3rd International Turkic World Conference on Chemical Sciences & Technologies

ITWCCST - 2017

10-13 September 2017, Baku / Azerbaijan

Université Ferhat Abbas Sétif 1

High sensitivity biosensor based on a photonic crystal waveguide

Pr. Ameur Zegadi

Laboratoire : Croissance et Caractérisation de Nouveaux Semiconducteurs,
Département d'Electronique, Faculté de Technologie, Université Ferhat Abbas Sétif 1, ALGERIA.
*Presenter : ameur_zegadi@yahoo.fr

Outline

- What's all about Photonic crystals ?
- Objectives and software ?
- Biosensor configuration ?
- Summary ?

Introduction

In recent years, the increase in the volume of data exchanged in telecommunications

Has resulted

The development of very high-speed telecommunication networks. These networks make it possible to convey light, and thus information, over long distances. However, at the local level, ie at inter- and intra-chip communication, information is always transported via metal interconnections

Due to the ever-increasing demand for higher bandwidth, the need for more dense integration of the components leads to a close proximity to all these interconnections, thus altering the performance of the optical networks.

The photonic crystals (PC), then appear as promising candidates for the realization of optical interconnections on the submicron scale.

What is a photonic crystal?

What are the properties of PCs?

What could it be used for?

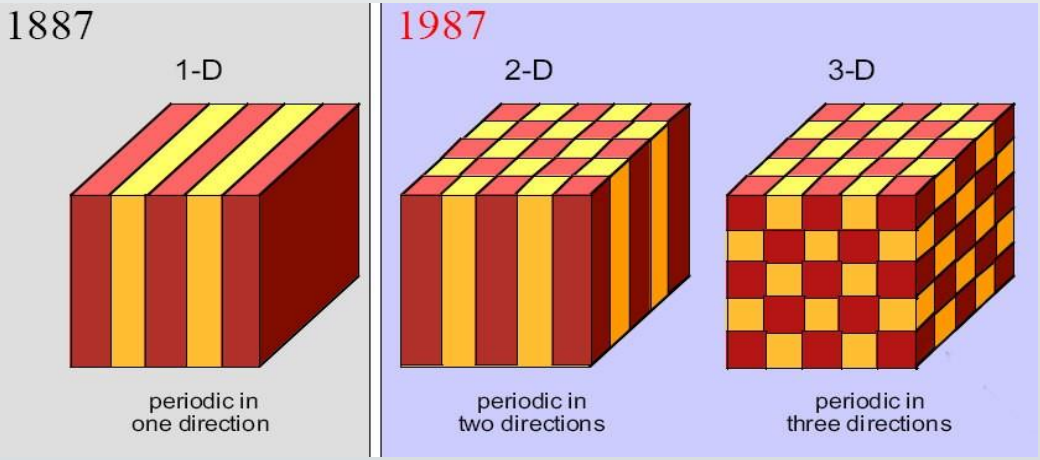
What is a photonic crystal?

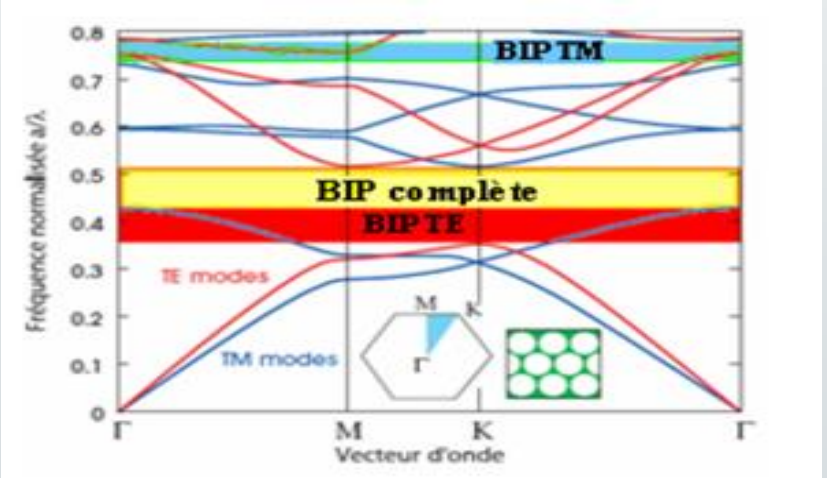
What are the properties of PCs?

What could it be used for?

A photonic crystal is a periodic arrangement of dielectric or metallic materials which does not allow propagation of light in a certain range of wavelengths, called:

Band gap (BIP).





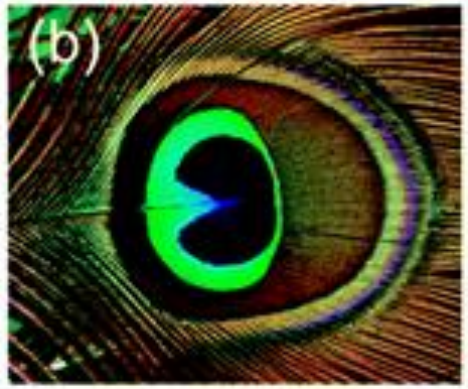
What is a photonic crystal?

What are the properties of PCs?

What could it be used for?

Nature has already preceded man, since such structures exist in the natural state.

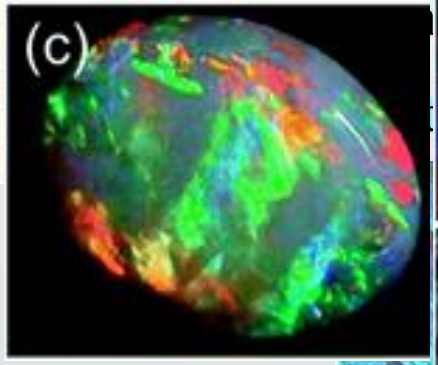
for example

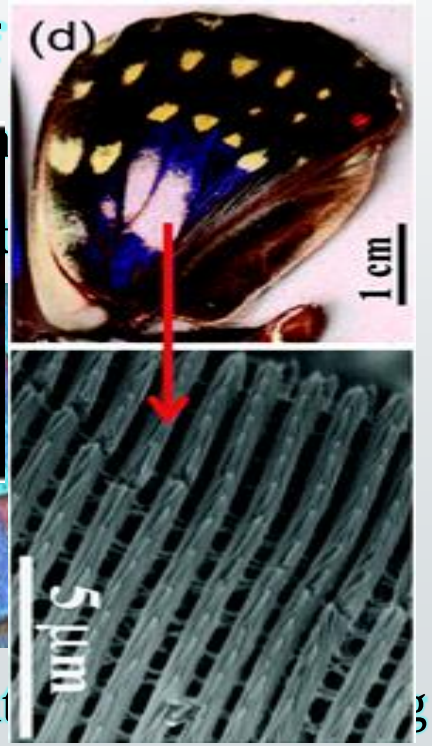


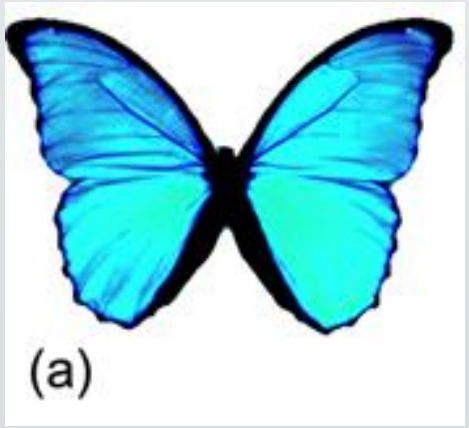
T… …e upper surface of …

M…

st…







The enlargement …g shows a periodic arrangement of the scales.

Periodicity

What is a photonic crystal?

What are the properties of PCs?

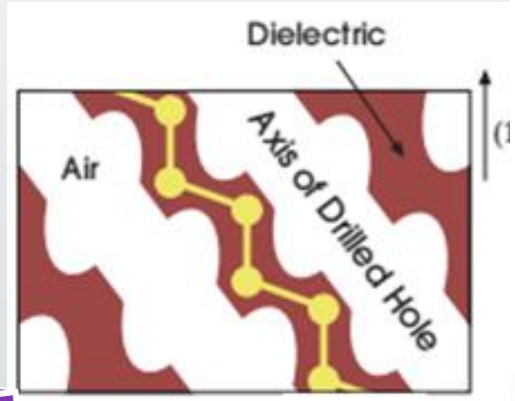
What could it be used for?

It produces on the electromagnetic properties an effect similar to that of the crystalline potential on the electrons in the crystals.

