A compact 1×4 wavelength demultiplexer by Inverse Design

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***Abstract*—A compact 1×4 wavelength demultiplexer is designed on silicon-on-insulator (SOI) platform by inverse method with channel spacing of 10 nm in C band. All four channels (1530 nm, 1540 nm, 1550 nm, 1560 nm) show the peak transmission of -1 dB.**

***Index Terms*—Inverse Design, WDM, SOI, Optimized Photonics**

I. INTRODUCTION

CMOS fabrication technology compatible silicon photonics devices have variety of application in the area of communication,sensing, defence, etc [1]–[4]. The conventional method to design photonics devices is based on the human intuition and manual tuning. When the design variables are large, it requires large number of sweep of the parameters to find the optimum one. It is highly time consuming and also sometimes lead to large footprint of photonics devices.

In the recent years, the application of inverse design (ID) methods in photonics advances the design process. One of the main advantage of ID methods is that it automates design process. It is used to design ultra compact photonics devices for a given target. [5]–[7]

We have designed a SOI based 1×4 wavelength demultiplexer by ID method with the footprint size of $6 \times 6 \mu m^2$. It is one of the fundamental photonics device which is used in optical communication to split the multilplexed channels spatially.

II. DESIGN PROCESS

We have approximated the device structure in 2 dimension with following assumptions:
(1) The device structure is invariance in z-direction.
(2) 'X' axis is the propagation direction.

In the design process, first the structure is initialized as shown in the Fig. 1. The design region (yellow color) is discretized into the rectangular pixels of 100 nm × 100 nm. Here, each pixel i.e. $\epsilon_r(x, y)$ is the design variable. It can be either silicon or air.

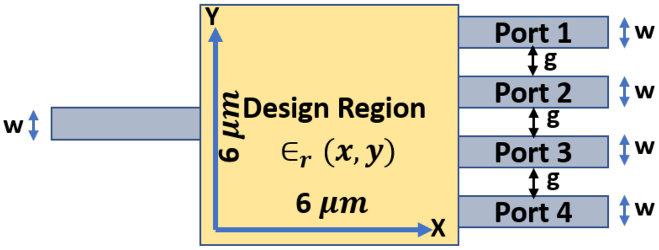

Fig. 1. shows the initialized structure of the device. The fundamental TE source is at the four channels is launched from left to right. Thickness of the device is 220 nm on SOI platform. Width of the input and the output waveguide is 350 nm. The target output profile is to split the channels 1560 nm, 1550 nm, 1540 nm and 1530 nm at the output Port 1, Port 2, Port 3 and Port 4 respectively.

The design process is expressed as an constraint optimization problem as follows:

$$\begin{aligned} \max_{\epsilon} \quad & F.O.M.(E_i(\epsilon)) \\ s.t. \quad & \nabla \times \mu_o^{-1} \nabla \times E_i - \omega_i^2 \epsilon E_i = -j\omega_i J_i \end{aligned} \tag{1}$$

In 1, the subscript 'i' is the operating wavelength. E_i is the electric field, ω_i is the operating wavelength, J_i is the modal source.

According to the 1, optimum value of permitivity is obtained at the each pixel for a maximum figure of merit (F.O.M.) subject to the satisfaction of maxwell equation.

We have used Ansys Lumerical 2D FDTD solver for Electromagnetic calculation [8]. The figure of merit is defined as the mode overlap integral [9] for a given wavelength given as

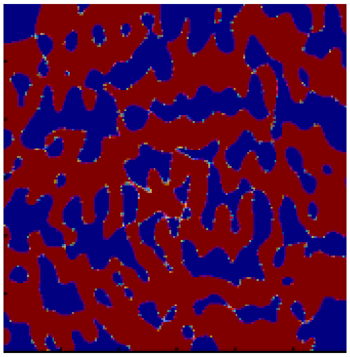

Fig. 2. shows the obtained permitivity distribution in the design region. Red color is the silicon and the blue color is the air cladd.

below:

$$F.O.M. = \frac{1}{8}\frac{|\int E\times\overline{H_m}.dS+\int\overline{E_m}\times H.dS|^2}{\int Re(E_m\times\overline{H_m}).dS} \tag{2}$$

In 2, E_m and H_m are the target mode field profile and 'E' and 'H' are the obtained field profile.

An adjoint based gradient optimizer [9] is used for faster convergence to a solution. The gradient calculation with respect to the all design parameters in the adjoint optimization requires only two simulation.

III. RESULTS

Fig. 2 shows the device obtained by the inverse method with the footprint size of $6\mu m\times 6\mu m$. In the structure, the red color shown is silicon and the blue color shown is the air cladd with silica substrate.

Fig. 3 shows the transmission responses of the channels 1530 nm, 1540 nm, 1550 nm and 1560 nm at the output Port 4, Port 3, Port 2 and Port 1 respectively. It shows transmission of all the channels is -1 dB whereas the maximum cross coupling is -13 dB at 1530 nm, 1540 nm and 1550 nm and -14 dB at 1540 nm.

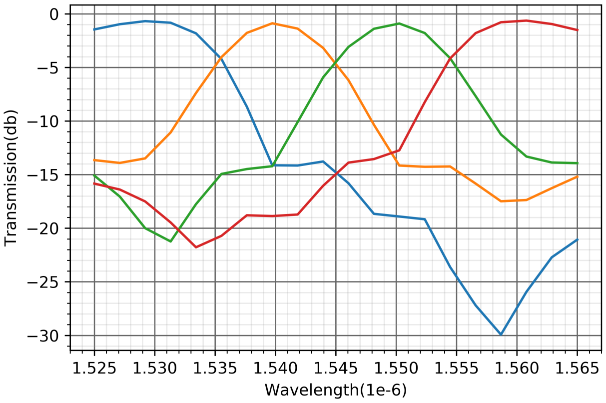

Fig. 3. shows transmission profile of all the channels at the Port 1 (Red), Port 2 (green), Port 3 (Yellow) and at the Port 4 (Blue).

IV. CONCLUSION

In this work, a SOI based 1×4 wavelength demultiplexer in C band with the channel spacing of 10 nm is designed by the inverse method. Size of the designed structure is $6\mu m\times 6\mu m$. The device shows a very high performance with very low crosstalks.

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