Optical Biosensors

& Applications

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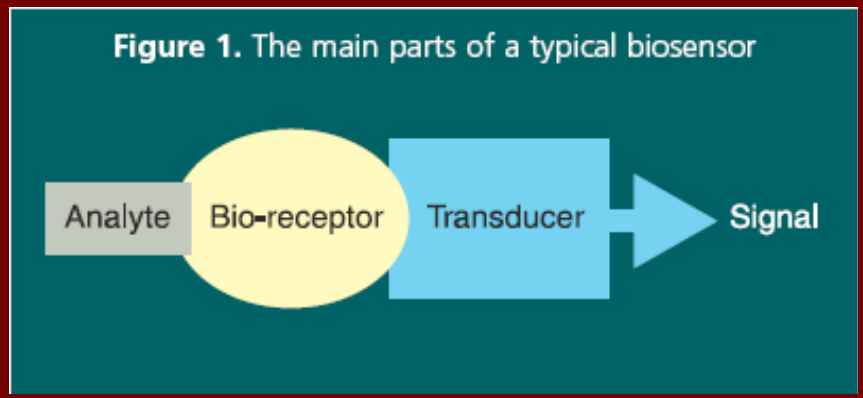
Outline

- What Are Optical Biosensors?
- Types of Optical Biosensors
  - Optical fibers
- Applications
  - Commercially available sensors
- Why Optical Biosensors?
  - Advantages? Disadvantages?
- Future Applications

What is an Optical Biosensor?

- Biosensor
- Measures changes in optical properties of substances
  - Absorbance in chemical reaction
  - Fluorescence
  - Reflectance
  - Refractive index
  - Phase shift
  - Light Energy (wavelength)
- Reaction will cause Luminescence

Biosensor



Transducers used in Biosensor development		
Category	**Principle**	**Examples**
Electrochemical	(a) potentiometric: depends on changes in potential of a system at a constant current (I=0)	Ion-selective electrodes, ion-selective field effect transistors, LAPS
	(b) amperometric: detects changes in current as a function of concentration of electroactive species	Solid electrolyte gas sensors, electronic noses
Optical	Link changes in light intensity to changes in mass or concentration, therefore, fluorescent or colorimetric molecules must be present	Optical fibres, surface plasmon resonance, absorbance luminescence
Piezoelectric	Sensitive to changes in mass, density, viscosity and acoustic coupling phenomena	Surface acoustic wave sensors
Thermal	Detect changes in temperature	Calorimetric sensors

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Types of Optical Biosensors

- Four main types:

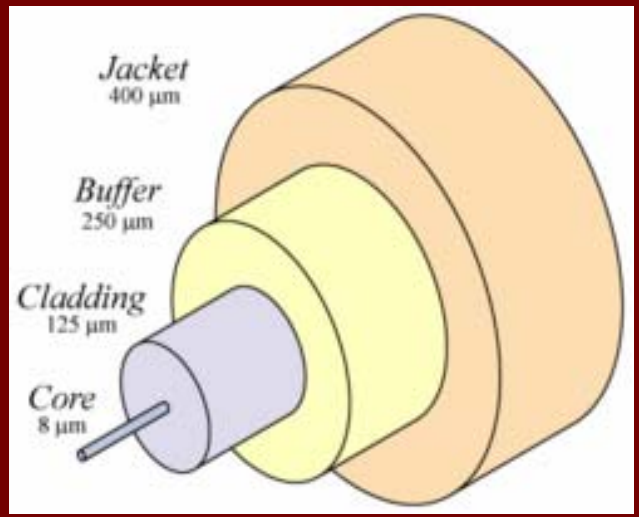
1. Fiber Optics
   a. Indicator mediated
   b. Immunoassay
2. Surface Plasmon Resonance (SPR)
   -Immunoassay
3. Absorbance
4. Luminescence