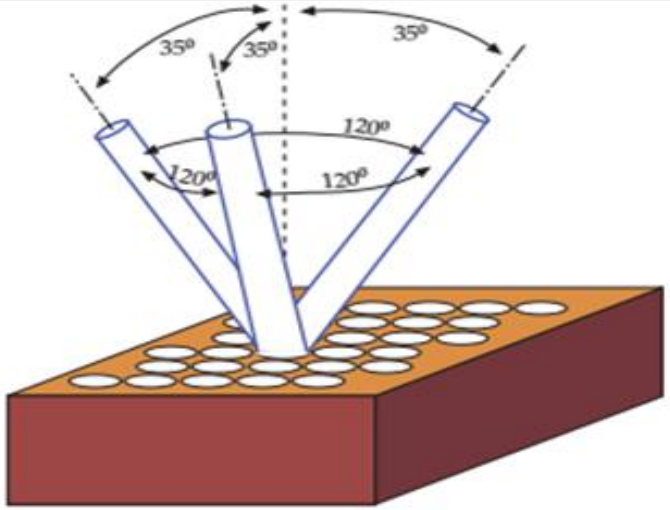
Forbidden bands of energy for photons appear, prohibiting the propagation of light in certain directions and for certain energies.

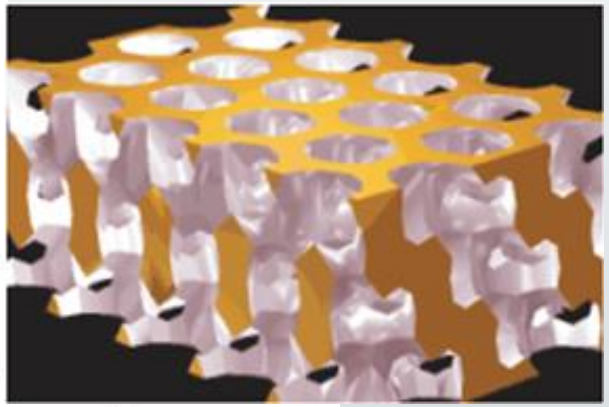
The periodicity may be:

- 1 dimension
- 2 dimensions
- 3 dimensions



(a')





(b)

A 3D photonic crystal is a structure which presents a periodic modulation of its dielectric permittivity in two directions of space and homogeneous in the third.

The dielectric constant is structured periodically in all three directions. Its goal is to obtain a BIP for all directions of space in order to inhibit the spontaneous emission of light.

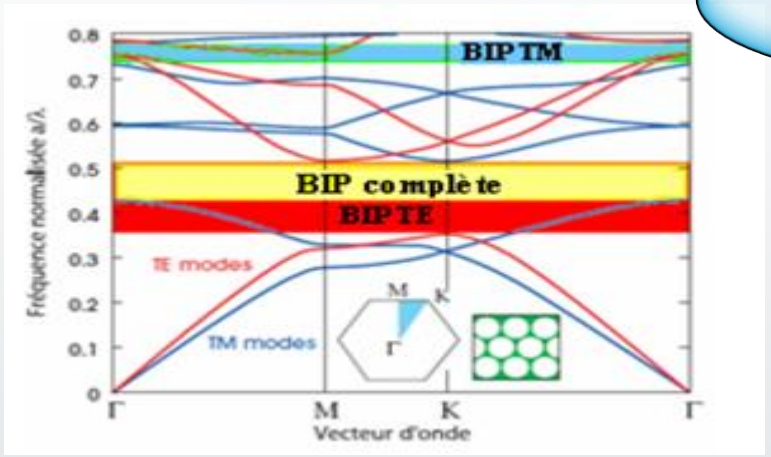
What is a photonic crystal?

What are the properties of PCs?

What could it be used for?

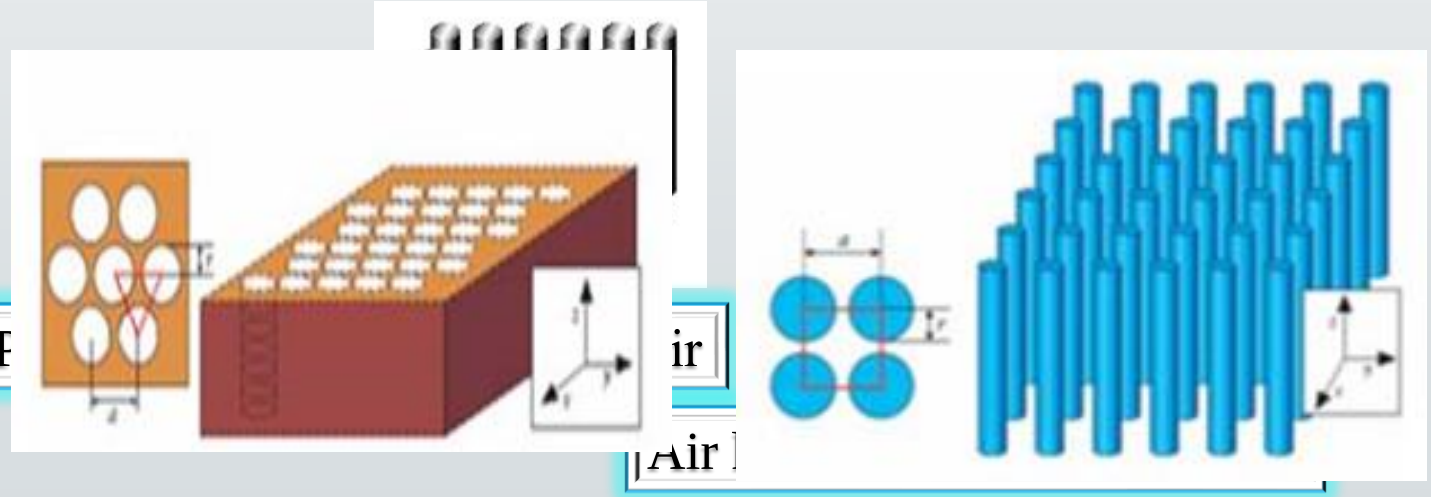
The main feature of the PCs is the BIP

It is responsible for the behavior of light in PCs.



In this work, we focused on the study of components based on 2D PCs, where CPs are composed of a periodic network of

We have two networks:



What is a photonic crystal?

What are the properties of PCs?

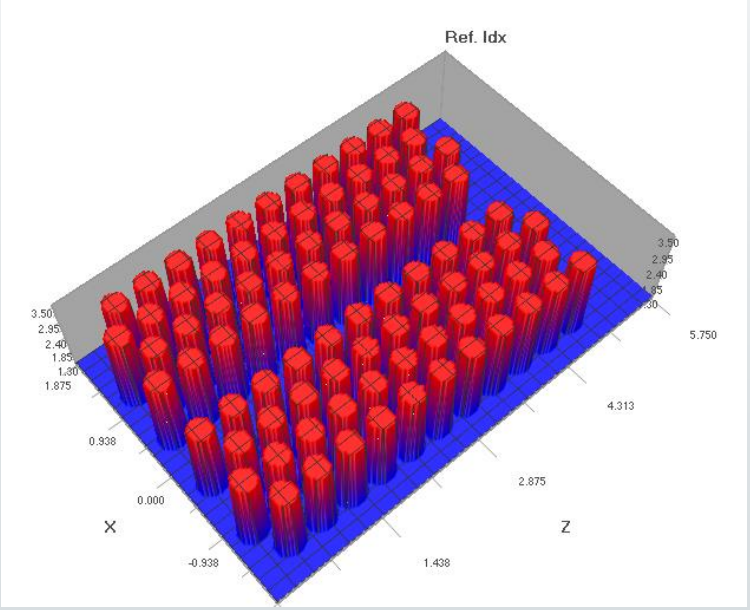
What could it be used for?

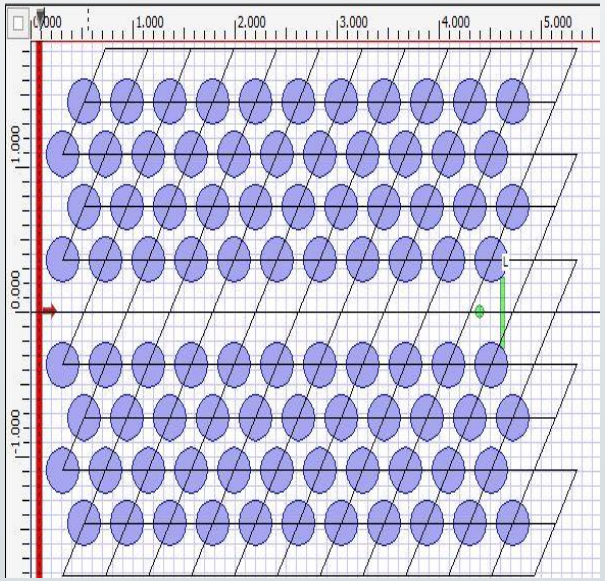
In order to have a propagation frequency permitted within a band of forbidden frequencies, it is necessary to introduce defects, which consists in the elimination of one or more rods.

