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A Double L7 Cavity with W1 Waveguide Photonic Crystal Structure for Detection of Different Fluids

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Abstract: In this paper a fluid sensor has been proposed based on two dimensional photonic crystal cavity. The cavity is a L7 cavity with W1 waveguide below the cavity for coupling light into the cavity. A dip in the output transmittance has been observed and the quality factor of the dip is found to be ~629. Further, to improve the performance of the cavity another L7 has been introduced below the W1 waveguide. The quality factor of the proposed structure is found to be ~3413. The proposed PCC structure has been used as a fluid sensor for the sensing of kerosene, heptane, cotton seed oil, methanol, cresol and acetic acid. The proposed structure has high quality factor and will be easy for fabrication and hence can be used as an ideal fluid sensor.
Keywords: Photonic crystal, two L7 microcavities, W1 waveguide, hexagonal lattice, transmittance.

I. INTRODUCTION

Exploring the resonant properties of photonic crystals by developing a wide range of geometries through optical cavities have been done earlier, so as to perform sensing and various other applications [1]-[3]. However, Quality factor Q plays an important parameter as it depicts the potential to confine light by optical cavities or it can be said that Q is a criteria of enclosed confinement of electromagnetic energy. Utilizations of optical cavities are as assorted as their properties, extending from media transmission to quantum electrodynamics. Notwithstanding the stage, optical cavities put together sensors to depend with respect to the wavelength shift of the resonant cavity because of an adjustment in the refractive index of the neighboring fluid. Upon expansion of the example of the fluid, the refractive index of the fluid changes marginally, shifting the frequency of the resonant cavity making the photonic crystal to be used as a sensor [4]-[6]. The basic idea of a structure has been taken from double L7 structure, in which emission of two L7 microcavities were studied [7]. However, with a modification of including an extra W1 cavity, it yields high quality factor and by use of this particular photonic crystal structure, a fluid sensor has been analyzed for different liquid analytes in this paper.

Earlier, work has been done with the help of L cavities for other applications like for LASER [8]. However, the structure used in that paper which is L3 cavity structure provides low quality factor. Earlier different types of liquids have been used for sensing operation for a different photonic crystal structure [9]. However, they do not determine the corresponding quality factors which is also evaluated in this paper. Earlier by introducing small modifications in the W1 cavity [10] have been studied which resulted in high quality factors, however our paper not only deals with providing high quality factors but also sensitivity for different fluids. Various types of defects introduced can also vary the value of quality factor as in the paper mentioned, a H1 defect [11] introduced produced low quality factor. However, in this paper two L7 along withW1 defect introduced can have good sensing along with analysis of quality factor. For L7 cavity, earlier the highest quality factor for this structure has been reported to be 2400 as per our research [12], but by introducing some modifications we have increased the value of quality factor.

Thus in this paper we will have an analysis of two L7 along with W1 structure and try to find out whether this can act as a liquid sensor or not.

II. DESIGN OF PROPOSED PHOTONIC CRYSTAL STRUCTURE

Figure 1 illustrates the photonic crystal structures used for computation purposes. This photonic crystal structure is a L7 type. A 2D hexagonal lattice structure with circular holes is chosen with dimensions of 17 and 15. In this particular structure arrangement, an array of 7 holes on one side of W1 cavity which is removal of all holes of a single line are made to be removed along Γ-K direction as depicted in the below figure. The parameters which are made for this particular structure in order to obtain desired results is chosen. The lattice constant (a) of the given structure is made to be 0.42 and the radius of the holes is chosen to be 0.39a. Slab height of the structure is chosen to be 0.22 and the value slab delta is made to be 2.4. The wavelength at which launching is to be taken place is 1.74 micrometers and the grid size is chosen to be 0.05, 0.07 and 0.05 respectively. Also, the stop time of the simulation is taken to be 10000 for each of the simulations that are performed for examining the performance for this structure.

