Elec 413 Project 1

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1 Introduction:

For this project, we aim to design a functional laser devices using Bragg grating. The Bragg grating contains freedom in a few parameters, namely the waveguide width (W), corrugation width (Δw), the grating period, the number of grating, and last the cavity length, if any.We aim to create transmission peak at the designed wavelength (1310nm), while obtaining the highest quality factor for the model.

3 Theory:

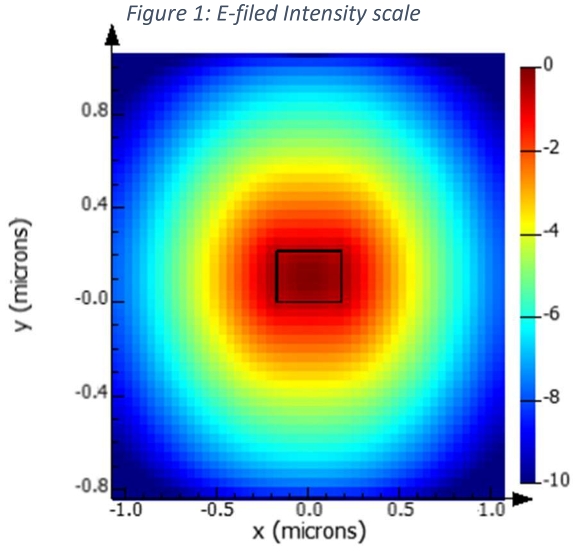
4 Modelling and Simulation:

To begin with, we would need to simulate the waveguide of the system, which would be done in Lumerical mode. For this component we first assume the waveguide width as 350nm, which is the default setting for the Bragg structure with wavelength 1310nm.

We could simulate such structure, of silicon waveguide with 220nm thickness and 350nm width in Lumerical mode in order to acquire the information about the effective and group index of the Bragg structure.

In order to acquire an accurate effective index, we need to arrange the Eigenmode solver in the way that at the edge of the solver, the E-field intensity has sufficiently decayed. Which should look like the figure 1 below.

Figure 1: E-filed Intensity scale



Hence we could acquire the plot for effective index and group index by varying wavelength it in Lumerical mode. Which I design it range from 1290 to 1330 nm, which is the range of our design.

From which we could acquire a plot as shown in figure 2. By which if we analyze the plot, we could find out the effective index and wavelength characteristic to find out the effective index for the 1310nm wavelength that we desire. Which the effective index that we found out is around 2.43, which for the TE polarized wave length at that point the group index is around 4.432.

In order to find out the polynomial expression of the designed waveguide, we use the mode script provided to modulate the expression such that the expression (green line), modulate the neff data (blue line). Which would have result as in figure 3. Which the polynomial expression for the neff:

$$\text{neff} = 2.05123 - 1.62894(\lambda - \lambda_o) - 0.2104(\lambda - \lambda_o)^2$$

Figure 2: neff vs wavelength

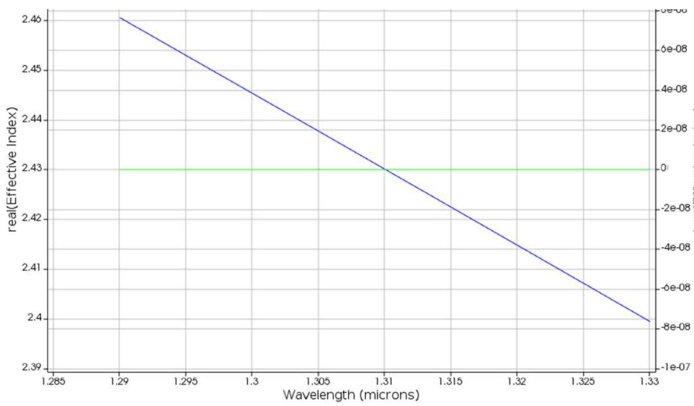
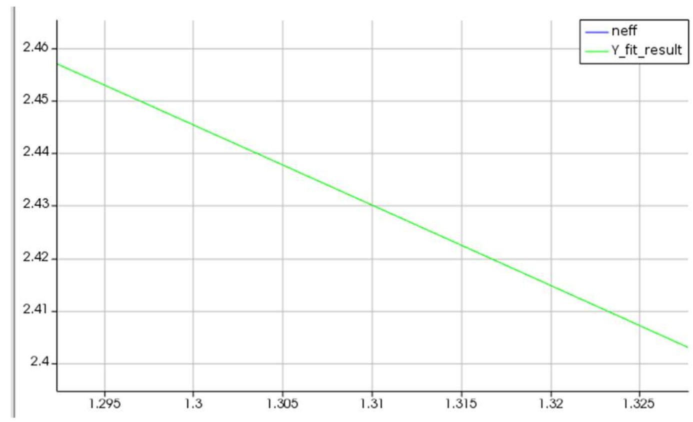


