Detection of Dengue using Photonic Biosensor

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***Abstract*— Biosensor refers to a device that is utilized to detect the analytes or particles of a sample by using the Binding Mechanism. In this paper, a biosensor based on 2D photonic crystal is designed which can detect infected platelets in the Wavelength range of 1620 nm to 1800nm. The proposed biosensor has a quality factor of 104.33 and sensitivity of 50 nm/RIU. The holes in the sensor is filled with platelets of sample blood. The sensing mechanism is based on change in refractive index of the normal platelet and infected platelet which leads to the change in peak resonant wavelength. Finite Difference Time Domain method has been used for the analysis.**

Keywords—Photonic Crystal, Refractive Index, Dengue, Finite Difference Time Domain Introduction

I. INTRODUCTION

Dengue is a rapidly growing pandemic – prone disease in many parts of the world. The frequency of Dengue has expanded by 30 fold in the course of 50 years. Almost 50-100 million infections are currently estimated to occur every year in more than 100 endemic nations and this has put 80% of the total population in danger .Hence it is important to detect Dengue more efficiently which helps in early treatment which in turn reduces the death rate. Dengue infections are spread to individuals through the bite of a contaminated Aedes species mosquito. Then the infected humans become the fundamental transporters and multipliers of the infection, serving as a source of the virus for uninfected mosquitoes. The infection which causes Dengue is called Dengue infection (DENV). There are four DENV serotypes (DENV 1-4), which imply that it is conceivable to get tainted by dengue multiple times. While numerous DENV contaminations produce just mellow sickness, it can likewise cause an intense influenza like ailment. At times this forms into a conceivably deadly intricacy called extreme dengue. A little level of people who have recently been tainted by one dengue serotype have draining and endothelial hole upon contamination with another dengue serotype. This disorder is named serious dengue (otherwise called as Dengue Hemorrhagic Fever(DHF)). At the point when rewarded, extreme dengue has a death pace of 2%-5%, in any case, when left untreated, the death rate is as high as20%. Dengue gets indicative following a 4-to 10- day contamination period (extend, 3-14 days). Dengue indications generally keep going for 2-7 days. Albeit less normal, individuals with extreme dengue will encounter difficulties related with serious dying, organ disability or plasma spillage. Soon after the fever breaks (3-7 days after manifestation beginning or at times inside24 hours prior), indications of plasma spillage show up, alongside the improvement of hemorrhagic side effects, for example, seeping from destinations of injury, gastrointestinal dying, and hematuria. In this paper we use platelets from patients' blood, two kinds of tests are taken, first from the patient experiencing dengue and another from a normal person. The refractive records for the normal platelets, contaminated platelets are 1.39, 1.35. All structure and simulationis performed using the FDTD tool.

II. THEORY

Photonic crystals are periodic dielectric structures that permits or rejects the propagation of EM waves belong into a particular range of frequencies by designing the energy band model for photons. Hence this photonic band structure is also called as optical insulator. This makes the photonic crystal ideal for light related applications. Photonic crystals are of 3 types and they are 1D (1 dimensional), 2D (2 dimensional) and 3D (3 dimensional). 2D structures are easy to design instead of 3D because of the availability of full band gap in 2D. Usually 2 types of design in 2D structure is possible. They are holes in air type and rod lattice. Here we have have designed a 2D photonic crystal using air holes in dielectric wafer structure.

III. MAXWELL'S EQUATION

In physics, electromagnetic field and their behavior is principled by Maxwell equation the derivative of the light and optical phenomenon are obtained with the help of this equation

$$\nabla X(-\nabla \in \times H) = C^2$$

In this equation speed of the light is given by C and H defines speed of magnetic field, gives the permittivity and w gives the resonant frequency. The sensing parameter is got when there is change in the RI which in turn causes the change in wavelength shift.

IV. DESIGN OF BIOSENSOR

In this paper the biosensor 'Holes in slab' setup is utilized for this structure. Indeed, even Rods in air can be utilized. Triangular or square cross section structure might be utilized yet here hexagonal grid structure is liked. SiO2 is used as base material which has a refractive index of 1.48. Above this base material a photonic crystal sensor is placed with holes in slab configuration with silicon as material. Silicon has a refractive index of 3.45. The hole's radius is 138 nm and the Lattice constant is 520nm which is the distance between the adjacent holes denoted by constant 'a'. The holes in the sensor is filled with the analyte i.e., platelet. Grid consistent is picked to be 520nm since it is anything but difficult to figure recurrence and frequency.

The sensor usually consists of 2 ports. They are input and output. The main purpose of these ports is to transmit and examine the optical signal consisting of various wavelength. A Gaussian source is utilized at left finish of the deformity and the output is obtained at the right finish of deformity. An essential bar of silicon is shaped at the middle and afterward it is copied in both x and y heading to get the square cluster of poles. First the left and right line abscond are made by changing the refractive record or dielectric consistent of the openings in those lines. Next the roundabout deformity is made by a similar procedure of changing dielectric steady of fitting poles. The source is put at left finish of the structure and yield transition is estimated at the left end.