We will say that the defect is linear if we eliminate a complete line

so

A waveguide W1 is obtained





qu'est-ce qu'un cristal photonique ?

What are the properties of PCs?

What could it be used for?

The source of numerous studies and developments in optics, for example, CPs are now unavoidable in the future of telecommunications. They are currently:

- Inhibition or improvement of spontaneous emission
- Highly reflective omnidirectional mirrors.
- Low-loss waveguides
- Optical filters
- Biosensors,
- Optical resonators for low-threshold lasers

Our study focused on biosensors.

biocapteurs

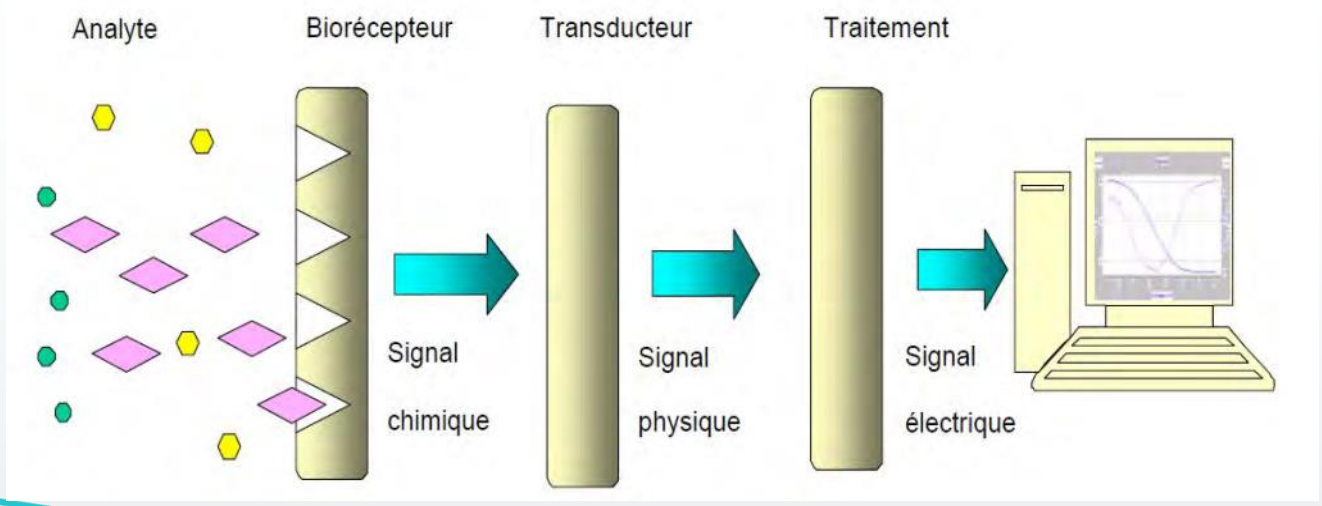
Definition and constituent elements

Definition

It is an analytical system that transforms biological recognition into a physically measurable signal.

Constituent elements

- A sensitive biological layer
- A transducer
- An output signal



Contains a bioreceptor

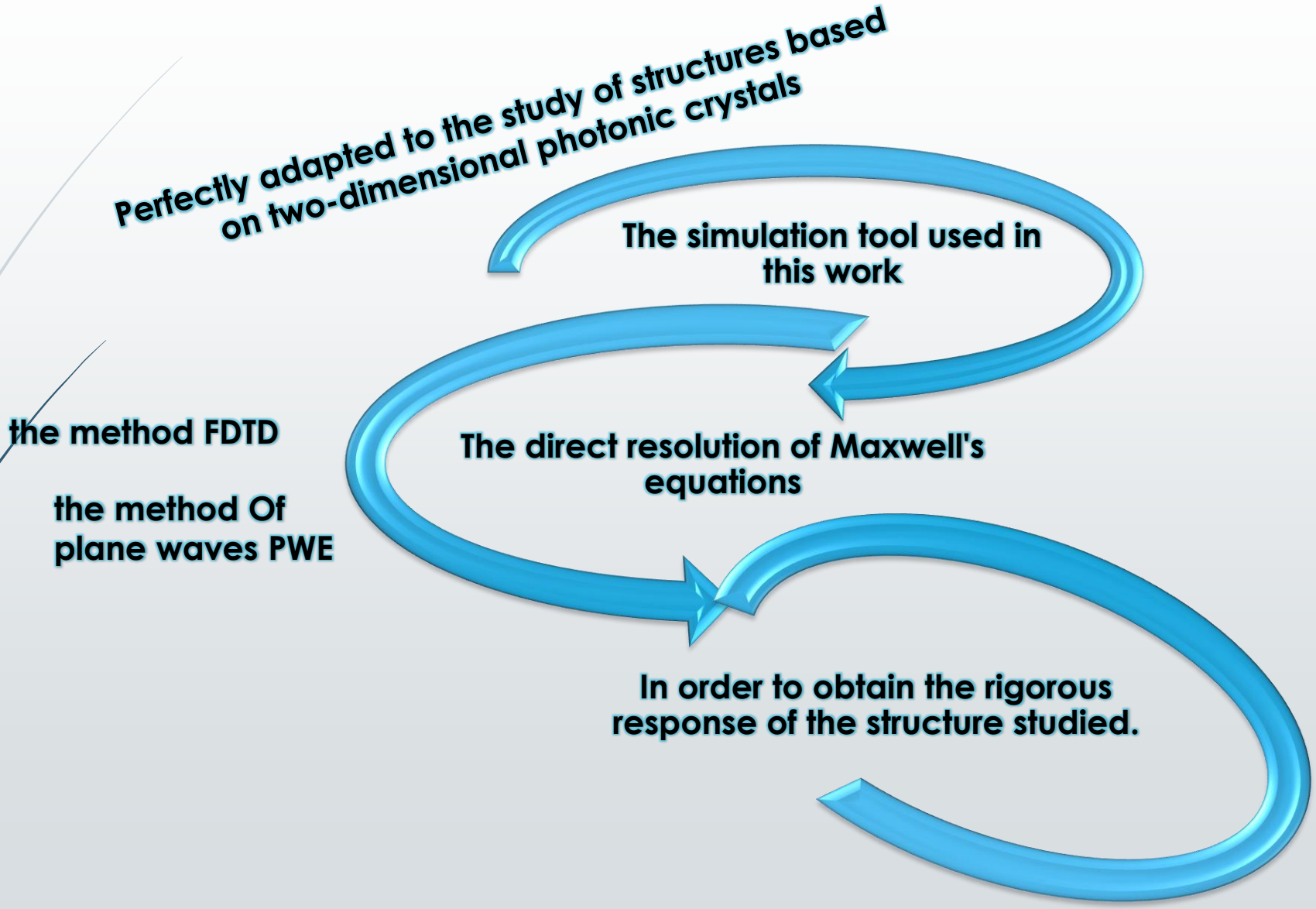
Recognizes the desired biological species and is immobilized on the transducer

Ensures the conversion of the biological response into a physical phenomenon

Allows the measurement of the physical phenomenon elaborated by the transducer

This level often contains amplification and display steps that are appropriate and user-interpretable.

OptiFDTD


Perfectly adapted to the study of structures based on two-dimensional photonic crystals
The simulation tool used in this work
the method FDTD
the method Of plane waves PWE
The direct resolution of Maxwell's equations
In order to obtain the rigorous response of the structure studied.

