Compact Air-To-Waveguide Coupler Design Based on Neural Networks

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Abstract: A novel approach based on neural network is presented for compact photonic devices. The proposed approach uses 100nm x 100nm bitwise square Si- cells to construct 2D photonic structure having a footprint of 2µm x 4µm. A coupling efficiency of 99% was obtained from the optimized air-to-waveguide coupler with a conversion ratio of 10:1. The optimized coupler design is easy-to-fabricate via optical lithography techniques and quite compact compared to its conventional counterparts. According to corresponding numerical results, neural networks can be considered as a powerful optimization method enabling highly efficient photonic designs for optical system applications such as polarization-splitting, beam manipulation and optical interconnects.

1. Introduction

Recently, there have been a great number of studies about the use of optimization algorithms for efficient photonic structure designs. As already known, traditional theoretical approaches may not give exact solutions in complex photonic structures. Moreover, theoretically designed systems may not fully satisfy desired performance requirements such as compactness, efficiency, bandwidth and energy loss drawbacks. For this reason, different optimization methods such as evolutionary algorithm [1], inverse optimization [2] and topology optimization [3] have been utilized to design efficient photonic integrated structures.

2. Methodology and Results

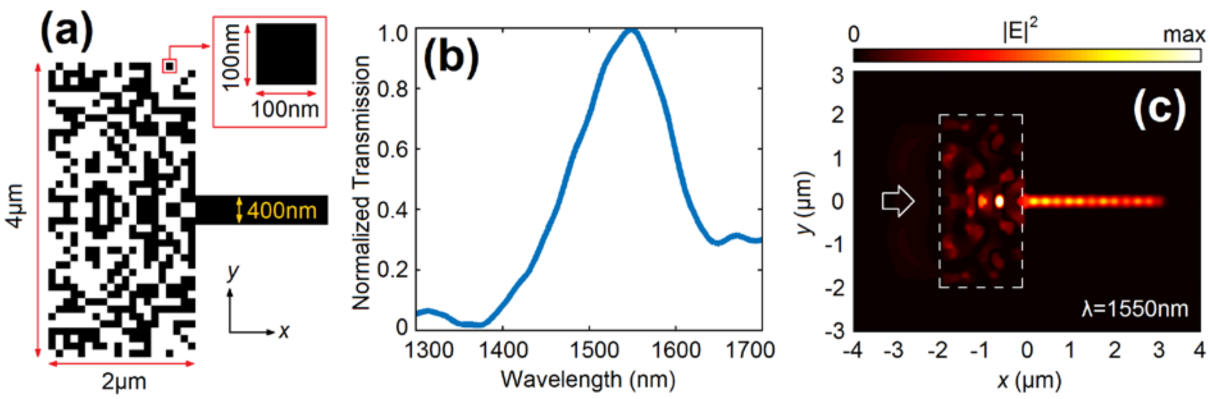

Fig. 1. (a) Optimized 2D photonic structure design for air-to-waveguide coupling application. (b) Corresponding transmission efficiency spectrum within telecom wavelengths. (c) Spatial field intensity distributions of the optimized structure calculated in *xy* plane (*z*=0) for the incident wavelengths of λ= 1.55µm. The dashed box represents the structure boundaries.

In this study, an efficient air-to-waveguide coupler design is made by using neural networks approach. This optimization algorithm, which is called attractor selection, was firstly presented in [4], in which human brain was inspired to develop such an artificial neural network model. The optimized photonic structure is constructed with 100nm x 100nm Si- or air pixels and the corresponding footprint of coupling section is 2µm x 4µm. A Si-waveguide with 400nm width is butt-coupled to the optimized structure and the corresponding coupling efficiency is calculated inside the waveguide in the case of Gaussian beam incidence from free space. In analytical modelling of photonic structure, neural network system decides in which place to add either air or Si-pixels according to the calculated coupling efficiency.

The final optimized structure designed by the neural network is plotted in Fig. 1(a) with its geometrical parameters. The designed structure is illuminated from its left-side and the corresponding efficiency is calculated in the butt-coupled waveguide, see Fig. 1(b). Maximum coupling efficiency of 99% is obtained in the case of the optimized structure and the corresponding 3dB bandwidth is calculated to be 130nm, which covers the telecommunication wavelengths. In order to better visualize the coupling performance of the optimized coupler, corresponding spatial field intensity is calculated at the incident wavelength of 1550nm and the corresponding intensity distribution is shown in Fig. 1(c). As can be seen from the figure, the illuminated beam is strongly compressed through the coupling region with a beam compression ratio of 10:1 and well-confined into the 400nm-width narrow output waveguide. Such a strong coupling in the optimized structure may be attributed to multiple scatterings encountered in air and Si pixels, which provide constructive interference of propagating waves at the output channel [5]. Obtained results may claim that owing to the proposed coupler optimized with neural network, strong coupling can be achieved from air-to-waveguide, from which a system can be implemented for compact integrated circuit design.

3. Conclusion

In conclusion, an all-dielectric free space-to-waveguide coupler was designed utilizing a neural network optimization for the first time. The performance of optimized photonic structure was analyzed employing FDTD calculations. The footprint of the whole optimized system is 2μm x 4μm, which is very compact compared to its counterparts in the literature. A maximum coupling efficiency of 99% was calculated for the optimized photonic structure and the corresponding 3dB bandwidth was calculated to be 130nm within the incident wavelengths of 1475nm-1605nm. The obtained strong coupling effects can be can be implemented for compact and dense integrated device applications.

Acknowledgment. MT and EB gratefully acknowledge the financial support of the Scientific and Technological Research Council of Turkey (TUBITAK), project 116F182.

4. References

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