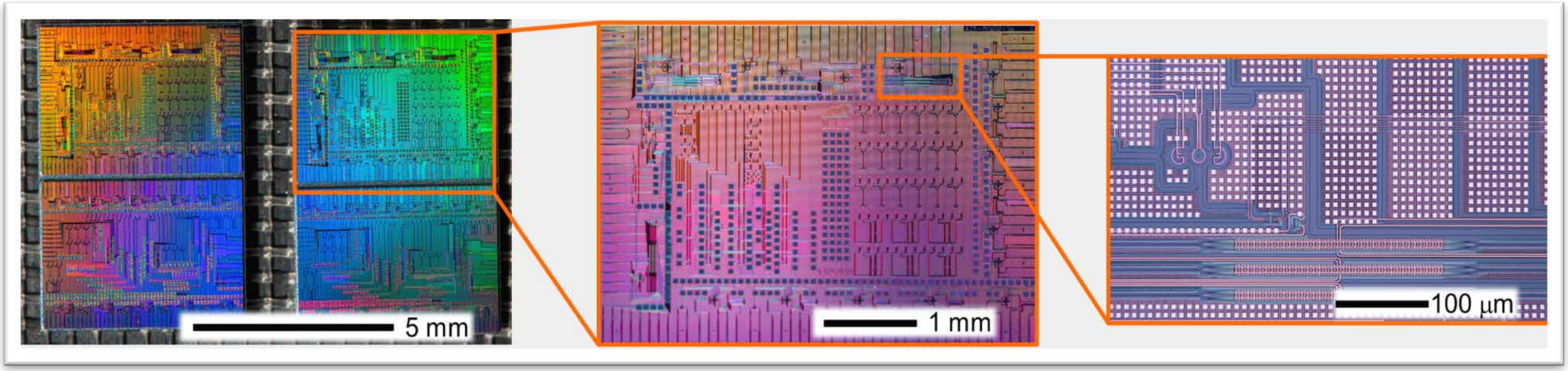
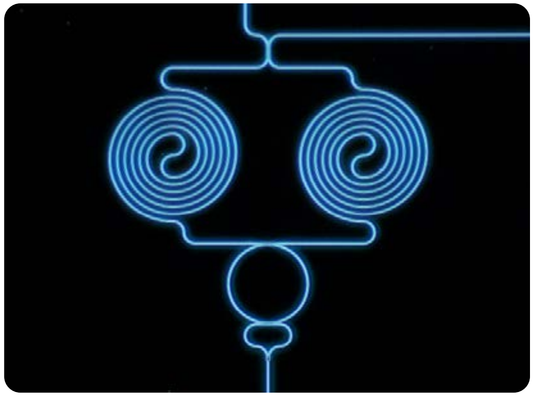
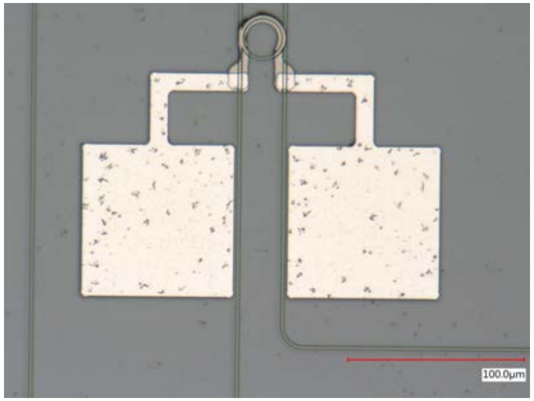
- What is Integrated Photonics?



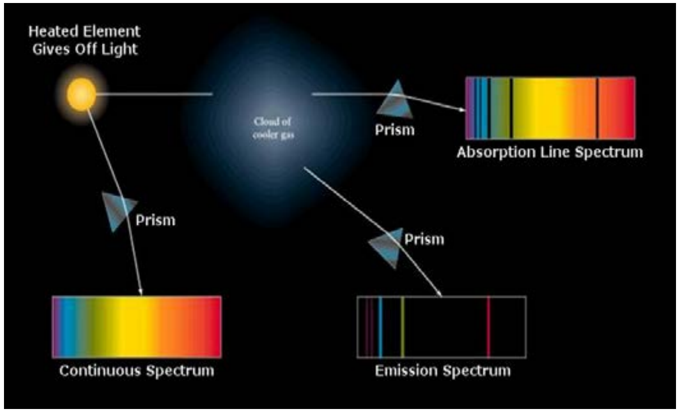




Images Courtesy of Dr. Stefan Preble

Background

- Spectroscopy and Astronomy
  - Involves recording an Object’s frequency spectrum and position in the sky
  - Two main methods
    - Scanning and Post-Processing
    - Specially designed Gratings/Optics



