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# Design and analysis of Wilkinson power divider using 2D photonic crystal

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# Design and analysis of Wilkinson power divider using 2D photonic crystal

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**Abstract**. The next generation Photonic Integrated Circuit (PIC) make use of optical power divider for achieving high operating speeds in the field of optical communication. A Wilkinson power divider is designed using 2D Photonic Crystal in this paper. Wilkinson power divider is three port network which is lossy. But when the output ports are matched, it has unique property of becoming losslesss. The divider also achieves isolation between output ports. The power dissipated is from the power that is reflected. The propagation of wave and photonic band gap were obtained by Finite-difference Time-Domain (FDTD).The designed structure has a resonant wavelength of 1550 nm. The simulation is performed using Opti FDTD software. For the two port Wilkinson power divider 55.4% of input power was coupled at the output. For the 4 port 55% of input power was coupled at the output port.

## 1. Introduction

Photonic crystals (PC) are designed to affect the motion of photons with the help of electronic energy bands. To affect the propagation of electromagnetic waves within the structure, photonic crystals are designed with the help of dielectric constant materials in all the three dimensions (1D, 2D & 3D). PCs have great advantages in designing ultra-compacted all optical integrated circuits with significant reduction in the size and power consumption [1-3]. The photonic band gap (PBG) is obtained as the result of this periodicity when the transmission light becomes zero at certain frequencies. To control the light, the periodicity and the PBG of the structure is affected which is done by introducing line and point defect which leads to the design of Photonic crystal based optical devices. The PBG prevents the light propagating through the planes [4-5].

In the RF/microwave domain, the Wilkinson power divider is used for splitting or combining signals. It consists of a resistor and simple transmission lines. It provides the characteristics of an ideal power divider by taking advantage of the properties of quarter wavelength transmission line sections. It divides a given input signal into two or more signals as required by the circuit or system. One common application of a power divider is to divide a signal to feed a number of low power amplifiers, and then recombine the signals from the amplifiers into an output signal that has high power. Another typical application is within a phased antenna array system [6-7]. Wilkinson power divider is a popular power divider because it is easy to construct and has some extremely useful properties like it is matched at all ports, output ports have large isolation, and most importantly when the output ports are matched it is reciprocal and lossless. There is symmetry in the circuit and it can be exploited to make the S parameter calculations easier [8-9].

The rest of the paper is organized as follows: The design and simulation of Wilkinson power divider and the design and analysis of modified Wilkinson power divider is detailed in Section II. The design of the hybrid coupler is detailed in section III. The results of power divider and its inference is discussed in Section IV and the major findings are concluded in Section V.

## 2. Proposed optical Wilkinson power divider

In this paper, the design of Wilkinson power divider which is used for coupling is designed. The structure consists of 17 x 17 square array of photonic crystal rods. The refractive index is 3.1 in air is used for this structure. The dielectric constant (ε) for the dielectric rods is set to 11.56. The radius is set as 0.3a and lattice constant a=650nm. The photonic band gap region for this structure is obtained as $0.33<a/\lambda<0.476$ and $0.409<a/\lambda<0.510$ with the band gap of 0.134 and 0.101respectively as shown in Figure 1. For this the wavelength range is obtained as 1389nm<λ<1948 nm and 1273 nm<λ<1587 nm [7].

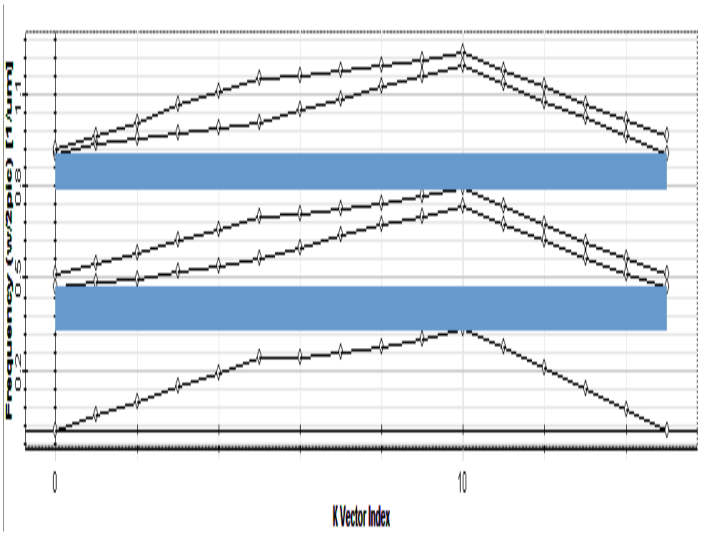


**Figure 1.** Photonic band gap for the proposed design.

The photonic crystal structure for 2 port Wilkinson power divider is shown in Figure 2. The wafer properties are of length 21 µm and width 18 µm. The power divider is constructed with the rods of radius r = 0.3 × a. As seen from the structure, the center region has semi curved structure with more number of point defects created so as to divert the light entering into this region can be splitted into the two output port that are created using line defects. This PCRR has resonant wavelength at λ = 1550 nm.