First, we define

The study structure

It is a 2D PC with a rod network Si

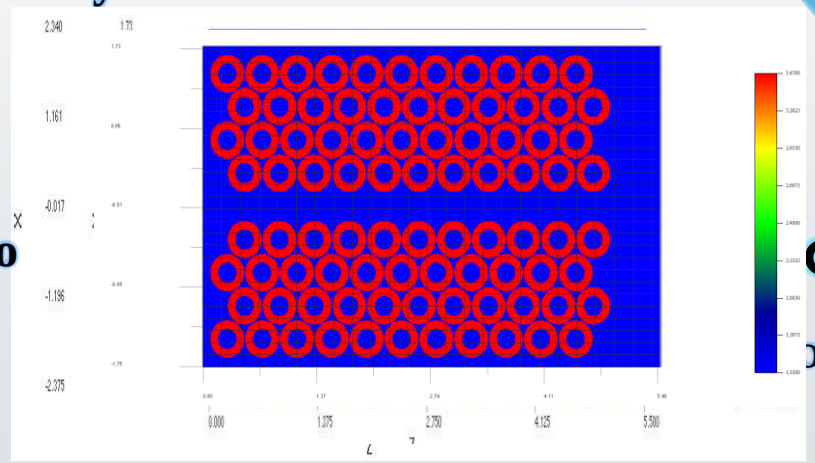
Refractive index is 3.47 surrounded by air

The shape of the rods may be:

Circular

annular

A combination of the two



Network selection

A triangular network

A square network

of

on

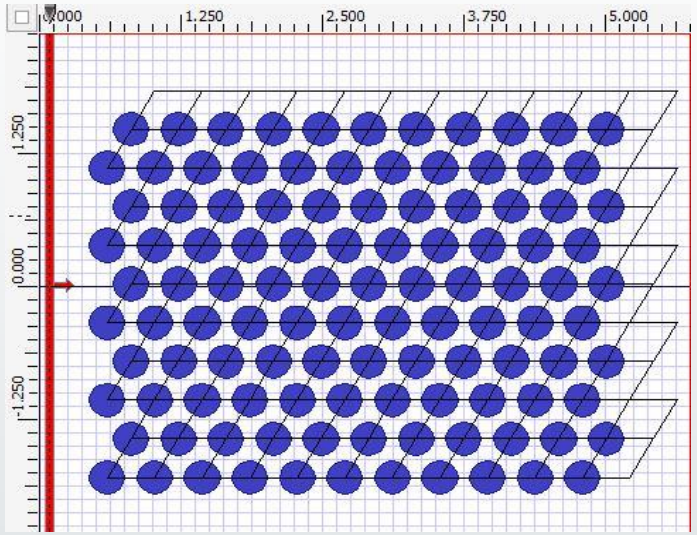
ons

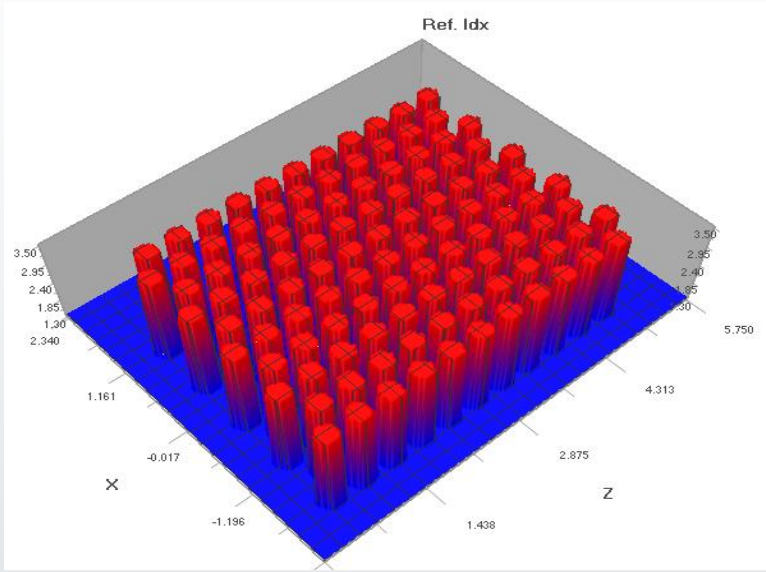
Parameters that must be taken into account

The structure

Before examining the characteristics of structures without defects in terms of sensitivity, it is advisable to present their maps and diagrams of bands in order to fix the parameters of the crystal.

The first structure 1 studied is:

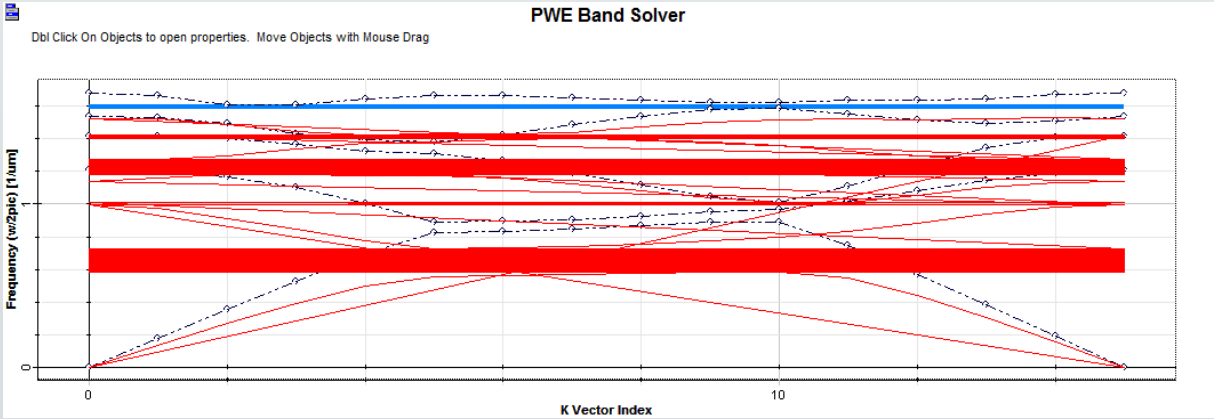




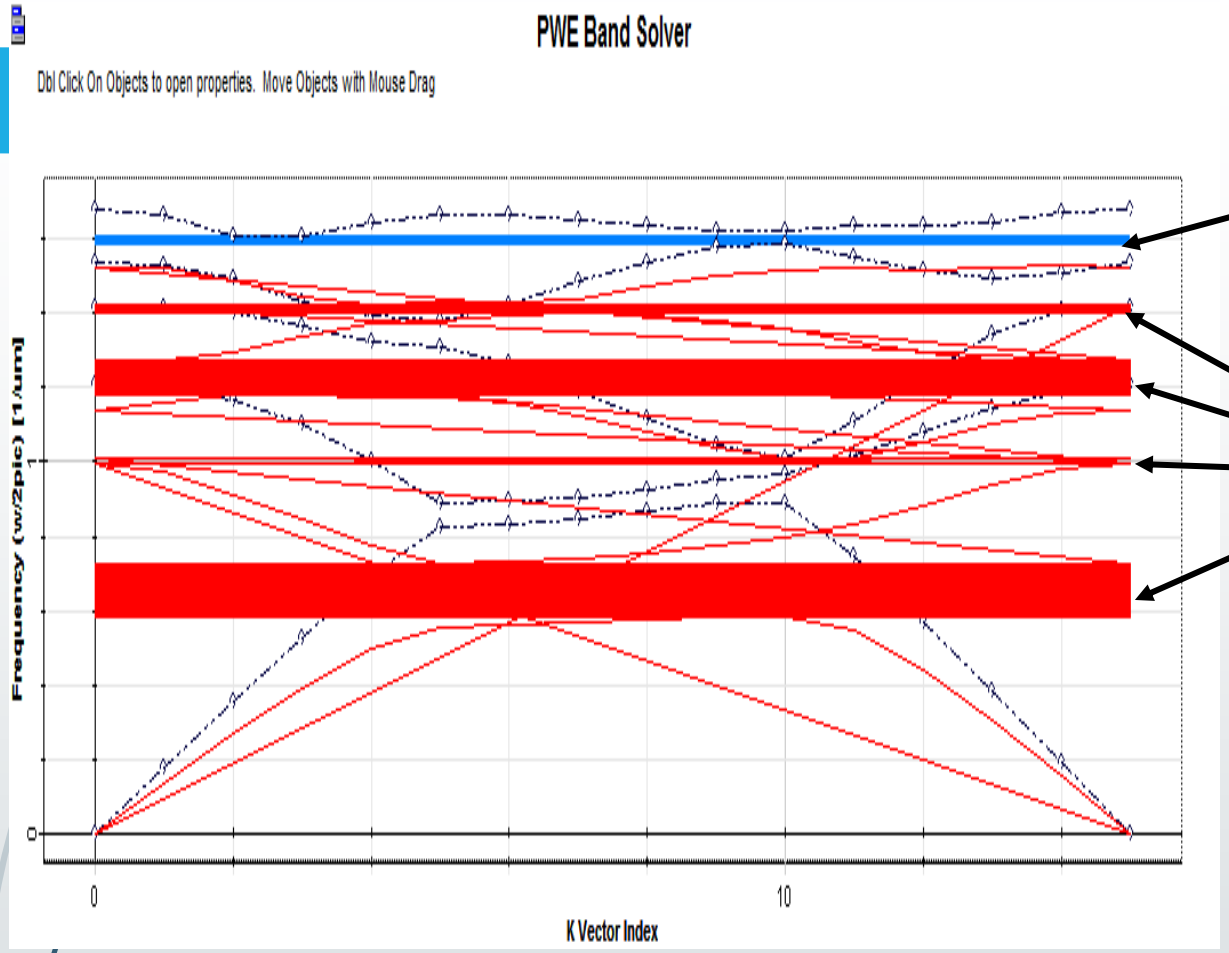
r = 0.1575µm

a = 0.42 µm

The following BIP was obtained:



Presentation of the structure



The TM polarization

A single band gap, but narrow

Four photonic forbidden bands (BIP)

Polarization TE

The largest BIP is obtained with a triangular array of Si rods in TE polarization.

