Introduction

Photonics is the backbone of modern Fiber Optic Communication. In Fiber Optic Communication, information is encoded in the form of light pulses and transmitted via Optical fibers at the speed of light. Light from a light source such as a Semiconductor Laser goes to an Optical modulator, where it gets modulated, then passes through an Optical fiber, and is detected by a Photodetector which converts it back into an electrical signal.

Silicon Photonics involves fabricating Photonic components using standard Complementary Metal Oxide Semiconductor (CMOS) processing techniques. A light source, Optical modulator, Optical waveguide which is analogous to an Optical fiber for guiding light, and Photodetector are made on a Silicon substrate. Due to CMOS scaling to 5-10nm, several operational problems and heating issues have arisen, mainly due to copper interconnects between different CMOS components. In Si Photonics, Optical waveguides are replaced with the conventional copper interconnects. This method of data transmission greatly reduced the heat dissipation and improved the performance and bandwidth. The data transmission through Optical waveguides needed all the Photonic components to be integrated on a single chip, which is called the Si Photonics technology.

Theory

In this project, a standard Optical modulator such as Mach-Zehnder Interferometer is implemented on a Si chip. Experimental data is compared to the simulation results and basic principles of the modulator are understood. The circuit consists of Fiber gratings connected to a Mach-Zehnder Interferometer on either side. Fiber gratings are used to couple light into and from the CMOS Optical waveguide to an Optical fiber. A Mach-Zehnder Interferometer has a Y splitter that splits incoming light into two channels and a coupler at the other end that combines the two light signals. The path length or phase shift of the light passing through the channels is varied. If the path length or phase shift in both channels is the same, light undergoes constructive interference, equivalent to a high Voltage and a digital output of 1. If the path length or phase shift between the channels is different, destructive interference occurs, equivalent to a low Voltage and a digital output of 0. The modulation of phase or path length in active Interferometer is performed by varying the current or temperature across the semiconductor.

In the current project, a passive Interferometer is designed. Light from an external laser source with center wavelength at 1.55um, and transmission spectrum from the Interferometer is measured by scanning the wavelength of the laser source. The Interferometer consists of one input port, 2 output ports. The input port consist of fiber grating coupler, joined with a y-splitter. The waveguides, labelled Waveguide 1,2 stemming from the y-splitter have different lengths needed to create the desired phase shift. Then the light passes through a bi-directional coupler which combines the signals and routes them to the 2 different output ports. The waveguides joining the coupler and fiber gratings also have different lengths. Fig.1 shows the schematic of the Interferometer made using K-layout with preexisting SiEPIC libraries.

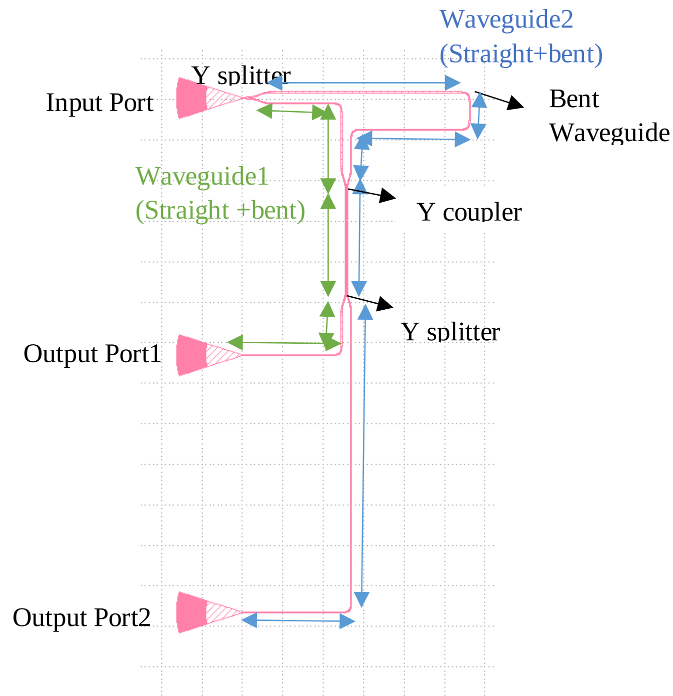

Fig.1: Schematic of an Interferometer showing Fiber Bragg Gratings which have an Input port, 2 Output ports, Y splitter, Broad band directional coupler consisting of Y splitter and combiner, Waveguide 1= 65.028um, Waveguide 2=150um

The Waveguide 2 length is set to 150um for the main design and varied to 200um, 250um, 300um, 350um for the other designs. The difference in lengths of the waveguides lead to different path lengths, and thereby different free spectral range. The main design with Waveguide2 length of 150um is included five times to study the fabrication variations. A layout of the designs is shown below, in Fig.2, 3, 4.

