*Research Article*

# Photonic Crystal Based Optical Biosensor for Melanoma Cancer cell Detection

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**Abstract:** Cancer may be a disease in which uncontrolled growth of cells begins in human body and this growth spreads to other organs of body. When cells get older or damaged, new cells take their place. Sometimes this process breaks down, and abnormal or damaged cells grows, multiply when they shouldn't. These cells will form tumors, which are visible tissue lumps. Tumors can be cancerous or not cancerous (benign). Melanoma is a kind of cancer disease which begins in cells that grows as melanocytes, which are make melanin (the pigment that gives skin its color). Most melanomas form on skin, melanomas can also form in other pigmented tissues, during the year 2017, 96 lakhlives are estimated to died from the varied sorts of cancer. Every 6$^{th}$ death on our planet earth is due to cancer disease, making it the 2$^{nd}$ leading explanation for death – second only to diseases related to heart.biosensorsare used to detect a biological analyte's, biosensorstransduceanalyte's characteristics into an electrical signal that can be analyzed. Proposed work comprised a novel of Photonic Crystal structures for the carcinogenic sensing application consist of two types of resonator to a complex bus waveguide so as to achieve high quality factor and high sensitivity. Sensor is designed and analyzed in Rsoft photonic design software. Novel design is achieved by creating two types of resonator i.e. triangular and ring resonators connecting to a bus waveguide.For both the types FDTD simulations are performed for the detection of melanoma cancer cell. The sensitivity for rods in airconfiguration was found to be 1200nm/RIU and holes in slab was found to be 800nm/RIU respectively. Remarkable Q factor 2902 obtained during the simulation shows feasibility for future fabrication.

**Keywords:** Bio sensor, Melanoma, Photonic crystals (PHc), Photonic band gap,Refractive index(RI) Resonator.

## 1. Introduction

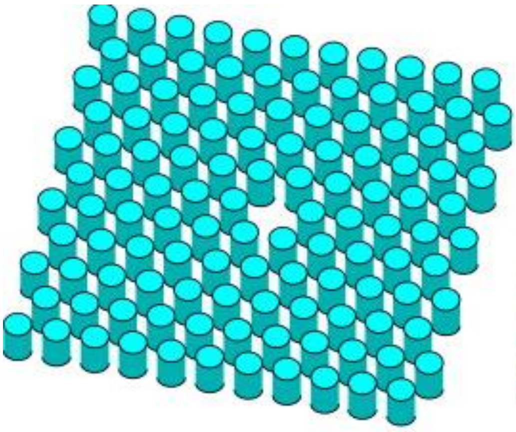
Now a days, the cancer disease is most common and increasing rapidly leading to numerous numbers of deaths. the regulartissue present in human body may contains a cancerous or a noncancerous tissue. Melanoma skin cancer has been major cause of death. Human body contains melanocytic cells. These cells present on the skin. rapid climb of abnormal melanocytic cells causes melanoma. Due to malignancy feature skin cancer is also known as melanoma. Melanoma usually develops in a mole or suddenly appears as a new dark spot on the skin. exposure to the ultraviolet radiation from sun and genetic defects is the main cause of skin cancer. melanoma tumor appears as brownish or black colored. The most dangerous cancer form is malignant melanomas. Since it can easily affect the other parts of the body. Normally this is visible on the surface of skin, then malignant Melanoma grows deep in to the skin and reaches to the blood vessels. Later on, it will spread to other vital organs.

### 1.1 Photonic Crystal

The photonic crystal phenomenon is depending on how the propagation of light happens in periodic structure,

Light photons can be controlled by photonic crystals, Similar to how electrons are controlled in semiconductor circuits, photonic crystals exhibit RI periodicity. A periodic dielectric structure has ability to allow or block photonic bands. Thus,light propagation for a particularband of frequencies can be allowed or blocked. Therefore, the gaps in the frequency spectrum are known as Photonic Band Gaps.

In photonic band gap devices, propagation of light depends on the refractive index. by changing the material refractive index values, compact optical sensors can be designed. Because of the physical properties such as high level of sensitivity, reflectance and transmittance, photonic crystals can be used as biosensors. At present, Analyte sample is analyzed for detection of melanoma cancer cell.



