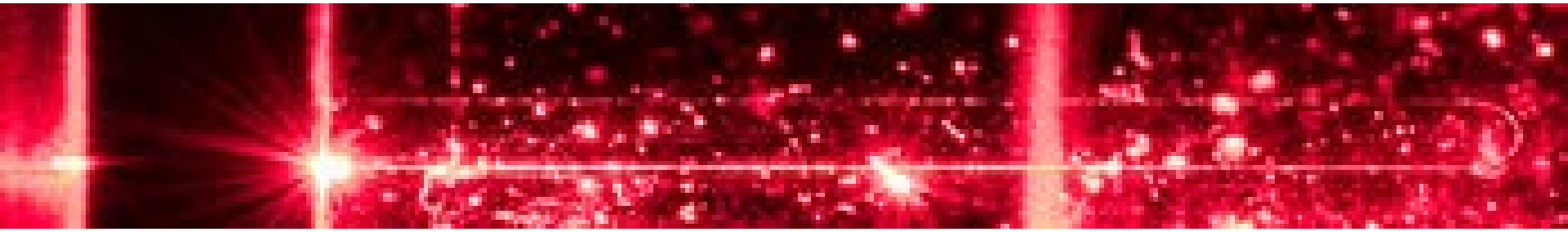
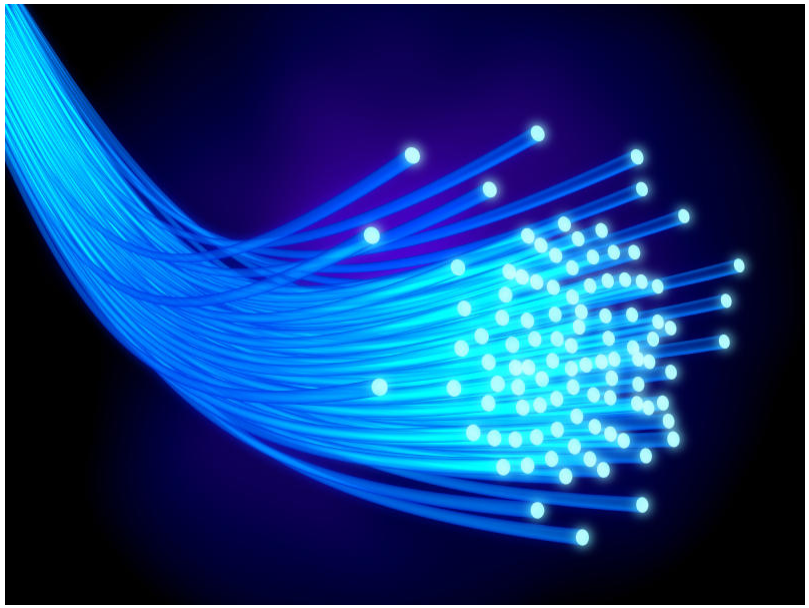
Direct Write Optical Waveguide Fabrication in Organic Films using a Heidelberg Laser Writer

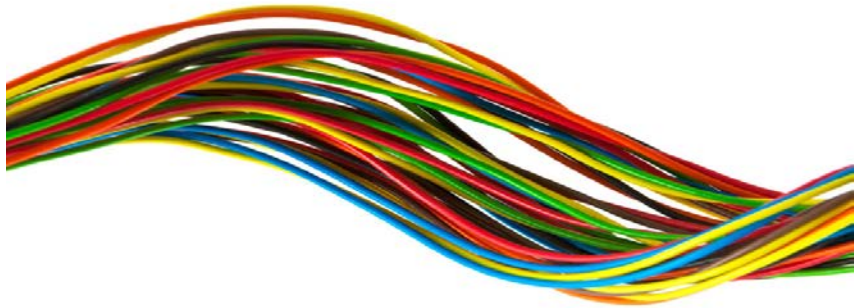


Project by Ryan Moss
Advisor- Dr. Stefan Preble
Special Thanks Dr. Hirschman,
Dr. Ewbank, Dr. Pearson

Optical vs. Electronic Interconnects

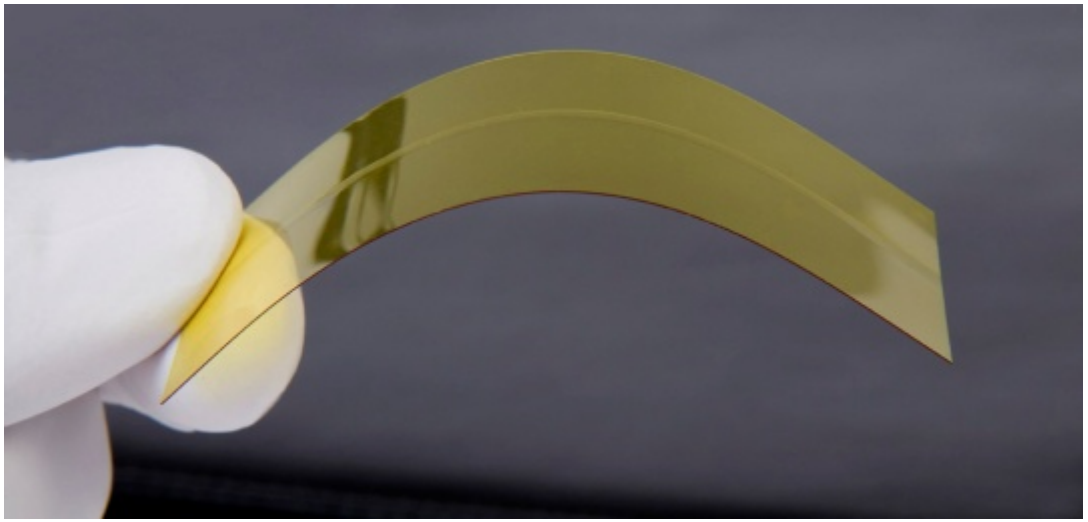
- Optical connections have a higher data density due to the high frequency of light.
- Lower power consumption





Organic/Printing Motivations

- Printing waveguides is a simple/ cheap way to fabricate onto any substrate
- Flexibility
- Biological Applications for throw away photonics