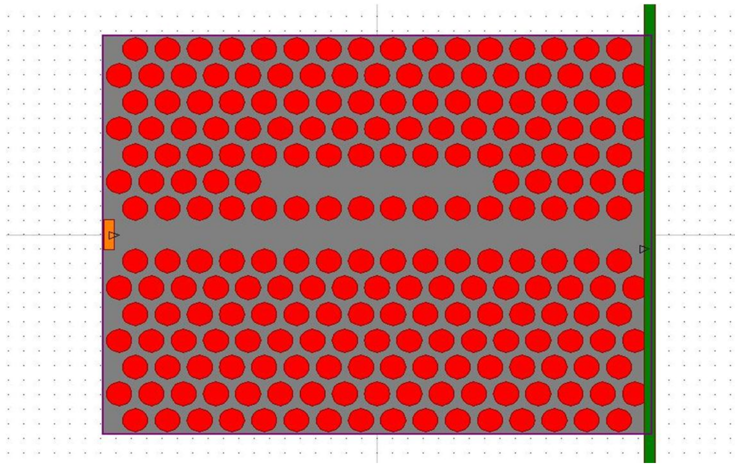

Fig.1. Schematic diagram of one L7 with W1 photonic crystal structure.

Also, extra defect of L7 cavity is introduced along the other side of W1 cavity with the parameters same as that for oneL7 with W1 cavity in order to analyze which of the above two structures gives more quality factor, so that particular structure will be utilized for sensing purposes. The structure of two L7 with W1 cavity is given in figure 2.

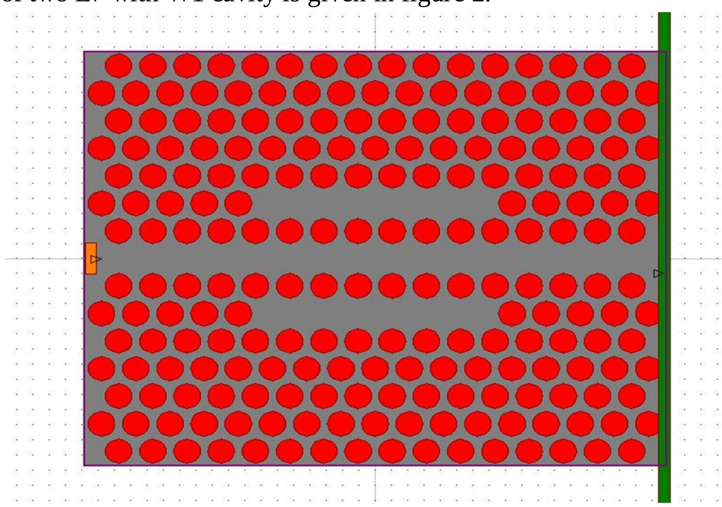

Fig. 2 Schematic diagram of proposed two L7 with W1 photonic crystal structure

III. TRANSMITTANCE AND QUALITY FACTOR OF THE STRUCTURE

The simulation of the structures in order to obtain Quality factor (Q) and its corresponding sensitivity is performed using FDTD and PWE algorithms, which uses Maxwell's equations to evaluate the result at each point and thus give a collective result to perform computations [13]. The transmittance graph of the one L7 W1 structure with a quality factor of 629 is depicted in figure 3.

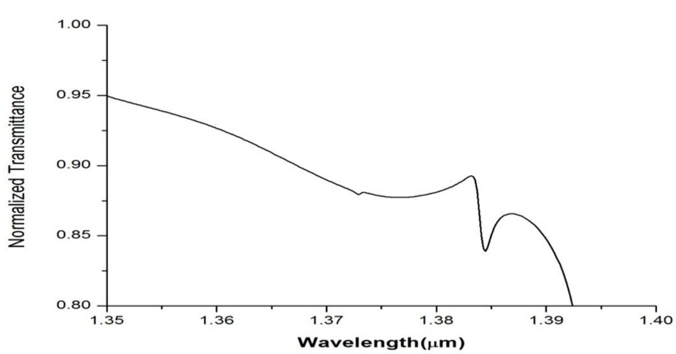

Fig. 3. Normalized Transmittance graph of one L7 W1 photonic crystal structure

The Transmittance graph of two L7 W1 structure with the quality factor of 3413 is depicted in figure 4.

