Calculation of Bragg's reflectivity for different refractive index stack arrays alternatively placed

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***Abstract* - The purpose of the study was to calculate the Bragg's reflectivity for 30 alternatively stacked layers with three different indices groupings. The evaluation of such stacks was to determine the Transmission Characteristics of such stacks and the bandwidth achievable as a function of the various groupings of the R.I. The study used MATLAB simulation for the in-band and out of band ripple behavior of such stacks.**

***IndexTerms* – Distributed Bragg reflector(DBR), Resonant tunneling, Transfer matrix method, Quantum confinement**

I. INTRODUCTION

Bragg reflectors have widespread commercial application in Lasers, anti-reflection coatings and nano-photonics. A distributed Bragg reflector (DBR) are used in optical waveguides, such as optical fibers as frequency selective filters. In monochromatic lasers the DBR enable the tuning and stimulated emission characteristics optimization [1].It is a structure formed from multiple layers of alternating materials with varying refractive index. The aim of distributed Bragg reflector is to enhance photon recycling and achieve high resonance at selected frequencies [2]. Higher the refractive index, higher will be the reflectivity. The tunneling through multiple quantum barrier in different hetero-structures could be calculated using transfer matrix approach [3]. The effect of barriers width of the transmission coefficient of the electrons has been investigated for different pairs of semiconductors materials that are gaining much importance easily.These include CdS/CdSe and AlGaAs/GaAs. So, by these barriers dimensions reached from 20nm to 5 nm to observe the effect of scaling on tunneling properties. The computation is based on transfer matrix method using MATLAB. The mathematical model based on relativistic approach has been proposed earlier for the determination of transmission coefficient within the energy range of $\boldsymbol{\varepsilon} < V_0$, $\boldsymbol{\varepsilon} = V_0$, and $\boldsymbol{\varepsilon} > V_0$, for multi-barrier GaAs/Al_yGaI_yAs heter-structure [4].The effect of number of barriers and number of cells in the well and barrier regions on the resonant energies are studied in detail [5]. An additional resonant peak in resonant energy spectrum indicated the presence of a new state. The resonant tunneling of the electron wave is one of the important phenomena of the quantum mechanics. Here the same resonance effect is applied in the DBR where the net resonant tunneling in the Braggs mirror determines the maximum reflectivity. The concept of the resonant tunneling through the multi-barriers is used in the Distributed Bragg reflectors [6]. We have the application of the Block wave analysis and the transfer matrix method to calculate the energy dispersion equation for copper pairs in finite Superconducting Quantum well structures. The possibility of energy levels and the sub-bands formation for Copper pairs within the bulk energy gap has been shown and each gap is derived only when the Bragg condition for Bloch wave number is satisfied. The energy dispersion relation and the Bloch wave analysis have importance in the calculation related to Distributed Bragg reflectors. The Quantum well structures are ultrafine layered media capable of confining electrons and quasi-particles with quantized energy levels. The quantum phenomenon in which the transmission properties of the carriers interacting with potential barriers in the graphene has been reviewed earlier [7]. This phenomena is similar to which we see in the Distributed Bragg reflectors. The tunneling of electrons and holes in the quantum structures of grapheme is found to be contrast with other systems. The tunneling of electrons and holes in the quantum structures of grapheme is found to be contrast with other systems. Here the transmission matrix are calculated using the transfer matrix model and the phenomena has a wide application in the recent technologies [8]. The interaction between the carriers with electrostatic barriers can be related to the propagation of electromagnetic waves in media with negative refractive indices, also known as metamaterials [9].The application of this phenomena has its importance in the Distributed Braggs reflector. This tunneling is known as Klein tunneling.

The fundamental of Bloch waves has been used in the concept of Braggs mirrors where the energy reduces periodically with the transmission of the waves to the series of periodic potential barriers and the corresponding reflection probability can be calculated and the resonant tunneling phenomenon describes the maximum reflectivity [10]. The problem deal with finding the wavelength at which maximum reflectivity is achieved and obtain the Full Width Half Maximum (FWHM) by plotting it with the help of MATLAB simulation software. Distributed Bragg reflector (DBR) consists of large numbers of layer pairs which are alternatively arranged and have different refractive indices. The primary objective of DBR is to obtain the high reflectance. The concept of reflectance can be described on the basisi of its relation with the wavelength of the incident light. The reflectance of the DBR, which can also be called as the Bragg mirror, varies with the wavelength and obtain the waveforms.

