Chapter 1

INTRODUCTION

Cancer is a group of diseases characterized by the uncontrolled growth and spread of abnormal cells in the body.
These abnormal cells can invade nearby tissues and can spread to other parts of the body through the blood and lymph systems. There are many different types of cancer, including lung cancer, breast cancer, prostate cancer, and skin cancer, among others.

Each type of cancer is caused by a different set of circumstances and has its own set of symptoms and treatments. But in general cancer cells differ from healthy cells as they don't obey the normal cell cycle regulation and keep dividing. And they can also form tumors which can grow and compress other organs or structures

Cancer is a leading cause of death worldwide, and it affects people of all ages, races, and economic backgrounds. Cancer can cause serious illness, disability, and death, and it places a significant burden on individuals, families, and society as a whole.

Developing a cure for cancer would greatly reduce the number of deaths caused by the disease and improve the quality of life for those who are affected by it. Additionally, finding a cure for cancer would also have a significant economic impact, as the cost of treating cancer is high.

1.1 PROBLEM STATEMENT

Cancer is a group of diseases characterized by the uncontrolled growth and spread of abnormal cells. These abnormal cells can form tumors and damage nearby tissue, including vital organs.
Cancer can develop in almost any part of the body, and there are over 100 different types of cancer. Some of the most common types include lung cancer, breast cancer, colon cancer, prostate cancer, and skin cancer.
The exact cause of cancer is not known, but various factors such as genetics, lifestyle, and environmental exposures have been identified as possible causes.
Some of the common symptoms of cancer include fatigue, unexplained weight loss, pain, changes in the skin, and changes in a mole.
Cancer is treated using a combination of therapies, including surgery, radiation therapy, chemotherapy, and targeted therapy.
Prevention of cancer includes early detection and screening, avoiding known risk factors, and maintaining a healthy lifestyle.

Awareness about cancer including early detection, symptoms and preventive measures, research funding, and cancer patients support groups have increased the survival rate of cancer over the years. However, cancer remains one of the leading causes of death worldwide.

Cancer is a leading cause of death worldwide. According to the World Health Organization (WHO), cancer is the second leading cause of death globally and was responsible for an estimated 9.6 million deaths in 2018. The most common types of cancer vary by country and region, but some of the most common types of cancer worldwide include lung cancer, breast cancer, colorectal cancer, prostate cancer, and stomach cancer.

In the United States, the National Cancer Institute (NCI) estimates that in 2021, there will be an estimated 1,806,590 new cancer cases diagnosed and 606,520 deaths from cancer. The most common types of cancer in the US are expected to be prostate cancer, breast cancer, lung cancer, and colon and rectal cancer.

It's worth noting that Cancer mortality rate has been decreasing over time due to the advancements in cancer treatment, early detection and the adoption of healthier lifestyles. With the ongoing research in the field of cancer, there is hope for even more effective treatments, and even a cure for cancer in the future

1.2 PROPOSED SYSTEM

- Optical sensor is presented for cancerous cell detection in various parts of the human body (i.e., cervix, adrenal gland, breast, skin, and blood).
- An optimized structure based on compact cladding is successfully designed with enhanced sensitivity and very low confinement loss. The parameters like effective area (Aef), V-parameter (Vef), spot size (Wef), numerical aperture (NA), and beam quality factor are investigated over the wavelength region 1.4–2.5 μm.
- The consummation of relative sensitivity is also calculated and is superior to other previous work. The numerical investigation indicates that cancerous cells have higher sensitivity than normal cells.
- The values investigated for the sensitivity of cervical cancer, adrenal gland cancer, skin cancer, blood cancer, and breast cancer of type I and type II are 94.96%, 95.15%, 94.13%, 94.84%, 95.40%, and 95.51% in X-polarization, respectively, which are higher than the calculated values from any prior works.
- The explored structure is mono mode PCF, with silica as a dielectric material. The finite element method (FEM) has been implemented for investigating the numerical values, implemented on COMSOL Multiphysics (version 5.3). The simple design ensures easy fabrication with ongoing techniques

CHAPTER 2

ANALYSIS AND SYSTEM REQUIREMENTS

2.1 LITERATURE SURVEY

Literature review is a systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners.