https://www.tes.com/lessons/RRdD9qmkX6Hb8A/spectroscopy-in-astronomy

- Downsides of Traditional Spectroscopy
  - Large
  - Expensive
  - Cumbersome

Integrated Photonics provides an elegant solution to these problems!

Proposed Instrument

- Photonic Integrated Spectrometer
  - Array of Grating Couplers
  - Waveguides to channel the light
  - Ring Resonators to pick off frequencies
  - Photodetectors to measure the light

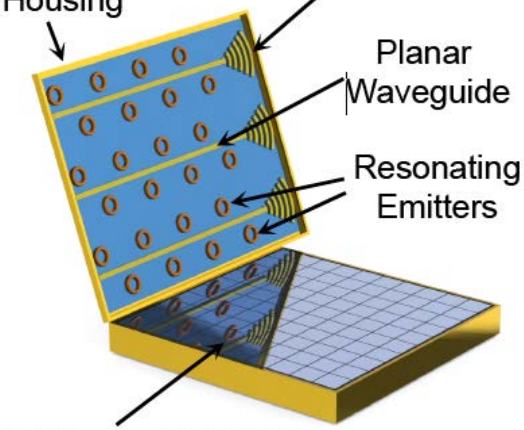
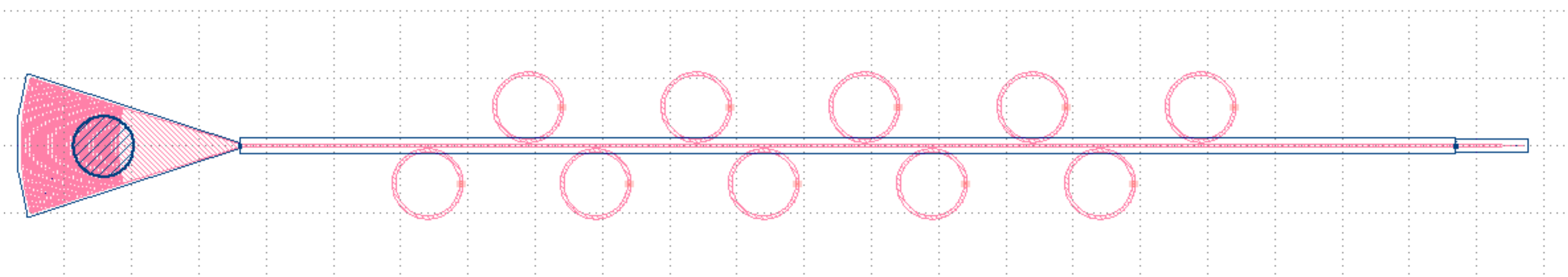
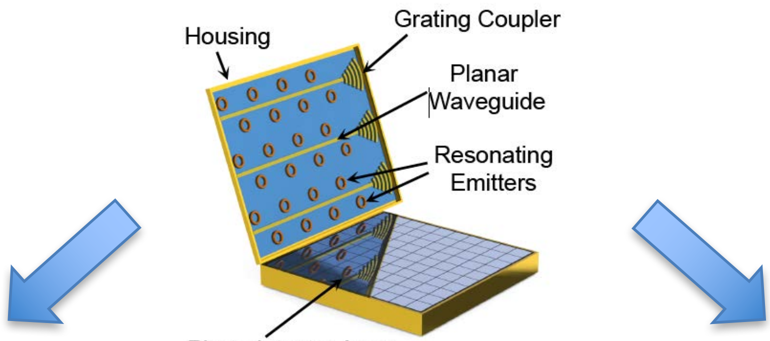


