TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA
ROMANIA

Faculty of Electronics, Telecom and Info Technology

Lecture 12

Optoelectronic Sensors with Industrial Applications

Lab on a chip: plasmonics

Associate prof Ramona Galatus
Basis of Electronics Department

Outline: Applications

- Part 1 – Lab on a chip
- Part 2 – Plasmonic
- Part 3 – Plasmonic components

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(wileyonlinelibrary.com) DOI: 10.1002/jmr.1138

Survey of the 2009 commercial optical biosensor literature

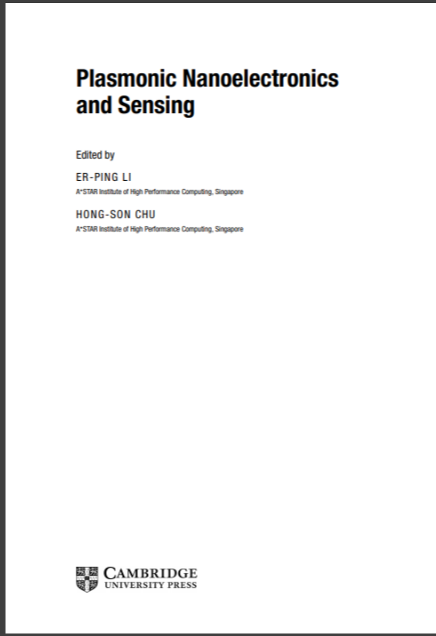
Rebecca L. Rich[a] and David G. Myszka[a]*

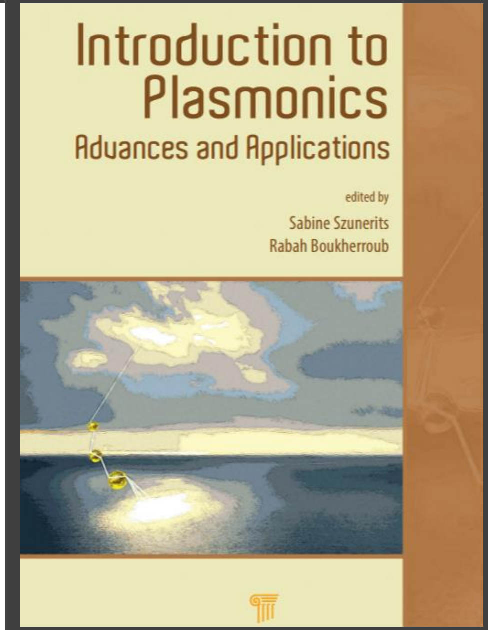
We took a different approach to reviewing the commercial biosensor literature this year by inviting 22 biosensor users to serve as a review committee. They set the criteria for what to expect in a publication and ultimately decided to use a pass/fail system for selecting which papers to include in this year's reference list. Of the 1514 publications in 2009 that reported using commercially available optical biosensor technology, only 20% passed their cutoff. The most common criticism the reviewers had with the literature was that "the biosensor experiments could have been done better." They selected 10 papers to highlight good experimental technique, data presentation, and unique applications of the technology. This communal review process was educational for everyone involved and one we will not soon forget.

Keywords: affinity; Biacore; biolayer interferometry; biomolecular interaction analysis; evanescent wave; kinetics; resonant mirror; surface plasmon resonance

References

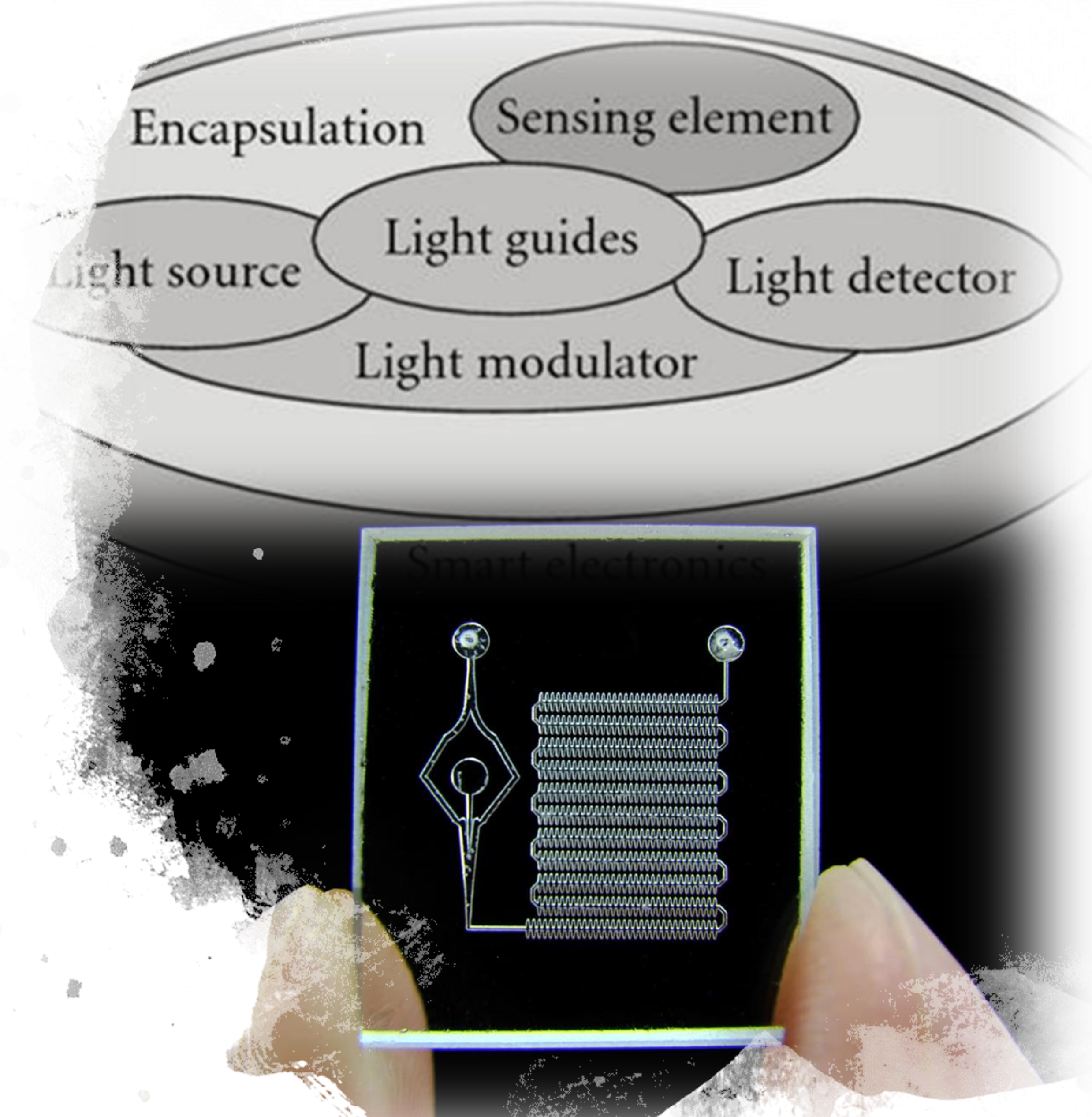
https://www.fierceelectronics.com/





Integrated optics advantages

- Small size, low power consumption
- Flexible design
- Efficiency and reliability of batch fabrication
- Integration with electronics (Front-end, signal processing)
- New functions
  - Integration micro mechanical, micro optical, microfluidic components.



Lab on a chip example. Source: University of Hull
https://www.hull.ac.uk/work-with-us/research/groups/lab-on-a-chip

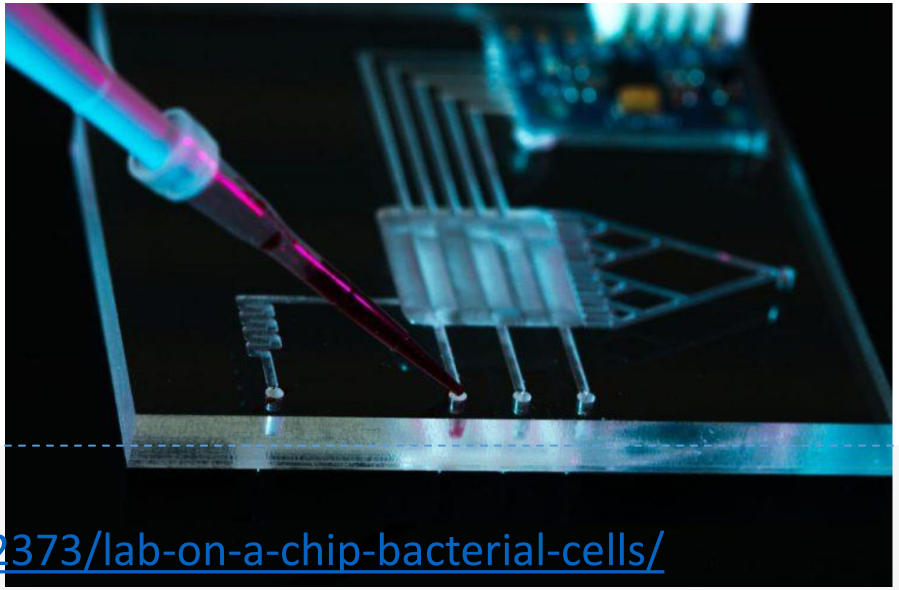
Lab-on-Chip

Nanotechnology

The Future is Tiny,

Michael Berger

Nanowerk LLC, Berlin, Germany, 2016



Source: https://www.europeanpharmaceuticalreview.com/news/72373/lab-on-a-chip-bacterial-cells/

Definition LOC

- Lab-on-a-chip (LOC) is a term for devices that integrate (multiple) laboratory functions on a single chip of only millimeters to a few square centimeters in size and that are capable of handling extremely small fluid volumes down to less than pico liters. However, strictly regarded "Lab-on-a-Chip" indicates generally the scaling of single or multiple lab processes down to chip-format, whereas "µTAS" is dedicated to the integration of the total sequence of lab processes to perform chemical analysis.
- The term "Lab-on-a-Chip" was introduced later on when it turned out that µTAS technologies were more widely applicable than only for analysis purposes.

- Lab-on-a-chip devices are a subset of MEMS devices and often indicated by "Micro Total Analysis Systems" (µTAS) as well.
- Microfluidics is a broader term that describes also mechanical flow control devices like pumps and valves or sensors like flowmeters and viscometers.

Source: https://www.gene-quantification.de/lab-on-chip.html

Advantages LOC

LOCs may provide advantages, very specifically for their applications.

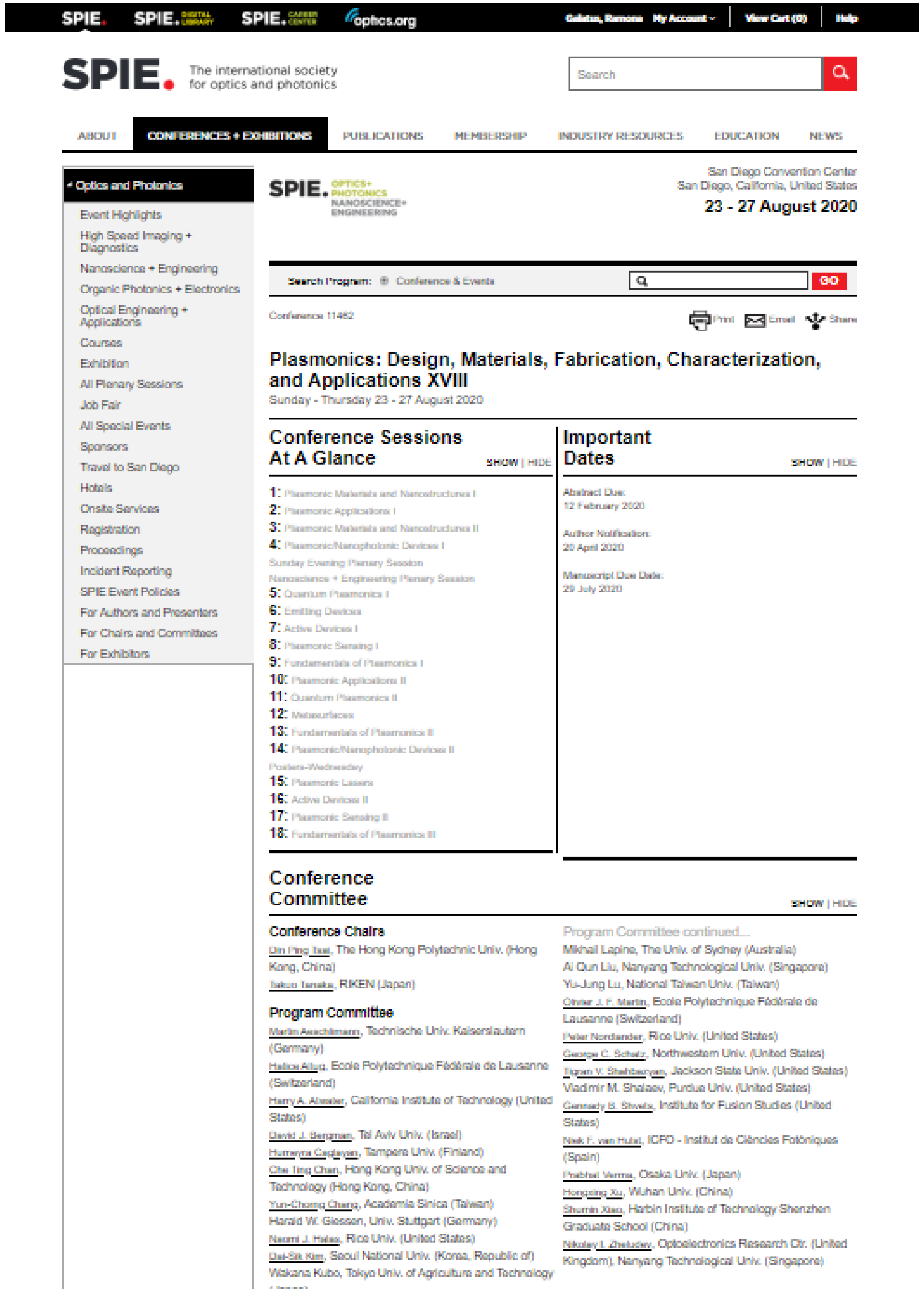
Typical advantages are:

- low fluid volumes consumption, because of the low internal chip volumes, which is beneficial for e.g. environmental pollution (less waste), lower costs of expensive reagents and less sample fluid is used for diagnostics.
- higher analysis and control speed of the chip and better efficiency due to short mixing times (short diffusion distances), fast heating (short distances, high wall surface to fluid volume ratios, small heat capacities).
- better process control because of a faster response of the system (e.g. thermal control for exothermic chemical reactions).
- compactness of the systems, due to large integration of functionality and small volumes.
- massive parallelization due to compactness, which allows high-throughput analysis.
- lower fabrication costs, allowing cost-effective disposable chips, fabricated in mass production.
- safer platform for chemical, radioactive or biological studies because of large integration of functionality and low stored fluid volumes and energies.

Conference

https://spie.org/OPN/conferencedetails/plasmonics-design-materials-fabrication-characterization-applications?SSO=1#session-2

1: Plasmonic Materials and Nanostructures
2: Plasmonic Applications
3: Plasmonic/Nanophotonic Devices I
4: Quantum Plasmonics
5: Emitting Devices
6: Active Devices
7: Plasmonic Sensing
8: Fundamentals of Plasmonics
9: Metasurfaces
10: Plasmonic Lasers



Plasmonics history

1. **1902**, Wood reported the
   - “uneven distribution of light in a diffraction grating spectrum”
   - he observed patterns of unusual dark and bright bands in the light
   - reflected from a metal backed diffraction grating.
   - speculated the possible interaction of the grating-metal arrangement

   with the incident light (no obvious and clear reason for the observed phenomenon was provided).

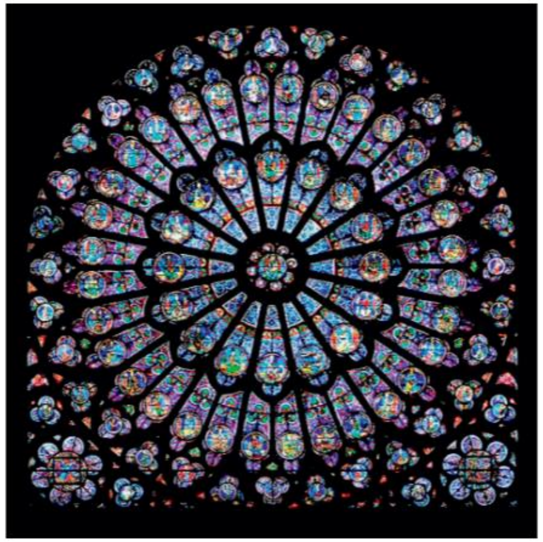
2. **1907**, Lord Rayleigh, The first theoretical description of these anomalies was provided when he published the dynamical theory

   of gratings.

3. **1957**, Ritchie for the first time coined the word ‘**surface plasmons**’ while explaining the characteristic losses of energy experienced by **fast electrons** when they travel through thin metal films and demonstrated theoretically that the surface plasmons could be excited on the surface of a **thin metal film**.

Plasmonics in real life

- The *Lycurgus Cup*is the oldest example (year ~400) of this kind of staining.
- 1968 – Otto Configuration
- 1971 – Kretschmann Configuration
- For a metal nanoparticle, the polarization enhanced at certain frequencies of light.
- For noble metals, this occurs for visible light, which gives strong colors.

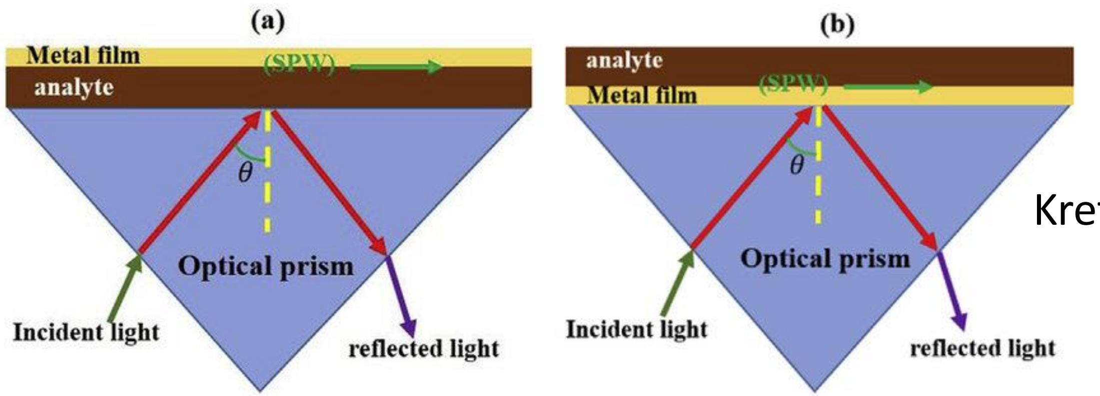


Gothic stained glass rose window of Notre-Dame de Paris. The colors originate from localized surface plasmons, excited in Au colloids, nanoparticles, that are embedded in the glass matrix.

ambient light   light inside cup

British Museum

Otto



Kretschmann

Kretschmann

In 1971, Kretschmann and Raether modified the Otto configuration by directly coating the metal film on the base of the prism.

In this case, the leaky radiation through the prism– metal interface excites surface plasmons at the metal and outer dielectric medium interface.

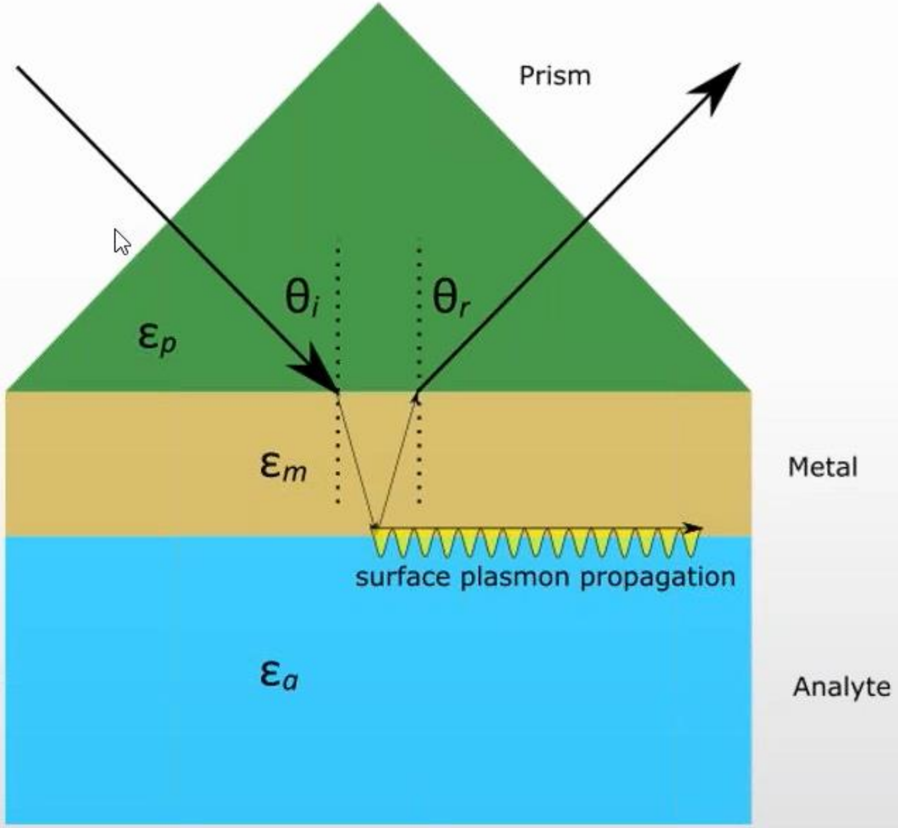
This search revolutionized the world of surface plasmons.

