# Photonic Wire Bonding with 3D Laser Lithography

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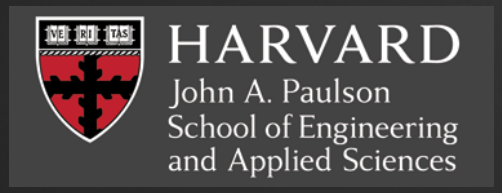
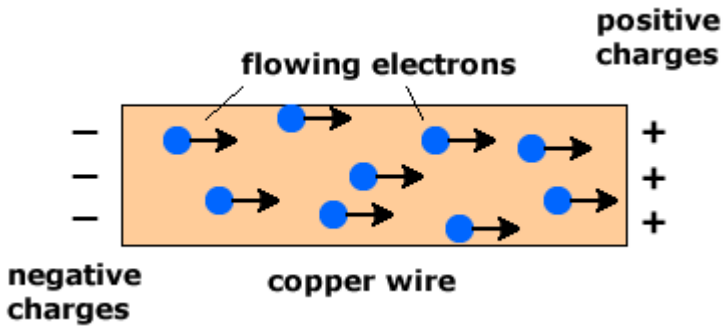
PRELIMINARY RESEARCH AND PHOTOS COURTESY OF WENBO MAO

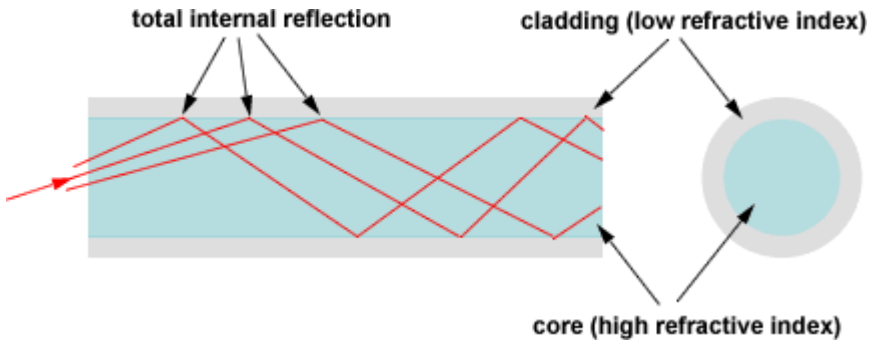





# What is Photonics?

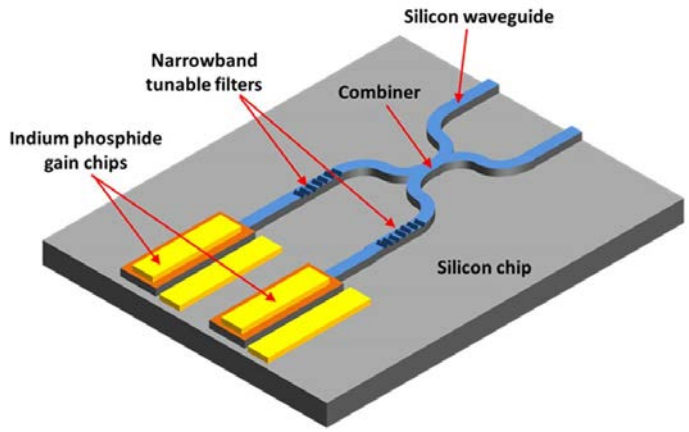
- Photonic systems rely on light to send a signal.
- Alternative to electrical systems, which use electrons.
- Photonic signals are many times faster than electrical signals, but also much harder to contain.
- Photonic wires rely on the principle of total internal reflection.

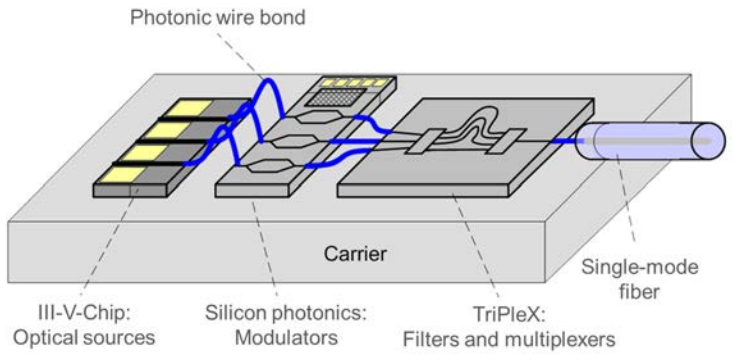


# The Current State of Photonics

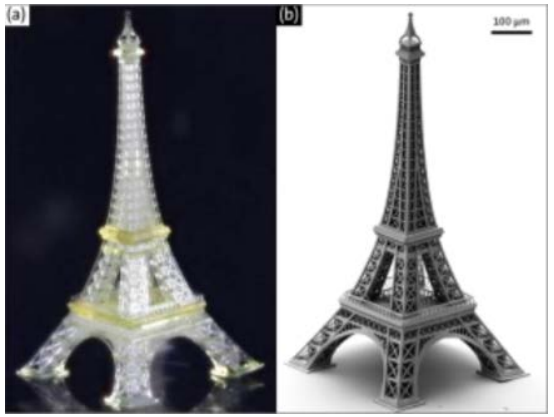
- The current goal of photonics is an all-optical computer.
- Photonic wire research has resulted in integration onto computer chips.
- Connections between photonic wires on different chips are necessary.
- 3D Laser Lithography may provide a solution.