Image Courtesy of Dr. Michael Zemcov



Proposed Instrument



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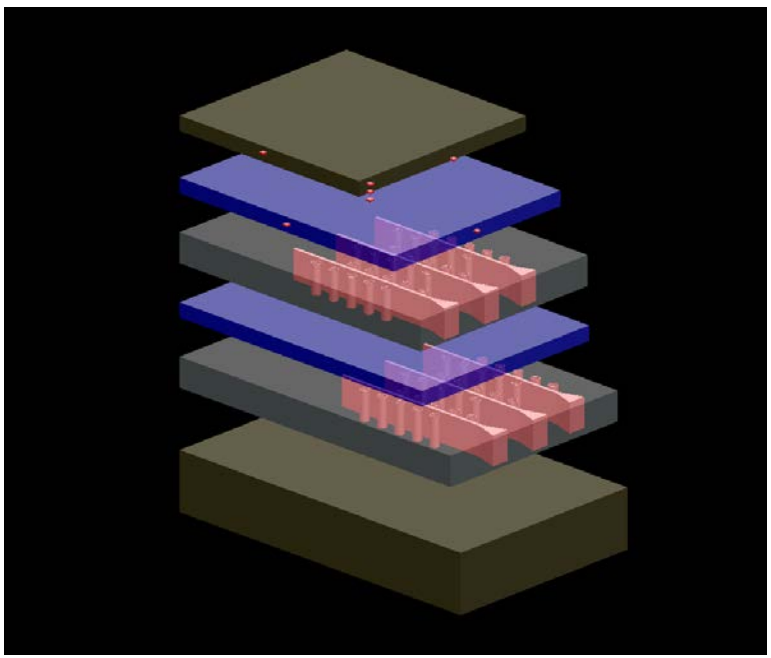
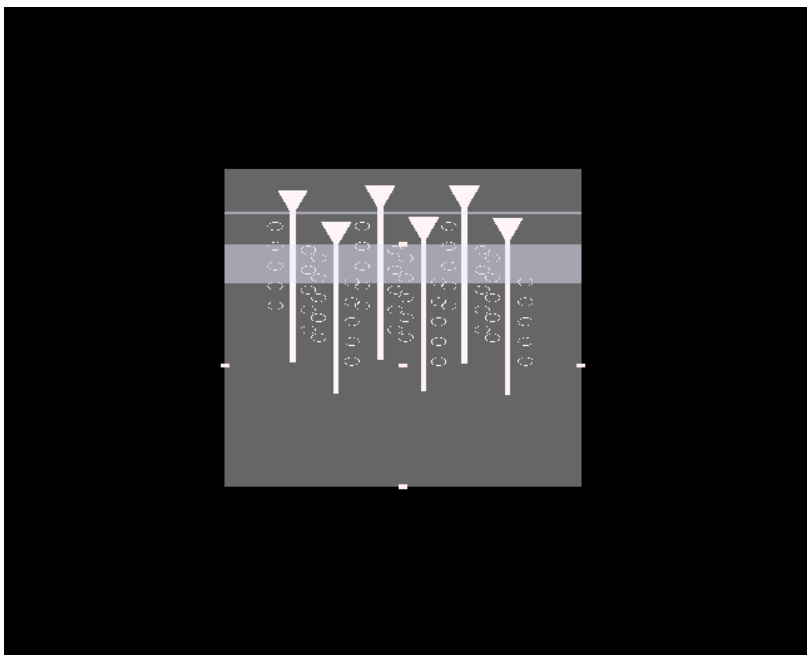
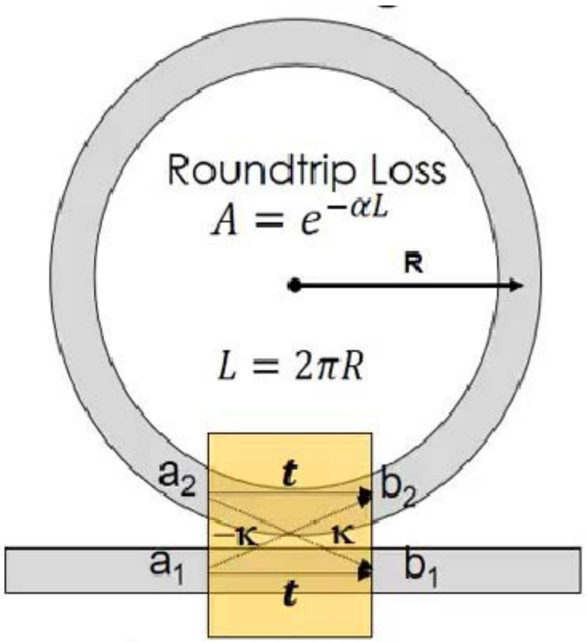