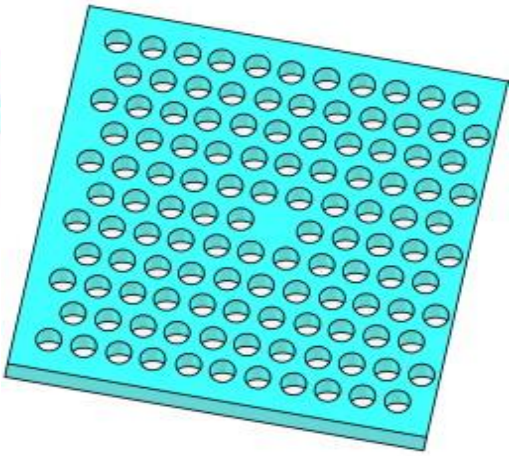


Fig. 1.1.Rods in air configuration Fig. 1.2Holes in slab configuration

The above figures indicate rods in air configuration and holes in slab configuration

**1.2Equations of Electromagnetic Wave**

In a region with no charges (ñ = 0) and no currents (ȷ = 0), such as,
Maxwell's equations in vacuum reduce to:
∇.E=0 -----(1)
∇.B=0 -----(2)
Taking the curl (∇×) of the curl equations, and using the curl of the curl identity
∇ × (∇ × X) =∇ (∇·X) − ∇2X we will get

C $=\frac{1}{\sqrt{\mu o \varepsilon o}}$ , i.e. 2.9972 $x10^{8}$ m/s -------(3)

$v_p = \frac{1}{\sqrt{\mu o \varepsilon o \mu r \varepsilon r}}$ ---------(4)

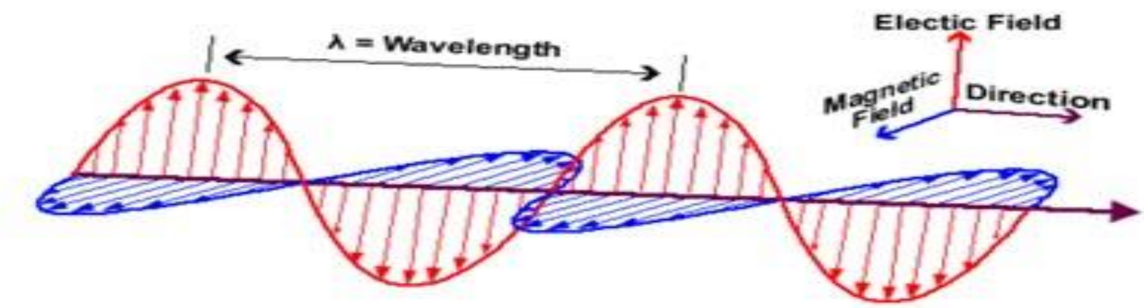



Fig.1.3Linearly polarized wave

Above figureshows a plane linearly polarized wave propagation,

## 2. Literature survey

**[1]**Ayyanar, N., and et:Photonic crystal fiberbased refractive index sensor for early detection of cancer. IEEE Sens. J. 18(17), 7093–7099 (2018)

In the above work authors propose a totally unique biosensor usingPHc fiber to detect the cancer cells in breast, cervical and other parts of body. The analyte testing samples are taken and infiltrated into the fabricated cavity using selective infiltration method. The proposed structure is additionally optimized with its structural dimensional property for increasing the sensitivity.

**[2]**Joannopoulos, and et: Photonic crystals molding the flow of light. Princeton University,[2] Princeton (2007)

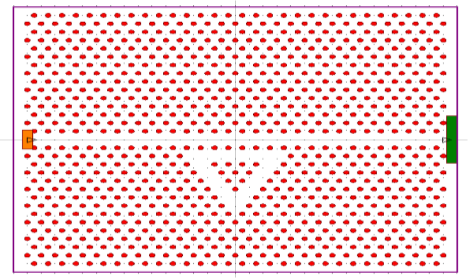
authors explained how the properties of photonic crystals on localized light can be put to work in filter and splitter devices.

**[3]** Li, and et: Polarizationdependent coupling in gold filled dualcore photonic crystal fibers.[3] Opt. Express 21, 5232 (2012)

In this paper authors investigated dispersions and loss of single / dual Polarizationdependent coupling filled with gold wires, investigations show that introducing of surface plasmonic resonance can improve the beams polarization properties

**[4]**Rashmi Priyadarshini B K,Design, Modelling and Analysis of Surface Plasmonic Biosensor for Human Blood Transfusion Application, The author demonstrated the uses of surface plasmonic bio sensors which are designed for human blood transfusion.

