver.The metal layer is sufficiently thin to allow some of light energy to penetrate through.Therefore,for angles less than Critical Angle ,there is incomplete reflection from metal surface. Above the critical angle, all light is reflected except for a range of angles where momentum-matching conditions of the light are such that surface electromagnetic wave mode (Surface plasmon) of the interface between the metal and lower refractive index medium is excited.

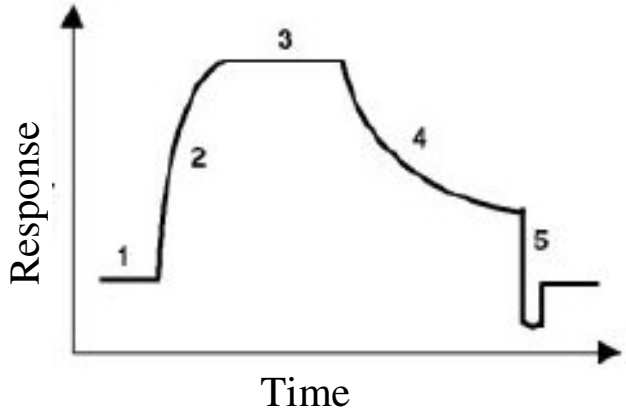
Surface plasmon electric field decays into lower refractive index medium in an exponential fashion similar to evanescent field.However Surface intensity of the field is more than for equivalent Evanescent field arrangement.

This means that the interaction between the light and surface chemical or refractive index effects can be much stronger and sensitivity to surface changes is higher.

Optical fiber sensors:principles and components,
edited by John Darkin & Brian Culshaw,Artech House,1988

Bio-optic Sensing using SPR

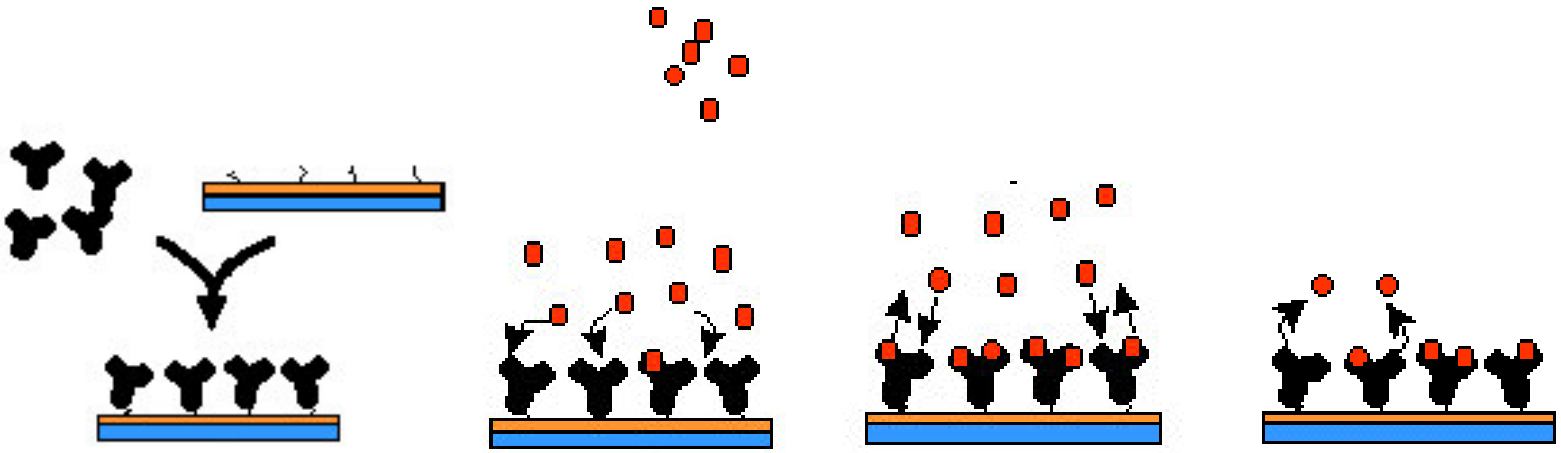




1. *Intial base line (buffer)*
2. *Association*
3. *Steady state*
4. *Dissociation(buffer)*
5. *Regeneration*

