ELEC413 Project 2 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.

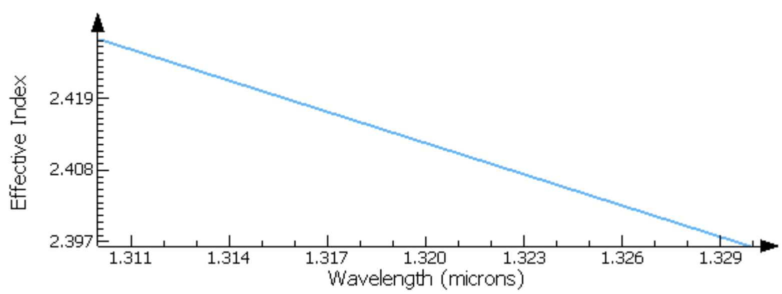


Figure 1 Effective index of the 350nm wide waveguide.

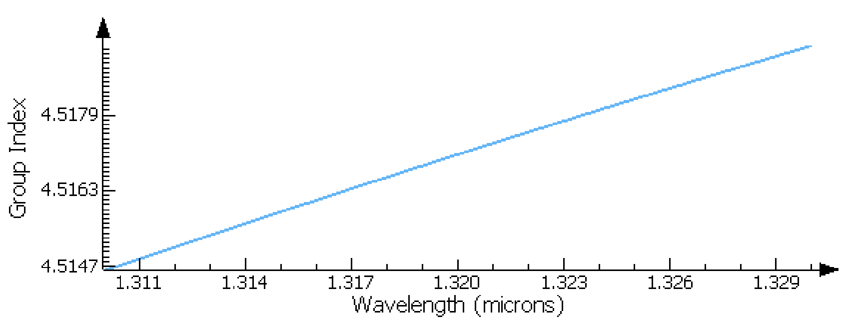


Figure 2 Group index of the 350nm wide waveguide.

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.

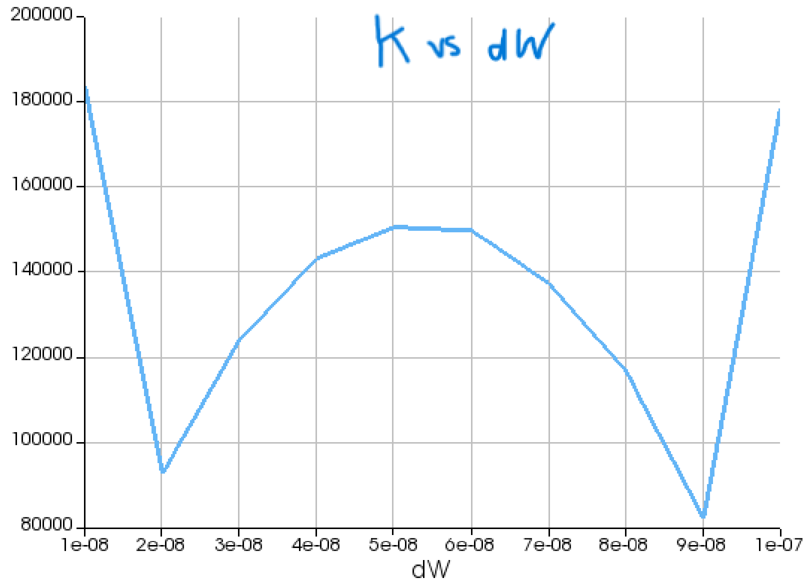


Figure 3 Kappa vs corrugation width.

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. To achieve an FSR of <0.2nm, the length of the cavity must be at least 1500nm.

