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Research Article

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Optimal Design of Broadband Optical Waveguide Coupler Using Social Spider Optimization Algorithm

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Abstract

In photonic integrated circuits (PICs), one of the most crucial building blocks is optical waveguide couplers, which are usually utilized in Mach-Zehnder interferometer-based devices, for instance, power monitors, filters, and N-by-N optical switches.Such devices' responses are needed to be wavelength insensitively for increment the operating bandwidths, particularly more than the C+L band for real-time applications (the wavelength's spectral range = 1530 - 1630 nm). Hence, an optical waveguide coupler including a precise and broadband is necessary. In the platform of silicon-on-insulator (SOI), the typical directional couplers have containedtwo parallel waveguides and are broadly utilized in PICs due to their compactness and integrability.To achieve effectiveness in broadband optical waveguide coupler, a new design has been proposed in this work. For optimally designing broadband optical waveguide coupler, Social Spider Optimization algorithm is utilized. The proposed approach is implemented in the platform of MATLAB. And the simulated results have shown that the proposed approach has

provided a better Optimal Design of Broadband Optical Waveguide Coupler than the existing approach.

Keywords: Optical waveguide couplers, photonic integrated circuits, Social Spider Optimization algorithm, and wavelength dependency

1. Introduction

For combining light among two waveguides, in photonic incorporated circuits, the optical 3-dB couplers are fundamental gadgets. The three fundamental sortsof optical 3-dB couplers are directional couplers [1, 2], multimode interference (MMI) couplers [3, 4], and adiabatic couplers [5–7]. The fundamental working standard of MMI couplers and directional couplers comprise of the interference among various modes, which results in inevitable insertion loss (IL) and imbalance in power due to the errors in the modular phase. What's more, to the regular MMI couplers and traditional couplers, the operating transfer speed is constrained, since the gadget length is controlled through the two most minimal request modes' beat length, which is a wavelength-dependent amount owing to the modular scattering.

Such gadgets responses are necessary to be wavelength insensitive for incrementing the operating transfer speeds, especially more than C + L band for real-time applications (the spectral range for $\lambda = 1530 - 1630$ nm). Subsequently, an exact and broadband optical waveguide coupler is necessary. In the platform of silicon-on-insulator (SOI), the traditional directional couplers have includes the two equal waveguides, and broadly utilized in PICs inferable from their conservativeness and integrability.In light of the CMT (coupled-mode theory), the standardized coupled optical power has the structure sin2(κLT), where the total propagation length is mentioned as LT and the coupling coefficient is indicated as κ [7-9]. In any case, κ is intrinsically exceptionally sensitive to the wavelength, and in this manner operating transmission, capacities are mostly restricted.

Some past research works have appeared to lessen wavelength reliance on an optically coupled framework. From these examinations, we gathered that the techniques presented in these exploration works upgrade the operating transfer speeds by applying explicit capacities to the waveguide geometry and, henceforth the spread constants higher than a broad spectral range be able to resolve. Hence, it is sensible to find that the accuracy and functioning transfer speed might be additionally upgraded. The ideal variable mix was controlled by a hereditary calculation. In any case, they have missed upgrading the coupling productivity of the optically coupled framework.

The contribution of this paper is described as follows:

- For obtaining the optimal values of the gap between waveguide and widths of the waveguide, *Social Spider Optimization (SSO) algorithm* is presented. Depend on the selected values of gap and widths, propagation constants and coupling coefficients are chosen from the lookup table.
- In the working stage of MATLAB, this proposed strategy is effedssddfugmjpfmjmflmfdiomvket-v;m,w8i- /lk;tuated. This proposed strategy's performance is appraisedbased on coupling efficiency, propagation loss, and optical output ratio.

This paper's rest of the part is organized as followed. Section 2 relates some previous literature thatfocused research on the design of optical waveguide coupler. Section 3 proposes the Optimal Design of Broadband Optical Waveguide Coupler Using a social spider optimization algorithm. Section 4 discusses the results of the proposed scheme. At last, this paper's conclusion is described in section 5.

2. Related works

Morino, H., *et al* [10] had analyzed the reduction of wavelength depends on the coupling characteristics using si optimal waveguide curved directional coupler. Directional couplers were widely used as one of the key components of optical integrated circuits. The traditional directional coupler's coupling efficiency was for wavelength sorely sensitive.To the wavelength division multiplexing transmission, this sensitivity decrements the characteristics of the device possessing directional couplers. The experimental resultshows the Si wire curved coupler was promising to wavelength or temperature-independent operation of integrated photonic devices.

In the platform of silicon-on-insulator, the sub-wavelength grating slot implemented the compact high-performance adiabatic 3-dB coupler, which was presented by Xu, L., et al. [11]. Utilizing subwavelength grating effectively increments the refractive index of the gap region of two coupling waveguides, whichprovideda way to compact design footprint and high-performance operation. By utilizing electron beam lithography, the designed adiabatic 3-dB coupler was manufactured and the size of the feature utilized in the design was CMOS suitable. The fabricated gadgets were categorized in the range of wavelength 1500nm and 1600nm accompanied by a measured power-splitting ratio superior to the average insertion loss.