After this, scores of studies were performed to find the effects of prism material, choice of metals and their thickness for efficient coupling of excitation light to surface plasmons

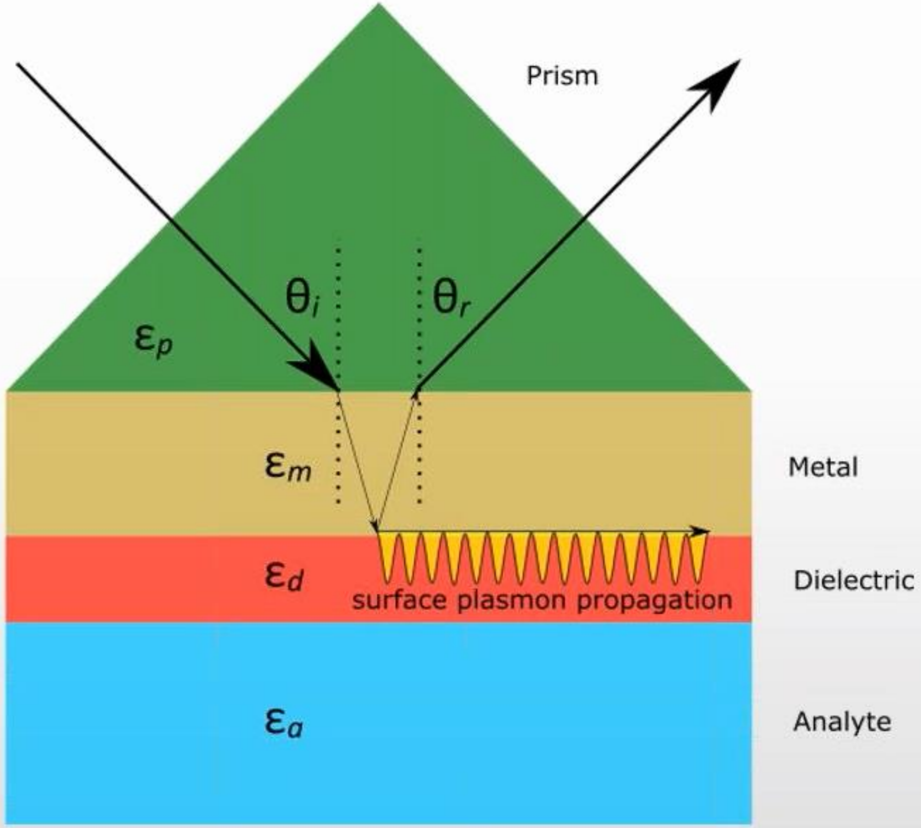
Definition – Surface plasmon polaritons

- Waves confined to metal-dielectric interfaces
- Characterized by exponentially decaying fields in the direction perpendicular to the interface
- Multiple interfaces/layers on the waveguide classified as:
  - Insulator-metal-insulator (IMI)
  - Metal-insulator-metal (MIM)
- **Surface plasmon polaritons (SPPs) are defined as electromagnetic waves coupled with charge oscillations of free electrons in a metal that propagate along the boundary between the metal and a dielectric medium. When SPP excitation is optically induced, it is referred to as SPR.**

Single/Multiple layers

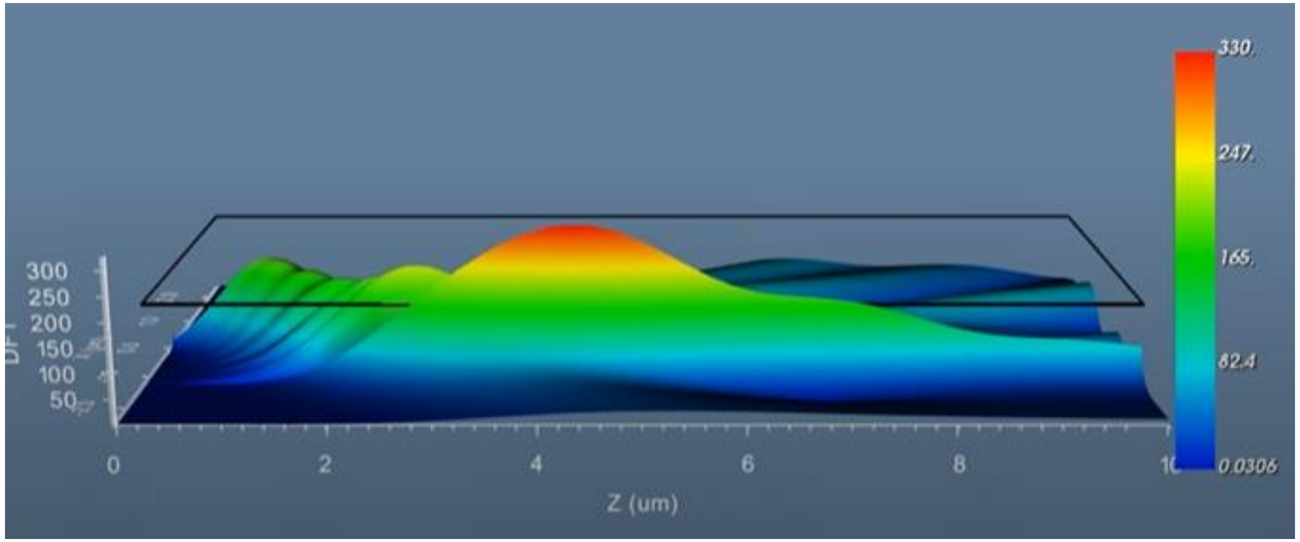


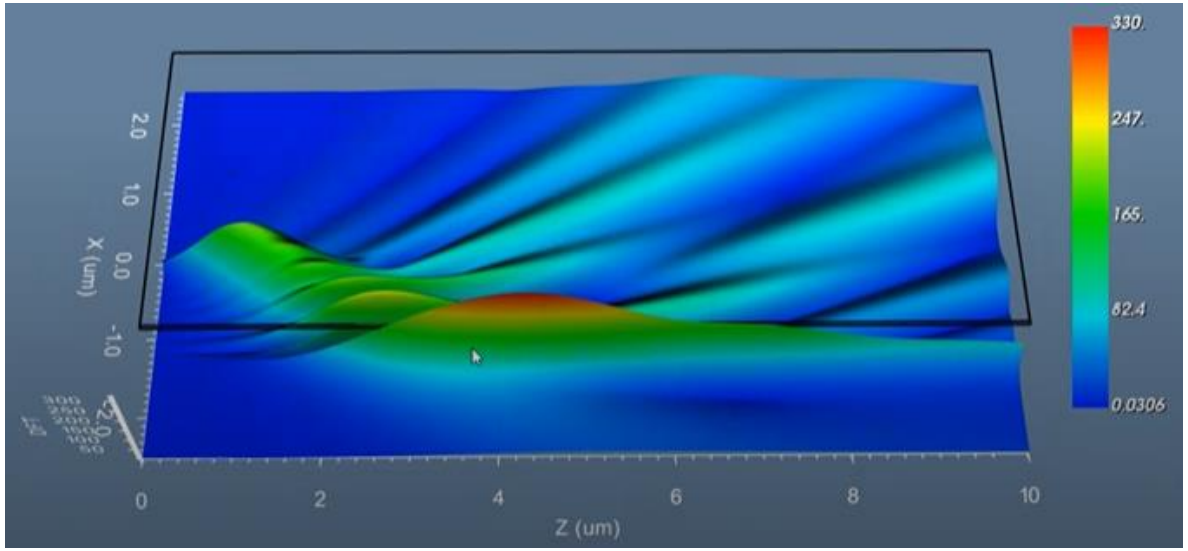
Single Layer Kretschmann Configuration [1]



Double Layer Kretschmann Configuration [1]

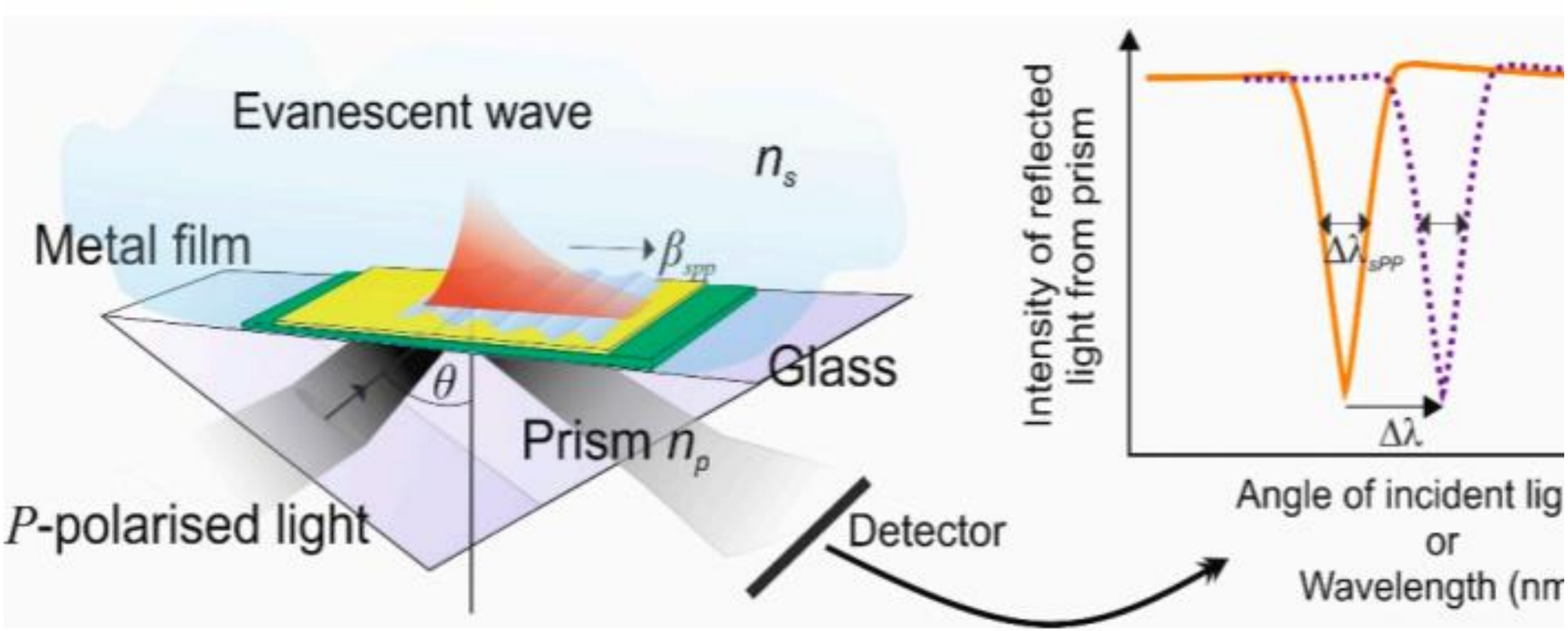
Electromagnetic field – Ex,z component





Frequency domain

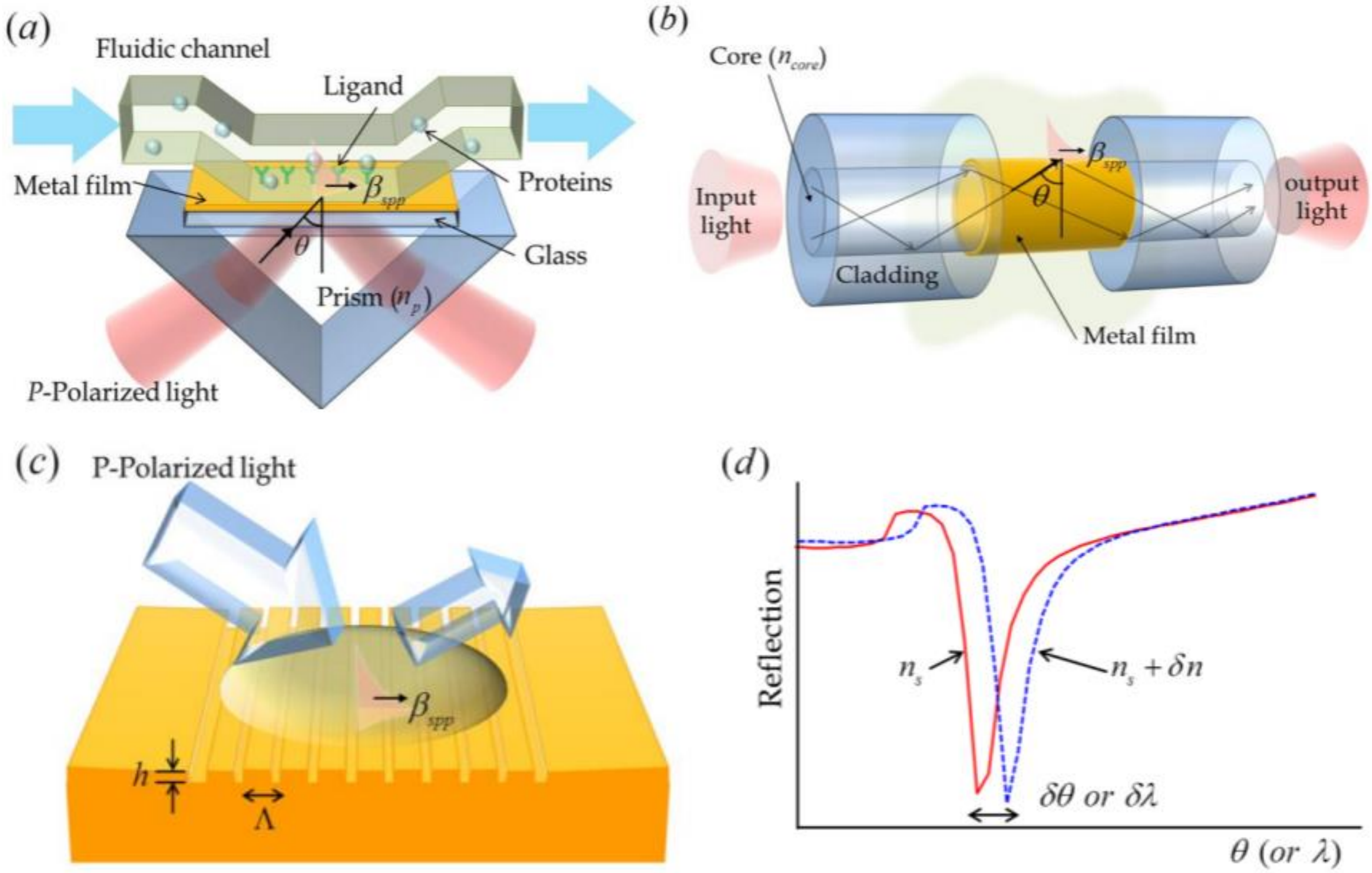
Basic configuration - Kreitschmann Configuration



A Review: Evolution and Diversity of Optical Fibre Plasmonic Sensors, November 2019, School of Computing, Communications and Electronics, University of Plymouth, Plymouth PL4 8AA, UK

Basic structures

Basic schemes for SPR sensors with (**a**) Kretschmann configuration based coupling; (**b**) waveguide based coupling; (**c**) and grating coupling; (**d**) Reflection ratio of light due to SPR with angular modulation or wavelength modulation.



Implementation examples-Biacore, Xantec

Principles of Surface Plasmon resonance (SPR) used in Biacore™ systems

https://www.youtube.com/watch?v=o8d46ueAwXI

https://www.youtube.com/watch?v=o-qUQsUmttY

https://www.xantec.com/products/index.html

We want portable devices! – not expensive

Resonance condition

When TM-polarized (p-polarized) light is illuminated on the bottom side of a thin metal film through the prism, the resulting evanescently decaying field penetrates into the metal layer and reaches the upper boundary between the metal and sensing medium. This process effectively excites SPPs at the thin metal film. When SPR occurs, the incident light is absorbed by the metal film. Therefore, a resonance dip is produced in the reflection spectrum. The resonance condition is described as :

$$\frac{2\pi}{\lambda} n_p \sin\theta = \beta_{ev} = \mathrm{Re}\left(\beta_{spp}\right),$$

where n_p is the refractive index of the dielectric prism, λ the wavelength in free space, and θ the incident angle of the illuminating light. To achieve a measurable resonance, the propagation constant β_{ev} of the evanescent field induced from the TM incident light should correspond to the real part of complex β_{spp}, which is the excited SPP propagation constant.

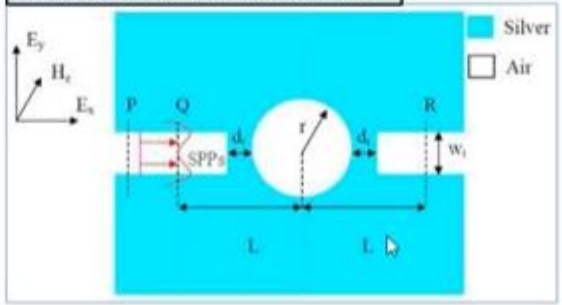
Plasmonic solutions

Optiwave
DESIGN SOFTWARE

Waveguide Filters

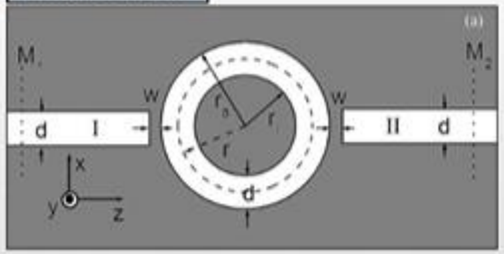
- Resonators and waveguides used together can form filters
- Ring or disk resonators are popular choices
- MIM structures offer high confinement and acceptable loss
- 2D FDTD simulations are not terrible choices for SPP simulations

Channel drop with disk resonator



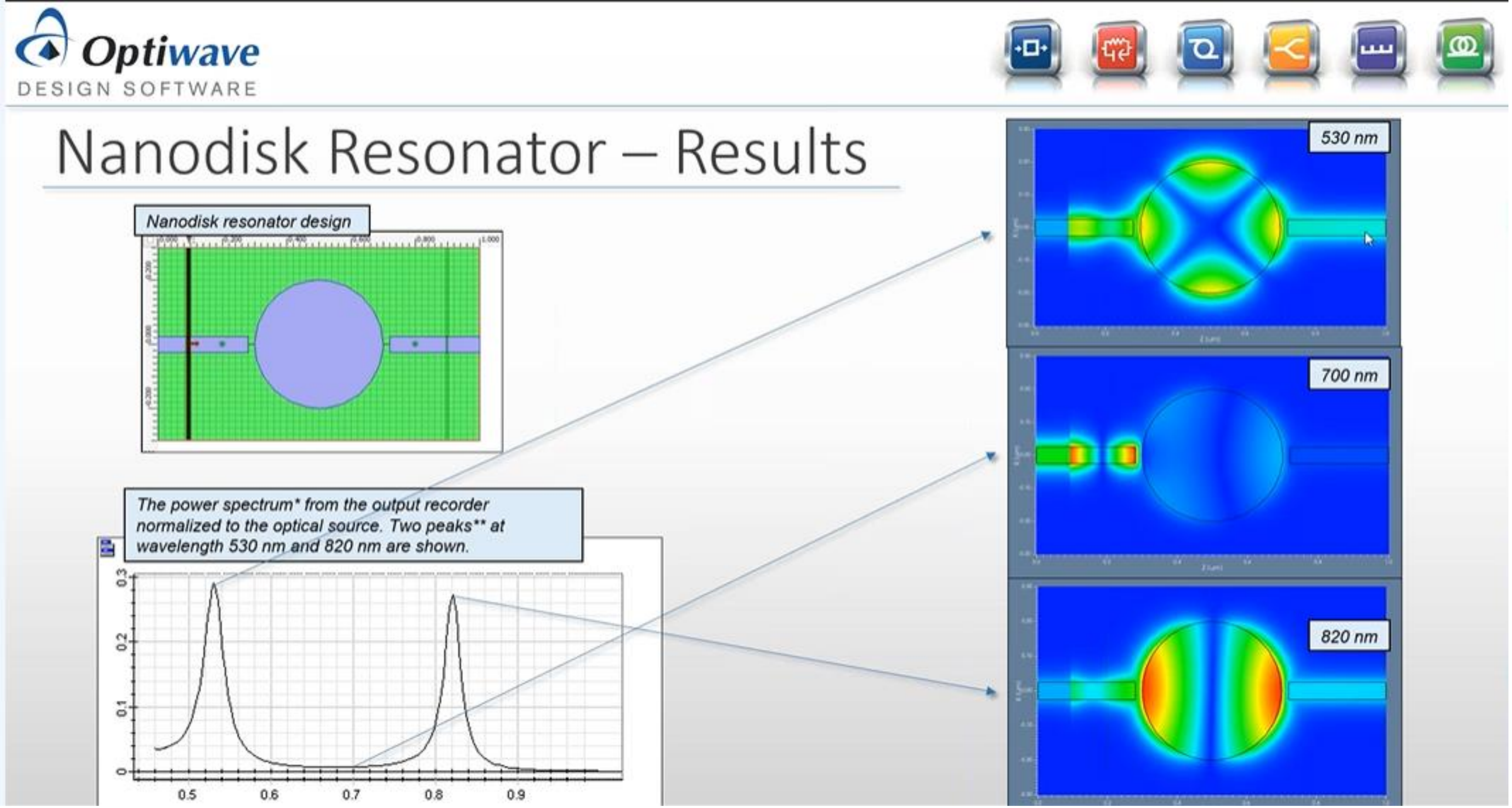
Lu, et al., Opt. Exp. 18, 17922-17927 (2010)