Application of Photonics



$|\kappa|^2$ Power transfer from/to waveguide to/from ring

$|t|^2 = 1 - |\kappa|^2$ Power remaining

α Waveguide Loss [cm^{-1}]

$\beta = \frac{2\pi n}{\lambda}$ Propagation Constant [cm^{-1}]

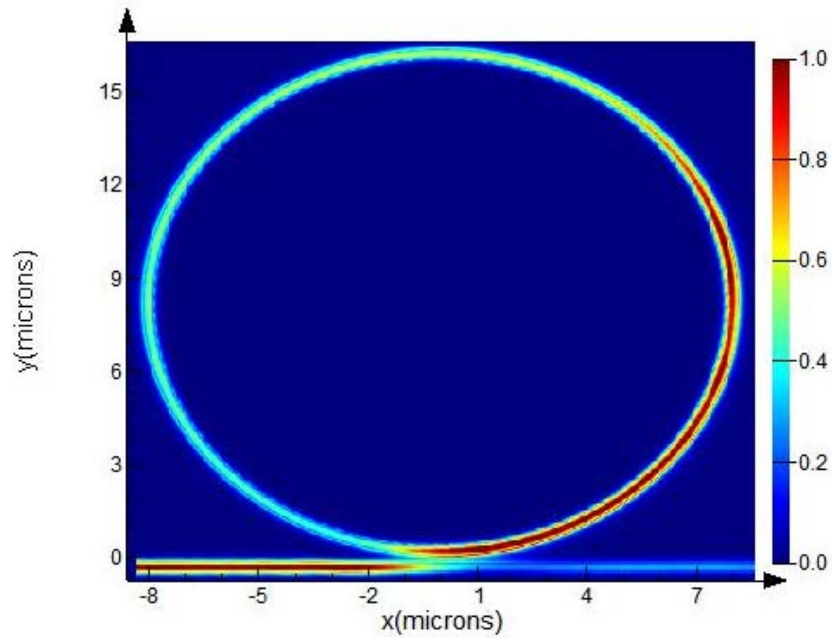
On Resonance when: $\beta L = m 2\pi$

$$m\frac{\lambda}{n} = 2\pi R$$

Critical Coupling

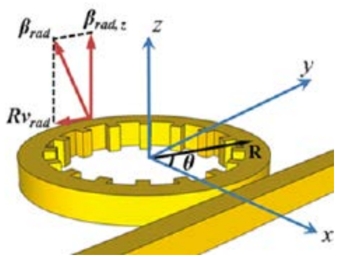
Transmission is zero when:

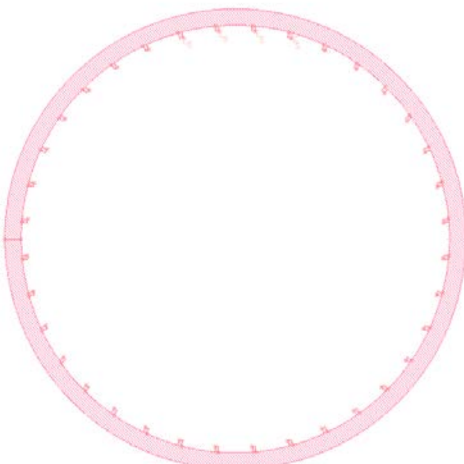
$$t = e^{-\frac{\alpha L}{2}}$$

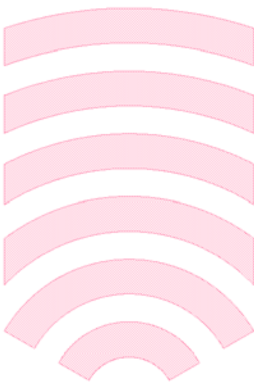


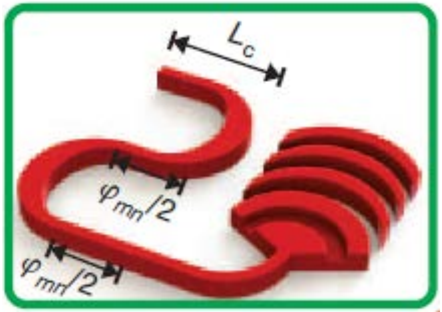
- Main focus of project at the moment
  - Two proposed directions for the project
- Specific structures build to channel light in the Z Direction

