

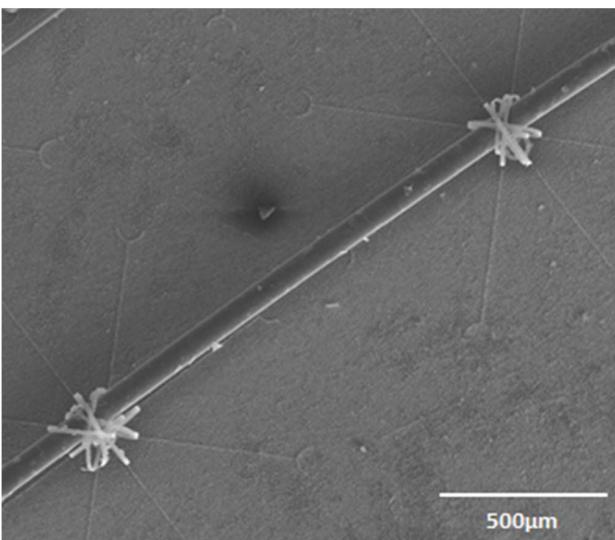
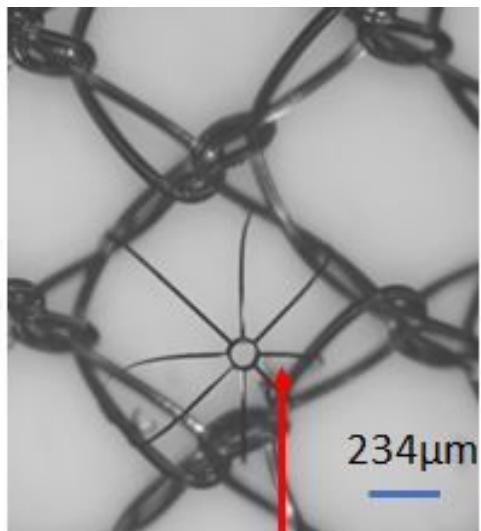
Project: Electrical Characterization of MEMS Microgrippers in Circuits

Nathan Song, UC Berkeley

Dr. Cindy Harnett, University of Louisville

Intro: What are MEMS Grippers?

Past Grippers



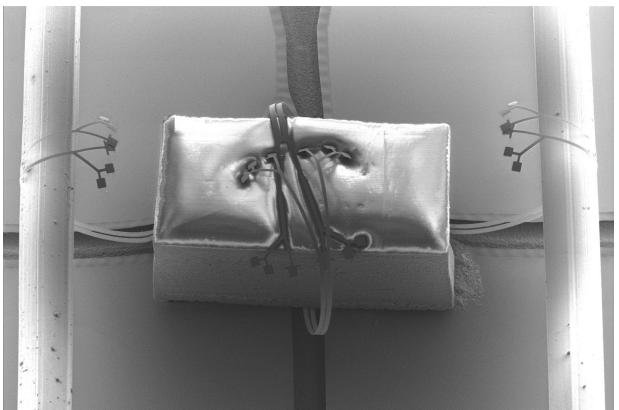
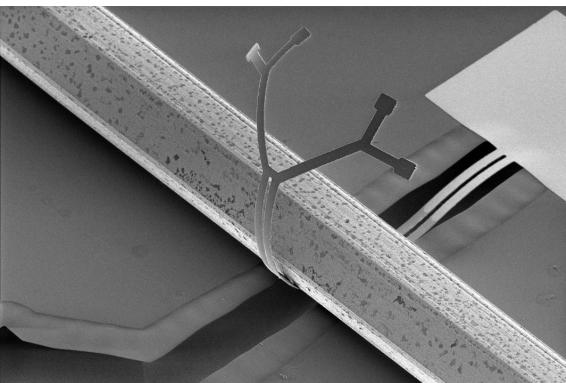
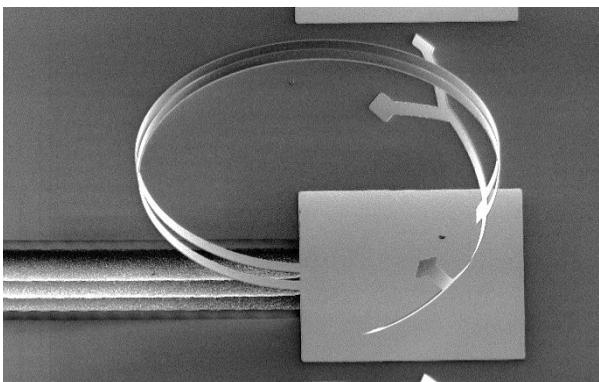
Successful grasp at 234 μm distance
from nearby fabric

- Successful latch onto fibers
- Electrically Conductive
- Mechanical-load bearing potential

Pictures: Credit to Challa et. al.-2019, Fiber Crawling Microrobots; Challa et. al. 2019, Transferring Microelectromechanical devices to breathable fabric carriers with Strain-Engineered grippers

Intro: What are MEMS Grippers?