Ring resonator

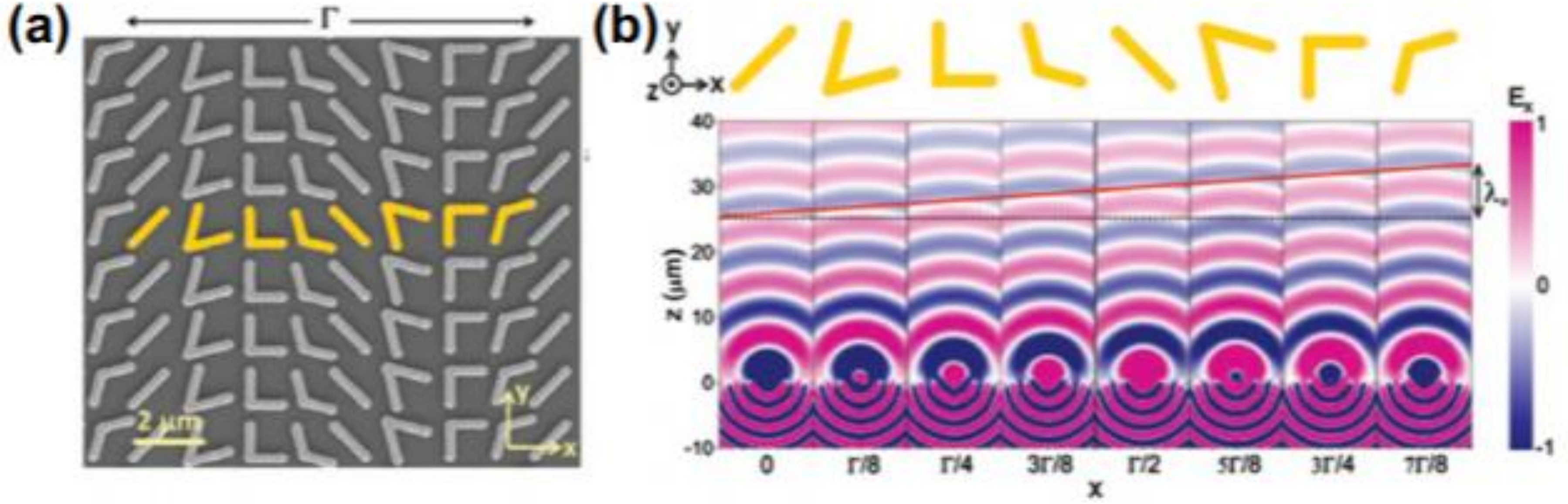


Wang, et al., Opt. Exp. 17, 24096-24101 (2009)

Plasmonic filters- example

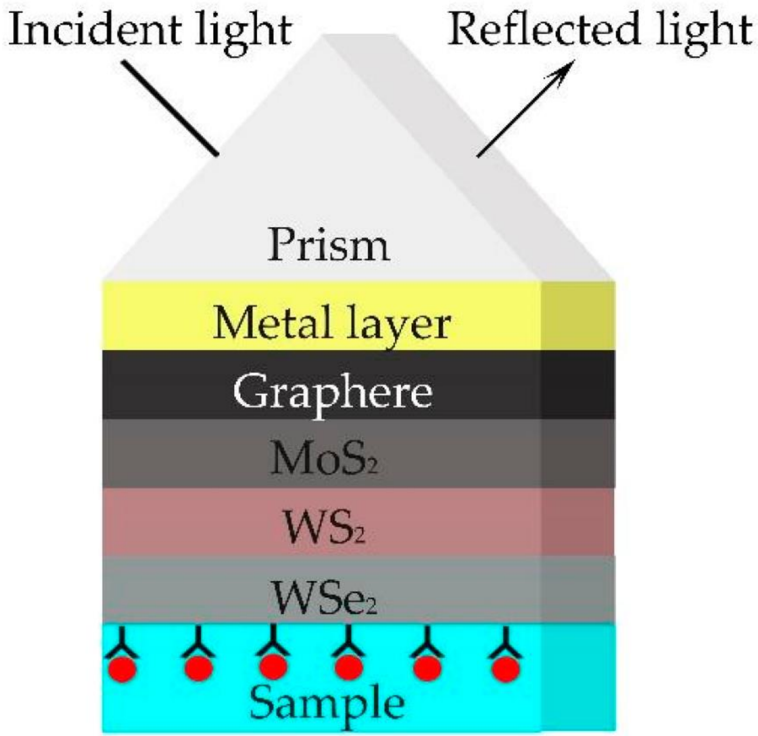


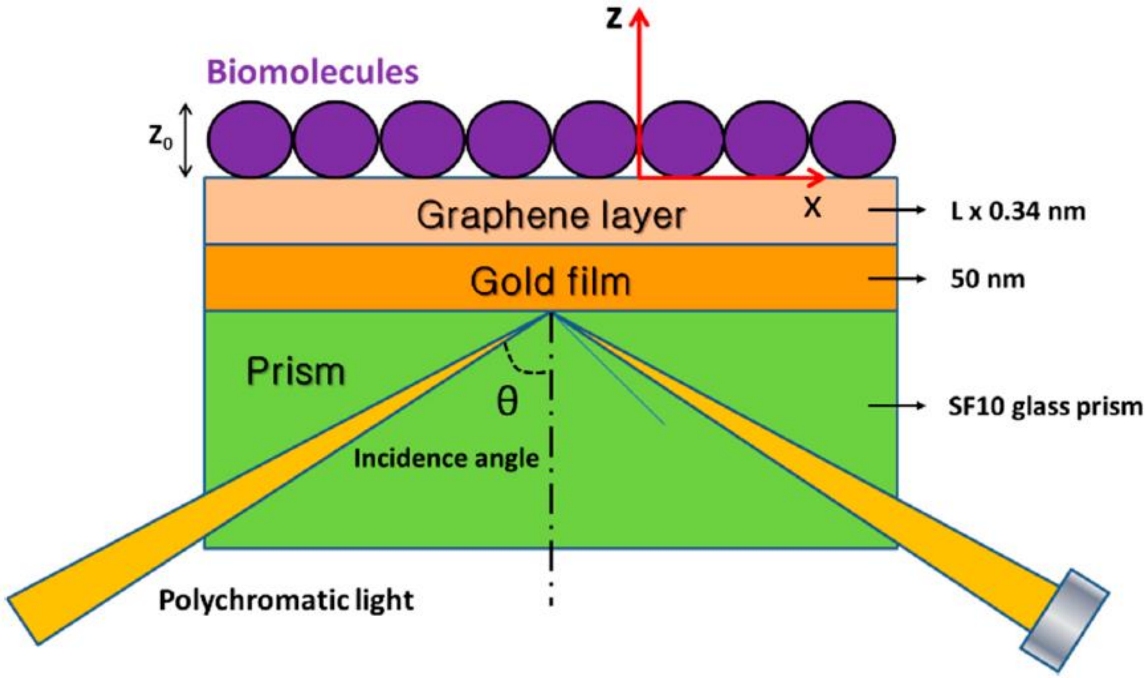
Plasmonic nanoantennas



(a) 2-D array of V-shaped plasmonic nanoantennas, fabricated for operation in the infrared range. (b) Corresponding full-wave simulations of eight selected nanoantenna geometries, demonstrating full phase control of the cross-polarized scattered fields (from [4.45]).

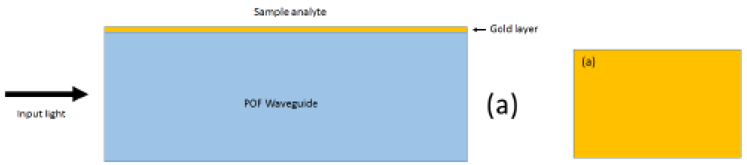
Multilayer implementation structures





Design of surface plasmon resonance sensor in plastic optical fibers based on nano-antenna arrays

Nunzio Cennamoa*, Ramona Galatusb, Francesco Mattielloa, Reem Sweida, Luigi Zenia, Springer 2016



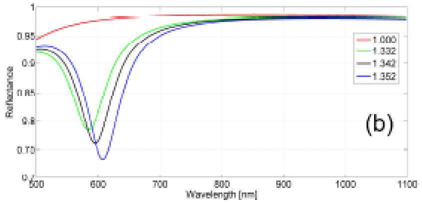


Figure 1: Pol.1 (a) Side view and top view of the SPR Sensor with continuous gold film, (b) Reflectance vs wavelength for various refractive indices of the analyte

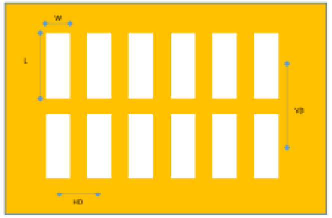
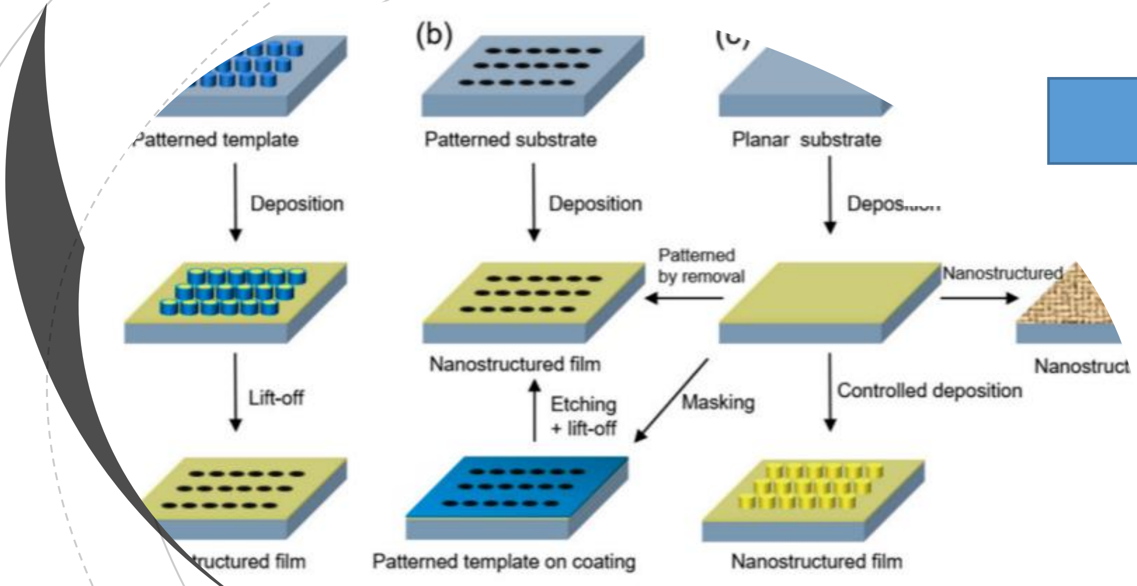


Figure 2: Top view of Nano-slot antenna array

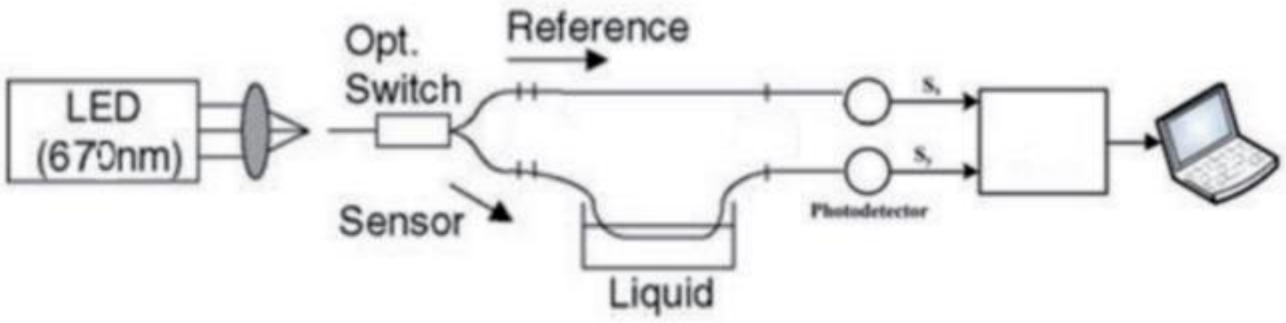


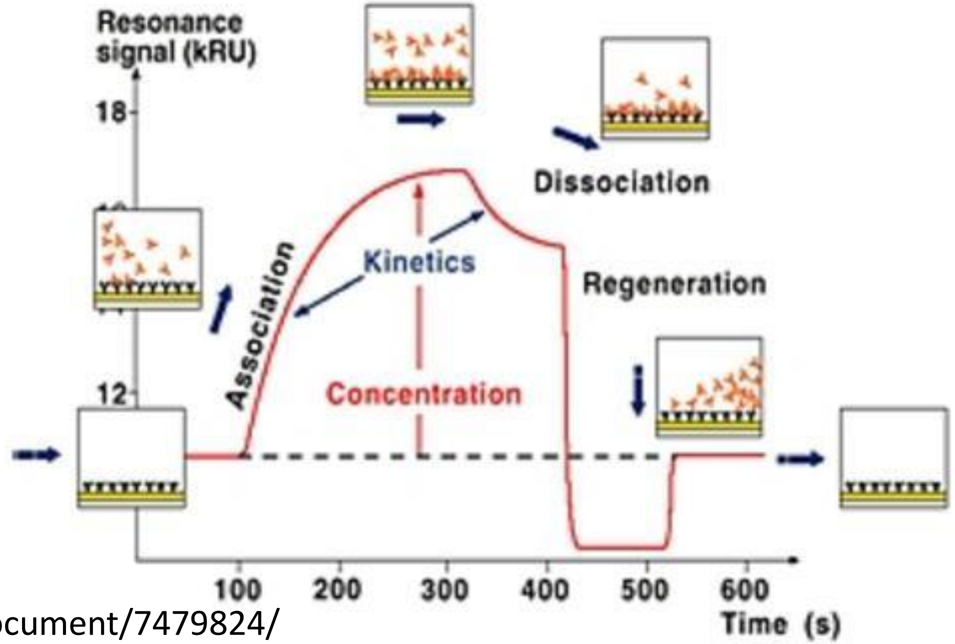
…chematic of commonly applied strategies for the synthesis of plasmonic-ac… from (a) deposition on patterned template, (b) deposition or… …bstrate, and (d) transfer on planar substrate.

Nanoshapes

https://www.tandfonline.com/doi/abs/10.1080/09500340.2019.1610521?journalCode=tmop20

1. Experimental set-up: intensity analysis





A simple arduino-based configuration for SPR sensors in Plastic Optical Fibers
2015, N. Cennamo ; D. Massarotti ; A. Della Monica ; A. G. Di Bussolo ; A. Fiorillo ; L. Zeni
Galatus Ramona Voichita ; Emil Voiculescu ; Nunzio Cennamo ; Luigi Luongo ;
Luigi Zeni, Augmented workplace for SPR sensor application, Sensors Applications Symposium (SAS), 2016 IEEE, Catania, Italy, IEEExplore, DOI: 10.1109/SAS.2016.7479824 , http://ieeexplore.ieee.org/document/7479824/

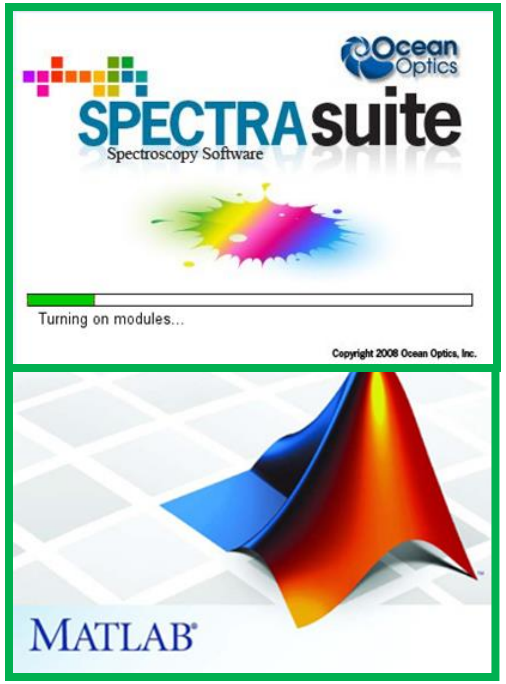
http://www.nbs-c.at/spr.html

Optical Sensors: New Developments and Practical Applications, IntechOpen, 2014

https://books.google.ro/books?id=uDehDwAAQBAJ&pg=PA140&lpg=PA140&dq=cennamo+zeni+surface+plasmon+resonance&source=bl&ots=y-Von22LSK&sig=ACfU3U1vmniGwQXxENGxUjY822VNyJtLpA&hl=ro&sa=X&ved=2ahUKEwio5qWS8cDpAhXlkIsKHb6vBnMQ6AEwBXoECAsQAQ#v=onepage&q=cennamo%20zeni%20surface%20plasmon%20resonance&f=false

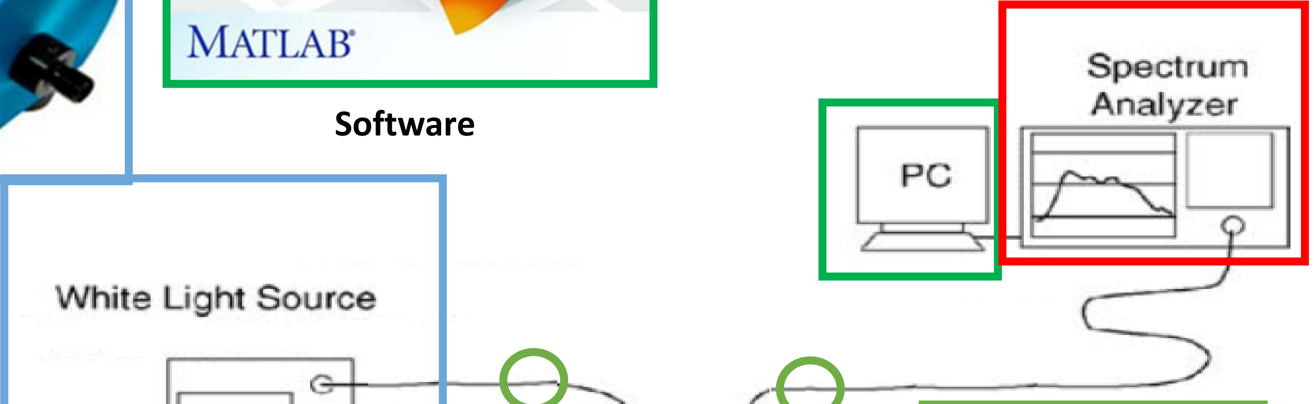
2. Experimental set-up: spectral analysis

White Light Source
(360 ÷ 2000 nm)



Software

Spectrum analyzer
(200 ÷ 850 nm)