In the platform of silicon-on-insulator,Fu, P.H., et al [12] presented a broadband optical waveguide couplers' generalized design accompanied by arbitrary coupling ratios. The device was bifurcated into 34 short segments, where the constant of propagation and every section's coupling coefficient were viewed as variables in the course of the process of optimization. Through a genetic algorithm, the optimal variable combination was determined. Accompanied by fewer degrees of freedom, they attain a performance better than other design strategies. The lengths of the device were 34 μm and the ±2% bandwidths were all over 100 nm in thecenter wavelength of 1580 nm for the 75%/25%, 50%/50%, 25%/75%, and 0%/100% couplers.

Accompanied by Si-wire waveguides, the optical directional couplers were analyzed and also exhibited their basic characteristics by Yamada, H. et al. [13]. Owing to strong optical coupling amongst the waveguide cores, their coupling-length was short supremely, numerous micrometers. Also, to gadgets with a long-coupled waveguide, wavelength demultiplexing functions were exhibited. Experimental results show the optimal outputs can be transmitted through the parallel and cross ports.

To the optical directional coupler modulators, a coplanar strip slow-wave structure was implemented by Jae-sangOh,et al. [14]. In GaAs optical waveguides, for conjoining the RF/microwave modulation signal phase velocity to the optical wave velocity, it was designed.Retains the characteristic impedance in 50 using the CPS accompanied by series inductances and shunt capacitances. For narrow gap CPS structures, that slow-wave framework bestows the design's flexibility. This design's efficacious characteristic impedance and refractive index were measured for a range of frequency up to 45 GHz, and with simulation was compared. To mode selective switching, Thermo optically controlled vertical waveguide directional couplers had been evaluated by Huang, Q., et al [15]. To a waveguide that backing those three spatial modes, they structuring and fabricate two specific gadgets with a polymer material to demonstrate that idea. The devices' performances to the light's polarization state were sensitive weakly. They presented switches of mode-selective, which possess measurable structure and less consumption of power, for applications in reconfigurable mode-division-multiplexing networks, might be implemented into different active mode-controlling gadgets.

Utilizing three coupled waveguides nonlinear directional coupler based on semiconductor, an optimal logic gate was developed by Ghadi, A., et al [16]. In that article, the waveguides' input intensity, the logic NOR, NAND,AND,and OR, gates were structuring in a distinct configuration accompanied by various lengths. The analyzehandled accompanied by the CW region (continuous waves) and, accompanied by a period longer than the lifetime of FC, the outcomes were valid for short optical pulses' limit.

By utilizing the numerical technique of finite difference time domain (FDTD), a plasmonic directional coupler's performance in two-dimensional plasmonic waveguides was analyzed and simulated by Dolatabady, A., et al [17]. By using two separate wave components, the directional coupler's directional property was produced, which add in phase at the coupled port and were canceled at the isolated port. Accompanied by the analytic considerations, the simulation results were in good agreement.

The Social Spider Optimization (SSO) was a novel swarm algorithm based on the social spider's cooperative characteristics by Luque-Chang et al [18]. In SSO, search agents were a group of spiders that move together in accordance with the colony's ecology. SSO described male and female search agents. In this way, problems in numerous SI techniques might be reduced.

The optimal design method was used by Bashir et al. [19] to propose a class of broadband non-radiative dielectric (NRD) guide devices. The NRD guides described include low crosstalk crossing waveguide, T-branch, 90°-bend, and Z-bend. At 60 GHz, they exhibited transmission efficiency of 99.5%, 49.5%, 99.4%, and 99.9%.

3. Optimal Design of Broadband Optical Waveguide Coupler Using SSO

3.1. Overview

In this methodology, we concentrate onthe decrement of wavelength reliance and improvement of coupling effectiveness of waveguide directional couplers. To accomplish these goals, an optical waveguide directional coupler is to be structured by optimizing the planning parameters, like, the gap between the waveguides and width of the waveguides. For optimizing these planning parameters, Social Spider Optimization (SSO) calculation is exhibited. As this calculation performs with great combination speed, ideal arrangement, or planning parameters are gotten. In this calculation, the deviation of the coupling ratio is taken into account as an objective function for achieving the ideal structuring parameters. As a result of this presented approach, the constructed optical waveguide coupler is obtuse toward the dependency of wavelength.

3.2. System model

At the bottom right, in common view accompanied by the coordinate axes labeled, an optically coupled framework's schematic diagram is depicted in Figure 1. Keith joint's position in the z-axis is represented as z_i. Two SOI strip waveguides contain in this framework, named WE0 and WE1.Light starts at the WE0's input port and goes out from the cross and the bar ports. The heights of waveguide h are kept up constant on account of the wafer preparation's limitation. The functions of z are the gap G among WE0 and WE1 and the waveguide widths, d0 and d1 when the light beam spreads at the z-direction. Or thereto equitably, the WE0 and WE1's propagation constants, which are indicated as ε_0 and ε_1, individually, are the functions of z. For the edges of WG0 and WG1, the distances betwixt the central line x = 0 are both equal to H=2.

Accompanied by main components Ex and Ey of the electric field, every strip waveguide implements two guided modes, which are usually delineated as quasi-TE and -TM modes. Usinga similar technique, accompanied by quasi-TE and -TM modes able to attain individually connection of design, which is remembering that. Here in the discussion we takings the quasi-TM mode as an instance.