The literature review establishes the fact that you have familiarized yourself with the particular area(s) or discipline(s) in which you are conducting research.

A literature review will summarize the existing scholarly literature on your chosen topic, establish relationships between different research projects of the past, show where there are gaps in past research, and show how the past published work relates to your own work.

A literature survey includes the following:

• Existing theories on the subject that are broadly acknowledged.

• Books that have been written on the topic, both broad and particular.

• Field research is frequently conducted in the sequence of oldest to most recent.

• Major challenges being faced and on-going work, if available.

OBJECTIVES OF LITERATURE SURVEY

• Provide a solid foundation of knowledge about the subject.

• Identify areas of prior scholarship to prevent redundancy and give credit to other researchers.

• Access to the most current innovations, methods, and theories.

• It indicates whether the evidence already available solves the problem effectively without requiring further investigation.

2.1.1 RELATED PAPERS

1. TITLE: DESIGN AND MODELLING OF PHOTONIC SENSOR FOR CANCER CELL DETECTION – 2014

AUTHORS: DR. PREETA SHARAN, BHARADWAJ S M, FLEMING DACKSON GUDAGUNTI, POOJA DESHMUKH.

This paper tells about the early detection of cancer cell by using photonic band gap method. System level cancer cell detection has been done with the dielectric constant (at optical frequency) as the input. Comparison of normal cell and cancerous cell has been done and a precise frequency shift has been observed. The input dielectric constant values of normal cell vary from 1.8225 to 1.8769 and for cancer cell it varies from 1.9376 to 1.9628. Even though the change in the input is very small, a micron change in the frequency has been observed. Thus, photonic crystal based sensor will differentiate the normal cells from cancerous cell.

Keywords: Cancer cell, Dielectric constant, Photonic Band gap, Photonic Biosensor

LIMITATIONS:

Experiences difficulty in fabrication process thermal profile as an additional outcome

2.TITLE: A PHOTONIC CRYSTAL SENSOR FOR ANALYSIS AND DETECTION OF CANCER - 2015

AUTHORS: POONAM SHARMA, DR. PREETA SHARAN, POOJA DESHMUKH

In this paper, a 2D photonic crystal sensor using gratings has been designed for the analysis of Basal, Breast and Cervical cancer cells. The grating design, incorporated in the photonic crystal waveguide increases the efficiency and sensitivity of the designed sensor. The fact that index of refraction of the cancer cells differs from the normal cell, it can be differentiated and detected using optical techniques. The shift in the wavelength and intensity levels in the reflection spectrum has been observed for cancer and normal cells. FDTD method has been used for analyzing cells. MEEP simulation tool has been used for modeling and designing of sensor.

Keywords: Basal cancer, Breast cancer, Cervical cancer, FDTD, Integrated photonics, MEEP, Photonic crystal sensor.

LIMITATIONS:

Operating wavelength was very small and application tolerance was not introduced.

3.TITLE: ENHANCED SENSITIVITY OF CANCER CELL USING ONE DIMENSIONAL NANO COMPOSITE MATERIAL COATED PHOTONIC CRYSTAL-2018

AUTHORS: N. R. RAMANUJAM, I. S. AMIRI, SOFYAN A. TAYA, SAEED OLYAEE, R. UDAIYAKUMAR, A. PASUMPON PANDIAN K. S. JOSEPH WILSON, P. MAHALAKSHMI, P. P. YUPAPIN

We theoretically analyze the detection of a cancer cell in the one-dimensional photonic crystal by infiltrating different sample cells in the cavity layer. The defect modes appear in their transmission spectra only if the nanocomposite layers are included on either side of the cavity layer. This analysis is carried out by a dielectric constant and the transmittance peak of the cancer cell is compared with the normal cell. The transmittance peak shifts are analyzed with various filling factors for optimization purposes. Through the shifting spectrum, the sensitivity of cancer cell from the normal cell is obtained from a minimum of 42 nm/RIU to a maximum of 43 nm/RIU.