It is this polarization that we exploit in our study.

The aim of our work is to determine S and then to improve it

Simulation et interprétation

Mechanism of detection

First must create a

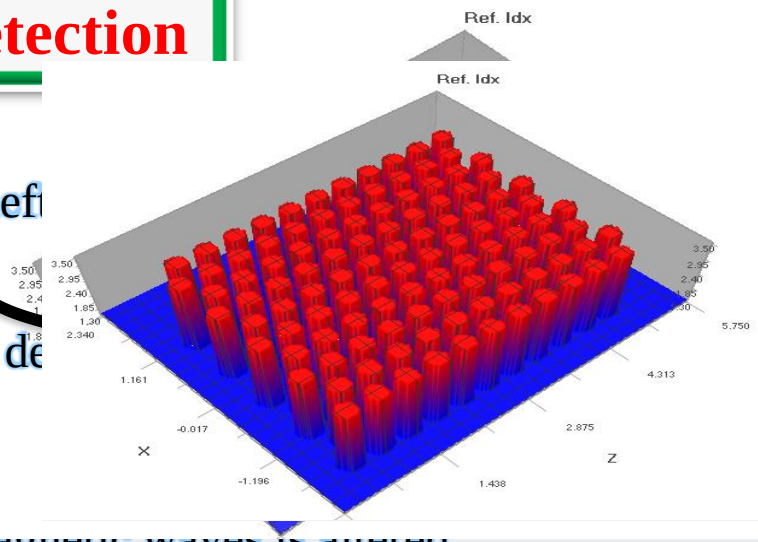
waveguide in structure 1

The light enters by the lef

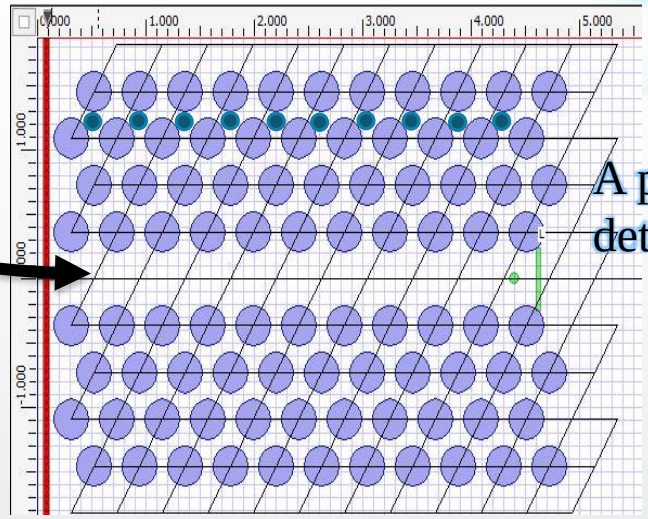
The liquid analyte is de

A change in the refractiv

the nature of the electromagnetic waves is altered.

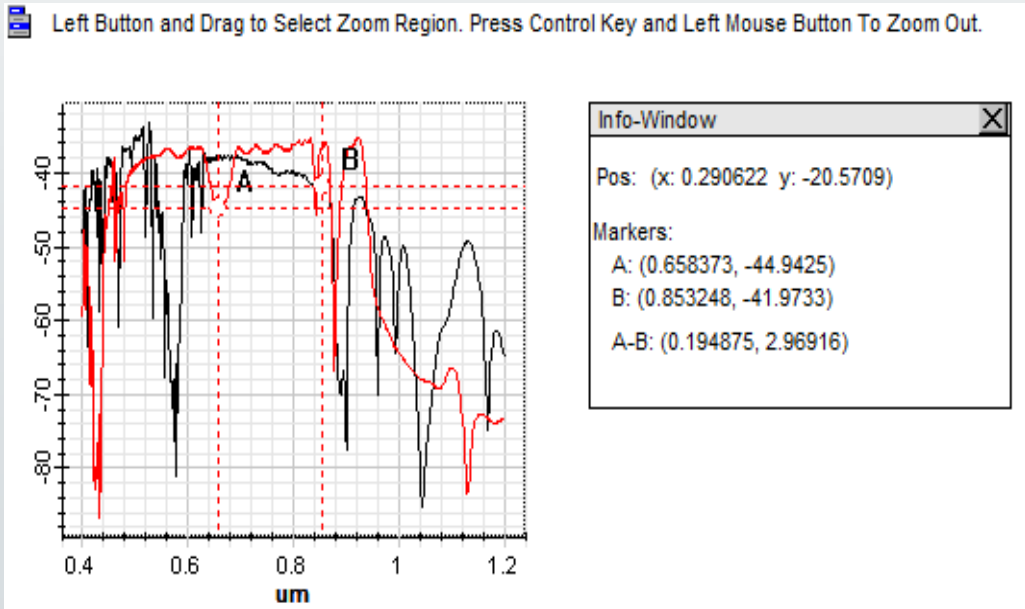


Presentation of the structure



A photodetector detects light

The following spectrum was obtained for two refractive indices:



The sensitivity of the sensor is: 577.493nm / RIU.

This sensitivity is remarkable compared to research already published.