Figure 3:polynomial plot



And the figure 4 below shows the group index (ng) vs wavelength, which gives us the group index at around 4.432.

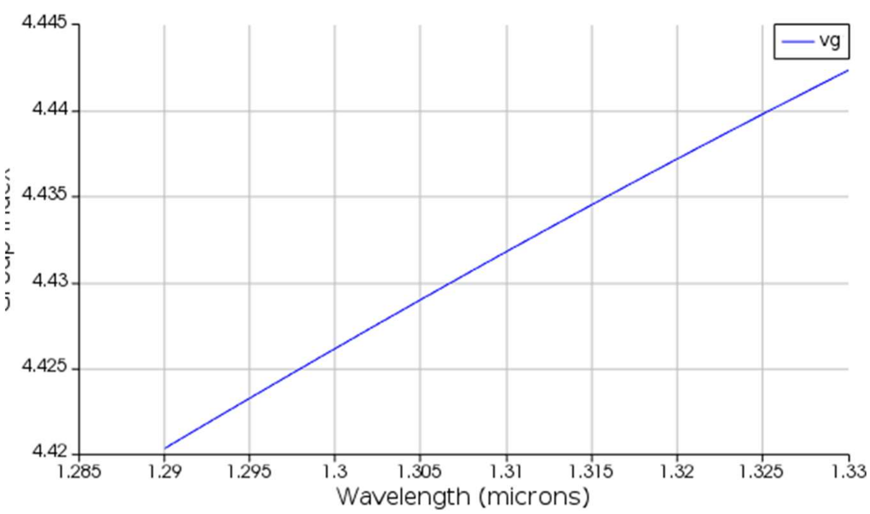


Figure 4: Group index vs wavelength

TMM:

In order to simulate the transmission and the reflective spectrum, we use the Transfer Matrix Method (TMM), to simulate the Bragg grating in Matlab. There are two types of matrix that we would use, the homogeneous matrix and the indexstep matrix.

The homogeneous matrix modulates the silicon wave guide with the same width, which indicates the same neff. Hence we would have two different neff for the homogeneous matrix, n1 and n2 corresponding to $\mathrm{n1} = \mathrm{neff} - \frac{\Delta \mathrm{n}}{2}$ and $\mathrm{n2} = \mathrm{neff} + \frac{\Delta \mathrm{n}}{2}$. The indexstep matrix describe the transformation from one effective index to the other; for example, from n2 to n1 or n1 to n2.

The general TMM setup would contain two unit matrices. One is from n1 to n2 repeating and the other is from n2 to n1 repeating.

```
Tp=T_hw1*T_is12*T_hw2*T_is21;
Tp1=T_hw2*T_is21*T_hw1*T_is12;
```

And then we would attach the two unit matrices together and add a homogeneous cavity in between. Each of the Bragg would then have a power of NG to simulate the number of grating for the Bragg grating. The cavity matrix is simply the homogeneous matrix, with a designed length L. Thus result in the following matrix that simulate a Bragg grating put back to back and have a cavity in between.

```
T=(Tp^NG)*(T_is12*T_hww)*(Tp1^NG);
```

Through numerical calculation the corresponding period for a 1310 nm wavelength with 350nm waveguide width should be around 270nm. Yet when we plot such values, the transmission peak is slightly off the 1310nm according to figure 4, hence we need to adjust until we find a period that have the transmission peak central at 1310nm, which is

269nm and have spectrum as figure 5. In this case specifically I set the cavity length as 0, which means I simply takes two Bragg grating and put them back to back together.