LIMITATIONS:

SPR surface Plasmon resonance technique for sensing gained very low sensitivity

4.TITLE: NUMERICAL MODELING OF CELL TRAJECTORY INSIDE A DIELECTROPHORESIS MICRO DEVICE DESIGNED FOR BREAST CANCER CELL SCREENING

AUTHORS: VAHIDEH SHIRMOHAMMADLI AND NEGIN MANAVIZADEH

This paper deals with mathematical modeling of the particle trajectory inside a microfluidic device based on the application of DC Di electrophoresis (DEP). The proposed device is designed to separate the breast cancer cell lines (e.g. MDA-MB-231 and MCF-7) from normal blood cells in the specific outlets. A complementary mechanism is employed in the channel that involves the drag and DEP forces acting cooperatively on the cells to deflect the cells into corresponding outlets. Closed-form equations are yield for predicting the particle position along the x and y-axis versus time. Effect of both DEP and drag forces are considered and Newton's second law of motion is exploited for formulations. The initial values required by the particle trajectory equation, including the primary location and velocity, and the physical features of different cells, are determined. The proposed microchannel is numerically simulated using finite element simulation software and the results are compared to the data derived from modeling equations. Our findings confirm the capability of the proposed model to accurately track the location of all types of under-study cells inside the proposed microchannel. In this paper, a user-friendly software package is designed and implemented in the MATLAB environment to predict the cell trajectory of different cells with various diameters. Results for different cells with various diameters reveal that this software is capable of predicting the cell trajectory with an error less than 7%.

Keywords— Di electrophoresis, Modeling, breast cancer, Trajectory, Circulating tumor cell, Cell motion.

LIMITATIONS:

Sensitivity was improved but detection limit was low.

5.TITLE: SURFACE PLASMON RESONANCE BASED TITANIUM COATED BIOSENSOR FOR CANCER CELL DETECTION, AUGUST 2019

AUTHORS: MD. ASADUZZAMAN JABIN, MEMBER, IEEE, KAWSAR AHMED, MEMBER, IEEE MD. JUWEL RANA, MEMBER, IEEE, BIKASH KUMAR PAUL, MEMBER, IEEE, MAHEEN ISLAM, MEMBER, IEEE, DHASARATHAN VIGNESWARAN, MEMBER, IEEE, MUHAMMAD SHAHIN UDDIN

A new optimized bowl-shaped mono-core surface Plasmon resonance based cancer sensor is proposed for the rapid detection of different types of cancer affected cell. By considering the refractive index of each individual cancer contaminated cell with respect to their normal cell, some major optical parameters variation is observed. Moreover, the cancerous cell concentration is considered at 80% in liquid form and the detection method is finite element method with 2 100 390 mesh elements. The variation of spectrum shift is obtained by plasmonic band gap between the silica and cancer cell part which is separated by a thin (35 nm) titanium film coating. The proposed sensor depicts a high birefringence of 0.04 with a maximum coupling length of 66 μm. However, the proposed structure provides an optimum wavelength sensitivity level between about 10 000 nm/RIU and 17 500 with a resolution of the sensor between 1.5×10^{-2} and 9.33×10^{-3} RIU. Also, the transmittance variance of the cancerous cell ranges from almost 3300 to 6100 dB/RIU and the amplitude sensitivity ranges nearly between −340 and −420 RIU^{-1} for different cancer cells in major polarization mode with the maximum detection limit of 0.025. Besides, the overall sensitivity performance is measured with respect to their normal cells which can be better than any other prior structures that have already proposed.

Keywords: Cancer cells, Cancer Sensing and Detection, Mono-core Bowl shaped SPR, Birefringence, and Sensitivity.

LIMITATIONS

Although sensitivity performance was improved but detection limit was low

6.TITLE: DESIGN AND FABRICATION OF AMOEBA FACED PHOTONIC CRYSTAL FIBER FOR BIO SENSING APPLICATION

AUTHORS: MD. ASADUZZAMAN JABIN, YANHUA LUO, GANG-DING PENG, MD. JUWEL RANA, KAWSAR AHMED, TRUONG KHANG NGUYEN, BIKASH KUMAR PAUL, VIGNESWARAN DHASARATHAN