Fig 1.The structure for detecting dengue

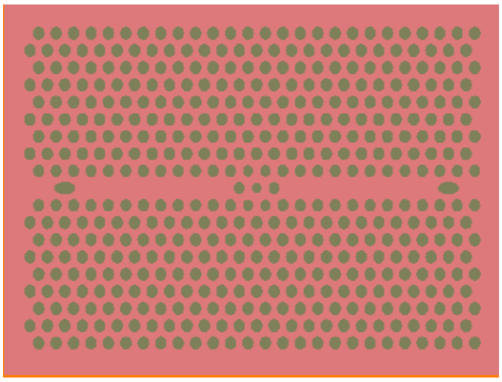

Fig 1 represents the top view of the proposed two dimensional photonic crystal sensor. Defect is introduced by removing the holes between the input waveguide and the output waveguide.

The structure is optimised by changing the parameters of holes such as radius of holes, adjacent distance between the holes. The radius of all the holes and the lattice constant remain same. The holes are filled with the platelet of blood sample. The ultimate goals are to obtain maximum Quality Factor and maximum Sensitivity at the same time. Sensitivity determines how output of the designed sensor is changing with minute change in input and Quality Factor determines how Selective it is i.e., the resonant peak obtained must be efficient and sharp enough so that thus peak can be easily differentiated from unwanted noise peak.

The table gives all the parameters required for the design.

SL.NO	PARAMETERS	VALUES
1	Radius of holes	138 nm
2	Lattice constant	520 nm
3	Refractive index of base (SiO2)	1.48
4	Refractive index of sensor (Si)	3.45
5	Refractive index of normal platelet	1.39
6	Refractive index of infected platelet	1.35
7	Refractive index of normal cell	1.34
8	Wavelength of Gaussian light source	1.62 to 1.8µm

Table1.Design Parameter and its value in Biosensor

V. IMULATION AND RESULT

The performance deliberated by 2D finite difference time domain (FDTD).The holes in sensor are first filled with the normal platelets obtained from the normal blood sample of a person with refractive index of 1.39.The Gaussian light of wavelength 1600 to 1800nm is passed through the input port and the resultant spectra are plotted in the output window. Next the holes are filled with the platelets obtained from the blood sample of infected patient with the refractive index of 1.35. Again light is fed through the port; the wavelength shift in the output spectra indicates that the patient is infected with dengue. The quality factor is defined as a dimensional unit. It is given as the ratio between resonator's centre wavelength to the change in the wavelength.

Quality Factor(Q) and Sensitivity(S) is calculated as shown below:

$$Q = \frac{Peak\ wavelength}{FWHM}$$

The quality factor obtained for this sensor is 104.33.

$$S = \frac{\Delta\Lambda}{\Delta n}$$

The sensitivity obtained for this sensor is 50 nm/RIU.

After FDTD simulation, it is observed that for the first case a resonant wavelength of 1669 nm is obtained. This wavelength is shifted to 1674 nm in the second case. Results are shown in Fig 2.The wavelength shift depends on the refractive index of the sample.

This property of spectral shift of resonant wavelength for different refractive indices of biomolecules can be utilized insensing applications. This structure of biosensor is adequate for detecting dengue pathogens. This sensor gives a decent exactness, better transmission and real time application with cost effectiveness. The sensor is designed using Lumerical software and simulated using FDTD method.

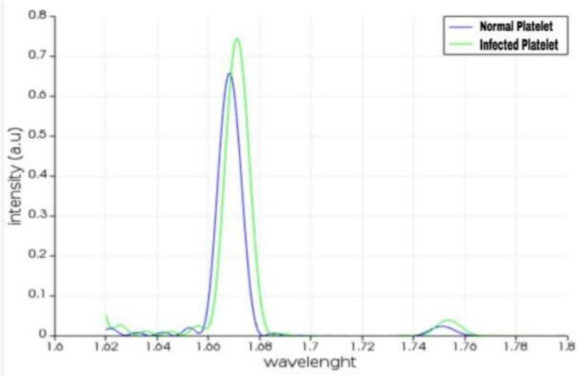

Fig 2. Output spectrum for platelet

CONCLUSION

In this paper, we have designed a biosensor which detects dengue in blood platelets using 2 dimensional photonic crystals. The sensor we have designed is very simple and compact, also it operates at a very high speed with rate of loss being very negligible. By just varying the RI, material transmission is obtained here.

In this structure the input port which is the Gaussian light source has a wavelength of about 1600-1800 nm range. The designing and simulation are performed in Finite Difference Time Domain (FDTD).

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