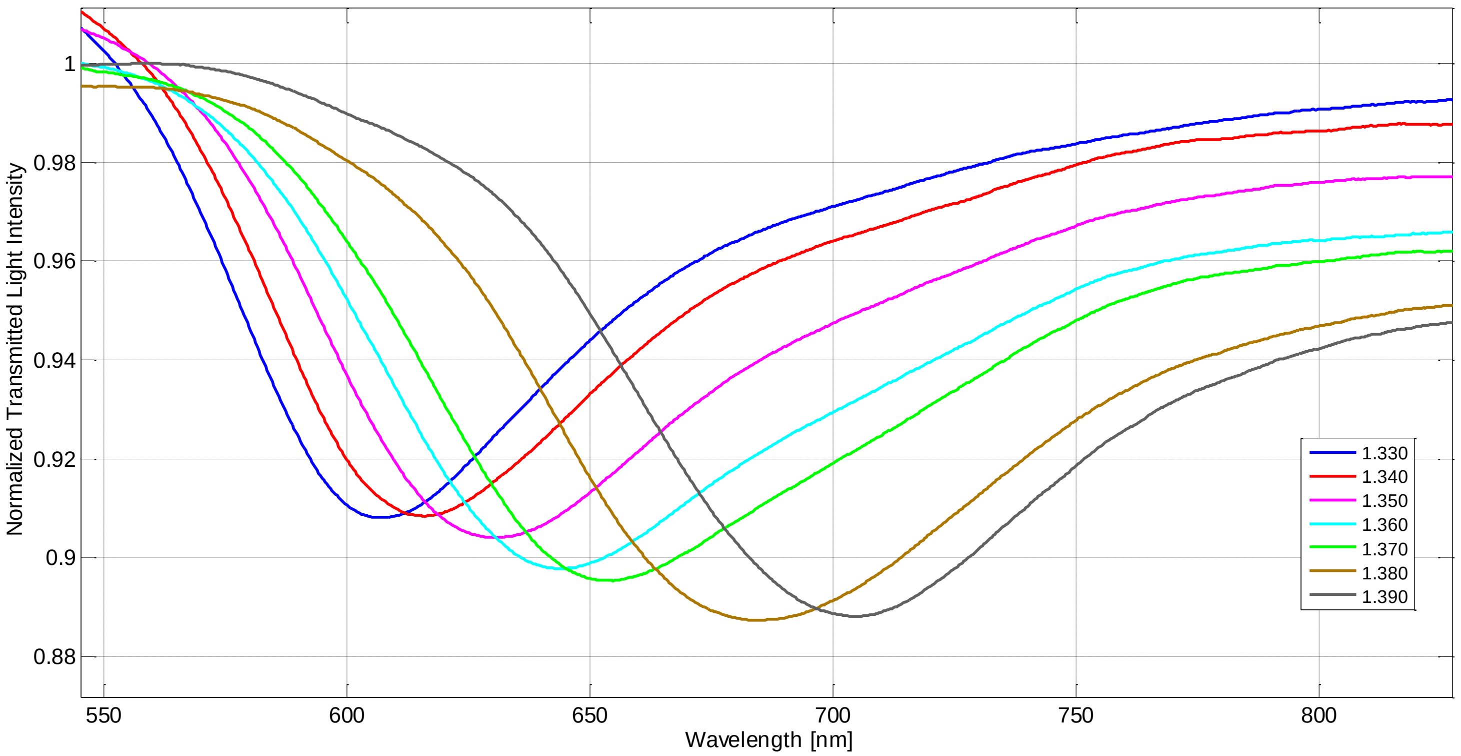


SMA connectors

Optical Sensors: New Developments and Practical Applications, IntechOpen, 2014

Optical platform for biosensor implementation

Basic platform characteristics

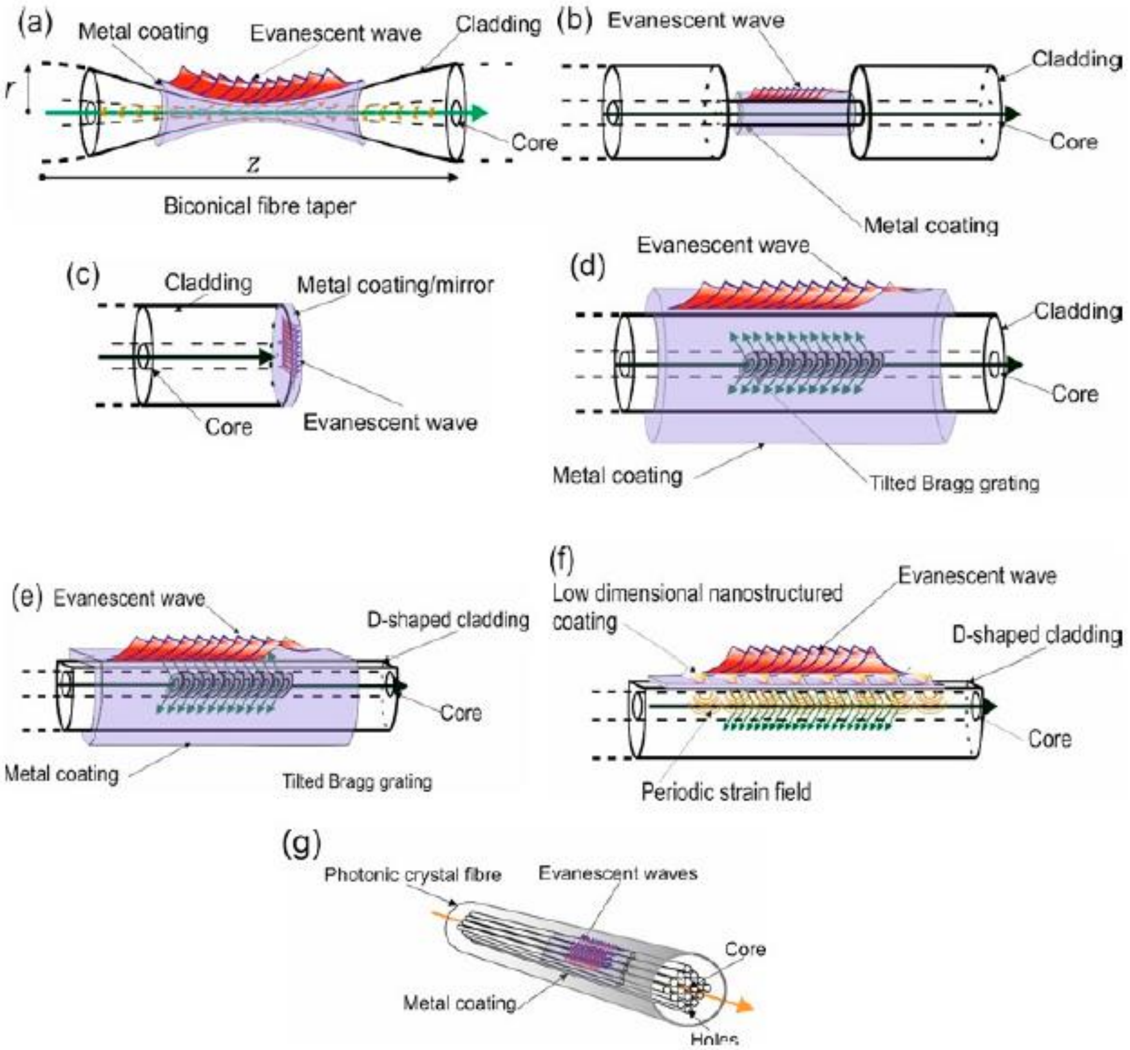


$S = 10^{3} \div 10^{4}$ [nm/RIU]

Optical Sensors: New Developments and Practical Applications, IntechOpen, 2014

After Luigi Zeni DIII-SUN, Erasmus invited professor at TUCN

Basic structures on optical fibers



(**a**) Biconical tapered optical fibre surface plasmon resonance sensor

(**b**) Cladding removed fibre, the coating adhered directly to the core of the fibre.

(**c**) An end-face reflection mirror/coating for the generation of the surface plasmons.

(**d**) and (**e**) Conventional cylindrical optical fibre and D-shaped optical fibre, respectively, with a metal coating with the light coupled from a grating structure; tilted.

(**f**) A low-dimensional nanostructured material/coating using a periodic strain field as the coupling mechanism for the light.

(**g**) Photonic crystal fibre with the metal deposited on the inside of the holes of the fibre which support the surface plasmons.

A Review: Evolution and Diversity of Optical Fibre Plasmonic Sensors, Sensors Journal, 2019, Thomas Allsop and Ron Neal, School of Computing, Communications and Electronics, University of Plymouth, Plymouth PL4 8AA, UK

Table 1. Summary of various fibre tapered plasmonic sensors.

Tapered Fibre Description	Coating (nm)	Sensitivity nm/RIU	Wavelength (nm)	Resolution RIU^{-1}	Index Range	R
Biconical tapered Localised surface plasmons	Au, 24 ± 3	51	537	3.2×10^{-5}	1.33–1.40	
Tapered fibre probe mirrored	Au, 200	400	530–920		1.35–1.42	
Biconical tapered	Ag, 55	2100	500–850	5×10^{-4}	1.326–1.375	
Biconical tapered asymmetric coating	Au, 26	50×10^3	900–1600	1×10^{-5}	1.44–1.446	
Multi-biconical tapered	Cr, 1.6 and Au, 50	2×10^3	500–1000	2×10^{-4}	1.335–1.380	
Multimode Biconical tapered	Au, 50	15×10^3	580–700	1×10^{-5}	1.333–1.343	

A Review: Evolution and Diversity of Optical Fibre Plasmonic Sensors, Sensors Journal, 2019, Thomas Allsop and Ron Neal, School of Computing, Communications and Electronics, University of Plymouth, Plymouth PL4 8AA, UK

Table 2. Summary of various fibre cladding-removed plasmonic sensors.

Unclad Fibre Description	Coating (nm)	Sensitivity nm/RIU	Wavelength (nm)	Resolution RIU^{-1}	Index Range	R
Tip and Nano-patterened, Multimode	Au, 50 ('triangular' size Au, 140 nm)	1610	520–750	3×10^{-4}	1.333–1.346	
Multimode fibre, Two bare sections	Au, 50 and Au, 50 nm+ silicone gel, few mm	1700	600–1400	1×10^{-4}	1.333–1.35	
Multimode fibre, Two bare sections	Ag, 30–50 and Ag, 30–50	2000	500–850	1×10^{-3}	1.33–1.38	
Single section multicoatings	ITO, 80 Ag, 40	3×10^{3}	580		1.33–1.36	
Multimode fibre, Two bare sections	Ag, 40 and Cu, 40		500–840	2.4×10^{-5}	1.3365–1.5859	
Single section and molecular imprinted polymer	Ag, 40	8×10^{3}	400–800	3.5×10^{-5}	1.38–1.385	
Polarisation maintaining fibre exposed core	Au, 55 and Ta_2O_5, 15	3150	770–880	4×10^{-4}	1.33–1.35	
coreless fibre connected to multimode fibre	Au, 40	2.7×10^{3}	350–1100	8×10^{-5}	1.3335–1.4019	
PCF D-shaped with rectangular lattice	Au, 30	8.1×10^{3}	600–900	1.2×10^{-5}	1.33–1.41	

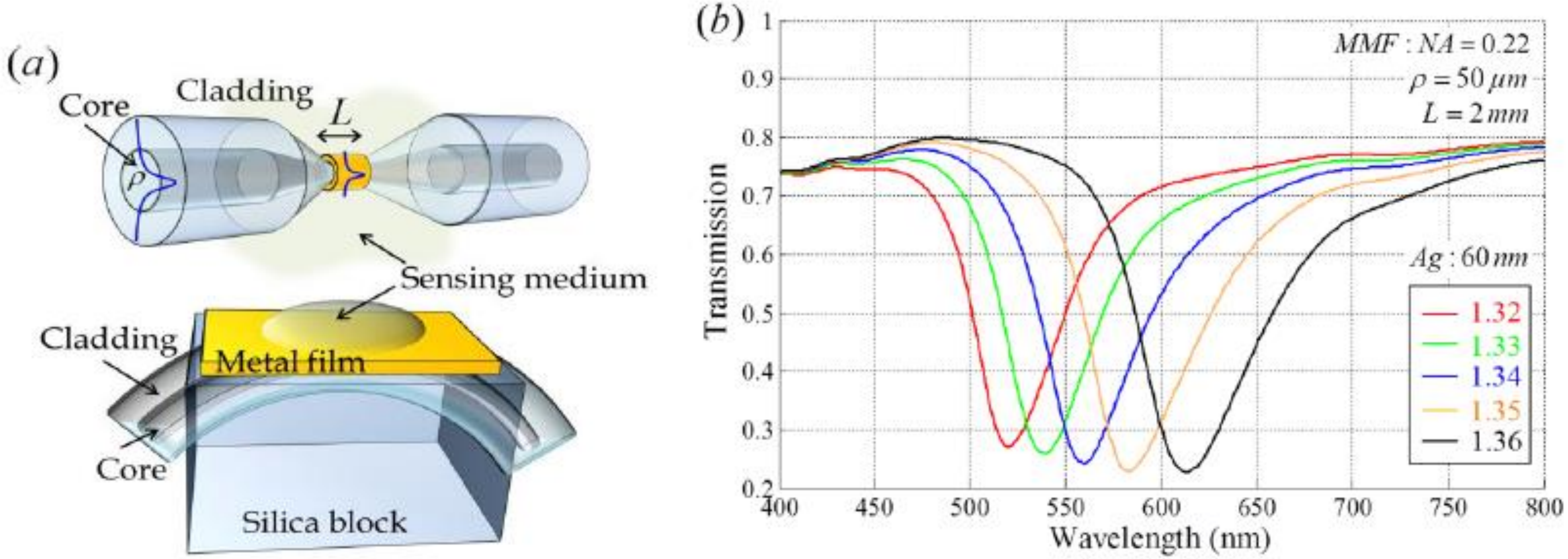
A Review: Evolution and Diversity of Optical Fibre Plasmonic Sensors, Sensors Journal, 2019, Thomas Allsop and Ron Neal, School of Computing, Communications and Electronics, University of Plymouth, Plymouth PL4 8AA, UK

Table 4. Summary of various fibre grating plasmonic sensors.

Grating Fibre Description	Coating (nm)	Sensitivity dB or nm/RIU	Wavelength (nm)	Resolution RIU^{-1}	Index Range
Single mode fibre small angled FBG, D-shaped	Au, 32	3365	1220–1700	5×10^{-6}	1.30–1.38
Single mode fibre with LPG	Au colloids, 8.4 ± 2.8	23	1510–1550	3.2×10^{-4}	1.33–1.4344
Single mode fibre, angled FBG	Cr, 2–3, Ag, 20–50	8100	1440–1550	1×10^{-5}	1.34–1.3408
Single mode fibre with LPG	Au, 20–50	12	653–667	1×10^{-5}	1.33–1.38
Single mode fibre small angled FBG,	Au, 50	1000	1450–1560	1×10^{-4}	1.3363–1.3364
Single mode fibre small angled FBG,	Au, 10–30	470	1520–1560	6×10^{-5}	1.3335–1.4019
Single mode etched fibre small angled FBG,	Cr, 2 and Au, 30	510	1520–1590	6.8×10^{-5}	1.335–1.432
Single mode fibre mid-range angled FBG,	Au, 50	5515	1280–1560	1×10^{-8}	1.30–1.44 and Air

A Review: Evolution and Diversity of Optical Fibre Plasmonic Sensors, Sensors Journal, 2019, Thomas Allsop and Ron Neal, School of Computing, Communications and Electronics, University of Plymouth, Plymouth PL4 8AA, UK

Plasmonic on optical fibers



Surface plasmon sensors

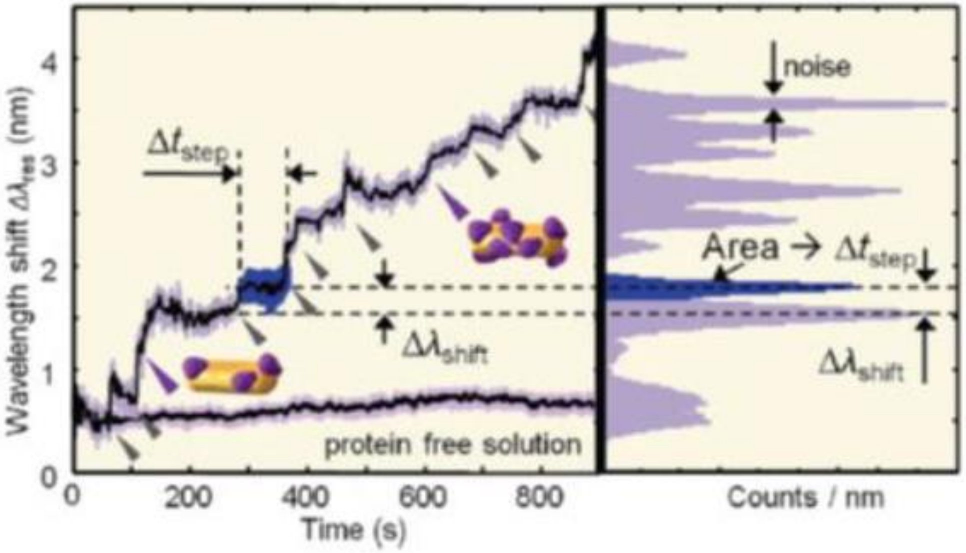
- Properties
  - Highly sensitive (10^{-4} to 10^{-6} RI units)
  - Very local (10-100nm from sensing surface)
  - Directly indicative (of interactions between sensor and environment)
  - Readily referenced to compensate for background fluctuations (e.g. drift)
- How is it used (SPR = transduction mechanism)?
  - Non-functionalized = bulk refractive index
  - Functionalized = specific analytes

Biosensor: A device that uses specific biochemical reactions mediated by isolated enzymes, immunosystems, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signals with appropriate transduction mechanism.

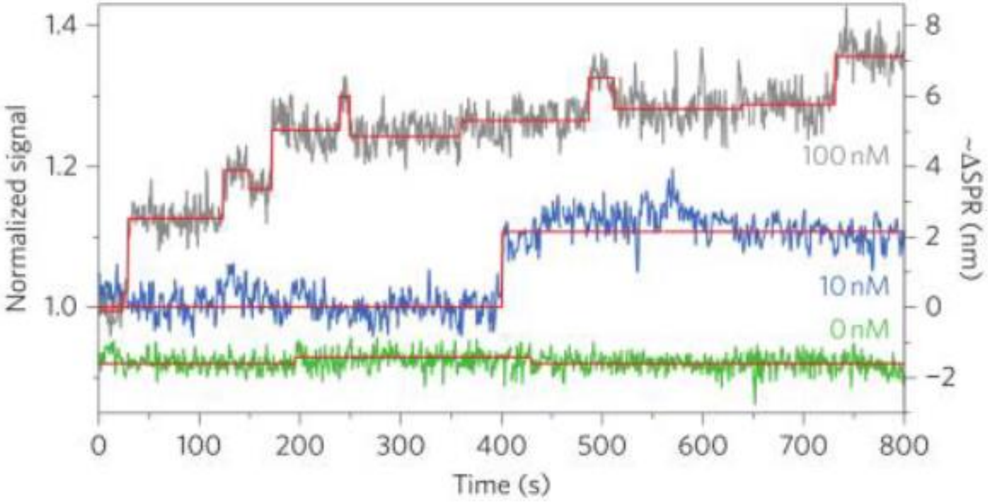
Non-functionalized: Single molecule detection

Very large proteins adsorbing directly on the surface.

Help of complementary techniques can make it slightly better…



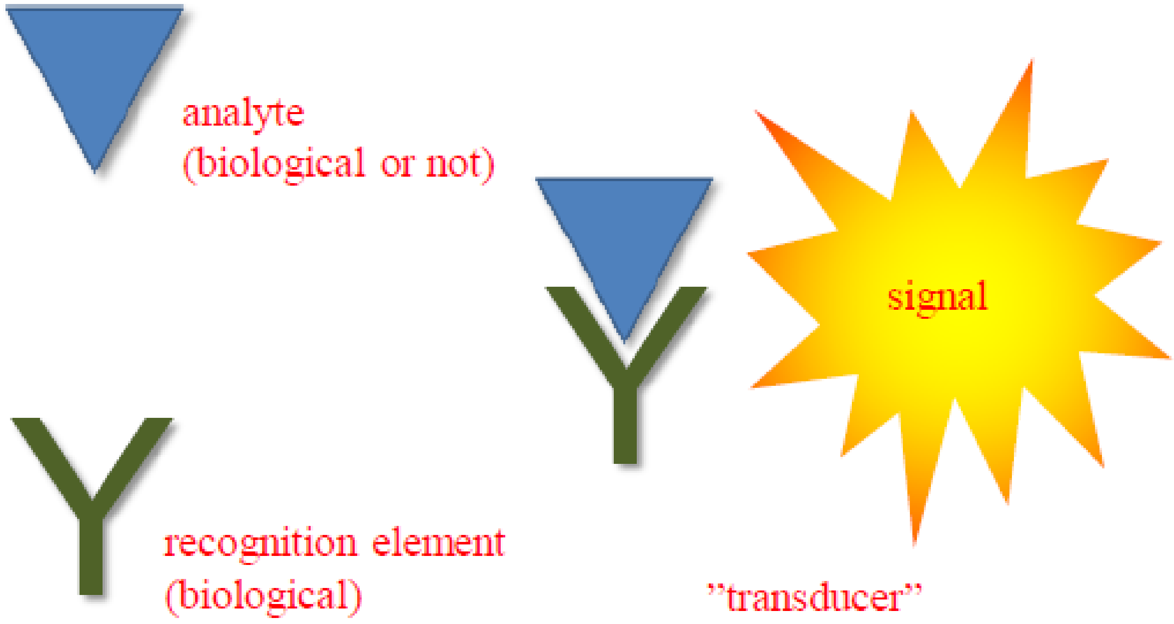
Ament et al.
Nano Letters **2012**



Zijlstra et al.
Nature Nanotechnology **2012**

Functionalized surface

The use of recognition elements (or *receptors*) is sometimes referred to as "affinity based" biosensing.