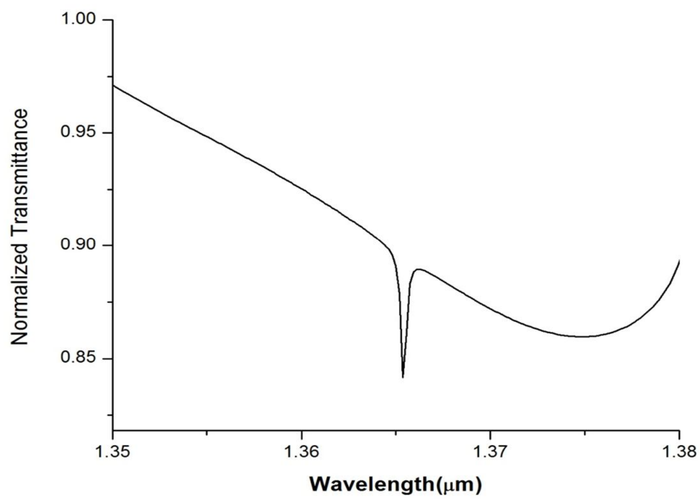

Fig. 4. Normalized Transmittance graph of two L7 W1 photonic crystal structure

The quality factor for both of the structure is computed and it is observed that the quality factor of two L7 W1 structure is much higher than that of one L7 W1 structure. Thus, in order to have better sensing for different fluid analyses, two L7 W1 structure is chosen to have better performance.

IV. SIMULATION RESULTS

By utilization of the two dimensional photonic crystals, we have planned a fluid sensor. A fluid sensor is one which takes the given information tests for the client and figures out what liquid example was given. Here 2-D photonics crystal is utilized in light of the fact that it is progressively delicate than the 1-D photonic crystal and simple to break down when thought about to 3-D photonic crystals. The given measure of test is taken and our 2-d structure with 2L7 and W1 cavity is dunked in the arrangement which results in change in foundation material. At the point when there is an adjustment in that our waveguide mode moreover changes. At that point change in move is contrasted and standard structure. Since various liquid has unique thickness we can without much of a stretch relate our adjustment in wavelength or recurrence to the given liquid example. It is utilized to detect the various sorts of liquid dependent on their thickness esteem. The photonic crystal can be utilized as the liquid sensor by making L7 and W1 deformity in a photonic crystal. The simulation results obtained for 2L7 with W1 cavity observes a dip which occurs at a wavelength of 1.3654 micrometers and the quality factor observed for this particular cavity with is 3413 whereas the simulation results of photonic crystal structure with one L7 along with W1 cavity shows a dip at a wavelength 1.3845 micrometers with quality factor of 629. Since, the quality factor of one L7 along with W1 structure is less than the quality factor of two L7 along with W1 structure, so, the further sensing operation is applied on the two L7 along with W1 structure.

Below is the table which illustrates the liquids and their corresponding refractive indices for which sensing is performed.

Table1. Refractive Index for Different Fluid [9]

Liquid Name	Refractive Index
Kerosene	1.44
Cotton seed oil	1.4580
Heptane	1.387
Methanol	1.3284
Cresol	1.5398
Acetic acid	1.3716

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When the refractive index for the given photonic crystal structure is changed to 1.44 in order to have a change, then the value of the quality factor equals 2771 with an observed dip at a wavelength of 1.3856 micrometers, making a wavelength shift of 0.0202 micrometers. Similarly, for a change of 1.4580 in its refractive index makes the value of quality factor to 2773 with an observed dip at a wavelength of 1.3866 micrometers, thus making a wavelength shift of 0.0212 micrometers. Similarly, for a change of 1.387 in its refractive index makes the value of quality factor to 2765 with an observed dip at a wavelength of 1.3828 micrometers, thus making a wavelength shift of 0.0174 micrometers. Similarly, for a change of 1.3284 in its refractive index makes the value of quality factor to 4599 with an observed dip at a wavelength of 1.3797 micrometers, thus making a wavelength shift of 0.0143 micrometers. Similarly, for a change of 1.5398 in its refractive index makes the value of quality factor to 2319 with an observed dip at a wavelength of 1.3916 micrometers, thus making a wavelength shift of 0.0262 micrometers. Similarly, for a change of 1.3716 in its refractive index makes the value of quality factor to 3455 with an observed dip at a wavelength of 1.382 micrometers, thus making a wavelength shift of 0.0166 micrometers.