Figure 5: 270nm period

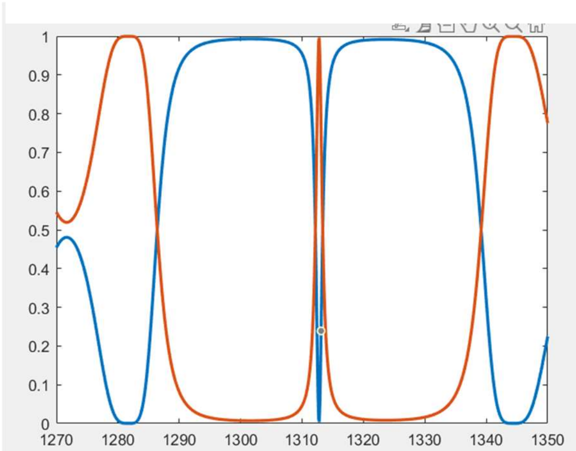
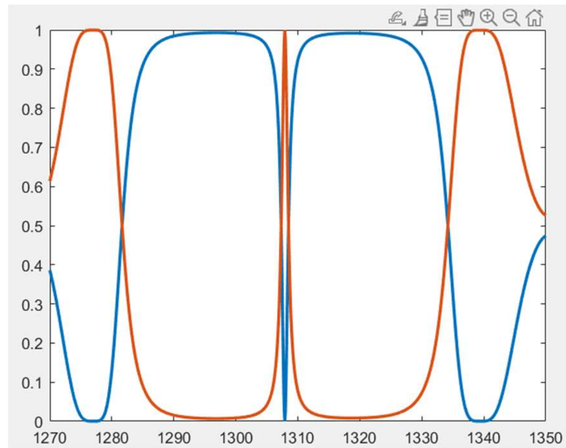


Figure6 :269nm period



FDTD:

Afterward we would need to acquire the Δw parameters as well as the kappa value for the model in FDTD. I input the effective index of 2.43 and group index of 4.432 for the FDTD modeling to find out the central wavelength and the kappa for the corresponding corrugation width. Hence we could get a satisfying result for central wavelength and kappa, which allow us to calculate the Δn that is needed to model this question. And as the result shown in the figure 7, we would take a Δw = 50nm as our corrugation width.

We choose 50nm because as shown in figure 7 and 8 we can see that kappa peaks at around 50nm, and the central wavelength has a bizarre drop when the Δw is lower than 40nm and higher than 55nm.

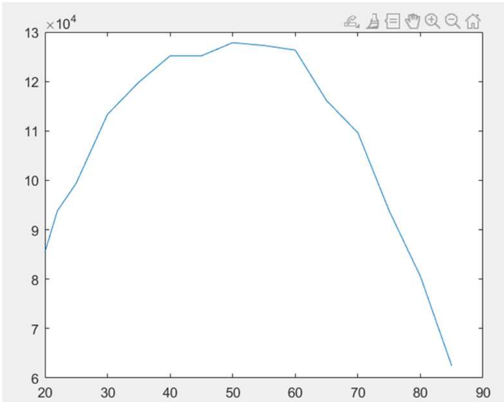


Figure 7: kappa vs deltaw

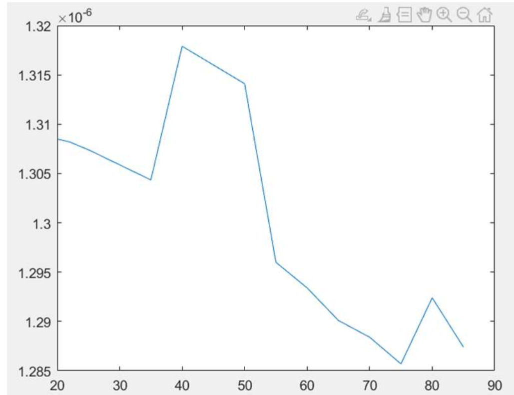


Figure8:central wavelength vs delta w

Simulation:

After we acquire the Δw we then put everything back into matlab and use the collected data and put it in the TMM code used above. If we increase the number of Bragg grating, the quality factor of the structure would increase, yet if we increase the number of Bragg gratings too much, the transmission would be little to detect. And through this modeling we want to number of grating such that the transmission is around 0.01, or -20dB in the dB scale. For this component, we assume the loss for the Bragg grating is 2.4dB and loss for the waveguide itself is around 1.0dB. Which gives us the number of grating as 120 for each of the Bragg grating.