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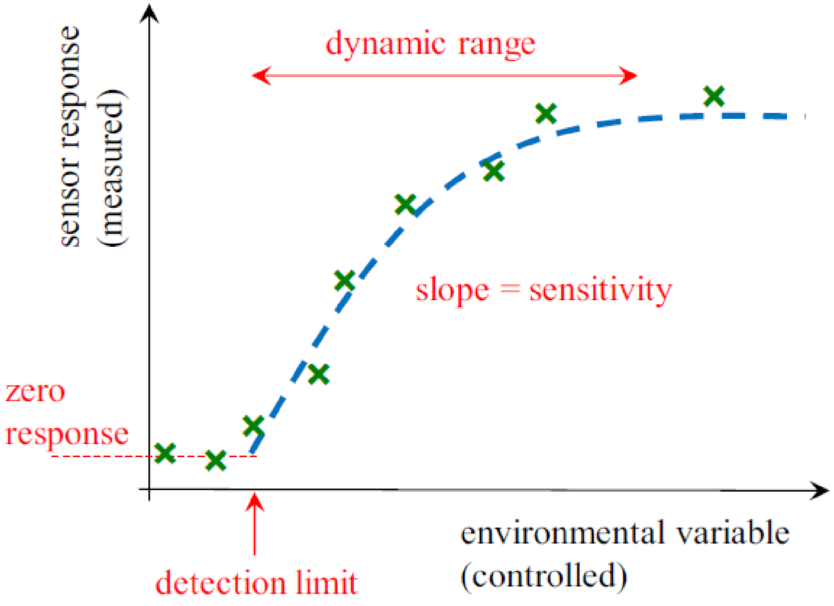
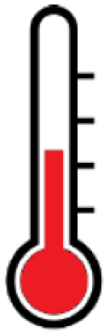
https://www.adahlin.com/teaching.html

Calibration curve

Most sensors, not the least biosensors, need to *calibrated*. In a calibration experiment the response to known doses of the variable of interest is measured.

The *sensitivity*, *dynamic range* and *detection limit* are defined from the calibration curve.



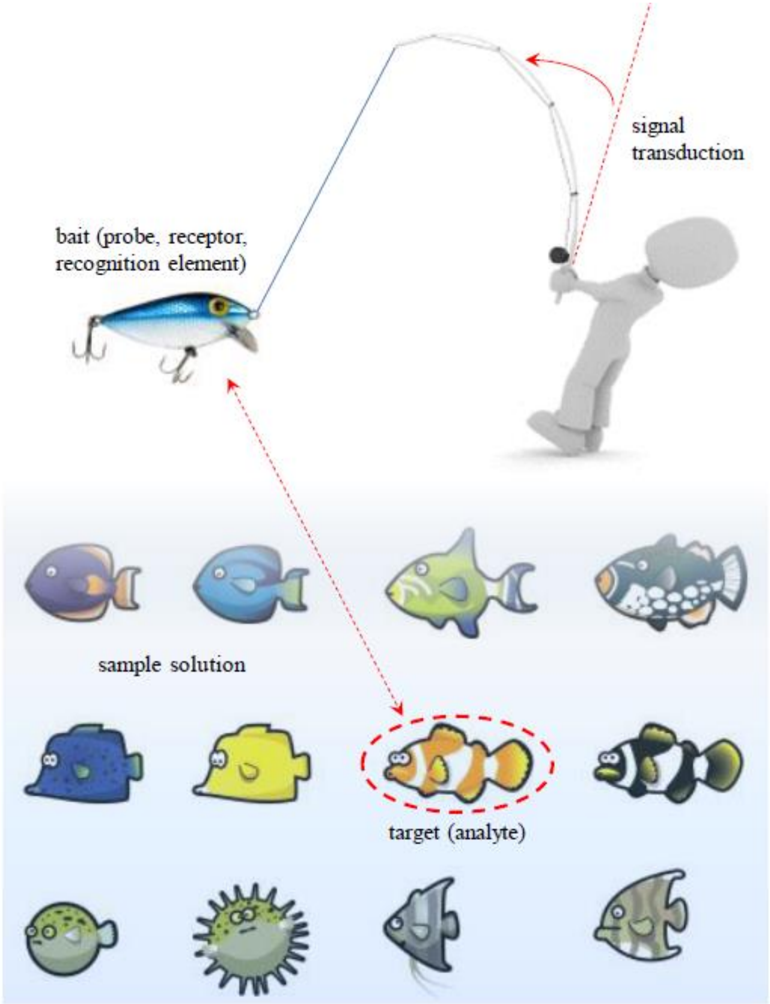


Specificity

Most biosensors need to operate *label-free* to be useful. This means that they work even if the analyte does not carry any artificial label.

When operating label-free, the biggest problems in biosensor technology is arguably false positive results.

When we search for analytes (fish) in biological samples we will always have a lot of other molecules (fishes) present that can interfere with the detection.



Parameters

- instrument used in analysis
- dentity,
- source,
- molecular weight of ligand and
- Analyte
- surface type
- immobilization condition
- ligand density
- experimental buffers
- experimental temperature
- analyte concentrations
- regeneration condition
- figure of binding responses with fit overlay of replicate analyses
- model used to fit the data binding constants with standard errors

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Biofunctionalized surface

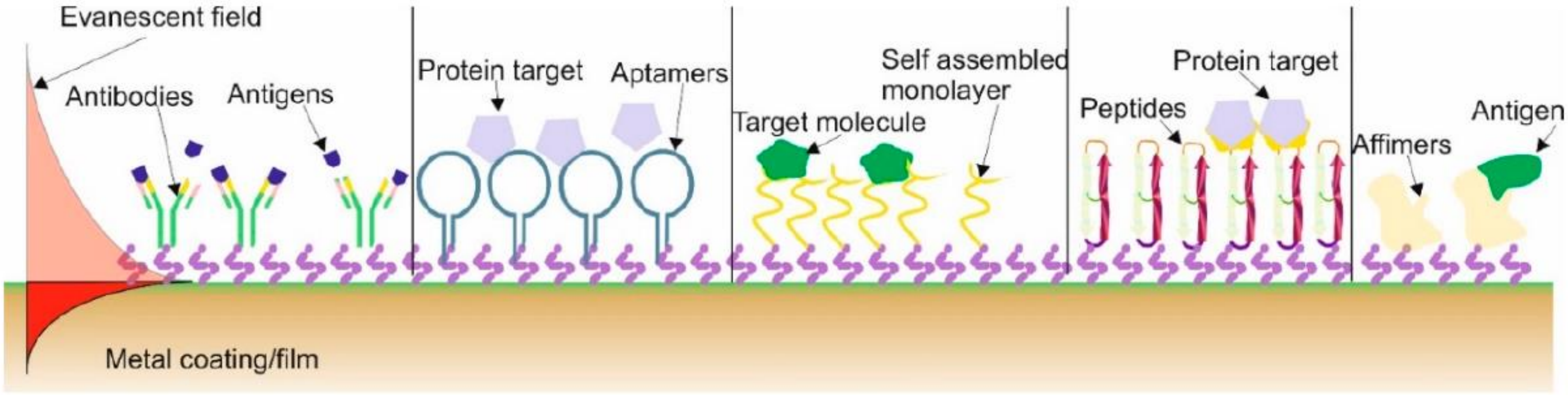


Figure 6. Schematic of a biofunctionalised metal-coated optical fiber surface with the most commonly used strategies to attract specific analytes.

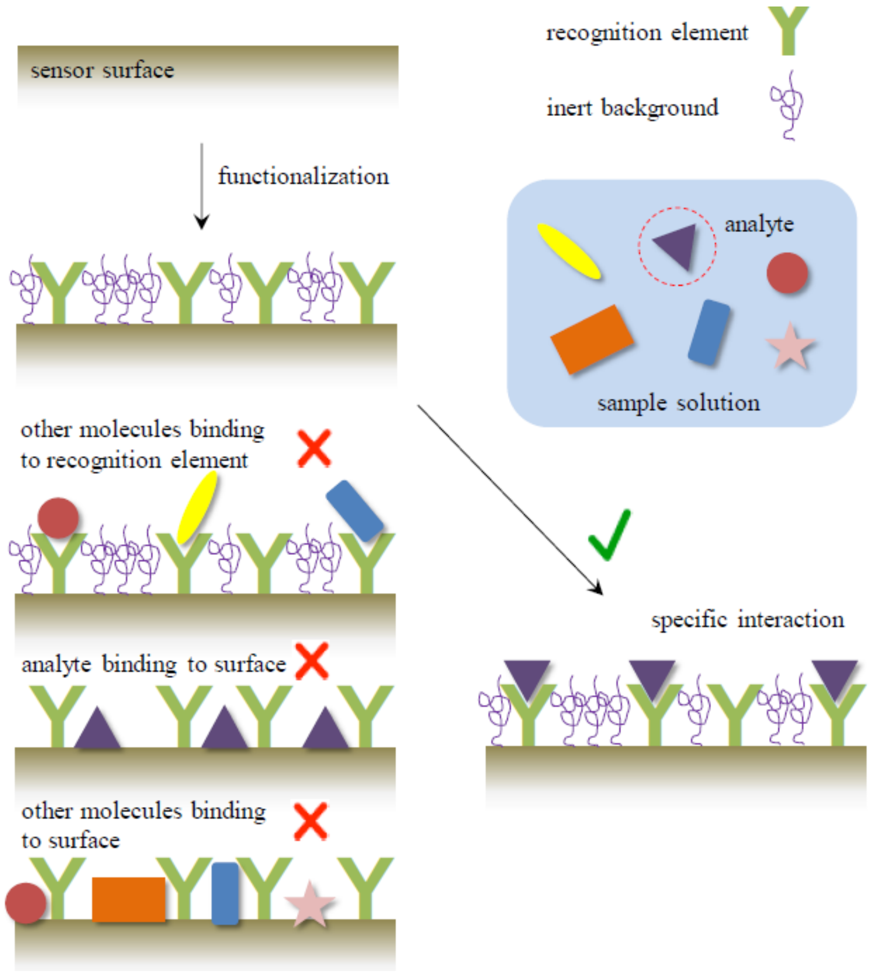
A Review: Evolution and Diversity of Optical Fibre Plasmonic Sensors, Sensors Journal, 2019, Thomas Allsop and Ron Neal, School of Computing, Communications and Electronics, University of Plymouth, Plymouth PL4 8AA, UK

Surface functionalization

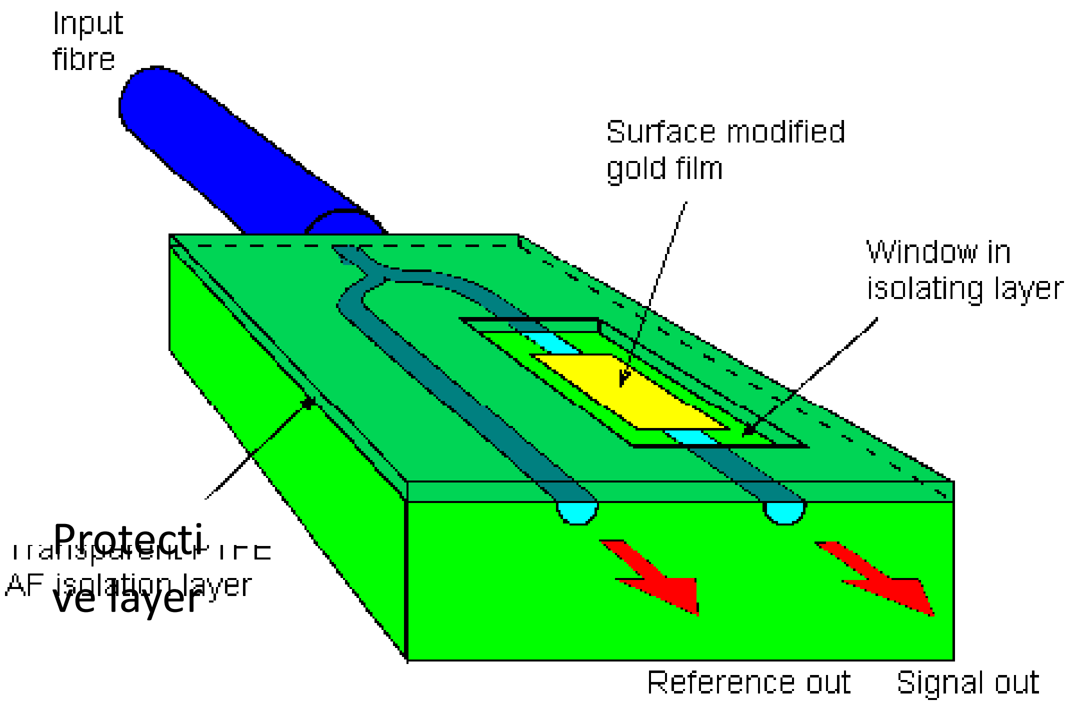
The surface must be chemically functionalized such that only the analyte binds.

The techniques work in real-time, which gives information about *binding kinetics*.

Optical techniques like SPR often enable *multiplexing* , detection of multiple targets, by imaging mode.



Integrated surface plasmon resonance sensor



Optical Sensors: New Developments and Practical Applications, IntechOpen, 2014

After Luigi Zeni DIII-SUN, Erasmus invited professor at TUCN

Next: Presentation adapted after Prof Luigi Zeni DIII-SUN, Erasmus invited professor at TUCN, 2015

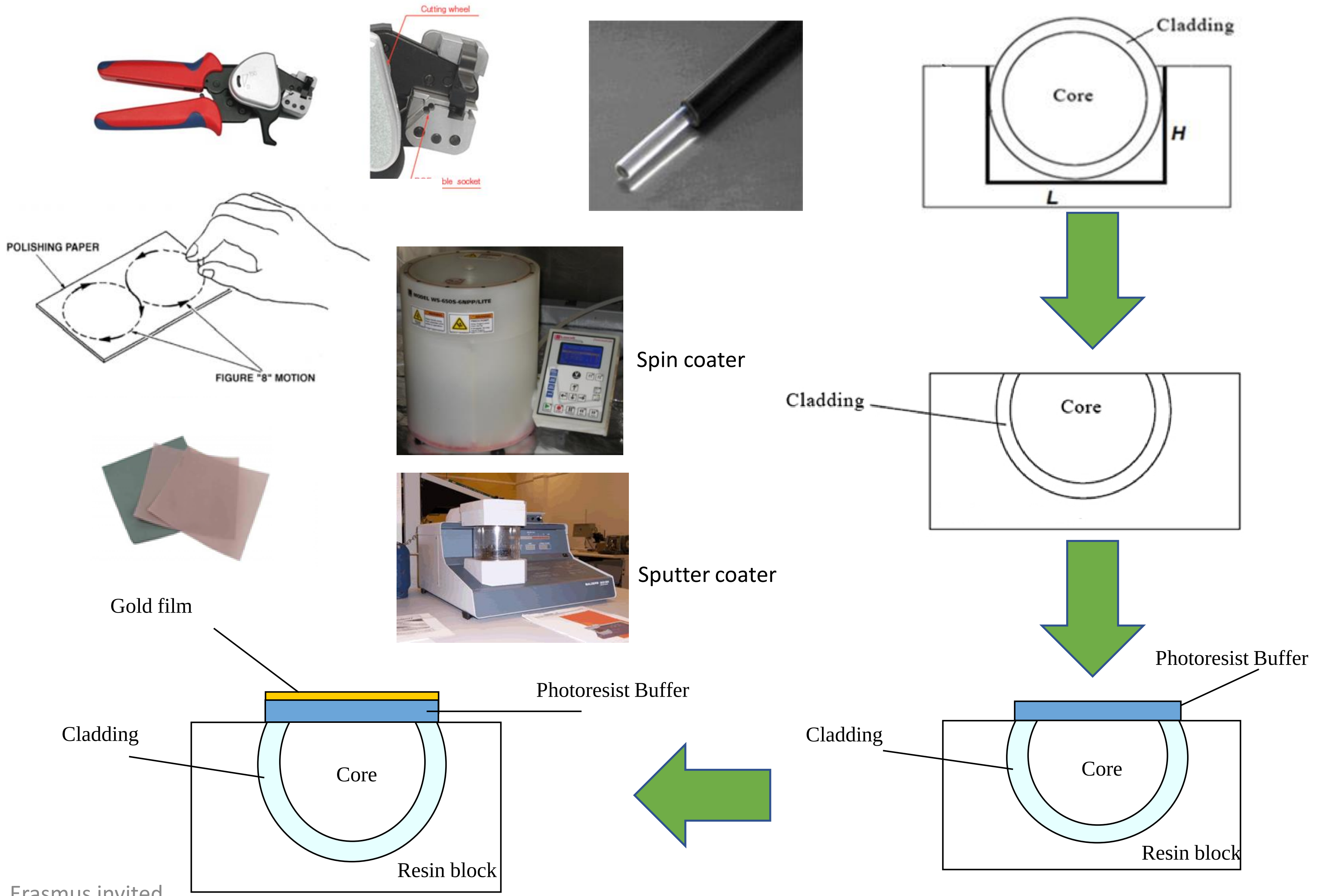
Papers about SPR, published with TUCN and UNINA cooperation at:

http://www.bel.utcluj.ro/~galatusr/pubs.html

And National Research Council in Italy:

http://www.irea.cnr.it/en/index.php?option=com_comprofiler&task=userprofile&user=913&Itemid=100

Fabrication: A simple optical platform - SPR in POF



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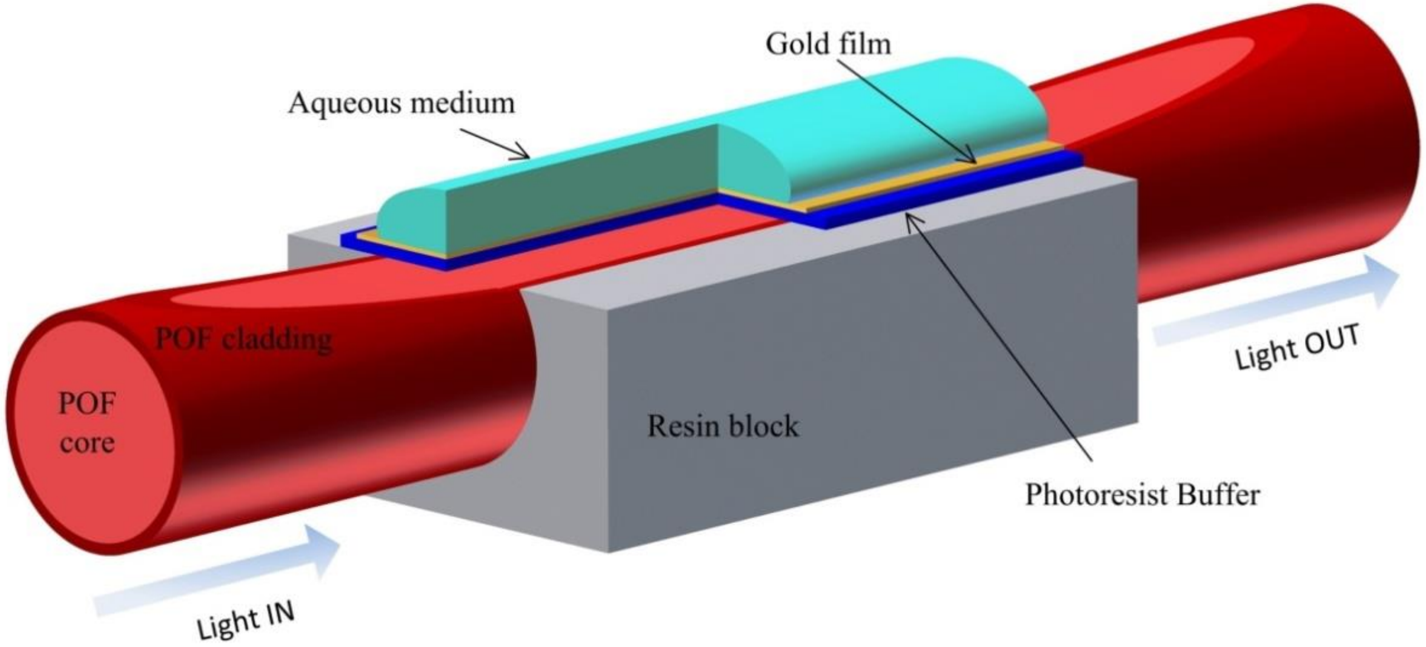
A simple optical platform: SPR in POF

- Core (PMMA) 980 µm ; RI=1.49
- Fluorinated cladding 20 µm; RI=1.41
- Microposit S1813 Photoresist 1.5 µm; RI=1.61
- Gold film 60 nm



POFs are especially advantageous due to their excellent flexibility, easy manipulation, great numerical aperture, large diameter, and the fact that plastic is able to withstand smaller bend radii than glass!