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: 1500um

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: 84.99%

Minimum Transmission: -10.97dB

Bandwidth: ~20nm

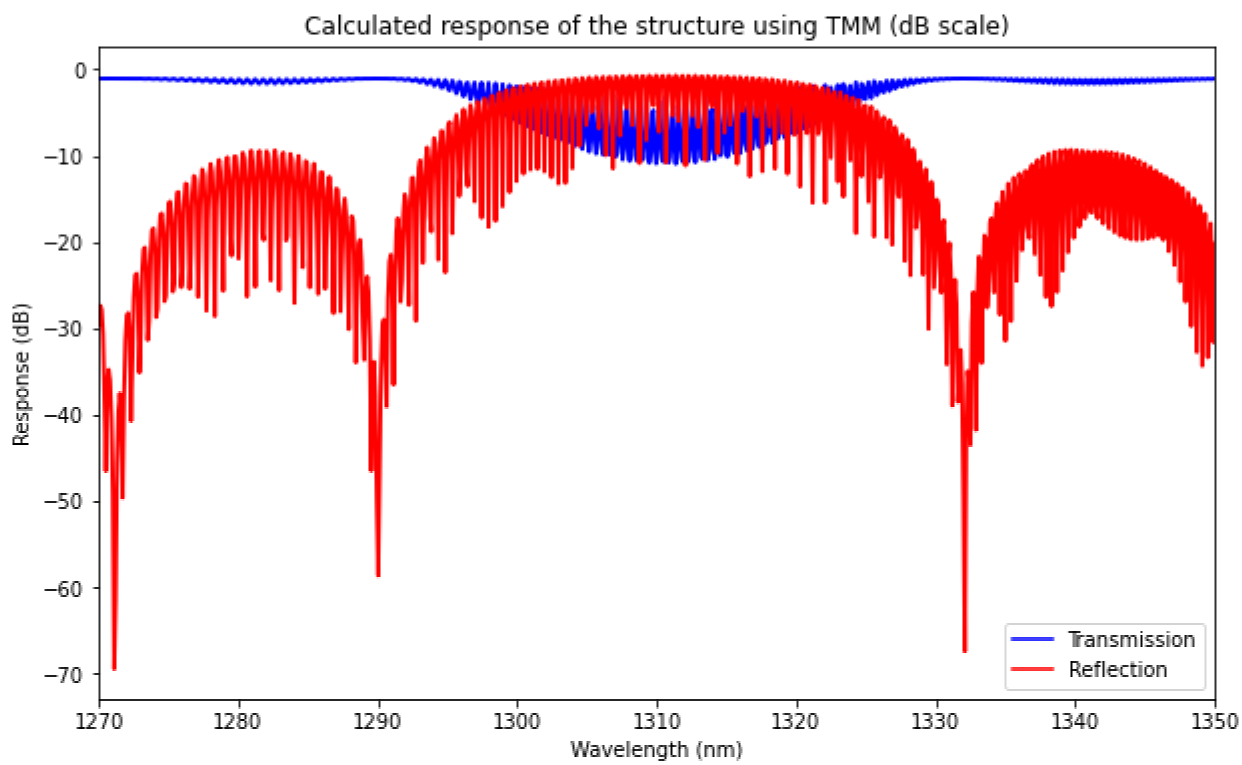


Figure 4 Python TMM transmission and reflection plot.

