

I. Project Objectives

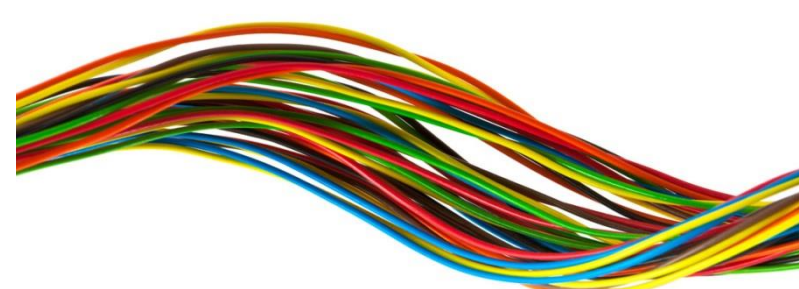
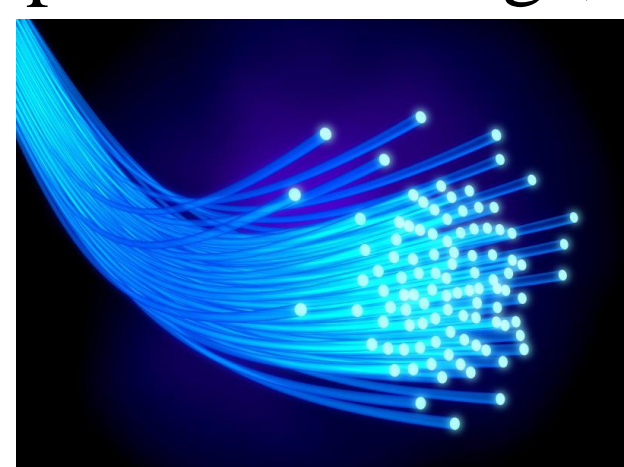
Goal: Optical Waveguide Devices.

- Material selection
- Fabrication
- Testing

II. Motivation

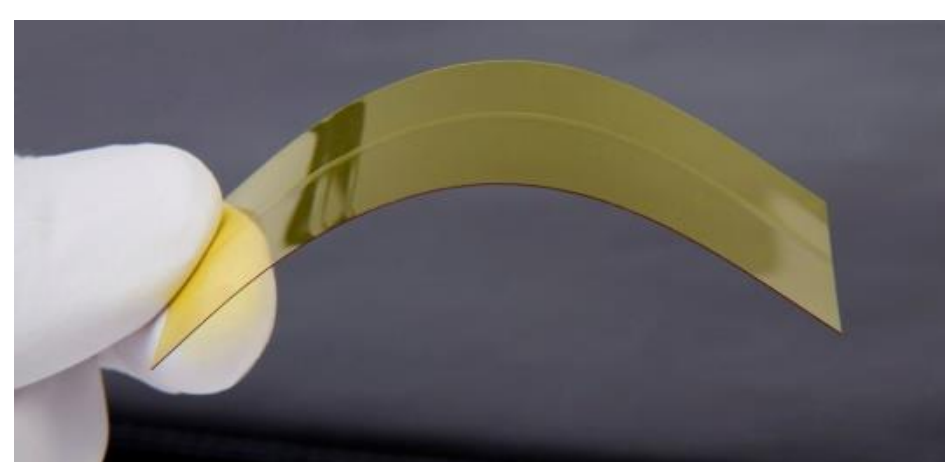
Optical vs. Electronic Connections

- Higher data density due to the frequency of light
- Lower power consumption
- coplanar crossings, couplers, and splitters



