Design of a Fabry-Perot Cavity for High Quality Factor

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***Abstract*— In this report, the design and testing of a Fabry Perot Cavity is outlined. Bragg gratings and Fabry Perot cavities were studied and simulated using the Transfer Matrix Method in MATLAB and models in Lumerical.**

***Keywords—component, formatting, style, styling, insert* (*key words*)**

I. Introduction

The goal of this project is to design a resonator with the highest quality factor (Q-Factor). The design, simulation, fabrication and testing of the resonator will be presented in this paper. The resonator, consisting of two Bragg gratings and a central waveguide, is designed to operate at a central wavelength of 1310nm.

II. Device Design and Parameters

A. Device Overview

The device consists of three grating couplers on the left where light will be injected into the Bragg grating cavity and exit for experimental data points. The main focus is the resonator, which is a waveguide cavity sandwiched by two Bragg gratings.

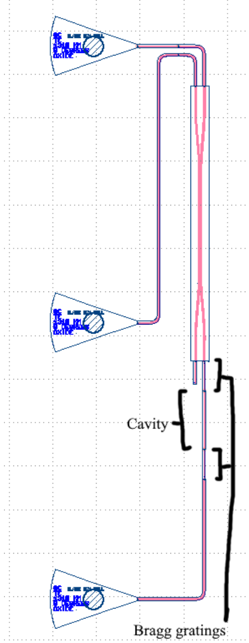

Figure 1. Example design of a resonator

B. Lumerical Mode FDE

The resonator is to be operated at a Bragg wavelength of 1310nm. Using Lumerical Mode FDE, a waveguide is modeled and solved using an eigensolver.

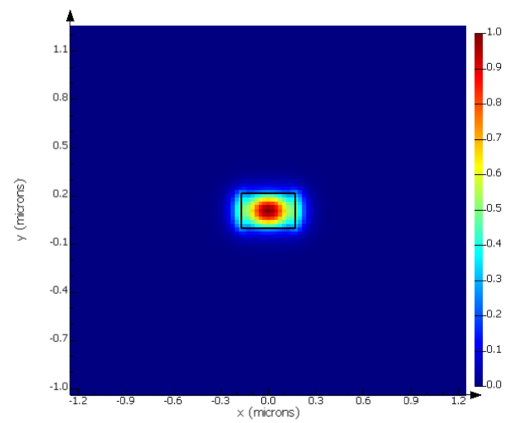

Figure 1. TE mode of a waveguide with width of 335nm and height of 220nm

A frequency sweep is ran using the first TE mode to find the effective index and group index for wavelength = 1310nm.

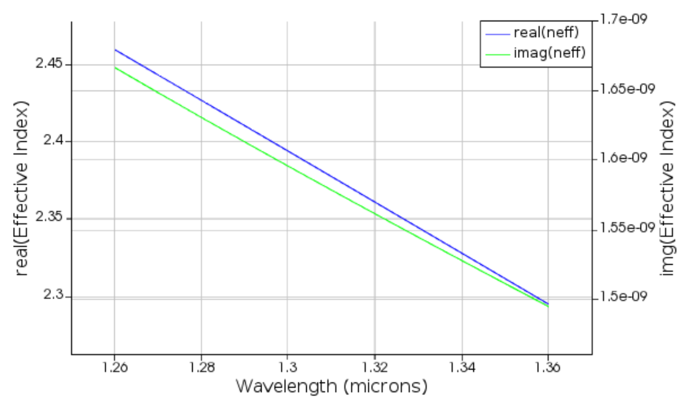

Figure 2. Frequency sweep for the effective index of a waveguide with width of 335nm and height of 220nm

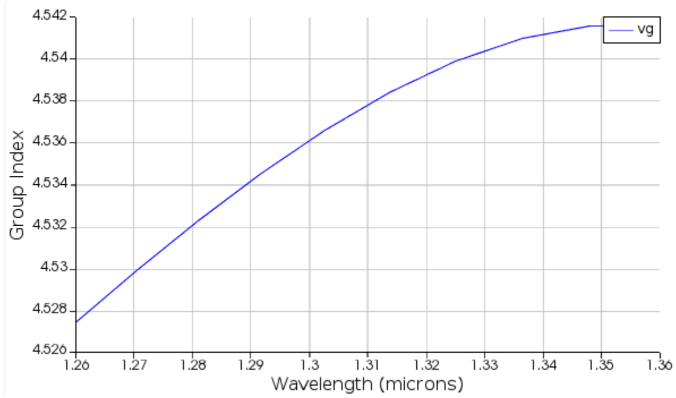

Figure 3. Frequency sweep for the group index of a waveguide with width of 335nm and height of 220nm