1. Optical fibers

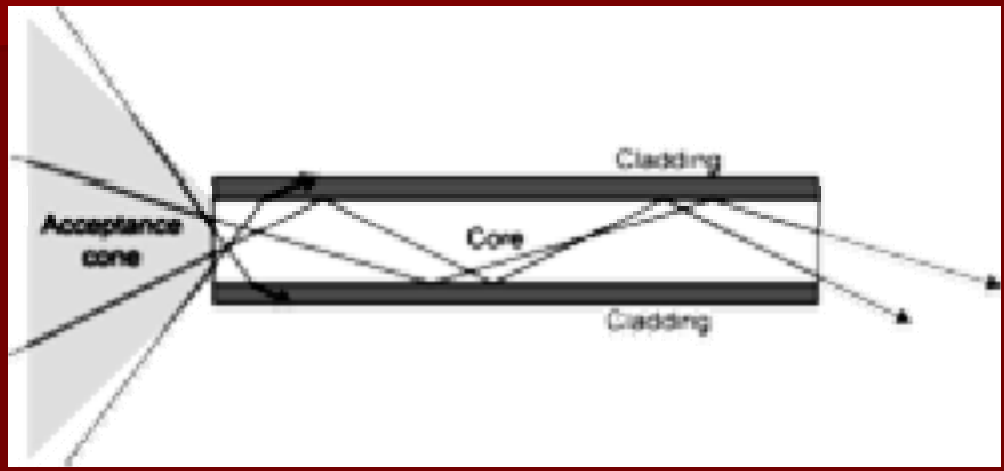
- Used to transmit light from one position to another
- Made of glass, plastic or silicon

Refractive index =

velocity in free space : velocity in certain material



Light Propagation Through Optical Fibers

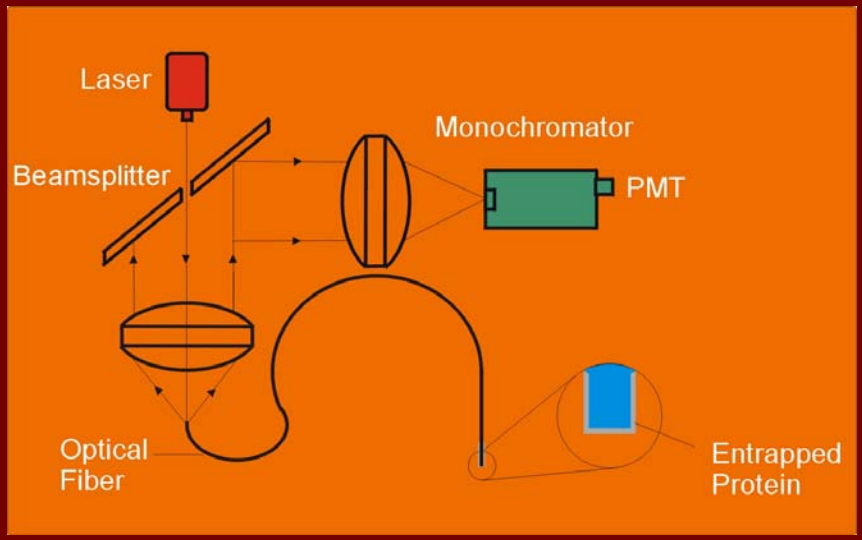


- Refractive index of core is greater than cladding
- Light propagates through the core
- Total internal reflection
- Light of different wavelengths will not interfere

Indicator-Mediated Fiber Optic Receptor

- Light interacts with reagents that are placed near the tip of the optical fiber
- After this interaction, light will return with an intensity attenuation as a function of analytic concentration
- Few biochemical substances have an intrinsic optical absorption or fluorescence principle
- Reaction needs to be transmitted into an optical signal

