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Silicon Photonic 2 X 2 Power Splitter with S-Bend Configuration

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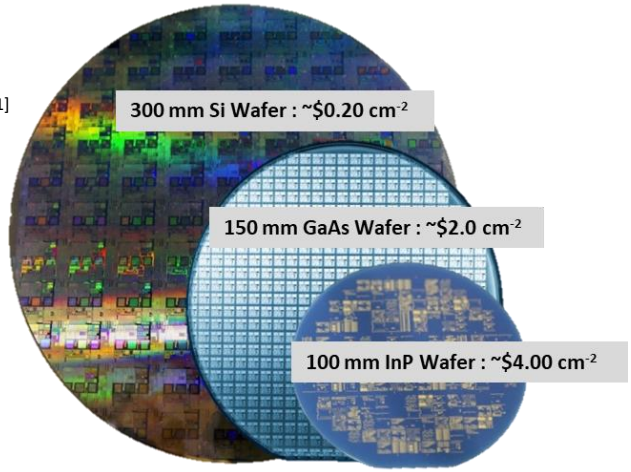
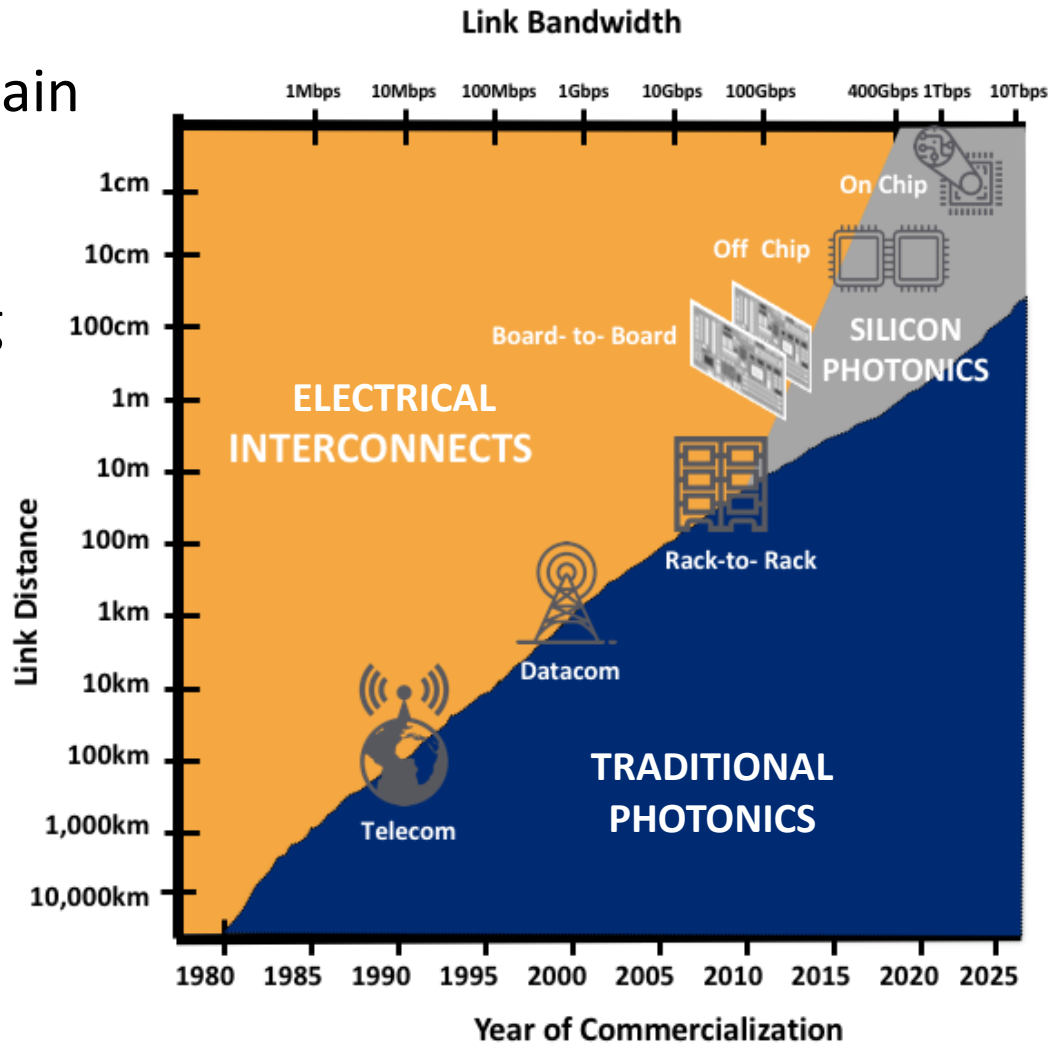
Outline

- **Introduction**
  - What is Si Photonics
  - Si Photonic Components
  - Power Splitters
- **Simulation Set-Up**
- **Results**
  - Variation of coupling length
  - Variation of coupling gap
  - Lumerical Mode Solutions comparison
- **Summary/ Future Works**

Introduction

- Utilizes semiconductor infrastructure and supply chain
- Delivers low cost solutions
- Applications:
  - Performance Computing
  - Data Centers
  - Defense
  - Life Sciences



