Apodized Vertical Grating Coupler using Digital Photochemical Etching Method

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Motivation

- Grating couplers are used to efficiently provide light in-coupling and out-coupling into a device where the coupling efficiency has a strong dependence on:
  - geometrical parameters of the grating structure
  - position of the optical fiber
- Few studies have shown that the coupling efficiency of a grating can be significantly improved by varying the vertical component, but it is very difficult to fabricate and is costly.
- Digital photochemical etching method circumvents the aforementioned limitations by permitting groove height variations in a single processing step with color intensity variation of a projected digital photomask.

Background

- An apodized grating coupler is a type of grating coupler that varies the height and period of the small grating structures.
- The apodization allows for higher efficiency.
- Separately, vertically tapered waveguides that consist of a wedge structure and produce larger collection efficiencies compared to planar structures.
- Combining the merits of both grating coupler and tapered waveguides, apodized vertical grating coupler is expected to increase the collection efficiency.

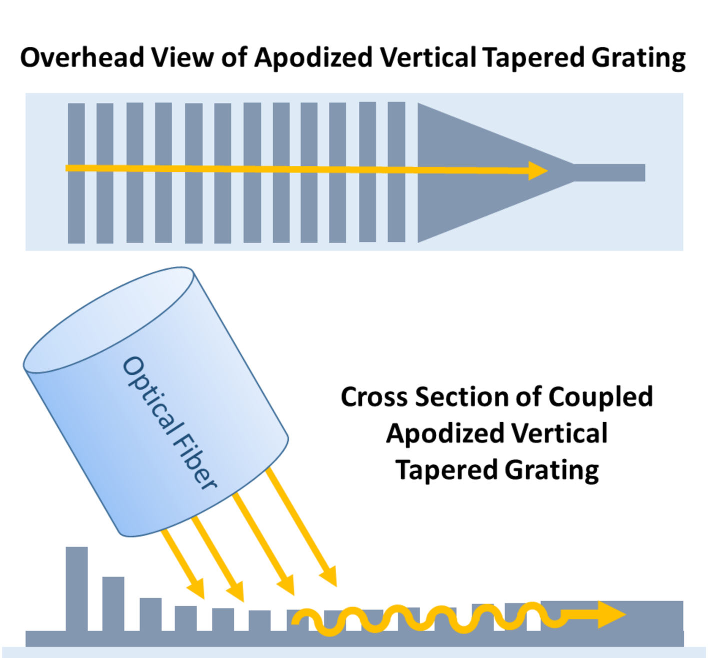
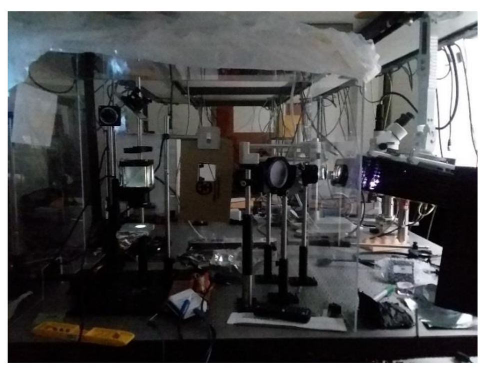
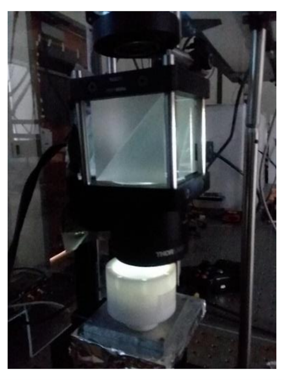