Indicator Mediated Transducer

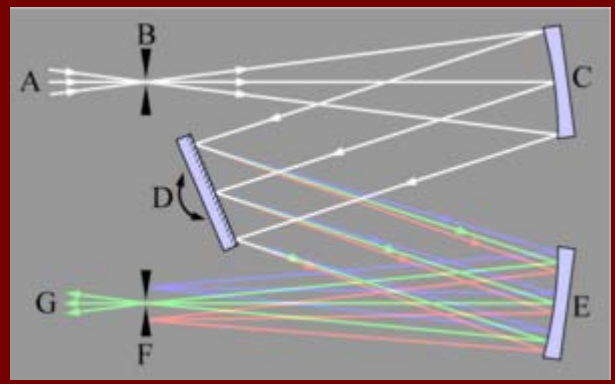


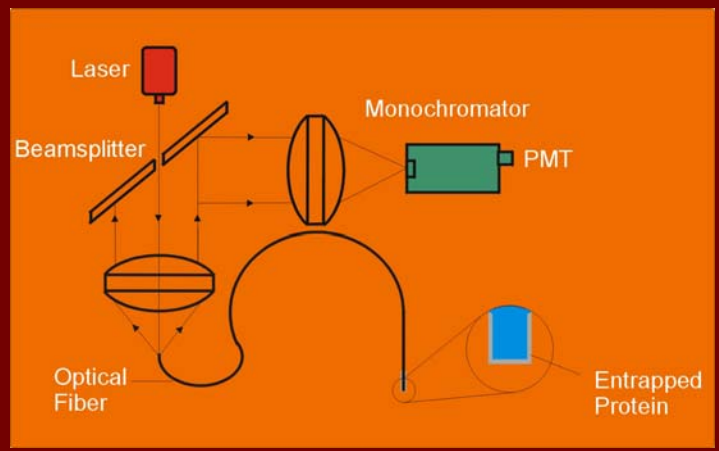
- Detects specific target analytes from a given mixture
- Light comes back through single fiber at a different wavelength
- Transducer includes: Monochromator, lenses, and Photomultiplier tube

Monochromator

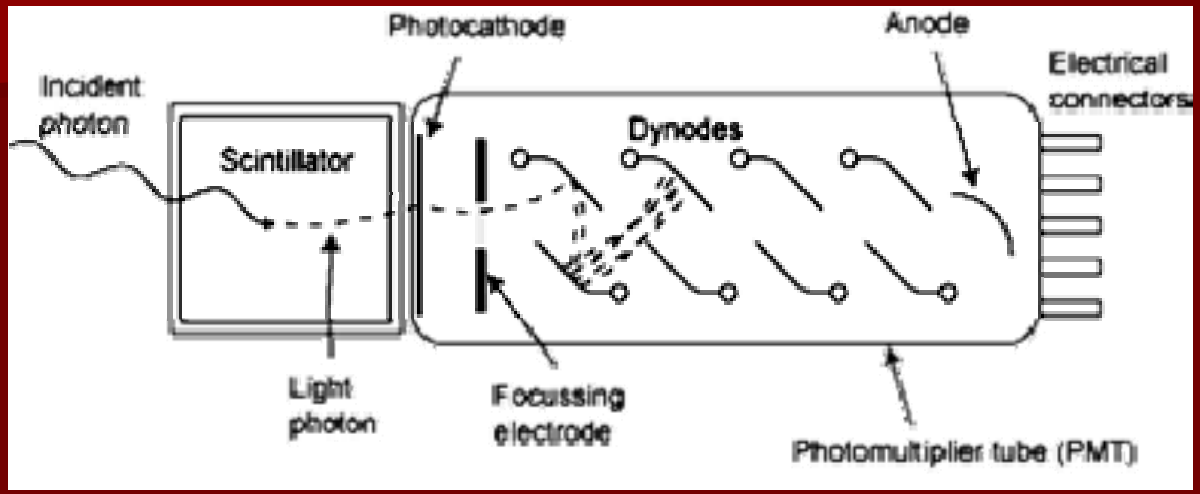
‘Mono’ – One, ‘Chromate’ - Colour

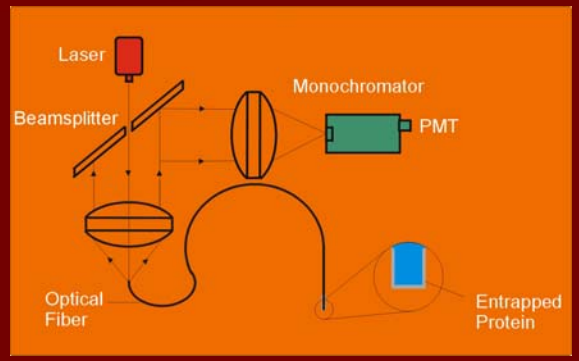
- Czerny-Turner design
- At C, light is collimated (focused at infinity)
- Light is diffracted at D
- Refocused at E