A newly designed Amoeba faced photonic crystal fiber (A-PCF) is introduced for the first time in the fields of fiber for bio sensing and particularly to detect cancerous cells for instances-blood cancer (Jurak), cervical cancer HeLa), adrenal glands cancer (PC12), breast cancer (MDA-MB-231, MCF-7) and skin cancer (Basal), etc. In fact, proposed PCF is fabricated after the simulation studies and the application for sensing is numerically investigated by the discrete finite element method (D-FEM) by the simulation of about 22105 mesh elements. Moreover, the numerical analysis is justified by full vector simulation software COMSOL V-5.1 and

considering the refractive indices from it. Also, different sections are considered for the analyze cavity to analyze the performance variations. Nonetheless, few parameters like birefringence, coupling length, power fraction, transmittance, wavelength sensitivity, and transmittance sensitivity are evaluated through the refractive indices of the cancerous cell compared to its normal cell and the most optimum profile are respectively to 3.5 × 10-3, 900 μm, 0.891, -178 dB,18115.94 nm/RIU and 6071.42 dB/RIU. Nonetheless, the fabrication of the PCF can be achieved by using current fabrication technology such as stack-and-draw, sol-gel or the extrusion and drilling techniques that help to overcome all the primary difficulties of the proposed PCF.

Key Terms: Amoeba PCF, Cancer sensing, Power fraction, Birefringence, Transmittance, Sensitivity.

LIMITATIONS:

New Amoeba Structure where more Optical Parameters are analyzed but, the Relative Sensitivity response was not good

7.TITLE: DESIGN OF LOW DISPERSION AND LOW LOSS PHOTONIC CRYSTAL FIBER, DEFECTED CORE CIRCULAR-OCTAGON HYBRID LATTICES- 2019

AUTHORS: G. DHANU KRISHNA, V.P. MAHADEVAN PILLAI, K.G. GOPCHANDRAN

Photonic crystal fibers consisting of a novel hybrid structure providing low values for both dispersion and confinement loss were simulated using finite element method. The studies on different arrangements, polygonal and circular, of air holes as cladding of PCFs have shown that circular PCFs results in a structure with low dispersion, air filling fractions remaining same. Circular PCF with dispersion 103.50 ps/nm.km and confinement loss 5.97 × 10−6 dB/m was restructured by replacing its first ring with octagonal air hole lattice having eight air holes. This hybrid circular-octagon PCF has shown a dispersion of 33.15 ps/nm.km and a confinement loss of 2.52 × 10−6 dB/m. The introduction of air hole defects in the hybrid fiber core with three identical air holes in an equilateral triangular lattice was found to modify dispersion by reducing its value to −11.63 ps/nm.km with confinement loss 9.51 × 10−5 dB/m.

LIMITATIONS

To achieve low loss and nearly zero flattened dispersion we need to use hybrid cladding pcf lattice structures.

8.TITLE: PHOTONIC CRYSTAL FIBER BASED REFRACTIVE INDEX SENSOR FOR EARLY DETECTION OF CANCER

AUTHORS: N. AYYANAR, G. THAVASI RAJA, MOHIT SHARMA AND D. SRIRAM KUMAR

This paper proposes a novel cancer sensor based on dual core photonic crystal fiber for the detection of cancer cells in cervical, breast and basal parts. The samples are taken in fluid form and infiltrated into the farmed cavity using selective infiltration method. Each fluid form has its own refractive index values which give the various responses in the transmission and loss spectrum. The spectral shift is obtained by inducing the coupling mechanism between silica core and cancer cell core for its launching input optical field which is investigated by finite element method. The proposed structure is also optimized with its structural dimensional property for enhancing the sensitivity. The sensing performances for the cervical cancer cell are obtained as high as 7916 nm/RIU for x-and 10625 nm/RIU y-polarization with the detection limit of 0.024. The sensitivity to breast cancer cells for x and y-polarization is 5714.28 nm/RIU and 7857.14 nm/RIU with detection limit of 0.014 respectively. Similarly, the sensitivity to basal cells can also reach 4500nm/RIU for x-polarization and 6000 nm/RIU for y-polarization. To the best of our knowledge, such sensitivities are the highest reported thus so far.

Keywords— Cancer cell cavity, coupling mechanism, birefringence, peak wavelength and sensitivity.