Current Grippers

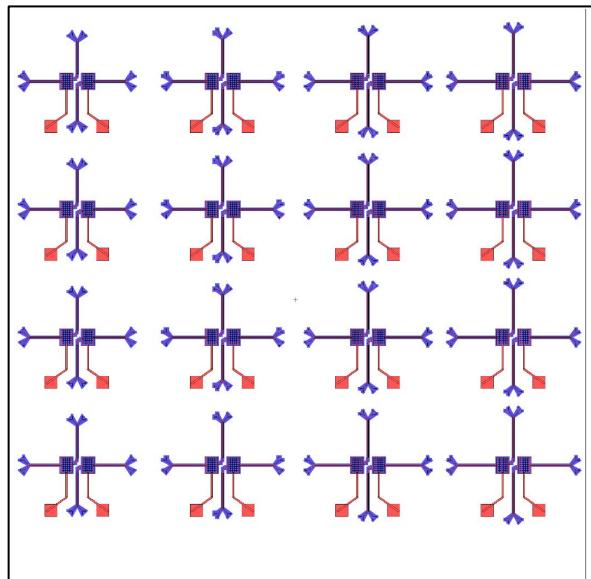


100 μm

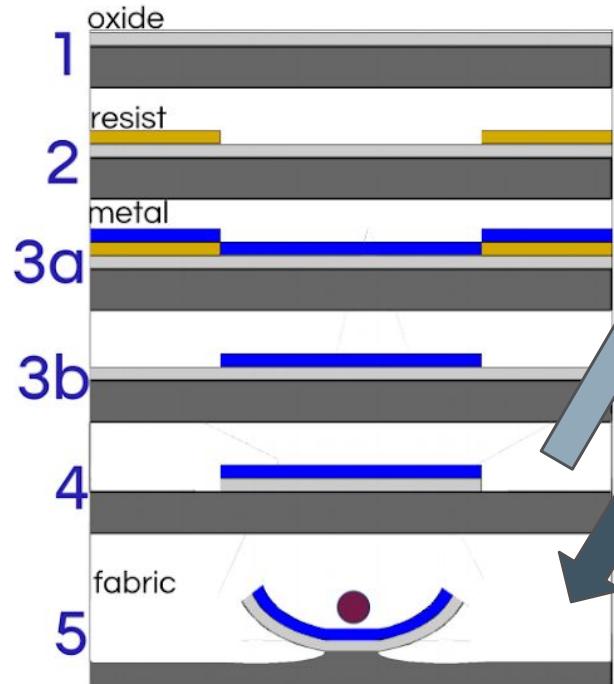
- Electrical contact with bare copper wires (and more!)
- Characterized *Resistance v. Temp v. Current*
- **Successful powering of electrical load (LED)**

Intro: How are Grippers made?