- Grated Ring Resonator
- Dielectric Antenna







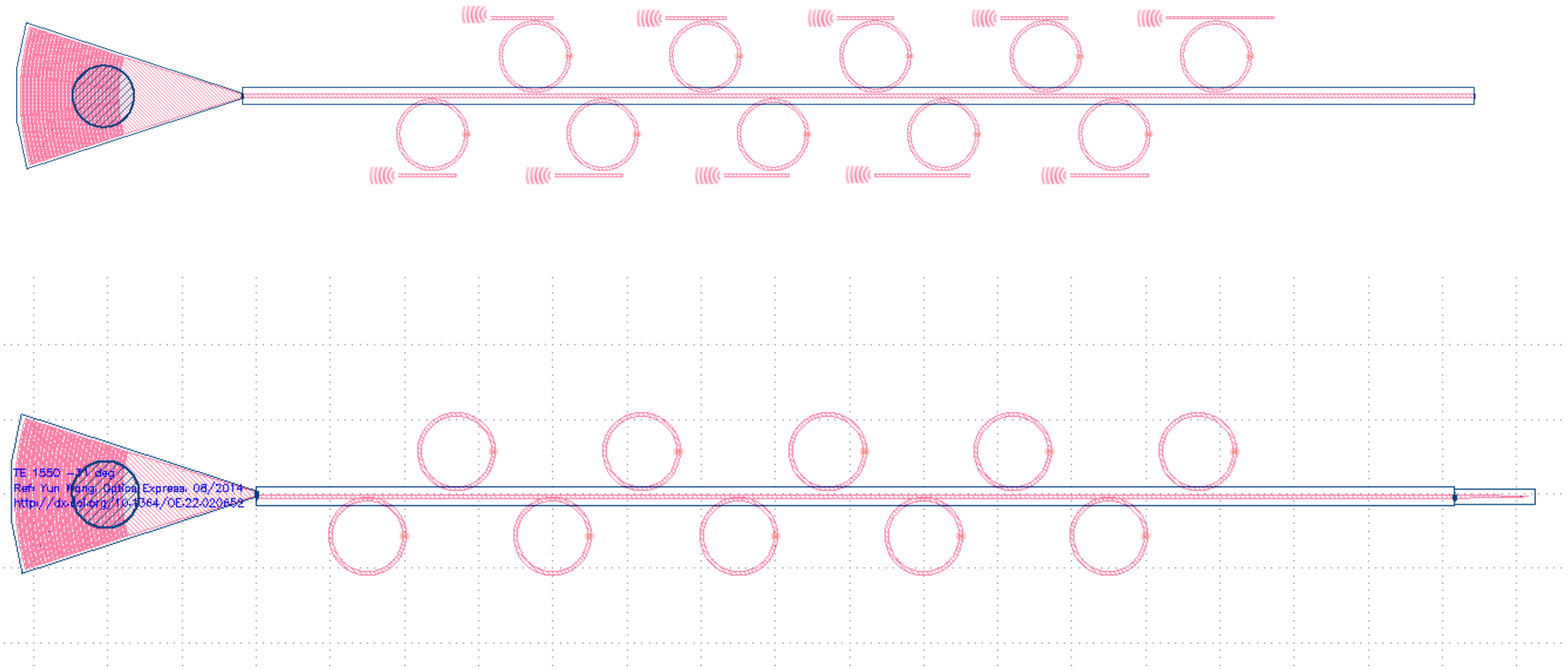


- Which is better???