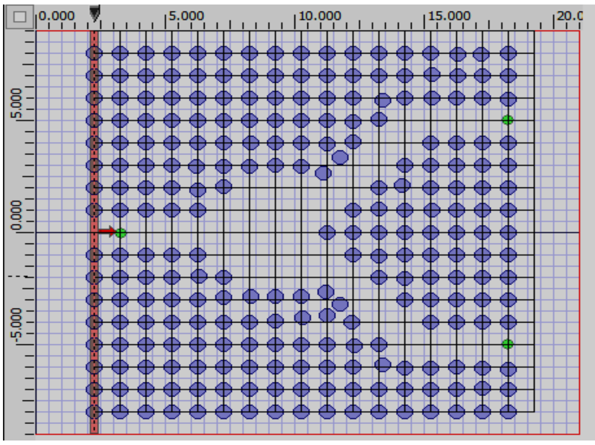


**Figure 2.** Schematic representation of the proposed 2 port Wilkinson power divider.

Upon entering port 1 (left side in design), the signal splits into output signals that have equal-amplitude and equal-phase at ports 2 and 3.No current flows through the isolation resistor as each end of it between the ports 3 and 2 is at the same potential and hence it is decoupled from the input. Both the output port terminations must be converted to 2xZ0 at the input port, as the will add in parallel such that they combine to Z0. This is accomplished by the quarter-wave transformers present in each leg. In the absence of the quarter-wave transformers, the impedance of the two outputs when combined at port 1 would give Z0/2. When ports 2 and 3 are terminated in Z0, the characteristic impedance of the quarter wave lines should be 1.414x Z0 so as to ensure that the input is matched.

### *2.1. Design of 4 port Wilkinson power divider*

Here, the 4 port hybrid Wilkinson power divider is designed and analyzed at the resonance frequency of 1550 nm. The schematic of the proposed 4 port divider is shown in Figure 3. The photonic band gap range of 0.1032 and 0.067 is obtained. The 4 port divider is an extension of the two port divider with more number of point defects created at the end of the line waveguide of 2 ports. Here, the objective is to divide the power into one fourth of the total input power.

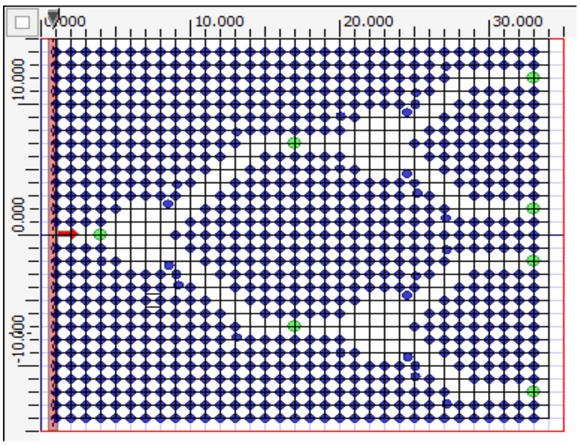


**Figure 3.** Schematic of the proposed 4 port Wilkinson power divider.

### *2.2. Design of 4 port Wilkinson power divider with line defect*

In this section, we modified the basic two port structure by introducing line defects and hence realizing a four port power divider with one half power being delivered in the output ports. The Figure 4 displays the schematic representations with the introduction of line defects.