LIMITATIONS

Comparatively low sensitivity was observed from the structure. Here it could detect for only three types of cancer.

2.2 HARDWARE AND SOFTWARE REQUIREMENTS

2.2.1 HARDWARE REQUIREMENTS

A system for the detection of cancer cells using a photonic crystal-based sensor would likely involve a number of different components, including the sensor itself, a light source, and a system for analyzing the data generated by the sensor.

The sensor itself would likely be made up of a photonic crystal, which is a material with a periodic structure on the scale of the wavelength of light. This structure can be used to control the flow of light through the material in a way that allows it to be used to detect the presence of specific molecules or cells.

The system would need a light source, such as a laser, that would be directed through the sensor. When cancer cells are present in a sample, they can interact with the light in a way that can be detected and analyzed by the sensor. The sensor would need to be configured to detect the specific type of cancer cell being searched for.

Data collected by the sensor would be analyzed by the system, which would use algorithms to identify and classify the cancer cells. This analysis would be done in real-time and the results could be used to inform a diagnosis or guide treatment decisions.

The system would need to be designed to be easy to use and portable, with the ability to operate in different environments. It would also need to be designed with safety, security and privacy in mind, as sensitive medical information is being handled.

It's important to note that such kind of system isn't yet available and is still in the research phase. Additionally, the development of a system that can detect all types of cancer cells using a single photonic crystal-based sensor is a highly complex process, and would likely require significant advancements in materials science and nanotechnology to achieve.

Using Raspberry Pie the required output (it will say whether the patient has cancer or not) will be displayed.

2.2.2 SOFTWARE REQUIREMENTS

MEEP SOFTWARE

Maxwell's Electromagnetic Equation Propagation (MEEP) is simulation tool. MEEP is an open-source implementation of the finite-difference time-domain (FDTD) algorithm.

And also simulation can be done in 1D, 2D and also in 3D.The computation of transmission spectrum, reflection spectrum, frequencies and also resonant modes in dielectric structures is also done using MEEP. MEEP is a time domain tool.

$$P(\omega) = \mathrm{Re}\, \hat{\int} E\omega(x) * H\omega(x) d2x$$

It can compute the propagation of an electromagnetic wave through very complicated structures, using realistic material models (including dispersion, conductivity, anisotropy or nonlinearities), distributed computing and combination of time-domain and frequency-domain solver.

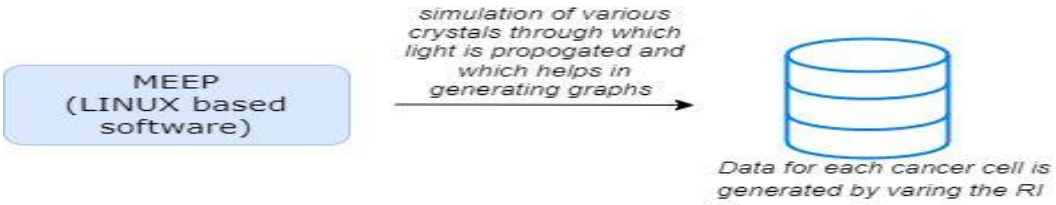

Figure 1 Activity flow of MEEP

2.2.3 AI TECHNIQUES

- Using **binary classification** technique, a AI model is developed for the detection of various cancer cell.