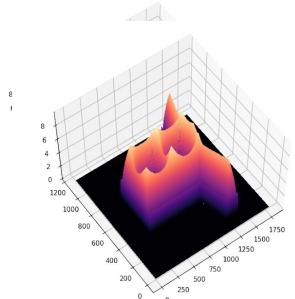
1. Design



2. Photolithography

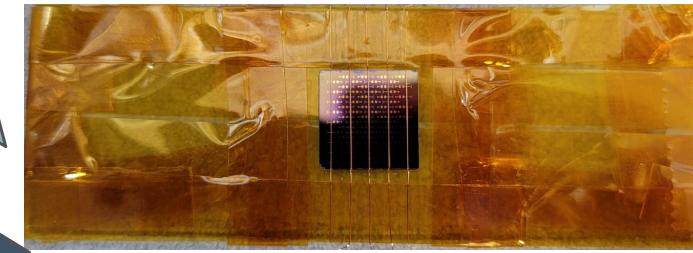


Iax. Etch Distance:
~8 μm

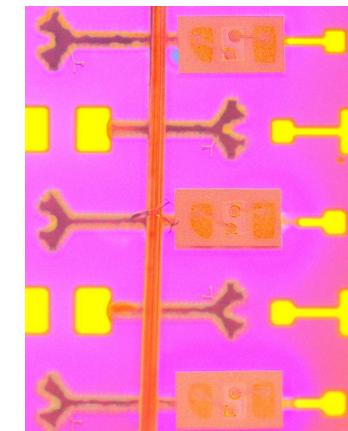


5. Etch Cycles Needed:
~7-15 Cycles

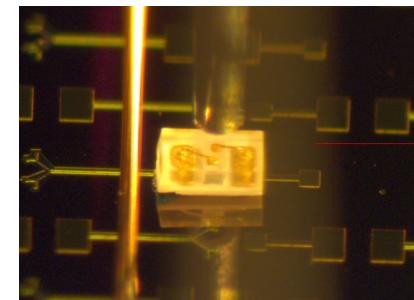
3. Manufacturing



Wafer diced, Wires laid across on test sample



