Design Proposal for a Bragg Grating Resonator

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Abstract – This report outlines the design process used to create a Bragg Grating Cavity device with a high quality factor that was simulated through the Transfer Matrix Method and simulated using Matlab and Lumerical. A design constraint for the thickness was set at 350nm, while other parameters were varied. This design proposal outlines the first draft for the design which chronologically outlines the process used to create the design.

I. INTRODUCTION

The concept of Bragg Gratings (BG) was first introduced in the 1900s, and since then, they have been widely used in a variety of fields. With the surge in silicon photonic development, for its popular use in consumer electronics, the demand for nanofabrication has significantly increased. A Bragg Grating Cavity is a type of optical resonator that is widely used for a wide range of applications, including laser stabilization, spectroscopy, and sensing. This design proposal report aims to outline the specifications, materials, design procedure and tools used to create a Bragg Grating Cavity with a high quality factor and low FSR given certain design constraints.

II. THEORY

The goal of this project is to design and fabricate a Bragg Grating Fabry Perot Cavity (BGFPC) device with a distinct transmission spectrum and high quality factor, Q, at a central wavelength of 1310nm. Q is defined by the following equation:

$$Q = \frac{\omega}{\Delta\omega_{\frac{1}{2}}} \qquad (1)$$

where $\Delta\omega_{\frac{1}{2}}$ is the width of the signal at the -3dB point. The BGFPC can be created using a waveguide cavity in between two Bragg grating waveguides. The waveguide core is made using silicon and the cladding is made out of silicon dioxide. The BG cavity only allows specific wavelengths to be transmitted. The design also includes grating couplers for optical gain.

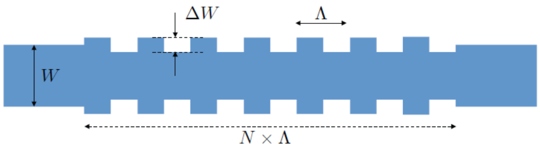

Figure 1: Schematic of a Bragg Grating [1].

The parameters for the BG schematic in Figure 1, and the ones that will be varied in this design are: ΔW, the corrugation width, W, the waveguide width, **Λ**, the grating period, N, the number of grating periods and L, the grating length. Additionally, the type of waveguide is a parameter such as rectangular or sinusoidal.

III. DESIGN

The aim is to design a BGFPC with a center wavelength of 1310 nm, also known as the Braff wavelength, and is given as:

$$\lambda_B = 2\Lambda n_{eff} \qquad (2)$$

where Λ is the grating period and the n_{eff} is the average effective index.

To design a BGFPC with a high quality factor, we need to consider the distributed mirror loss which depends on the peak reflectivities, R_1 and R_2, of the Bragg gratings, and the length of the cavity L_{cav}. Based on coupled-mode theory, the reflectivity and the coupling coefficient of the grating, κ, can be adjusted through the design. The coupling coefficient for a rectangular grating profile is:

$$\kappa = 2\frac{\Delta n}{2n_{eff}}\frac{1}{\Lambda} = \frac{2\Delta n}{\lambda_B} \quad (3)$$

For this project, I designed a symmetric BGFPC, where two Bragg gratings were the same such that R1 = R2. I set the average width (ω_{avg}) to be 335nm, and the grating period (Λ) to be 275.36nm. For a 220nm thick core layer made of silicon with a silicon dioxide cladding, the Bragg wavelength was close to around 1310nm.

A modal analysis was completed using Lumerical Mode to obtain a mode profile and to calculate the effective index in the TE mode given by a Taylor polynomial around the center wavelength.

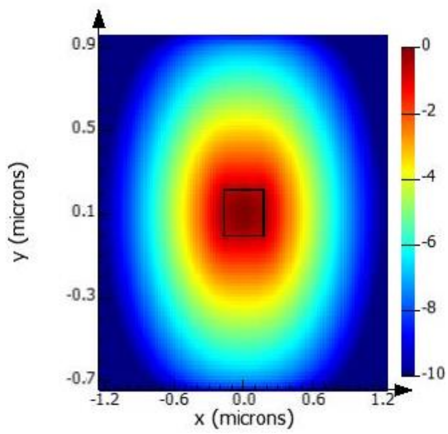

Figure 2: TE Mode profile for the waveguide

The effective index data as a function of wavelength was modelled and extracted using Lumerical Mode by completing a frequency sweep, and was fit into a third order polynomial, as described below:

$$n_{eff}(\lambda) = 2.3787 - 1.6564\lambda - 0.075\lambda^2$$

The polynomial coefficients were obtained using Matlab through a compact model analysis for the waveguide. By completing a frequency sweep, the group index, n_g, was obtained around 4.55.