Organic/Printing

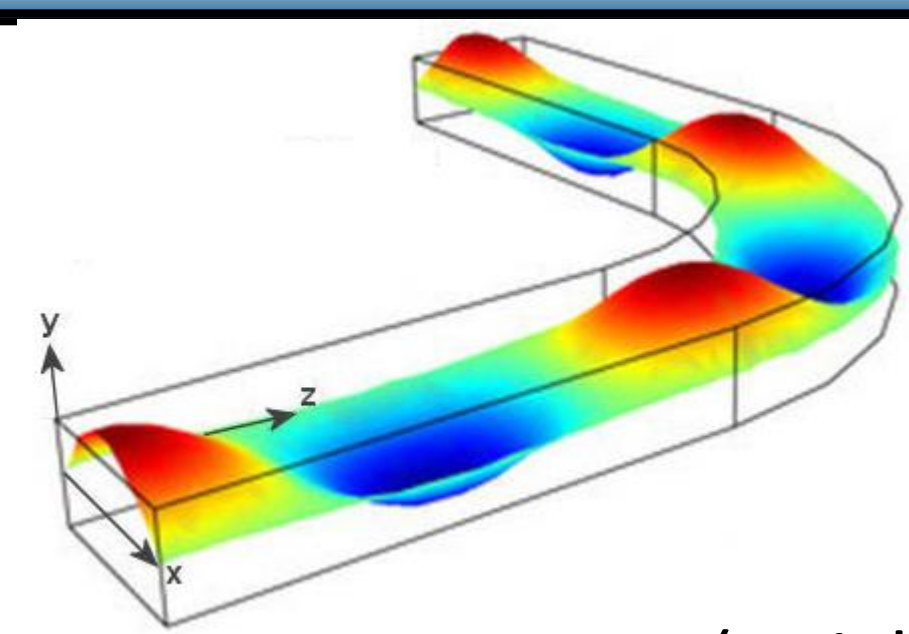
- simple/cheap
- any surface



Example Applications

- Throw away biological sensors
- Devices on flexible surfaces
- optoelectronic devices

III. Theory



Y (Height)

Critical Angle

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

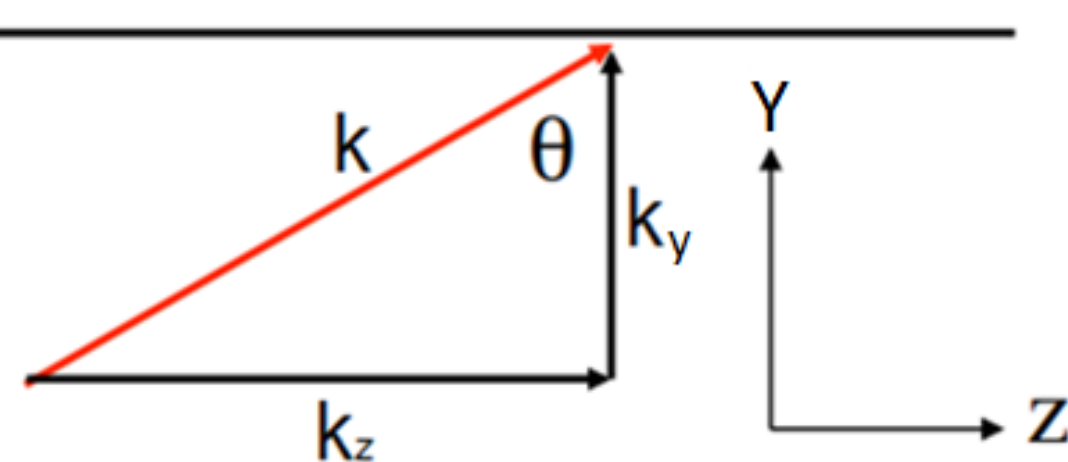
Calculating Resonant Modes

$$k_x = \frac{n_w \omega}{c} \cos \theta \quad k_z = \frac{n_w \omega}{c} \sin \theta$$

Cladding

Propagating Light

Substrate



IV. 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

V. 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) Development in PGMEA 3.5 minutes.

5) Cladding NOA 65

Spin speed 3000rpm, UV flood cure 4.5[J/cm²]

6) Scribe/Cleave....

