ELEC413 Project 1 Report

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1 Introduction

The goal of this project was to create a Fabry-Perot cavity with Bragg grating and optimize its parameters for a high Q-factor. The investigated parameters were Bragg grating period, number of periods in each grating, and grating corrugation width. The cavity was simulated numerically in Python, Lumerical MODE and Lumerical INTERCONNECT.

2 Modelling and Simulation

2.1 Lumerical MODE Waveguide Simulation

A silicon waveguide in SiO2 cladding was simulated in Lumerical MODE with the following parameters:

Thickness: 220nm

Width: 350nm.

The results of the simulation returned the effective index (n_eff), group index (n_g), and other parameters such as loss and dispersion.

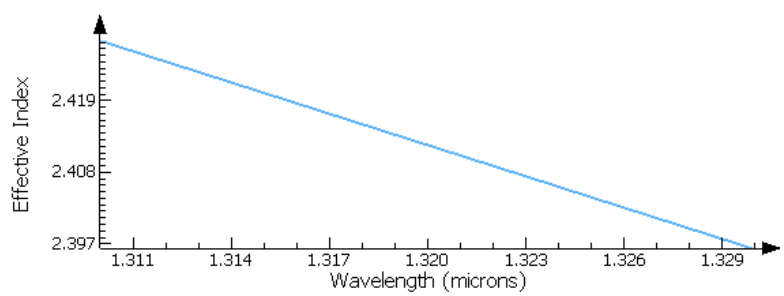

Figure 1 Effective index of the 350nm wide waveguide.

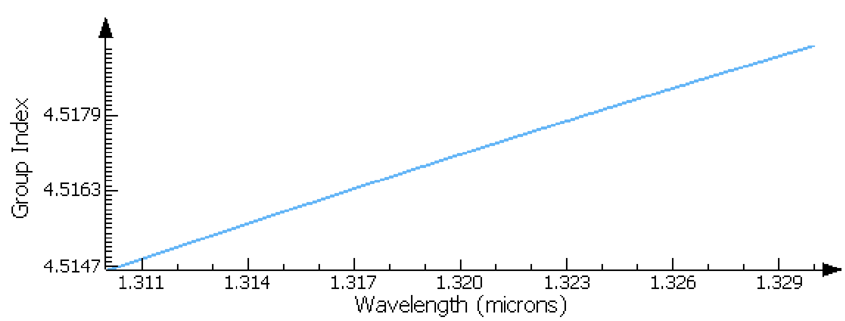

Figure 2 Group index of the 350nm wide waveguide.

The effective and group indices were curve-fitted in Python and the resulting curves are:

$$n_{eff} = 4.51183683 - 1.59057228 \cdot 10^6 \lambda + 1.0\lambda^2$$

$$n_g = 4.17164362 + 2.61689952 \cdot 10^5 \lambda + 1.0\lambda^2$$

2.2 Unit Cell Lumerical FTDT Simulation

A single unit cell of the Bragg grated was simulated in Lumerical FTDT. A parameter sweep was then performed for coupling coefficient (kappa) vs the corrugation width of the grating.

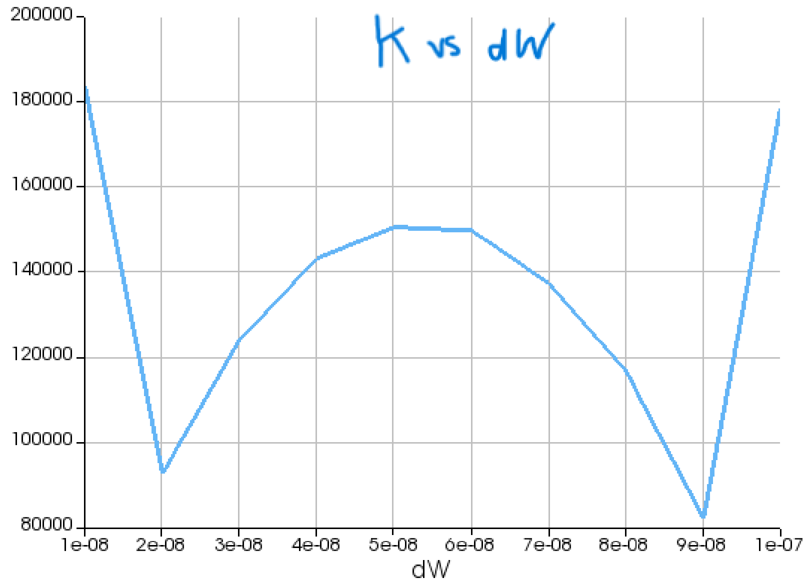

Figure 3 Kappa vs corrugation width.