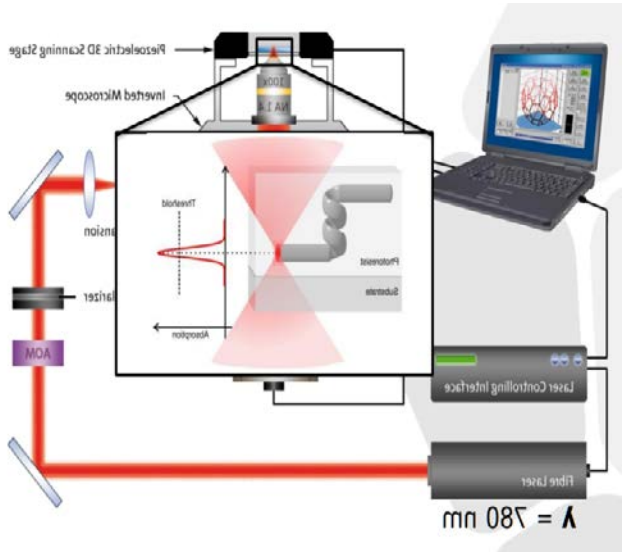



# 3D Laser Lithography and Nanoscribe

- Nanoscribe is a 3D Laser Lithography system.
- Nanoscribe uses a laser to polymerize a negative photoresist in layers. Removing the leftover liquid resist leaves behind a 3D structure.
- Relies on the two-photon absorption effect.
- Creates a “voxel” (a pixel in 3 dimensions)

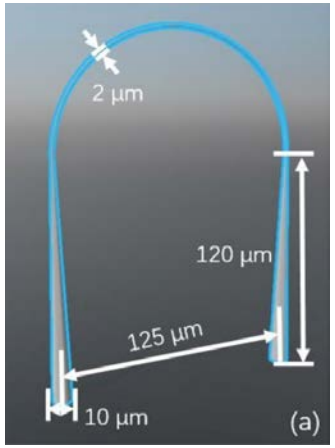




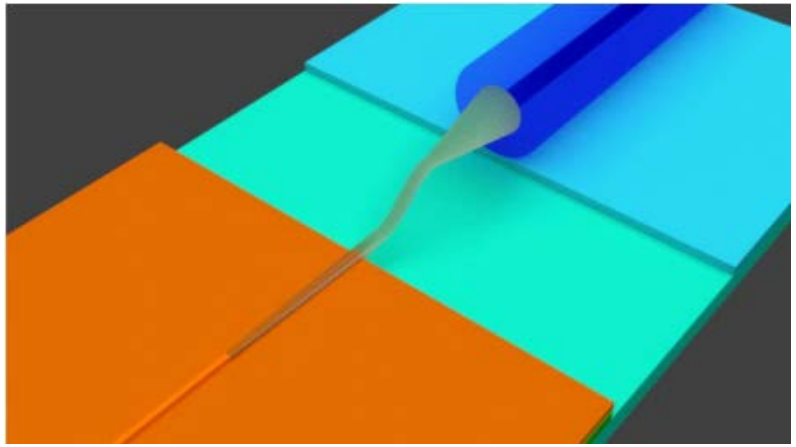


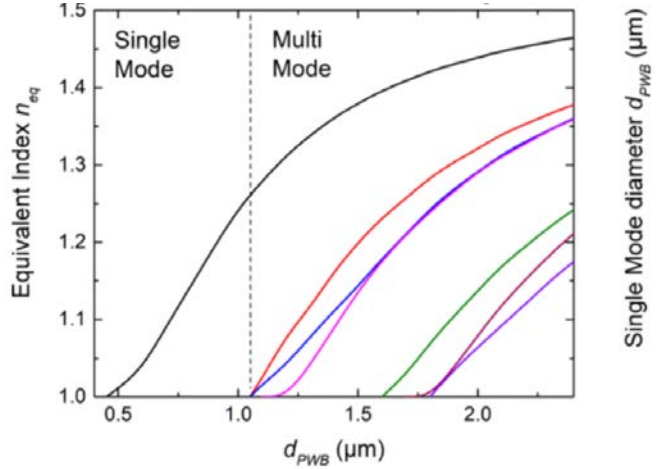
# Research by Wenbo Mao

- Wenbo Mao began researching the use of Nanoscribe for Photonic Wire Bonding (PWB).
- Determined the best 3D shape for the bonding with simulation software: Lumerical Finite-Difference Time-Domain (FDTD) Solution
- Printed PWB in a pigtail configuration and a waveguide configuration