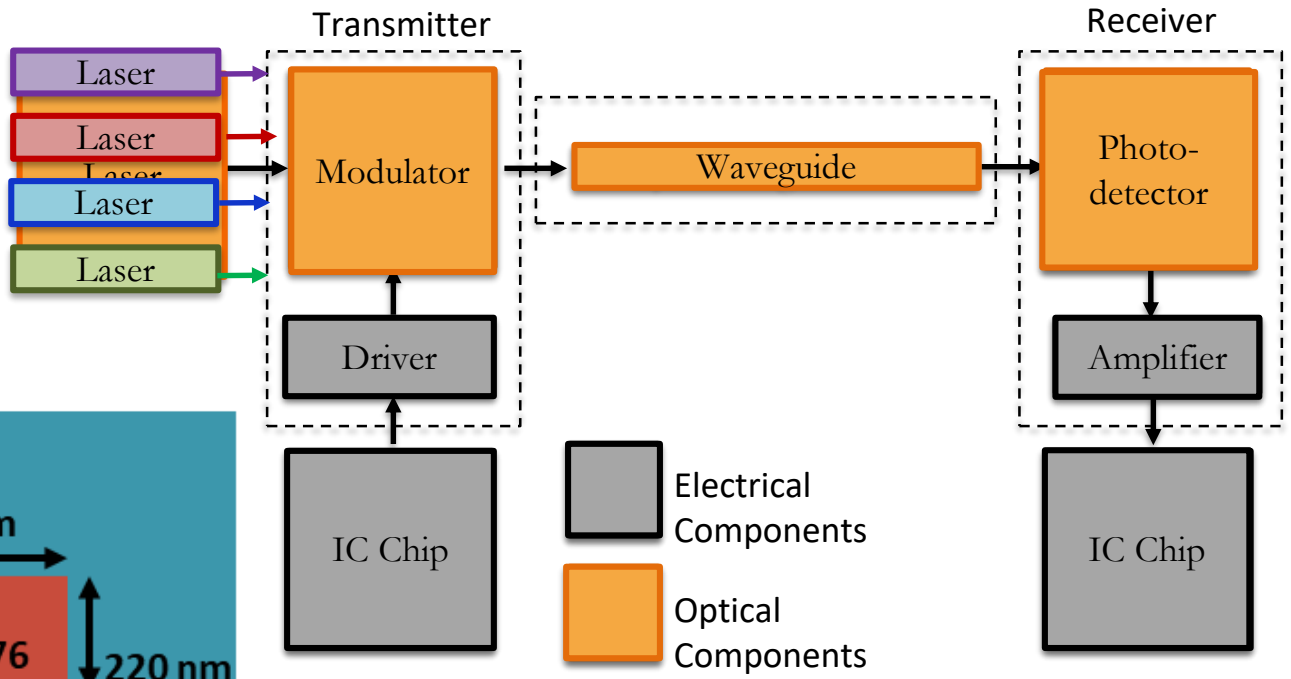


[1] Liehr, Michael. 16 Nov. 2017, Albany.

Si Photonic Components

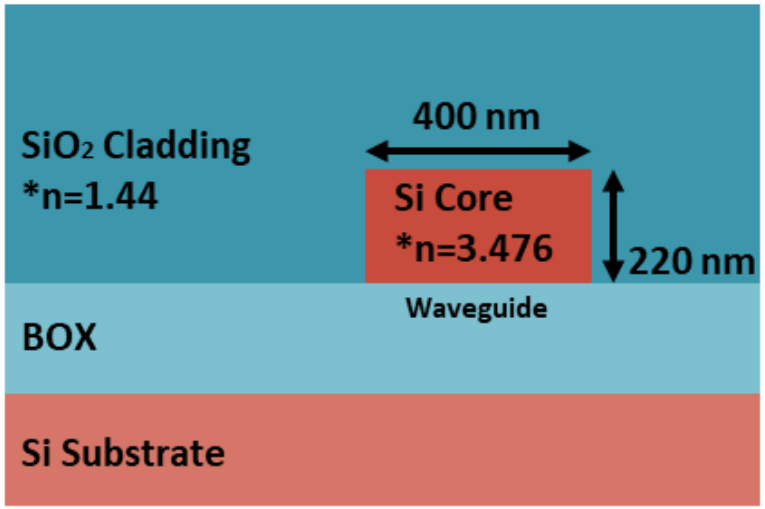
- High refractive index contrast
  - Low loss propagation
  - Light confinement
  - Compact footprint
  - Small bend radii

Photonic Link



LASER: Light Amplification by Stimulated Emission of Radiation
IC Chip: Integrated Circuit Chip

Cross-section view



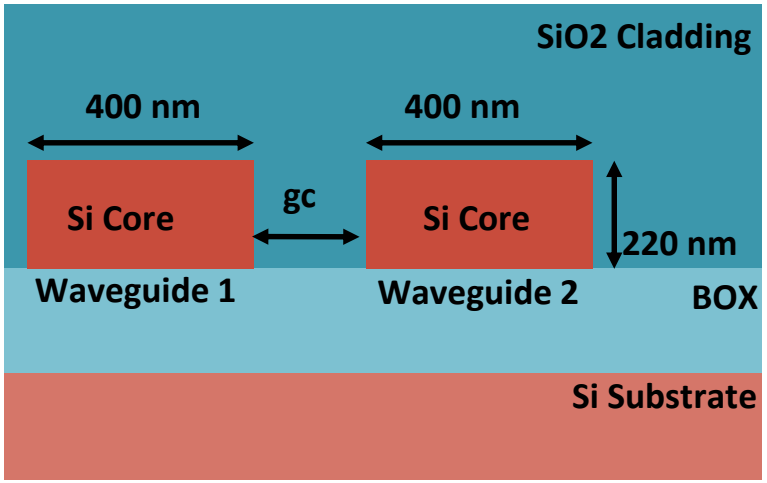
* @1550 nm wavelength

[1] "Intel® Silicon Photonics." *Intel*, http://www.intel.com/content/www/us/en/architecture-and -technology/silicon-photonics/silicon-photonics-overview.html.