The transmittance graph for Kerosene with a quality factor of 2771, resonant wavelength at 1.3856 µm and a wavelength shift of 20.2 nm is observed.

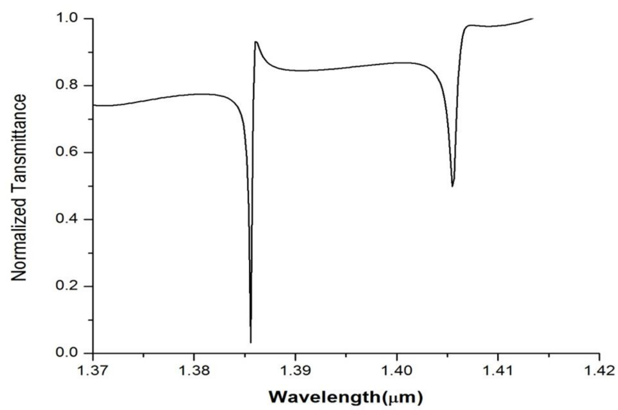

Fig.5. Normalized Transmittance graph of kerosene

The transmittance graph for cotton seed oil with a quality factor of 2773, resonant wavelength at 1.3866 µm and a wavelength shift of 21.2 nm is observed.

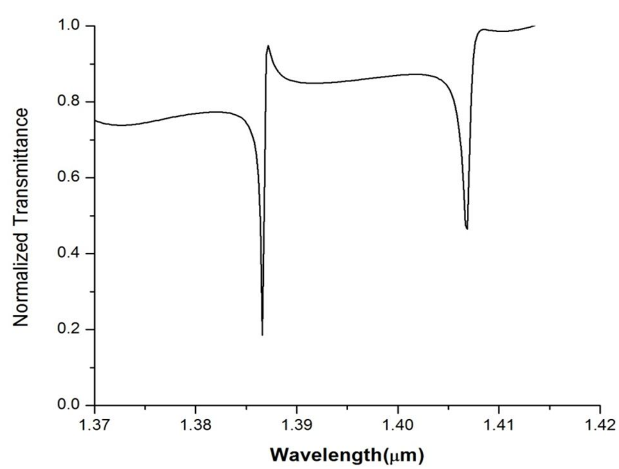

Fig.6. Normalized Transmittance graph of Cotton seed oil

The transmittance graph for heptane with a quality factor of 2765, resonant wavelength at 1.3828 µm and a wavelength shift of 17.4 nm is observed.

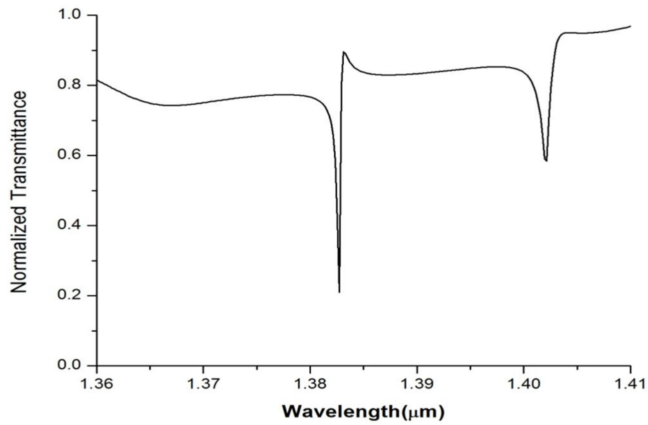

Fig.7. Normalized Transmittance graph of heptane

The transmittance graph for methanol with a quality factor of 4599, resonant wavelength at 1.3797 µm and a wavelength shift of 14.3 nm is observed.