The mode amplitudes of WE0 and WE1 are indicated as $V_0(\lambda, z)$ and $V_1(\lambda, z)$, respectively to an optically coupled framework depicted in Figure.1, and fulfill the equations of coupled-mode [26]:

$$\frac{\partial}{\partial z}\begin{bmatrix} V_0(\lambda, z) \\ V_1(\lambda, z) \end{bmatrix} = -j\begin{bmatrix} \bar{\varepsilon}(\lambda, z) + \Delta\varepsilon(\lambda, z) & \rho(\lambda, z) \\ \rho(\lambda, z) & \bar{\varepsilon}(\lambda, z) - \Delta\varepsilon(\lambda, z) \end{bmatrix}\begin{bmatrix} V_0(\lambda, z) \\ V_1(\lambda, z) \end{bmatrix} \quad (1)$$

At z=0, suppose $V_0(\lambda, z)$, and $V_1(\lambda, z)$ are launched, the solution is provided by:

$$V_0(\lambda, z) = -\left(V_1(\lambda, 0)\frac{j\rho\, sin(\vartheta z)}{\vartheta} + V_0(\lambda, 0)\left(cos(\vartheta z) - \frac{j\Delta\varepsilon\, sin(\vartheta z)}{\vartheta} \right) \right) e^{-j\bar{\varepsilon}z} \quad (2)$$

$$V_1(\lambda, z) = \left(V_1(\lambda, 0)\left(cos(\vartheta z) + \frac{j\Delta\varepsilon\, sin(\vartheta z)}{\vartheta} \right) - V_0(\lambda, 0)\frac{j\rho\, sin(\vartheta z)}{\vartheta} \right) e^{-j\bar{\varepsilon}z} \quad (3)$$

Where,

$$\vartheta(\lambda, z) = \sqrt{\rho^2(\lambda, z) + \Delta\varepsilon^2(\lambda, z)} \quad (4)$$

$$\bar{\varepsilon}(\lambda, z) = (\varepsilon_0(\lambda, z) + \varepsilon_1(\lambda, z))/2 \quad (5)$$

$$\Delta\varepsilon(\lambda, z) = (\varepsilon_0(\lambda, z) - \varepsilon_1(\lambda, z))/2 \quad (6)$$

Regarding the value $\varepsilon(\lambda, z)$, $\bar{d}(\lambda, z)$is the corresponding waveguide width.On account of the error that can emerge if is decided by the electric fields' overlap integral, the traditional CMT is known to be only accurate to weakly confined and weakly coupled waveguides [26]. In this instance, through the FEM based a single and coupled waveguides' solving the eigenvalue issues, all the variables necessary in the coupled-mode equations inclusive of, ε_0, ε_1, ρ, and ϑ are acquired[27], where, compared to the one acquired by the overlap integral, ρ is more accurate. [7]

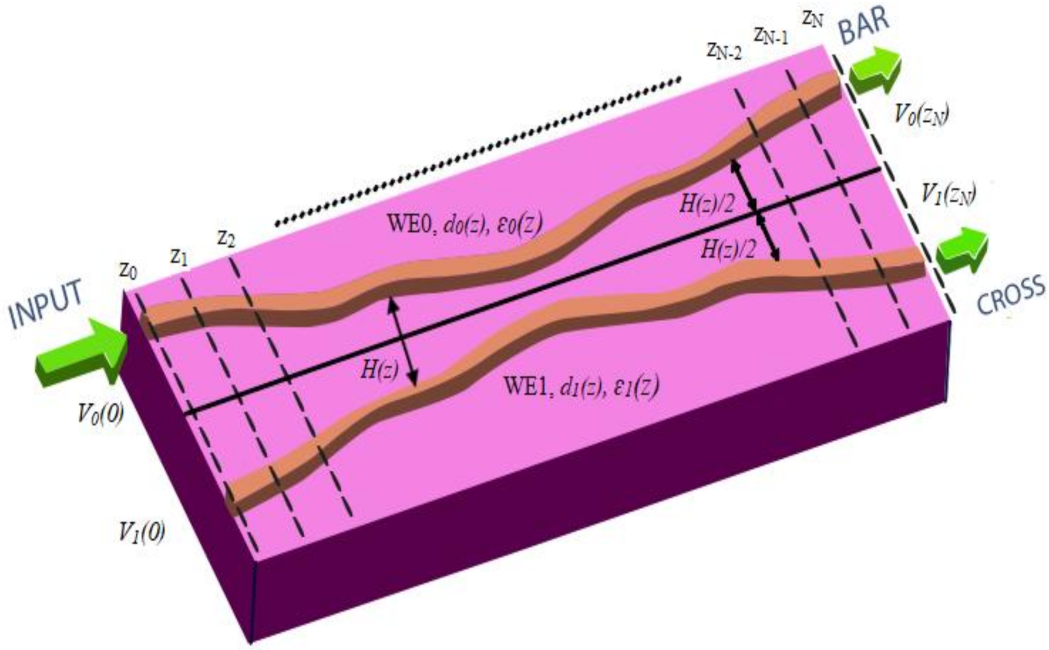

Figure 1: Simplified diagram of the optically coupled system

The GA-based optimization process is utilized to determine the values of $d_0(z)$, $d_1(z)$ and H (z), and as result, the gadgetsare divided into distinct trapezoidal segments accompanied by the lengthΔz. UtilizingQsmall rectangles accompanied by the length $\Delta z'$,every trapezoidal section is approximately appraised, and $N$is the net number of little rectangles. The n^{th} rectangle is depicted in Figure 5 where,

