ELEC 413 - Bragg Gratings with a Fabry-Perot cavity utilizing sidewall corrugations

Albert Yu

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Introduction

- The objective of this project is to create a Bragg Grating design with a Fabry-Perot cavity built into it, whilst maximizing Q (preferably ¿100k at the very least).
  - Maximizing Q means minimizing loss (lower loss for same reflection coefficient.
  - Will need to consider design choises such as between having strong κ and short grating length versus weak κ and long grating length.
- Additional requirements include:
  - Central wavelength being 1310nm.
  - Thickness fixed at 220nm, with width being close to 350nm.
  - Pushing the FSR down below 0.2nm, with the bandwidth staying between 1270nm-1330nm.
  - Minimum transmission at bandwidth (-20 to -30 dB).
  - Having extensive simulations in Lumerical MODE, Interconnect, and FTDT to show verification of design.
- Push for at least ten different variations of parameters to find optimal result.
- Models will be printed by Applied Nanotools using Electron Beam Lithography techniques, where there is a 15nm bias (350nm will be 335nm). The design will still be fore 350nm.

Specifications

- TE Transmission
- Central Wavelength: 1310nm

- Strip waveguide Width: 350nm
- Thickness: 220nm

Waveguide Simulation

The waveguide simulation was done in Lumerical MODE, and used to find the effective index, n_{eff} and group index, n_g. The parameters listed in the specifications section were used to create the waveguide. The following figures below show the simulations used to obtain n_{eff} and n_g:

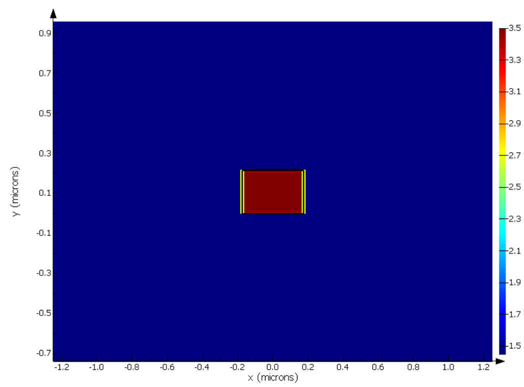

Figure 1: Diagram of Mesh Structure Used in Testing

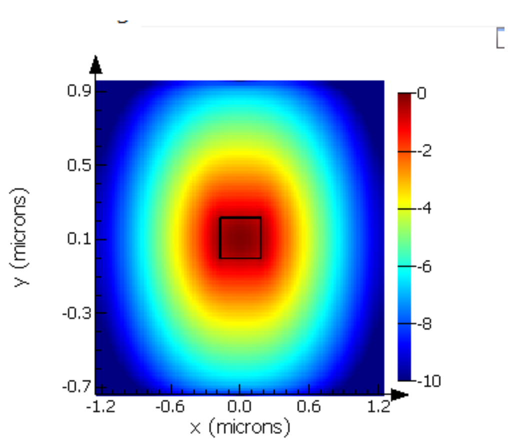

Figure 2: Log Scale of Waveguide Simulation

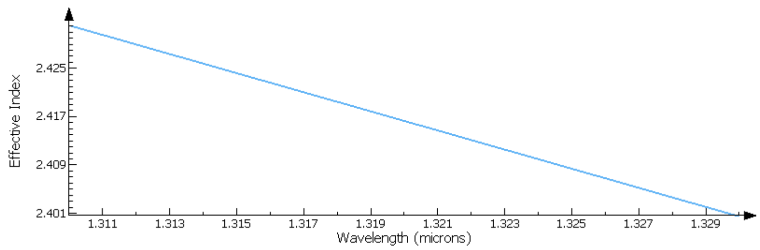

Figure 3: n_eff Plot

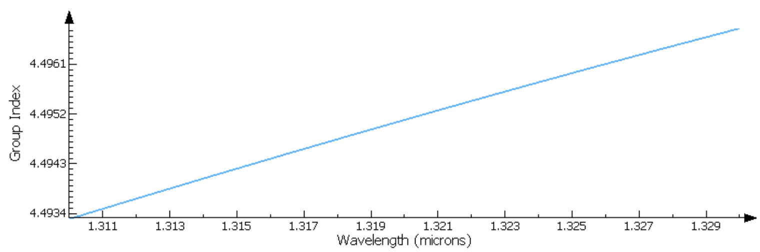

Figure 4: n_g Plot

The results show that n_{eff} and n_g are equal to 2.43211 and 4.493322 respectively at 1310nm. The frequency sweep also had its data exported to Matlab, where a script was run and the polynomial coefficients found to be 2.43211, -1.57349, -0.0649549.