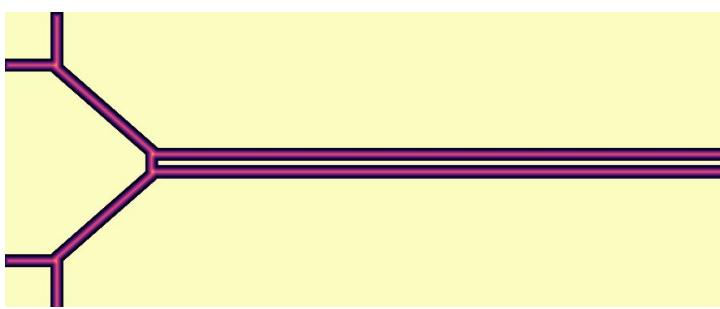
LEDs on Wafer



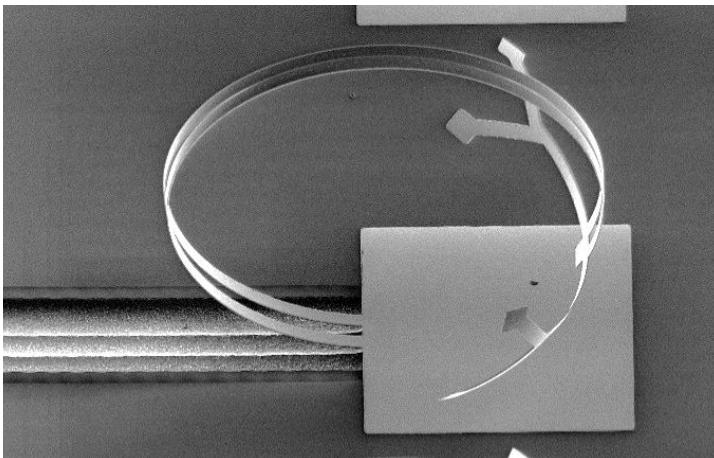
NEXUS System
placing LEDs

Intro: Simple Gripper Example

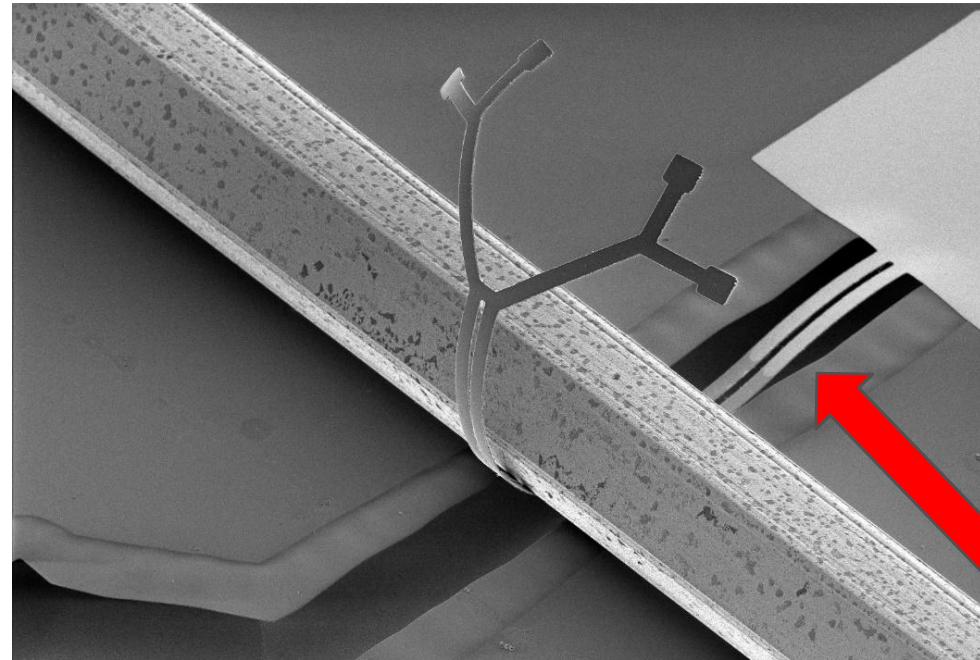
700 μm



Initial Design

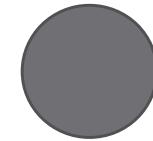


Free release

