ELEC 413 Draft Report

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1 ABSTRACT

This report details the design process of a Mach-Zehnder Interferometer with an input wavelength of 1310 nm and a 25 GHz Free Spectral Range. The interferometer was simulated as a de multiplexer, but can be used as a multiplexer or a de multiplexer.

2 INTRODUCTION

Fiber optic cables are essential to our ability to communicate quickly and with reliability. They are common in both telecommunication and computer networking applications due to their durability and low attenuation levels. [1] In order to make efficient use of these physical cables, it is advantageous to be able to send multiple different signals along the same cable. This can be achieved through multiplexing, a process by which multiple signals are sent along the same cable at slightly different frequencies to allow for signal reconstruction at the output.

This report focuses on the design of the optical circuit used to reconstruct the separate signals using Mach-Zehnder interferometers (MZIs) [insert MZI image here], MZIs function as frequency filters, splitting an incoming beam of light into 2 and forcing the light to travel paths with different lengths. When these paths meet again at the Bragg Coupler, one beam of light will have a phase shift relative to the other due to the path length difference. The coupler allows for some interference between the 2 beams, though it is the wavelength of the input that determines whether the 2 beams interfere constructively or destructively. Therefore we are able to filter out different signal frequencies by varying the path length difference. When modeling the output of such a device, it is common to test a small range of input frequencies to determine the free spectral range. This range is defined to be the distance from peak to peak of the output power graph [insert image here of spectral range]. The focus of this report will be on a de multiplexer that takes in light around 1310 nm in wavelength and produces a free spectral range of 25 GHz.

3 THEORY AND CALCULATIONS

To begin, the path length difference must be determined depending on the parameters laid out above. To calculate an appropriate path length difference, the following formula was used with $FSR = 25GHZ$, $\lambda = 1310$.

$$\text{FSR} = \frac{\lambda^2}{n_g \cdot \Delta L}$$

3.1 Lumerical Modeling for the Group Index (n_g)

To determine a proper approximation for the group index, a model was developed in Lumerical using a waveguide segment to identify the group index for all possible modes in the waveguide.

[insert modeling procedure here]

As shown, the group index for the first TE mode is approximately 4.1, therefore $n_g = 4.1$ in the FSR formula above.

Rearranging to solve for delta L gives a path length difference of approximately 3mm.

4 DESIGN

Now that an appropriate path length difference has been determined, the circuit can now be drawn using Klayout. The circuit must fit within a 605nm x 410nm rectangular foot print, must contain 1 input port for light coming from the fiber optic cable, and 2 output ports for each beam of split light. As well, this circuit was designed with a height of 220 nm and a width of 500 nm, in future iterations this chosen width will be varied to optimize for low loss.

[insert detailed procedure for KLayout Design Here.]

The final Preliminary design for this circuit is shown below. [Insert image of klayout design]

5 RESULTS AND SIMULATIONS

Once the circuit was completed in Klayout, Lumerical Interconnect was used to simulate the behavior of the circuit to ensure it operates as expected. The Interconnect simulator generates a plot of wavelength vs intensity at each output. The modeling of this circuit resulted in the plot below [insert plot image here]

To determine whether this matches the expected results, the following formula can be used to the expected spacing in units of wavelength instead of units of frequency

$$\Delta\lambda = \frac{n_g \cdot c}{\lambda^2} \cdot \text{FSR}$$

By substituting $n_g = 4.1$, $\lambda^2 = 1310^2$, $c = 3 * 10^8$, and $FSR = 25 * 10^9$, the expected $\Delta\lambda$ value is 0.7 nm. The plot generated by Lumerical has tighter spacing than what is expected, with an approximate $\Delta\lambda$ value pf 0.5 nm. This could be due to some of the approximations made in calculating the path length difference including: using an approximate value for n_g and an approximate value for ΔL.

5.1 Conclusion

Presented above is the design and simulation process for a Mach-Zehnder Interferometer intended to produce a 25 GHZ free spectral range from an input light beam of 1310 nm. Based on the simulation outputs, this device does not function exactly as intended, with a narrower range than desired. To rectify this, the next design iteration should aim to use more accurate parameters for a more exact path length difference. As well, future revisions should experiment with varying the waveguide width to determine the effect different waveguide dimensions have on the loss and the free spectral range profile.