Photomultiplier Tube





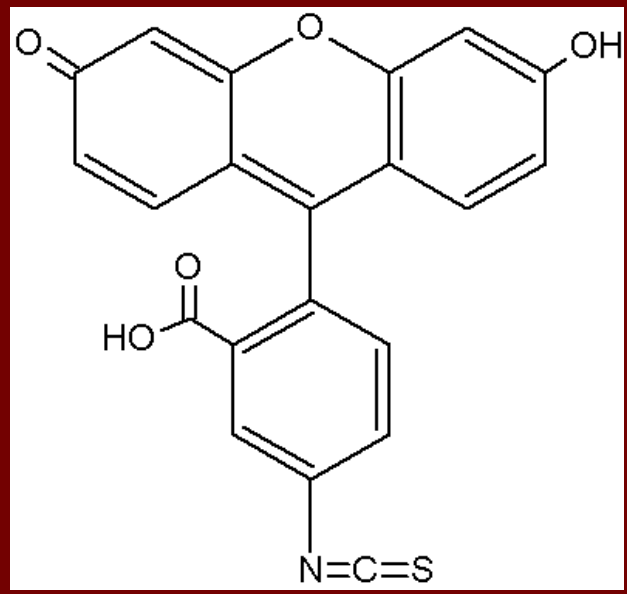
- Multiplies the signal from single photons
- Each dynode is more positively charged than the previous ones
- results in a sharp voltage pulse

Immunoassay Sensors

- Used in immunological diagnostics
- Detects reaction products of ligand binding
  - antibody-antigen binding
- Capable of ‘selective recognition’ in a mixture
- Why are these helpful?
- Array of sensors

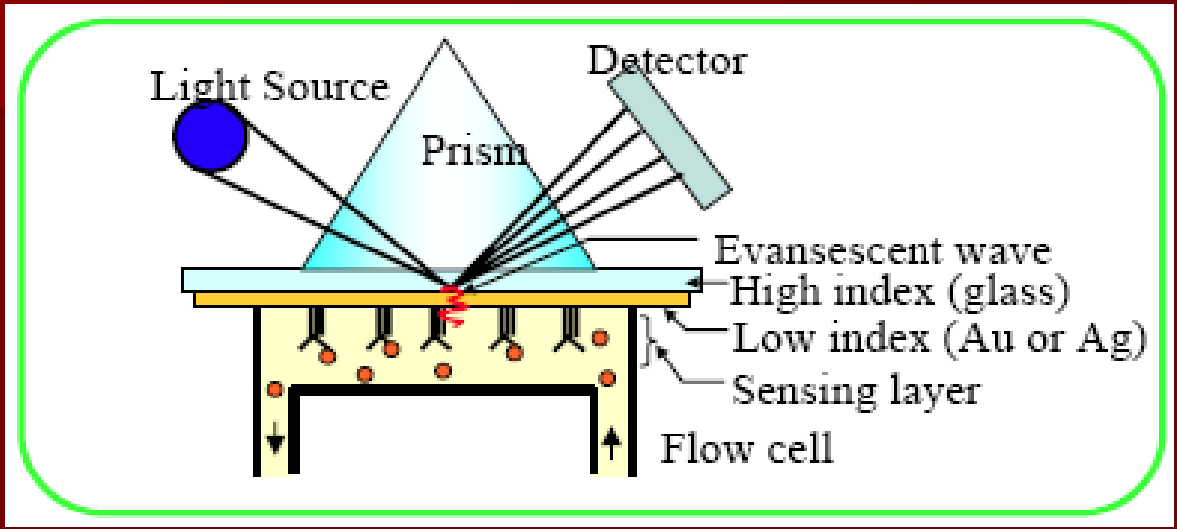
Fluorescence

- Fluorophores are integrated into antibodies
  - Will absorb energy and re-emit it at a different wavelength in the form of light
  - Will fluoresce when their environments are changed
  - Must not interfere with binding of antigens