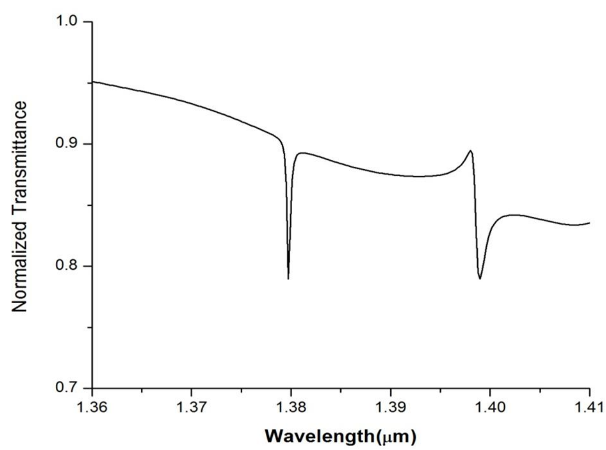

Fig.8. Normalized Transmittance graph of methanol

The transmittance graph for acetic acid with a quality factor of 3455, resonant wavelength at 1.382 µm and a wavelength shift of 16.6 nm is observed.

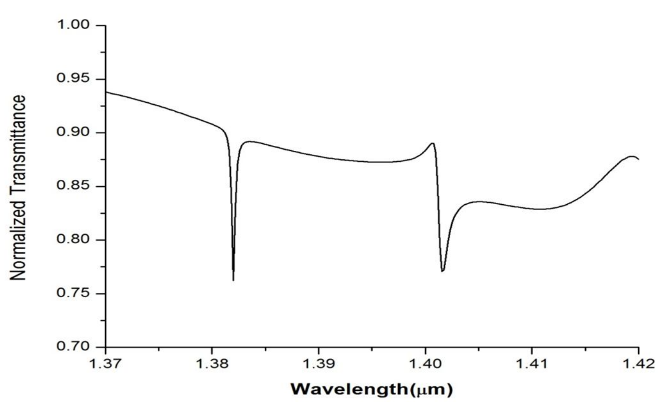

Fig.9. Normalized Transmittance graph of acetic acid

The transmittance graph for cresol with a quality factor of 2319, resonant wavelength at 1.3916 µm and a wavelength shift of 26.2 nm is observed.

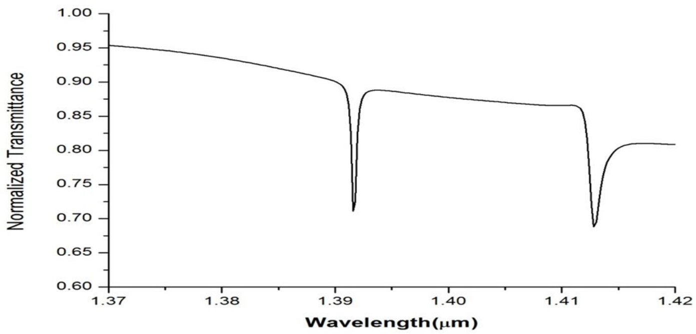

Fig.10. Normalized Transmittance graph of cresol

Table 2. Quality Factor And Wavelength Shift For Different Fluids

Fluid name	Corresponding Quality factor	Wavelength shift (in nm)
Kerosene	2771	20.2
Cotton seed oil	2773	21.2
Heptane	2765	17.4
Methanol	4599	14.3
Cresol	2319	26.2
Acetic acid	3455	16.6

V. CONCLUSION

In this paper, 2L7 W1 photonic crystal structure has been designed to work as a fluid sensor. Earlier, 1L7 W1 structure was analyzed to measure quality factor but with the modification in the structure to 2L7 W1 cavity the quality factor of the structure increased from 629 to 3413. Thus, the later structure was used to perform sensing for different fluids like acetic acid, cresol, methanol etc., as it provided better results. As the refractive index of the fluids is increased the corresponding quality factor decreases while the corresponding wavelength shift increases. Thus, the liquid present is clearly identified by the sensor.

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