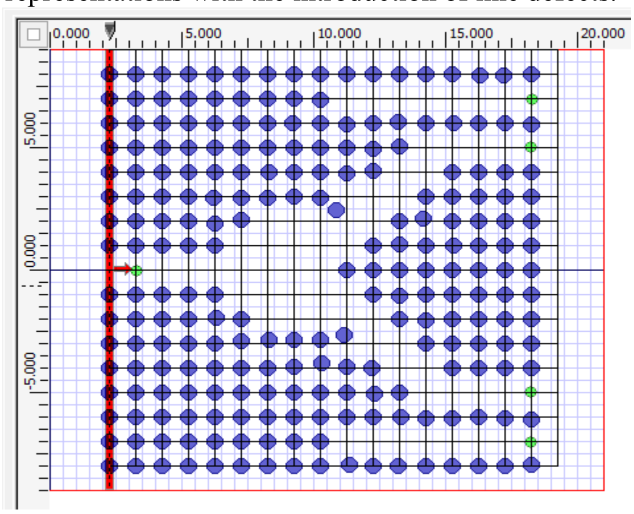


**Figure 4.** Proposed 4 port Wilkinson power divider with line defect.

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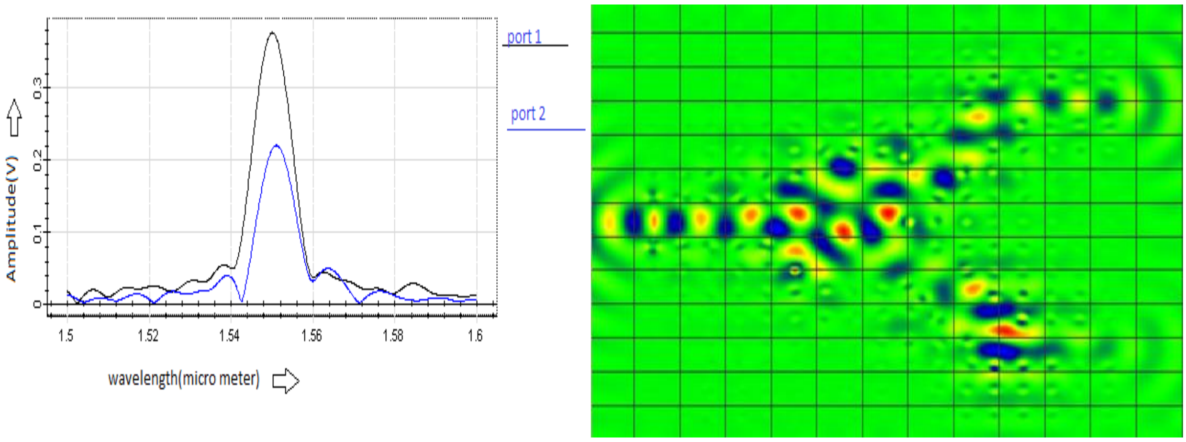
The 4 port divider in Figure 4 is very unique of its kind as provide 50% of the total input power in all the output port and the light coupled fall within the range of 1500 to 1600 nm. Hence, this coupler can very well be used for CWDM system.

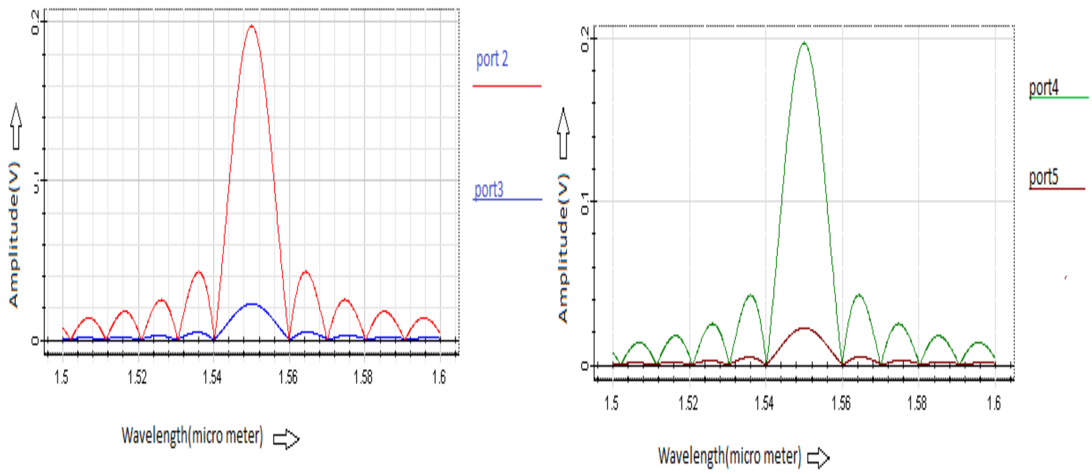
## 3. Result and discussion

The Wilkinson Power Divider was implemented using 2D Photonic crystals in TE mode using Opti FDTD software. The photonic band gap obtained falls in the resonant wavelength region of 1550 nm with tolerance of 0.1. By introducing defects, the output power coupled at the various ports was found to vary but the wavelengths fall within the CWDM range.