Current and emerging commercial optical biosensors,
Cheryl L. Baird and David G. Myszka,J.Moleular Recognition,2001:14-261-268

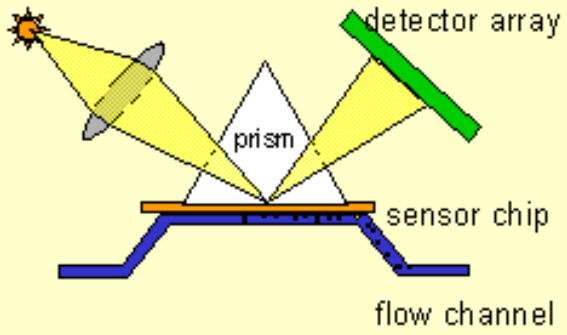
Biomolecular interactive analysis



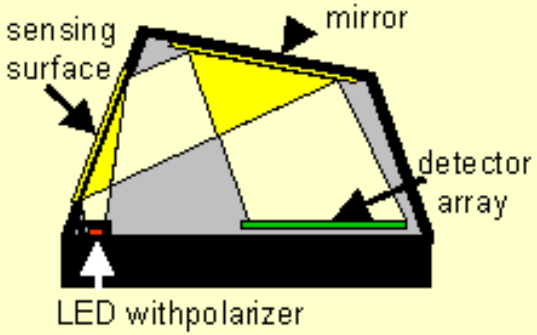
Immobilization *Association* *Steady State* *Dissociation*