VI. Simulation

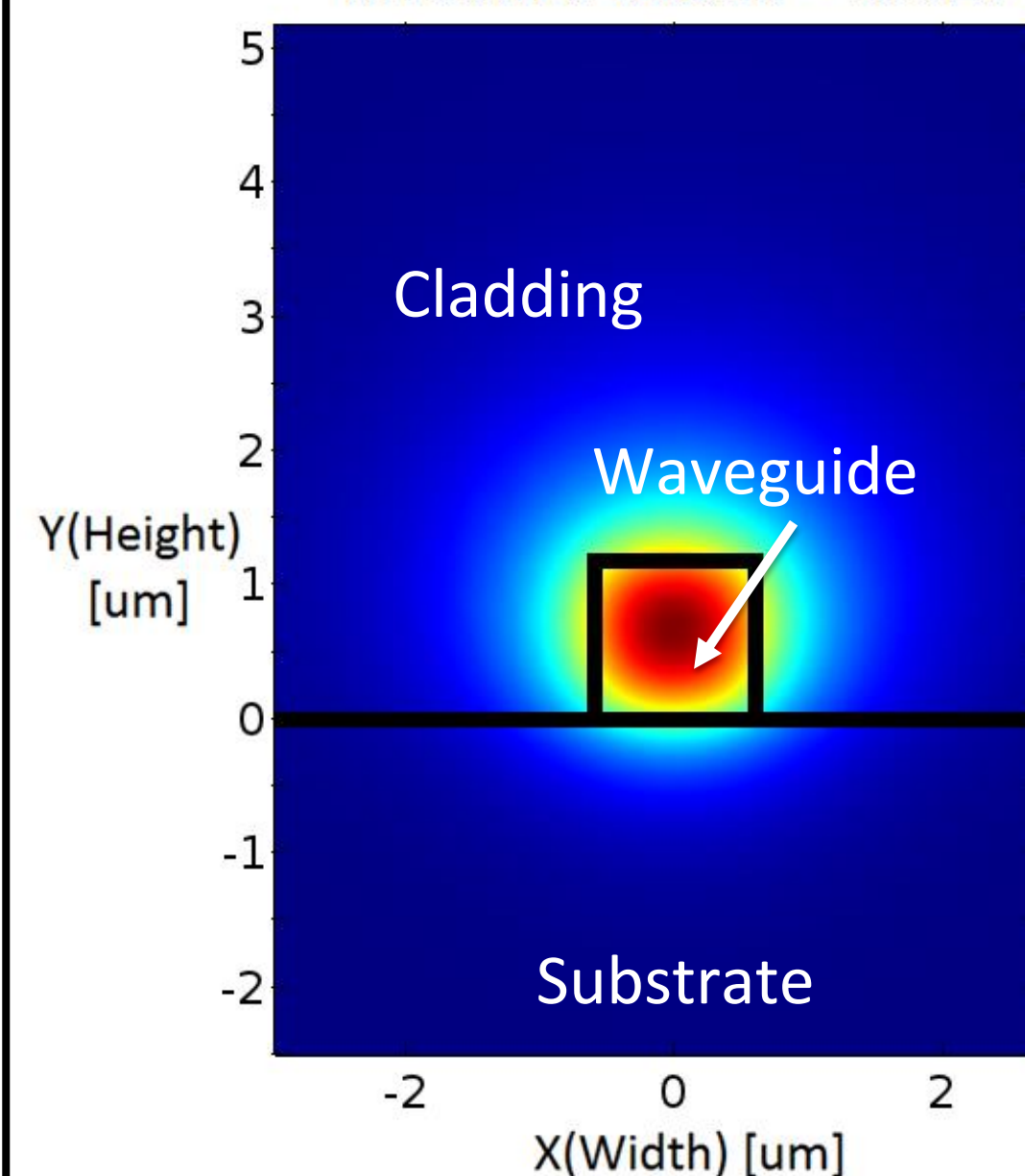
Simulation in Comsol Software-Indexes used shown in Theory

Dimension square-1.2um width by 1.18um height.