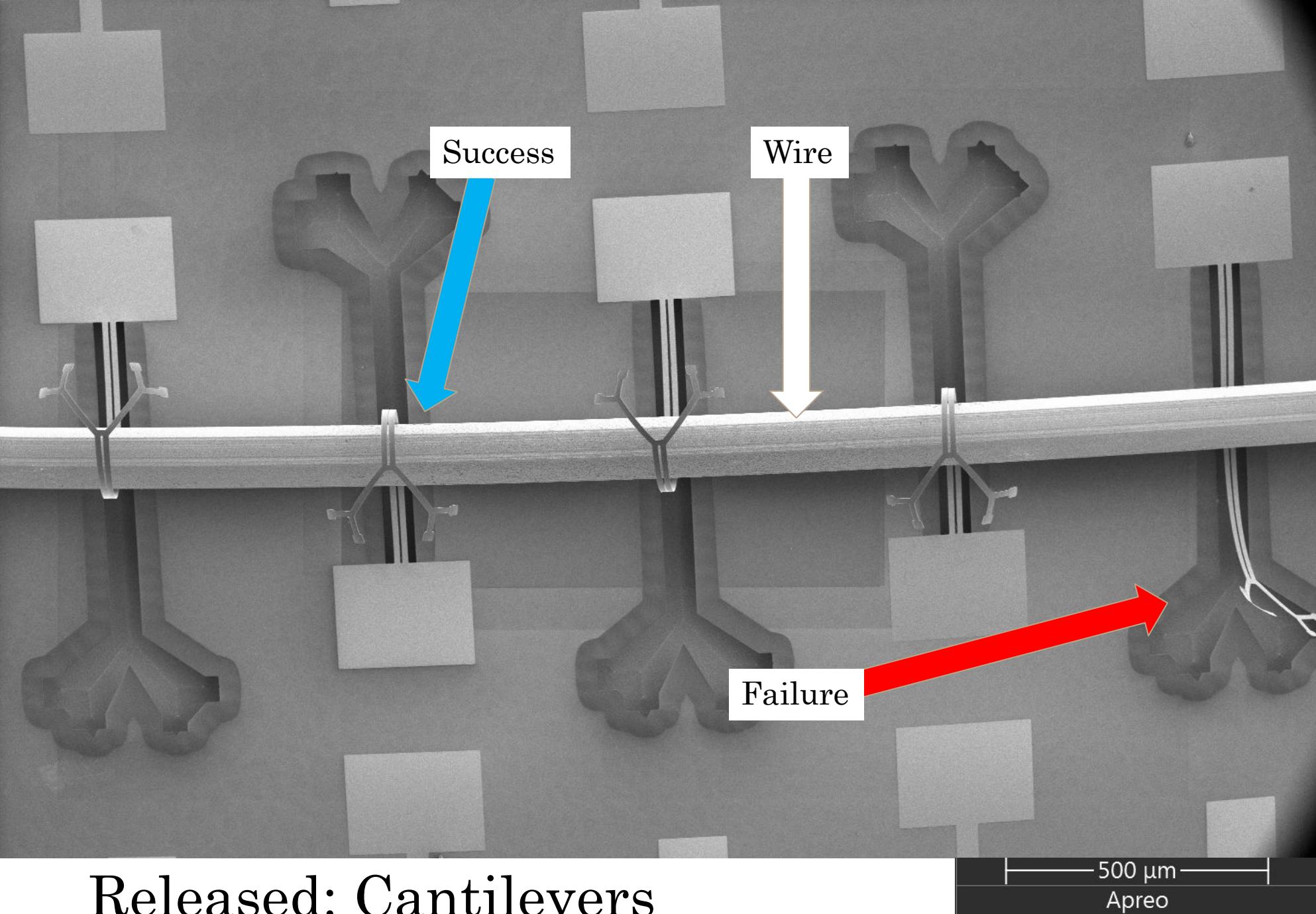


Release onto wire

Conductive Wire
~100 microns

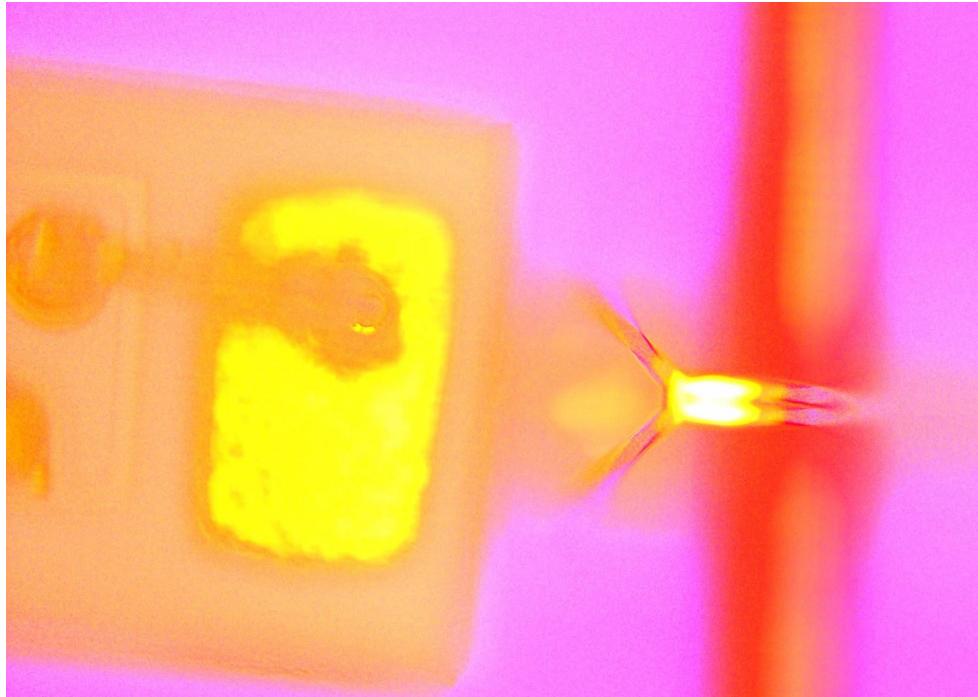


Visible strain

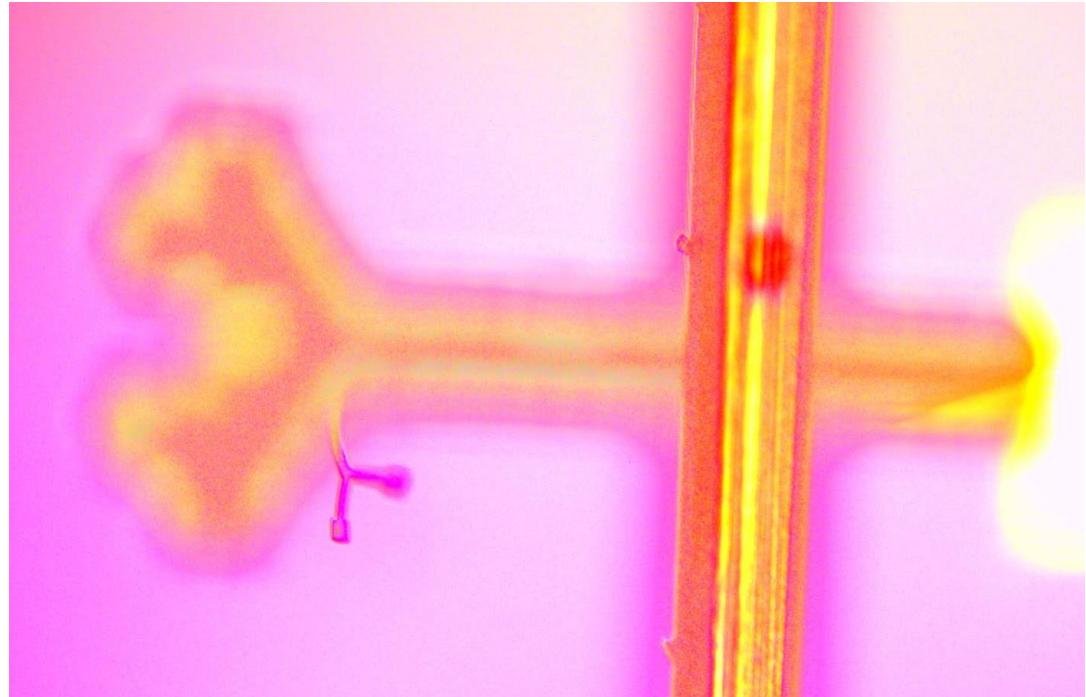


Released: Cantilevers

Gripper Connection Types



Type 1: Successful



Type 2: Failed
(Due to twisting, lithography error, etc.)