Figure 1: Apodized Grating Coupler Operation Principle

Digital Photochemical Etching Method

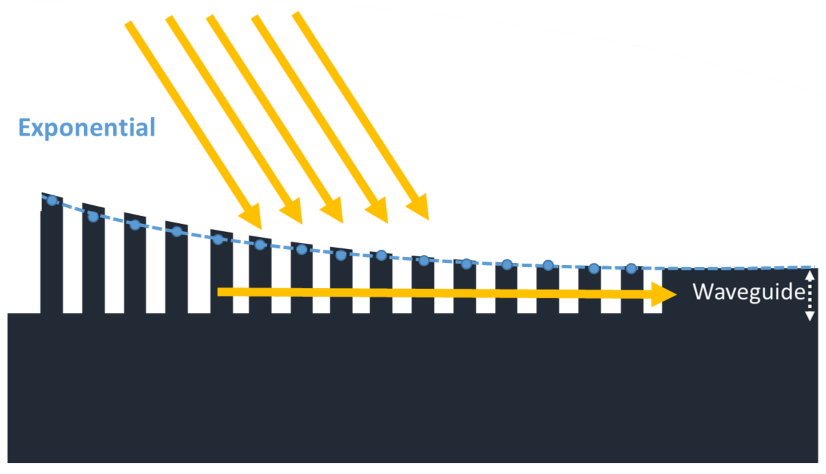
- Digital photochemical etching (PC) is a method of etching a substrate using an etchant, and controlling the etch with various colors and intensities.
  - Intensities govern etch depth.
  - Colors govern etch quality.
- PC method allows multiple heights to be etched in one processing step using a digital mask designed in Microsoft PowerPoint.
- Benefits: Cost effective and User Friendly Operation



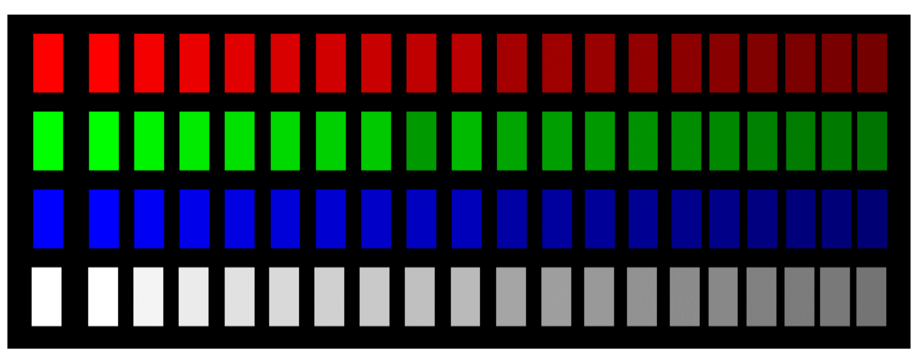


Methodology

- A Matlab script was developed to calculate the heights of a grating surface given the n_{Eff} constant from a certain set of waveguide dimensions, and the characteristics of the incoming light.
- The heights are converted to RGB values to alter the etch heights of the master mold.

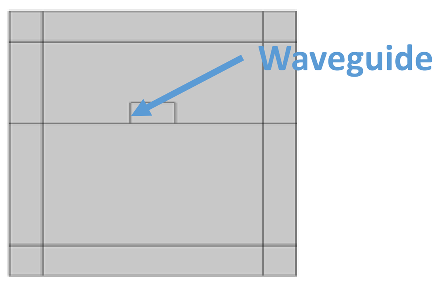


- A digital mask was created using the Matlab script. 5 RGB values were selected for testing to gain insight into the groove height and intensity relationship.



Color	Intensity					Time (min)
Green	0	32	64	128	255	10
Blue	0	32	64	128	255	10
White	0	32	64	128	255	10

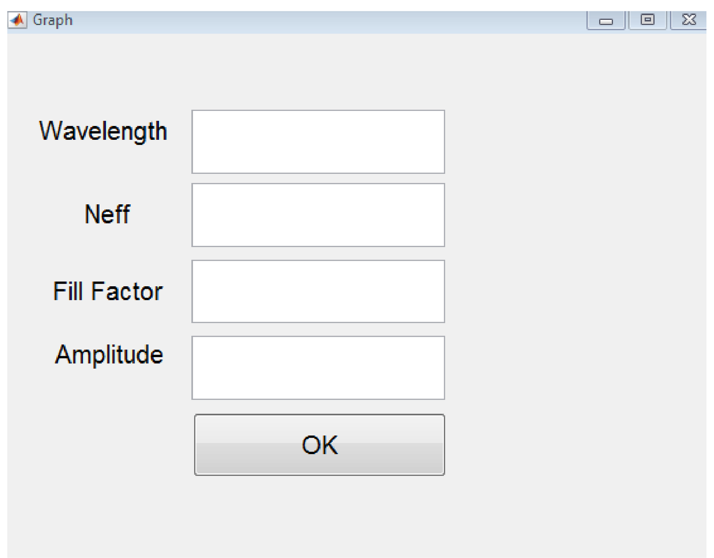
- COMSOL simulation was used to determine the optimal waveguide dimensions.