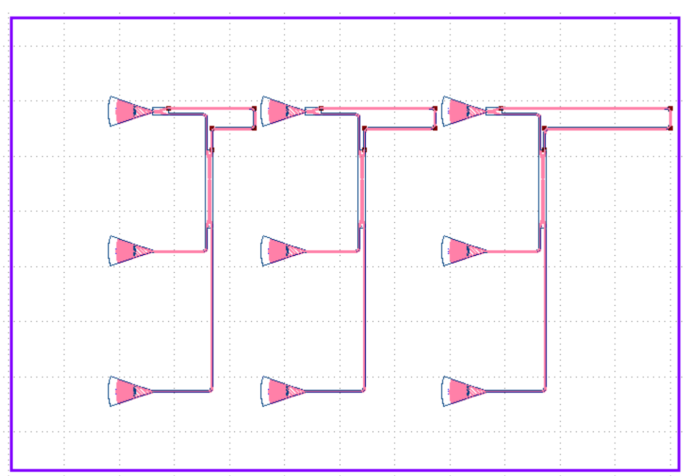

Fig.2: Schematic of Interferometers with Waveguide1 Lengths 150um, 200um, 300um

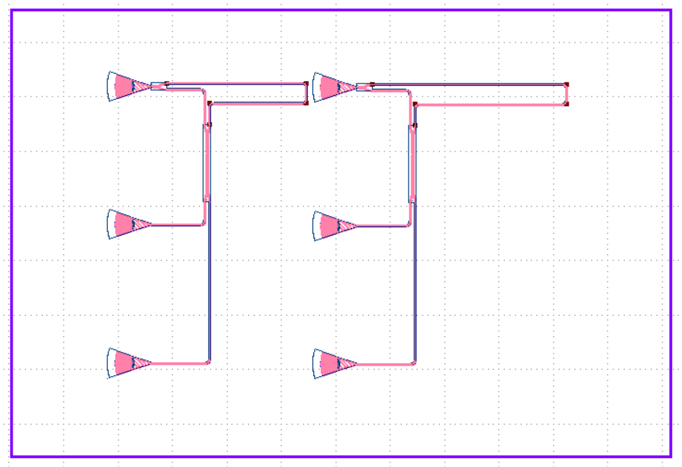

Fig.3: Schematic of Interferometers with Waveguide Lengths 250um, 350um

Cell name	Design Name	L1(um)	L2(um)	deltaL(um)	FSR(nm)
MZI1	opt_in_TE_1550_device_MZI1	65.028	150	84.972	6.73
MZI2	opt_in_TE_1550_device_MZI2	65.028	200	134.972	4.24
MZI3	opt_in_TE_1550_device_MZI3	65.028	250	184.972	3.09
MZI4	opt_in_TE_1550_device_MZI4	65.028	300	234.972	2.43
MZI5	opt_in_TE_1550_device_MZI5	65.028	350	284.972	2.01

Table1: Summary of different designs with path lengths, group index, free spectral range

The die size is 605um x 410um as indicated by the blue rectangle in the schematics. The fiber gratings are facing right and are spaced 127um apart to comply with fiber array spacing and testing convenience.

Modelling and simulation

The compact model of the waveguides included in the mask design will be calculated by Finite element modeling. The compact model consists of effective index, group index and higher order dispersion terms. Matlab and Python will be used to perform the simulations.

Compact equation for the waveguide: TBD

Transfer function of the device: TBD

Effective index vs Lambda: TBD

Group index vs Lambda: TBD

Variation in Length: The lengths of waveguides used in the Interferometers with corresponding path length difference is listed in Table1.

Free spectral range vs Length: The free spectral range vs length is calculated in Table1.

Power splitting vs Length: The corresponding output power in the branches in accordance with lengths will be determined.

Fabrication: TBD

Experiment data: TBD

Analysis: TBD

Conclusion: TBD

References