Material Selection

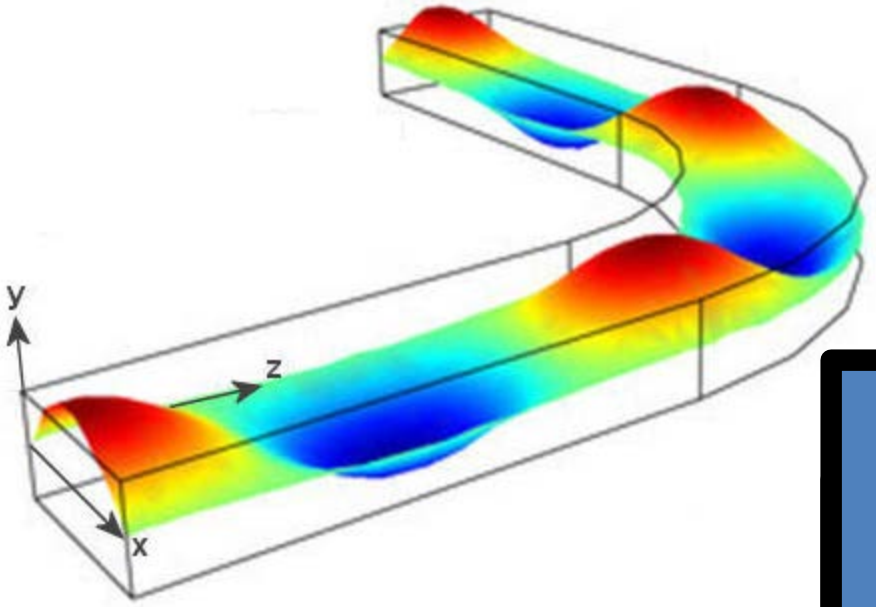
Waveguide (Photoresist Material)

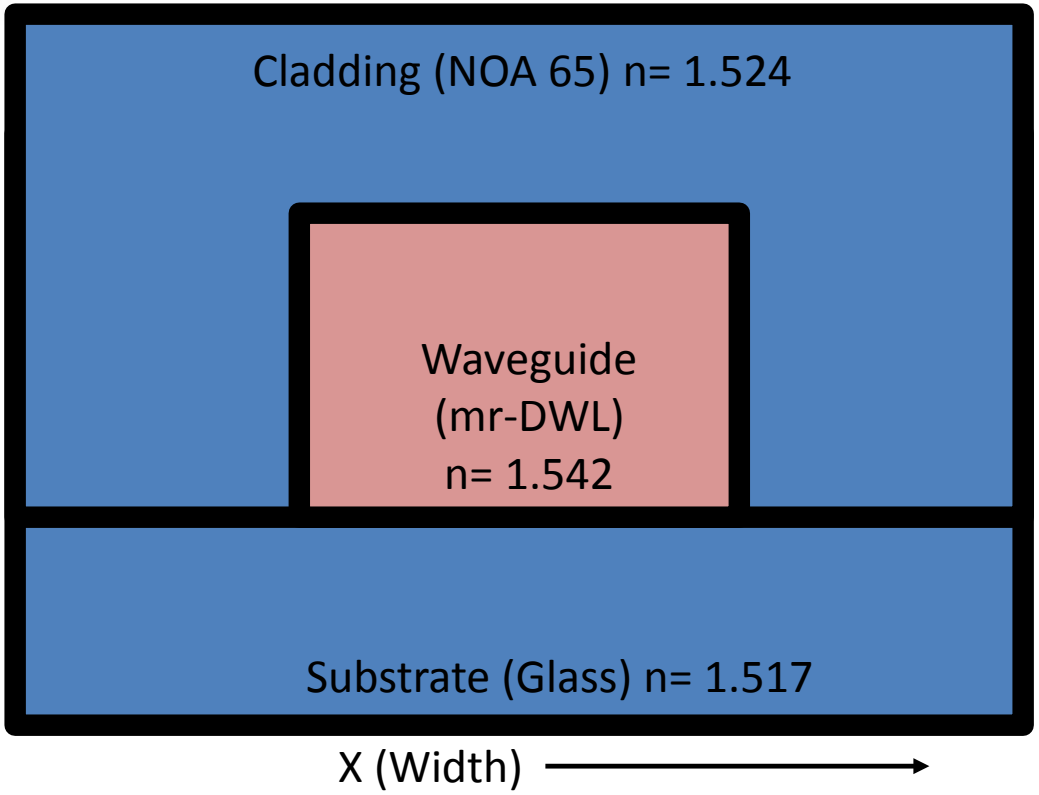
Optical Properties- A high refractive index difference is good for coupling while a small difference is good at suppressing higher order modes.

Exposure Requirement- Heidelberg DWL 66+ (405nm), Negative resist

Cladding (NOA 65)- Index should match substrate

Basic Design





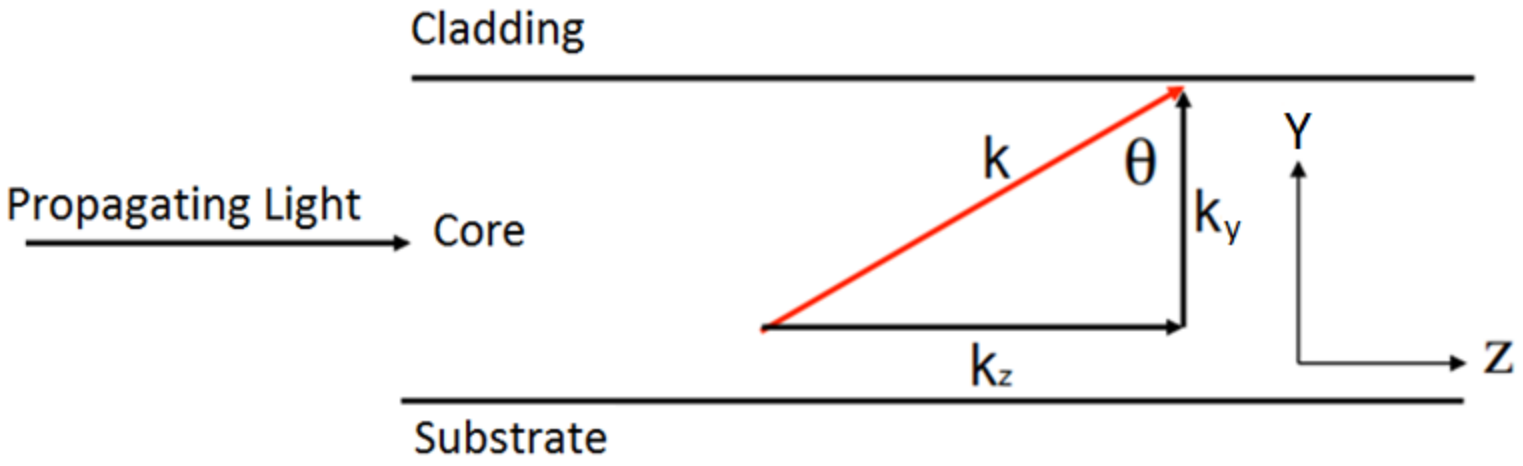
Theory

Critical Angle

$$\theta_{c2} = \sin^{-1}\frac{n_s}{n_w} \qquad \theta_{c1} = \sin^{-1}\frac{n_c}{n_w}$$