Influence of the shape of the stems

Influence of the network

Influence de l'introduction de défaut

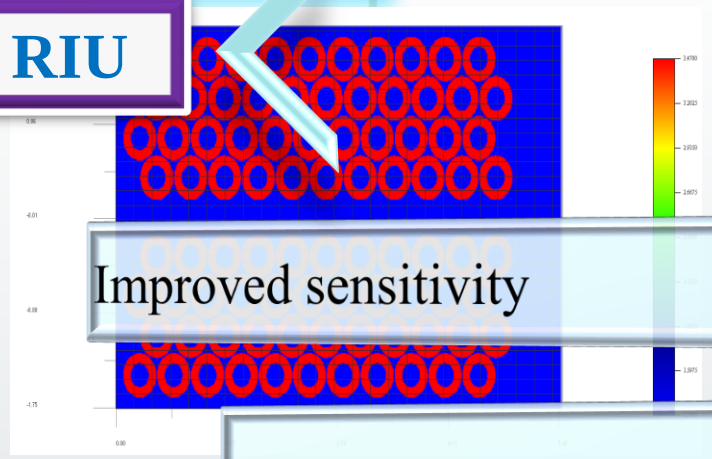
Influence de la taille des tiges

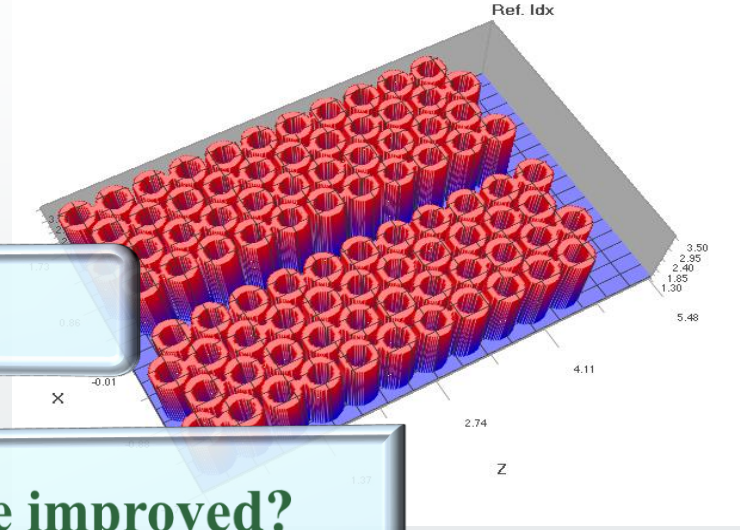
Ring ro

577.493nm/ RIU

Rint=0.1575a

Rext= 0.225a



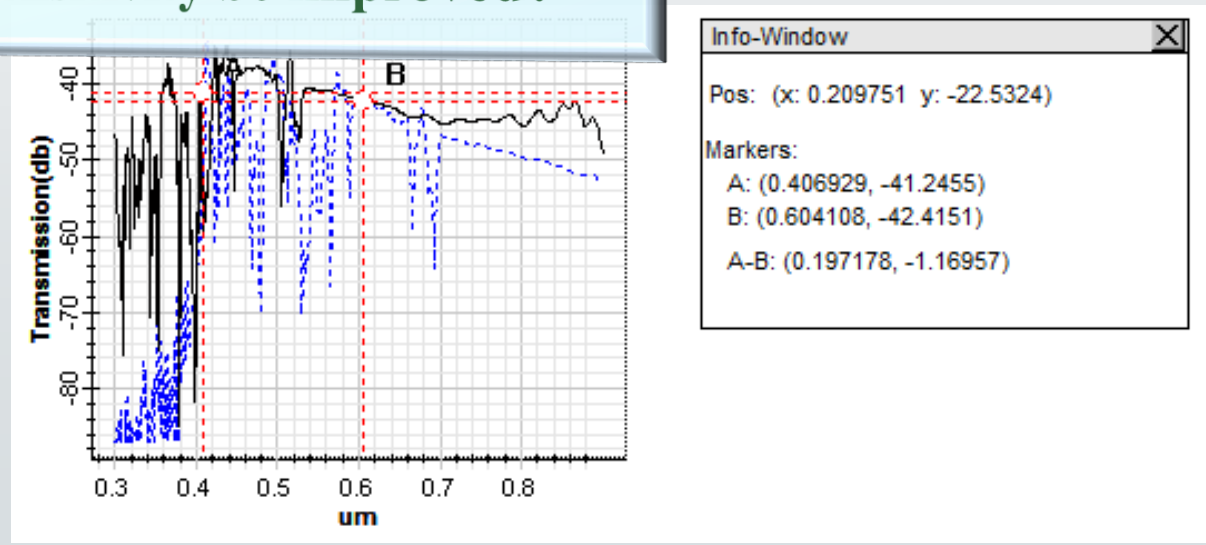


Improved sensitivity

Can this sensitivity be improved?

The transmission spectrum obtained is:

S= 597,5nm/ RIU

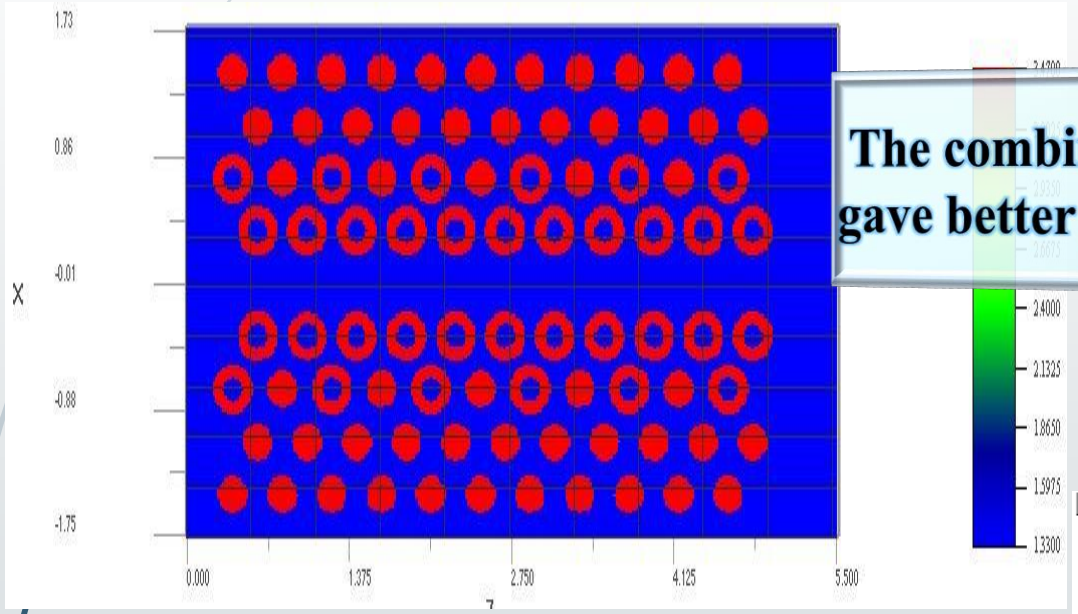


Influence of the shape of the stems

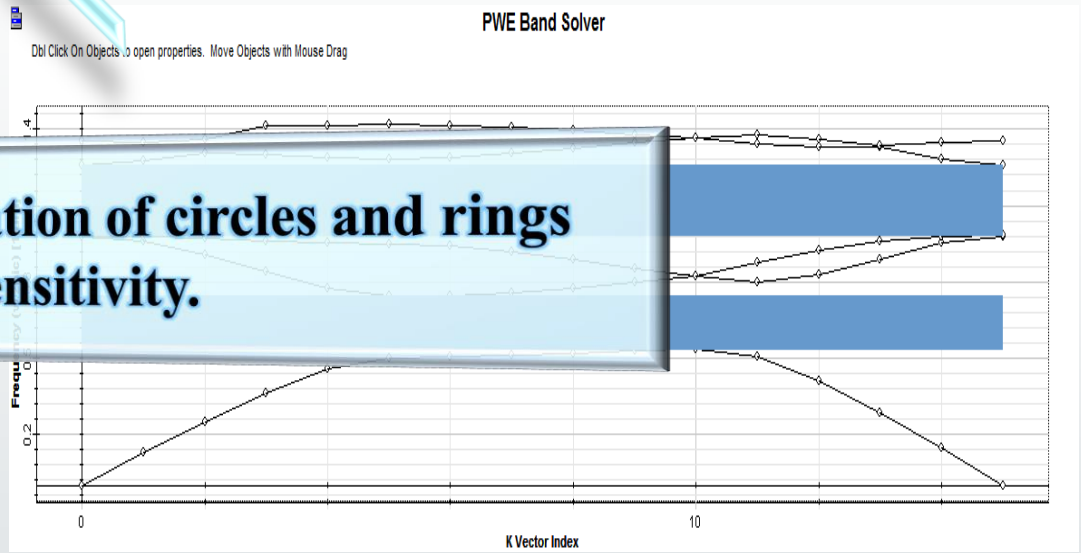
This can be done b… circles and rings …ure…t:

S= 597,5 nm/ RUI

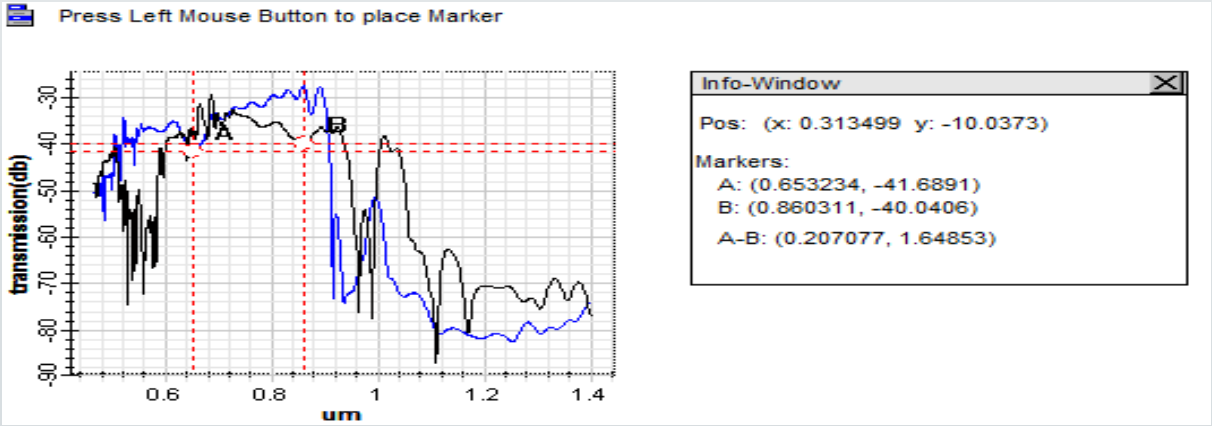
Sa BIP est la suivante :



The combination of circles and rings gave better sensitivity.