The compact waveguide model coefficients were also obtained and the waveguide can be modeled using the following equation:

$$n_{eff}(\lambda) = n_1 + n_2(\lambda - \lambda_o) + n_3(\lambda - \lambda_o)$$

where $n_1 = 1.978$, $n_2 = -1.676$, $n_3 = -0.05766$, $\lambda_o = 1310$nm. Using the following equation, we can find the desired Bragg grating period.

$$\Lambda = \frac{\lambda_b}{2n_{eff}}$$

Where Λ is the Bragg grating period, λ_b is the Bragg wavelength and n_{eff} is the effective index of the wave guide. Using the values found from Lumerical Mode, the Bragg grating period is found to be 280nm. A Bragg grating unit cell is then simulated in Lumiercal using the following parameters and the coupling coefficient, bandwidth and Bragg wavelength are found.

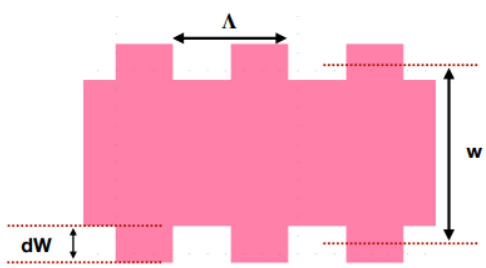

Figure 4. Bragg grating cavity with labelled parameters of grating period, waveguide width and corrugation width [2]

TABLE 1. Unit Cell Parameters

Bragg grating period (Λ)	280nm
Group index	4.538
Waveguide width (w)	335nm
Corrugation width (dW)	50nm

TABLE 2. Obtained Parameters

Coupling Coefficient	144557
Bandwidth	17.4nm
Central Wavelength	1310nm

C. *MATLAB Transfer Matrix Method*

MATLAB can be used to model a Bragg grating cavity using the Transfer Method Matrix (TMM). The propagation matrix of the waveguide cavity is defined as

$$T_{hw} = \begin{bmatrix} e^{j\beta L} & 0 \\ 0 & e^{-j\beta L} \end{bmatrix}$$

The matrix for change in two indices, n1 and n2, through a boundary, also know as the index step matrix is defined as

$$T_{is12} = \begin{bmatrix} \frac{1}{t} & \frac{r}{t} \\ \frac{r}{t} & \frac{1}{t} \end{bmatrix} = \begin{bmatrix} \frac{n_1 + n_2}{2\sqrt{n_1 n_2}} & \frac{n_1 - n_2}{2\sqrt{n_1 n_2}} \\ \frac{n_1 - n_2}{2\sqrt{n_1 n_2}} & \frac{n_1 + n_2}{2\sqrt{n_1 n_2}} \end{bmatrix}$$

A single period of a Bragg grating can then be defined as

$$T_p = T_{hw1} T_{is12} T_{hw2} T_{is21}$$

And for a Bragg grating cavity with N periods can then be defined as

$$T_{total} = Tp^N = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix}$$

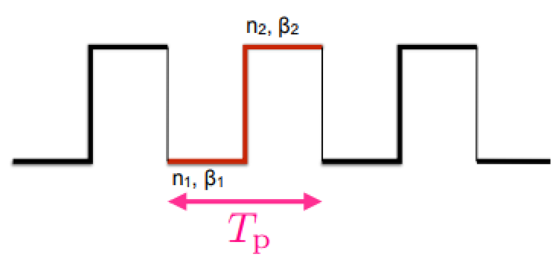

Figure 5. Parameters for a single period of a Bragg grating [2]

The two Bragg gratings can be presented by T_P^N while the cavity can be represented as $T_c = T_{is1c} T_{hwc} T_{isc1}$. The whole device can then be represented as

$$T_{FP} = T_p^N T_C T_p^N$$

And the corresponding transmission and reflection matrices are

$$T = (\frac{1}{T_{11}})^2, \qquad R = (\frac{T_{21}}{T_{11}})^2$$

Which can be plotted out on MATLAB.