Resonant Modes

$$k_{x,y} = \frac{n_w\omega}{c}\cos\theta \qquad k_z = \frac{n_w\omega}{c}\sin\theta$$



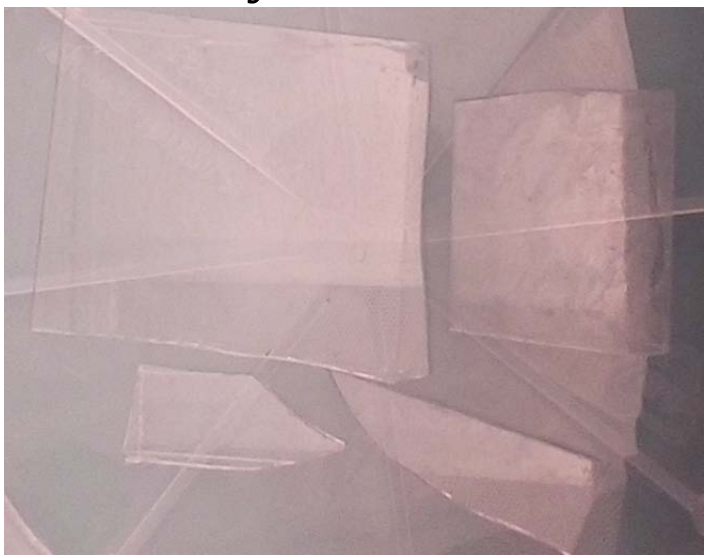
Fabrication

1) **Oxygen Plasma Surface Treatment**
2) **Coat mr-DWL-** 40mL/40mL dilution mr-DWL-5/SU-8 thinner

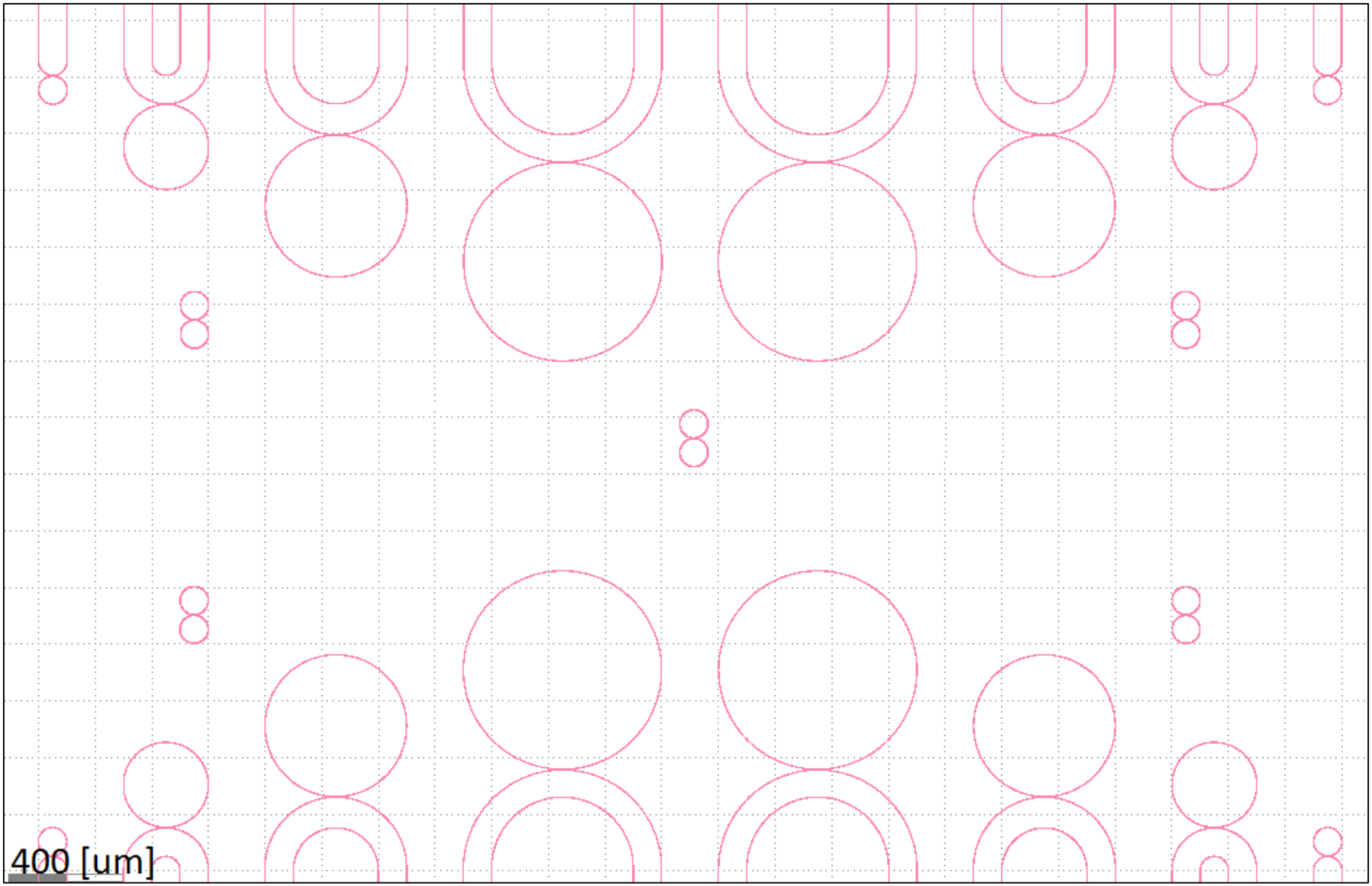
Spin Speed [rpm]	Thickness [um]
3000	1473
4000	1181
5000	1013