Band Structure Simulation

The simulation was created using scripts found on the github page for ELEC413, namely MAIN_Bandstructure.lsf and corresponding files. This was done in Lumerical FDTD. The mesh accuracy used is mesh = 2, which grants a medium accuracy simulation. Parameter sweeps of dW were used to find κ and bandwidth over a range of dW. In order to get very accurate results, 200 points were used which took the computer an entire night to run! From this, a dW of

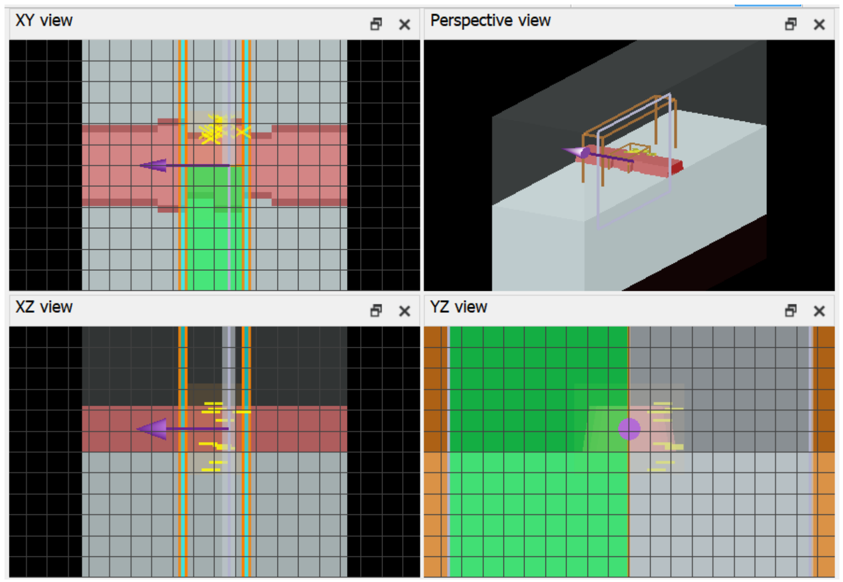

Figure 5: All Views of Band Structure

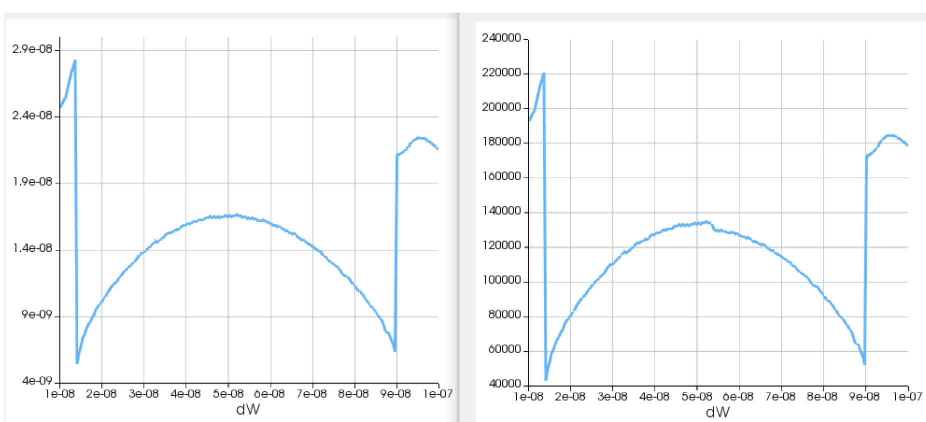

Figure 6: κ (right) and Bandwidth (left) Versus dW

50nm is chosen, giving a *kappa* approximately equal to 134000 and a bandwidth approximately equal to 16.5nm. The dW chosen was not one of the data points given, but instead interpolated to give these values of κ and bandwidth. In this project, I decided to go with a maximized κ and adjust other parameters to compensate. Period was also selected to be 270nm, which gives a central wavelength close to 1310nm.

There are anomalies in the dW graphs due to software limitations - FDTD has trouble handling extreme values of dW. Also, while loss can be calculated using FDTD, a different loss is used as the Lumerical FDTD application fails to take into account other factors, such as a bent versus striaght waveguide. Details on how loss is estimated are further below.

Circuit Model Simulation

The circuit model simulation utilizes Lumerical Interconnect. The model utilizes a Bragg Grating loss of 7dB/cm with the waveguide loss being 6dB/cm. The waveguide losses are provided from Applied Nanotools, assuming a bent 350nm waveguide. The Bragg Grating loss is the waveguide loss plus 1dB/cm to take into account the fibre grating couplers.