The data for kappa was curve fitted and the resulting equation is:

$$\kappa = -5.22756429 \cdot 10^{19}\kappa^2 + 5.59749405 \cdot 10^{12}\kappa + 2.32955944 \cdot 10^3$$

Maximum kappa occurs at 54nm corrugation width.

2.3 Python TMM Simulation

The Fabry-Perot cavity was simulated numerically in Python using the Transfer Matrix Method (TMM). The wavelength-dependent n_eff was defined using the equation in 2.1 and kappa was defined using equation in 2.3. Bragg grating period, number of gratings and corrugation width were varied to achieve the Bragg wavelength of approximately 1310nm and have several transmission peaks of at least -10dB while maximizing reflection.

The final parameters are listed below. Figure 4 shows the resulting transmission and reflection plot.

Bragg period: 270nm

Number of periods: 35

Corrugation width: 22nm

Cavity length: 100um

Actual Bragg wavelength: 1311.352nm

Loss: 7dB/cm

Kappa at Bragg wavelength: 100173.01 m^-1

N_eff at Bragg wavelength: 2.42

N_g at Bragg wavelength: 4.51

Maximum reflection: 90.65%

Minimum Transmission: -10.60dB

Bandwidth: ~20nm

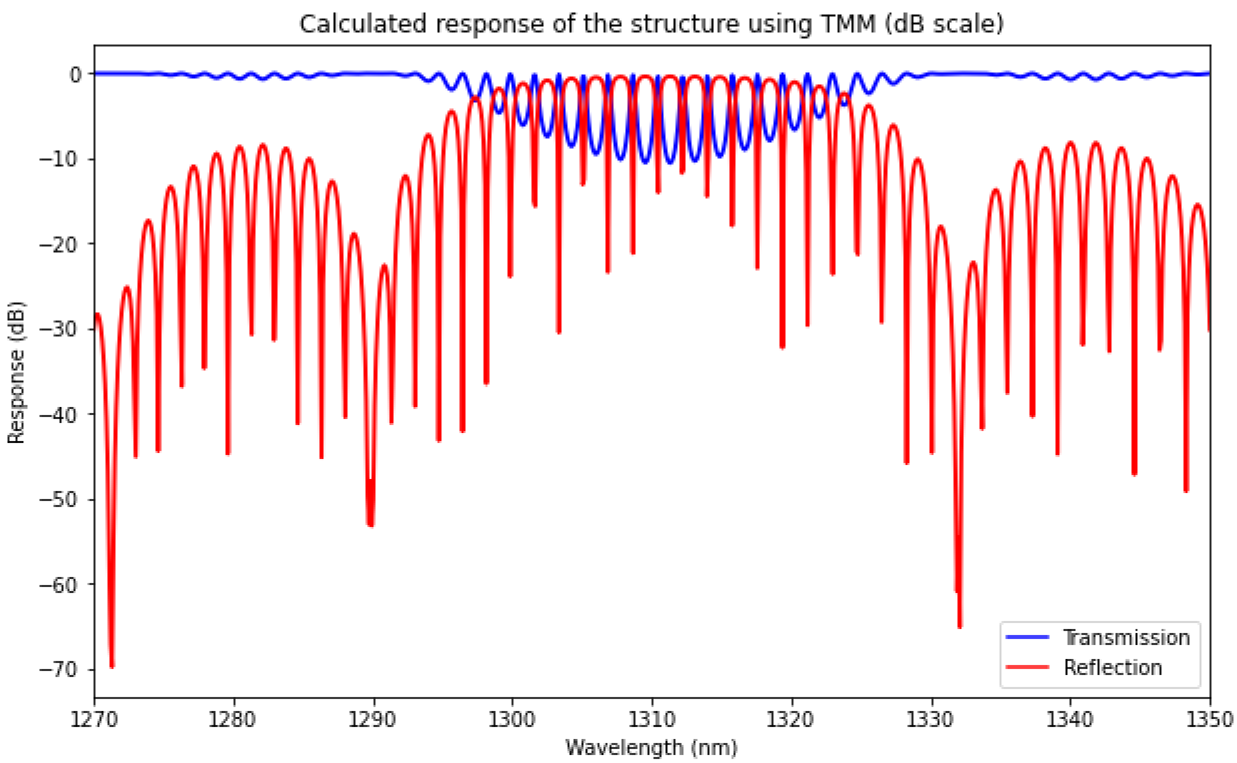

Figure 4 Python TMM transmission and reflection plot.

As one can see, the transmission peaks are approximately at -10dB and the reflection is still quite high at 90.65%. To achieve this, kappa had to be lowered by decreasing the corrugation width and fewer grating periods were used.

Lumerical INTERCONNECT Circuit Simulation

Finally, the Fabry-Perot cavity circuit was simulated in Lumerical INTERCONNECT.