Post Application Bake	
Temperature [°C]	Time [min]
65	4

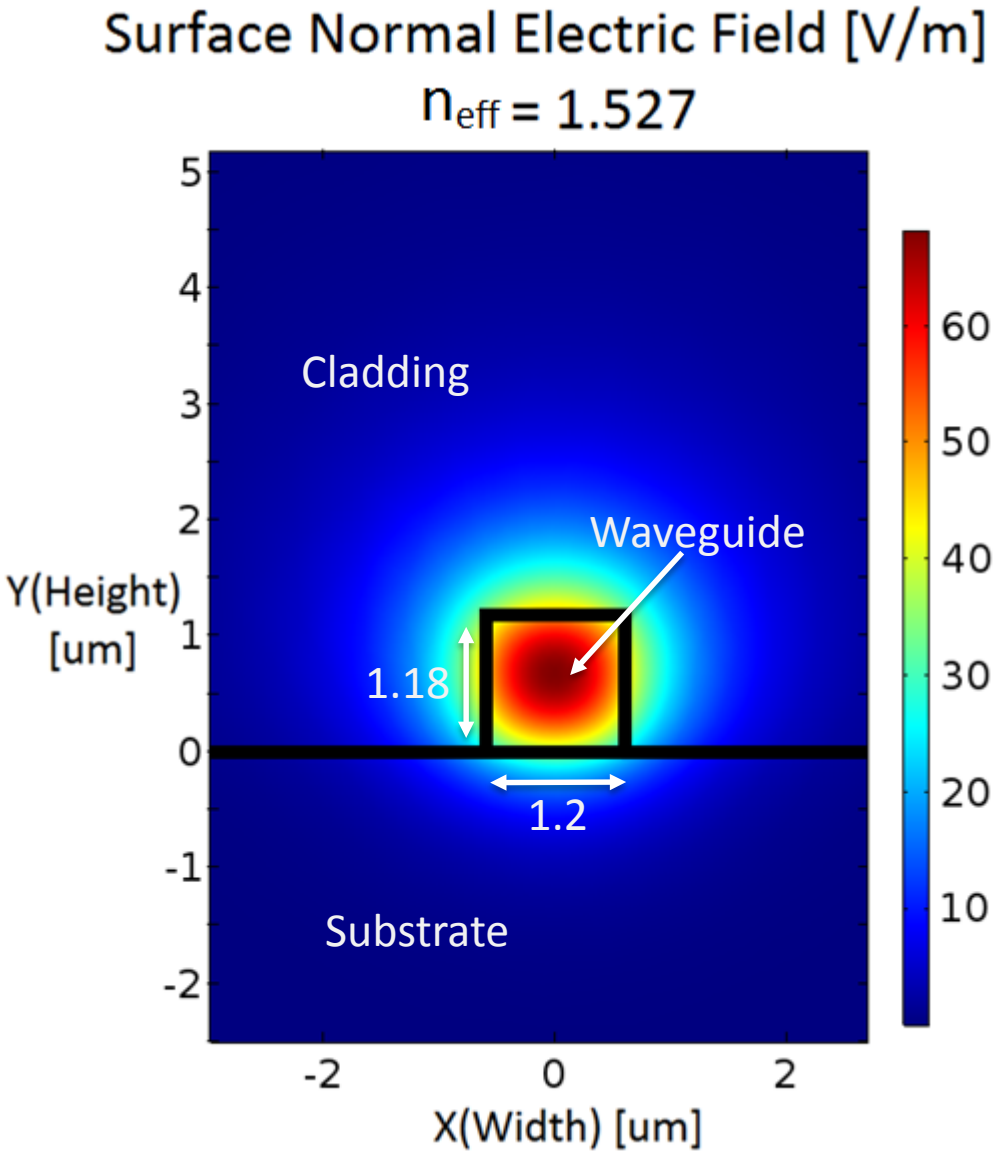
3) **Negative Exposure on Heidelberg**
   - Important Parameters- 60% Intensity, 200mW Power
4) **Post Exposure Bake-**1 minute 65°C followed by 3 minutes 95°C
5) **Development-** PGMEA 3.5 minutes.
6) **Cladding NOA 65**
   - Spin speed 3000rpm
   - UV flood cure 4.5[J/cm^2]
7) **Scribe/Cleave….**