The Bragg grating design I chose has a rectangular perturbation profile with a corrugation width (ΔW) of 50nm, following calculations obtained using a Lumerical FDTD model. Additionally, this gave a coupling coefficient (κ) value of ≈1.1e6.

The number of corrugations (N) for the grating was chosen to be 200. I ran some tests to vary design parameters, namely the corrugation width and the number of grating periods to see how that affected the central wavelength and the coupling coefficient and use this experimental data to determine appropriate values. The corrugation width sweeps on using the FDTD model shows how kappa and the center wavelength varies with corrugation width.

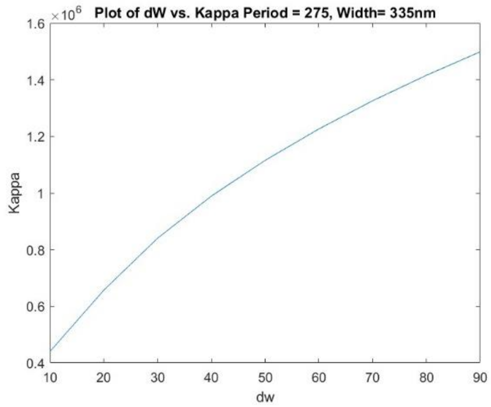

Figure 3: Kappa as a function of corrugation width using the FDTD model

IV. MODELLING & SIMULATIONS

The device was modelled using the transfer matrix method (TMM) to simulate the output spectrum of the device.

The propagation matrix defined by the TMM is:

$$T_{hw} = \begin{bmatrix} e^{j\beta L} & 0 \\ 0 & e^{-j\beta L} \end{bmatrix} \quad (4)$$

where β is the complex propagation constant for the field. A Matlab simulation was run for the parameters defined in Table 1 to obtain a simulation of the transmission spectrum of the design using coupled mode theory, as shown in Figure 3 below.

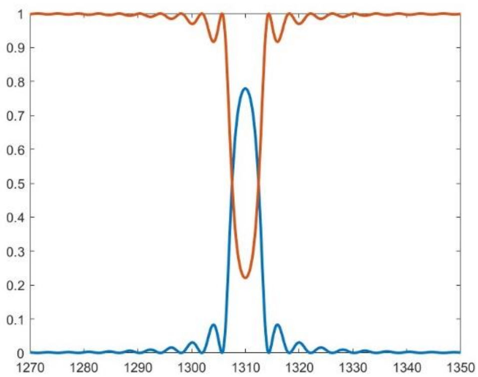

Figure 4: Transmission Spectrum simulation of design using TMM

I assumed a waveguide propagation loss of 1.5 dB/cm.

The structure can be modelled in Lumerical INTERCONNECT and multiple models can be compares to aim for the highest quality factor. The circuit design used in Lumerical is shown in Figure 5.

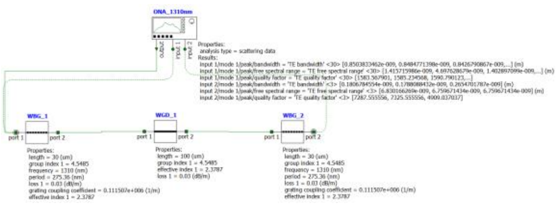

Figure 5: Lumerical INTERCONNECT Circuit Diagram

The quality factor obtained using the optical analyzer is 7857.56. The absorption and reflection spectrum is shown in Figure 6.

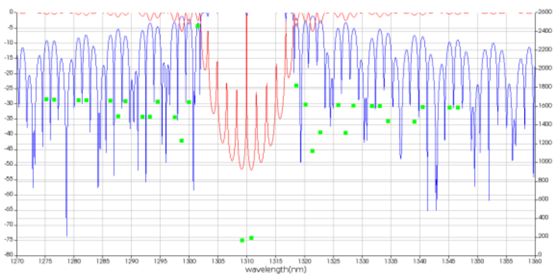

Figure 6: Reflection and Absorption Spectrum obtained from Lumerical INTERCONNECT

The KLayout structure of the design is shown in Figure 7. There are two Bragg grating's connected in series using a straight waveguide.

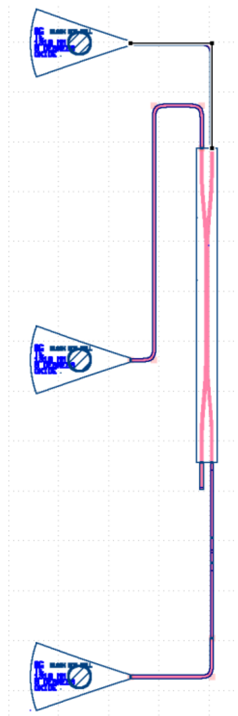

Figure 7: Bragg Grating Structure created using KLayout