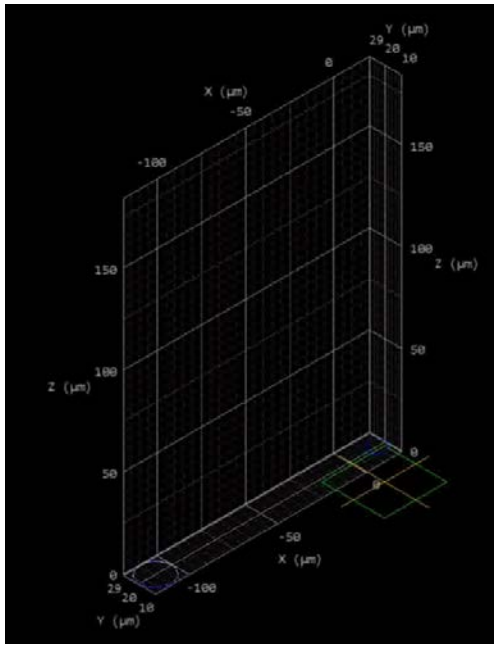




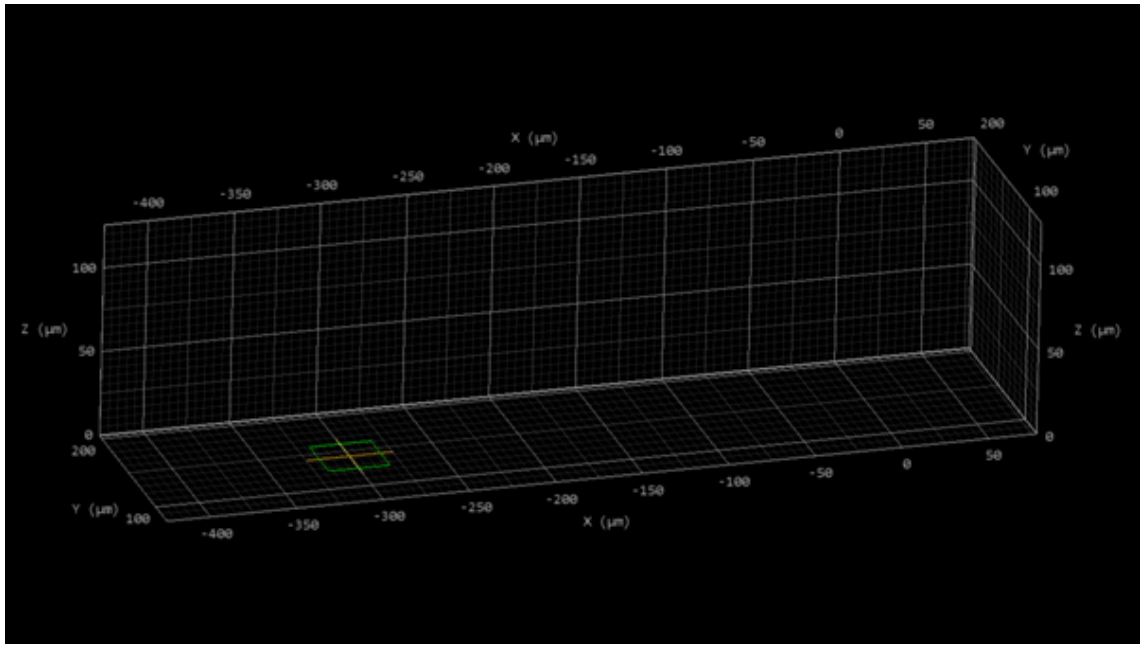
# Summer Objectives

- Print Pigtail PWB and Waveguide PWB reliably
- Design and build a sample holders for the Pigtail.
- Print PWB onto Pigtail. Print PWB onto Waveguide.
- Obtain real insertion loss values and compare to simulations data.