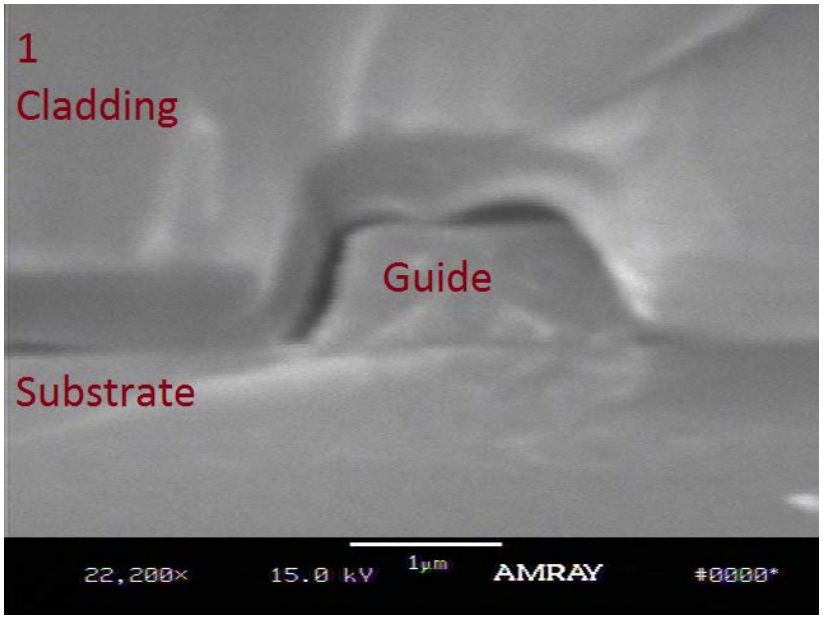
Final Layout



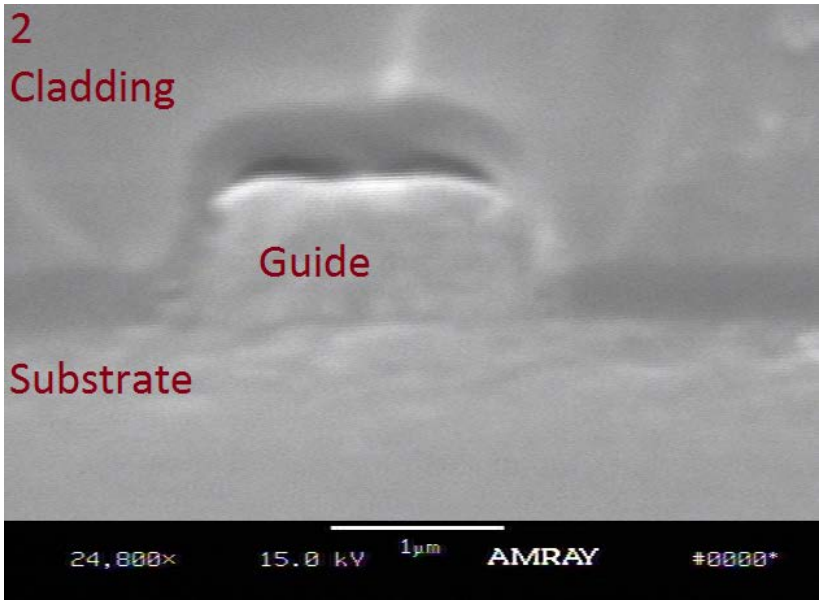
Simulation using Comsol

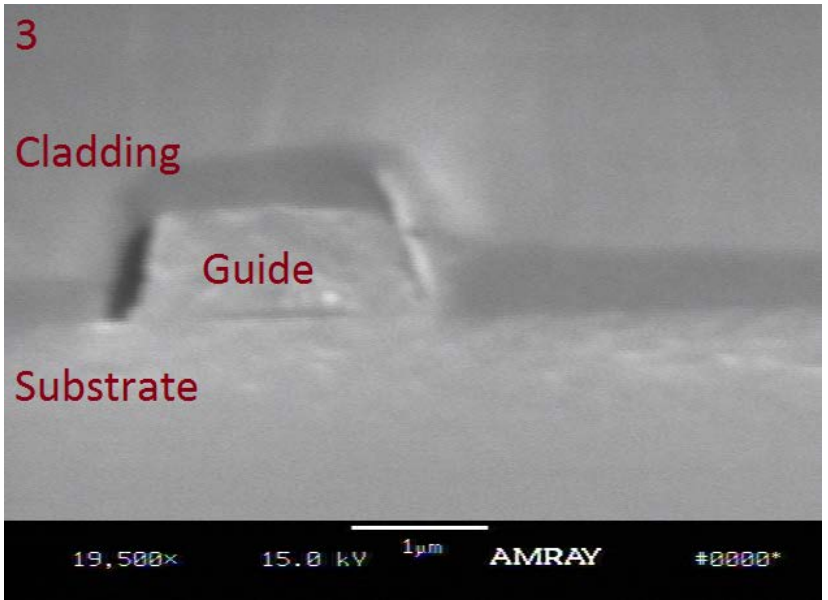


Scanning Electron Microscope

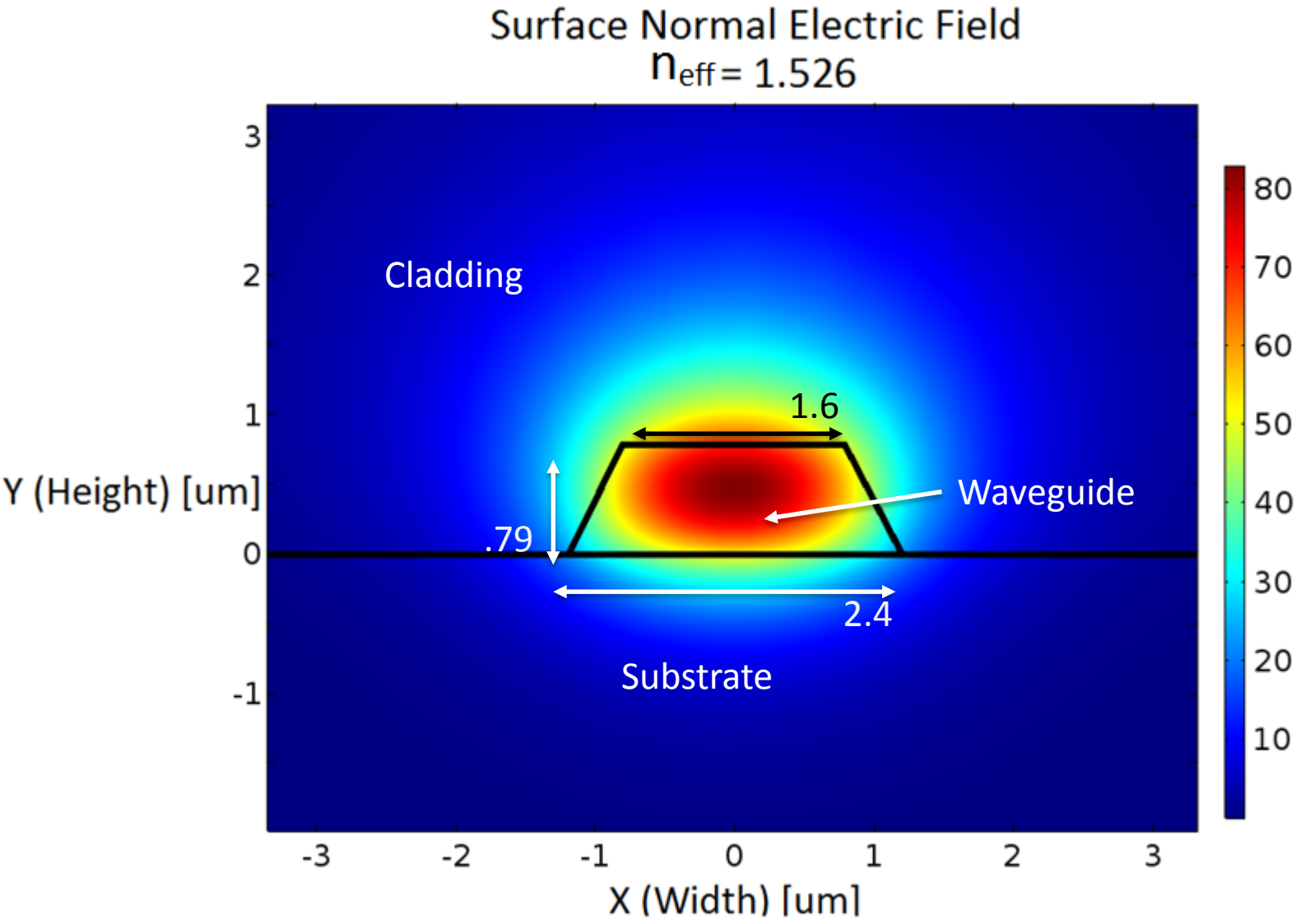


SEM Measurements [um]			
	1	2	3
Top	1.42	1.75	1.64
Bottom	2.35	2.41	2.50
Average Width	1.86	2.07	1.93
Average Height	0.79	0.79	0.79

