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Research paper

The Study of Bacillus Cereus on a Photonic Crystal Biosensor

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Abstract

The work involves the study of bacteria named bacillus cereus which is a type of pathogen that causes infections in the blood. This infection of the blood may lead to many more complications that may lead to life threatening. Hence immediate diagnosis becomes an important criteria. B. Cereus is a gram positive and hemolytic bacteria no matter where ever it is extracted from, it requires biomarker to make it recognised and hence the wavelength and refractive index will remain same. The paper includes the study of the presence of B. cereus in the blood with the knowledge of the refractive index of the bacteria with the aid of an photonic crystal nano sized biosensor. The sensor works on the principle of minute changes in the value of the given refractive index value. Namely here the blood samples with the presence of B. cereus and the normal blood sample. The simulation is done where in the design is excited with a Gaussian pulse source with the amplitude differences in wavelength of the two blood samples are observed/. The sensitivity was found to be 5.987µm /RIU and the Quality factor is given by 1692.2.

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Keywords:*B.creus; Biosensor; Photonic crystal; Refractive Index; Split ring resonator; wavelength.*

1. Introduction

Bacillus Cereus is an aerobic gram positive, spore forming, rod-shaped bacterium that is found everywhere in the environment. Bacillus Cereus is the most common human pathogen of the group. Bacillus Cereus can cause life threatening systemic infections in immune compromised patients [1]. Bacillus species

causes catheter-related bloodstream infections, especially among the patients with hematological malignancies [2]. Bacillus Cereus is abundantly found in hospital environment, soil, dust, fresh water and in gastrointestinal flora of prolonged hospitalized patients [3].

If the absorption of light is less and the crystal has different dielectric constants, then reflection and refraction of light takes place from different interfaces which produce same phenomenon for photons. Hence, the controlling of photons is done through Photonic crystal. These devices are in nano-scale range. A photonic crystal consists of dielectric structures arranged periodically [5]. A strong interaction is shown with EM radiation of periodicity. Photonic crystals are similar to semiconductor crystals where propagation of electrons is manipulated due to the presence of periodic

structures within the crystal. to normal crystals, photonic crystal divides the entire crystal into unit cells and the small parts of the entire crystal lattice is repeated throughout the crystal .In general, electromagnetic waves that are incident on photonic crystal structure are reflected, refracted and scattered due to the alternation of refractive index in the structure. With permitted and prohibited

2. History of Photonic Crystal

The phenomenon is based on the light propagation in periodic structures. Similar to control of electrons in semiconductor circuits, control of photons is done by photonic crystals. In particular they exhibit
refractive index periodicity. A periodic dielectric structure can create allowed or forbidden photonic bands. This means that the propagation of light for a certain range of frequencies can be allowed or inhibited [4]. Therefore, the gaps in the frequency spectrum are known as Photonic Band Gaps. The periodic dielectric structures as Photonic crystals (PhCs).

range of frequencies, photonic crystals possess energy band structures known as Photonic Band Gap (PBG)[6].
Therefore the choice of the material has an impact on the size of band gap. A photonic band gap (PBG) is considered as a structure which manipulates the light beam in the similar manner as semiconductor controls the current[8].
In photonic band gap devices, propagation of light depends mainly on the refractive index. Hence by changing the material refractive index, integrated optic sensors can be designed. Because of the physical properties such as high level of sensitivity, reflectance and transmittance, photonic crystals can be used as sensors. At present, analysis of blood sample is done for bacillus cereus that is to detect the bacterial content in blood.

3. Em Wave Equation

In a region with no charges ($\tilde{n} = 0$) and no currents ($\mathbf{J} = \mathbf{0}$), such as in a vacuum, Maxwell's equations reduce to:

$$\nabla . E = 0$$

$$\nabla . B = 0$$

Taking the curl (∇×) of the curl equations, andusing the curl of the curl identity