Regeneration

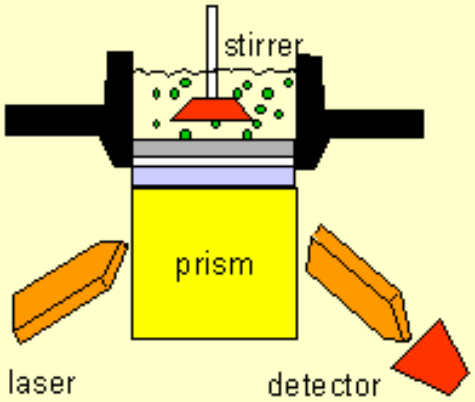
BIACORE



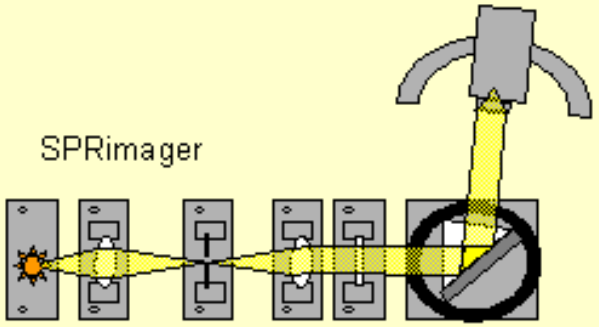
Spreeta Evaluation Module



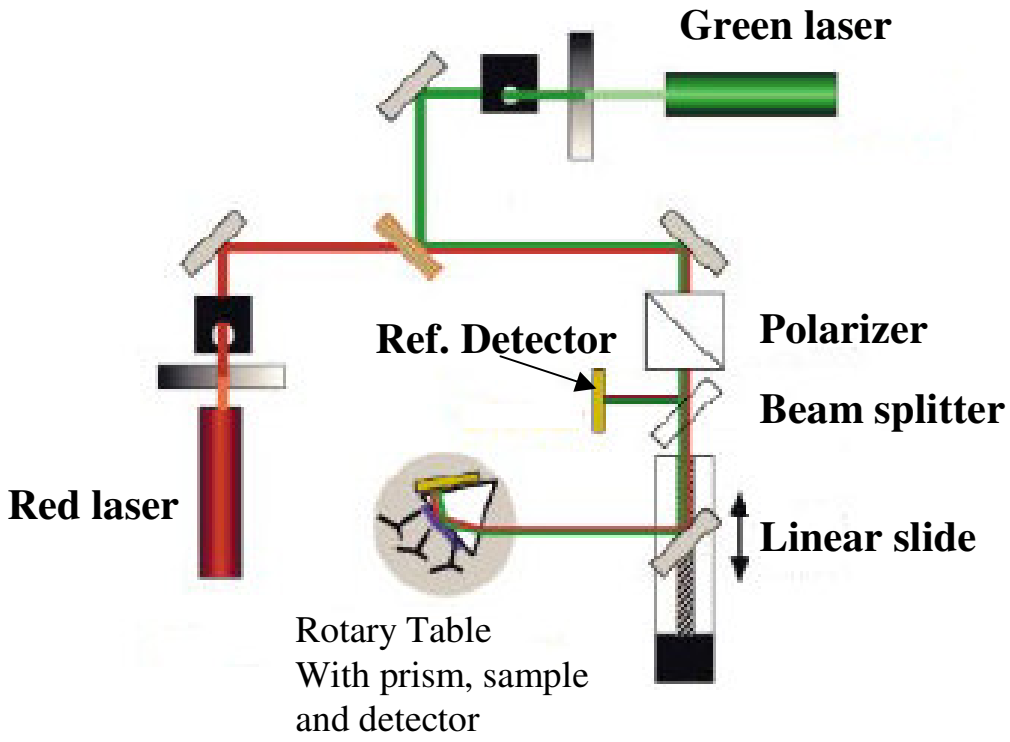
IAsys system



SPR imager

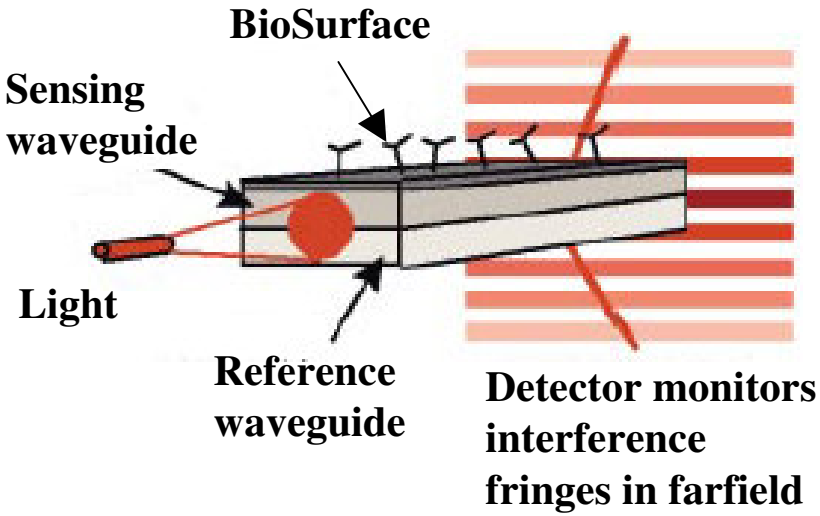


Emerging BioSensors



Current and emerging commercial optical biosensors,
Cheryl L. Baird and David G. Myszka,J.Moleular Recognition,2001:14-261-268