trapezoid- top 1.6um, bottom 2.42um by .79um height

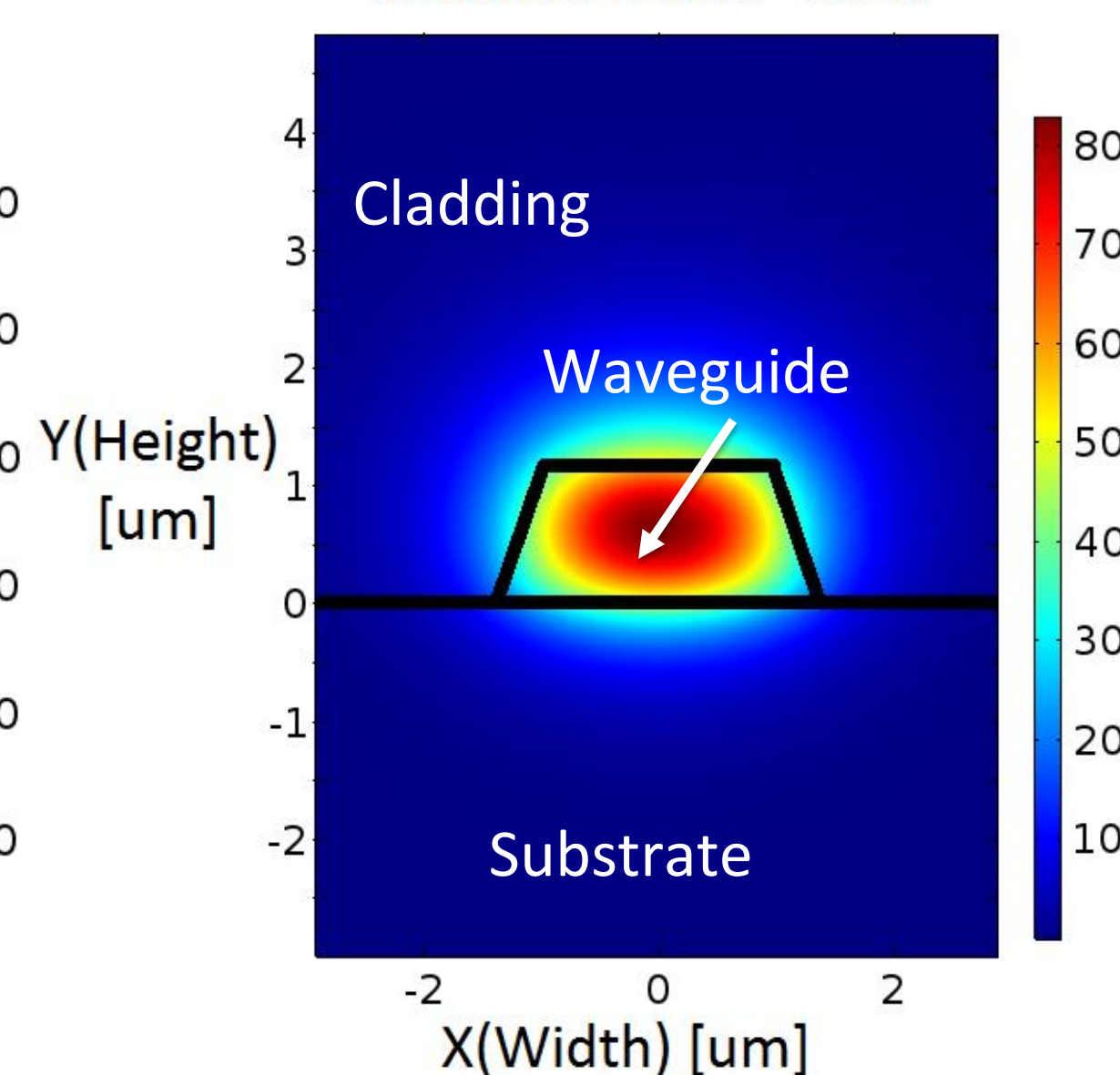
Surface Normal Electric Field [V/m]