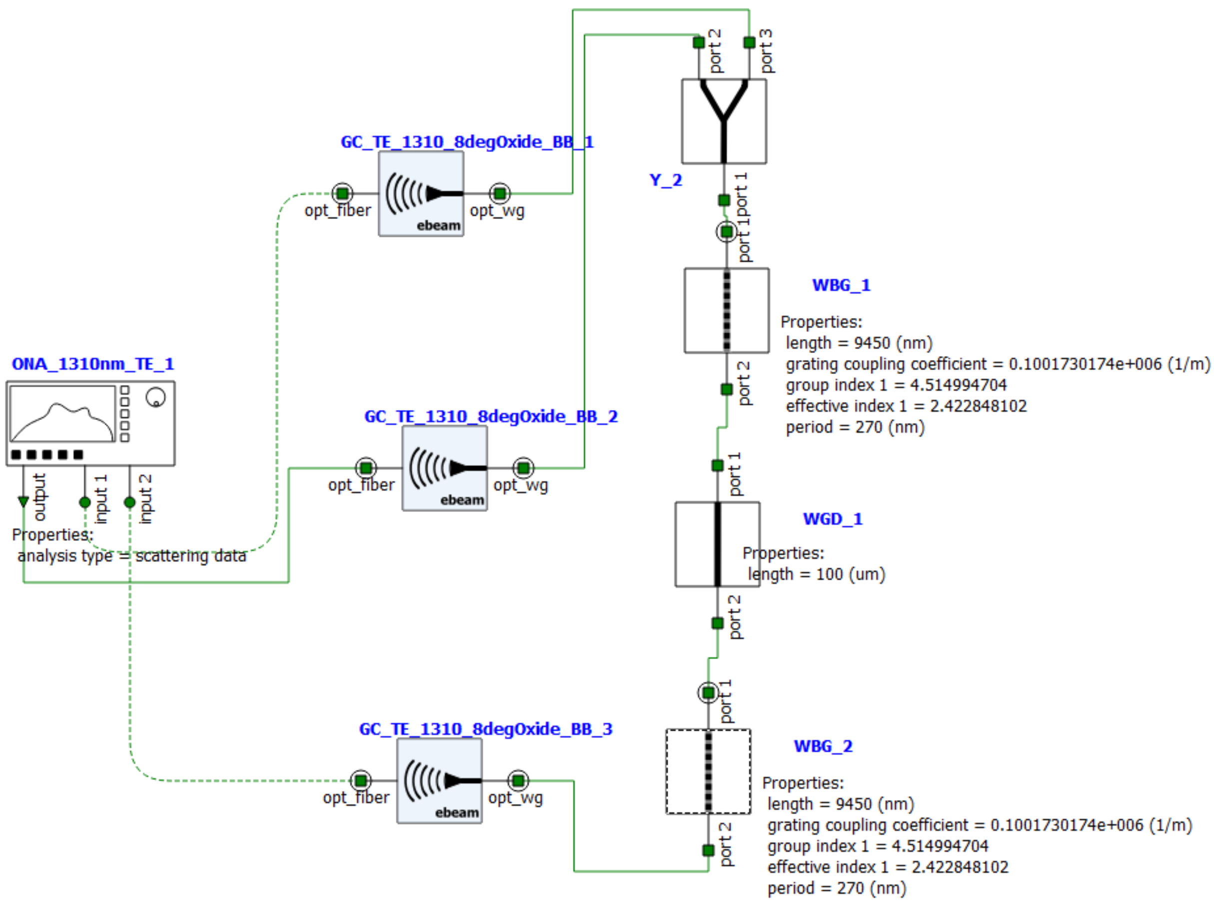

Figure 5 INTERCONNECT circuit.

The INTERCONNECT simulation results were quite different from the Python TMM results. Both the transmission and reflection were much lower than predicted by the TMM script.