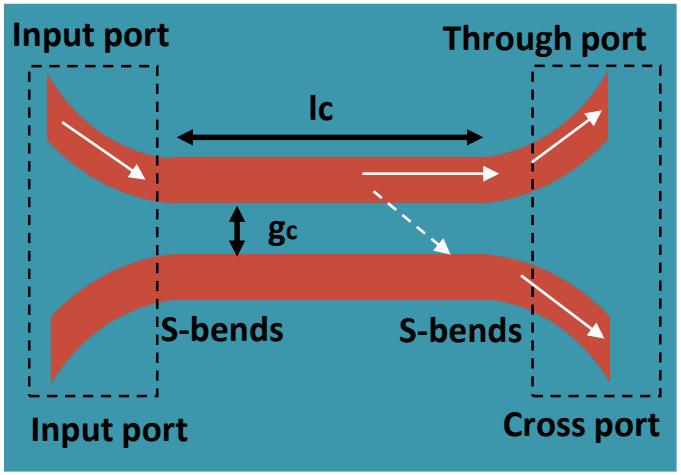
Waveguides

- Design Parameters:
  - Coupling Gap (gc): separation distance between waveguides
  - Coupling Length (lc): length of the parallel coupling region
  - S-bends: compact footprint and controlling coupling region

Cross-section view



Top-down view



Modeling of Power Splitter

- Objective
  - Validate COMSOL's ability to reproduce results from Lumerical Mode®, a popular optical modeling software
  - Parametric sweep of lc and gc
  - Compare power splitting ratio

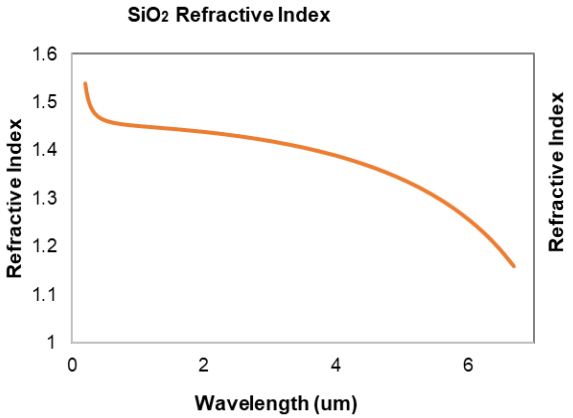
COMSOL

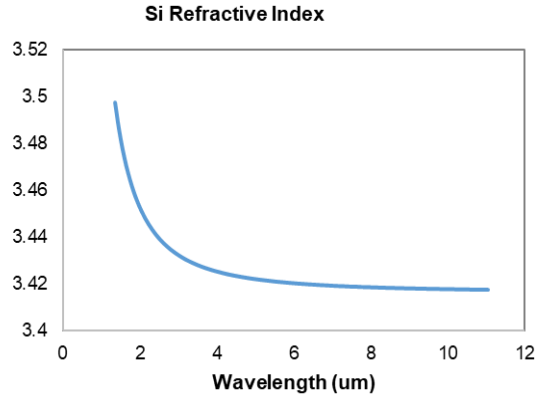
lumerical

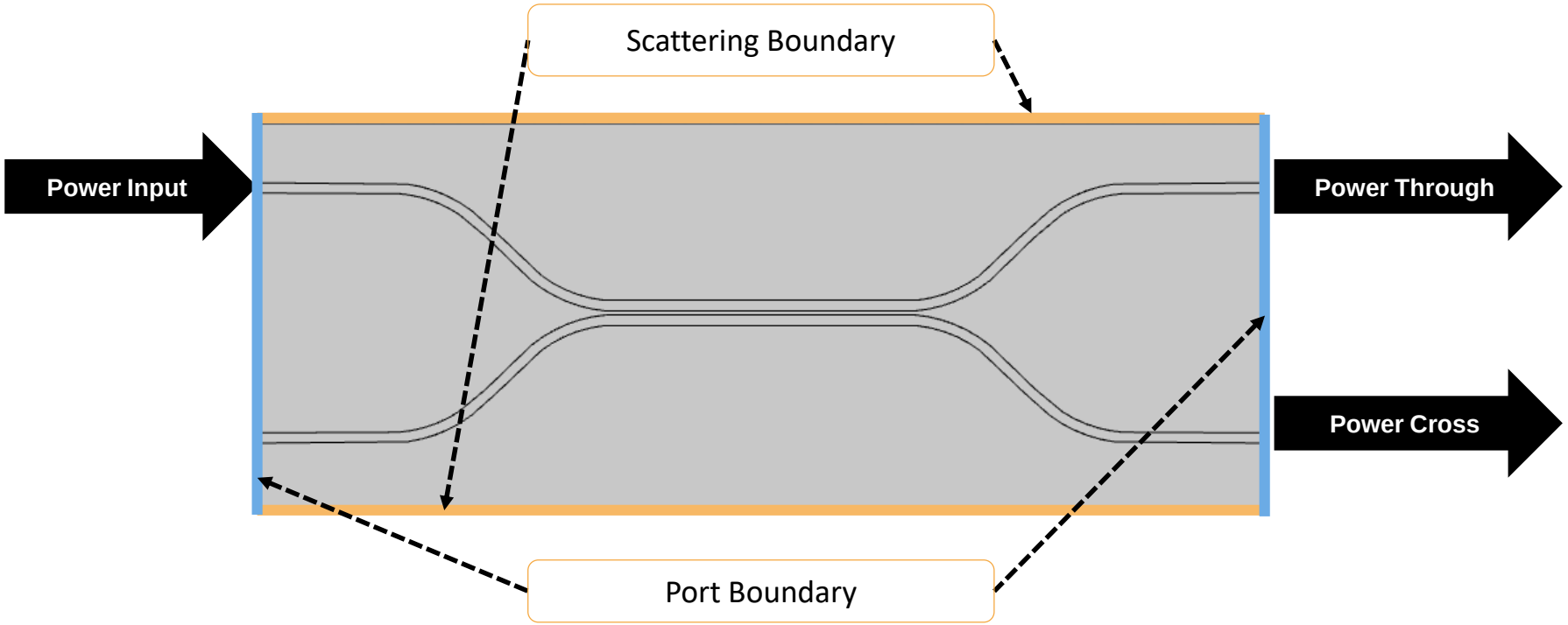
- Wave Optics Module
  - Electomagnetic Waves, Beam Envelope (ewbe)
- Model Solutions
  - 2.5D varFDTD (Finite Difference Time Domain)