For the control condition, a Bragg Grating length of N = 65 periods was chosen, along with a cavity length of N = 70, which is 189μm. In testing, cavity length will be dependent on N to make creation of testing variations easier. Additional variations will be built upon this control condition, with the results shown in the table and figures below:

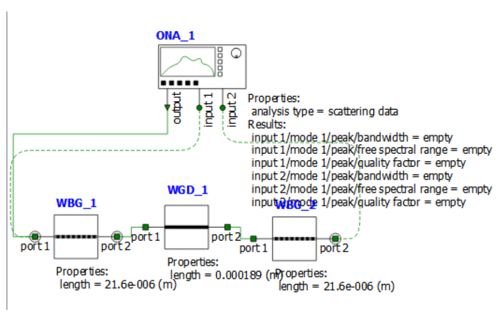

Figure 7: Diagram of Circuit Used in Interconnect

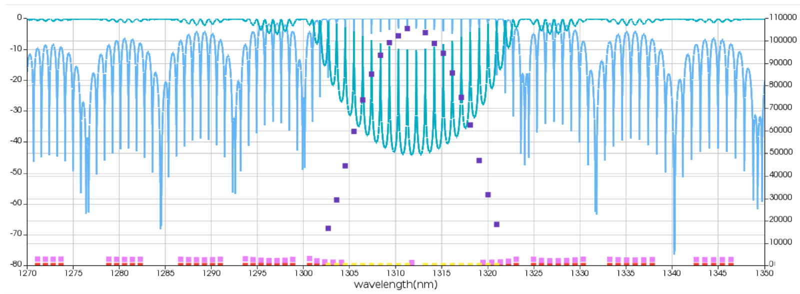

Figure 8: Response of Bragg Length N = 80 and Cavity Length N = 70

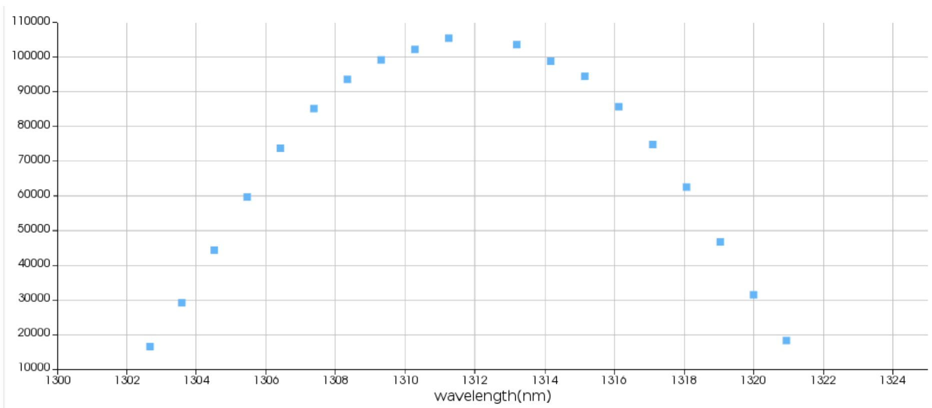

Figure 9: Quality Factor of Above Response

Bragg Grating Length (N)	Cavity Length (N)	Q	Insertion Loss (dB)
65	700	66038	4.96
70	700	79728	6.48
75	700	92081	8.15
80	700	105448	10.21
85	700	109495	12.45
85	750	N/A	N/A
80	750	105548	10.61
80	800	103547	10.98
80	850	105186	11.36
80	900	105159	11.72

The results in the table are peculiar due to the limitations of the Interconnect software. At high N for either Bragg length or cavity length, the software is unable to handle the amount of loss that occurs from insertion, thereby preventing it from calculating Q correctly (which is why for two of the entries there is an

N/A). If I were to repeat this simulation in the future, I would instead utilize straight waveguides rather than bent, to reduce the amount of loss I use in my simulations so that the software can handle the calculations correctly.

Layout

The above 10 variations were used to make the layouts, all within a total of 3 KLayout files. All layouts follow the previous parameters for width, period, grating shape, and other parameters listed above. All designs fit within the required space (shown in purple outline) and pass all design rules. Below is shows the layout of one of the files:

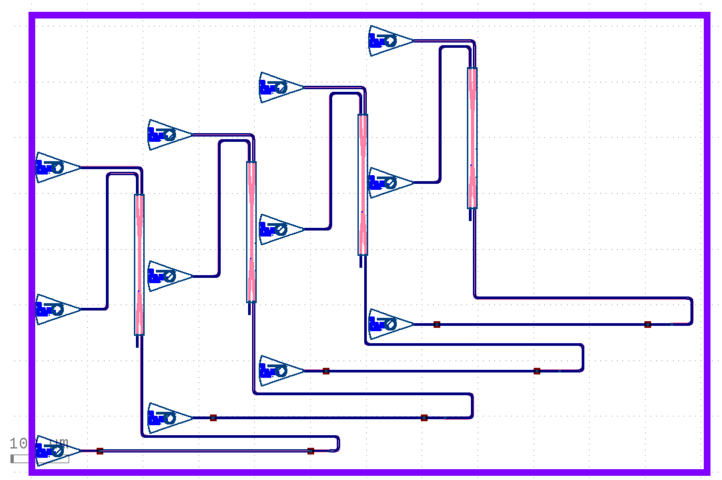

Figure 10: Diagram of Circuit Used in Interconnect