The concept is such that a light of a particular wavelength is incident on the DBR. Certain amount of the incident light gets reflected and certain amount gets transmitted in the form of refraction phenomenon. The reflectance of the DBR is to be calculated and this reflectance is affected by the wavelength of the light. The DBR has periodic dielectric layers stack arrangement. Each individual dielectric layer has a thickness $\frac{\lambda}{4}$ n, where n is the refractive index of the dielectric. Based on the quantum phenomena, here is a beam of electrons incident on the potential barrier and the phenomena of the transmission and reflection takes place. The transmission and reflection probability is to be calculated and the waveforms are to be obtained for the relation between reflectance and wavelength. From the waveform one can calculate the wavelength of which maximum reflectance can be obtained.

II. PROBLEM ANALYSIS

The analysis of the reflection and the transmission probability of the light can be done mathematically by the propagation matrix method. The propagation matrix shows the application of the Schrodinger wave equations. The waveforms showing the relation between the reflectance and the wavelength can be plotted using the MATLAB simulation software by coding the MATLAB program. The calculation of Braggs reflectance and the wavelength at which the maximum reflectance occurs. FWHM(Full Width Half Maximum) can be inferred from the plots obtained from the MATLAB coding.

III. USE OF PROPAGATION MATRIX

The propagation matrix is used to calculate the probability of an electron emerging on the right hand side of the barrier. We can solve for a particle of mass m and energy E moving in an arbitrary potential by dividing the potential into a number of potential energy steps. The use of the propagation matrix method is to explore what happens to electron transmission and reflection in a periodic data function potential. The introduction of Bloch theorem in this concept is to measure the impact of the symmetry of the periodic potential on electron wave function. We use Kronig and Penney model to describe electron motion in periodic potential and the application of the Bloch theorem may lead to calculation of the reflection and transmission probability.

IV. BLOCH THEOREM APPLIED TO PERIODIC POTENTIAL

We introduce a periodic potential V(x) in such a way that V(x) = V(x + n L), where L is the minimum spatial period of the potential and n is the integer. Under these circumstances, it seems reasonable to expect that electron probability through modulated spatially by the same periodicity as the potential.

The isotropic electron probability symmetry of free space is broken and replaced by a new probability symmetry which is translationally invariant over a space spanned by a unit cell size of L. We might describe electron probability that is same in each unit cell by the function $U(x)^2$. Given this, it is clear that one is free to choose an electron wave function that is identical to $U_k(x)$ to within a phase factor e^{ikx}. To find the phase factor, we need to solve for the eigen- states of the one-electron Hamiltonian

$$\hat{H}\psi(x) = \left(\frac{-\hbar^2}{2m}\frac{d^2}{dx^2} + V(x)\right)\psi(x) = E\psi(x)$$

The above equation states the Schrodinger wave equation where V(x)= V(x + n L) for integer n. The electron wave function must be a Bloch function of the form

Bloch theorem can be written in the following equation

$$\psi_k(x) = U_k(x)e^{ikx} \qquad \psi_k(x+L) = \psi_k(x)e^{ikL}$$

In words, Bloch's theorem states that a potential with period L has wave functions that ca ne separated into a part with same period as the potential and a plane wave term e^{ikL}.

V. GRAPHICAL INTERPRETATION

The refractive index of any medium is inversely proportional to the wavelength of the incident light. Higher the refractive index lower will be the wavelength. We consider X axis as wavelength and Y axis as reflectivity for which the following plots are obtained. We are also calculating that particular wavelength at which the reflectivity is maximum.

For reflective index 1.54 and 2.5

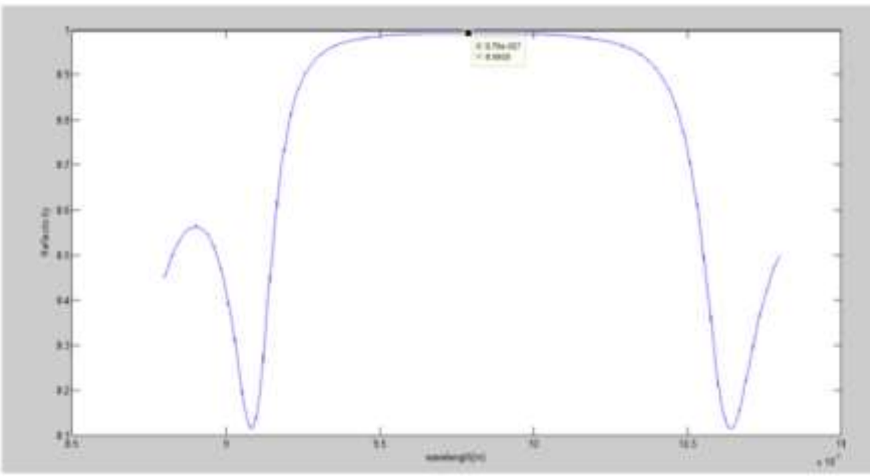

Figure 1: Graphical representation using MATLAB

As shown in Fig 1, maximum reflectivity is obtained at wavelength =979nm and Y (Reflectivity)= 0.9929 by using the MATLAB simulations for 30 stack layers or 15 pairs.