$\nabla \times (\nabla \times X) = \nabla(\nabla \cdot X) - \nabla^2 X$ we obtain

$$c = \frac{1}{\sqrt{\mu_0 \in_0}} = 2.99792458 \times 10^8 \ m/s$$

$$v_p \ =1/\sqrt{\mu_0 \mu_r \in_0 \in_r}$$

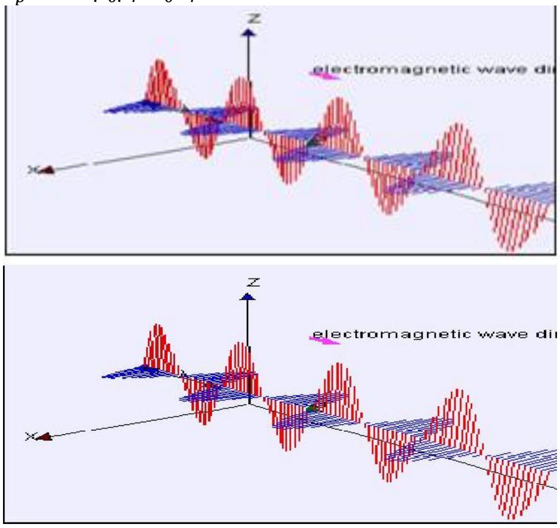

Figure 1. This 3D diagram shows a plane linearlypolarized wave propagating from left to right with the same wave

4. Proposed Ring Resonator

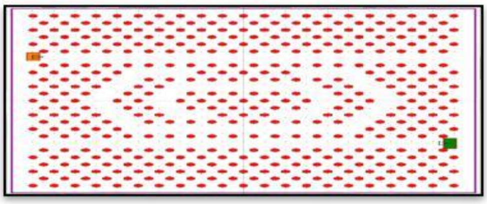

Figure 2. Proposed biosensor

The design consisting of two bus waveguides and a concentric hexagonal rings . The coupling of optical signal happens from bus waveguide to bent waveguide. The defect engineering enhances the quality factor by promoting

more magnetic susceptibility and confinement is seen The below specifications give the dimensions and the factors involved in designing of the sensor.Configuration= Rods placed in air.

Lattice structure 'a' = 1m
Rods radius 'r' =0.20m .

Silicon slab dielectric
constant = 11.56 .
Height of rods 'h' =
0.65ìm .
Phase = 21*21
Distance between rods = 200nm .

Gaussian input source with
= 0.45 and df = 0.12

Wavelength of light considered = 1550nm

A photonic crystal ring resonator (PCRR) sensor with double hexagon shaped, square lattice and rods in air configuration is designed above . The design consists of two hexagonal rings placed in-between two straight waveguides. Gaussian source is given as the input and is made to interact with the analyte therefore bacillus cereus. The blood sample with b. cereus interacts with the silicon rods present. The transmitted light is then observed using a spectrum analyser. The biosensor is also very sensitive to minute changes in the refractive index , hence a minute change in the refractive indices gives rise to differences in peak shifts of both wavelength and frequency.

5. Simulation Results

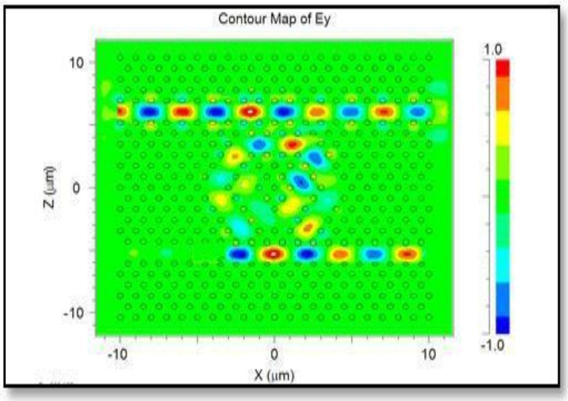

Figure 3. Excitation of the biosensor

From the above excitation schematic we can observe the propagation of the light into the hexagonal biosensor. The propagated light nteracts with the silicon rods which are placed part. The transmitted light is detected with the use of monitor which is placed at the end of the rod.

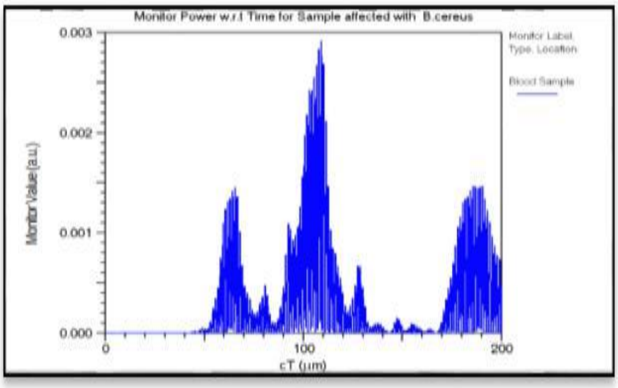

Figure 4. Monitor power graph with B.cereus

The Fig 4 represents the amplitude power spectrum with respect to the monitor time and power. We can observe that as the time increases the amplitude power peaks increases with decreases simultaneously.