- In machine learning, **binary classification** is a supervised learning algorithm that categorizes new observations into one of two classes.
- Classification is the process of predicting the class or category of a given input sample. Binary classification is a specific type of classification in which there are only two possible classes or categories.
- For example, a common binary classification task is to classify email as either “spam” or “not spam”. Another example would be classifying images of handwritten digits as either “0-9” or “not 0-9”.
- A common method to perform binary classification is using logistic regression.
- Logistic regression is a statistical method that is used to model a binary outcome.
- Other common algorithms for binary classification are SVM, Decision Tree and Random Forest, Neural networks. The choice of algorithm depends on the specific task, the amount and quality of data, and the resources available to train and deploy the model.
- An SVM algorithm finds the hyperplane that separates the data into two classes in such a way that the margin (i.e., the distance between the hyperplane and the closest data points from each class) is maximized. The data points closest to the hyperplane are called support vectors, and the algorithm is called Support Vector Machine because the boundary is fully determined by these support vectors.
- A decision tree consists of a set of branches and each branch represents a decision that is made based on the value of one or more input features. At the top of the tree is the root node, and it is connected to one or more internal nodes, which in turn are connected to leaf nodes. Each internal node corresponds to a test on the value of one of the input features, and each leaf node corresponds to a predicted output value.The Random Forest algorithm works by creating multiple decision trees during training and then averaging their predictions during testing. Each decision tree is created using a different subset of the training dat
- a, which is obtained by randomly sampling the data with replacement (i.e., bootstrapping). Additionally, when building each tree, a random subset of the features is used for each split at each node, this technique is called as "feature randomness".
- Neural networks are used for a wide range of tasks, including image recognition, natural language processing, and prediction. There are several types of neural networks, but the most basic and widely used is the feedforward neural network, also known as a multi-layer perceptron (MLP). An MLP consists of an input layer, one or more hidden layers, and an output layer. Each layer contains multiple artificial neurons, and the information flows through the network in a feedforward direction, from the input layer to the output layer, without looping back.

CHAPTER 3

SYSTEM DESIGN AND MODELLING

3.1 PRELIMINARY DESIGN

Preliminary design, also known as conceptual design or pre-design, is the initial phase of the design process for a project. It is the stage where the overall concept and general layout of the project are developed. During this stage, the designer will gather information and requirements from the client and other stakeholders, conduct research, and explore various options for the design. This may include developing sketches, models, or other visual aids to help communicate the proposed design to others. The goal of the preliminary design phase is to identify the key objectives, constraints and requirements of the project, and to come up with a general plan that can be used as a foundation for more detailed design work later on.

During this phase, the designer will also make estimates and calculations of the costs, materials, and other factors required to build the project. And also safety and accessibility factors. And also evaluate different alternatives to choose the one with the best balance between the requirements and constraints

In summary, the preliminary design phase is a critical step in the design process as it helps to establish the overall direction and scope of the project, and provides a basis for further design and development.

Steps involved in detection process are: -

- Input is taken in the form of fluids (blood, urine or sputum)
- This Bio Analyte is passed through an optical sensor
- From the values generated a OSA/Graph is formed
- These values are used to train the ML Model
- The output is displayed on GUI based system using Raspberry pie

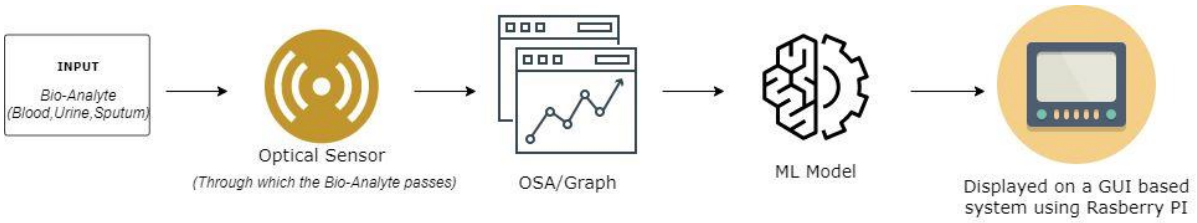

Figure 2: FIG: Flowchart representing the Design of the Model

Using the MEEP Software we are creating a Hexagonal structure through which wave guide is passed (Laser Light). This wave guide interacts with micro fluidic platforms (Blood, Urine & Sputum) which will give us certain values which will be used further training the ML Model.