## 3. Proposed design



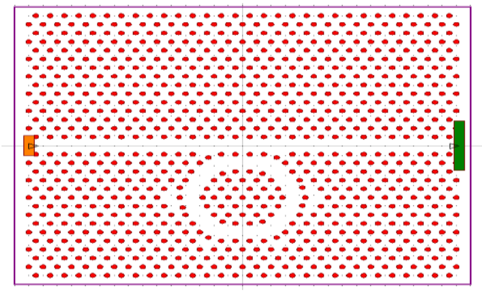


Fig.3.1. Triangular Ring Resonator StructureFig.3.2. Circular Ring Resonator Structure

The following specifications are used to design the rods in air configuration

1)Wavelength: 1550 nm

2)Rod radius: 0.18 µm

3)Lattice constant: 1

4)Crystal size: 30 x 35 µm

The fig 3.1, 3.2 depicts the biosensor in rods in air configuration where silicon rods of refractive index 3.45 are included in the design along with one input port and one output port which can be further expanded by selecting the other ends of ring resonators. The figure 3.3, 3.4 shows the excitation inside the holes in slab and the confinement of light inside the cavity.

The following specifications are used to design the holes in slab configuration as shown in fig 3.5, 3.6 below.

1) Wavelength: 1550nm

2) Holes radius = 0.18 µm

3)Lattice constant: 1

4)Crystal size: 30 x 35 µm

The Monitor Power during the light propagation in sensing layer is depicted in the figure 4.1

A photonic crystal triangular ring resonator, circular ring resonator sensor is designed with bothholes in slab and rods in airconfigurations, the design consisting of bus waveguide and a concentricring. The coupling of optical signal happens in bus waveguide from source to receive. The defect engineering enhances the quality factor by promoting more magnetic susceptibility and confinement is seen. Gaussian source is given as the input and is made to interact with the analyte therefore melanoma cancer cell. The sample analyte with melanoma cancer cell interacts with the silicon rods present. The transmitted light is then observed using a spectrum analyzer. The biosensor is having excellent sensitivity to minute change in the refractive indexes, and hence a very small changes in the refractive indices gives rise to notable differences in peak shifts of wavelength and frequency.