# Structures to Print



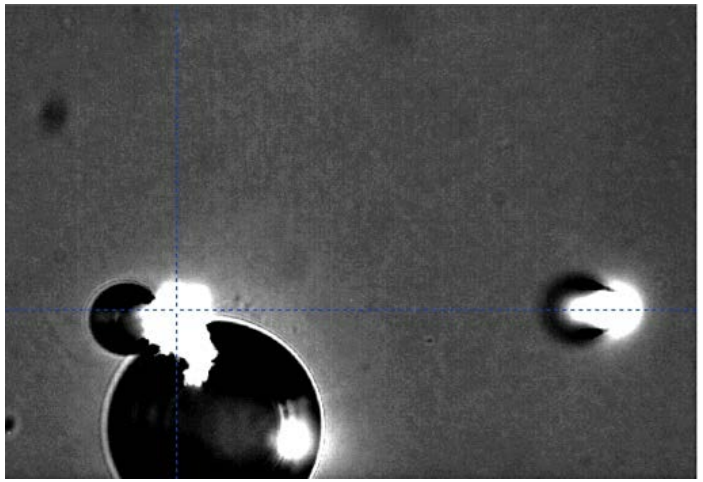

Pigtail PWB

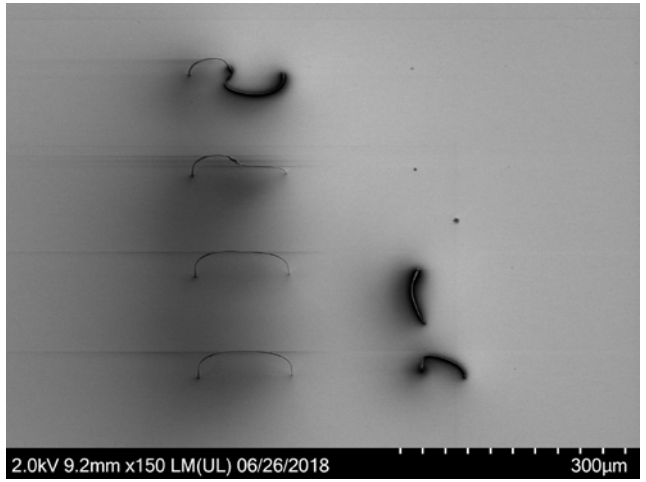


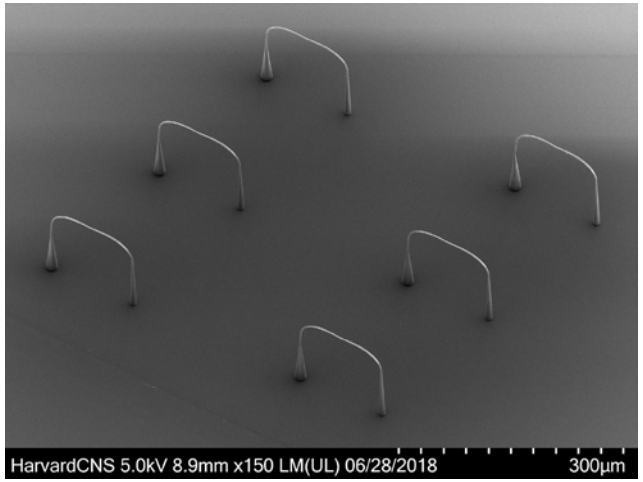

Waveguide PWB

# Consistent Pigtail PWB

- Observation of problem: Bubbles in top half of structure.
- Printing only top half of structure in a dose-test matrix.
- Printing full structure with best results from dose test

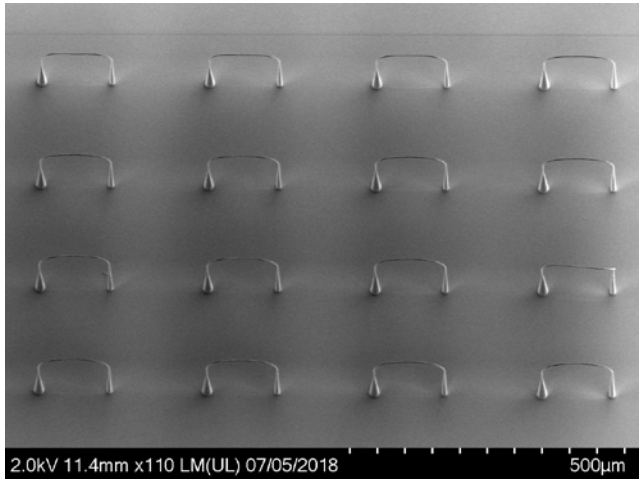


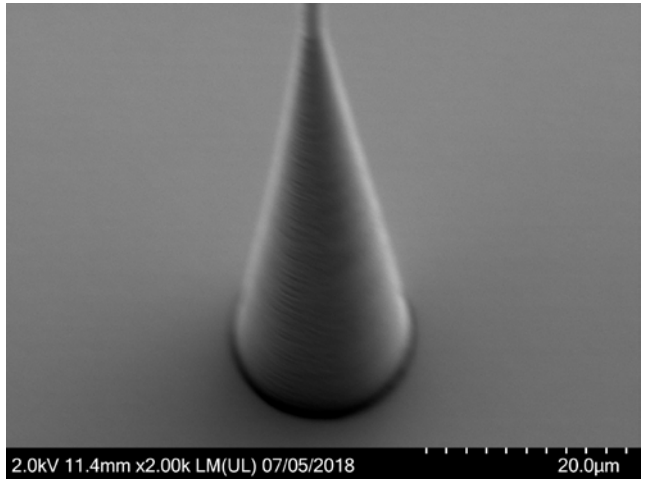


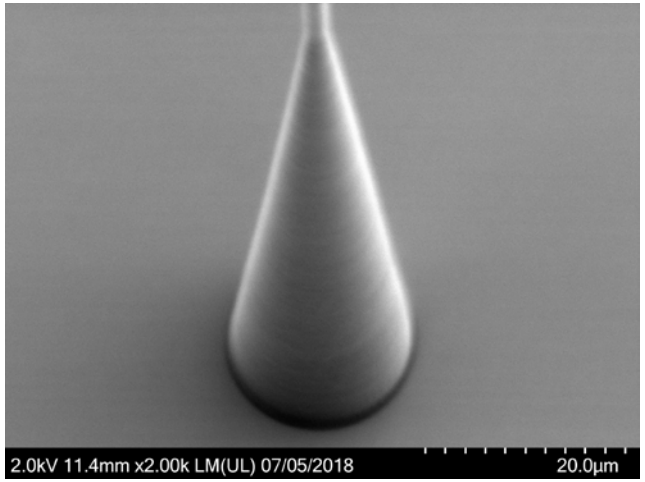



# Optimize Roughness of New Structures

- New structures were noticeably more rough than Wenbo's.
- Performed a matrix test where dose remained constant, but laser power and scan speed were increased.