$$\Delta z' = z'_{n+1} + z'_n , \tag{7}$$

$$\Delta z' = n\Delta z' \tag{8}$$

Every variables' notation is delineated as followed, Y_n is synonymous with $Y(z'_n)$ if Y is a function of z, where I can be V_0, V_1, $\Delta\varepsilon$, ρ, and ϑ. Through solving Eq. (1) accompanied while initial condition input amplitudes, the entire framework output, including $V_{0,N}$ and $V_{1,N}$, can be determined. Nevertheless, in this case, $\Delta\varepsilon$ and ρ are arbitrary, because while solving the differential equations, the variables cannot be separated. Therefore, to facilitate the calculations, a simplified form may be required. The coupled-mode equations become [26] if $\Delta\varepsilon$ and ρ be able to appraise approximately as constants inside a little segment enclosed by $z = z'_n$ and $z = z'_{n+1}$:

$$\begin{bmatrix} V_{0,n+1} \\ V_{1,n+1} \end{bmatrix} = \begin{bmatrix} V_{0,n} \\ V_{1,n} \end{bmatrix} \begin{bmatrix} \cos(\vartheta_n \Delta z') - \dfrac{j\Delta\varepsilon_\rho \sin(\vartheta_n \Delta z')}{\vartheta_n} & \dfrac{-j\rho_n \sin(\vartheta_n \Delta z')}{\vartheta_n} \\ \dfrac{-j\rho_n \sin(\vartheta_n \Delta z')}{\vartheta_n} & \cos(\vartheta_n \Delta z') + \dfrac{j\Delta\varepsilon_\rho \sin(\vartheta_n \Delta z')}{\vartheta_n} \end{bmatrix} e^{-j\bar{\varepsilon}\Delta z'} \tag{9}$$

$$= \begin{bmatrix} V_{0,n} \\ V_{1,n} \end{bmatrix} T_n \tag{10}$$

Eq. (4) has the form

$$Q_{n+1} = Q_n T_n, \tag{11}$$

Thus the output matrix Q_N can be evaluated in a the convenient way by using

$$Q_N = Q_0 \left(\prod_{n=0}^{N-1} T_n \right) \tag{12}$$

Where,

$$Q_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{13}$$

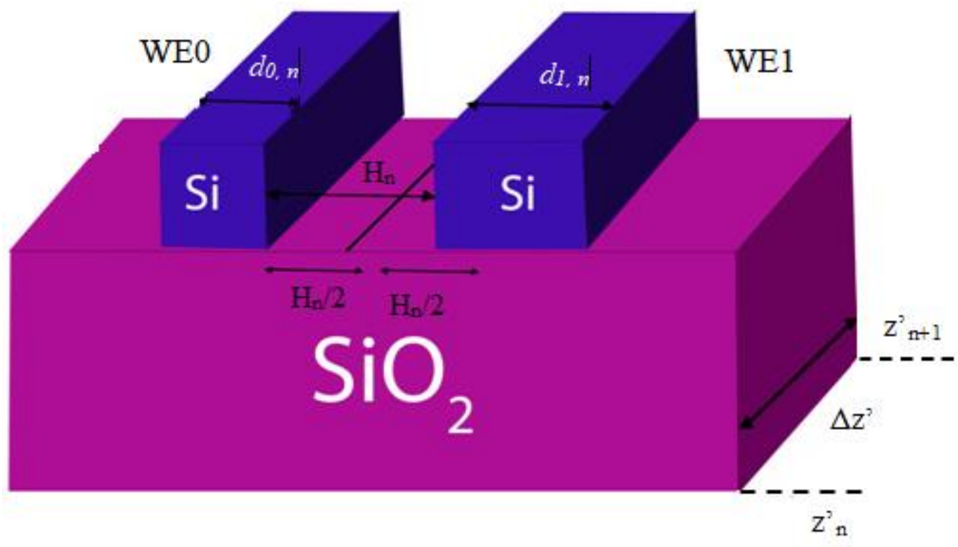

Figure 2: The n^{th} section of the device

3.3. Optimal design using SSO

This SSO algorithm performs based on the behavior of social-spiders in the communal web. This algorithm was introduced by Cuevas. The search space of this algorithm is considered as the communal web. The initialized spider and its positions are considered as a search agent and solution to the problem respectively. Spiders in the search space are categorized as Male spiders and Female spiders. Numbers of female spiders in the population are elected within the limit of 65-90% of the size of the population. Each male and female spider has a unique operator for movement. The best female and male spiders are used to execute the matting process for giving born to the brood. This new spider has replaced the worst spider in the search space. Optimization of gap and width of the waveguides using this proposed Social Spider Optimization algorithm is described as following:

Initialization:

Assuming the fan-out and fan-inareas where H ≥ 1 μm is necessary, the sudden variations of G with the gadgetsmighteventuate to a small coupling length (e:g: CL < 20μm), and as results the, CMT based transfer matrix technique's accuracy may be decremented seriously. A huge coupling length L = 34 μm is elected to assure the accuracy. To the structures of the waveguide,utilizing GA, the variables $d_{0,i}, d_{1,i}$, and $H_i$re designed.At this situation, the directional coupler is bifurcated into 34 trapezoidal segmentswhere $\Delta z = 1\,\mu m$, and as results,in the z-axis, the superscript of z_i is the position of iμm. To the optimization process, the number of variables can be decided through the lengths of CL and Δz,this might affect the optimumfitness value and convergence intricacy. For optimization, Δz = 1 μm and Ns = 34 is a proper beginning point in this case. For various parts of the system, to facilitate the connection and also to decrement the optimization complexity.H_i is established symmetricwhereas $\Delta \varepsilon_i$ is formedclosely anti-symmetric to z = 17 μm. Hence, $H_{34-i} = H_i$ .In another way, $d_{1,34-i} = d_{0,i}$ and $d_{0,34-i} = d_{1,i}$, except for i= 17.

Through a feasible solution (individual) S that includes a set of variables, the whole framework canbe discussed.

$$\vec{S} = \left[H_1, H_2, \ldots H_{17} \quad d_{0,1}, d_{0,2}, \ldots d_{0,17} \quad d_{1,1}, d_{1,2}, \ldots d_{1,17}\right] \tag{14}$$

$H$and $d_{0,i}$ be found at the interspace [0.15 μm, 1 μm] and [280 nm, 360 nm], separately during the optimization processes. Further, the adjacentsegments' width variations $\left|d_{0,i+1} - d_{0,i}\right|$, arelimited to 10 nm and the deviation angle caused by the variationof Hcannot exceed 2.5 degrees as referenced to the z-axis to assure the CMT's accuracy. After $\vec{S}$ is determined, to acquire a good accuracy for the computation of the transfer matrix,every trapezoidal segment is appraised approximately by ten little rectangles (*i*:*e*: *Q*= 10) accompanied the length $\Delta z' = \Delta z * 0.1 = 0.1\,\mu m$.Additionally, bylinear interpolation based on $\overset{\rho}{S}$, the parameters including all d_0, d_1, and *H*are computed. Thus, depending on the lookup table, $\rho(\lambda, z)$ and $\varepsilon(\lambda, z)$ for all λ and *z* can be appraisedand the output of the bar and cross ports for all λ can be computed.

Fitness calculation: To lessening the deviation of the bar port's coupling ratio $P_0 = \left|V0(CL)\right|^2$ and the cross port $P_1 = \left|V1(CL)\right|^2$ from 50% for λ = 1530−1630 nm, the GA is used and main intention and by that means the fitness function can be delineated in the form,

$$Fit = \sum_{l=0}^{10} \left(0.5 - P0(\lambda_l)\right)^2 \tag{15}$$

Where $\lambda_l = 10 \times l + 1530$ nm for $l = 0,1,2,....,10$ and by the value of *Fit*, the performance is appraised.In the fitness function, the utilized CMT is fulfilling the power conservation, and the net power is balanced to a unity, which is remembered, i:e:, $P_0 + P_1 = 1$.

Update the solutions: Each spider communicates with the other spider by sending the vibrations as information in the communal web. This vibration is defined based on the distance and weight of the spider. It can be calculated as follows,

$$D_{h,m} = e^{-r_{h,M}^2} * a_m \tag{16}$$

Where $r_{h,m}$ represents the Euclidean distance between the spiders in the position of *h*and *m*, whereas a_m represents the weight of the spider in the position of *m*. In SSO, each spider receives three types of vibrations that are described as follows,

- The vibration $D_{h,k}$ is transmitted by the spider*k*(t_k)to the spider *h*.The spider*k* which is nearest to the spider *h*and has a higher weight.

- The vibration $D_{h,g}$ is transmitted by the spider$g$(t_g) to the spider h.The spider has the best weight value in the entire population.
- The vibration $D_{h,b}$ is transmitted by the spider$b$(TB) to the spider h.The spider is the nearest female to the spider h.

Social-spiders play cooperative communication with other colony members relates to gender.The decision has been taken by the female spiders randomly for dislike or attraction over other spiders in SSO. According to the vibrations of female spiders, movement of repulsion or attraction over other spiders is generated and these vibrations are transmitted over the communal web. Movement of attraction is generated if the value of a uniform random number (l) within the range [0, 1] is less than the probability factor (al_b); otherwise,the movement of repulsion is generated. The model of movement operator of the female spider is described as follows,

$$b_h^{w+1} = \begin{cases} b_h^w + \alpha * D_{h,k} * \left(t_k - b_h^w\right) + \eta * D_{h,g} * \left(s_b - b_h^w\right) + \lambda * \left(rand - 0.5\right) & if \quad l < el_b \\ b_h^w - \alpha * D_{h,k} * \left(t_k - b_h^w\right) - \eta * D_{h,g} * \left(s_b - b_h^w\right) + \lambda * \left(rand - 0.5\right) & if \quad l < el_b \end{cases} \tag{17}$$

Where, $\alpha, \eta, \lambda, rand$ and $l$is the random numbers between [0, 1]. t_k and t_g denote the nearest spider with higher weight and the spider with best weight value in the entire population respectively, whereas w represents the iteration number. el_b representthe probability of repulsion or attraction. In this approach, the probability factor is decreased from 1 to 0 so that female spiders survey the global area well in the search space.