Structure of Fluorescein isothiocyanate , a fluorophore

2. Surface Plasmon Resonance (SPR)



- Monochromatic polarized light interacts with thin metal surface with a charge density oscillation
- Photon energy is transferred in electron packets – 'plasmons'
- Ligand binding changes the index of refraction and can be used to monitor surface interactions

SPR Applications

- refractive index changes
- avidin-biotin binding
- antibody-antigen binding
- specific detection of small molecules
- protein binding
- concentrations of analytes
- attachment of DNA complements

3. Absorbance Based

- Low technology
- Colorimetric test strips
- Cellulose pads embedded with enzymes and reagents
- Used in diabetes regulation:

1. glucose + O_2 $\xrightarrow{\text{glucose oxidase}}$ gluconic acid + H_2O_2

2. chromogen(2H) + H_2O_2 $\xrightarrow{\text{peroxidase}}$ dye + $2H_2O$

Strip includes: glucose oxidase, horseradish peroxidase, and a chromogen

When oxidized, the chromogen will be coloured

4. Luminescence Based

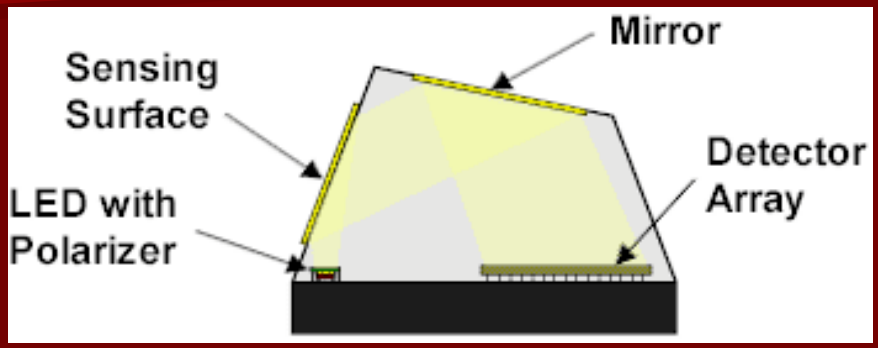
- Luminescence-light that is not primarily generated from heat
- Light output from a biochemical reaction
- Can be used in detection of bacteria
  - Uses Firefly luciferase (from the tails of wild fireflies)
  - Bacteria is lysed and yellow light is given off

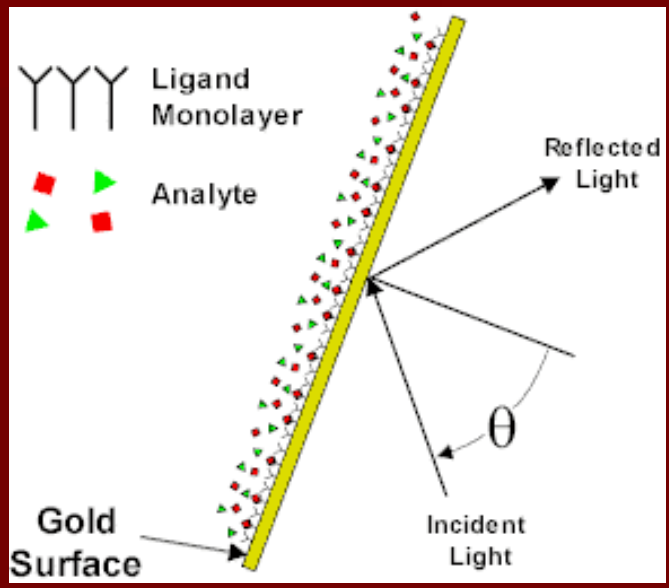
$$ATP + luciferin + O_2 \rightarrow AMP + PP_i + oxyluciferin + CO_2 + h\gamma$$

Applications

- Diagnostics
  - as seen in Immunoassays
- Drug Discovery and Delivery
  - determination of ligand binding
- Environmental Applications:
  - Determination of levels of toxins in air
- Commercial Applications
  - Blood-Glucose monitoring using colorimetric strips
  - Used in research