Model Set-Up: Boundary Conditions

- Wavelength Dispersion
- Port Excitation
  - TE Mode propagation
  - Unidirectional

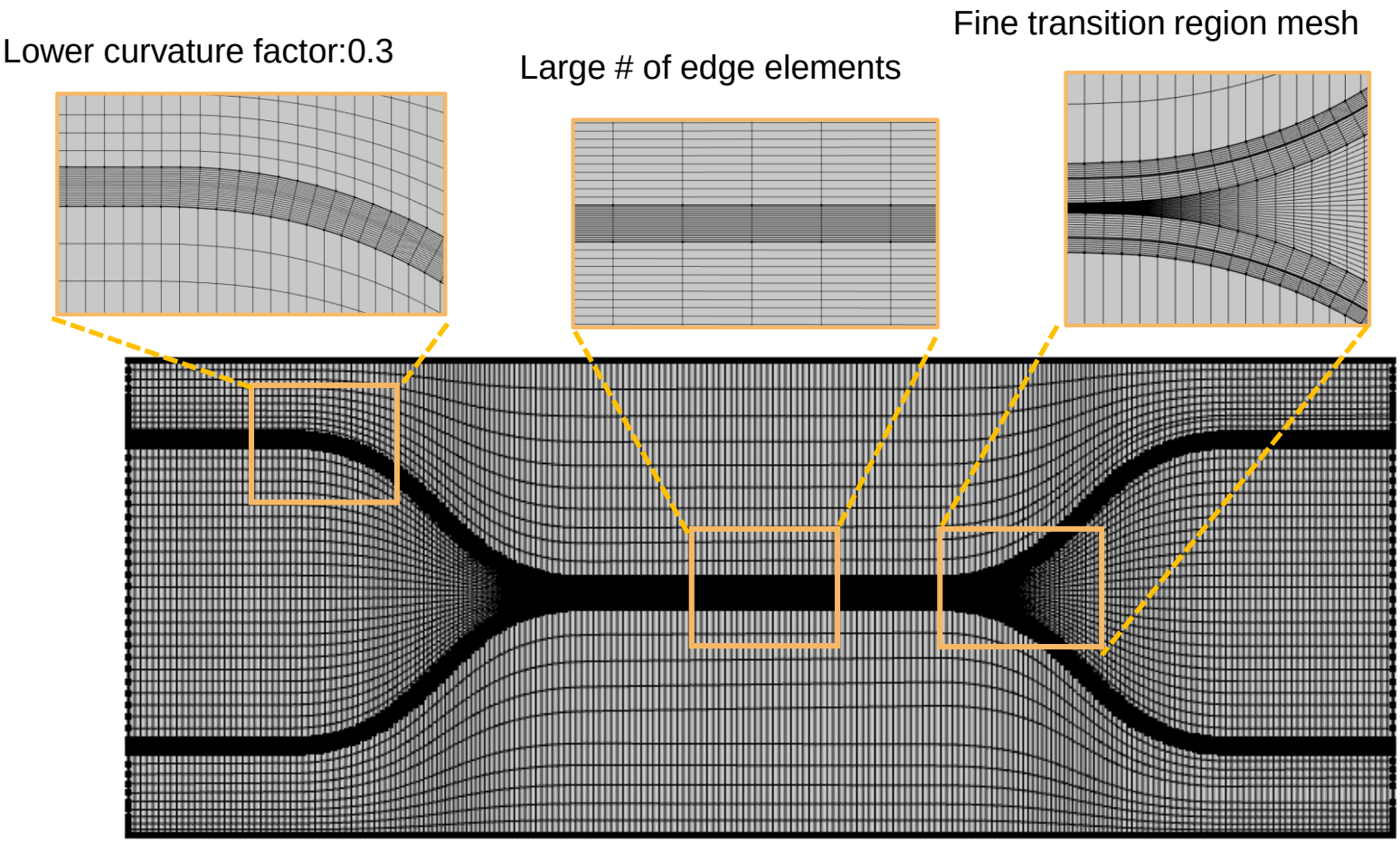






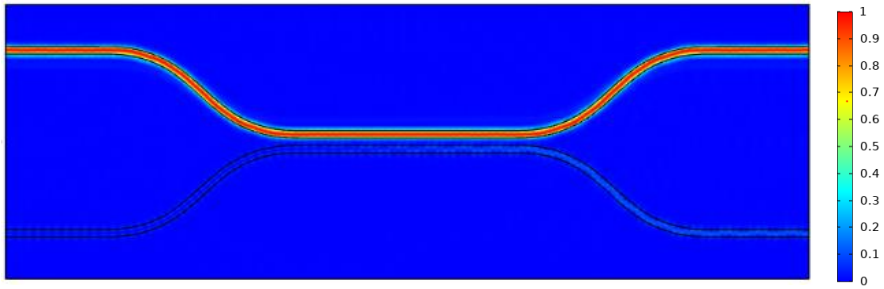
Model Set-Up: Meshing

- Max mesh element size must be a fraction of a wavelength
  - Max: 0.4 um

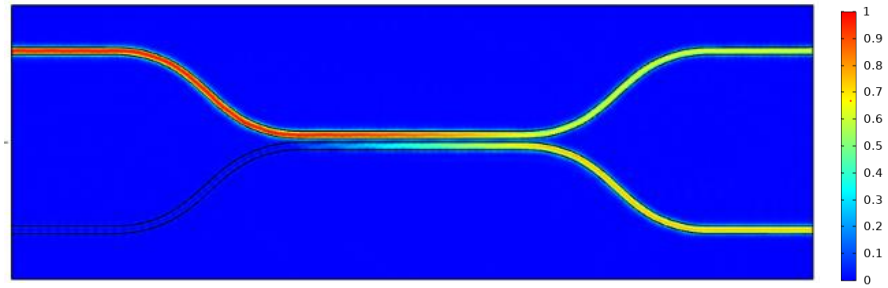


E-field Coupling Gap (gc)