Male spiders in the search space are categorized into two types that are dominant (F) and non-dominant (AF) male spiders. If the weight value of the male spider is greater than the median value, then it is considered as a dominant male spider; otherwise, the male spider is considered as a non-dominant male spider. The dominant male spiders are only attracted by the female spiders for mating. The model of the dominant male spider is defined as follows,

$$q_h^{w+1} = q_h^w + \alpha * D_{h,b} * \left(t_b - q_v^w\right) + \lambda * \left(rand - 0.5\right) \tag{18}$$

Where t_b denotes the nearest female spider of spider h. Non-dominant male spiders in the population of male spiders are moving to the center of the male population and perceive sources from other male spiders to perform as dominant spiders in the future. The model of the dominant male spider is defined as follows,

$$q_h^{w+1} = q_v^w + \alpha * \left(\frac{\sum_{u=1}^{A_q} q_u^w * a_{A_b+u}}{\sum_{u=1}^{A_q} a_{D_b+u}} - q_h^w \right) \tag{19}$$

Where $\frac{\sum_{u=1}^{A_q} q_u^w * a_{A_b+u}}{\sum_{u=1}^{A_q} a_{D_b+u}}$ indicates the male population's weighted mean, A_b denotes the number of female spiders,

Finally, the mating operation is done in SSO to generate new spiders. These new spiders replace the spider with the worst weight value. This mating functioningis accomplishedwith the support of dominant male spiders and female spiders within the defined range that is known as the mating radius. This mating radius (LQ) is calculated as follows,

$$l_q = \frac{\sum_{m=1}^{F} \left(e_m^{high} - e_m^{low}\right)}{2F} \tag{20}$$

Where F represents the dimension of the problem, whereas e_m^{high} and e_m^{low} denote the upper and lower bound respectively. A pair with higher weight produces the new brood. A roulette wheel method is presented to select the pairs from the more than one male and females make pairs in the mating radius. It is defined as follows,

$$e_{th} = \frac{a_h}{\sum_{m \in B^w} a_m} \tag{21}$$

Where p_{th} represents the influence probability to select the pairs from the pair set B^w.

Then the weightis calculatedfor the new spider. If the new spider is better than the worst spider in terms of weight, then the new spider replaces the worst spider; otherwise, the new spider is rejected. In the event of replacement, the new spider assigns the gender and index of the replaced spider.

***Termination*:** Above described phases of the SSO algorithm is continued until getting the optimal gap and widths of waveguides. Once the number of iterations is completed, the algorithm will be terminated.

4. Results and Discussion

In the working stage of MATLAB, this proposed SSO based optical waveguide coupler is effectuated. This proposed strategy's performance is appraisedbased on coupling efficiency, insertion loss, power splitting ratio, and transmittance. Besides, this proposed SSO based optical waveguide coupler design is compared with the existing GA based optical waveguide coupler design.

The performance metrics are described as follows:

Coupling efficiency (CE): It is defined as the optical power transfer between the power from the input port and the cross port of the directional coupler. It is defined as follows:

$$CE = 10\log\left(\frac{R_1}{R_{input}}\right)dB \tag{22}$$

Where Re_{input} denotes the input power of the directional coupler and R_1 denotes the power of the cross port.

Insertion loss (IL): It is defined as the loss of signal power from the input port to the bar port. It can be defined as follows:

$$IL = -10\log\left(\frac{R_0}{R_{input}}\right)dB \tag{23}$$

Figure 3 shows the coupling efficiency-based performance of the proposed and existing approaches for the wavelengths between 1500 nm and 1600 nm. The coupling efficiency has to be high for an approach to be considered an effective one. The wavelength when the coupling efficiency is attained by the proposed approach is from 1524.9661 nm to 1580.55 nm. The wavelength when the coupling efficiency is attained by the existing approach is from 1522.6843 nm to 1582.625 nm. When the efficiency is higher, the wavelength dependency gets reduced. From the graph, it is clear that the proposed approach has a lower wavelength dependency than the existing approach. Thus it can be known that the proposed approach is more efficient than the existing approach in terms of coupling efficiency.

Figure 4 shows the insertion loss performance of the proposed and existing approach for various wavelengths from 1530 dB to 1600 dB. The loss of signal power from the input port to the bar porthas to be low for an approach to be considered an effective one. When the wavelength is 1530 nm, the proposed strategy's insertion loss is -9.2 dB and the existing strategy's insertion loss is -9 dB. When the wavelength is 1560 nm, the proposed strategy's insertion is -6.3 dB and the existing strategy's insertion loss is -5.9 dB. When the wavelength is 1600 nm, the proposed strategy's insertion is -6 dB and the existing strategy's insertion loss is -5.5 dB. In these cases, the insertion loss of the proposed approach has been lower for the proposed approach than the existing approach. This case is the same for all the values of wavelengths. Therefore, it can be known from the graph that the proposed approach is efficient in terms of insertion loss.