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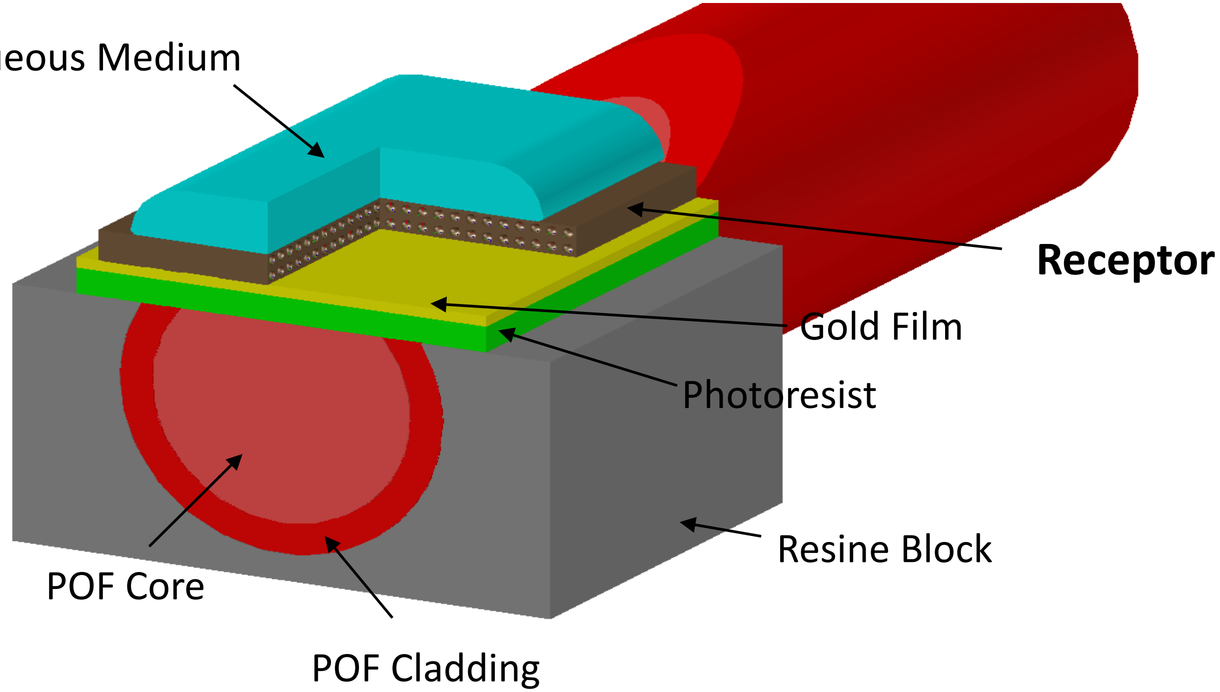
SPR Bio/Chemical Sensors



Platform exploiting a suitable receptor layer

Results have been achieved on the selective detection of:

- **TNT** for **security applications**
- **Furfural** (furan-2-carbaldehyde) for **industrial applications**
- **Butanal** for **environmental monitoring** & **food safety**
- **Transglutaminase/anti-transglutaminase antibodies (celiac disease), Fe(III), L-nicotine and Vascular Endothelial Growth Factor (VEGF)** for **clinical applications** & **cancer diagnosis**

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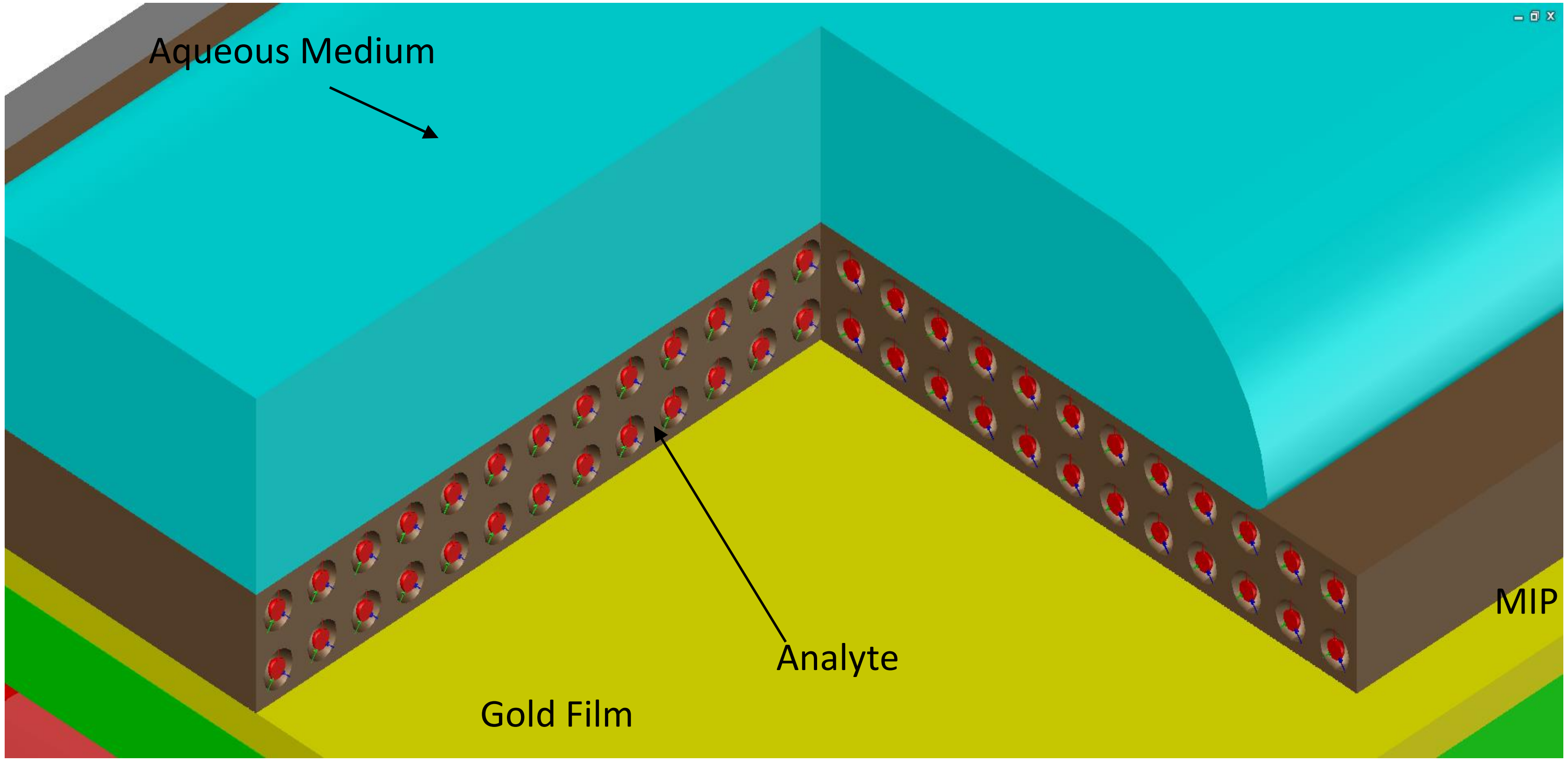
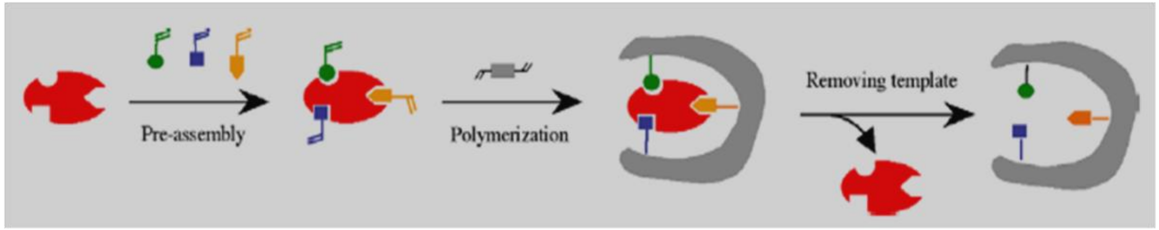
Synthetical Receptor: Molecular Imprinted Polymer (MIP)

A porous solid obtained by polymerization of the aggregate substrate-coordinating monomers after extraction of the template from the selective site.





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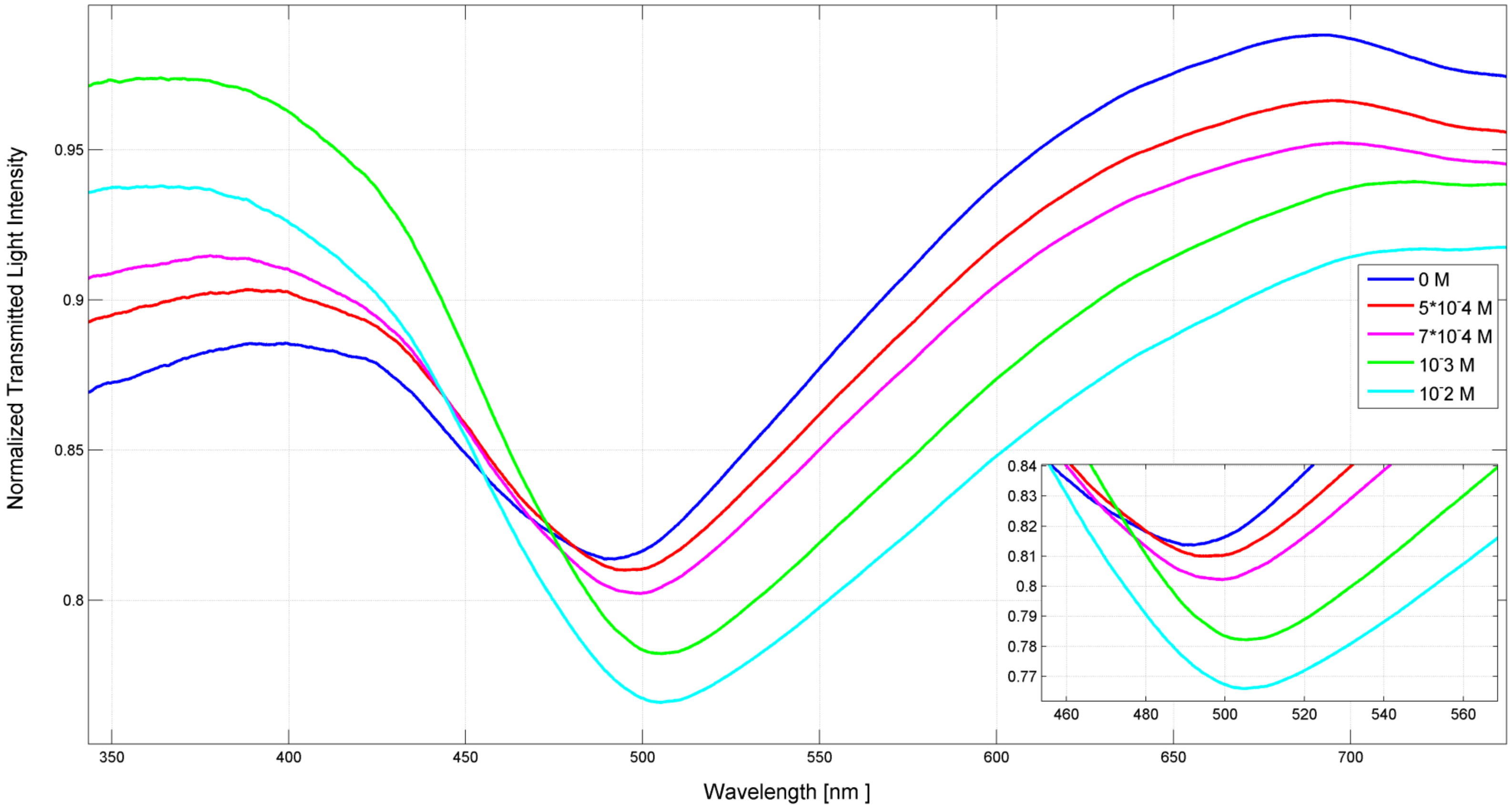
Clinical applications: MIP for the detection of L-nicotine



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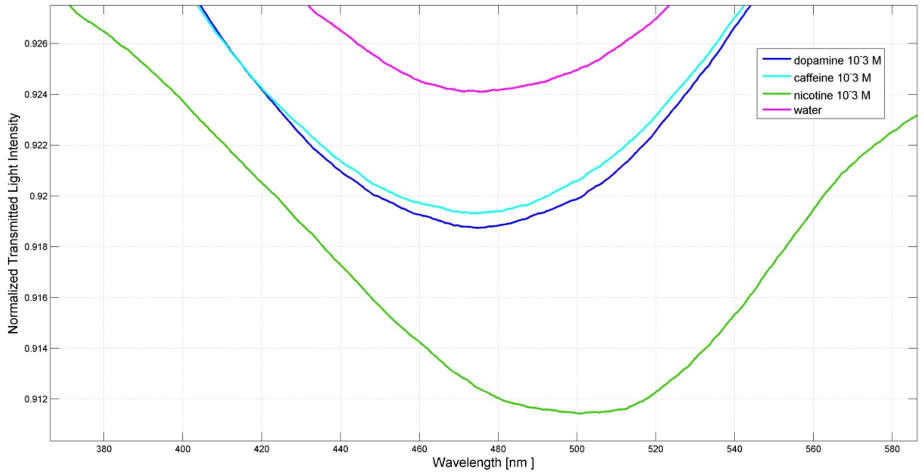
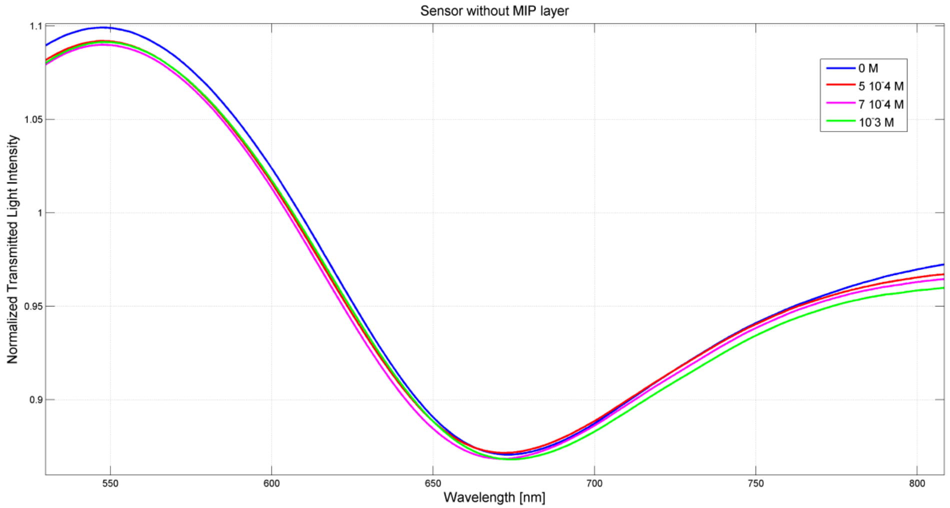
Clinical applications: MIP for the detection of L-nicotine

SPR transmission spectra for different analytes: L-nicotine, caffeine and dopamine. For comparison, the spectrum of pure water is reported

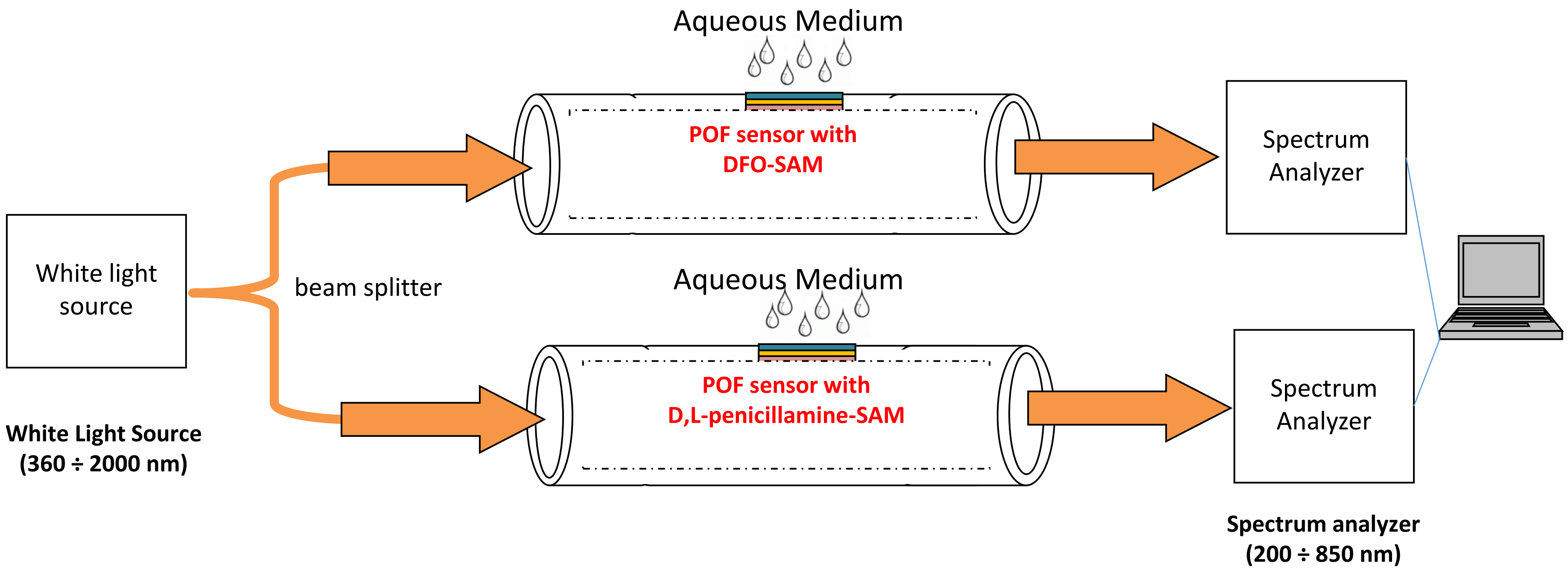


SPR transmission spectra, without MIP layer, for different concentrations of L-nicotine



Clinical applications: simultaneous detection of Fe(III) and Cu(II)

Experimental Setup to measure the transmitted light spectrum



Measurements were carried out with an experimental setup arranged to measure the transmitted light spectra and was characterized by a halogen lamp, a beam splitter, two optical chemical sensors and two spectrometers.

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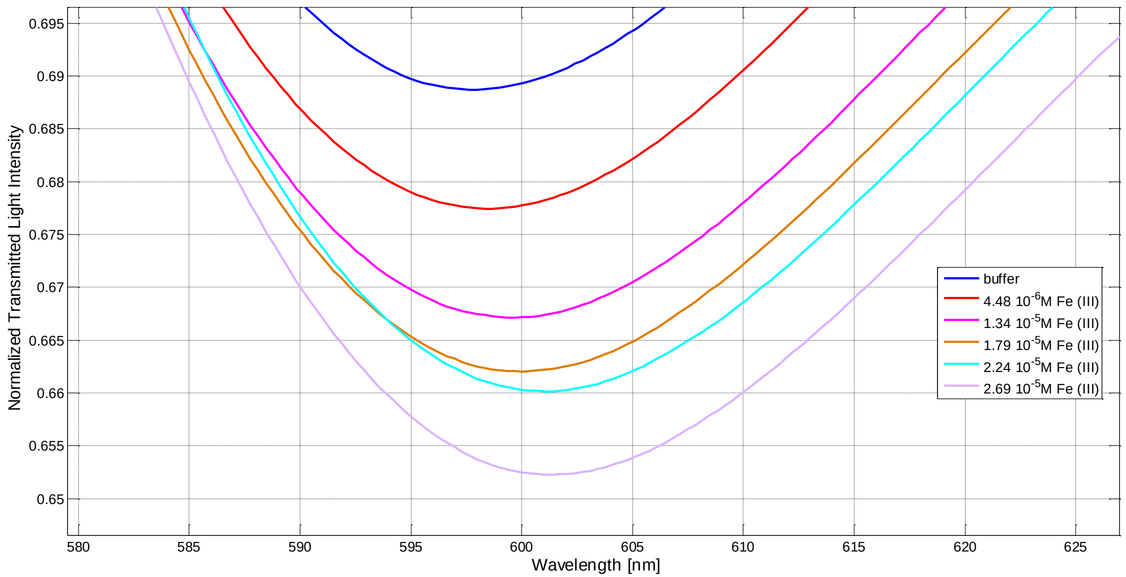
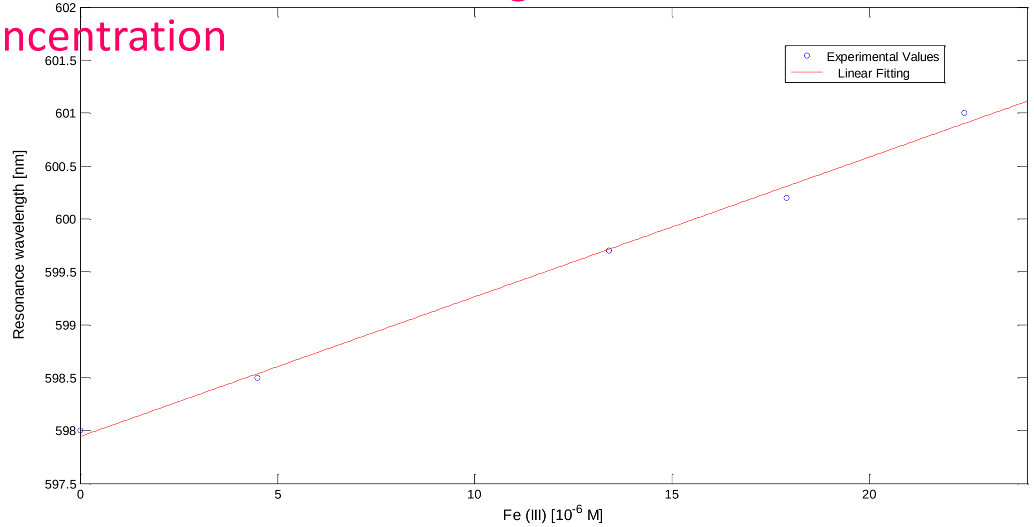
Experimental results: DFO-SAM-POF

Transmission spectra at increasing concentration of Fe(III)

