Multi-Viewing Angle Fiber Coupling Microscope Development

Duke ELECTRICAL & COMPUTER ENGINEERING

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Introduction

Objective: Design, construct, and test a robust & versatile light coupling platform with an integrated multi-viewing angle microscope for use in a variety of microscale photonic experiments.

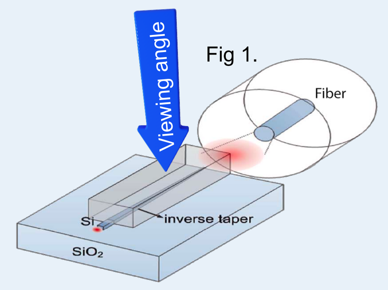
Background:

Nanoscale photonic devices

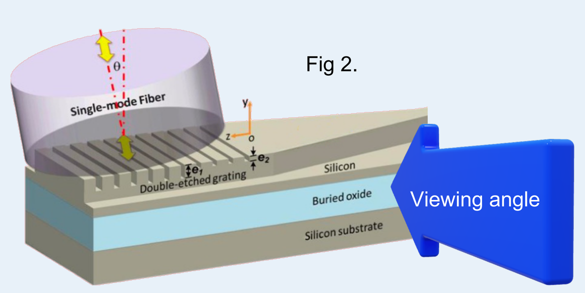
- Miniature light-manipulating devices, typically built on silicon chips
- Have the potential to facilitate ultra-fast data transfer within computer systems
- To perform experiments with nanoscale photonic devices, light must enter and exit the sample in a controlled manner (couple and decouple).

Light coupling

- Facilitated using either an inverse taper, or a grating.
- Light from the fiber must hit the grating or inverse taper at the correct orientation. For this to occur, the fiber and coupler must be in alignment, however both are smaller than can be seen with the naked eye. The multi-angle microscope overcomes this issue by magnifying the sample by 20x and facilitating precise manipulation of each fiber.



Horizontal coupling (above) requires overhead viewing angle. The microscope must be in the upright position.



Near vertical coupling (above) requires side viewing angle. The microscope must be in the angled position.

Methods

Design

- Illumination and imaging optical system designed in ray optics simulator
- 3D model designed in Fusion 360 CAD using manufacturer components (Thorlabs, Mitutoyo, Bobcat)
- Model motion control tested with CAD simulations
- Design approved by Dr. Litchinitser

Build

- Ordered components from Thorlabs at a cost of $4328
- Assembled microscope according to model
- Mounted microscope on tilt rail system

Test

- iPhone screen was selected for imaging due to known size of pixels
- Nanoscale waveguide was selected to demonstrate compatibility with intended application

Conclusions

Successes

- The microscope was successfully assembled and functioned as intended, demonstrating accuracy of 3D model and optics model
- The microscope successfully imaged the nanoscale waveguide, demonstrating usability in light coupling applications

Future work

- Fix the vibration issue and loss of focus during XY translation
- Replace or secure the pellicle in a more precise manner because it is highly difficult to keep in alignment.
- Determine actual resolving power by imaging a resolution target