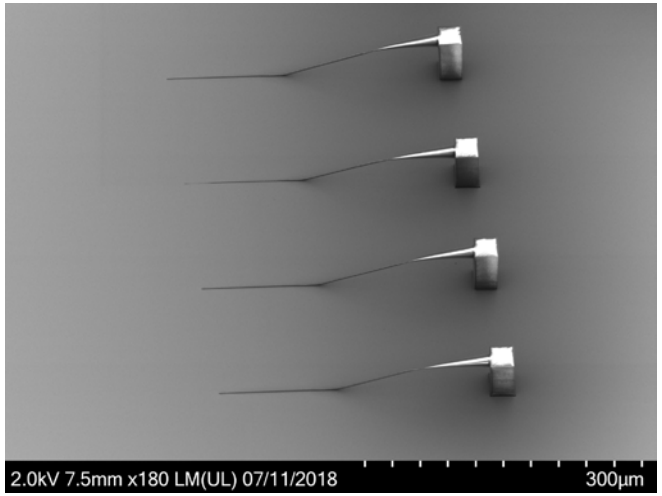


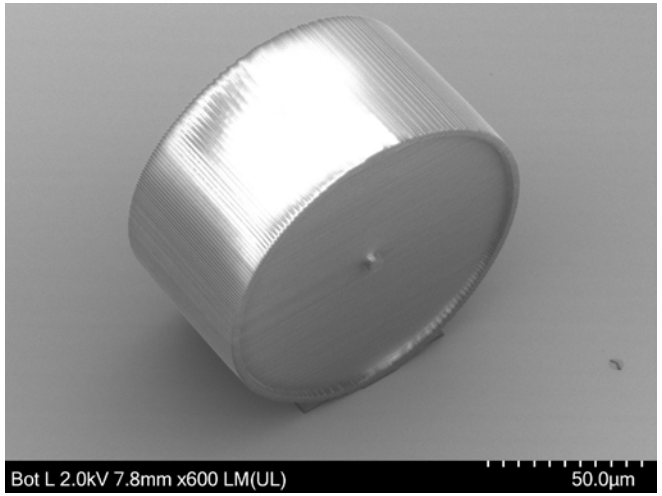



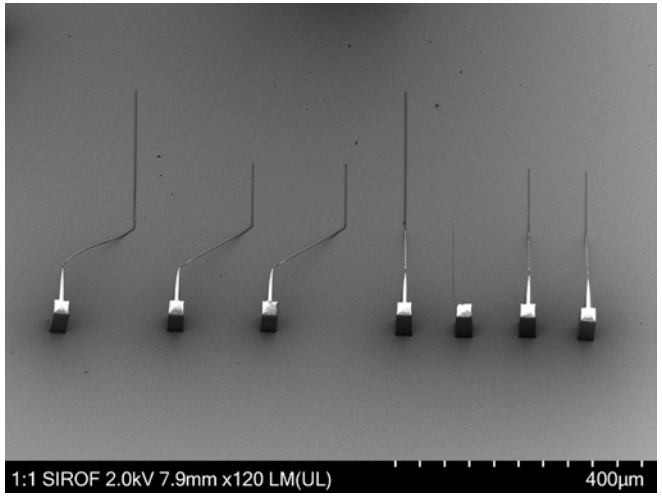



# Consistent Waveguide PWB

- Fiber-to-Waveguide printed reliably using new dose.
- Has to be printed upside-down and use MoveStage instead of Offset
- Created  structures for the PWB to latch onto.



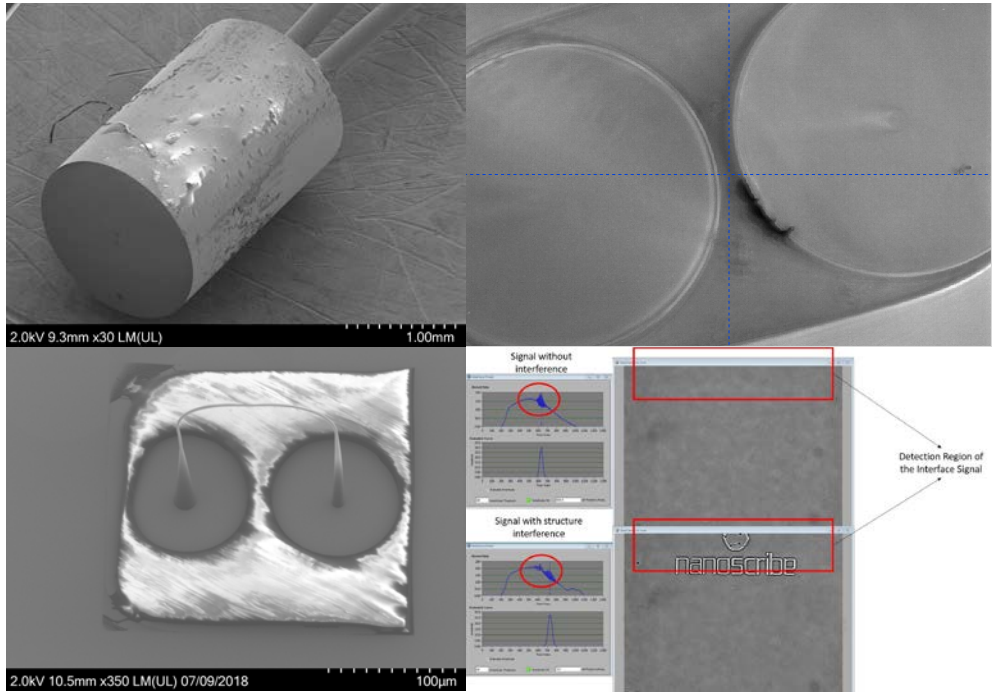
# Printing onto Pigtail

Challenges:

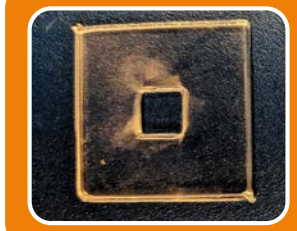
- Pigtails are Fragile
- Random Rotation of Pigtail
- Random Tilt of Pigtail
- Aiming

Solutions:

- Create Special Sample Holder
- Rotation can be corrected in Nanoscribe
- Tilting must be corrected in SolidWorks
- Use Offset or MoveStage
- Determine Autofocus Location

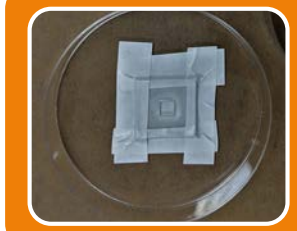


# Polystyrene and PDMS Sample Holder



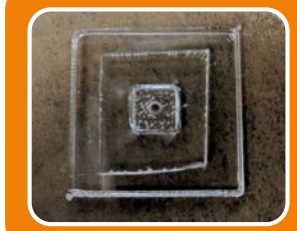
## Polystyrene Base

- Cut from Petri Dish
- Used Helix 75W Laser Cutter



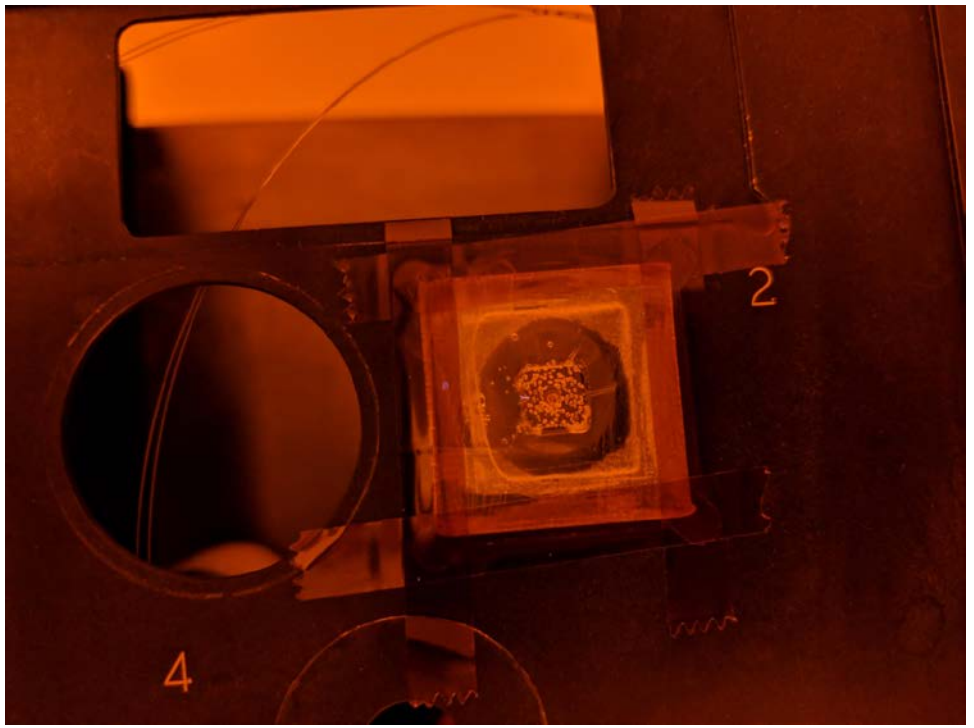
## PDMS Fill

- Poured over Base
- Cured for 3 Hours at 80 Celsius



## Hole Punch and Pigtail Insert

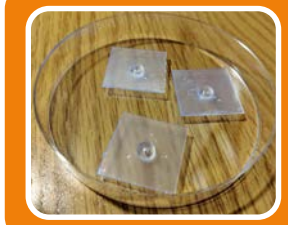
- Hole puncher used to create hole
- Inserted very carefully using tweezers