Iron detection



Plasmon resonance wavelength variation as a function of Fe (III) concentration



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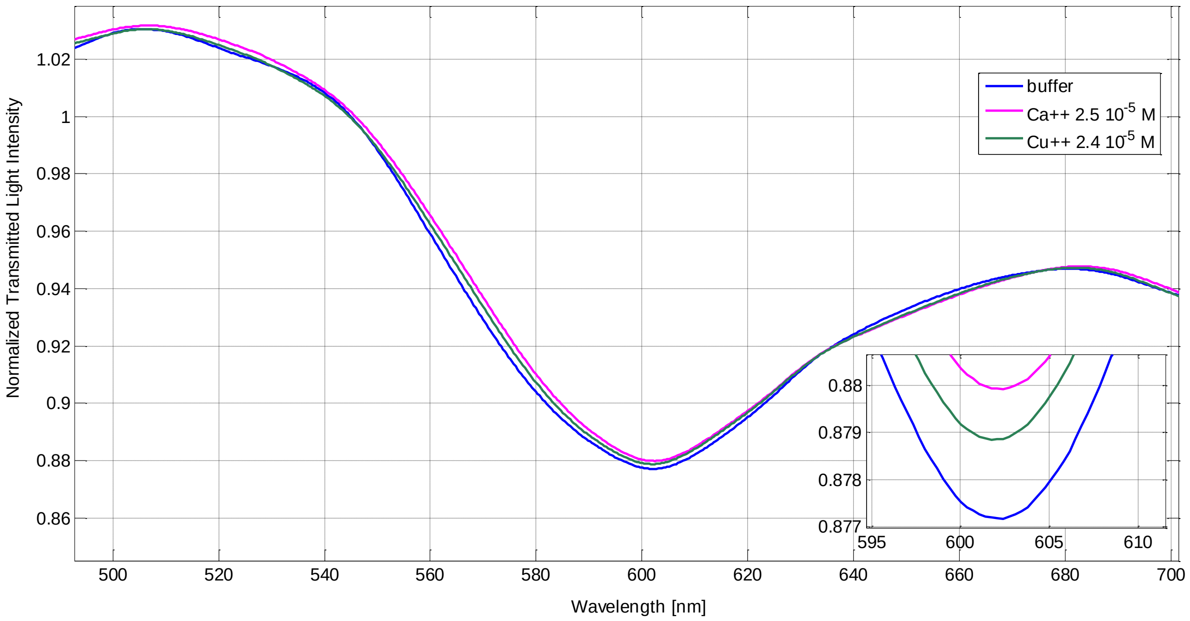
Experimental results: DFO-SAM-POF

Selectivity check: SPR transmission spectra obtained on DFO-SAM-POF sensor for Cu^{2+} and Ca^{2+}

Iron detection



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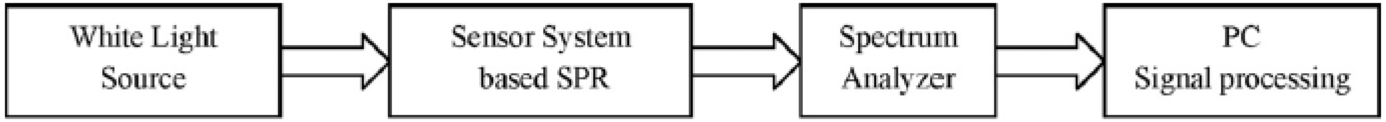
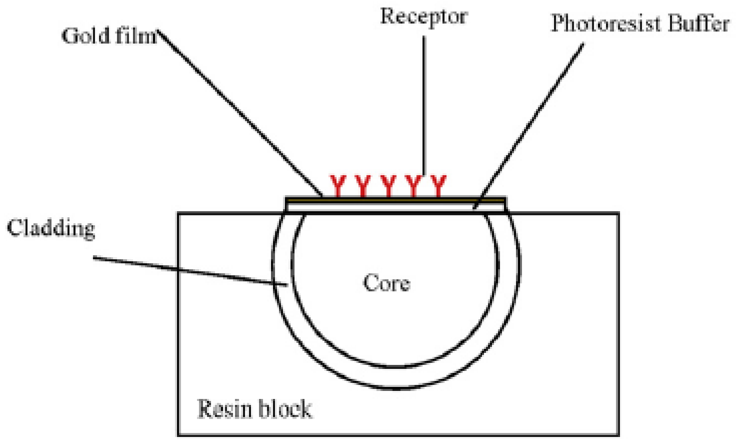
Clinical applications: the transglutaminase/antitransglutaminase complex





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Clinical applications: the transglutaminase/antitransglutaminase complex

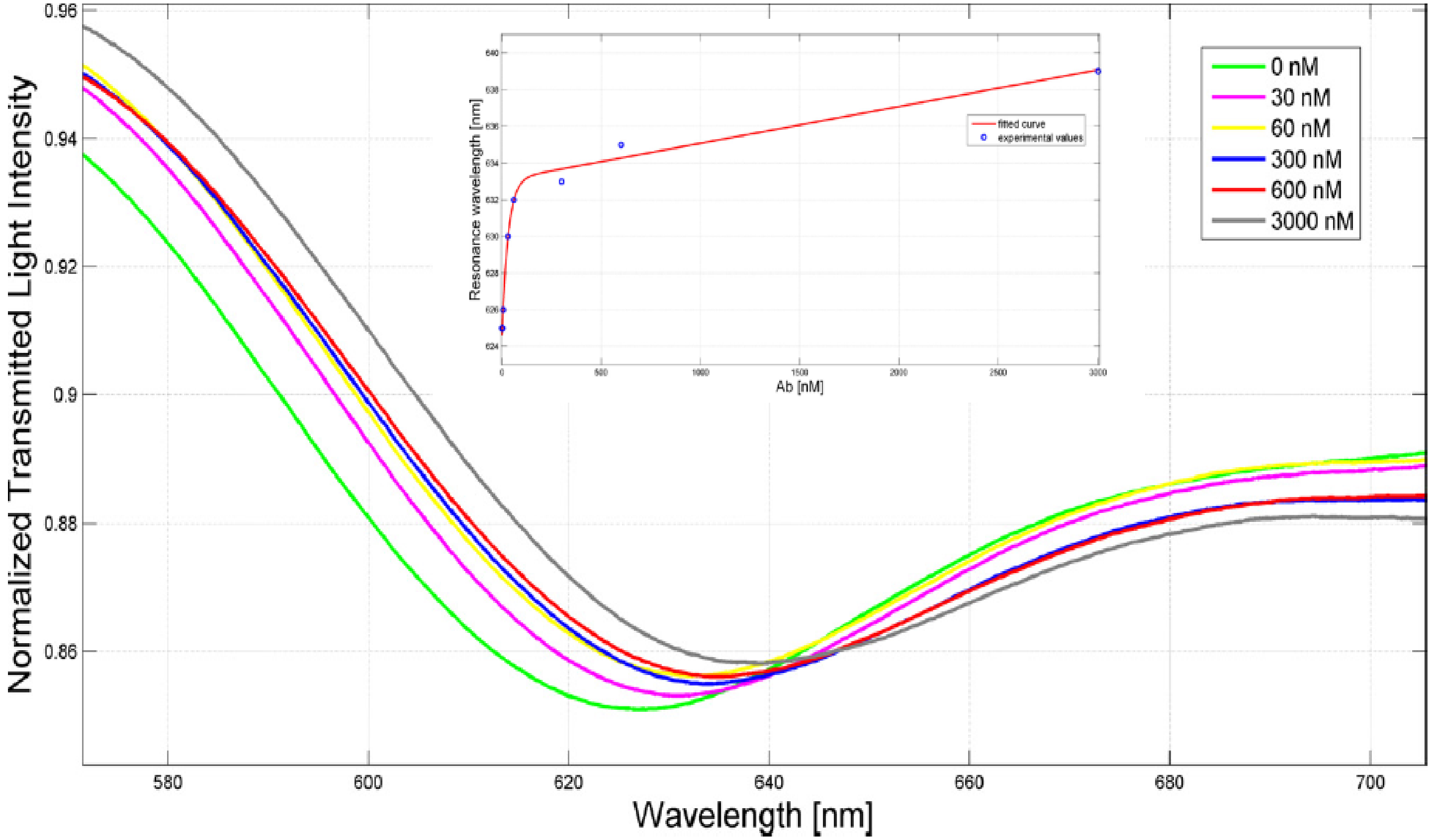


Fig. SPR transmission spectra, normalized to the air spectrum, for different analyte concentrations in the case of sensor with gold layer with tTG (bio-receptor).

Clinical applications: the transglutaminase/antitransglutaminase complex

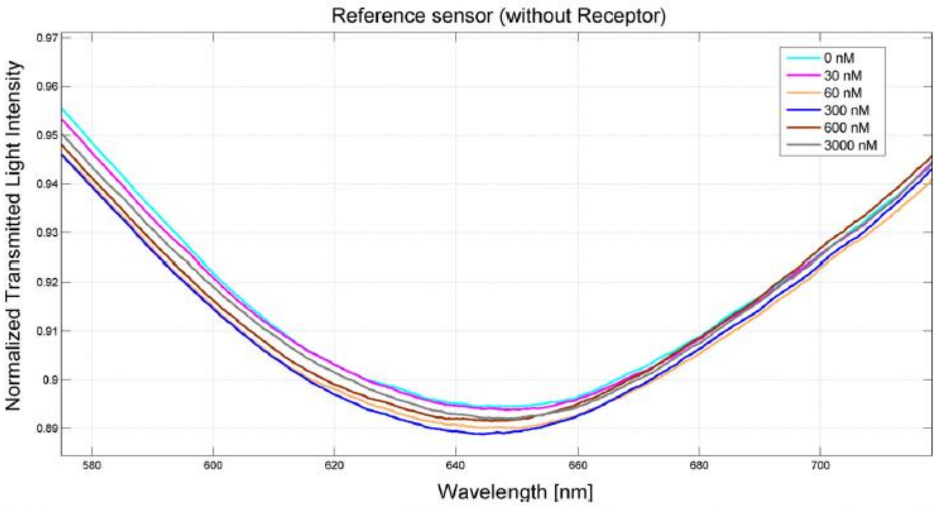


Fig. SPR transmission spectra, normalized to the air spectrum, for different analyte concentrations in the case of the reference sensor with gold layer without tTG (bio-receptor).

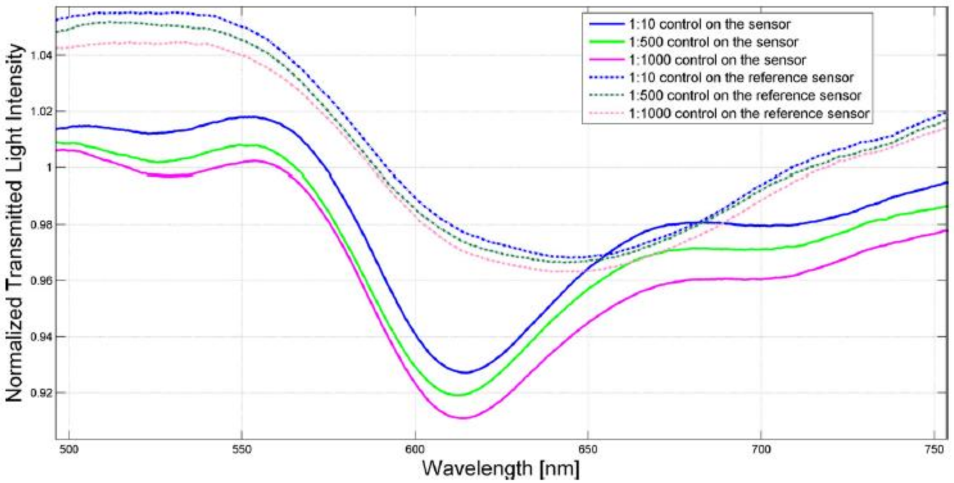
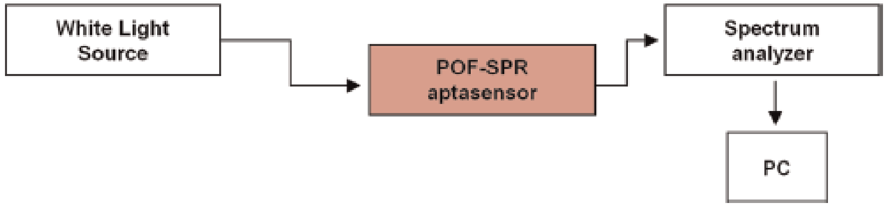
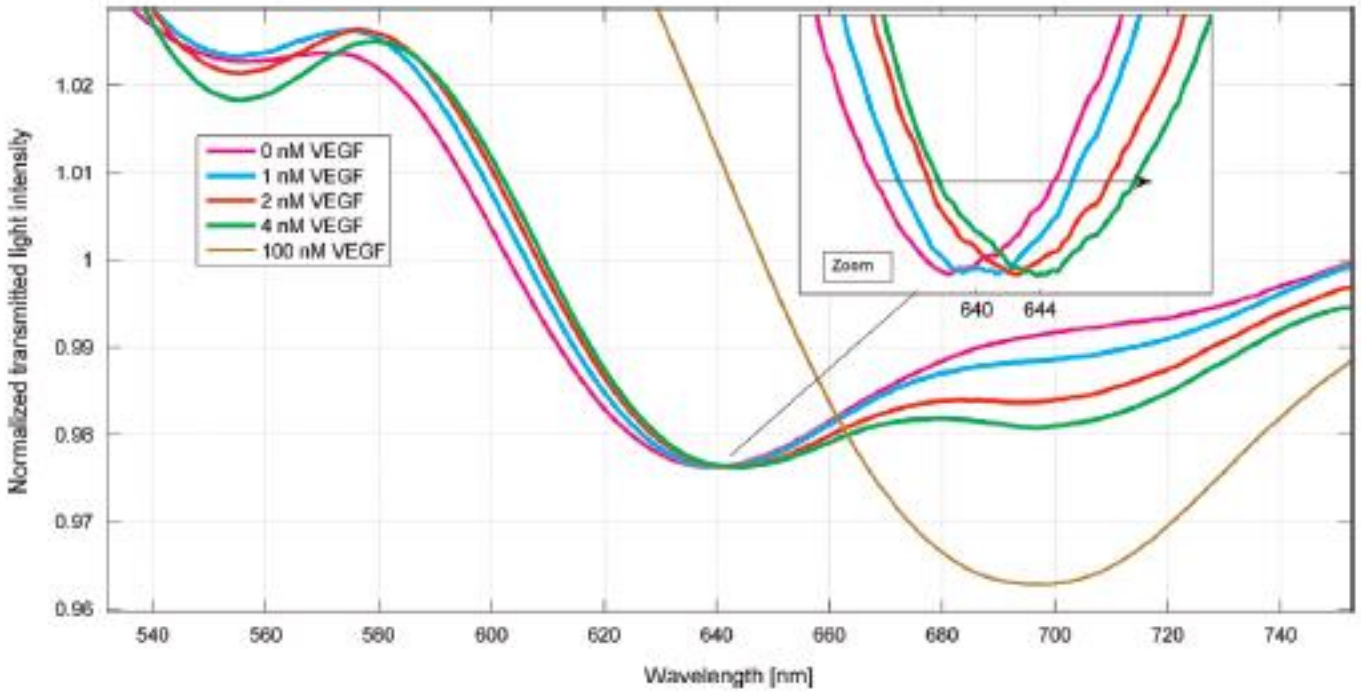


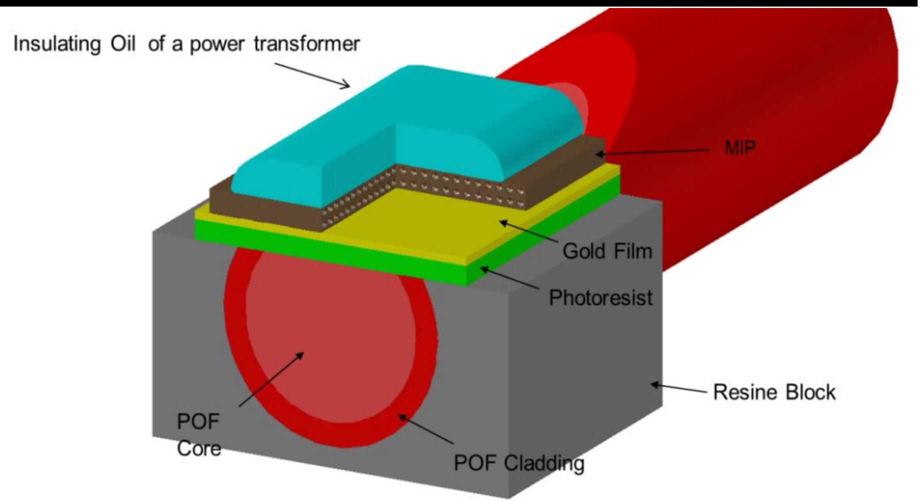
Fig. SPR transmission spectra, normalized to the air spectrum, for different control analyte concentrations for the both sensors (with and without tTG).

Clinical applications: Aptasensor for the detection of Vascular Endothelial Growth Factor

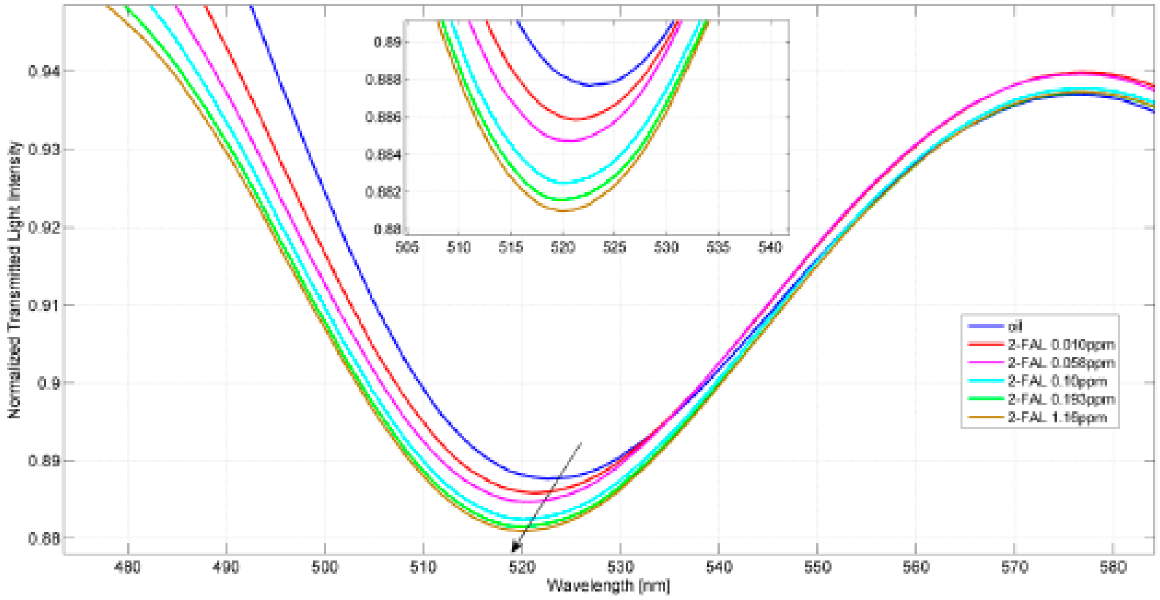




Industrial applications: Furfural in oil

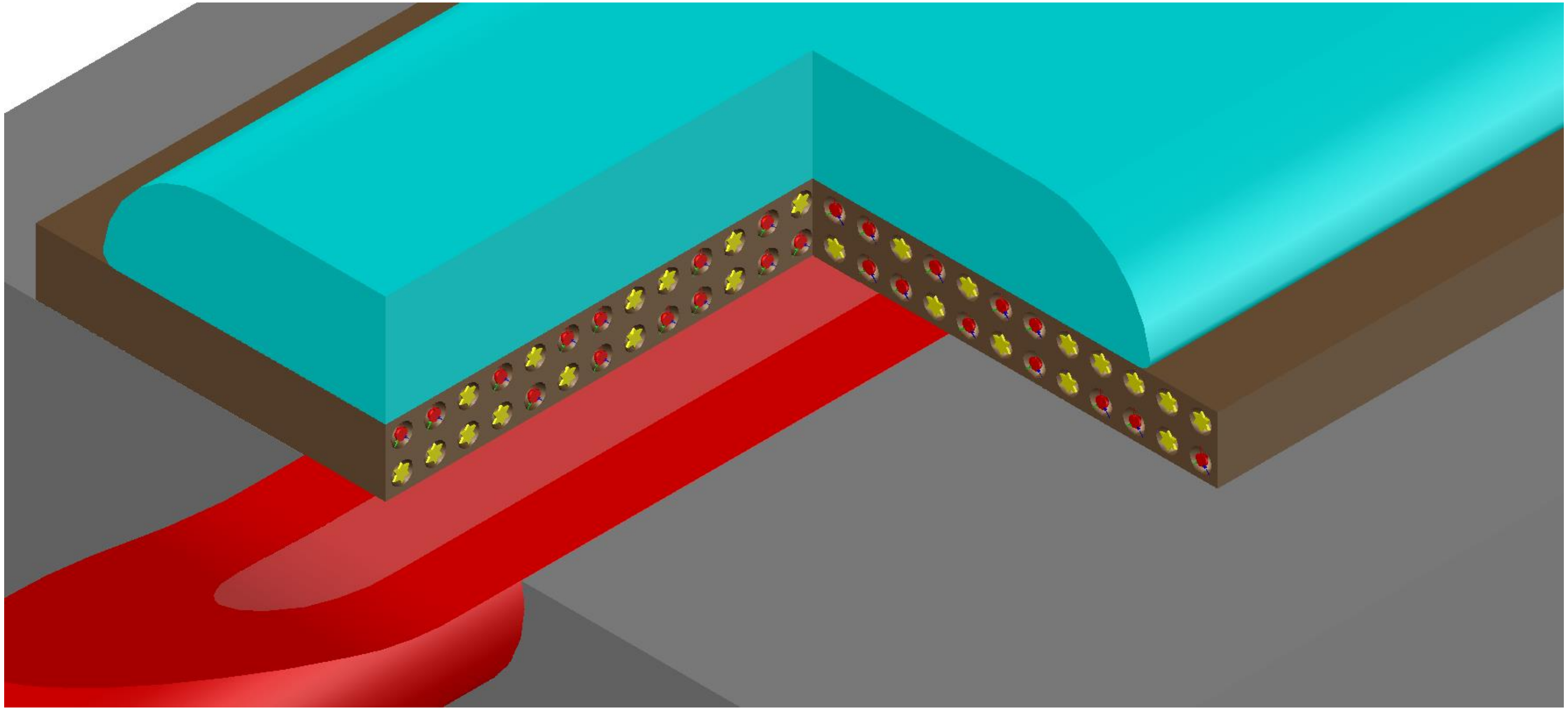


Sensing layer (MIP) for the selective detection of furfural in oil



Different chemical sensing layer

MIP with Gold Nano-Stars (GNS): Excitation of Localized Surface Plasmon Resonance (LSPR)