(a) (b)

**Figure 5.** (a) Transmission diagram and (b) Output power spectrum of 2 port power divider




(a) (b)

**Figure 6.** Transmission diagram of 4 port Wilkinson power divider at (a) Port 2 and Port 3 (b) Port 4 and Port 5

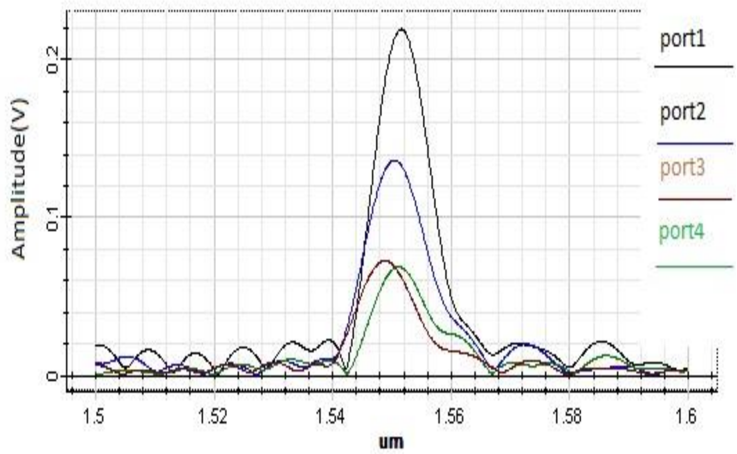



**Figure7.** Transmission diagram for 4 port power divider with line defect

The transmission diagram of the two ports Wilkinson power divider is shown in Figure 5(a). From the results it is found that the port 1 delivers 46.5% of the total input power and port 2 delivers 22% of the total input power for the wavelength of 1550 nm and 1555 nm, respectively. The output power spectrum for the two ports is shown in Figure 5(b). As seen from the display the region of more power is displayed with high intensity of power at port 1 and less intensity at port 2. The transmission diagram of the 4 port power divider without and with line defect is displayed in Figure 6 and Figure 7, respectively. As seen from the curves, the performance of 4 port Wilkinson power divider without line defect almost 20% power in two ports and 2% of power in other two ports. However, the 4 port Wilkinson power divider with line defect the unequal output power of 22%, 14%, 7% and 6.8% in each of the ports.

## 4. Conclusion

The Wilkinson power divider is designed with the help of 2D photonic crystal by using Opti FDTD with one input port and two output port in square lattice at the resonant wavelength of λ=1550nm. The power coupled at the two output ports is 55.4% or the 2 port divider and 55% for the 4 port divider. This proves the effectiveness of the design. The improved design with one input and four output ports at resonant wavelength 1550 nm is also implemented with 55% power coupling efficiency. The future work aims to improve the efficiency by introducing appropriate line and point defects and also introducing modification in the crystal properties.

## References

[1] Hema Saini 2013 Photonic crystal based rat race coupler for optical applications *Optik* 124 3146– 3148
[2] Mohammad Mehdi Karkhanehchi, Fariborz Parandin and Abdulhamid Zahedi 2016 Design of an all optical half-adder based on 2D photonic crystals *Springer Science Business Media New York*
[3] Mohammad A. Maktoomi 2016 Theory and Design of a Novel Wideband DC Isolated Wilkinson Power *Divider IEEE Microwave and wireless components letters*, p 26
[4] Shakila Naznin, RajibMandal,Shamlendu Sarker, Md. Tanveer Alam, Md. Shamim Ahsan and Md. Younus Ali 2016 Design and Optimization of Optical Add-Drop Filter and Sensor using 2D Photonic Crystal *Electronics and Communication Engineering Discipline Khulna University*
[5] Juhi Sharma, Ritu Sharma and Lalit Kumar Dusad 2015 Review and Analysis of Photonic

Crystal Beam Splitters for Optical Communication Applications 2015 *International Conference on Green Computing and Internet of Things (ICGCloT)* 160-162

[6] Arif Ahmed1, Md. Rokibul Hasan Robin, and Md. Osman Goni A 2014 Novel Approach to Design Photonic Crystal Based Optical Power Splitter with a Flow Control Mechanism 8$^{th}$ *International Conference on Electrical and Computer Engineering*

[7] Ting-Hang Pei and Yang-Tung Huang 2011 The Heterostructure Photonic Crystal Waveguide Splitter *IEEE Photonics Technology Letters*, **23** 16 1145-1147

[8] Xionggui Tang and Jinkun Liao 2013Novel Approach for Controllable Polarization Beam Splitter: Design and Simulation *IEEE Journal Of Quantum Electronics*, **49** 1 43-50

[9] Yoshihiro Akahan, Takashi Asano, Bong-Shik Song and Susumu Noda 2003 High-Q photonic nanocavity in a two-dimensional photonic crystal *Nature* 425 944-947