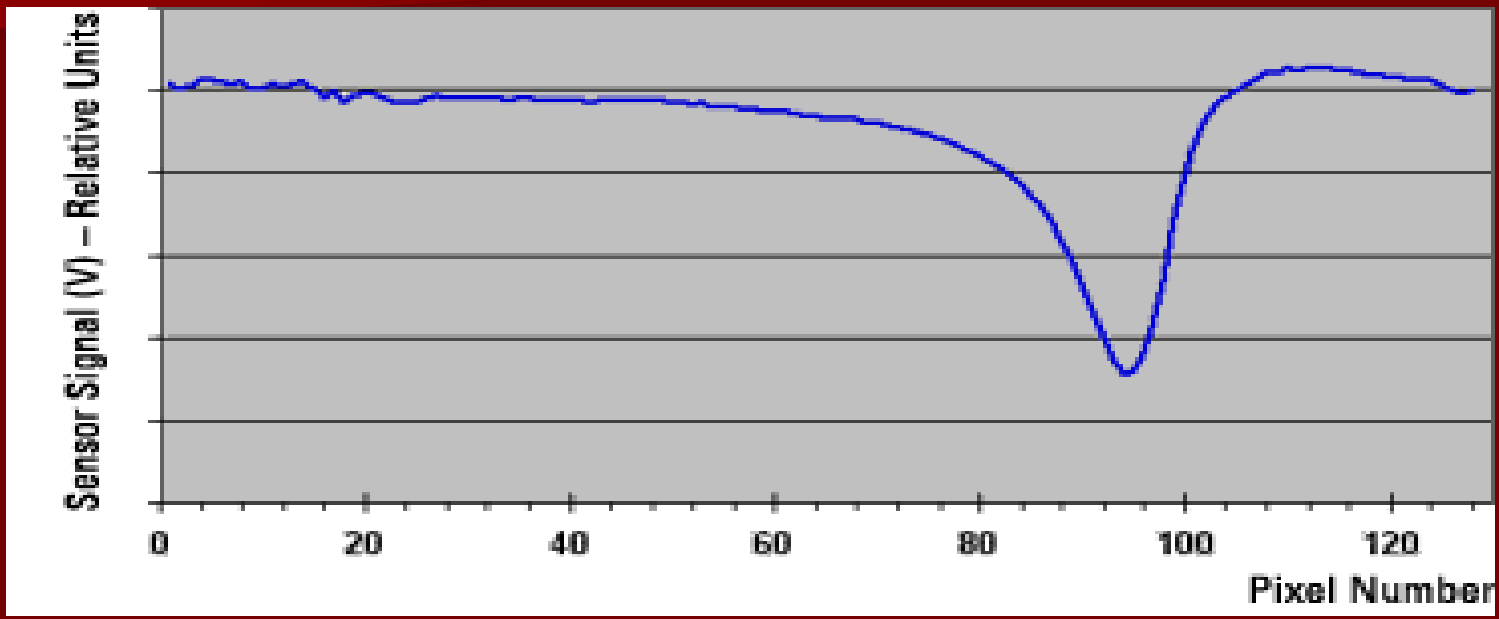
Spreeta by Texas Instruments

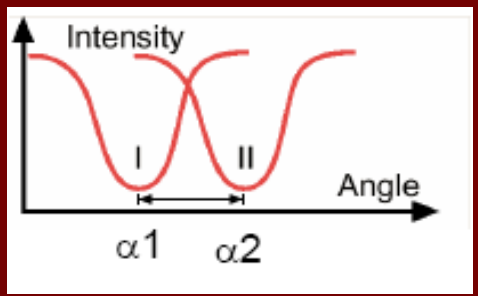




- Flow cell design, clamped on to sensing surface
- Simply measures the intensity
- Gold layer covered with bio-film
  - Biospecific coating enables measurement of specific interactions
- Cost: $50