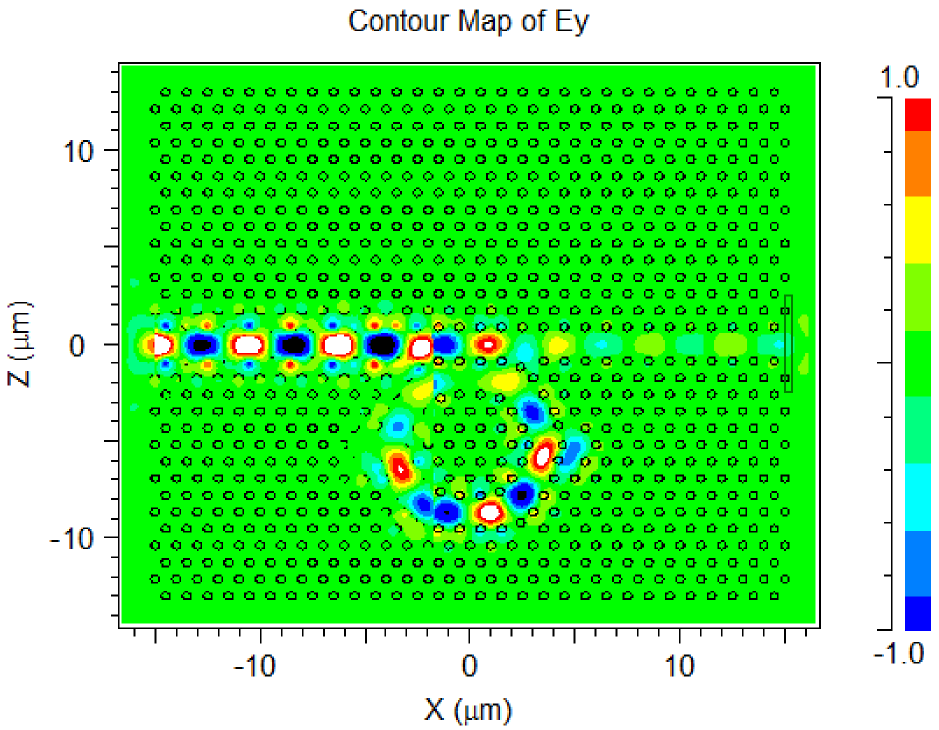
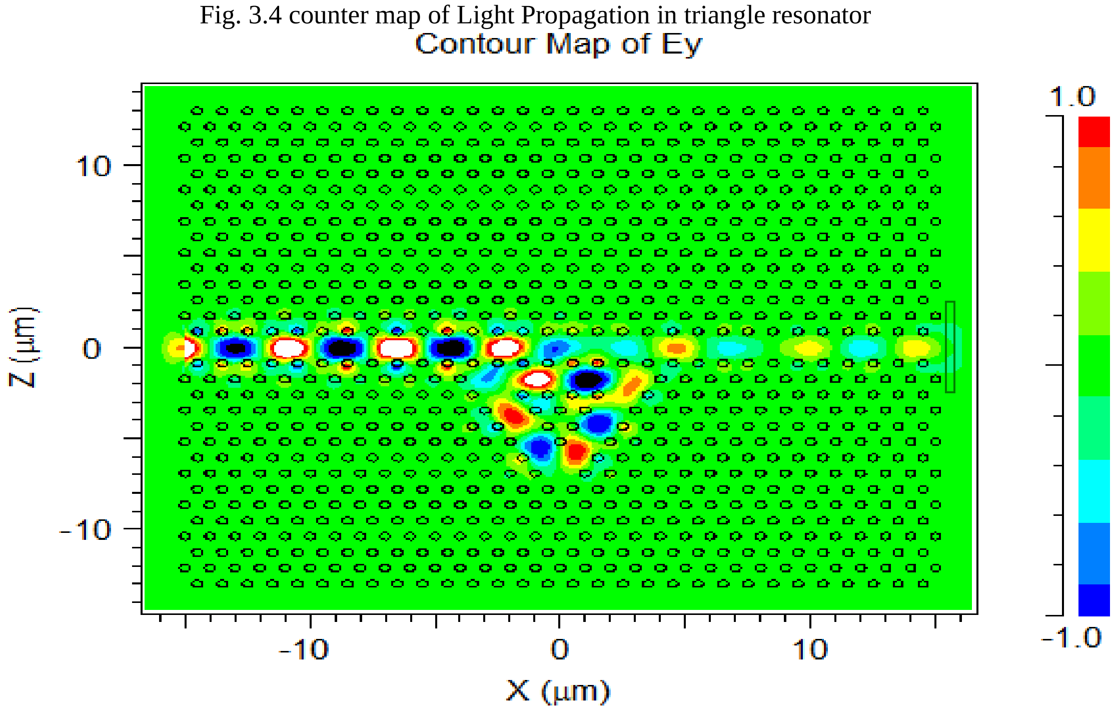



Fig. 3.3 counter map of Light Propagation in circular resonator

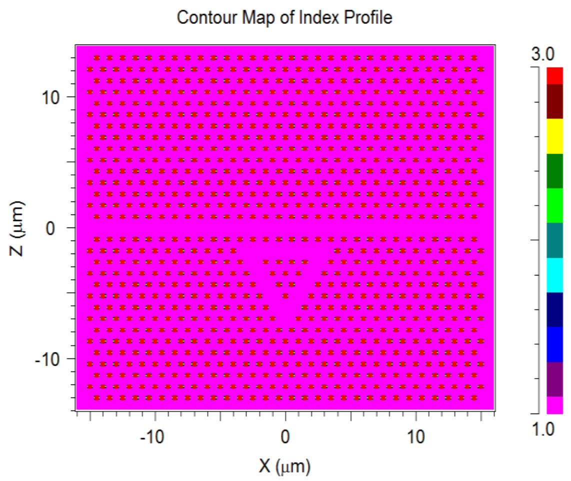
Fig. 3.4 counter map of Light Propagation in triangle resonator