Emerging BioSensors



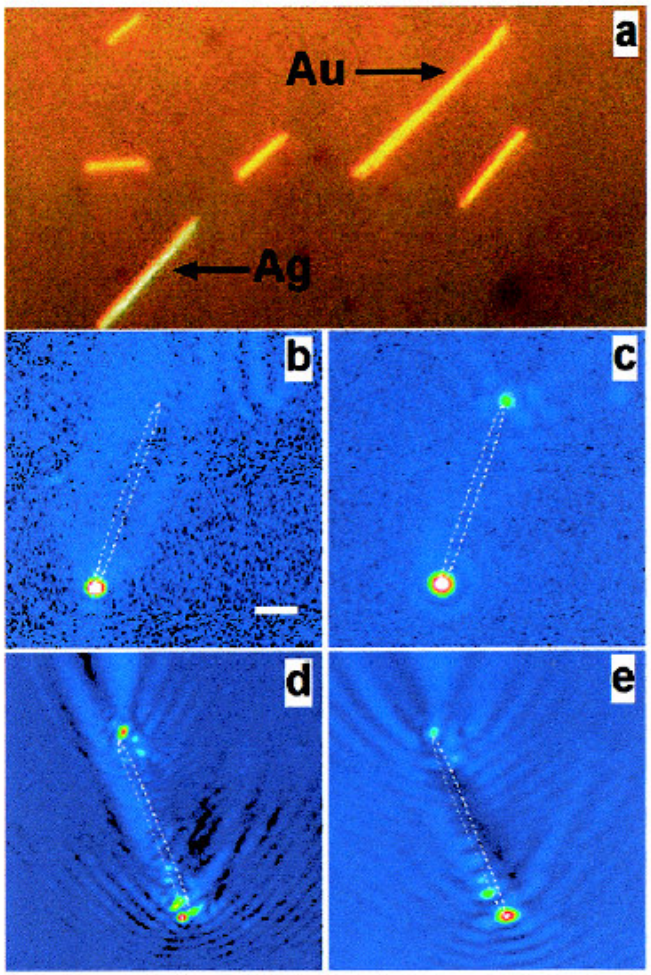
Current and emerging commercial optical biosensors,
Cheryl L. Baird and David G. Myszka,J.Moleular Recognition,2001:14-261-268

Surface Plasmon Resonance Imaging Measurements of DNA and RNA Hybridization Adsorption onto DNA Microarrays

SPR imaging is used to quantitatively detect the hybridization adsorption of short (18-base) unlabeled DNA oligonucleotides at low concentration, as well as, for the first time, the hybridization adsorption of unlabeled RNA oligonucleotides and larger 16S ribosomal RNA (rRNA) isolated from the microbe *Escherichia coli* onto a DNA array. interactions can be monitored in an array format under identical conditions. Recently, they demonstrated a multistep procedure to create DNA arrays on gold surfaces for use with SPR imaging. These arrays can be used to study affinity interactions for a variety of target molecules, including unlabeled proteins and nucleic acids.

Surface Plasmon Resonance Imaging Measurements of DNA and RNA Hybridization Adsorption onto DNA Microarrays,
Bryce P. Nelson,Timothy E. Grimsrud,Mark R. Liles,Robert M. Goodman,and Robert M. Corn, Anal. Chem.**2001,** 73,1-7

Unidirectional Plasmon Propagation in Metallic Nanowires



A bimetallic wire with a sharp Au/Ag heterojunction is shown to display both wavelength dependence and unidirectionality with respect to plasmon propagation across the heterojunction.

It is expected that these results will contribute to the growing interest in optical energy transport in molecular-level and nanoscale devices.

Unidirectional Plasmon Propagation in Metallic Nanowires,
Robert M. Dickson* and L. Andrew Lyon*, *J. Phys. Chem. B* 2000, *104,* 6095-6098

Extraordinary optical transmission through sub-wavelength hole arrays

The desire to use and control photons in a manner analogous to the control of electrons in solids leads to emphasis on

localization of light

microcavity

quantum electrodynamics

near-field optics

Constraint?

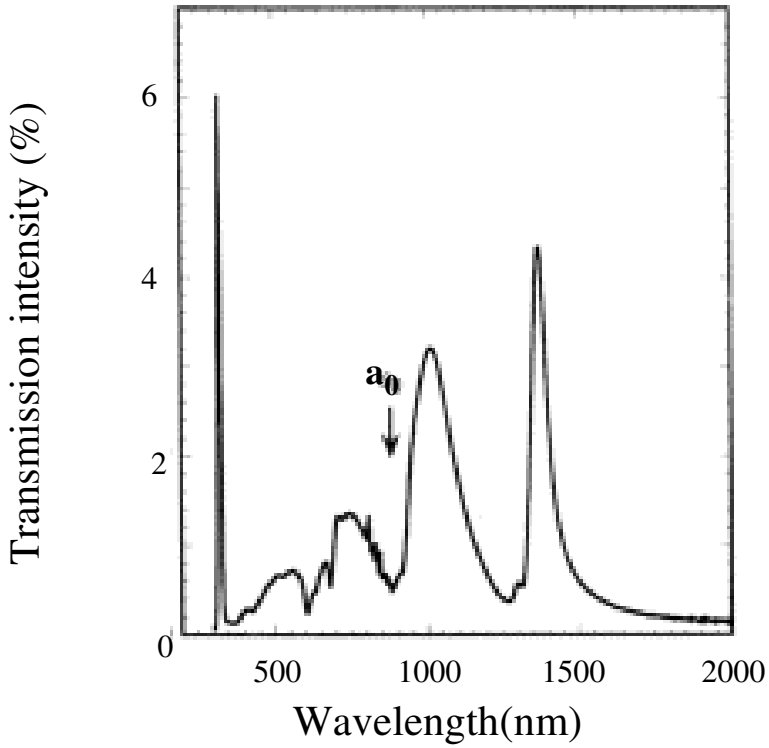
extremely low transmittivity of apertures smaller than the wavelength of the incident photon