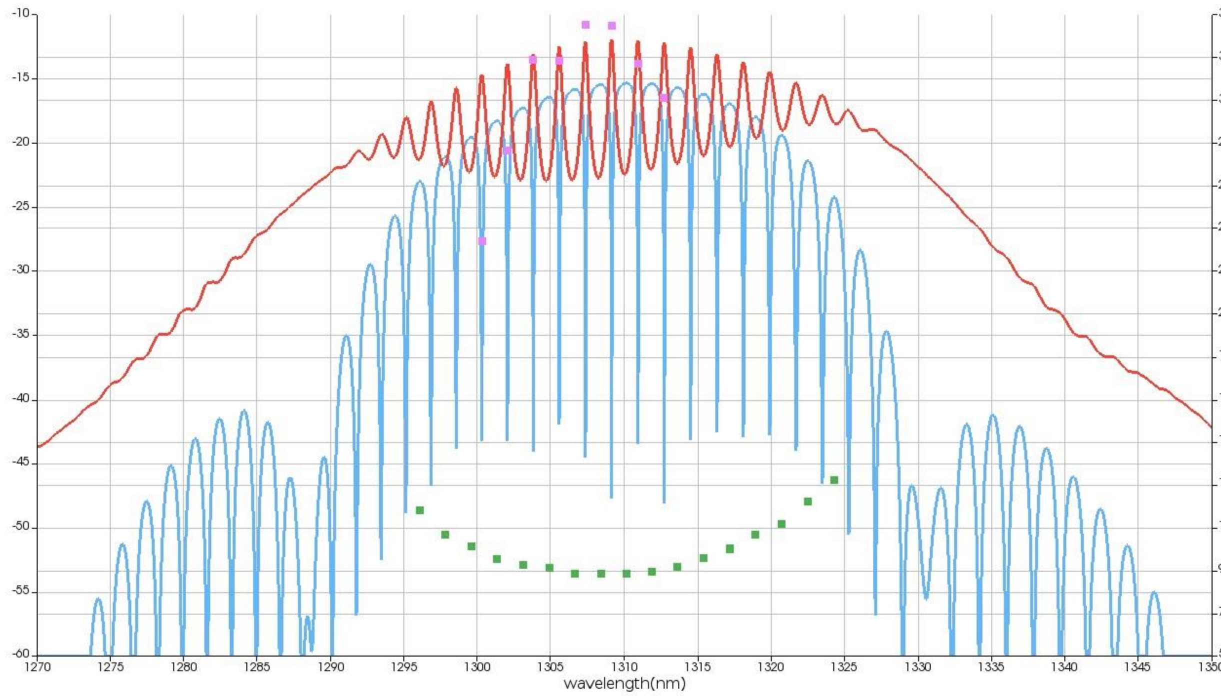

Figure 6 Transmission, Reflection and Q-factor plot from INTERCONNECT simulation.

Both the reflection and transmission were much lower in INTERCONNECT as compared to the TMM script. This is likely because losses were simulated more accurately in INTERCONNECT. The Q-factor for reflection is approximately 885nm at the Bragg wavelength, and 3500 for transmission.

Layout

The layout was created in KLayout using the SiEPIC compact model library components.

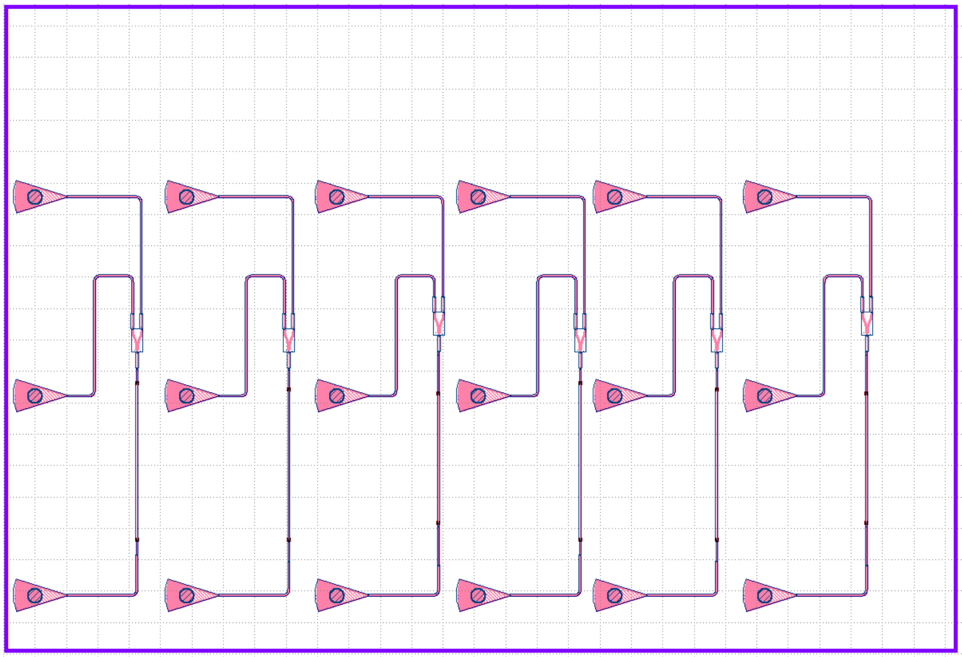

Figure 7 KLayout layout.

There are six variations where the corrugation width and number of grating periods were varied. From left to right, the variations are:

1. Corrugation width = 22nm, Number of gratings = 35
2. Corrugation width = 22nm, Number of gratings = 50
3. Corrugation width = 22nm, Number of gratings = 100
4. Corrugation width = 54nm, Number of gratings = 35
5. Corrugation width = 54nm, Number of gratings = 50
6. Corrugation width = 54nm, Number of gratings = 100

The reason higher corrugation width and number of grating periods were chosen for some variations, is to maximize reflection in those variations.