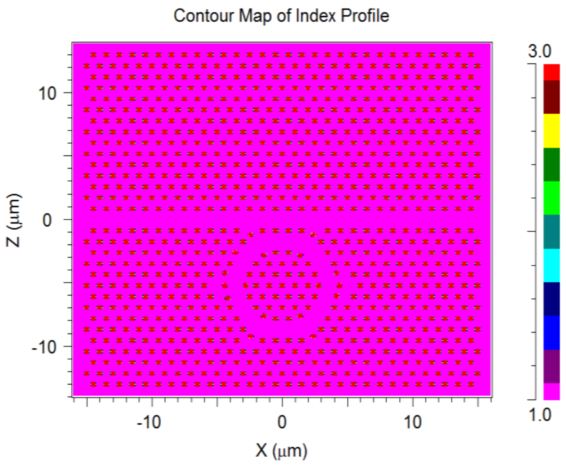



Similarly, we observed counter map of Light Propagation for both triangular, circular ring resonators for rods in air configuration.

From the above excitation image, we can observe the light propagation through the circular and triangular biosensor.The propagated light interacts with the silicon rods. The transmitted light through waveguide is detected using by using monitor which is located at the end of sensor.

Fig. 3.5 Index distribution of TRR in Rods in Air Fig. 3.6 Index distribution of CRR in Rods in Air




Above figures shows the index distribution of triangular ring, circular ring resonators in rods in air configuration

## 4. Results and discussions

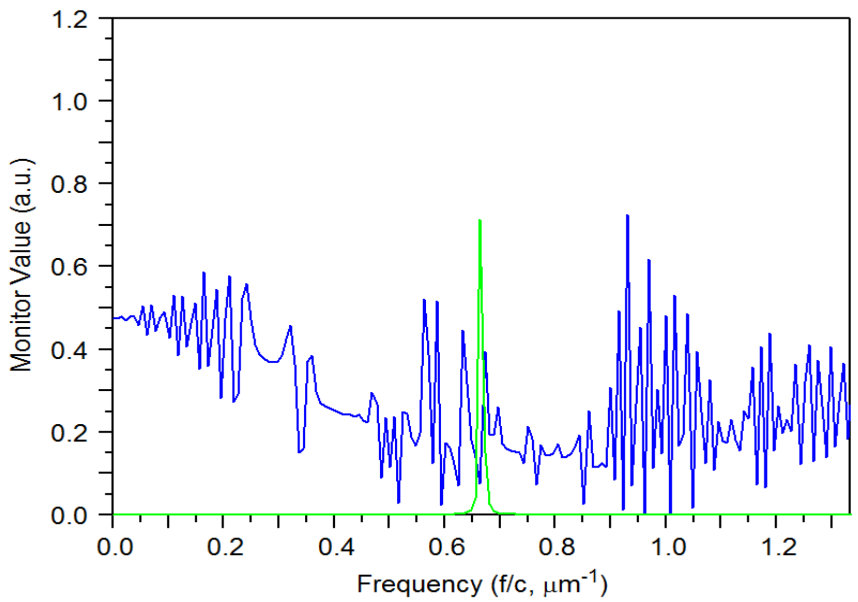



Fig. 4.1 Monitor Power during the light propagation in sensing layer

The above image shows monitor power when light propagates through the sensor with melanoma cancer analyte. the simulation results as shown in fig 4.1, simulation is carried out with analyte sample consistingof melanoma cancer cell. The peak varying from 0 to 0.65a.u is observed from graph.