Extraordinary optical transmission through sub-wavelength hole arrays
T. W. Ebbesen, H. J. Lezec, H. F. Ghaemi, T. Thio,
P. A. Wolff, *Nature* **391**, 667 (1998).

Preparation of 2D arrays of cylinderical cavities in metalic film:

Silver Film – 0.2 µm thick – Evoporation –on quartz glass

Arrays of holes –Micron Focused Ion Beam System (FIB)-hole size from 150 nm to 1 µm spacing between the holes (that is, the periodicity) a0-between 0.6 and 1.8 µm



Zero-order transmission spectrum of an Ag array (a_0 = 0.9 µ m, d = 150 nm, t = 200 nm).

ë= 326 nm the narrow bulk silver plasmon peak
Additional minimum when ë= a_0

The maximum transmitted intensity occurs at 1,370 nm,.
absolute transmission efficiency >= 2
In other words, more than twice as much light is transmitted as impinges directly on the holes.

Extraordinary optical transmission through sub-wavelength hole arrays
T. W. Ebbesen, H. J. Lezec, H. F. Ghaemi, T. Thio,
P. A. Wolff, *Nature* **391**, 667 (1998).

Their results demonstrate the strong enhancement of transmitted light due to coupling of the light with the SP of the two-dimensional array of sub-wavelength holes

How this Phenomenon is related to SPR:

Absence of enhanced transmission in hole arrays fabricated in Ge films.
Angular dependence of the spectra in metallic samples

In photonic bandgap arrays , the material is passive and translucent at all wavelengths except at the energies within the gap. In the present arrays, the material plays an active role (through the plasmons) and it is opaque at all wavelengths except those for which coupling occurs.

The demonstration of efficient light transmission through holes much smaller than the wavelength and beyond the inter-hole diffraction limit might, for example, inspire designs for novel nearfield scanning optical microscopes, or sub-wavelength photolithography. Theoretical analysis of the results would also be useful for gaining better insight into this extraordinary transmission phenomenon.

Appendix

Identifying a protein is not enough. We need to know when and where the proteins are synthesized, where do they go, what is there function and how do they interact with other molecules.

In addition, the adsorption of biomolecules to metal or synthetic (bio)polymers can be studied. This can be of great value in the development of prosthesis.(**Prosthesis**- An artificial device used to replace a missing body part, such as a limb, tooth, eye, or heart valve).

Lipid- Any of a group of organic compounds, including the fats, oils, waxes, sterols, and triglycerides, that are insoluble in water but soluble in nonpolar organic solvents, are oily to the touch, and together with carbohydrates and proteins constitute the principal structural material of living cells.

Kinetic rate analysis Kinetic rate analysis is used to investigate the behavior of the system. The analyte is flowed over the ligand and the association rate is monitored in real time. After a while the analyte if replaced by buffer and the dissociation rate of the analyte is monitored. Both the association and dissociation curve are fitted to one of the chosen models. Assessing the fit and calculated constants will reveal if the model is correct. In addition, the equilibrium constant can be calculated.

What is a Cell?

http://www.jmu.edu/biology/b101/b101r/cells.pdf