FWHM (Full width half maximum)

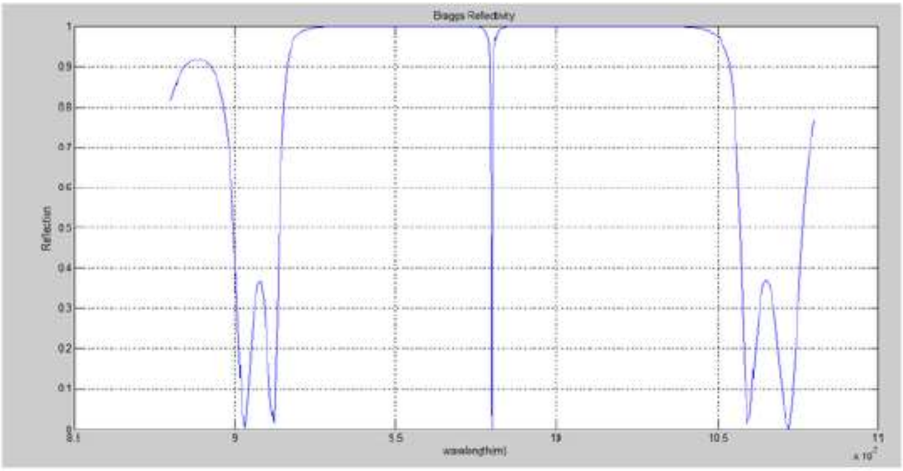

Figure 2: Graphical representation of Full Width Half Maximum using MATLAB

We can interpret from the FWHM graph plot that the FWHM obtained at the bandwidth is the maximum reflectivity of full width of wavelength. The graph before the bandwidth range has the high spiky features as compared to the graph beyond the bandwidth range. The Q resonant peak provides the maximum reflectivity.

For refractive index 2 and 13

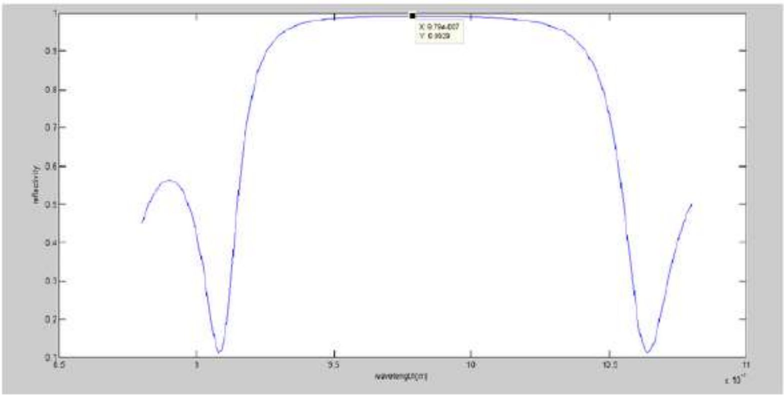

Figure 3: Graphical representation using MATLAB

As shown in Figure 3, maximum reflectivity is obtained at wavelength =980nm and Y(Reflectivity)=0.9929 by using the MATLAB simulation for 30 stack layers or 15 pairs.

FWHM (Full width half maximum)