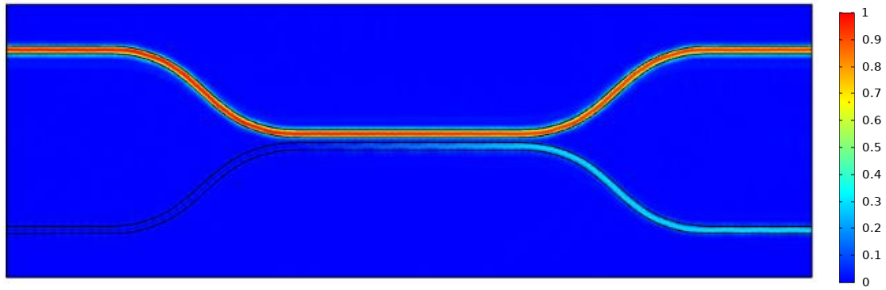
- Normalized E-field profiles @1550 nm:
  - Parametric sweep from 0.1 um to 0.4 um



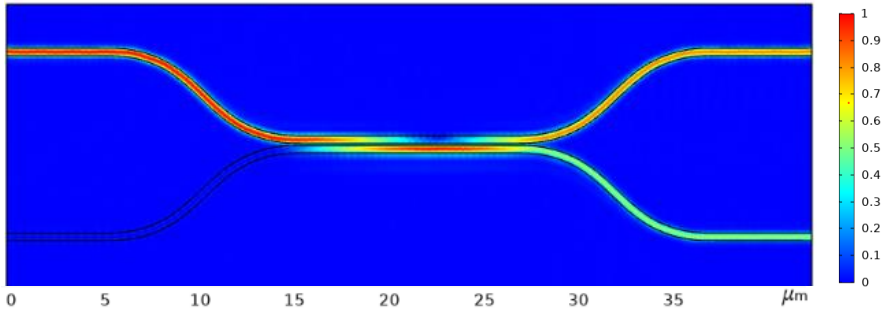
g_c: 0.4 um



g_c: 0.2 um



g_c: 0.3 um



g_c: 0.1 um

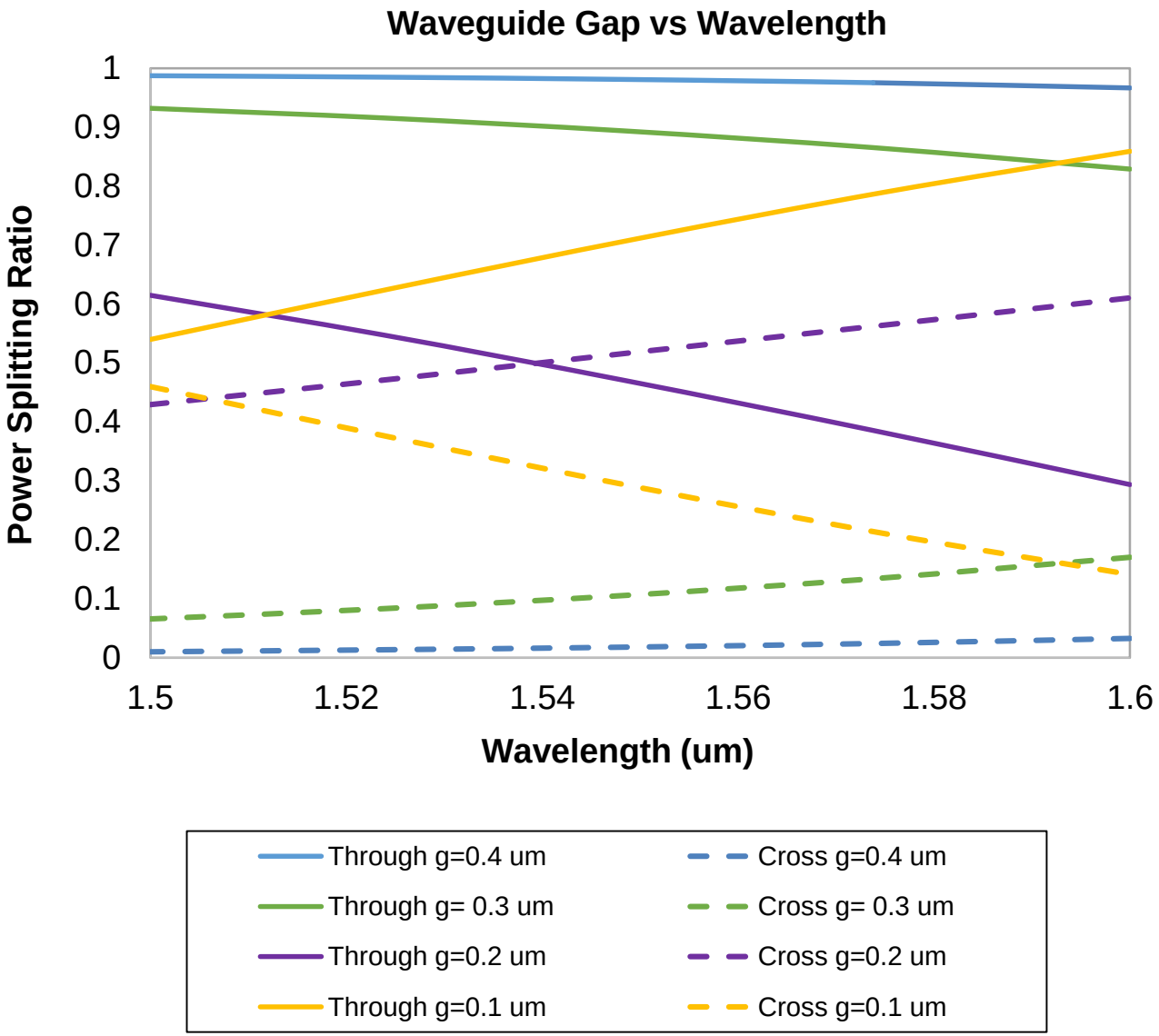
Power Splitting Separation Gap (gc)