Image Courtesy of Dr. Michael Zemcov

Research Lab of Electronics, MIT, Nature Vol. 493

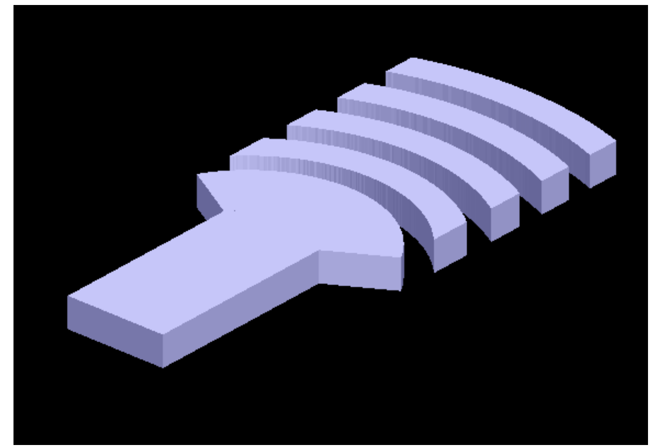
- Side By Side Schematic Comparison

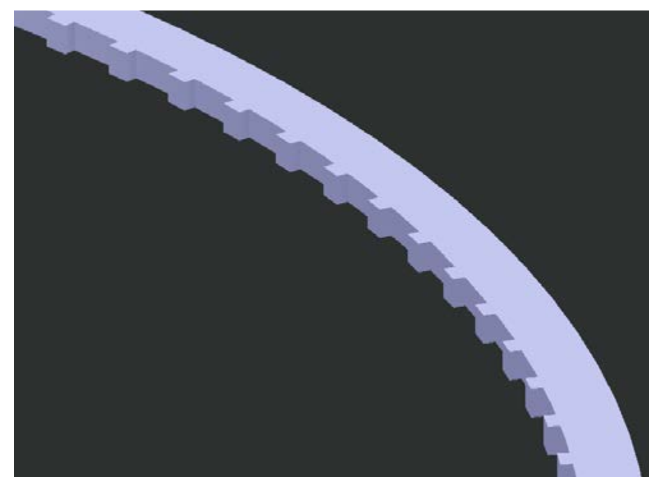


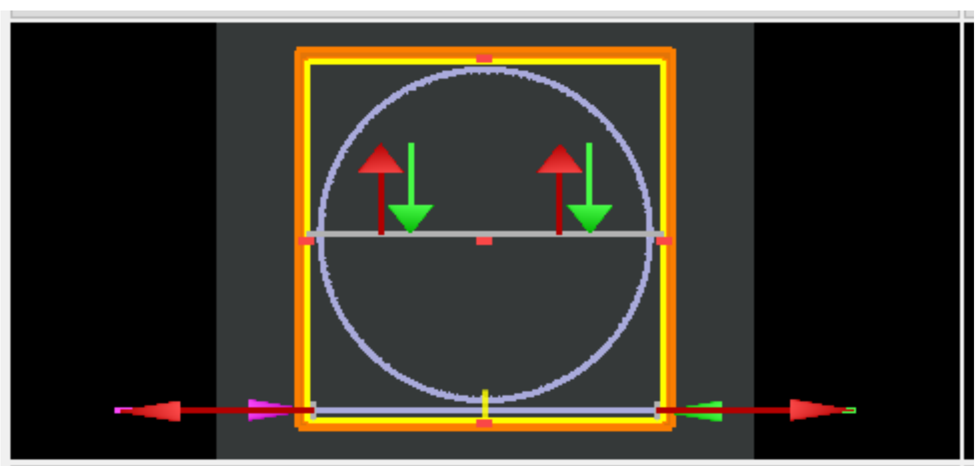
Modeling Structures

- Using Lumerical FDTD
  - Finite Difference Time Domain
  - Solving Maxwell's Equations
- Criteria for comparison:
  - Transmission in the Z direction
  - Maintaining Directionality