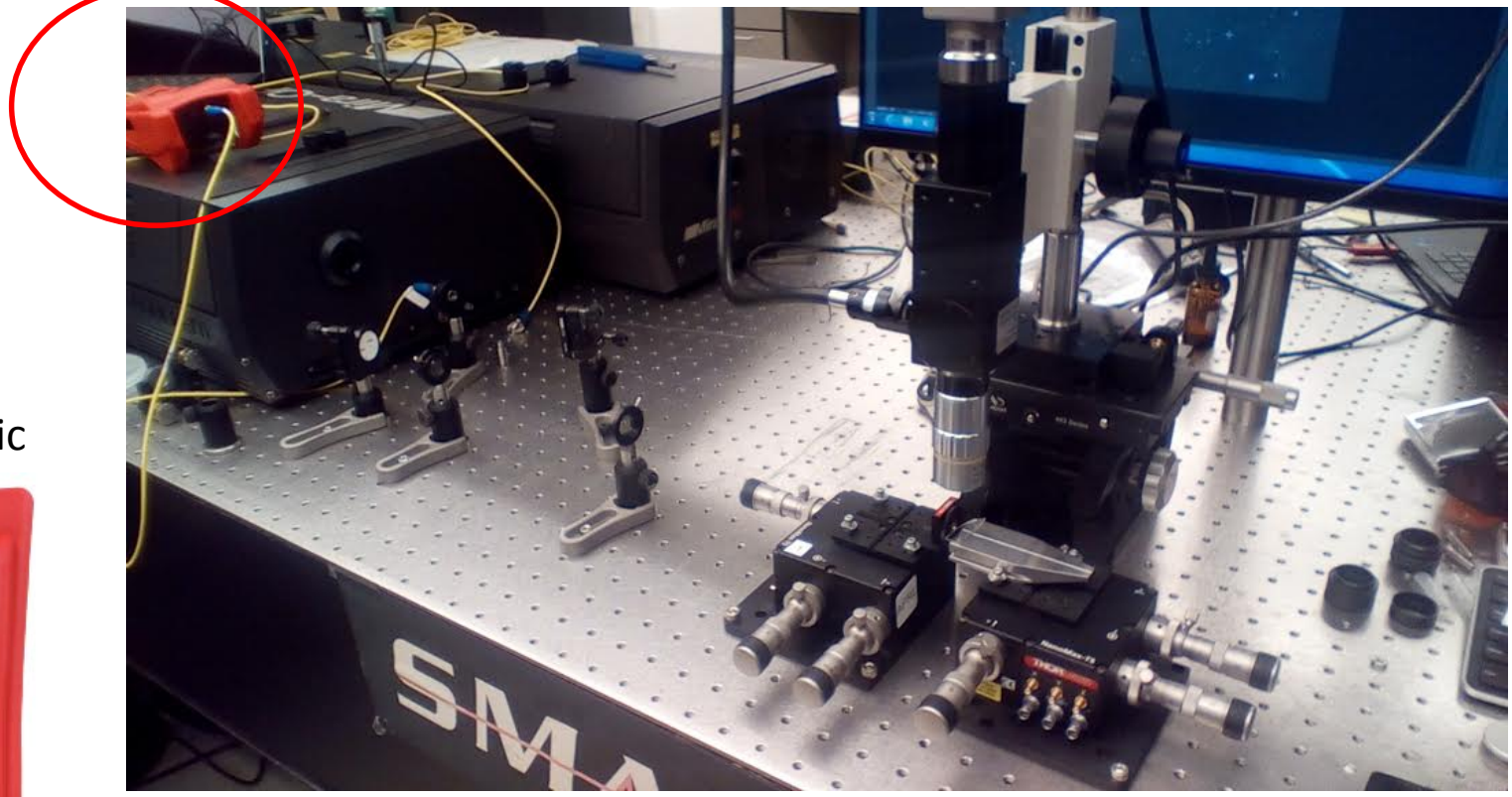




Simulation 2 SEM



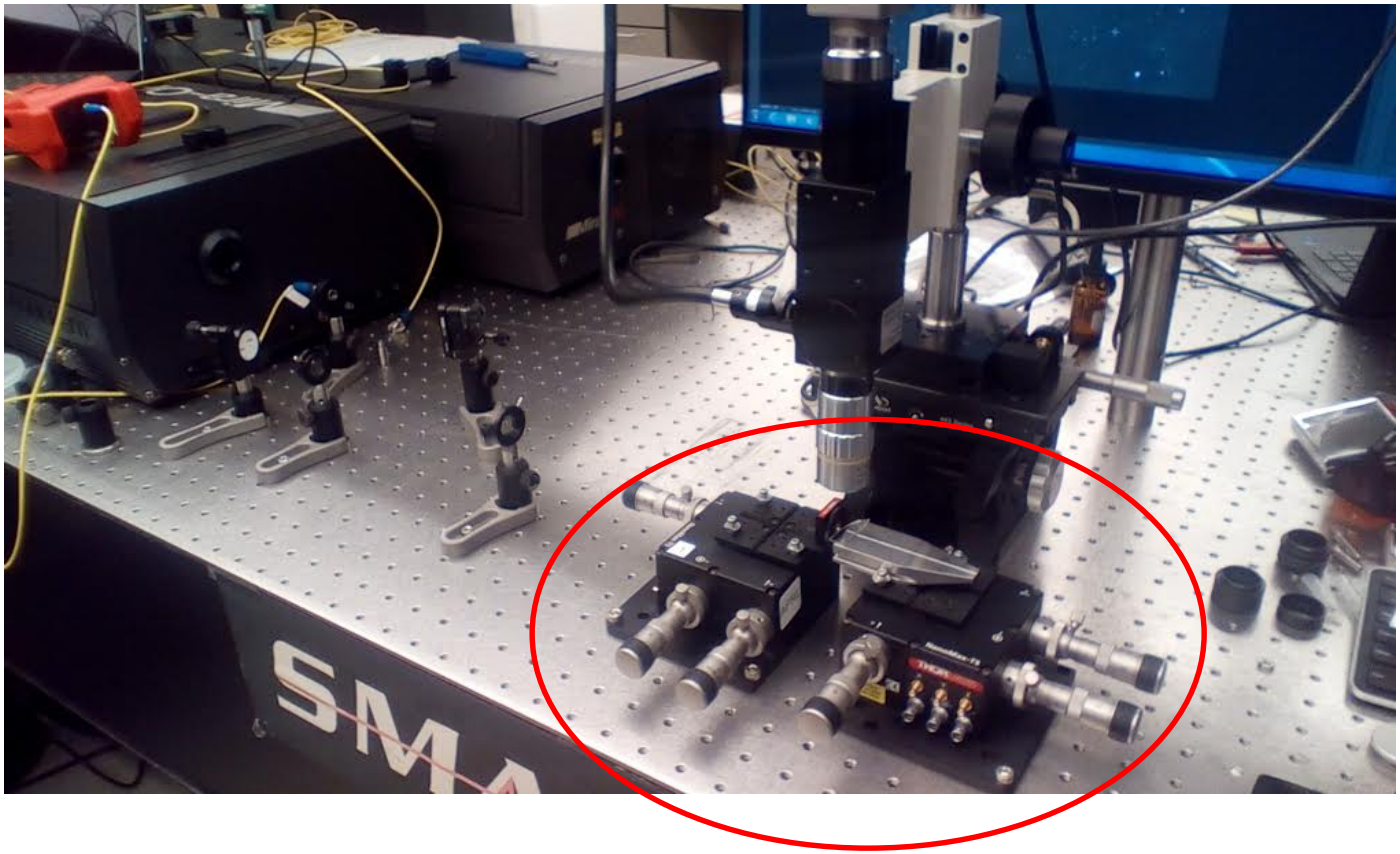
Testing



Light Source
Fisher Scientific

Outpower	1mW min
Wavelength	650nm Typ

Testing