SPR
sample output for water

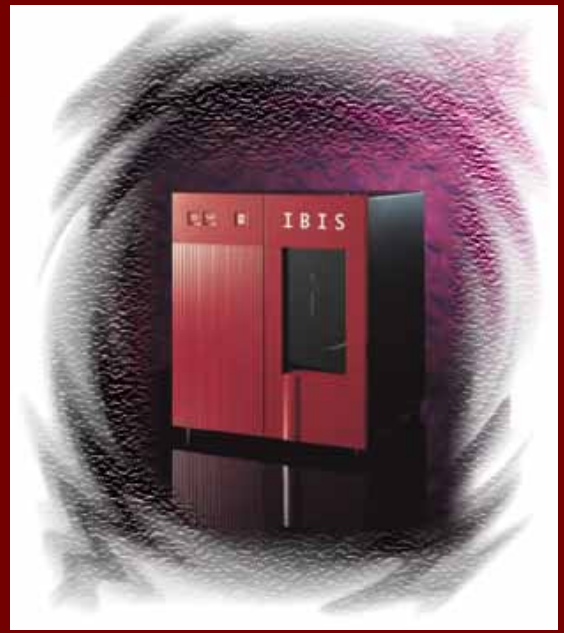


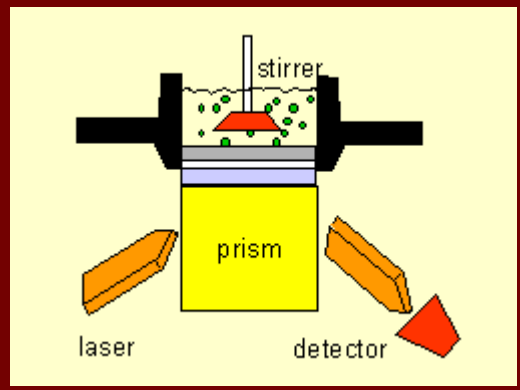


Phase shift occurs when refractive index changes: due to analyte binding

IBIS I by IBIS

- Cuvette System
  - No flow cell
  - Solution is stirred
- Gold layer
- Advantages of Cuvette System
  - Allows for analysis of viscous solutions
  - Allows for addition of analytes to existing solution





Cuvette System

Why Optical Biosensors?

- Advantages
  - Small
  - Flexible
  - Fast
  - Safe, no electrical device interacts with the body
  - Good biocompatibility (fibers are glass)
- Disadvantages
  - May be Invasive
  - Fluorescent signal may not be strong enough

Future Applications

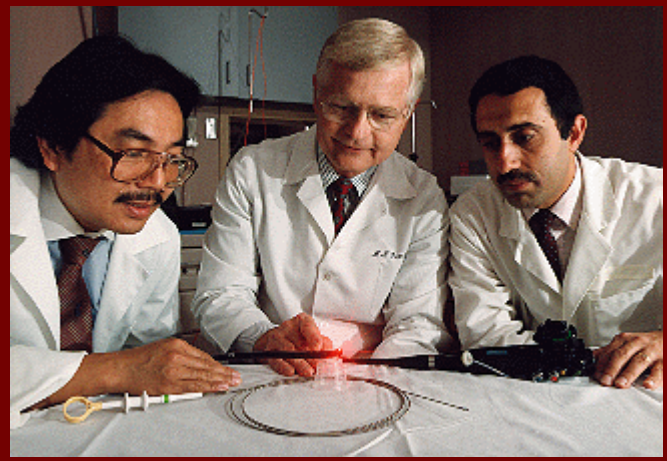
Test for Tuberculosis (TB)

- Cough into the tube and sputum is brought up
- Give positive reading if TB is present in the lungs

Breathalyser

optical biopsy sensor

- Detects if tumor in esophagus is cancerous or benign
- When illuminated, normal tissue and cancerous tissue will emit light at different wavelengths



Diagnosis is accurate over 98%

Medical Telesensors

- Universal Sensing Chip
- Multiple bio-sensing applications
- Measures blood-oxygen levels
- Colour of hemoglobin is transmitted when illuminated by light

Summary

- Various types of optical biosensors
- Optical biosensors can be a diagnostic tool by taking advantage of the optical properties of substances
- Optical biosensors detect ligand binding

  -Helpful for drug delivery and discovery
- Commercially available SPR systems have been compared

Discussion

- Medical Telesensors (revisited)
  - Civilian implant
    - Pros?, Cons?
  - ‘1984’ haunts us once again!!! Has Big Brother hidden his Wiley schemes behind biosensors?
- Technology needs to be market driven
  - Will there be a market?

Any Questions?

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