lumerical
illuminating the way



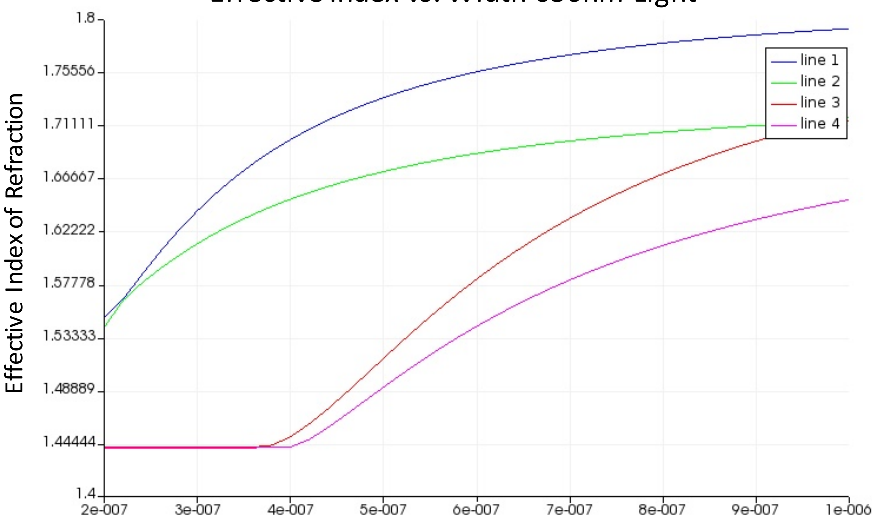




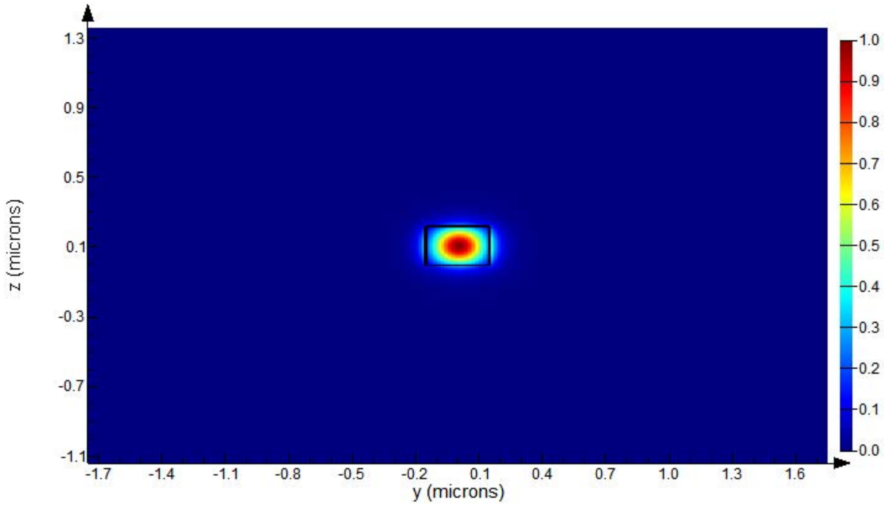
Challenges and Roadblocks

- Building in Si3N4 – Visible Light
  - Not the industry standard Si → Absorbs light < 1,100nm
  - Potentially Larger Structures
  - Potentially different parameters for everything
- Must confirm behavior of light from the beginning
  - Everything is interdependent
  - Beginning with how to confine optimally the light in a waveguide

Effective Index vs. Width 650nm Light



Fundamental TE Mode with 10um radius bend



Challenges and Roadblocks

- Lumerical is not great at running Resonant cavities

- Calculations suggest a grating size of ~10nm - 20nm → $\Lambda = \frac{\lambda}{2(n_{eff})}$
  - Optimal Tooth dimensions are 1/10th the grating period
  - Lower fab limit is ~60nm

- Optimization Algorithms take long time to finish

- After all that Fabrication imperfections can throw a ring off resonance
  - Heaters can be used to tune the Resonators