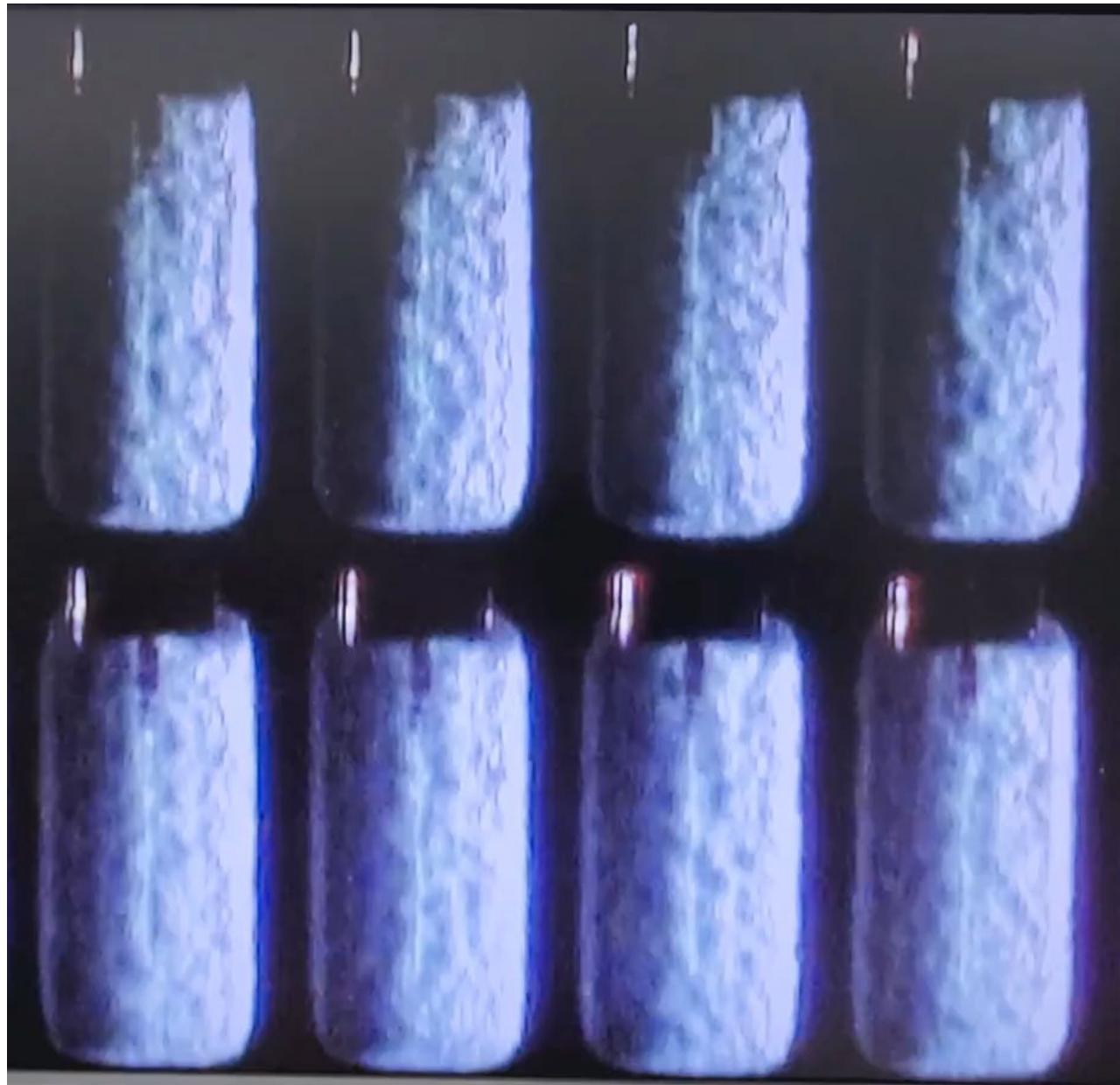
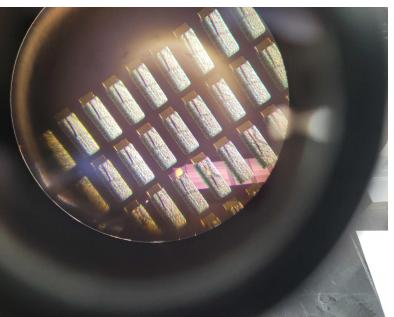
Preliminary Exp. : Cantilever Testing