Figure 5 shows the power splitting ratio based performance of the proposed and existing approaches for the wavelengths between 1520 nm and 1640 nm. The Bar and cross of the proposed approach and the existing approach are differentiated. For an approach to be considered effective in terms of power splitting ratio, the bar and cross of the approach should not vary much from each other while maintaining the position nearer to the optimal output power as much as possible. When the wavelength is 1560 nm, the bar of proposed is at 49% and the cross of proposed is at 50% while the bar and cross of the existing approach are at 48% and 51% respectively. From the values, the proposed strategy's power splitting ratio is less variant and nearer to optimal power ratio than that of the existing approach is seen obviously.Thus the proposed strategy has performed better than the existing approach in terms of power splitting ratio, which can be concluded that.

Figure 6 shows the Transmittance based performance of the proposed and existing approaches for the wavelengths between 1.5 nm and 1.6 nm. The Bar and cross of the proposed approach and the existing approach are differentiated. For an approach to be considered effective in terms of transmittance, the bar and cross of the approach should meet at the optimal transmittance. When the wavelength is 1.55 nm and 1.56 nm, the bar and cross of the proposed approach coincide with each other. Also, these coincided points lie on the optimal transmittance value of -3dB. But the existing approach's bar and the cross do not intersect at any point and also they are further away from the optical transmittance value. The proposed strategy's transmittance is less variant than that of the existing strategy which is seen clearly from the values. Thus, the proposed strategy has performed better than the existing strategy in terms of transmittance, which can be concluded that.

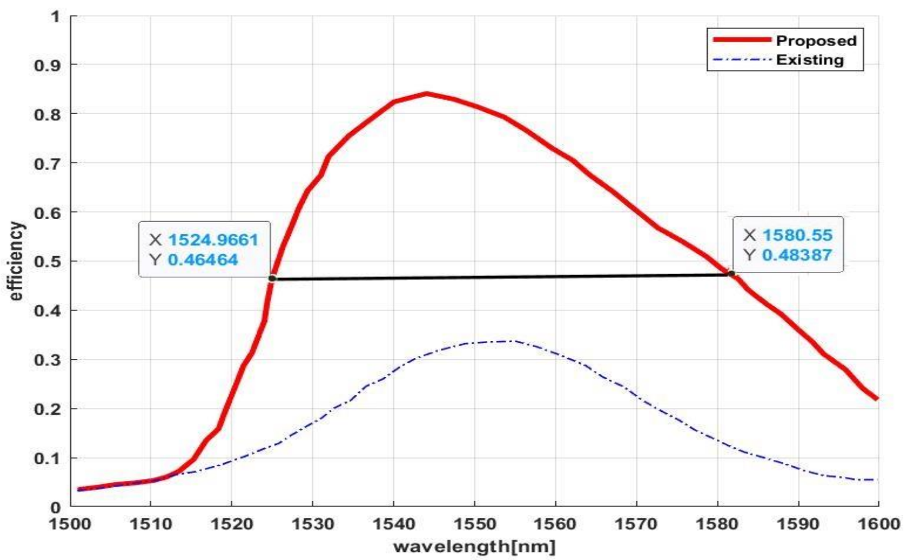

Figure 3: Wavelength Vs coupling efficiency

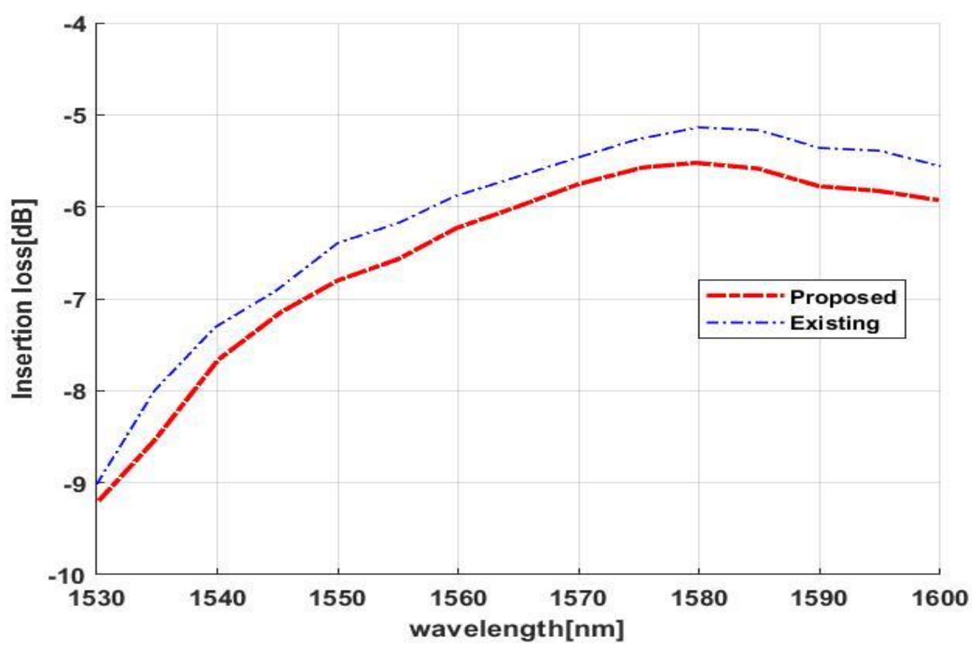

Figure 4: Wavelength Vs coupling efficiency

Figure 4 shows the insertion loss performance of the proposed and existing approach for various wavelengths from 1530 dB to 1600 dB.