Lumerical INTERCONNECT Circuit Simulation

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

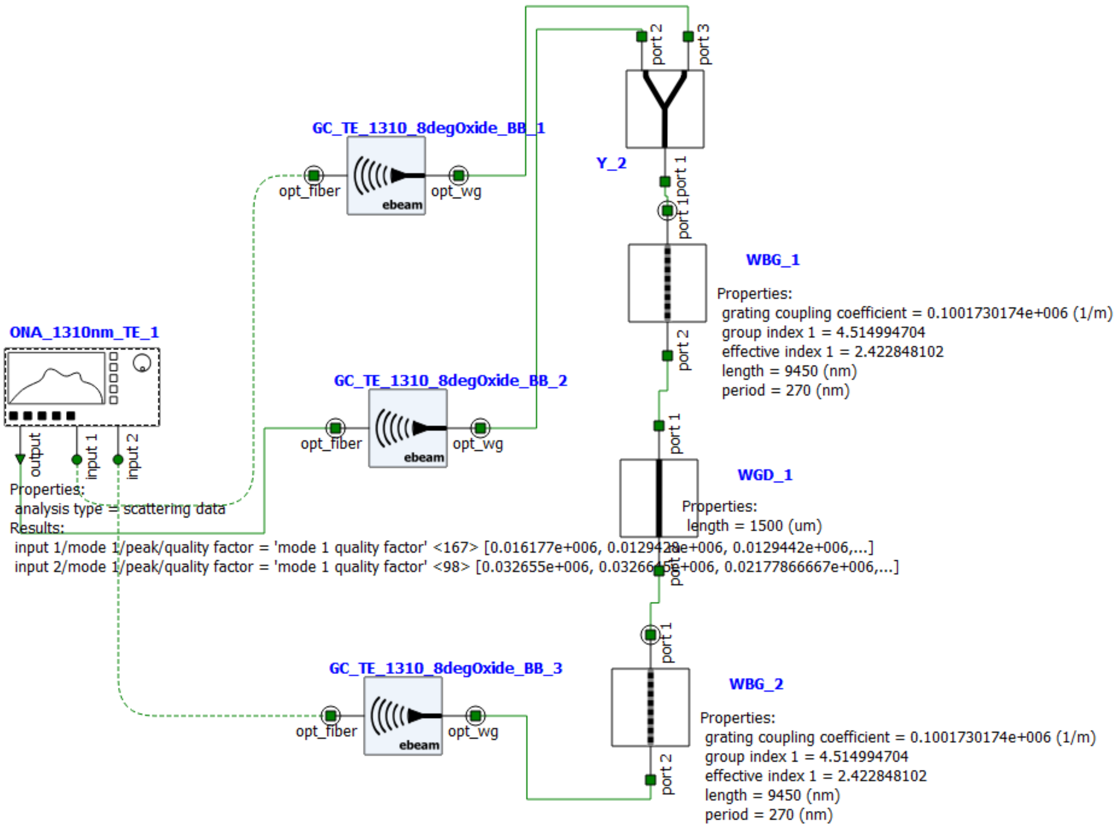


Figure 5 INTERCONNECT circuit.

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.

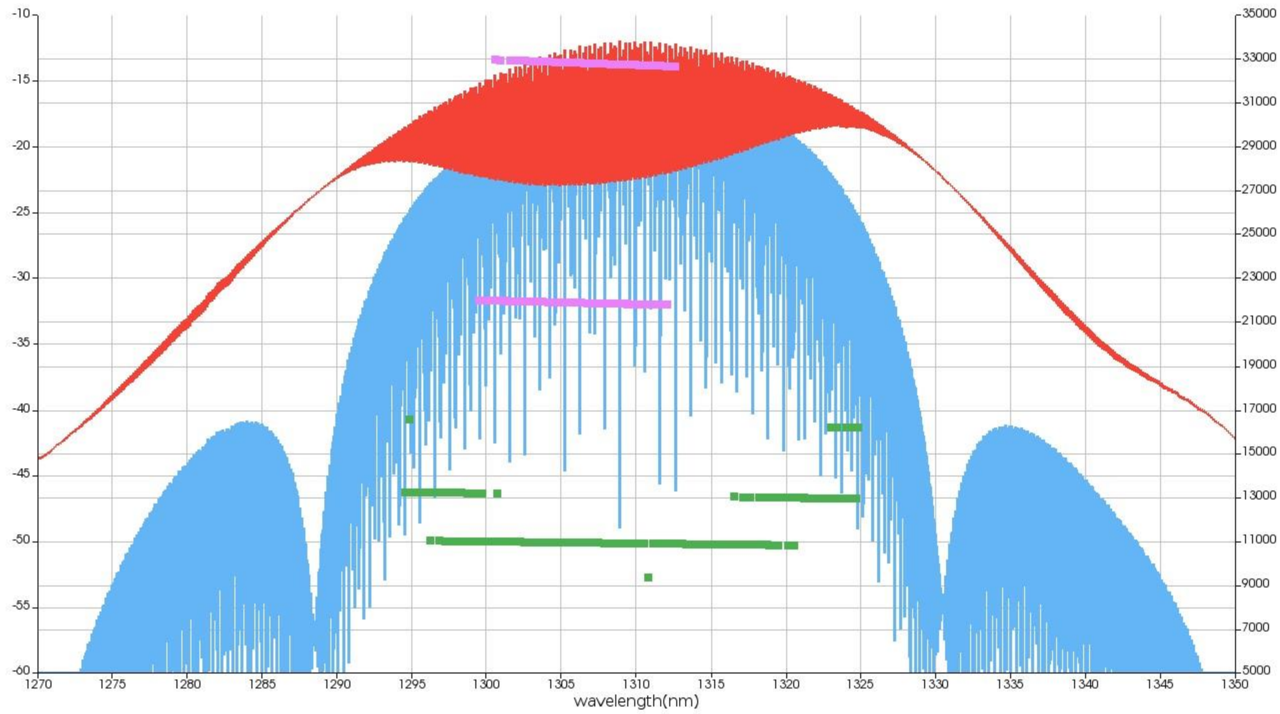
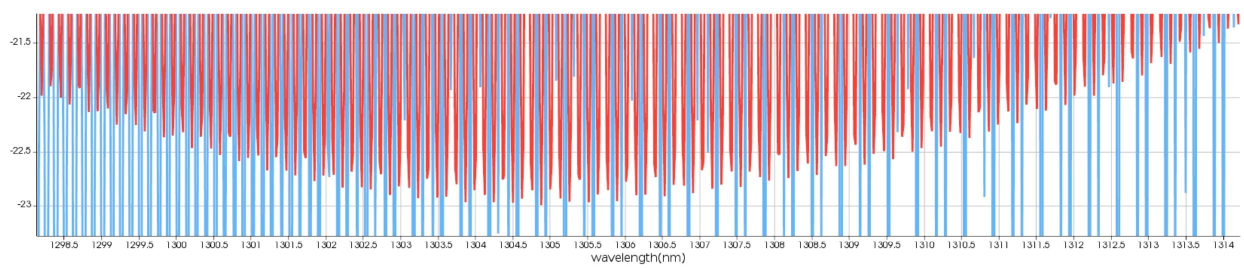