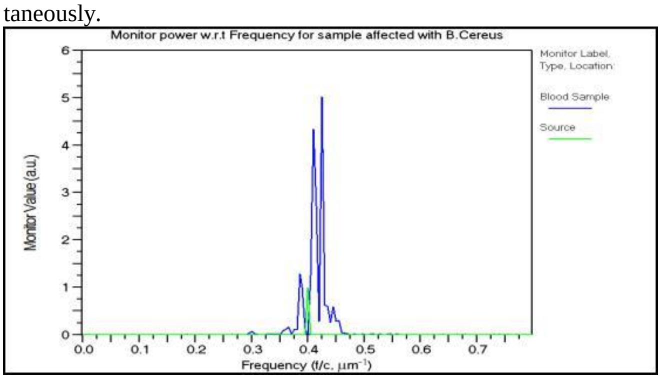

Figure 5. Frequency graph with B.cereus

The Fig 5 shows the amplitude peak of frequency for the simulation results that was done using the blood sample having bacillus cereus. We can observe from the graph that peak varies from 0 to 5a.u.

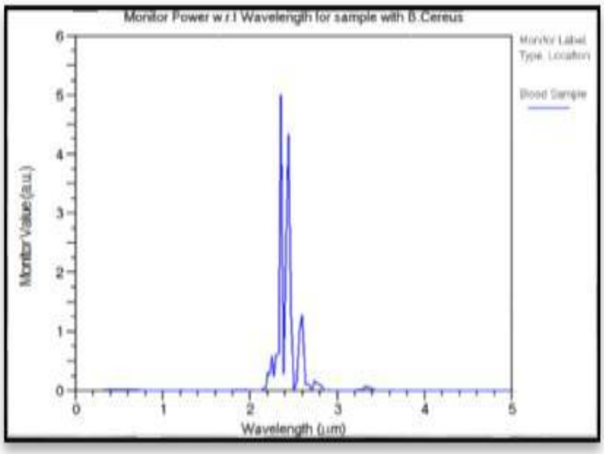

Figure 6. Wavelength graph with B.cereus

The Fig 6 shows the amplitude peak of wavelength for the simulation results that was done using the blood sample having bacillus cereus. We can observe from the graph that peak varies from 0 to 5a.u. Other than main peak, other minor peaks were observed after it occurring at 2.5µm, 2.75µm and 2.85µm respectively.

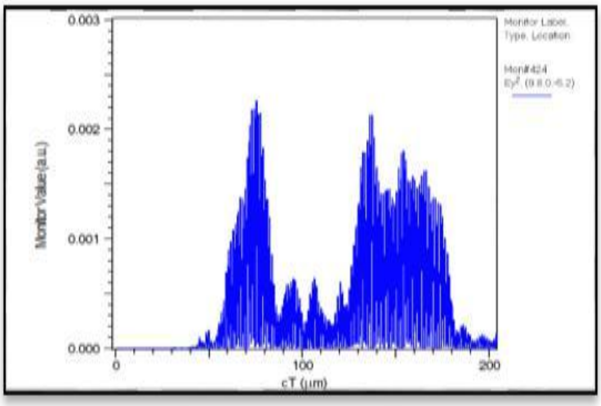

Figure 7. Time graph with respect to monitorvalue.

The Fig 7 shows the time graph that was done when the light source is passed through the sample. We can observe that the peack of the graph that varies from 0.000 to 0.003a.u. thus we can observe that the normal light which varies from 0 to 200µm.hence the light source becomes maximum at 0.0022 at wavelength of 45µm and the fall is at 0.006 for the wavelength of 100µm then there is again a pinch rise at 0.0021a.u for the wavelength 150µm.

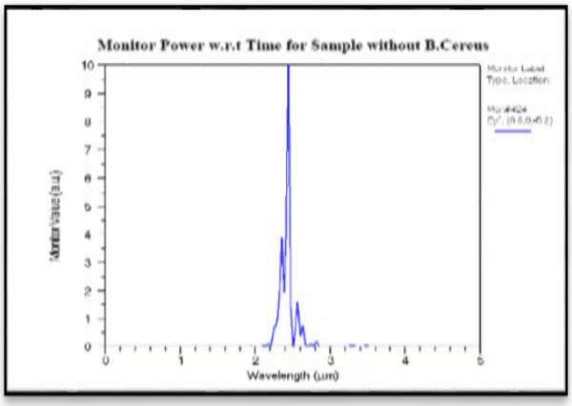

Figure 8. Wavelength graph without B.cereus

The above Fig 8 shows the amplitude peak of frequency for the simulation results that was done using a normal blood sample. We can observe from the graph that peak varies from 0 to 10a.u. Thus we can observe that the amplitude powers of a normal blood sample with that of an infected sample with B. cereus varies independently showing a huge range of difference. Here the adjacent lobes occurs at 2.4µm.