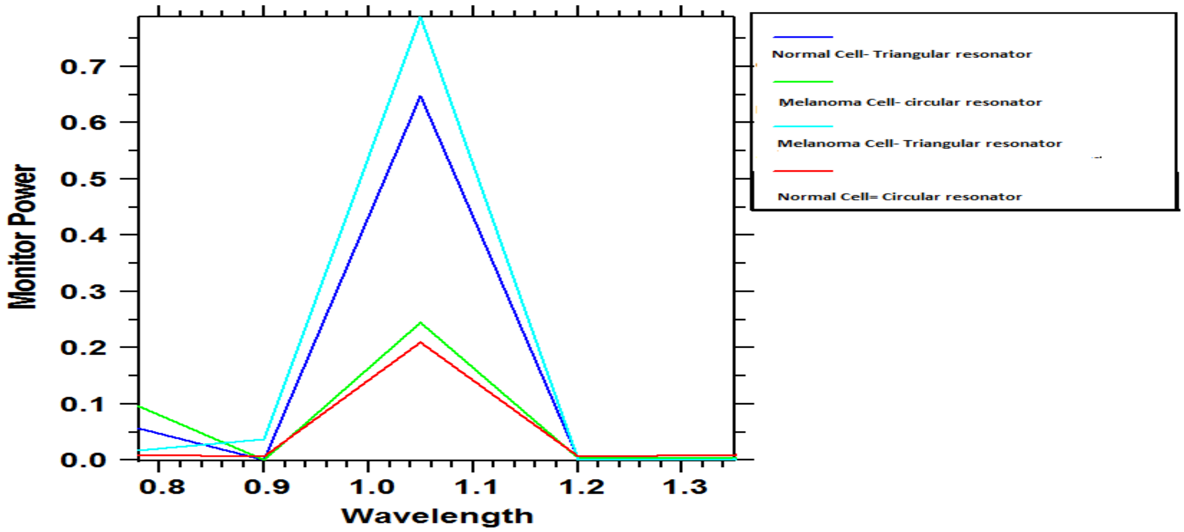



Fig. 4.2 Transmission Spectrum for rod in air configuration (monitor power unit (a.u), wavelength (µm)).

Above image shows the plot between monitor power vs wavelength in rods in air configuration, red line depicts normal cell response in circular resonator, green line depicts melanoma cell response in circular resonator. Similarly, purple line indicates normal cell response in triangular ring resonator, blue line indicates depicts melanoma cell response in triangular ring resonator.

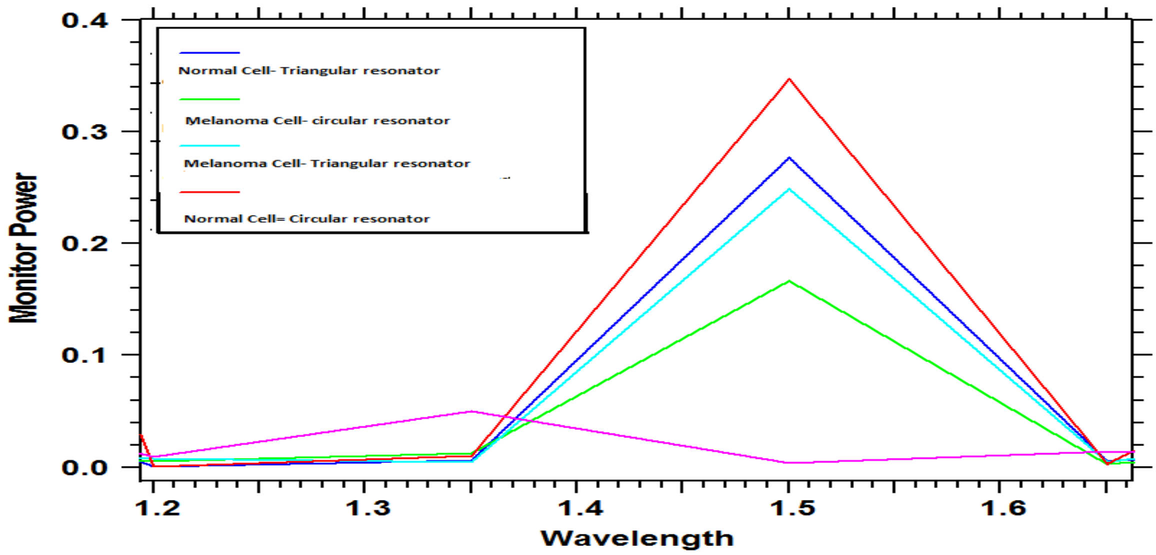



Fig.4.3 Transmission spectrum for holes in slab configuration (monitor power unit (a.u), wavelength (µm)).

Above image shows the plot between monitor power vs wavelength in for holes in slab configuration, red line depicts normal cell response in circular resonator, green line depicts melanoma cell response in circular resonator. Similarly,purple line indicates normal cell response in triangular ring resonator, blue line indicates depicts melanoma cell response in triangular ring resonator.