The transmission spectrum



S= 627.5 nm/RIU

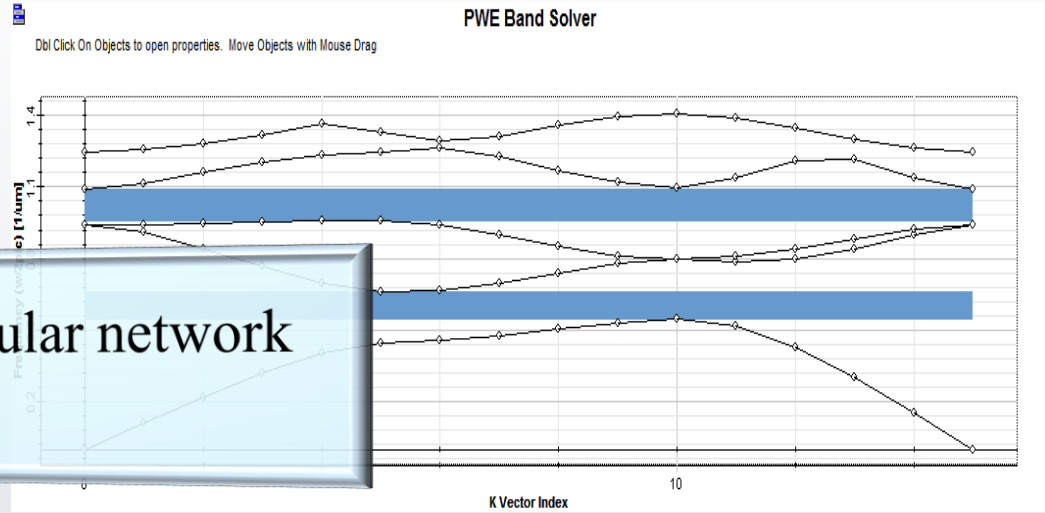
Influence of the shape of the stems

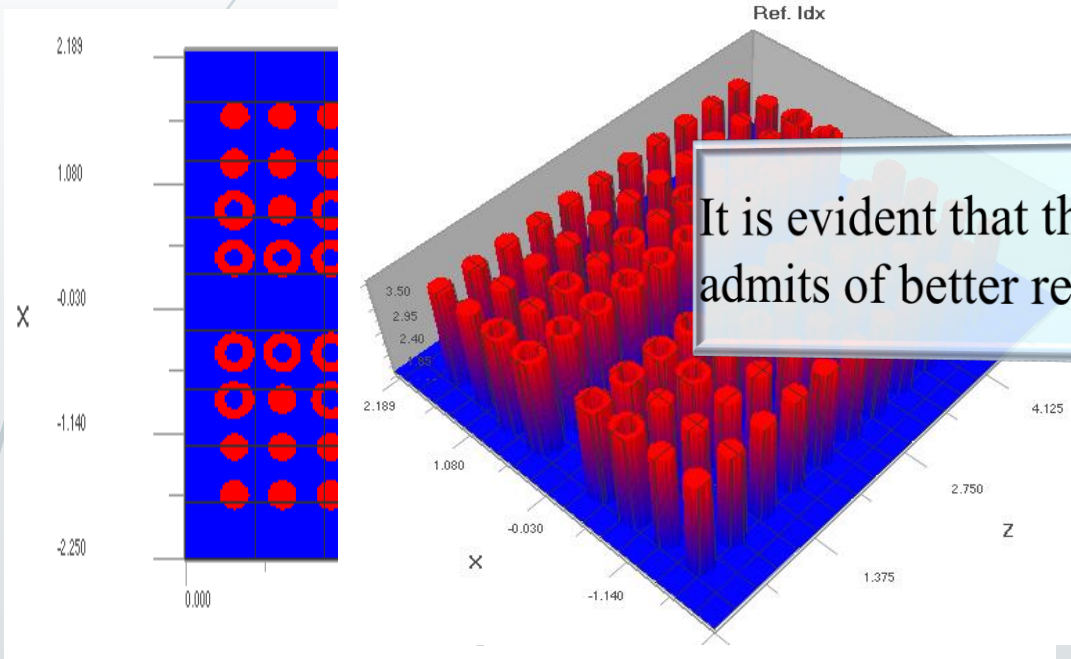
Influence of the network

For the triangular network we have already presented its structure as well as its [illegible] the square network.

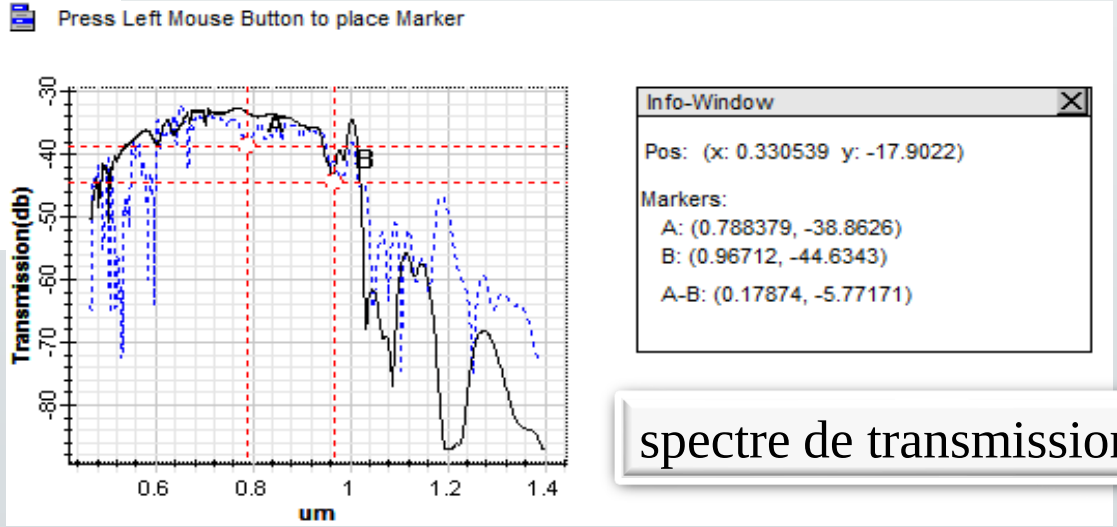
S= 627.5nm/RIU

BIP





It is evident that the triangular network admits of better results.