References

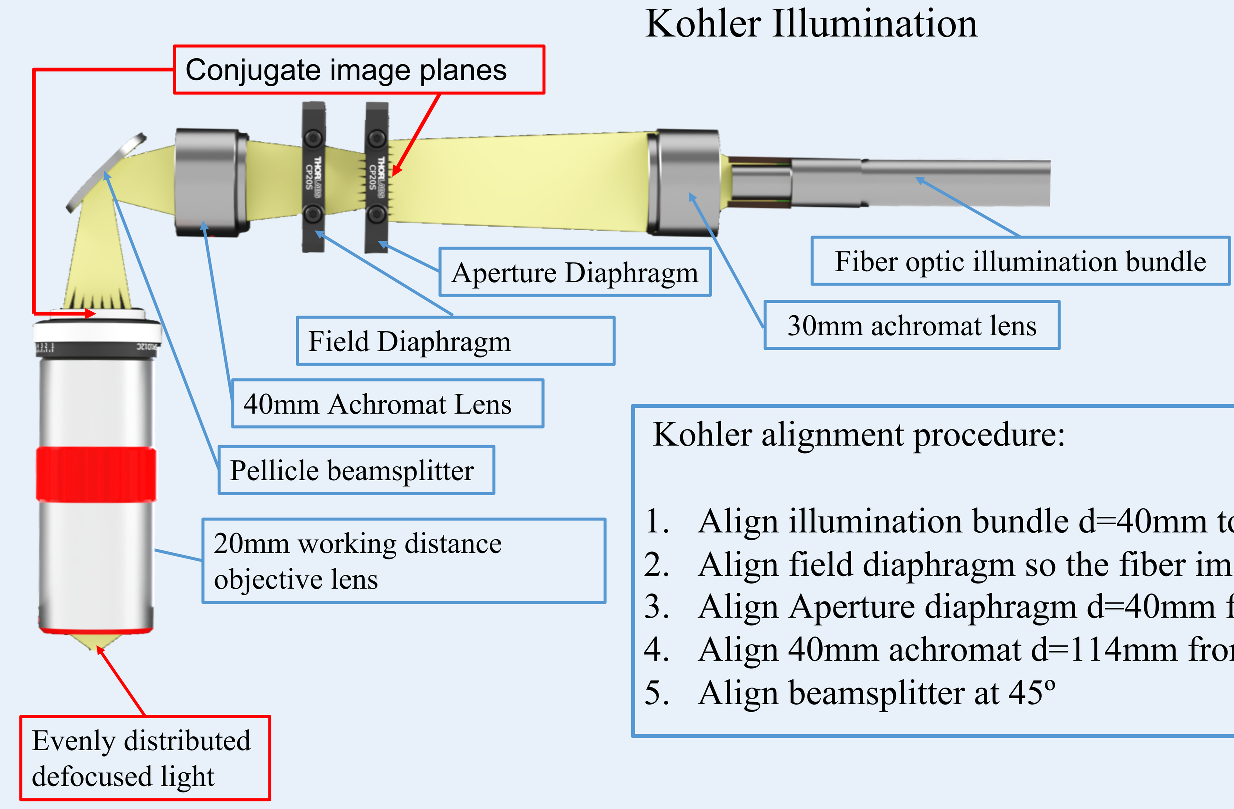
Li, C., & Zhang, H. (2013). CMOS-compatible high efficiency double-etched apodized waveguide grating coupler. Retrieved from https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-21-7-7868&id=251662

Jingshu, G., & Daoxin, D. (2018). Silicon nanophotonics for on-chip light manipulation. Retrieved from http://cpb.iphy.ac.cn/article/2018/1958/cpb_27_10_104208.html