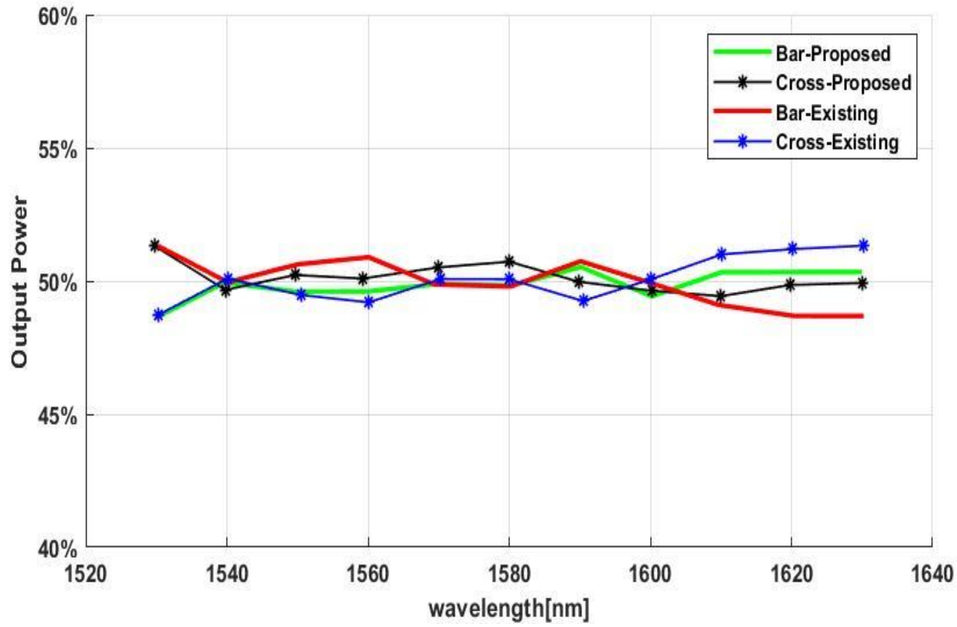

Figure 5: Wavelength Vs Output power

Figure 5 shows the power splitting ratio based performance of the proposed and existing approaches for the wavelengths between 1520 nm and 1640 nm.

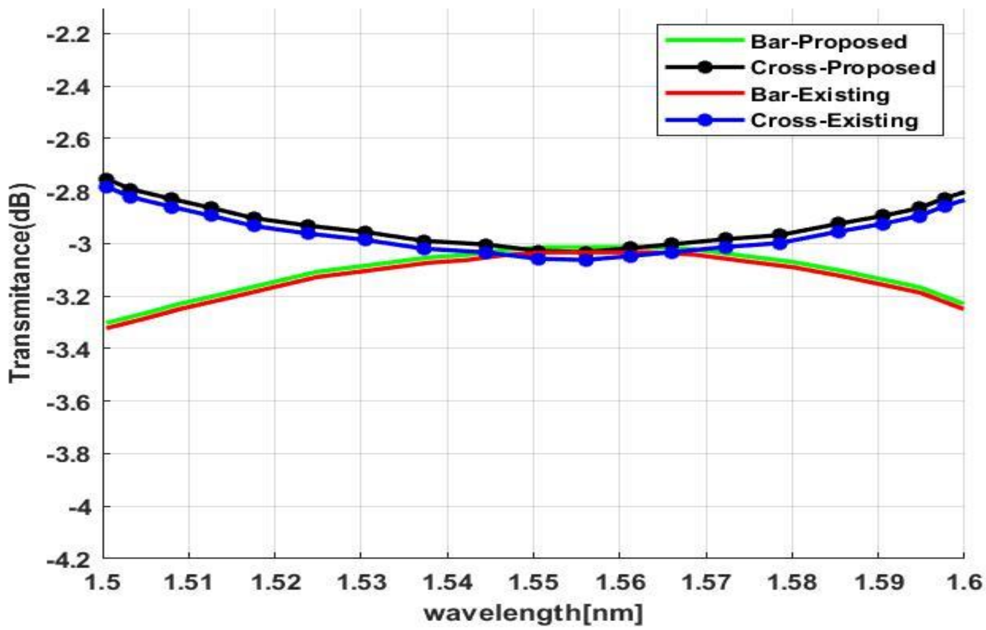

Figure 6: Wavelength Vs Transmittance

Figure 6 shows the Transmittance based performance of the proposed and existing approaches for the wavelengths between 1.5 nm and 1.6 nm.

The proposed strategy has performed better than the existing strategies in terms of coupling efficiency, insertion loss, power splitting ratio, and transmittance which is known obviously from the graphs

5. Conclusion:

Briefly, the optimization of the broadband optical waveguide couplers are proposed in this study.Social Spider Optimization algorithm is presented for obtaining the optimal values of the gap between waveguide and widths of the waveguide. Coupling coefficients and propagation constants are selected based on the chosen values of gap and width.The results have been simulated for the proposed approach and compared with one existing approach.The proposed strategy's performance is appraised in terms of coupling efficiency, propagation loss, and optical output ratio.The proposed strategy performed better than the existing strategy as per the results.

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