Through Port:

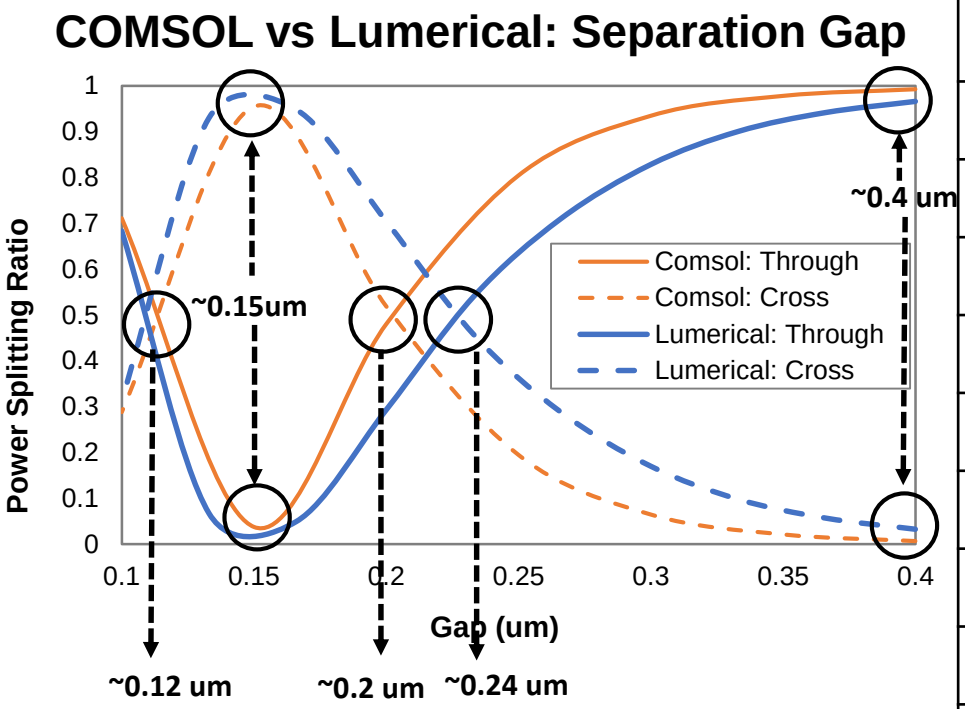
$$\frac{P_{through}}{P_{through} + P_{cross}}$$

Cross Port:

$$\frac{P_{cross}}{P_{through} + P_{cross}}$$



COMSOL & Lumerical Comparison

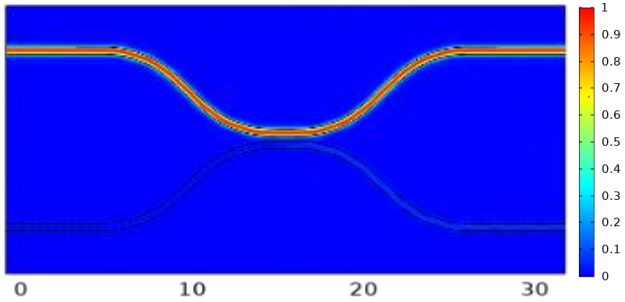


Coupling Gap (um)	COMSOL Multiphysics®	Lumerical Mode Solutions®
Through Port		
0.1	0.711	0.684
0.2	0.481	0.2937
0.3	0.935	0.829
0.4	0.993	0.966
Cross Port		
0.1	0.288	0.314
0.2	0.519	0.704
0.3	0.065	0.170
0.4	0.007	0.033

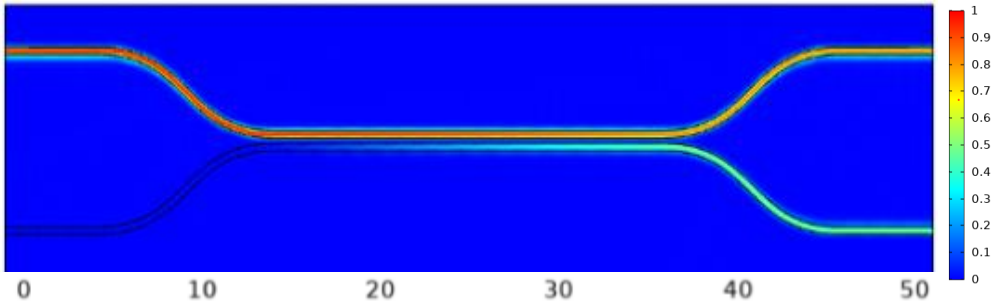
* 1550 nm wavelength

E-field Coupling Length (lc)

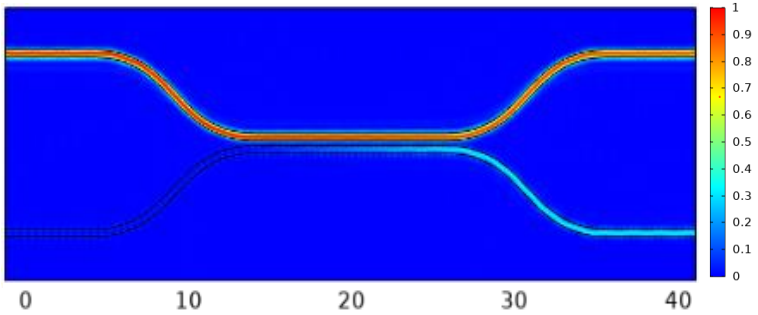
- Normalized E-field profiles @1550 nm:
  - Parametric sweep from 0 um to 30 um