Effective Mode = 1.527

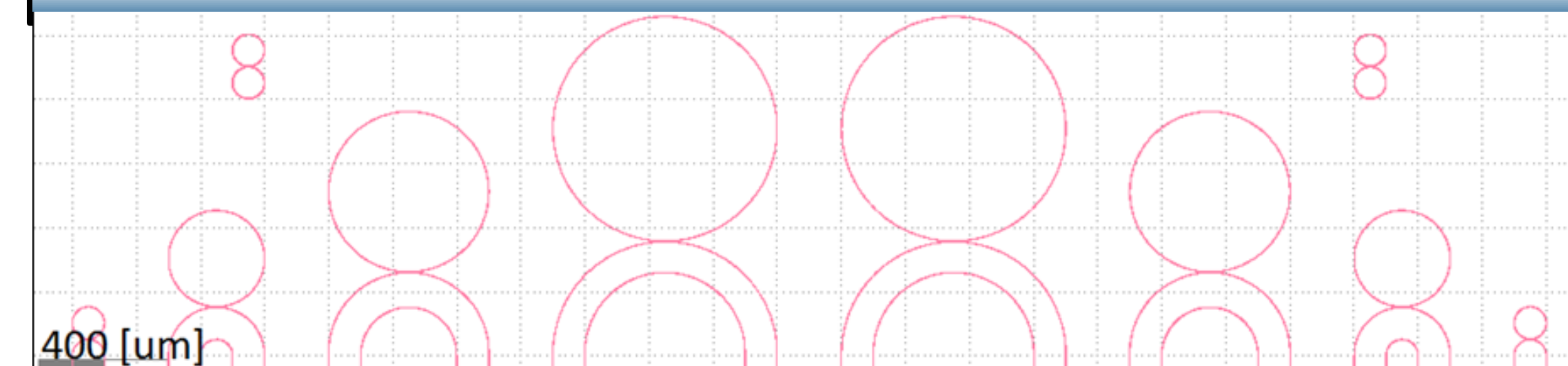


Surface Normal Electric Field [V/m]