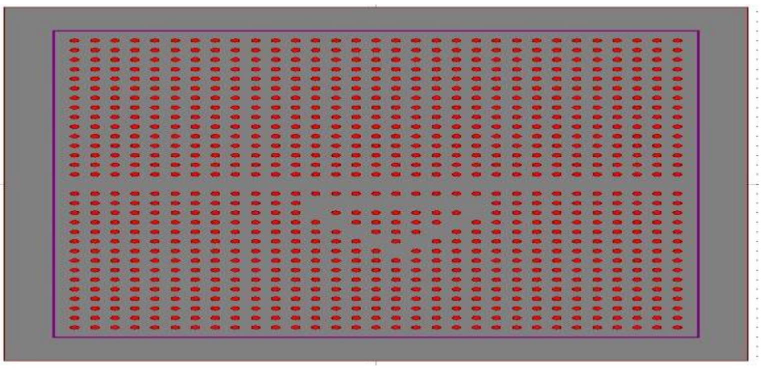


Fig. 4.4 Index distribution of TRR in Holes in slab Configuration

Above figure shows the index distribution of triangular ring resonator in holes in slab configuration

**Table4.1 Monitor Powerand Wavelength (Rods In Air configuration)**

| Analyte | Monitor Power (CRR)% | Monitor Power (TRR)% | Wavelength (CRR) | Wavelength (TRR) |
|---|---|---|---|---|
| Normal Cell | 20 | 65 | 1.05 | 1.052 |
| Melanoma cancer Cell | 25 | 75 | 1.053 | 1.054 |

The above table 4.1 shows the monitor power and wavelength of both normal and melanoma cancer cell in rods in air configuration

**Table4.2 Monitor Power and Wavelength (Holes In Slab configuration)**

| Analyte | Monitor Power (CRR) | Monitor Power (TRR) | Wavelength (CRR) | Wavelength (TRR) |
|---|---|---|---|---|
| Normal Cell | 35 | 28 | 1.51 | 1.53 |
| Melanoma cancer Cell | 15 | 25 | 1.545 | 1.546 |

The above table 2 shows the monitor power and wavelength of both normal and melanoma cancer cell in holes in slab configuration

**Table 4.3Refractive Indices And Q Factor For Rod In Air Configuration.**

| Analyte | Refractive index | Q-factor (TRR) | Q-factor (CRR) |
|---|---|---|---|
| **Normal cell** | 1.35 | 847 | 810 |
| **Melanoma Cell** | 1.59 | 2902 | 1800 |

The above table 3 shows the refractive indices and q factor of both normal and melanoma cancer cell in rods in air configuration

**Table 4.4 Refractive Indices And Q Factor For Holes In Slab Configuration**

| Analyte | Refractive index | Q-factor (TRR) | Q-factor (CRR) |
|---|---|---|---|
| **Normal cell** | 1.35 | 720 | 700 |

| | | | |
|---|---|---|---|
| **Melanoma Cell** | 1.59 | 2100 | 1200 |

The above table 4.4 shows the refractive indices and q factor of both normal and melanoma cancer cell in holes in slab configuration

**Table 4.5Sensitivity For Rod In Air And Holes In Slab Configuration**

| Configuration | Sensitivity (RIA) | Sensitivity (HIS) |
|---|---|---|
| **Triangular** | 980 nm/RIU | 650nm/RIU |
| **Circular** | 1200nm/RIU | 800nm/RIU |

The above table 4.5 sows the sensitivity of both types of resonators in rods in air and holes in slab configuration,

## 5. Conclusion and future work

Triangular and circular ring resonator structures are designed and analyzed for detection of melanoma cancer cell. figure 6.a. and Figure6.b. shows the transmission spectrum for triangular and circular ring resonator in holes in slab and rod in air configuration respectively.There is distinct shift in wavelength between normal cell and melanoma cancer cell in holes in slab and rod in air configuration. High quality factor observed in case of rods in air configuration compared to holes in slab configuration. Highest sensitivity of 1200nm/RIU is observedfor circular ring resonator. Power transmitted is high in case of triangular ring resonator compared to circular ring resonator. Quality factor of photonic sensing tool designed in obtained from R-Soft design module.

In future different materials with different refractive index values can be implemented in design, theses designs can be compared and the best design for fabrication can be advised to the fabrication, also sensor designs can be optimized further the proposed design can be suggested for the fabrication with advantages like compact, economical and low power consumingnano device.

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