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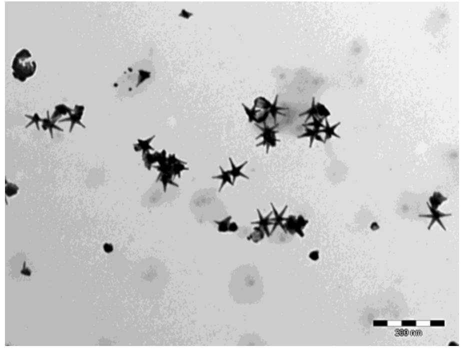
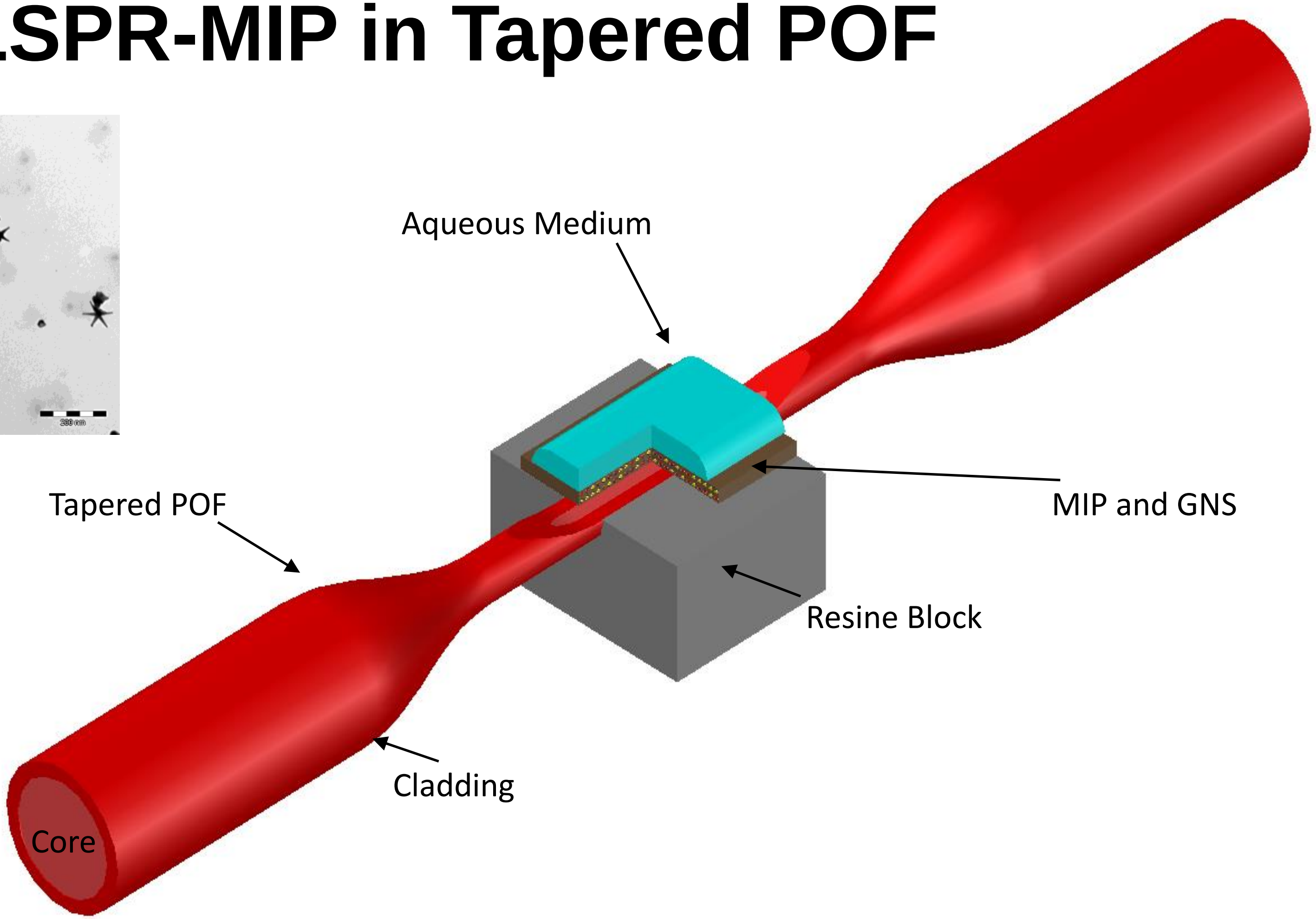
Security applications

Sensing layer (MIP with GNS) for the selective detection and analysis of 2,4,6-trinitrotoluene (TNT) in aqueous solution

LSPR-MIP in Tapered POF


TEM image of GNS



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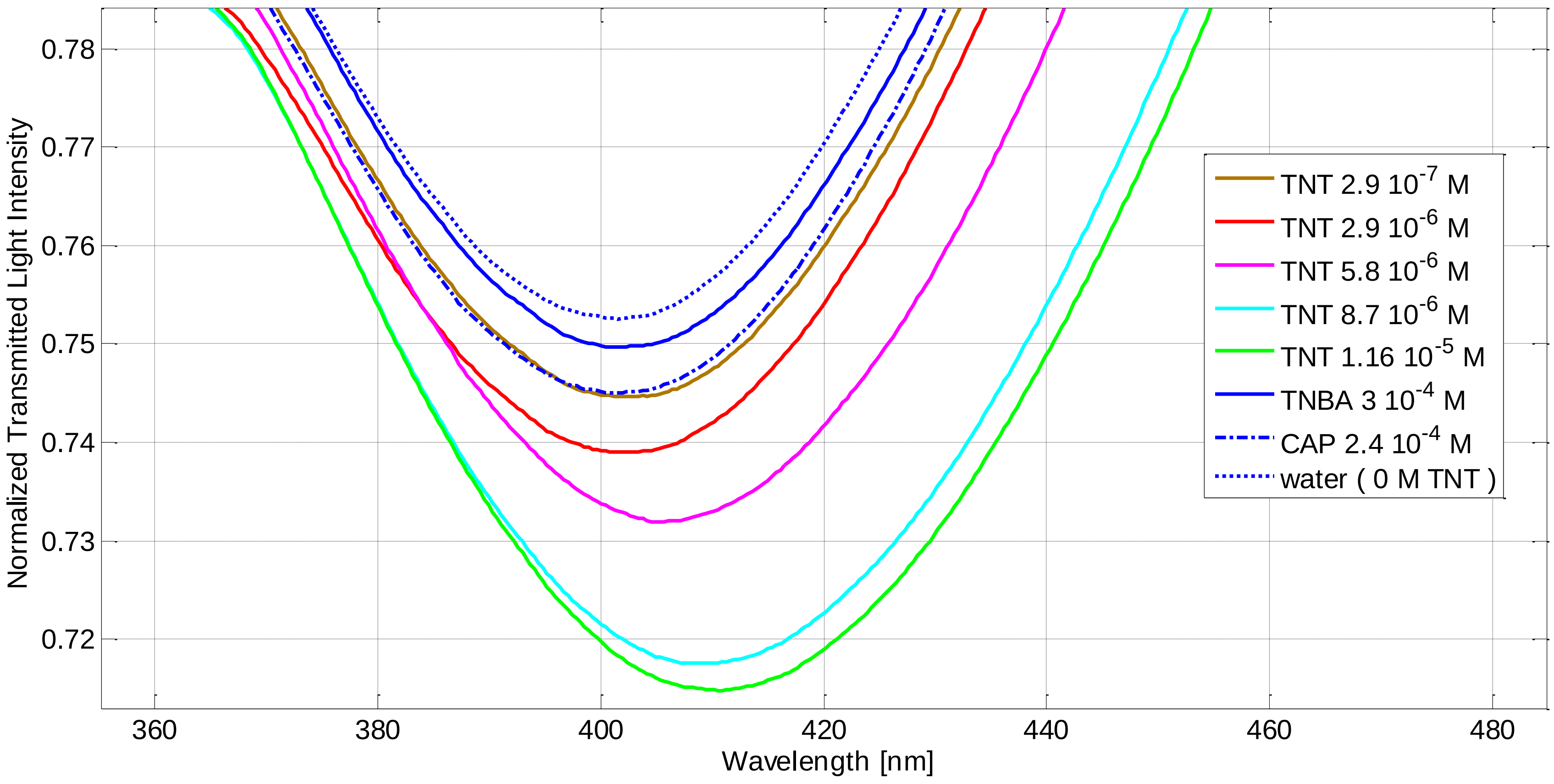
Security applications

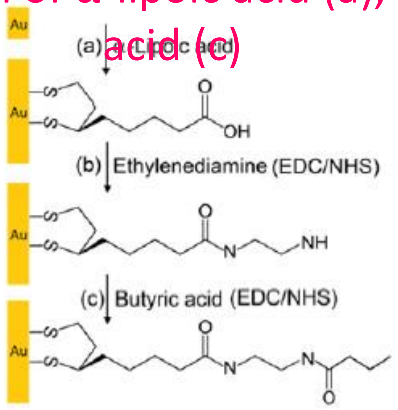
MIP with GNS for the selective Detection of TNT

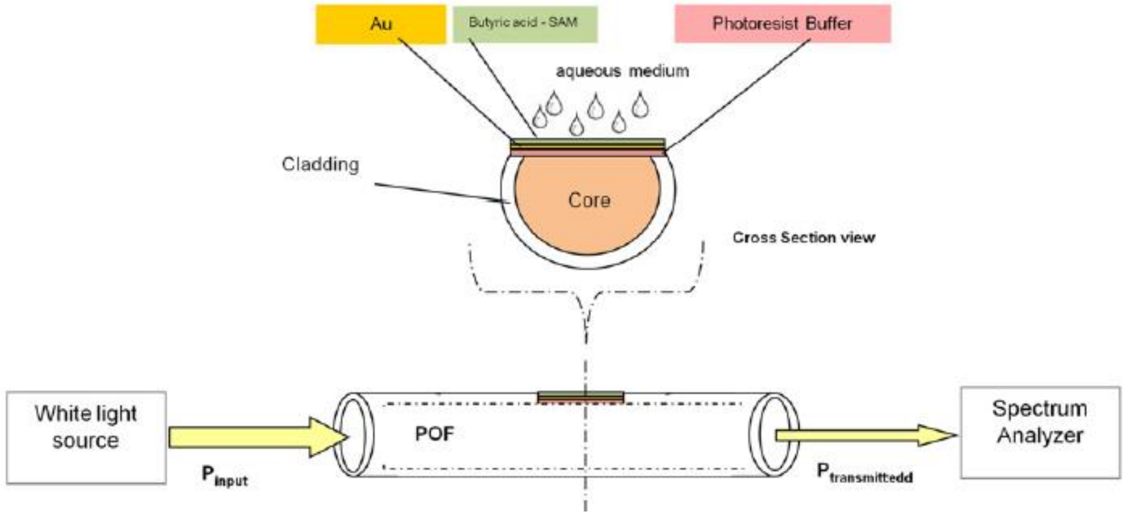


Food safety: detection of butanal by pOBP receptor

Scheme of synthesis of derivatized SAM on chip POF. The gold surface was treated sequentially with a solution of α-lipoic acid (a), ethylenediamine (b) and butyric acid (c)

pOBP:
Porcine
Odor
Binding
Protein





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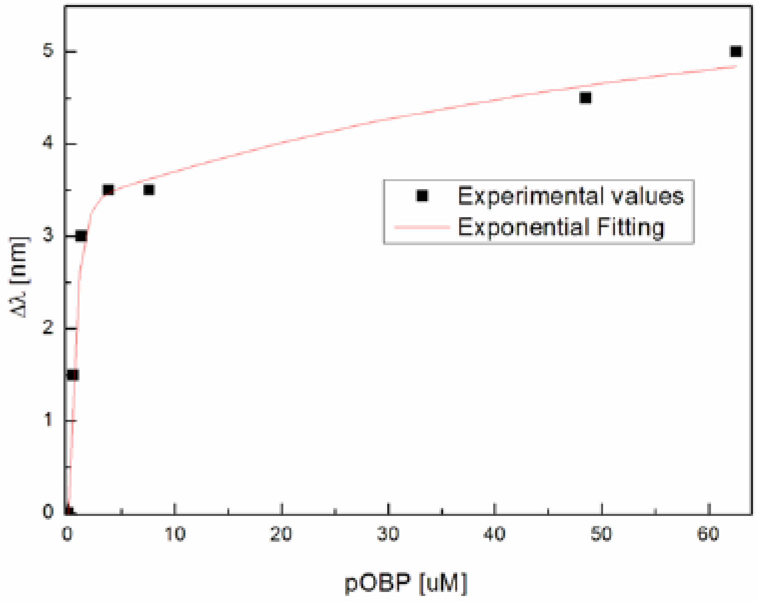
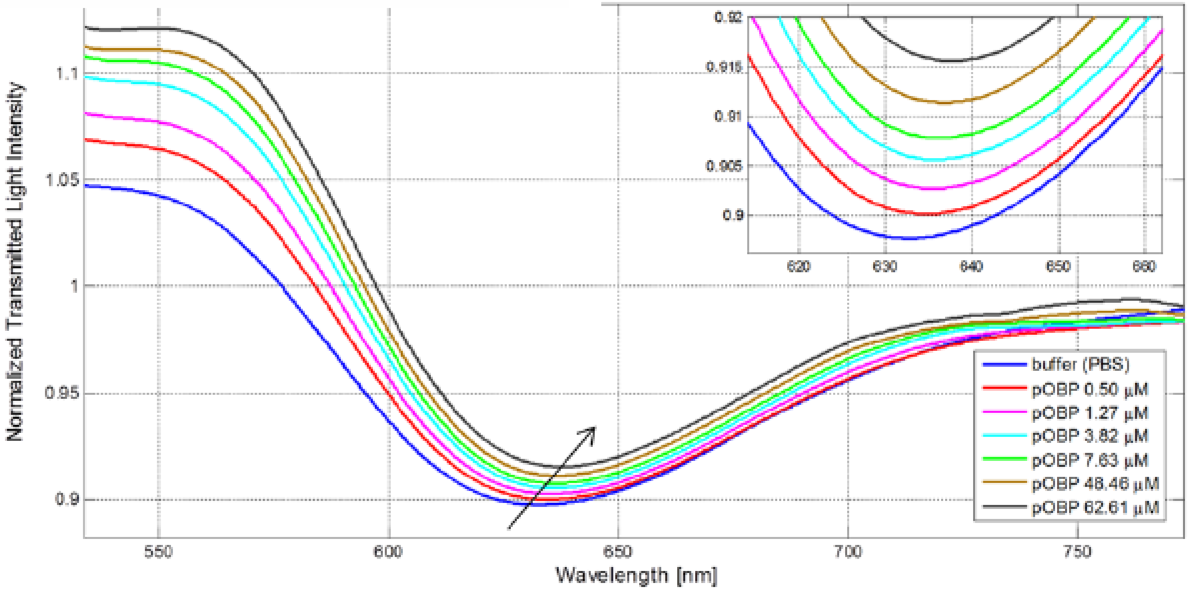
Food safety: detection of butanal by pOBP receptor



The resonance wavelength is shifted to higher values by increasing the concentration of pOBP, which demonstrates that pOBP is adsorbed at the derivatized sensor surface, clearly producing an increase of the refraction index of the medium.



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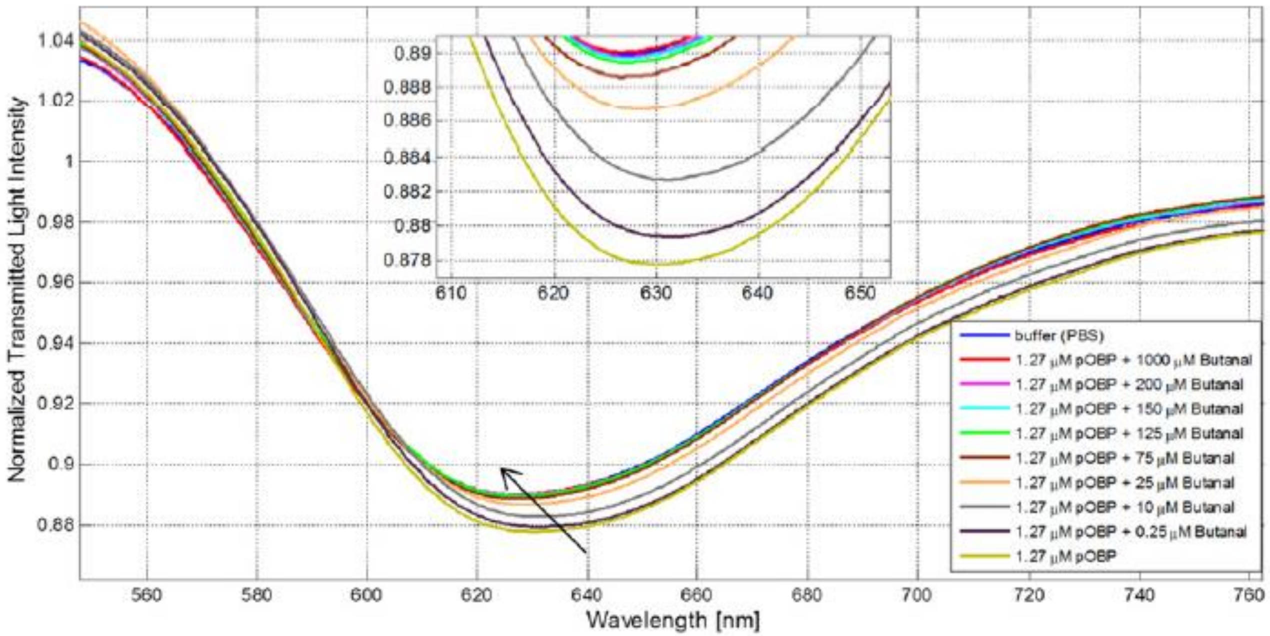
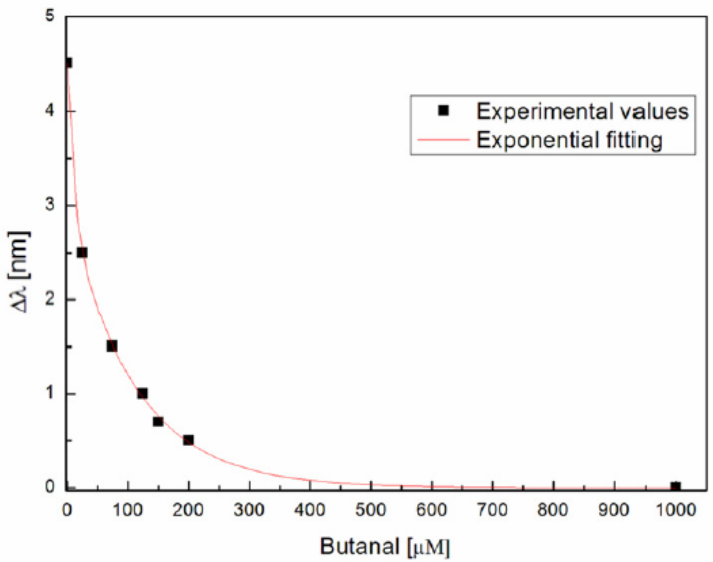
Food safety: detection of butanal by pOBP receptor



Competitive assay

Transmission spectra when **different concentrations of butanal are pre-incubated with a fixed concentration of pOBP (1.27 μM).** The resonance wavelength is shifted to higher values by decreasing the concentration of butanal in the solution with pOBP.



Conclusions

- A simple optical platform based on Plasmon Resonance in a plastic optical fiber is presented along with some specific implementations, ranging from clinical to industrial applications.

- The proposed sensing device, being low cost and relatively easy to realize, is very attractive and promising for other bio/chemical sensors implementation also exploiting localized surface plasmon resonance.