Effective Mode =1.53



VII. Layout

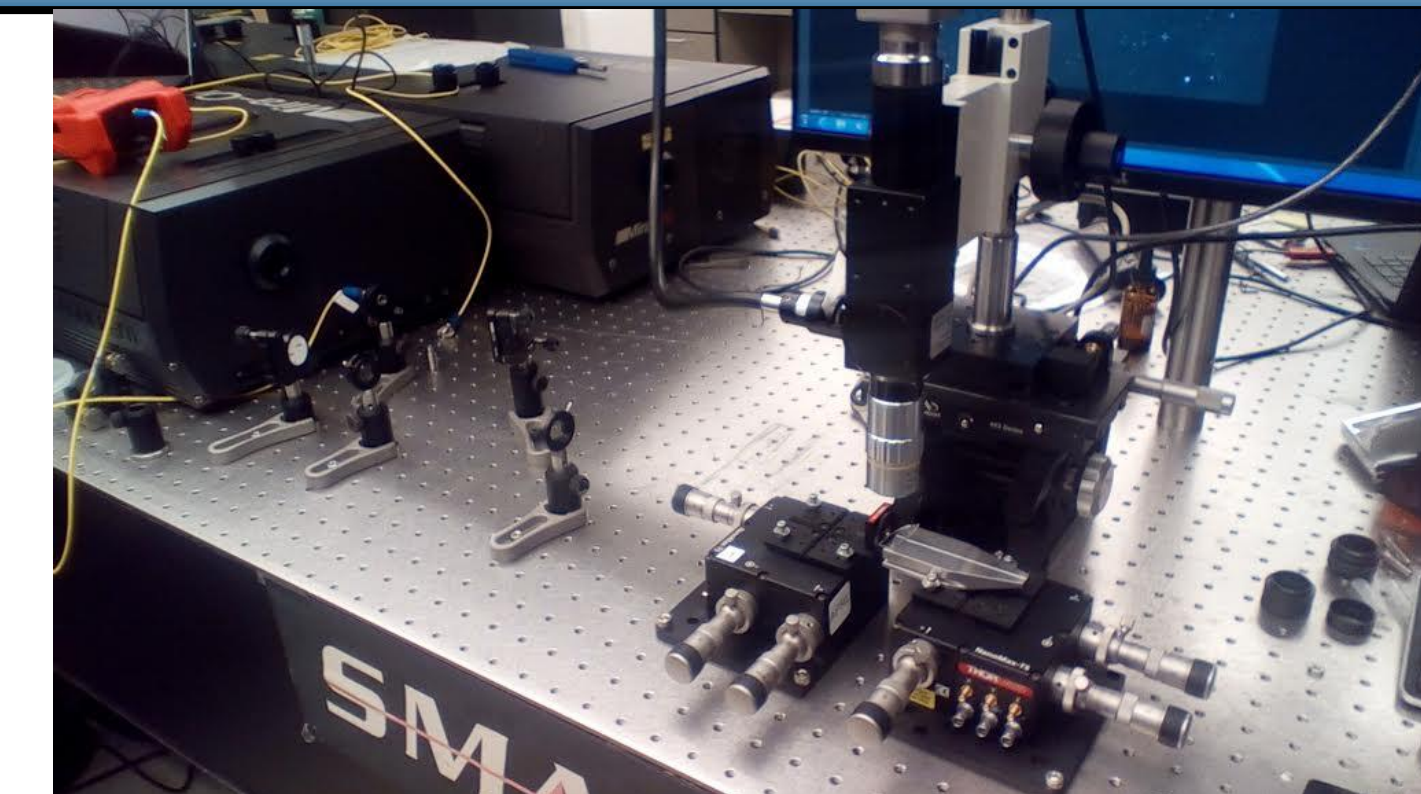


VIII. Testing

Light Source
Fisher Scientific



Outpower 1mW min
Wavelength 650nm Typ



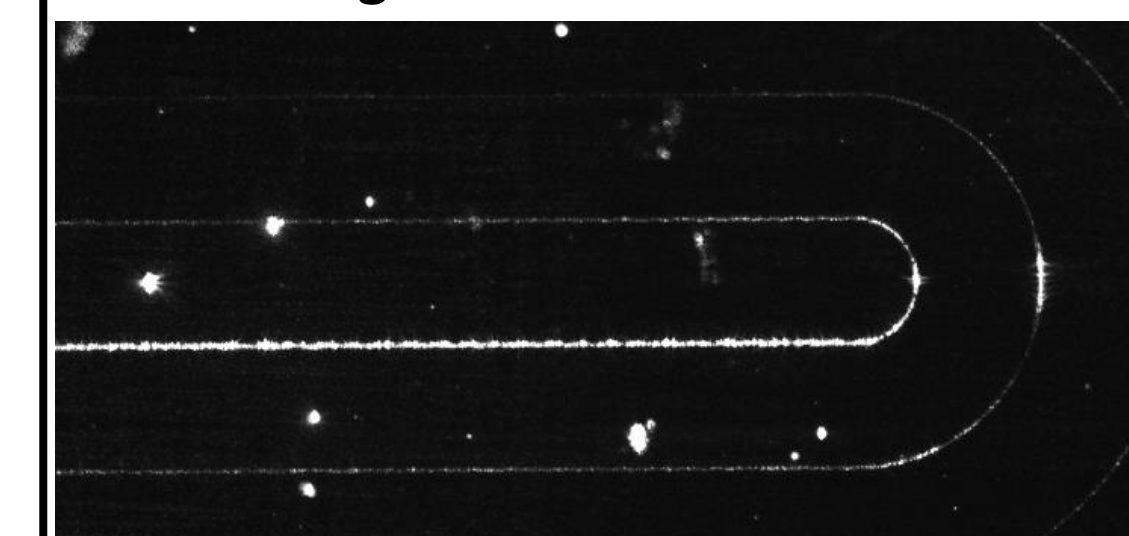
Focusing Lens stage
Lens is 4.5mm focal length
Initial beam alignment
Using X and Z controls

Sample Stage
Final coupling
Using movement in X,Y and Z
(no rotation controls)