Results

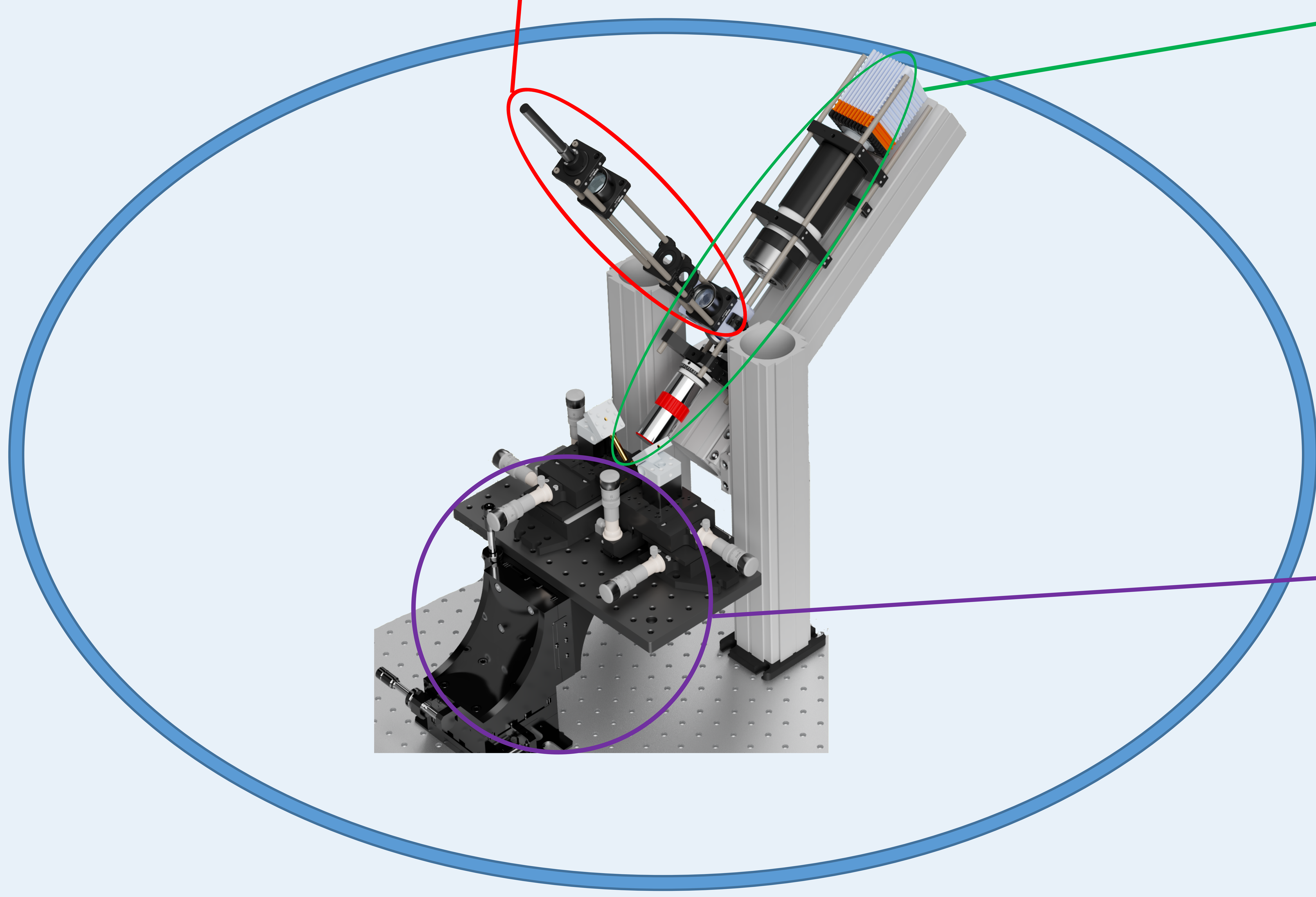
Design Results

Kohler Illumination

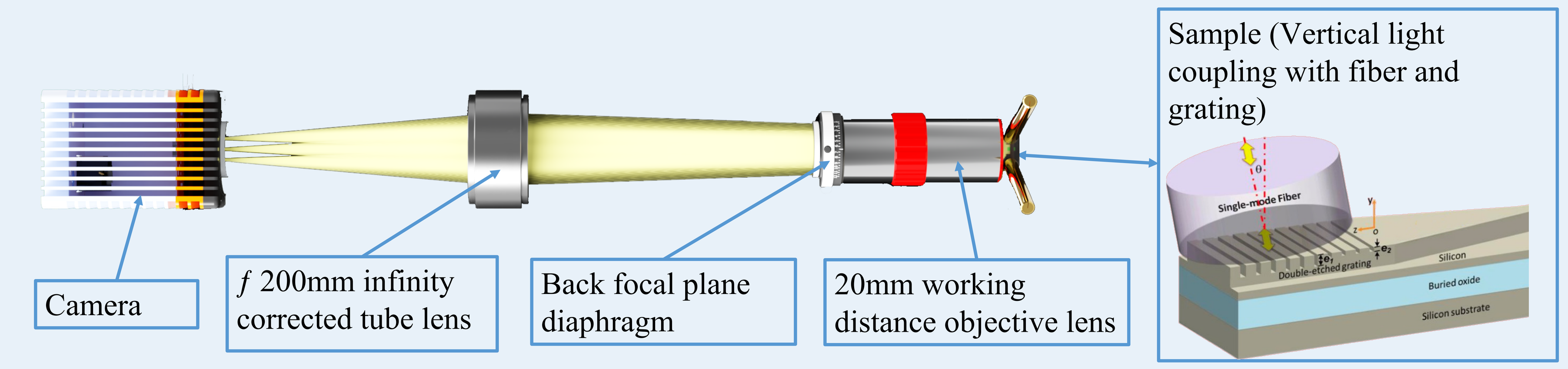


Kohler alignment procedure:

1. Align illumination bundle d=40mm to 30mm lens
2. Align field diaphragm so the fiber image is formed on diaphragm
3. Align Aperture diaphragm d=40mm from 40mm lens
4. Align 40mm achromat d=114mm from objective lens
5. Align beamsplitter at 45º



Imaging System



Objective Lens: The long working distance objective lens allows the sample to be 20mm away from the end of the objective lens. This is necessary so that the objective lens does not collide with the fiber or the photonic device.

Setup Procedure:

1. Focus tube lens and camera to ∞
2. Align objective d=140mm from tube lens
3. Align back focal plane aperture to objective
4. Adjust Z stage to focus sample

Ray optics imaging principles:

- Light reflects off the sample and enters the objective lens which focuses the light to ∞
- Objective lens back focal plane diaphragm blocks extraneous light from entering imaging system
- Infinity corrected tube lens creates an inverted real image at a distance of 148mm, at 20x magnification
- Image is projected on camera sensor, producing a clear picture which is viewed on a computer