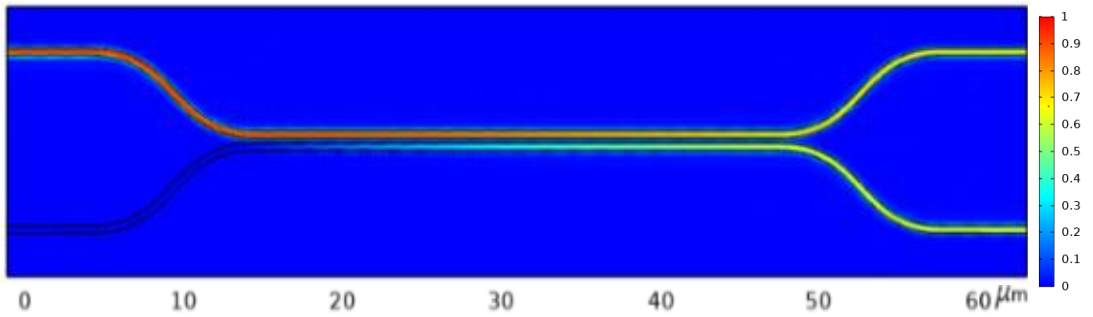
l_c: 0 um



l_c: 20 um



l_c: 10 um



g_c: 30 um

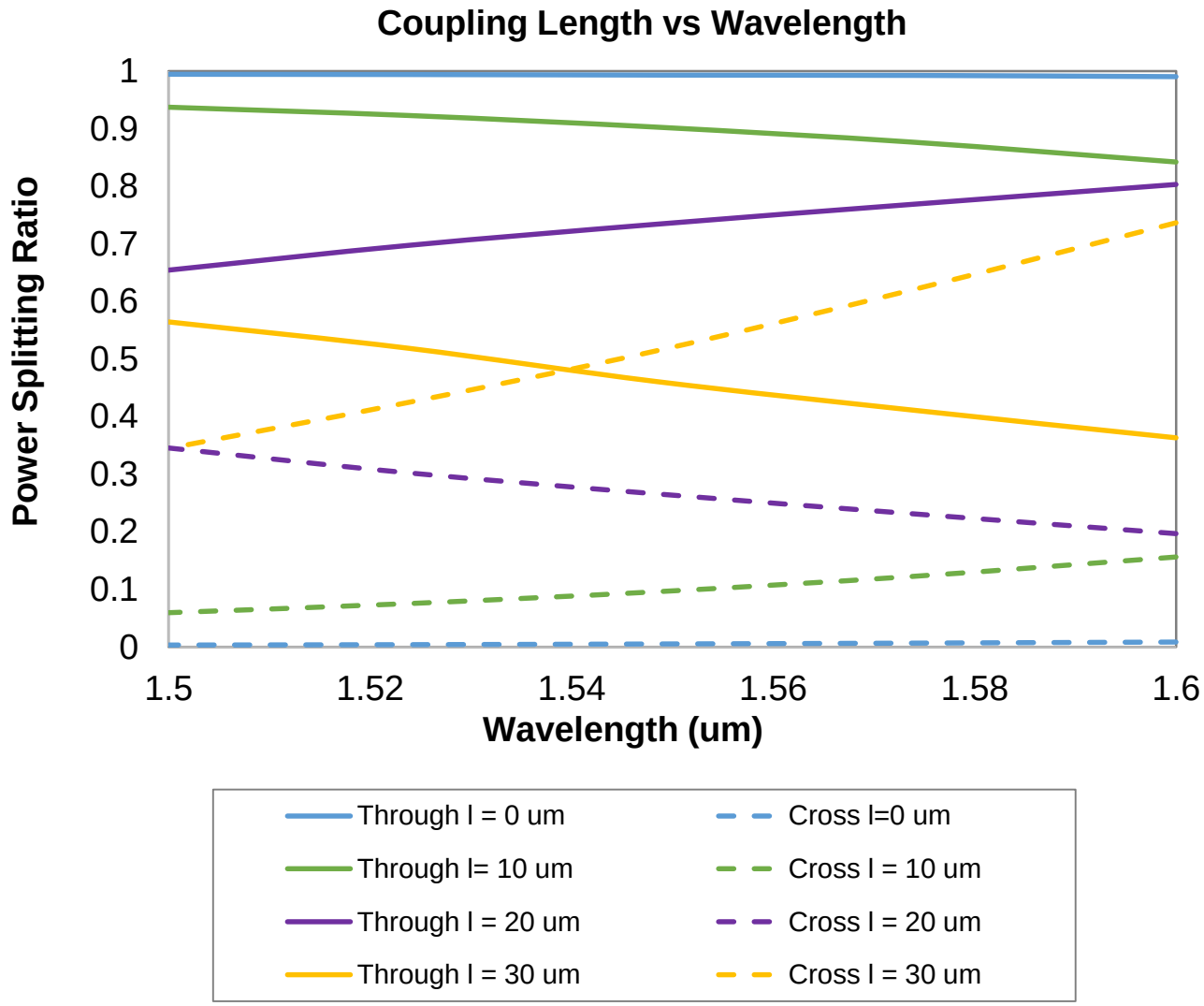
Power Splitting Coupling Length (lc)