Focusing Lens stage

Lens is 4.5mm focal length

Initial beam alignment

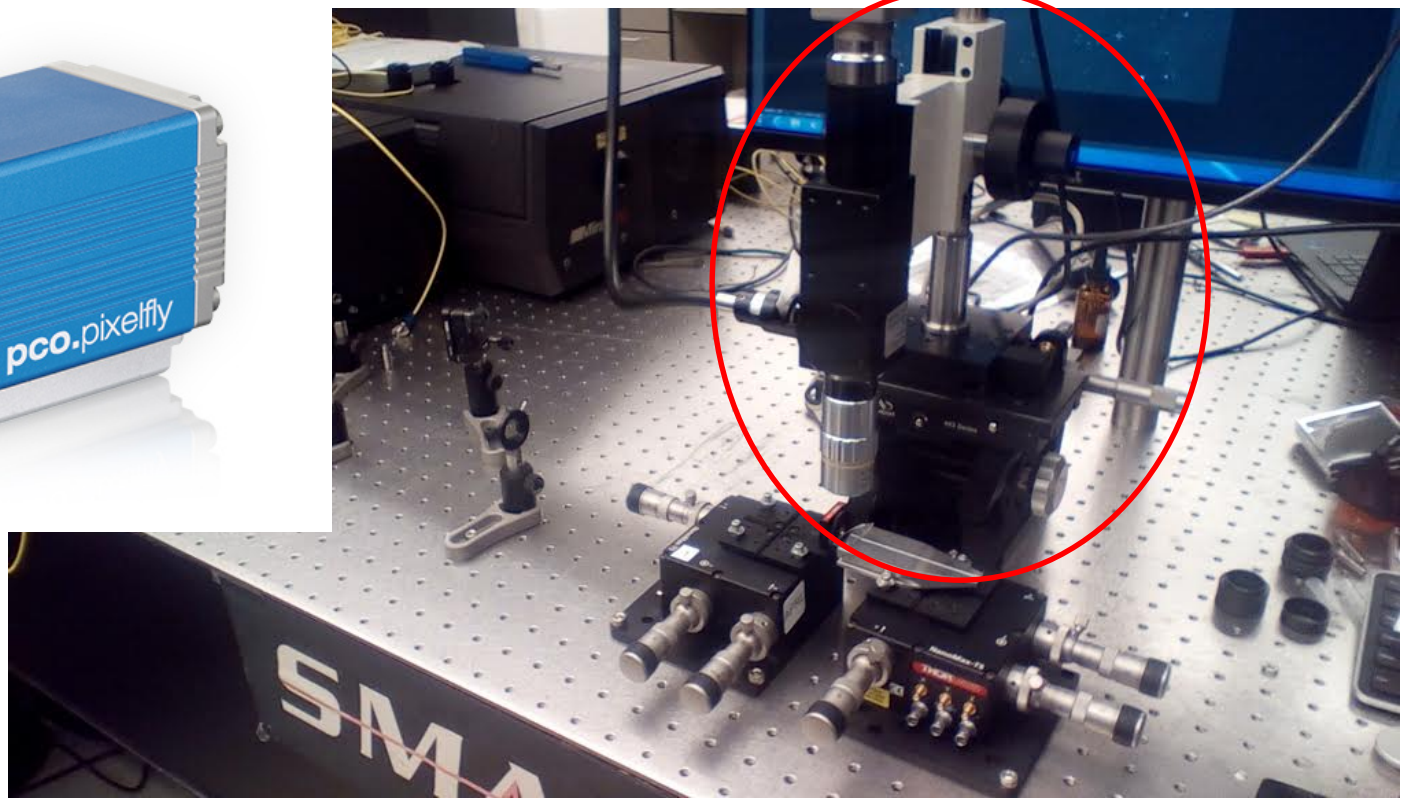
Using X and Z controls

Sample Stage

Final coupling

Using movement in X,Y and Z (no rotation controls)