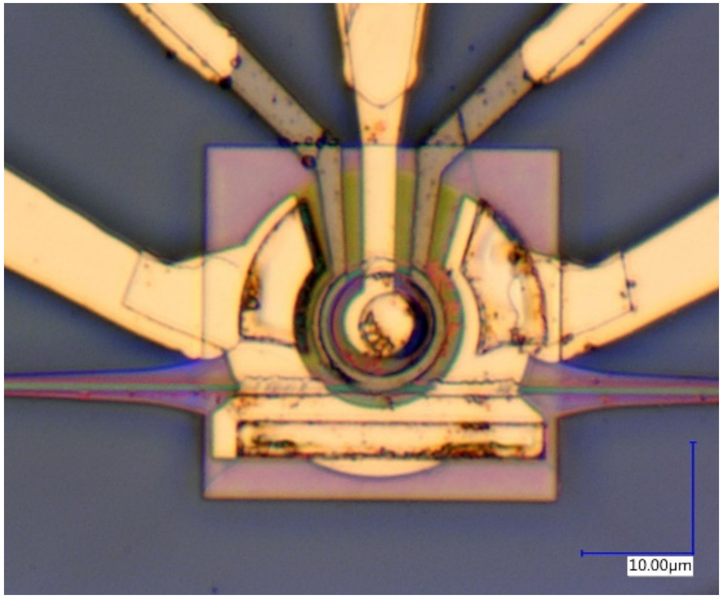


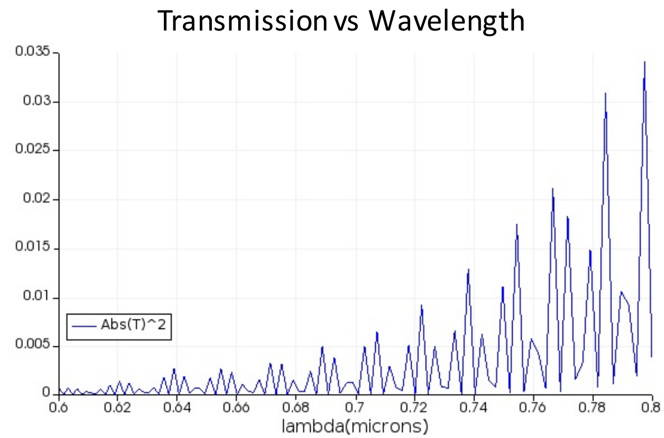
Image Courtesy of Dr. Stefan Preble

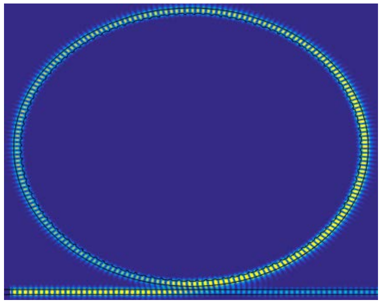
Simulation Methodology

- 1. Lumerical MODE
  - Verify the proper mode of light is contained
- 2. Theoretical Calculations
  - Find the Optimal Grating Tooth Sizes
- 3. Preliminary Simulations
  - Run Simulation with those parameters
- 4. Iterations and optimizations
  - Sweep several parameters to find optimal values

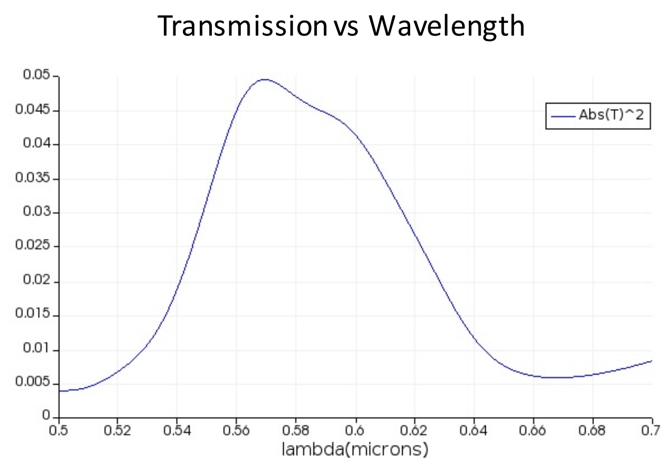
Preliminary Results

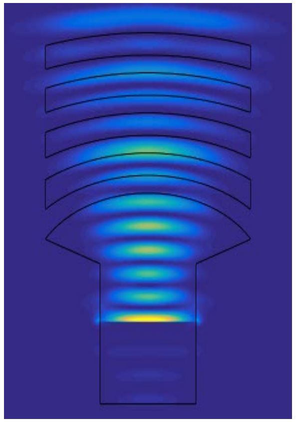
- Grated Ring Resonator
  - Transmission of 2-3%
  - Reasonable directionality





- Dielectric Antenna
  - Transmission of 4-5%
  - Poor directionality





Preliminary Conclusions

- Dielectric Antenna is more promising
  - Structures more suited for fab
  - Marginally better transmission
  - Broadband (Customization not needed)

- Future Plans
  - Optimize grating spacing and fill
  - Test Resonator coupling to antenna
  - Design for both TE and TM Modes

Acknowledgements

- AIM Photonics Future Leaders in Integrated Photonics Program
- RIT Integrated Photonics Group
- RIT Zemcov Research Group