Motion control

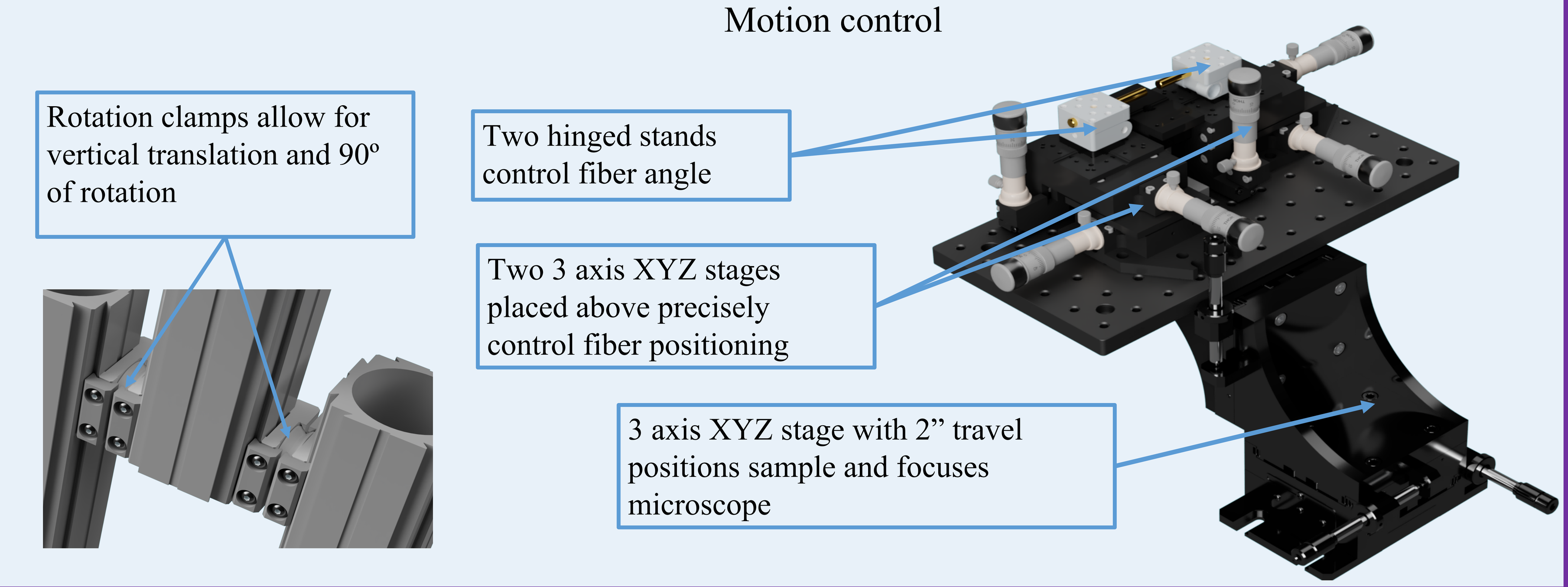
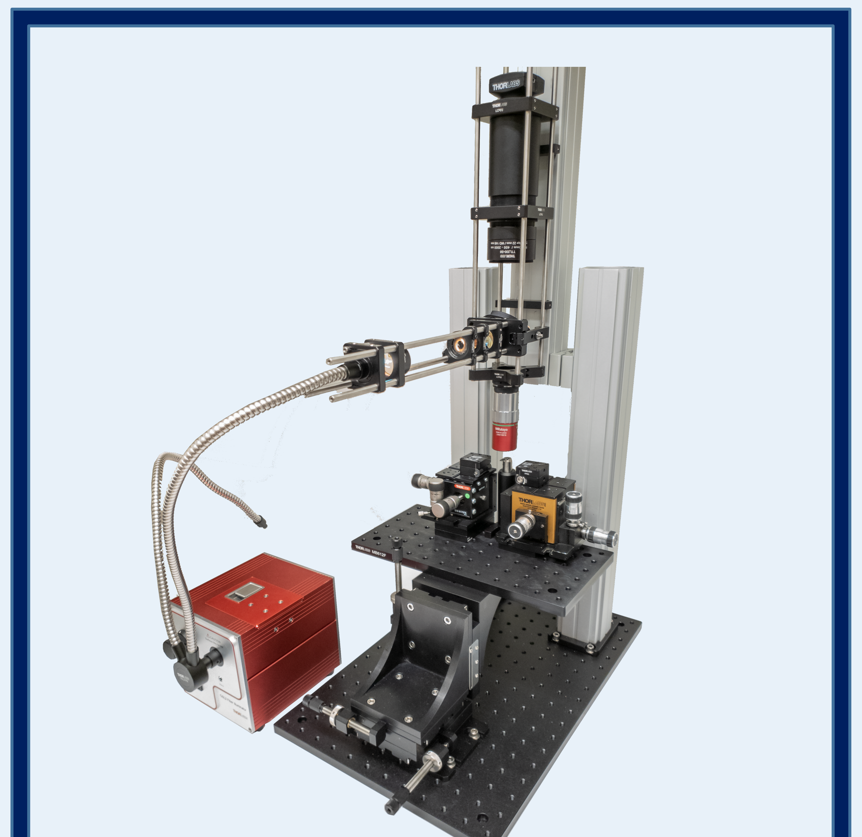


Photo of Assembled Microscope



Test Images

Image quality

- Resolution was comparable to commercial microscope
- Contrast and illumination was satisfactory
- Full spectrum of colors visible

Issues encountered

- Distortion due to unwanted vibrations
- Field diaphragm not centered due to pellicle beamsplitter alignment difficulties
- Image loses focus when base x or y stage is adjusted