Testing

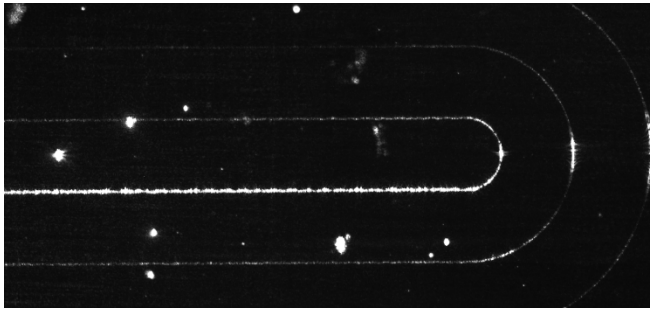


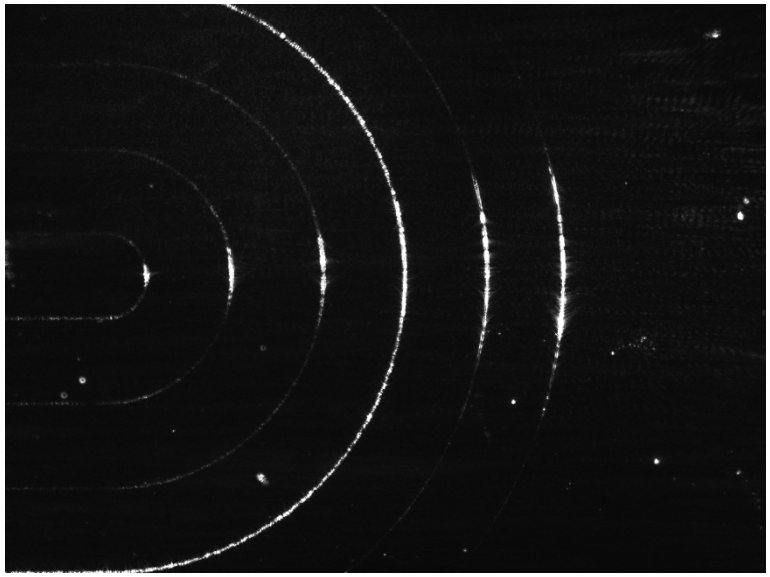
Microscope

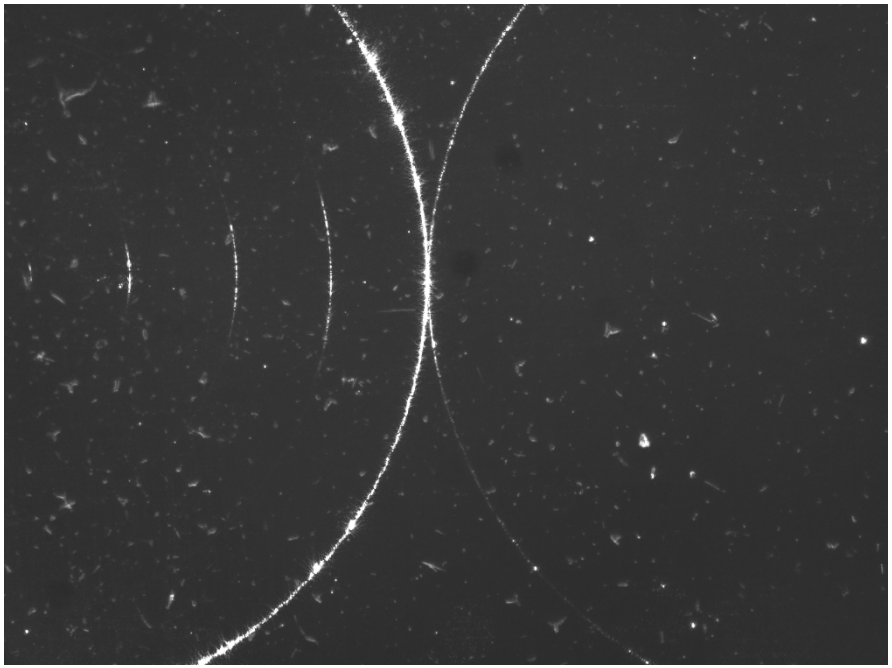
Pco.pixelfly camera mounted onto a microscope for alignment

Results

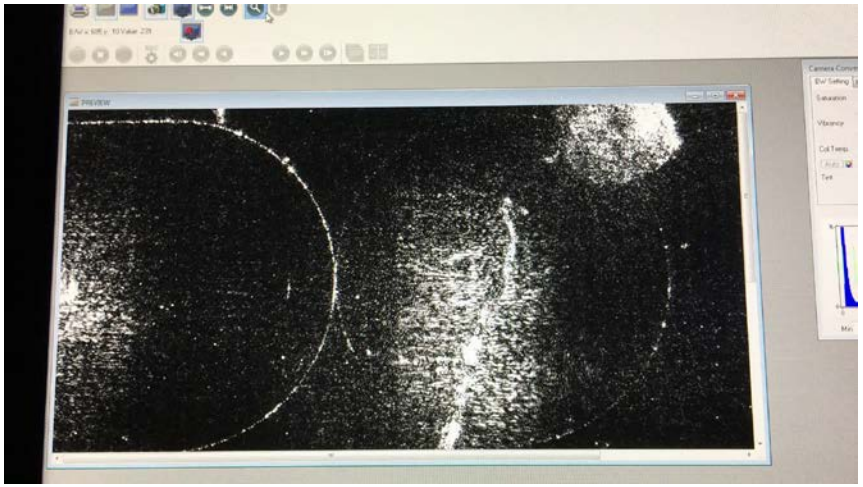
- Visual Results







Resonance!



- 350um radius with .9um nominal spacing

$$QualityFactor = \frac{\lambda}{\Delta\lambda}$$

- Quality Factor for T_e mode 75-90k
- Quality Factor for T_m mode 25-35k

Future

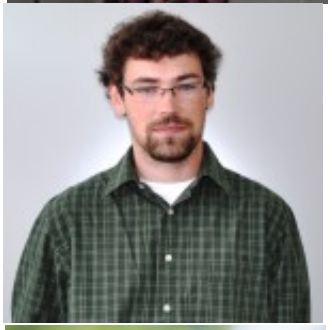
Next Step

- Optimization of processing and materials
- Acquisition of output data
- Additional optical devices

Long Range

- Short course for optical waveguide devices
- Additional substrates

Acknowledgements
RIT Nanophotonics Group



- Dr. Preble provided me with this project. His general mastery of optics was available to me throughout.
- Jeffrey Steidle was instrumental in getting the beam aligned and coupled into a waveguide.
- Michael Fanto provided the excellent visual picture for this presentation and was generally helpful

Acknowledgements

- Dr. Hirschman was instrumental in this project securing the Heidelberg tool for my use.
- He instructed me in it’s use
- And was available for my general abuse throughout the project

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Acknowledgements SMFL

- Sean O'Brien did the certification on every tool I used during this project.
- He helped me using the SEM.
- And he is the most able to help using the Heidelberg direct write system
- The SMFL staff is great at what it does

Pictures from the internet

- http://www.frankswebspace.org.uk/ScienceAndMaths/physics/physicsGCE/radioComms.htm
- http://www.ictxwavemedia.net/wordpress/2015/06/15/what-i
- http://joelynchelectrical.com/project/wiring-and-re-wiring/s-optical-fiber/