S= 541.63 nm/RIU

spectre de transmission

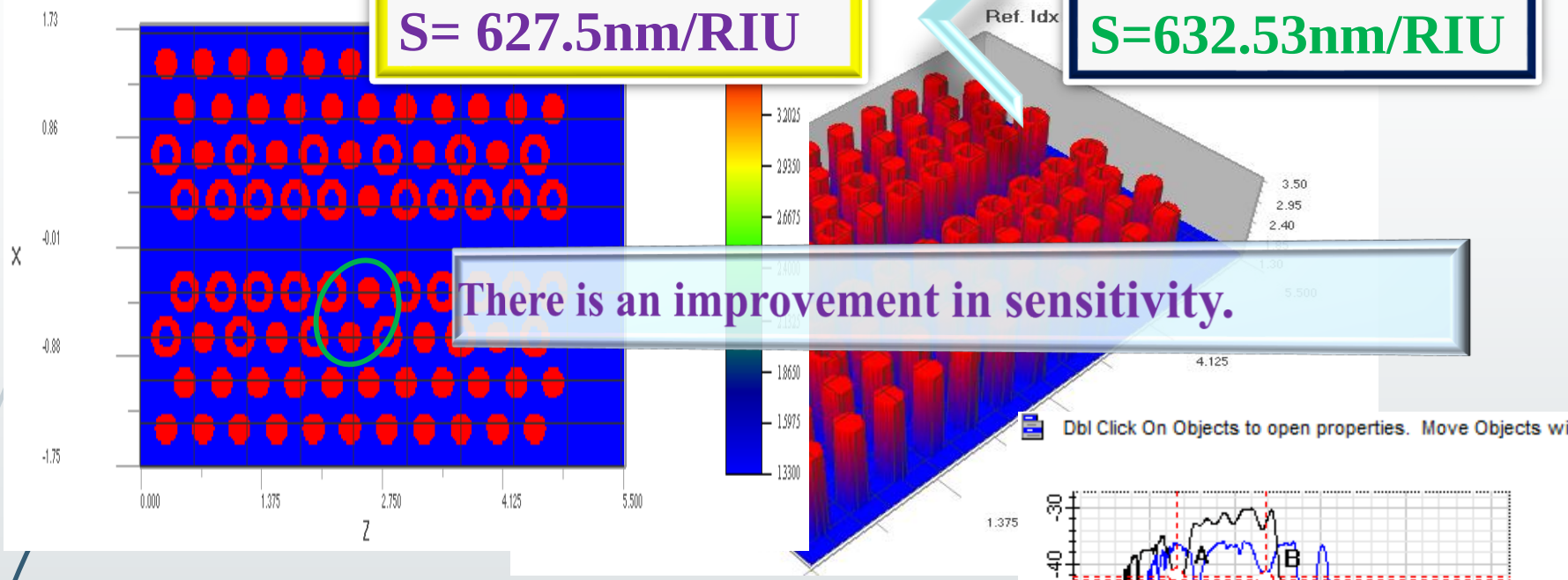
Influence of the shape of the stems

Influence of the network

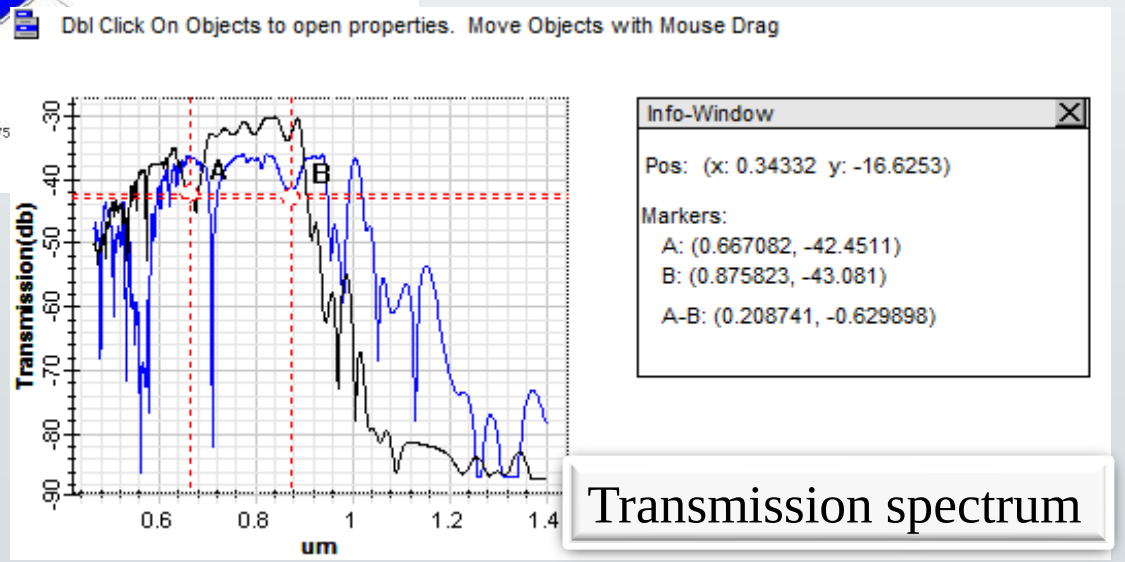
Influence of the introduction of defects

S= 627.5nm/RIU

S=632.53nm/RIU



There is an improvement in sensitivity.



Transmission spectrum

Influence of the shape of the stems

Influence of the network

Influence of the introduction of defects

Influence of stem size

We have fixed the c

S=632.53nm/RIU

Varied the internal radii and the outer radii of the annular rods

$A=r_{int}/r_{ext}$

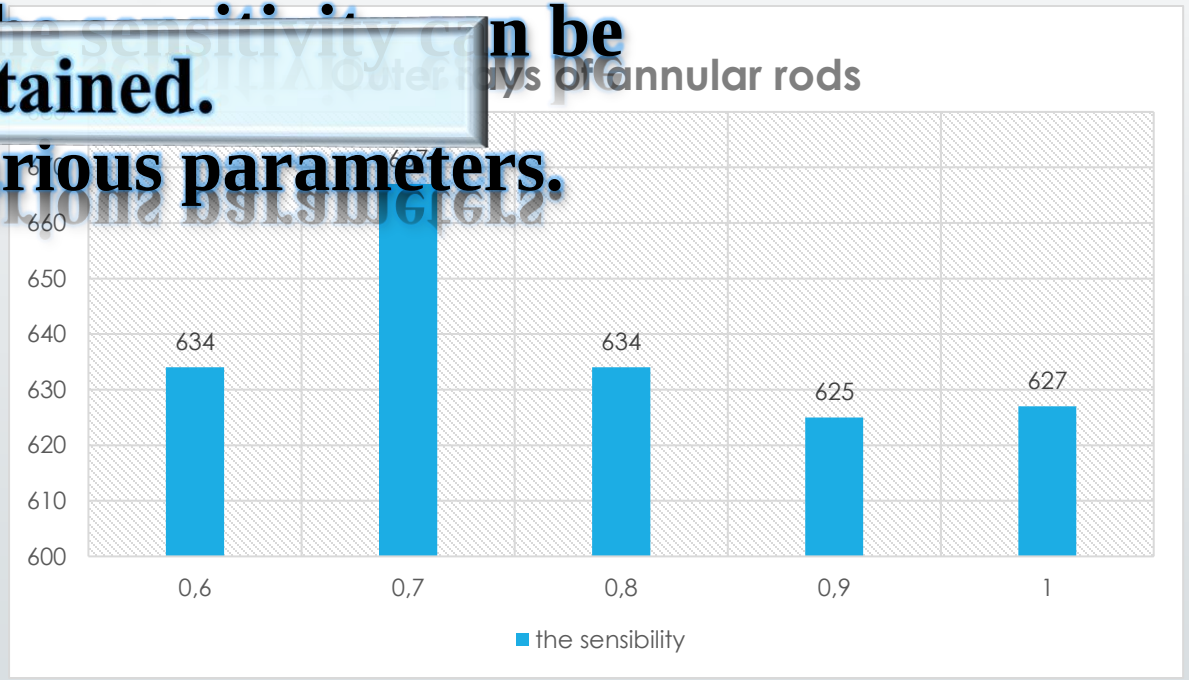
Varies from 0.6 to 1

It is the best S obtained.

optimizing Thus, the sensitivity can be improved by the various parameters.

The best sensitivity is obtained for a ratio of: 0.7 ($r_{int}= 0.7r_{ext}$)

S=667nm/RIU



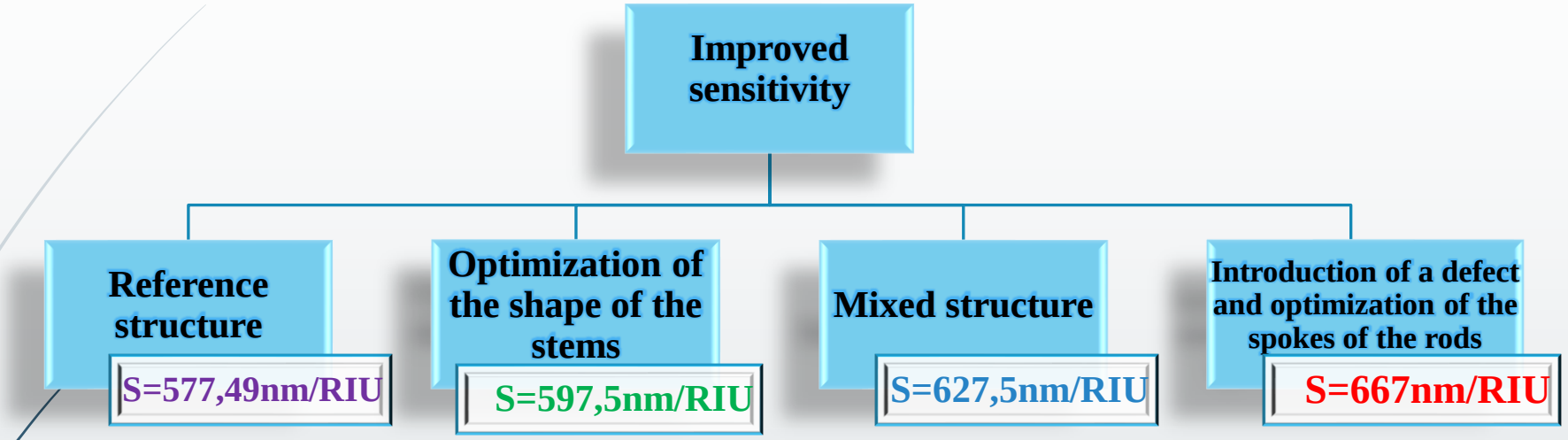
Conclusion

This work was devoted to a presentation of the general properties of photonic crystals, ranging from Maxwell equations to periodic media and the opening of the forbidden band to the utility of photonic crystals.

The interest of research on optical sensors is motivated by the growing need for specific sensors to enable rapid routine measurements in many areas of analysis in the areas of health, environment and quality control food.

Sensitivity is the important parameter for evaluating the performance of a sensor. The sensors based on the GO W1 PCs can be designed to achieve a very high sensitivity.

To improve the transmission and the sensitivity, an optimization of the initial reference structure was carried out,



The improvement in sensitivity makes it possible to detect low concentrations of analyte

Université Ferhat Abbas Sétif 1

thank you for your attention