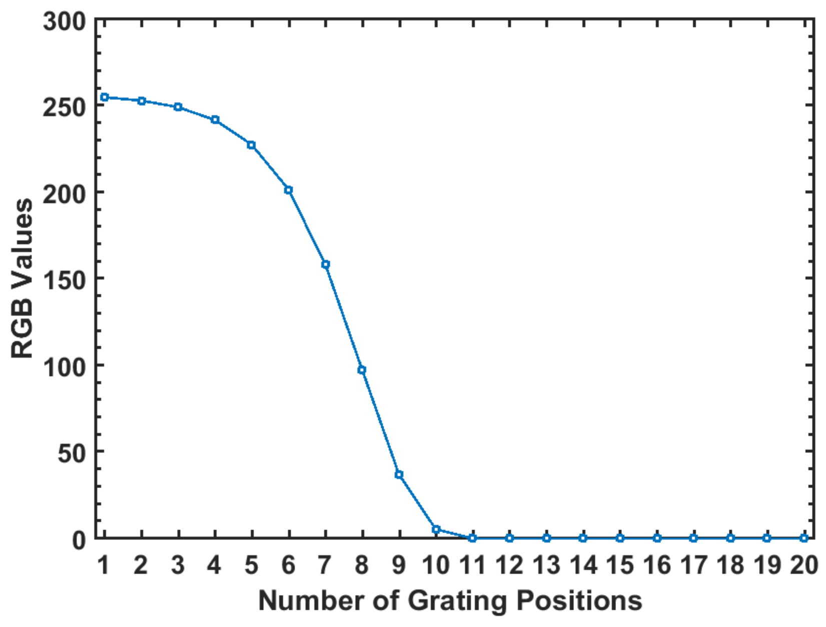


Width (μm)	1.7	1.8	1.9	2	2.1	2.2	2.3
Height (μm)	0.5	0.7	0.8	0.9	1	1.1	1.2

Preliminary Results

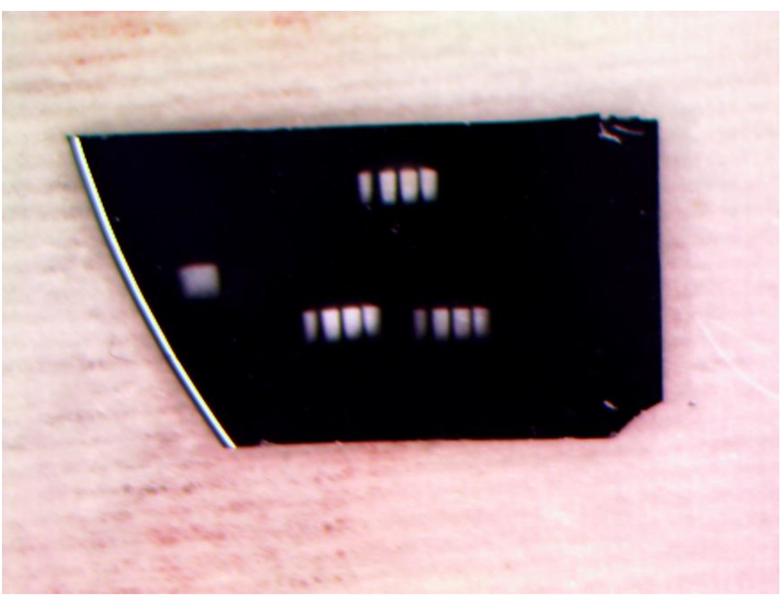
Grating Height Calculator using Matlab





- The left image is the screenshot of graphical user interface (GUI) to compute the grating parameters and height of grating features.
- The right is a graph of the heights based on an exponential profile.