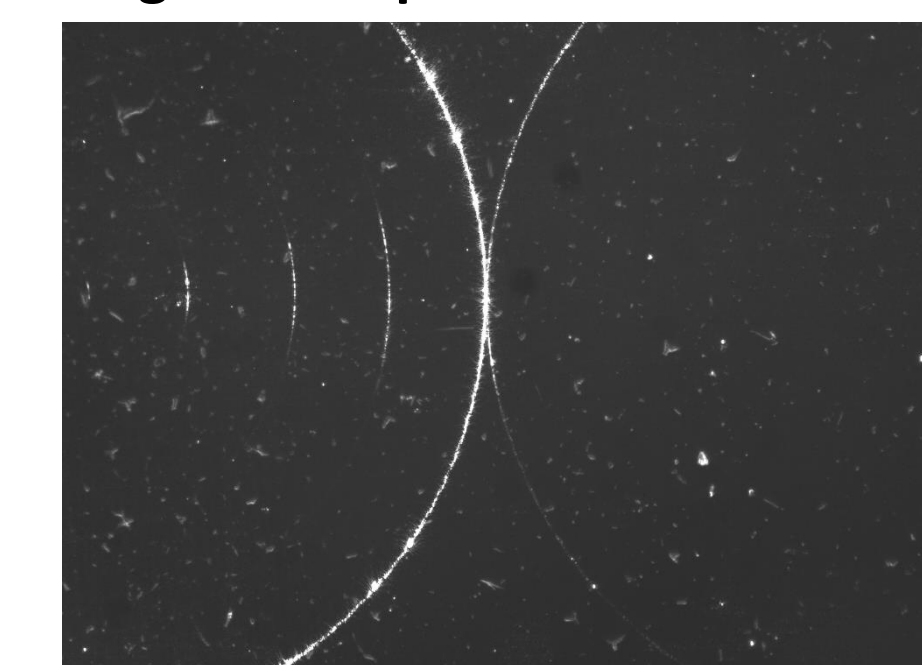
IX. Results

Visual results for nominal 1.2um devices.

50um radius bends have
high losses



Waveguide coupled into a resonator

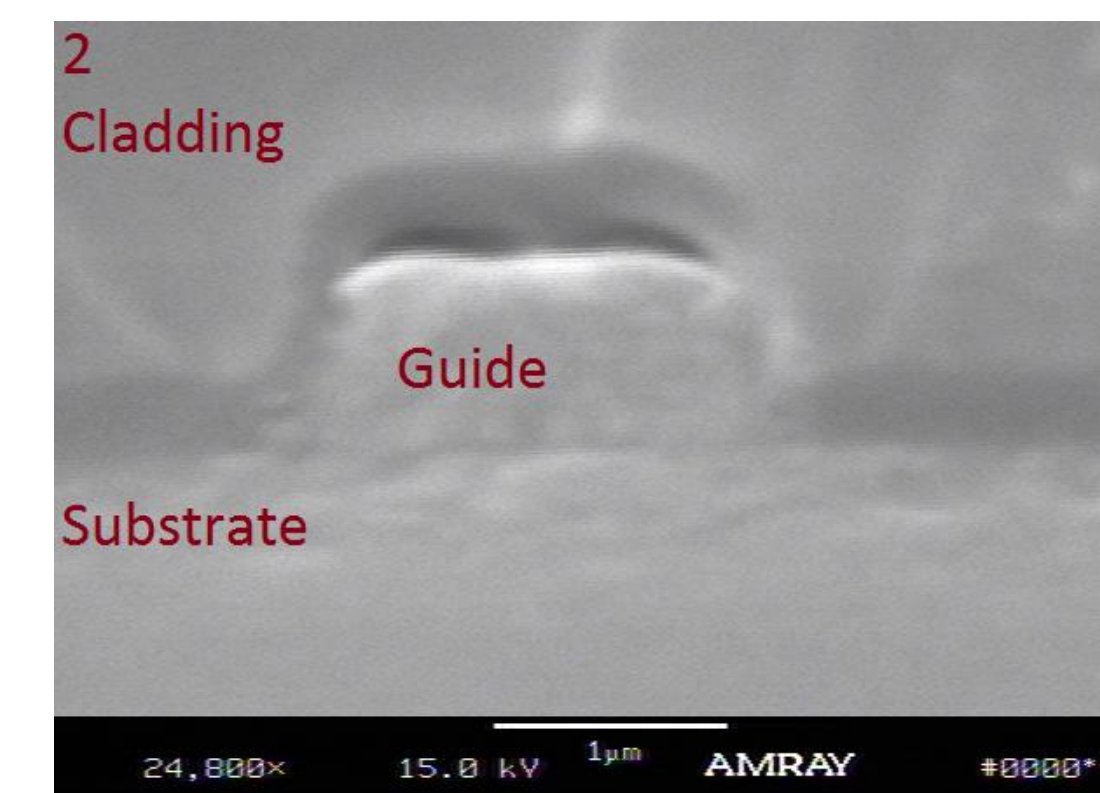


High Resolution Camera showing light traveling through a waveguide



Waveguides viewed with
Secondary 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 |



Acknowledgements

- Dr. Stefan Preble
-His graduate students: Michael Fanto, Jeffrey Steidle
- Dr. Hirschman, Dr. Ewbank, Dr. Pearson
- SMFL Staff specifically Sean O'Brien



X. Future

Short Course for direct write waveguides on the Heidelberg
Optimization of Processing
Expansion into additional devices.
Flexible Substrate.