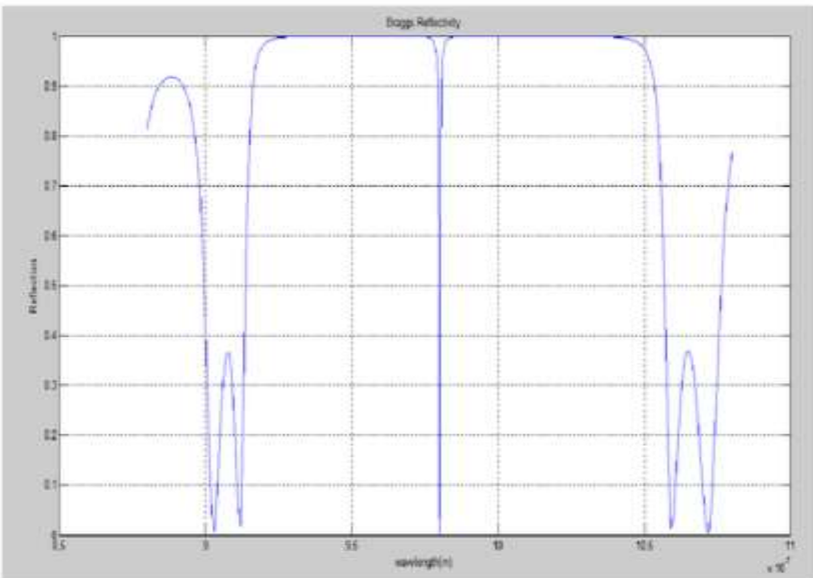

Figure 4: Graphical representation of Full Width Half Maximum using MATLAB

We can interpret from the FWHM graph plot that the FWHM obtained at the bandwidth is the maximum reflectivity of full width of wavelength. The graph before the bandwidth range has the high spiky features as compared to the graph beyond the bandwidth range. The Q resonant peak provides the maximum reflectivity.

For refractive Index 3 and 4.5

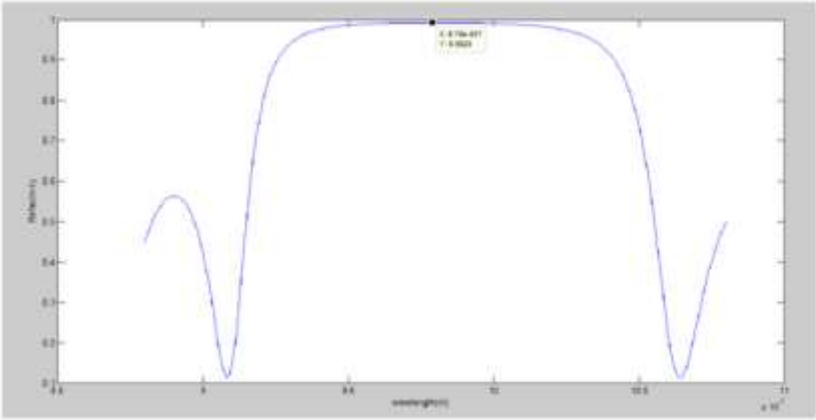

Figure 5: Graphical representation using MATLAB

As shown in Figure 3, maximum reflectivity is obtained at wavelength =976nm and Y(Reflectivity)=0.9929 by using the MATLAB simulation for 30 stack layers or 15 pairs.

FWHM (Full width half maximum)

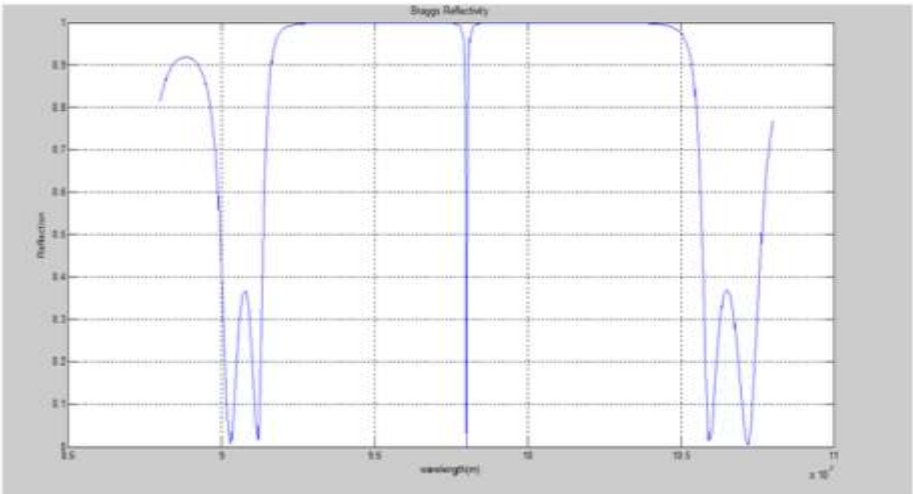

Figure 6: Graphical representation of Full Width Half Maximum using MATLAB

We can interpret from the FHWM graph plot that the FWHM obtained at the bandwidth is the half maximum reflectivity of the full width of wavelength. The graph before the bandwidth range has the high spiky features as compared to the graph beyond the bandwidth range. The Q resonant peak provides the maximum reflectivity.

VI. CONCLUSION

From the above graphical interpretations we can infer that the reflectivity of the surface and wavelength of the surface are inversely proportional. Maximum reflectivity is obtained at the Q resonant peak. As we compare the graphical interpretations we analyze that the materials with refractive index 2 and 13 have the maximum peak.

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