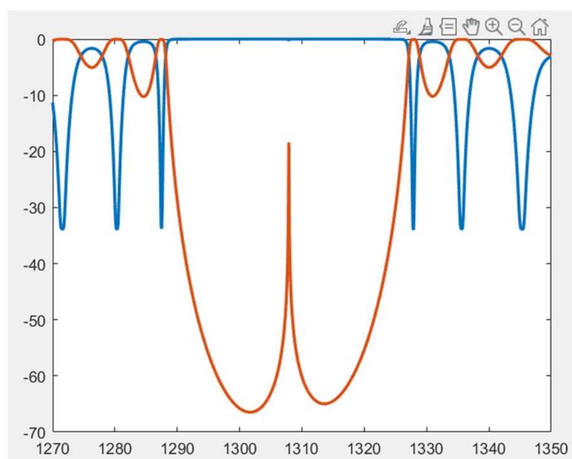


Figure 9:simulation with all parameters

After we acquire the Q factor by modeling the structure in Lumerical interconnect and compare multiple result to aim for the highest Q. I design the circuit in Lumerical interconnect in the way that they there is a straight waveguide that has length of one of the teeth of the Bragg grating (half the period). Which would have the diagram seems like the figure 10 below. From the optical analyzer we would acquire the quality factor Q which for this specific design it is around 7332. And it has the absorption and reflection spectrum as figure 11, which is very similar to the graph produced by the Matlab code.

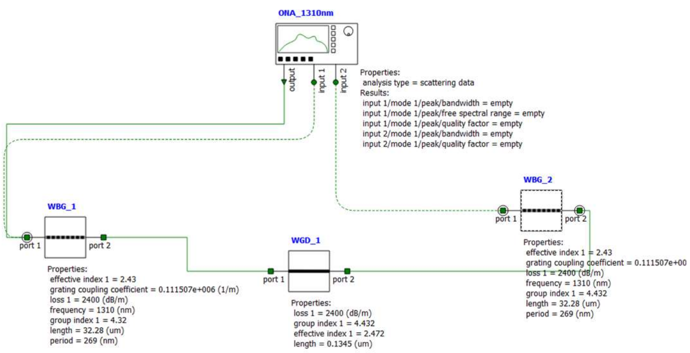


Figure 10: interconnect diagram

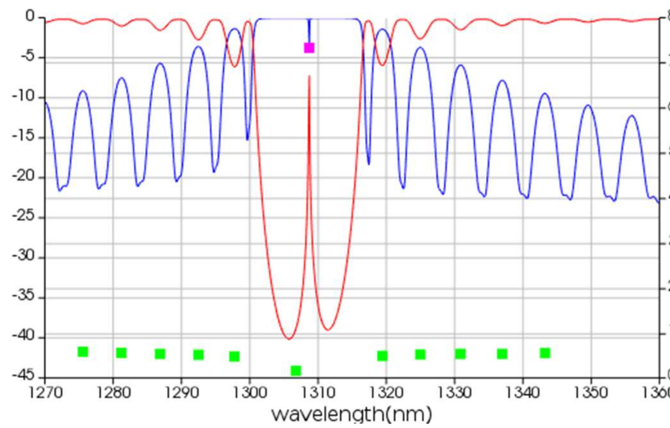


Figure 112: interconnect absorption reflection diagram

K-layout:

Figure 12: k-layout design

The K-layout structure is shown in figure 7. Which we connect the Bragg grating that is designed and attach it to a x branch, which one of the terminal is close. Hence we would have the input signal into the Bragg grating which at the two end of the Bragg grating, it would have transmission and reflection terminals that we could measure the data.

Even though we design for the wave guide width of 350 nm, during the fabrication process, it would be decreased by a 15nm. Therefore, in the k-layout design, the Bragg grating is actually 365nm, so the fabricated result would have 350nm width.

Table of parameters:

Design number	Waveguide width	Period	Δw	Cavity length	Number of grating	Assumed loss	Quality factor
1	350nm	269nm	50nm	0	120	2.4dB	7332.1
2	350nm	269nm	50nm	0	118	3 dB	