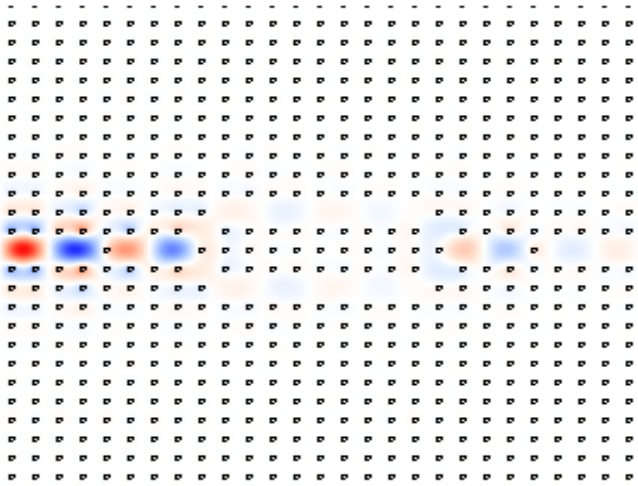

Figure 3: MEEP simulation of the photonic crystal

The values which we get from Circular Photonic crystal fibre (CPCF) is taken and a graph is plotted using scidavis software. The X axis of this graph is frequency while the Y axis is Amplitude. For each cancer cell different graphs are plotted using Refractive Index of respective cancer cells.