D. Lumerical Interconnect

The resonator can be modeled in Lumerical INTERCONNECT and the responses can then be viewed for gain. Each component has parameters that can be inserted

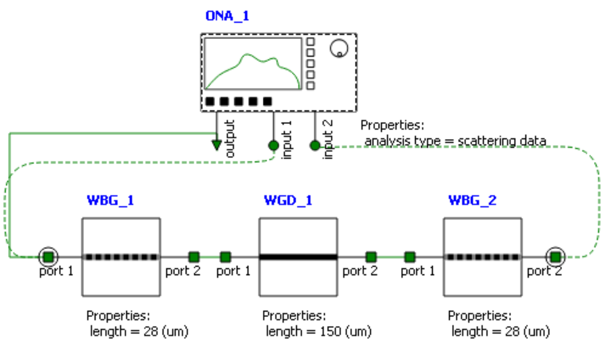

Figure 6. Example circuit of a resonator in Lumerical INTERCONNECT

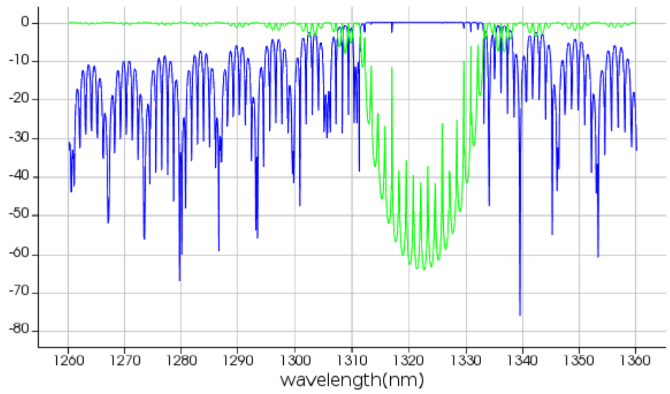

Figure 7. Transmission and Reflection responsse of the circuit in Figure 6

D. KLayout

The designs are drawn in Klayout to be manufactured. The technology used is the SiEPIC-EBeam-PDK to draw the components.

The waveguides used in the design are of width 335nm and a height of 220nm. The corrugation width used is 50nm. In the first 4 designs the cavity length is varied between 50-200um, in designs 5-9 the number of grating periods are varied from 50-200.

Design No.	Cavity Length (um)	# of Grating Periods
1	200	100
2	150	100
3	100	100
4	50	100
5	100	50
6	100	80
7	100	120
8	100	150
9	100	200

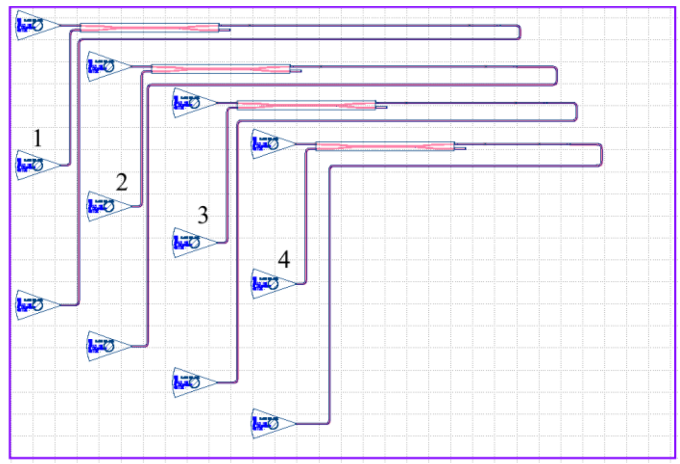

Figure 6. KLayout design for varying cavity lengths

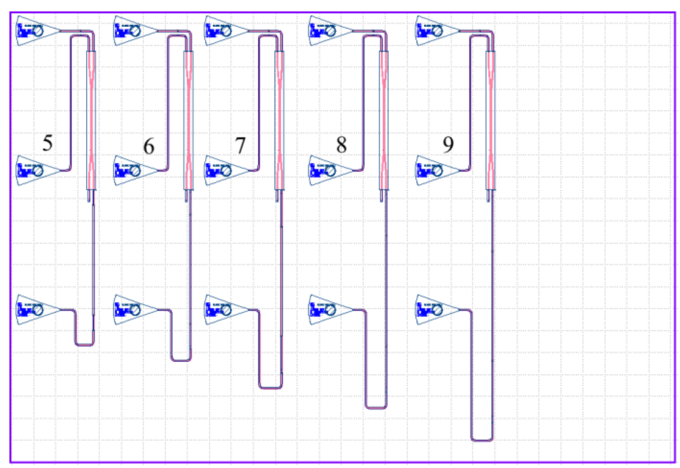

Figure 7. KLayout Design for varying number of grating periods

REFERENCES

[1] Chrostowski, Lukas, and Michael Hochberg. "4." Silicon Photonics Design: From Devices to Systems, Cambridge University Press, Cambridge, 2016.

[2] Chrostowski, Lukas, *Bragg Reflectors, VCSELs, Transfer Matrix Method, Waveguide Bragg Gratings, Bragg cavity design*[PowerPoint Presentation]. University of British Columbia, Vancouver, BC, Canada