Exercises

Directional Waveguide Coupler with Ansys Lumerical Software

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Ansys Software Used

This resource uses Ansys Lumerical MODE™ optical waveguide design tool.

Summary

This exercise explores the directional waveguide couplers using Ansys Lumerical MODE tool. It was originally developed by Dr. Prabhav Gaur, Dr. Andrew Grieco, Karl Johnson, Dr. Peter Ilinykh, Prof. Saharnaz Baghdadchhi, Prof. Yeshaiahu Fainman for the *ECE 184: Optical Information Processing and Holography* course at the University of California San Diego.

1. Objective

Design a coupler using Ansys Lumerical software; analyze propagating modes and other parameters.

2. Background

2.1 Coupler

Coupler basically consists of two parallel waveguides with the area where they are very close to each other. This area forms a coupling region as shown in Figure 1.

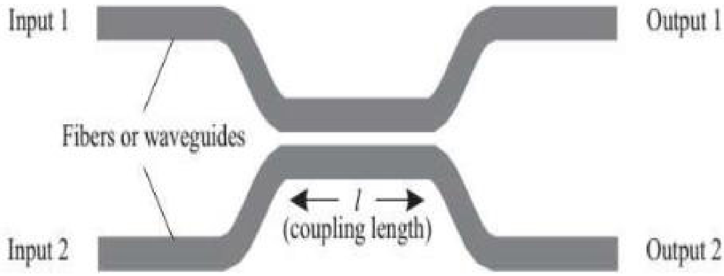

Figure 1.

The length of this coupling region, l, determines the coupling ratio from one waveguide to the other.

2.2 How Coupler Works

The intensity profile of light traveling down a single-mode waveguide is essentially Gaussian; that is, the intensity is greatest in the center and tapers off as boundary interface is approached. The tail of the Gaussian profile extends slightly through the boundary. This tail is called the evanescent wave. Figure 2 represents the cross section of a light wave in a waveguide. The vertical dashed lines represent the waveguide boundaries. The tails are the evanescent wave.

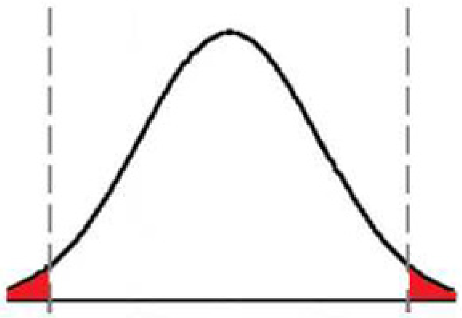

Figure 2.

If waveguides placed so close that the evanescent wave can “leak” from one waveguide into another. This allows an exchange of energy, analogous to the energy exchange that takes place with two coupled pendulums. The amount of energy exchange is dependent upon the proximity of the two waveguides, d, and the length l over which this exchange takes place.

We can calculate the coupling length by considering the difference in indices between the two coupled modes $\Delta n = n_1 - n_2$. If we initially have 100% of the power in waveguide 1, then the power in waveguide 2 is given by $P_2(l)=P_0\sin^2(\pi/\Delta n/\lambda_0)$, where P_0 is the input power, and λ_0 is the free space wavelength. It is easy, for example, to calculate the coupling length to achieve any desired power coupling to waveguide 2 by solving for l:

$$l = \lambda_0/(\pi\Delta n) \sin^{-1}(\sqrt{P_2}/ P_0)$$

For example, the length required to couple 100% of the light from waveguide 1 to waveguide 2 is simply $l_{100\%} = \lambda_0/(2\Delta n)$.

3. Experimental Part.

3.1 Coupler Simulation and Design

In this section, you will design and simulate a directional coupler in Ansys MODE Lumerical solver.
You will analyze the coupling length required to couple 100% of the light from waveguide 1 to waveguide 2, depending on the gap between waveguides, waveguide width, and wavelength.
Check the article (we will be doing only the FDE simulation part) https://optics.ansys.com/hc/en-us/articles/360042304694-Evanescent-waveguide-couplers

a) Download lms and lsf files from the article. Run lms-file.
- Set FDE active by right-clicking on it (If you don't see this option, click on the Layout button to change it in Run mode)
- Check the waveguide's widths and the gap size.
- Open Eigensolver Analysis and Calculate Modes. Check mode#2 cross-section picture.
- Record n_{eff} for mode#1 and mode#2.
-Calculate $L_{100\%} = \lambda_0/(2\Delta n)$.
- In Script Prompt type waveguide_couplers (without lsf- extension) to run this file.
- Save picture showing mode coupling as a JPG file for the report.
- Estimate $L_{100\%}$ and compare with the calculated one.

- If you want 100% of the power to remain in the input waveguide, what multiple of the coupling length would the device be?
- What would be the coupling length for a 50/50% power distribution? And for 25% of the power going to waveguide 2?

b) Coupling Length vs Gap
- Change the gap between waveguides from 50nm to 70nm by running the script in the Script Prompt:

```
# set the 70 nm gap
gap = 70e-9;
setnamed("left", "y", -( 500e-9 + gap )/2);
setnamed("right", "y", ( 500e-9 + gap )/2);
setnamed("mesh_gap", "y span", gap);
```

- Type waveguide_couplers in Script Prompt and estimate L100%
- Repeat above for gap = 100, 150, 200nm
- Plot $L_{100\%}$ vs gap and comment on its behavior

c) Coupling Length vs waveguides width
- Change the gap between waveguides back to 50nm
- Change the width of each waveguide from 500nm to 400nm
Edit Object -> Geometry -> y min=   (and do the same for right)
- Run waveguide_couplers in Script Prompt and estimate $L_{100\%}$
- Repeat for 600nm. Comment on the coupling length dependence on the waveguides width.

d) Coupling Length vs wavelength
- Change waveguides widths back to 500nm.
- Run waveguide_couplers in Script Prompt and estimate $L_{100\%}$ at λ_0 = 1.55µm
- In the Eigensolver Analysis window, change the wavelength to 1.3µm. Number of trial modes: 6.
- Run waveguide_couplers in Script Prompt and estimate $L_{100\%}$
- Repeat for λ_0 = 1.1µm and 1.7µm.
- Plot $L_{100\%}$ vs λ_0. Recall formula for $L_{100\%}$ and explain plot behavior.

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