-Heated from 30 -> 210 C

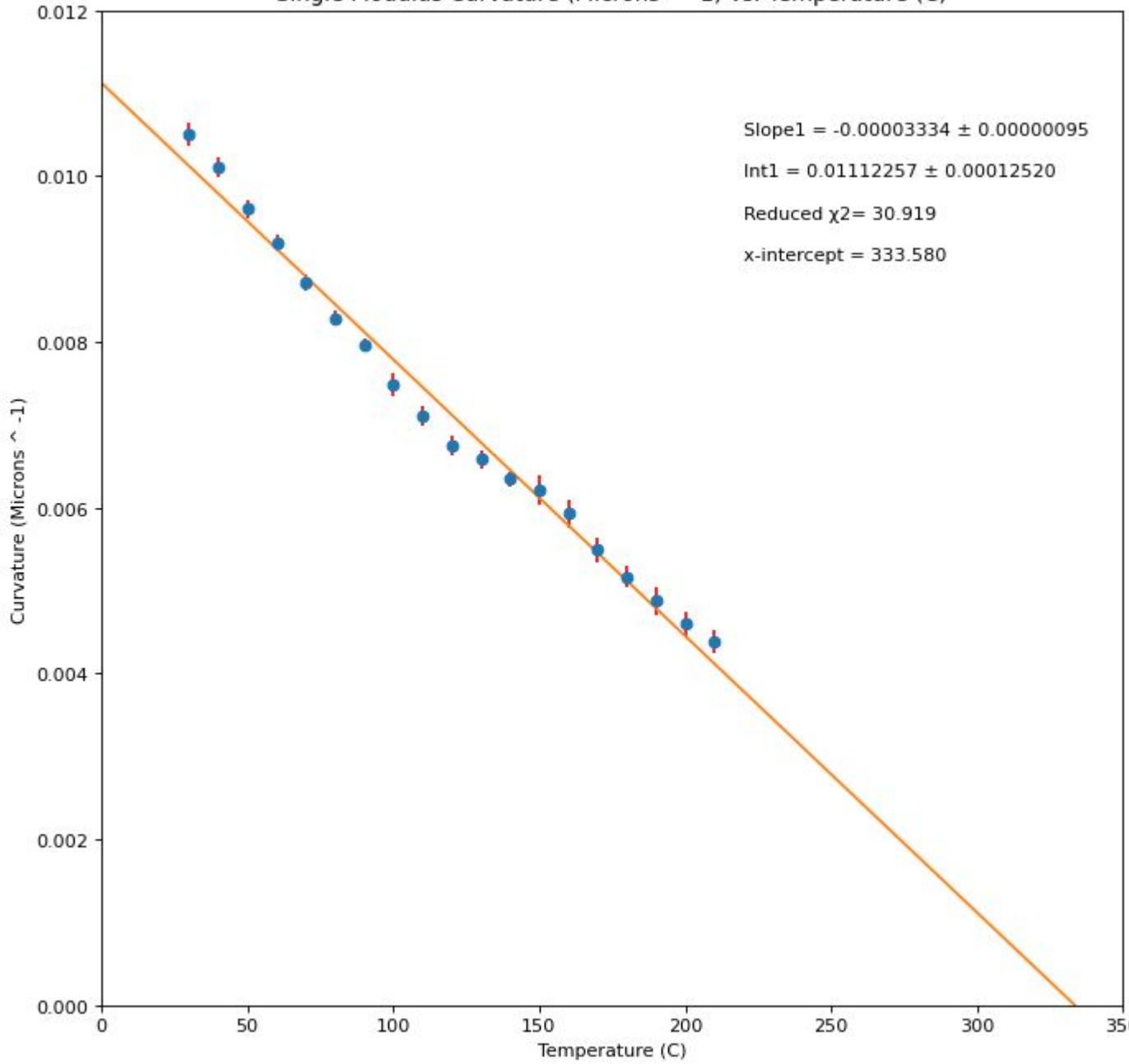
-Visible Uncurling of
Cantilevers

Until ~160 C, rigid behavior

~160 C -> 210 C,
“Spring”-like behavior,
cantilevers **highly sensitive**
to small vibrations



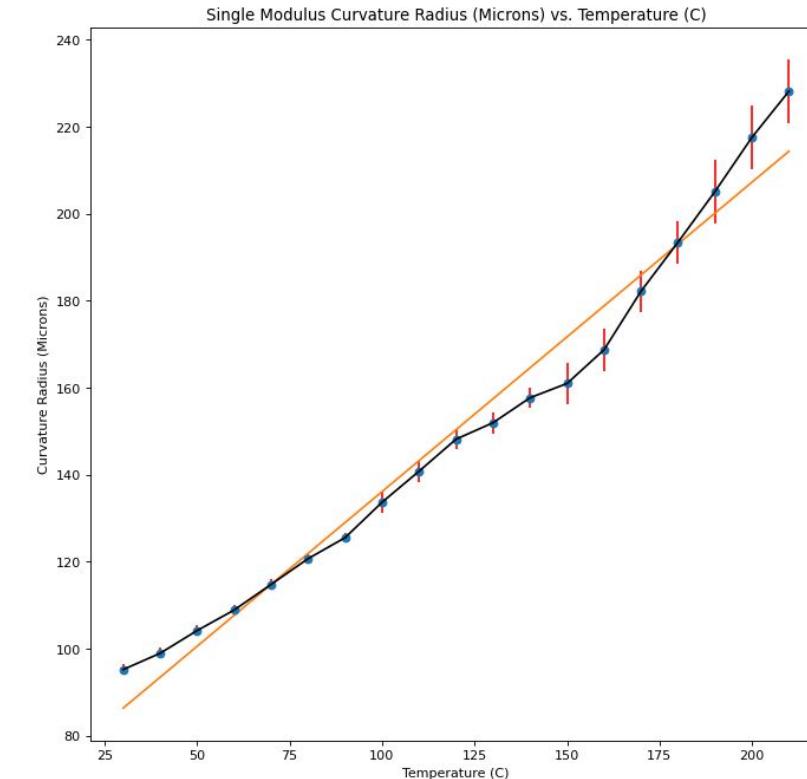
Single Modulus Curvature (Microns $^{-1}$) vs. Temperature (C)