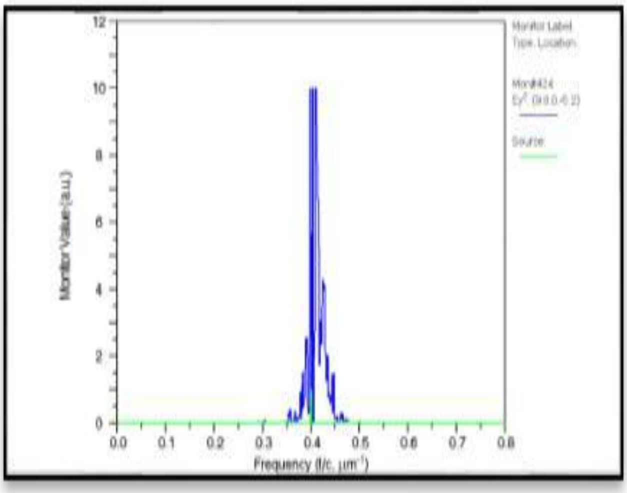

Figure 9: Frequency graph without B.cereus

The Fig 9 shows the frequency of the amplitude peak for the simulation results which was done using the blood sample having without bacillus cereus. We can observe from the graph that peak varies from 0 to 10a.u. Other than main peak, other minor peaks were observed after it occurring at 0.35µm, 0.4µm and 0.46µm respectively.

Table 1 :Comparision of wavelength amplitude differences

Factor	Blood Sample	Blood Sample
	With b.cereus	Without b.cereus
wavelengt	0-5a.u	0-10a.u
h Peak		
0-2a.u	2.3µm	2.2µm
2-4a.u	2.4µm	2.24µm
4-6a.u	2.75µm	2.36µm
6-8a.u	2.85µm	2.43µm
8-10a.u	-	2.7µm

The Table 1 shows the comparison of the blood sample with and without b.cereus where the wavelength varies at each and every interval of the sample hence forth it is very clear that the blood sample that is present shows the exact simulation of the sample of blood and the difference is being obtained for different blood samples.

Table 2 :Comparision of Frequency amplitude differences

Factor	Blood Sample	Blood Sample
	With b.cereus	Without
		b.cereus
Frequenc	0-5a.u	0-10a.u
y Peak		
0-2a.u	0.32µm	0.36µm
2-4a.u	0.34µm	0.38µm
4-6a.u	0.38µm	0.4µm
6-8a.u	0.41µm	0.43µm
8-10a.u	-	0.46µm

The above Table 2 shows the comparison of the blood sample with and without b.cereus where the Frequency varies at each and every interval of the sample hence forth it is very clear that the blood sample that is present shows the exact simulation of the sample of blood and the difference is being obtained for different blood samples.for the estimation of 0-5a.u for the effected blood sample it is 0-10a.u.

6. Conclusion

The band structures and spectral analysis on the propagation of optical signal has been done in photonic crystal. The properties of band structure with refractive index and the variation in transmission spectrum is studied. These sensors are smaller in size, lower cost and the results can be obtained within a short period of time .An optical sensor is designed and simulated in a photonic crystal for their respective applications. The shifts in the wavelength observed through the transmission spectrum briefs blood sample having bacillus cereus and the other with normal blood sample. The simulations were conducted for wavelength response for the samples with and without traces of Bascillus cereus and the from the graphical representation it was found that the positions of the adjacent peaks were exhibited mirror effect when compared with the main peak and there was similarity in the intensity that is 5.a.u and hence the occurrence of adjacent peaks at respective wavelengths acts as a identification parameter for the sensor. The sensor designed in this paper has the capability of sensing even a minute change in RI values. The sensitivity observed to be 5.987u / RIU and quality factor is found to be 1692.2
The Bacillus cereus design parameter can be used in both hexagonal ring and circular ring hence the further implementation can be done on testing lab. This can give a lot of benefit for the medical field as it can reduce the human effort that will show for both with and without effected blood. These B.cereus under test can give even a count on how much cells that have been effected by the blood so it can have measures to get rid of all the blood effected B.cereus..

Future Scope

Sensor design can be optimized further and also different materials with different R I values can be used in design. Designs can be compared and best design for fabrication can be proposed to the fabricator.

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