# 3D Printed Sample Holder

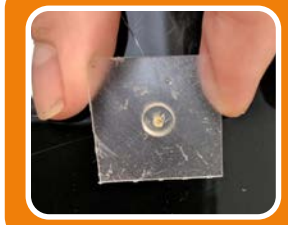
## Design

- Model Designed in SolidWorks
- Print Job Designed in PreForm



## Print

- Printed using Form2 3D Printer
- 1.95mm diameter hole



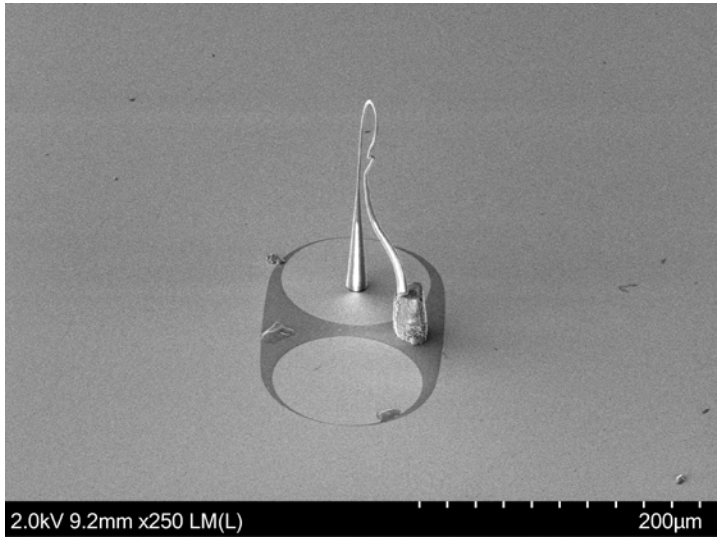
## Insert Pigtail

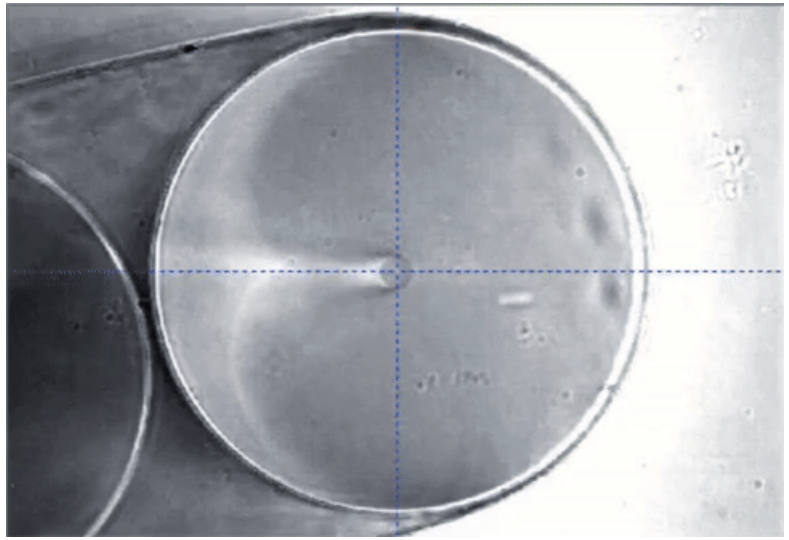
- Insert pigtail wire end first
- Like threading a needle

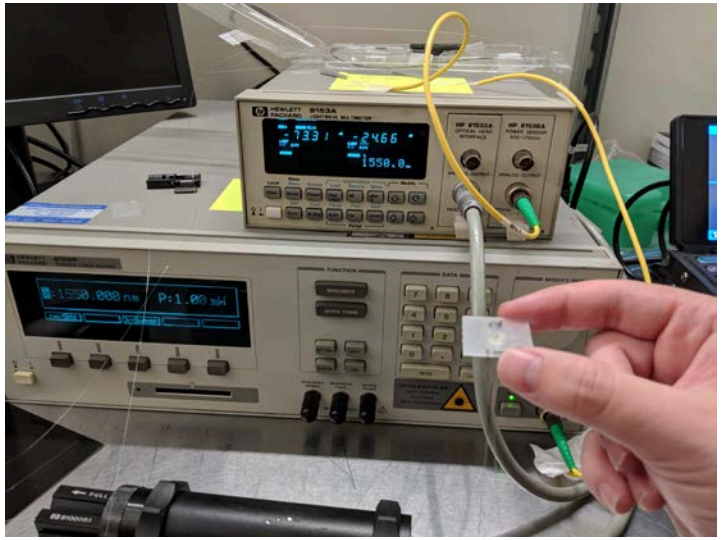
# Printing onto Pigtail Results

Successful

- Printing on the pigtail was a success using 3D Printed Holder
- Two prints: 1 misprint, 1 success
- Successful print resulted in poor data. Destruction during development.





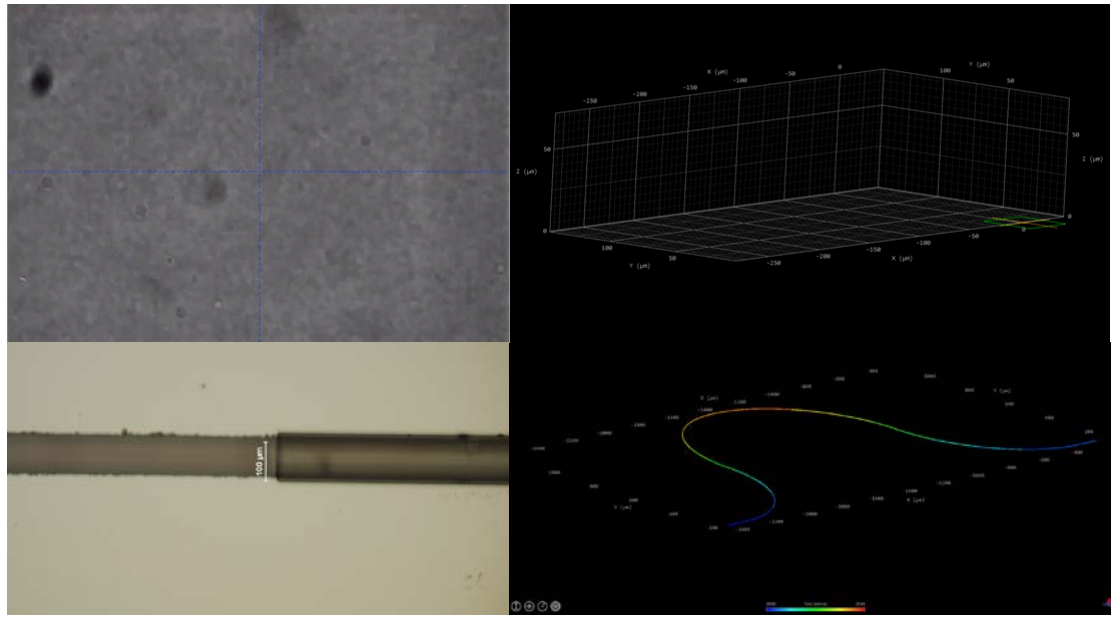
# Printing onto Waveguide

Challenges:

- Testable waveguide was unfinished
- Random Fiber Alignment
- Laser Interference
- Aiming

Solutions:

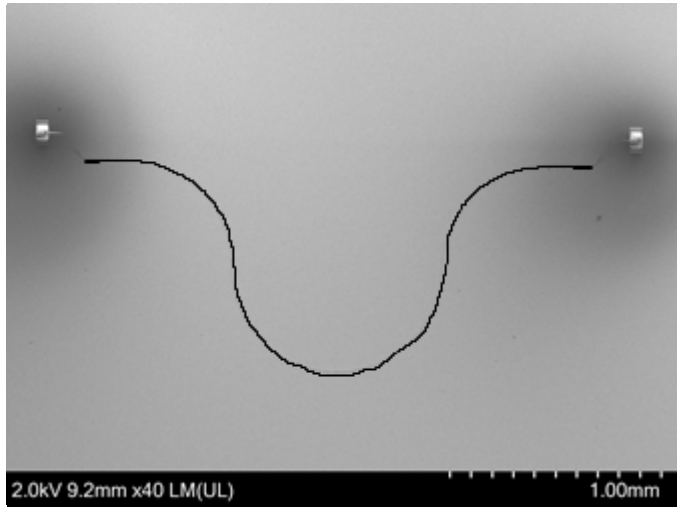
- Print waveguide with Nanoscribe
- Controlled Placement of Fibers
- Create an editable 3D file
- Dose Management
- Use Offset and StageMove

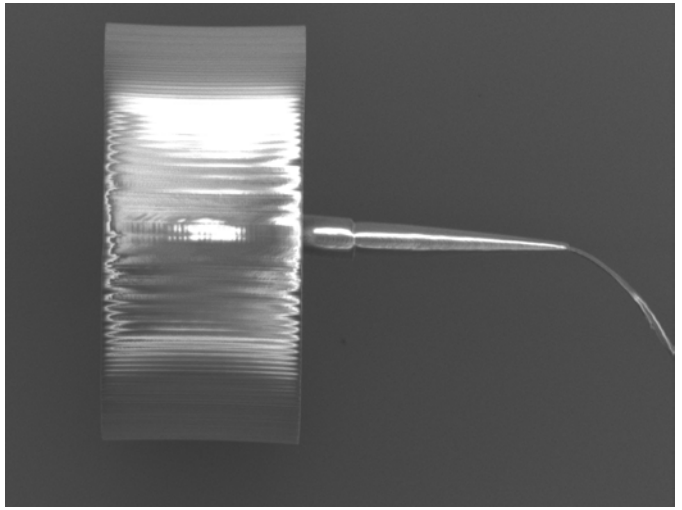


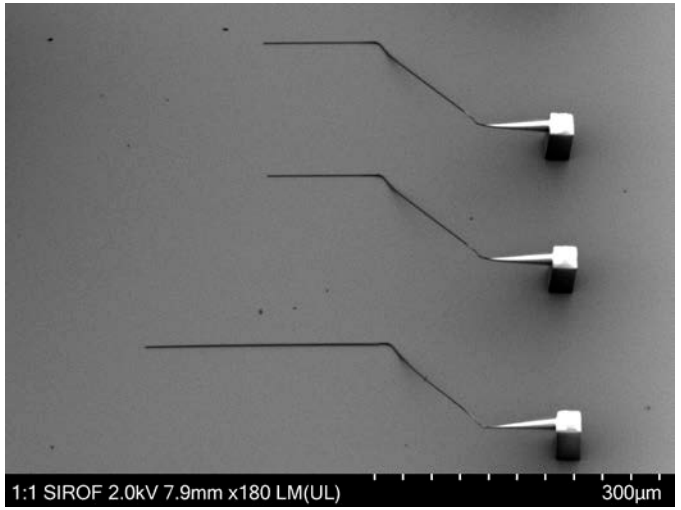
# Printing onto Waveguide Results

To be determined

- Successfully printed full wire-to-waveguide-to-wire PWB.
- Dose Management results in distorted surfaces
- Still laser interference when printed on fake Nanoscribe Fiber
- Designed editable 3D file to accommodate different wire positions





# My Experience with SEAS REU

- Learned to use industry-relevant machines and techniques: Nanoscribe, Maskless Aligner, Atomic Layer Deposition, Ellipsometer, ZEISS SEM, Hitachi SEM, Critical Point Dryer, Profilometer, Sputtering Coater, Laser Cutter, Form2 3D Printer, Spinning and Developing, PDMS Mixing and Curing, and Cleanroom and Wetbench Safety and Ettiquette.
- Gained a better understanding of the pace of research.
- Made important connections with Harvard CNS faculty, Harvard students, and other students from around the world.
- Reinforced my desire to get my PhD and do my own research.

# Questions?

*References:*


- Mao, W.; Deng, J.D.; Lončar, M.; Summer Internship Report: Photonic Wire Bonding. *Summer 2017.*
- 3D µ-printing by Direct Laser Writing; Technology Introduction Presentation. *April 30, 2015*


*Images:*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