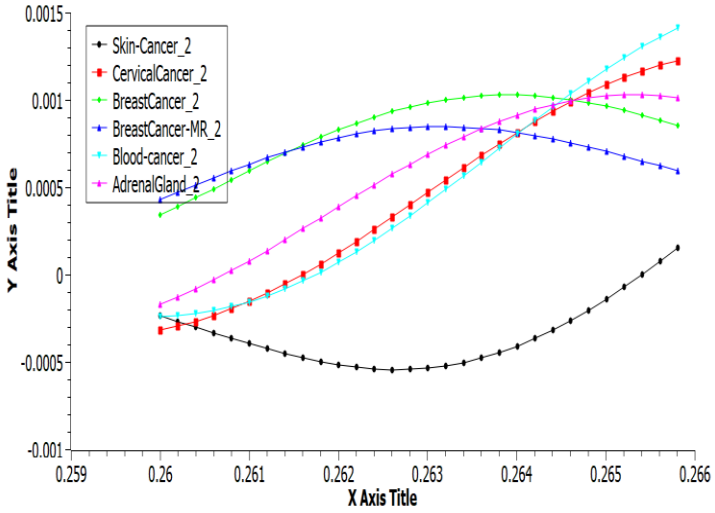

Figure 4: Graph generated from the photonic crystal values

3.1.1 SYSTEM ARCHITECTURE

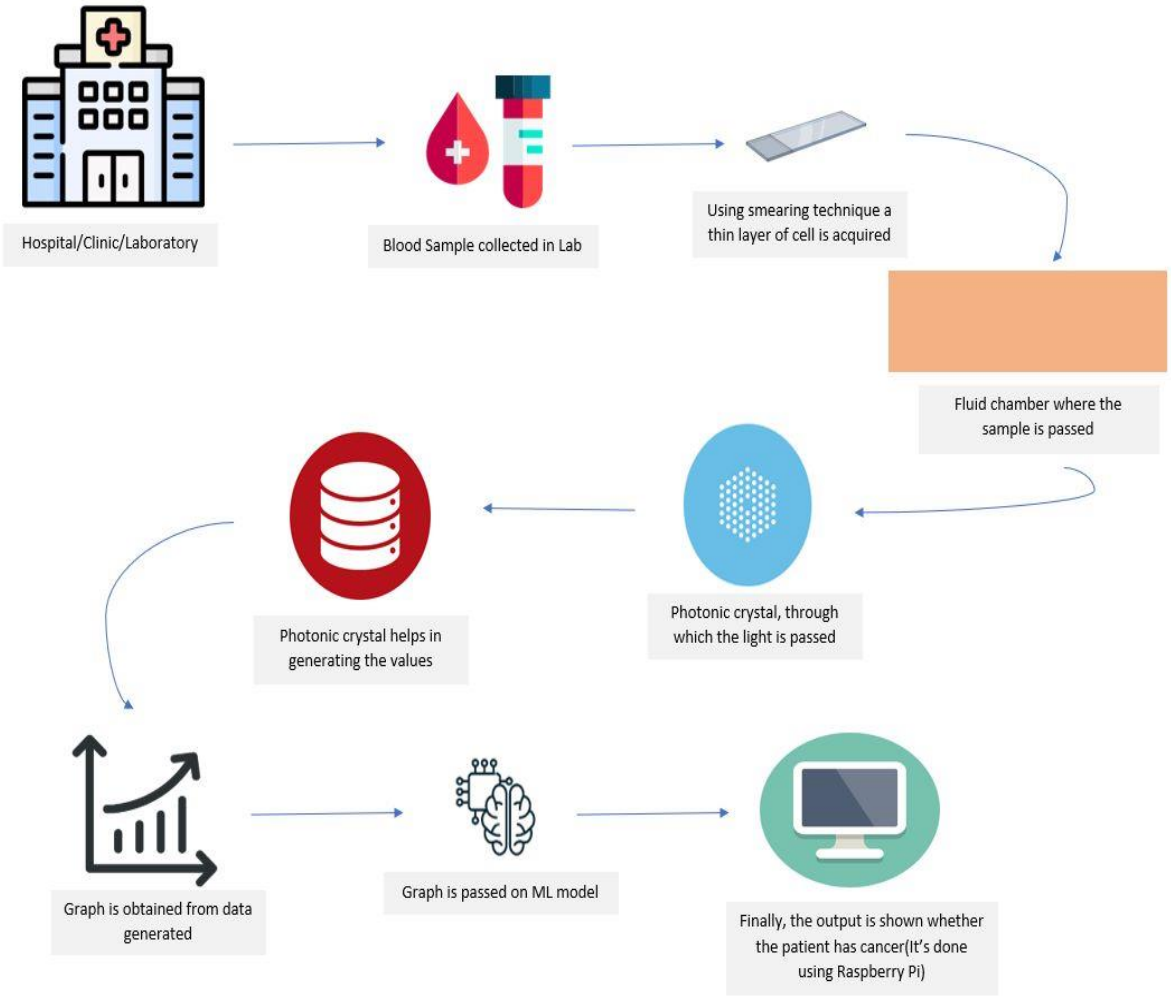

Figure 5: System Working Architecture

A system for the detection of cancer cells using photonic crystals involves the following components:

- A **light source**: This could be a laser or other type of light source that is capable of emitting light at a specific wavelength.

- A **photonic crystal**: This would be the core component of the system, and would be designed to interact with the light from the light source in a specific way. Photonic crystals have unique optical properties, such as the ability to diffract or bend light in specific directions, which makes them useful for a variety of applications, including cancer detection.

- A **detection system**: This could include a microscope or other imaging device that is capable of capturing the light that has interacted with the photonic crystal. This would allow researchers to analyze the light and determine if cancer cells are present.

- A **computer**: This would be used to process the data captured by the detection system, and could be used to analyze the images and make a diagnosis. Raspberry Pi is used for displaying the resulted output.

- A **display system**: This could be used to display the results of the analysis, such as images of the cells that were captured by the detection system.

Overall, the system would work by shining light through the photonic crystal, which would cause the light to diffract in a specific way depending on the presence of cancer cells. The detection system would then capture this diffracted light, and the computer would analyze the data to determine if cancer cells are present.

Collecting a blood sample for use with an optical sensor typically involves using a small needle and syringe to draw a small amount of blood from a vein, usually in the arm. The sample is then placed into a container, such as a test tube, for analysis. It's important to ensure that the equipment used is sterile, and that the person collecting the sample follows proper technique to minimize the risk of infection. The sample should be handled and stored according to the manufacturer's instructions for the specific sensor being used.

CHAPTER 4

CONCLUSION AND FUTURE WORK

In conclusion, the use of photonic crystals for the detection of cancer cells has shown to be a promising approach. Photonic crystals have unique optical properties that can be used to differentiate between healthy and cancerous cells, making them an attractive option for cancer diagnosis.

In our project, we have demonstrated the principle of using photonic crystals for cancer detection and have obtained encouraging results. We have also identified several challenges that need to be addressed for this approach to be practical for real-world applications.

For future work, several possibilities can be considered:

- Developing more sophisticated photonic crystal structures that can provide even higher sensitivity and specificity for cancer detection.
- Investigating the use of other bio-markers and functionalization methods to target cancer cells specifically.
- Improving the ease of fabrication and integration of photonic crystals into a diagnostic device.
- Studying the potential application of this technique in vivo, in order to make it a potential point-of-care diagnostic tool.

Overall, there is a lot of potential for using photonic crystals in cancer detection, and further research in this area could lead to the development of new and more effective diagnostic tools.

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