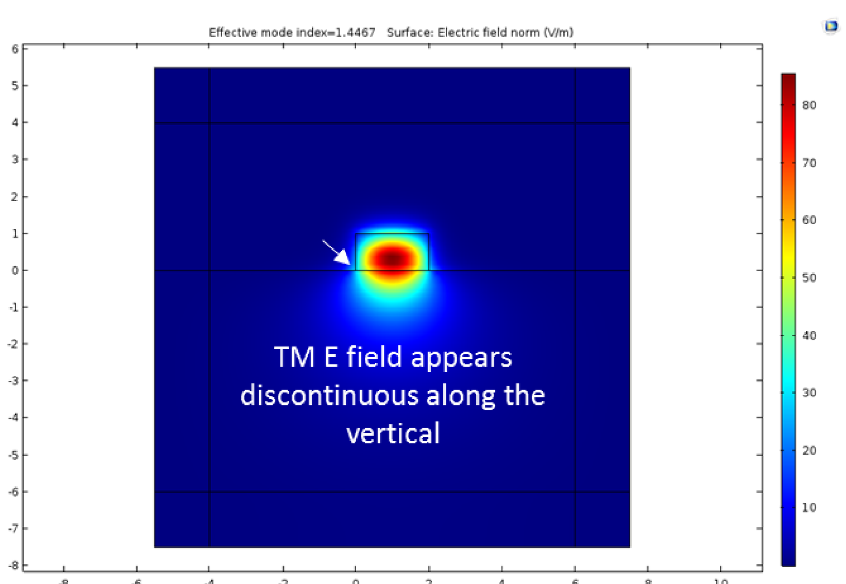
Photochemical Etching of Test Grating Structures



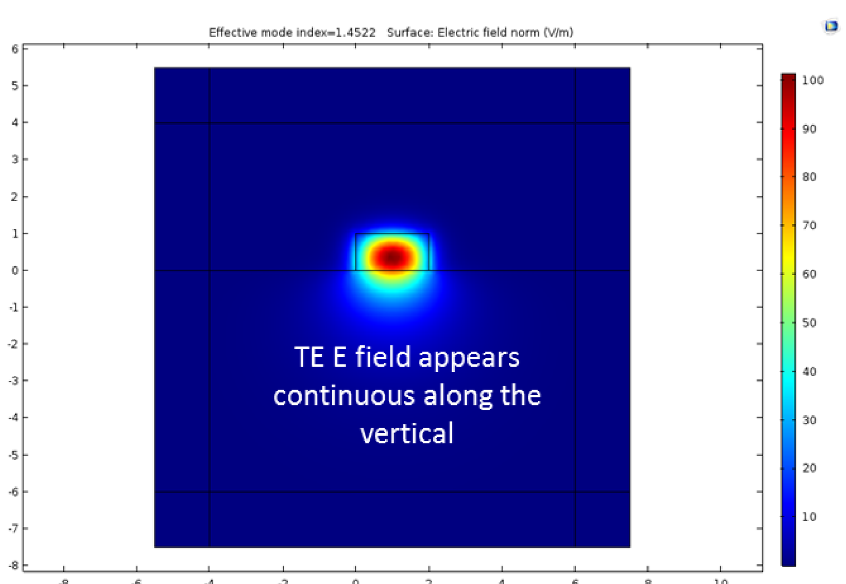
- Optical inspection of etched substrate based the experimental plan.
- The white figures are the etched structures, which took approximately ten minutes to etch for each set of structures.
- Different RGB values were used for each set, which is why some seem more reflective.

Simulation of Waveguide Dimensions using COMSOL

TM Mode



TE Mode



- Different widths and heights of the waveguide produced different confinement factors.
- Confinement is a measure of how much the light is within the waveguide.
- The waveguide is 2 um wide and 1 um thick.
- Left figure is the transverse magnetic (TM) mode and the right figure is the transverse electric (TE) mode.

Further Work

Short term goals includes:

- optimizing the exponential profile of the grating structures and their periods
- Vary the etch times for various RGB values and fine tuning the etch process.
- Use a fresh etchant to alleviate contamination from processing.

Long term goals

- Create the sub-master mold in gallium arsenide and perform nanoimprint lithography to create UV curable polymer apodized grating coupler.

Acknowledgements

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