Through Port:

$$\frac{P_{through}}{P_{through} + P_{cross}}$$

Cross Port:

$$\frac{P_{cross}}{P_{through} + P_{cross}}$$



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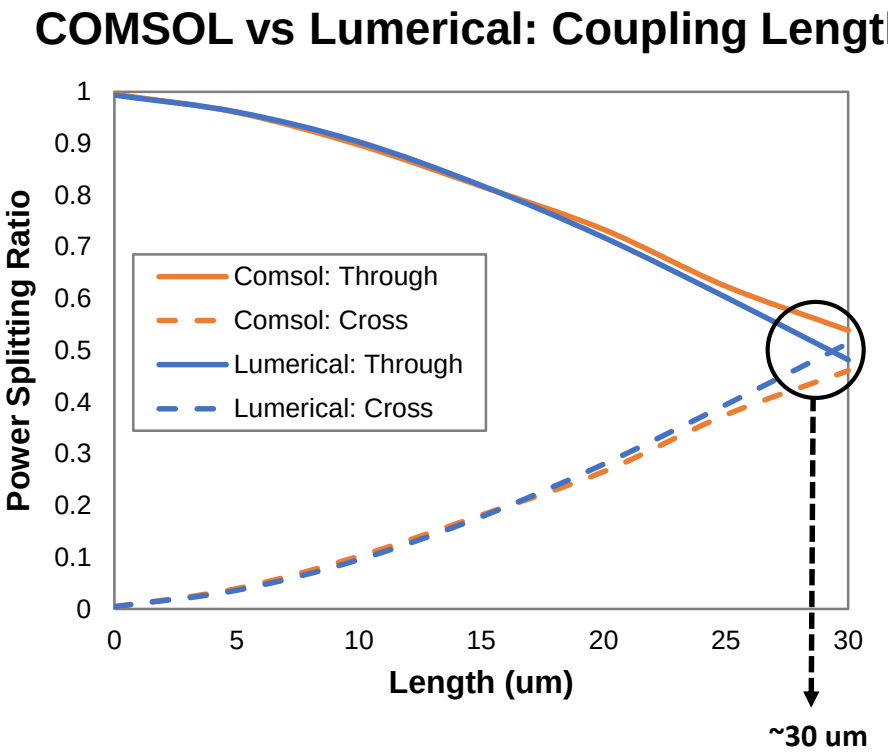
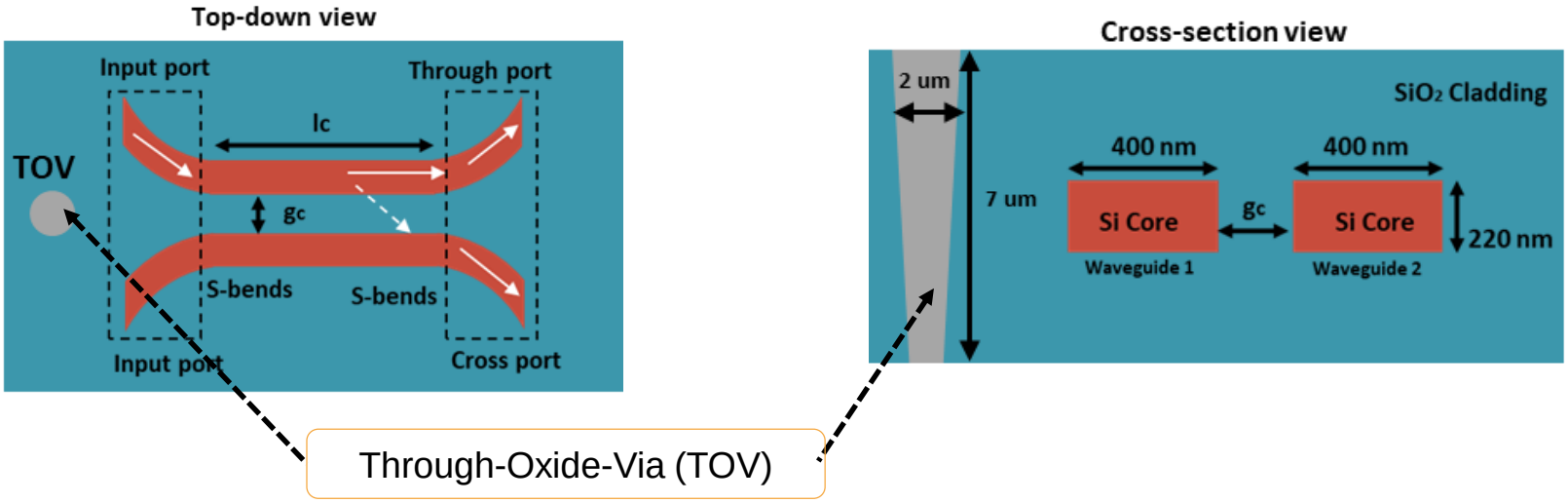


Coupling Length (um)	COMSOL Multiphysics®	Lumerical Mode Solutions®
Through Port		
0	0.995	0.993
10	0.897	0.903
20	0.734	0.718
30	0.538	0.482
Cross Port		
0	0.004	0.005
10	0.102	0.096
20	0.266	0.280
30	0.461	0.514

* 1550 nm wavelength

Summary/ Future Work

- Simulations show results from COMSOL and Lumerical are in good agreement
- Characterize stress induced fabrication shifts
- Couple Structural Mechanics Module
  - Solid Mechanics Interface
- Fabrication using 300mm wafer processing facility



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[1] Z. Lu et al., “Broadband silicon photonic directional coupler using asymmetric-waveguide based phase control,” (eng), Optics express, vol. 23, no. 3, pp. 3795–3806, 2015.

[2] R. K. Gupta, S. Chandran, and B. K. Das, “Wavelength-Independent Directional Couplers for Integrated Silicon Photonics,” J. Lightwave Technol., vol. 35, no. 22, pp. 4916–4923, 2017.

[3] G. F. R. Chen et al., “Broadband Silicon-On-Insulator directional couplers using a combination of straight and curved waveguide sections,” (eng), Scientific reports, vol. 7, no. 1, p. 7246, 2017.

[4] COMSOL Multiphysics, "The Wave Optics User's Guide", 2019

[5] Lumerical Solutions," Stress and Strain", 2019.

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Thank You

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