Coupled Mode Theory and 50/50 Splitter

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***Abstract*—In this work, we aimed to design a 50/50 splitter made a two-waveguide coupled system. First, we started with a pre-analysis with COMSOL to optimize the material of the waveguides, their width and thickness, alongside with a resonable gap to obtain a short in length splitter. Then, we followed to the theoretical modeling of the problem based on Coupled Mode Theory, ranging from the derivation of the coupling constant formula, the coupled mode equations, and a numerical method to calculate the coupling rate. At the end, we analysed two cases of beamplitter, the first with identical waveguides, and the second with one waveguide with doubled dimensions. We found that the second case is better to obtain a more compact splitter.**

***Index Terms*—Waveguides, Coupled Mode Theory, Beamsplittersnsing.**

I. Introduction

In this section, we aim to describe the investigation to choose the material and the geometrical parameters of the waveguides belonging the coupled system. In the first place, we considered SiO_2, TiO_2, Si_3N_4, and Ag_3AsS_3 as the possible materials due to their renowed applications in photonic integrated circuits (PIC). Fig. 1 displays the dispersion of each one of these materials. As it is evident, Ag_3AsS_3 has the greatest values of refracive index (RI) and SiO_2 has the lowest, while TiO_2 and Si_3N_4 are intermediate cases.

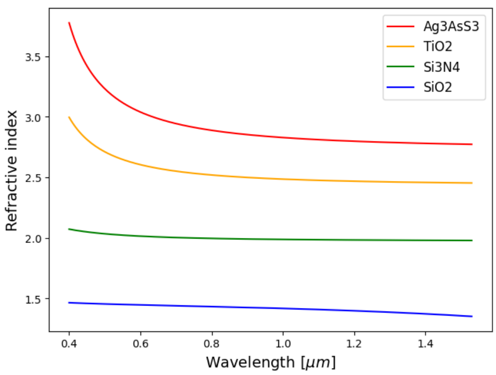

Fig. 1: Dispersion relation for the SiO_2, TiO_2, Si_3N_4, and Ag_3AsS_3.

Motivated by the common use of SiO_2 and TiO_2 in waveguides, and the info they present distinctive dispersion relations, TiO_2 presenting the highest values, we will focus on these materials as the candidates for the beam splitter. So, their dispersion relations are described by Eq. (1).

$$n_{SiO_2} = \sqrt{1 + \frac{0.6961663\lambda^2}{\lambda^2 - 0.0684043^2} + \frac{0.4079426\lambda^2}{\lambda^2 - 0.1162414^2} + \frac{0.8974794\lambda^2}{\lambda^2 - 9.896161}} \tag{1a}$$

$$n_{TiO_2} = \sqrt{5.913 + \frac{0.2441}{\lambda^2 - 0.0803}} \tag{1b}$$

To understand the number of modes in a waveguide with these materials, we plotted the characteristic equations for each material for the infinite dielectric slab case, which has a easier mathematical description. The generic characteristic equation is described by Eq. (2), and the case for SiO_2 is plotted in Fig. 3.

$$\begin{aligned} f_1(\sin(\theta)) &\equiv \tan\left[\pi\left(\frac{\sin(\theta)d}{\lambda} - \frac{m}{2}\right)\right] \\ &= \sqrt{\frac{\sin^2(\overline{\theta}_c)}{\sin^2(\theta)} - 1} \equiv f_2(\sin(\theta)) \end{aligned} \tag{2}$$

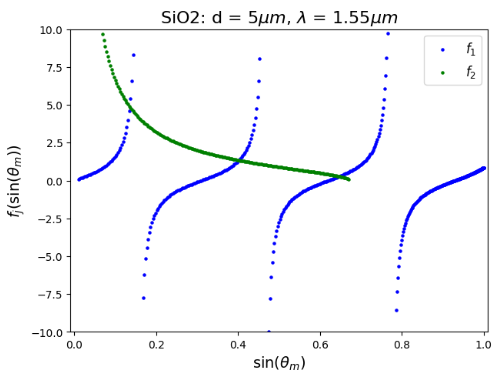

Fig. 2: SiO_2.

Fig. 3: Plot of the characteristic equations for the SiO_2 and TiO_2 infinite slab case.

II. Infinite dielectric waveguide

A. Theory development

B. Numerical analysis

III. Rectangular dielectric waveguide

A. Theoretical development

B. Solo waveguide

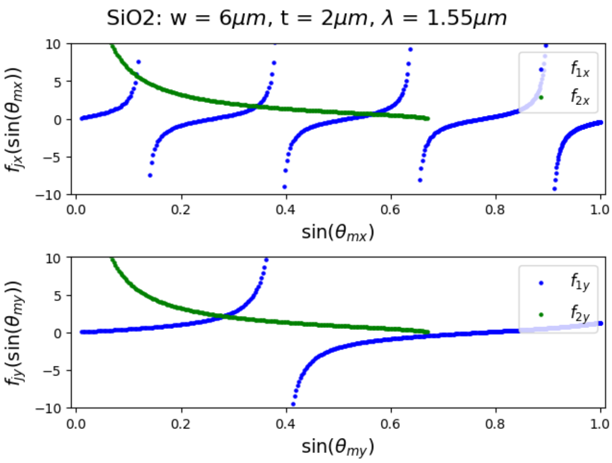

Fig. 4

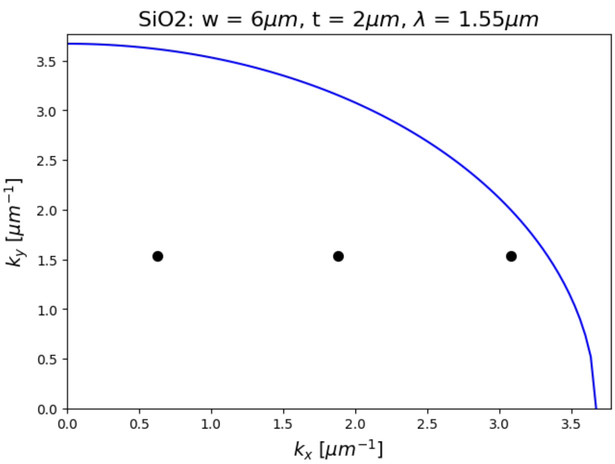

Fig. 5

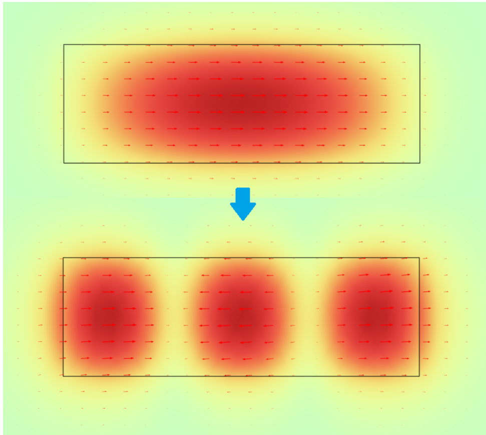

Fig. 6

C. Coupled waveguide

IV. Conclusion

Appendix