Figure 6 Transmission, Reflection and Q-factor plot from INTERCONNECT simulation.

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 11000 at the Bragg wavelength, and 33000 for transmission.

A closer view of the transmission peaks shows that FSR is indeed <0.2nm.



Layout

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

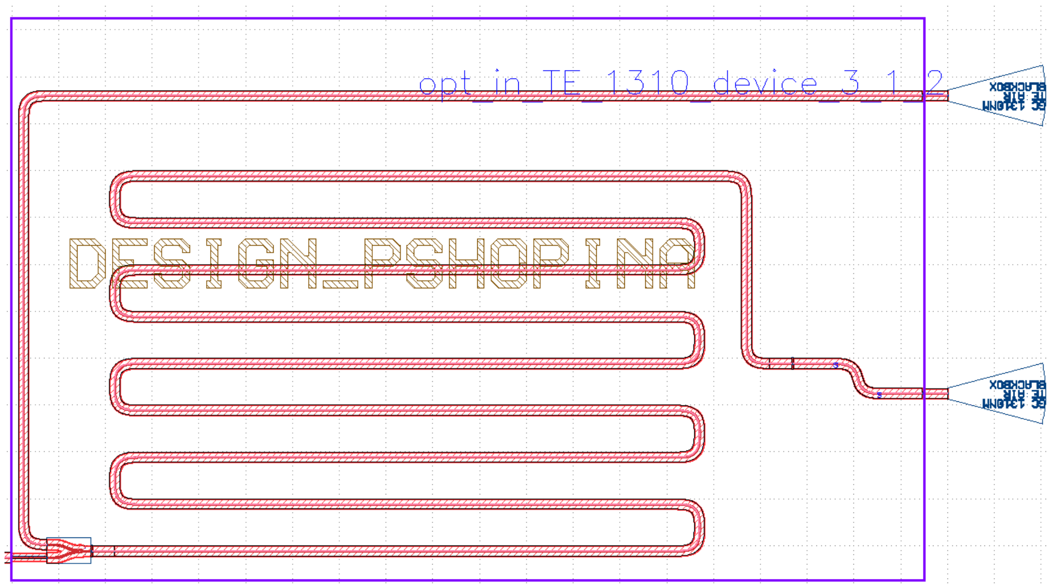


Figure 7 KLayout layout.

The overall length of the waveguide is:

250+20+250+20+250+20+250+20+250+20+250+20+250+20+250+20+270 = 2,430

This is much longer than required, which guarantees an FSR <0.2nm.