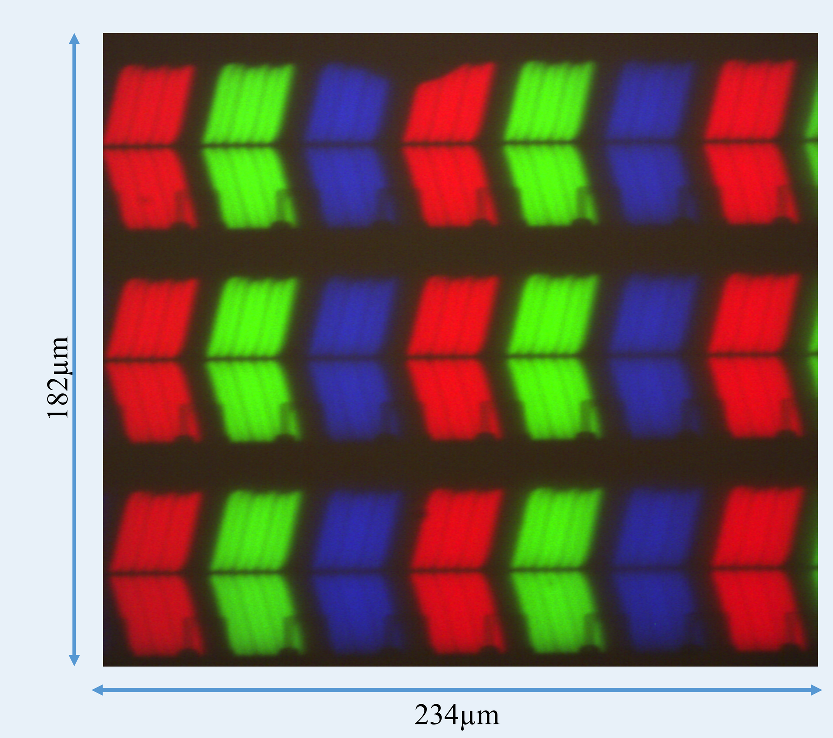


Fig 3: Microscope image of iPhone 8 pixels

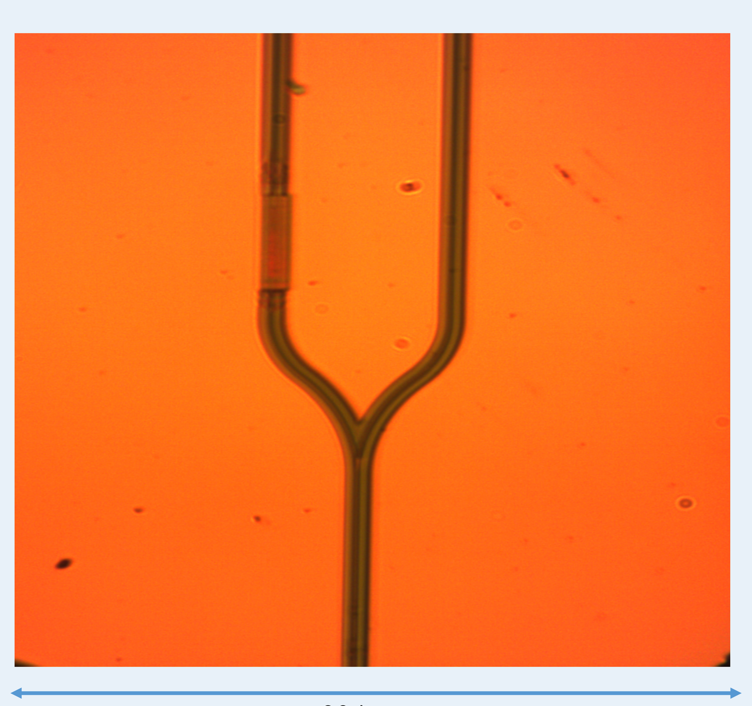


Fig 4: Microscope image of a nanoscale waveguide