Flat-Cantilever :
333.580 C

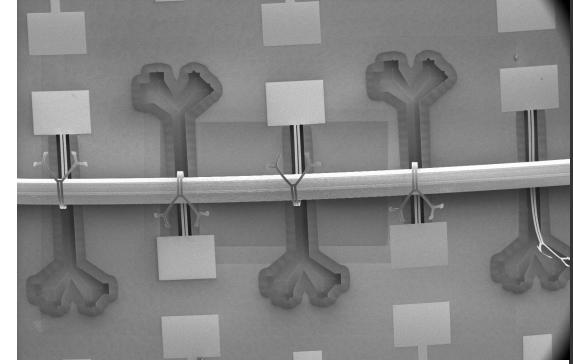
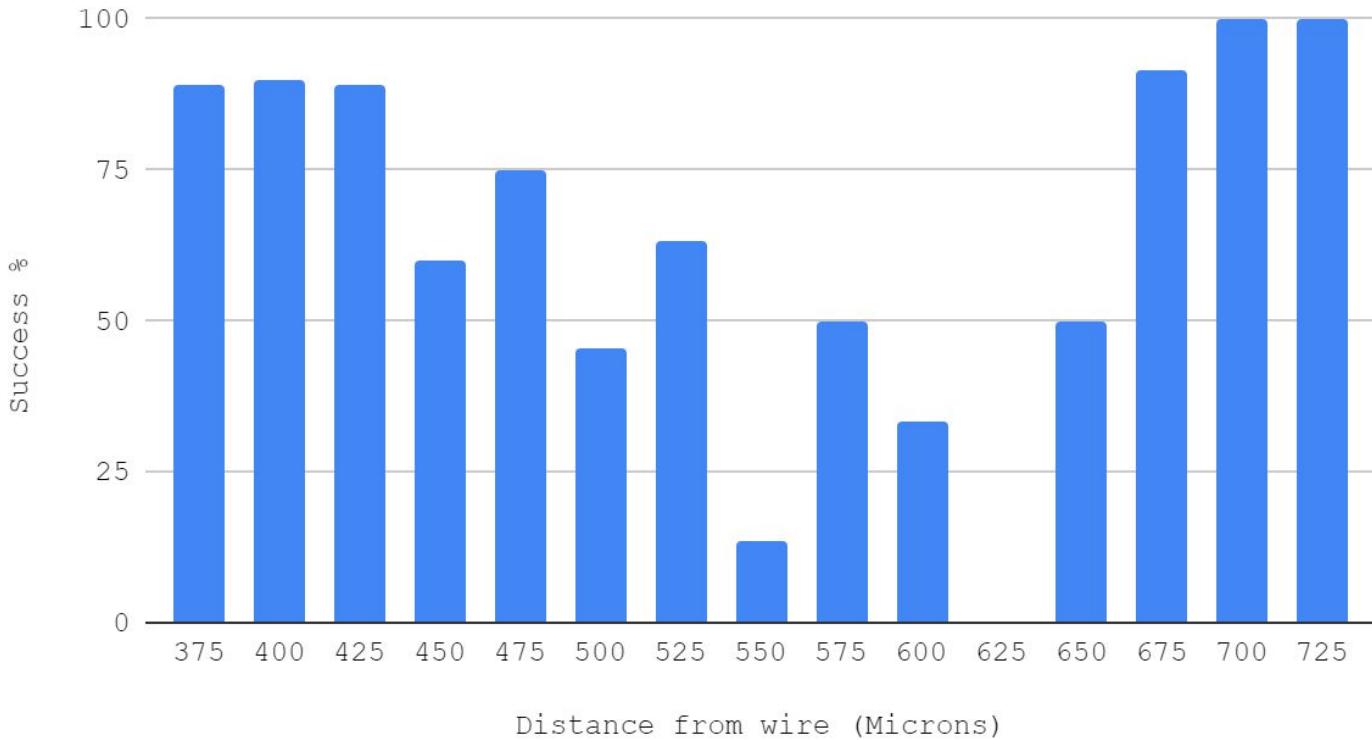
Previous Paper:
337 C

Simple Linear Model



Part 1: Gripper Characterization

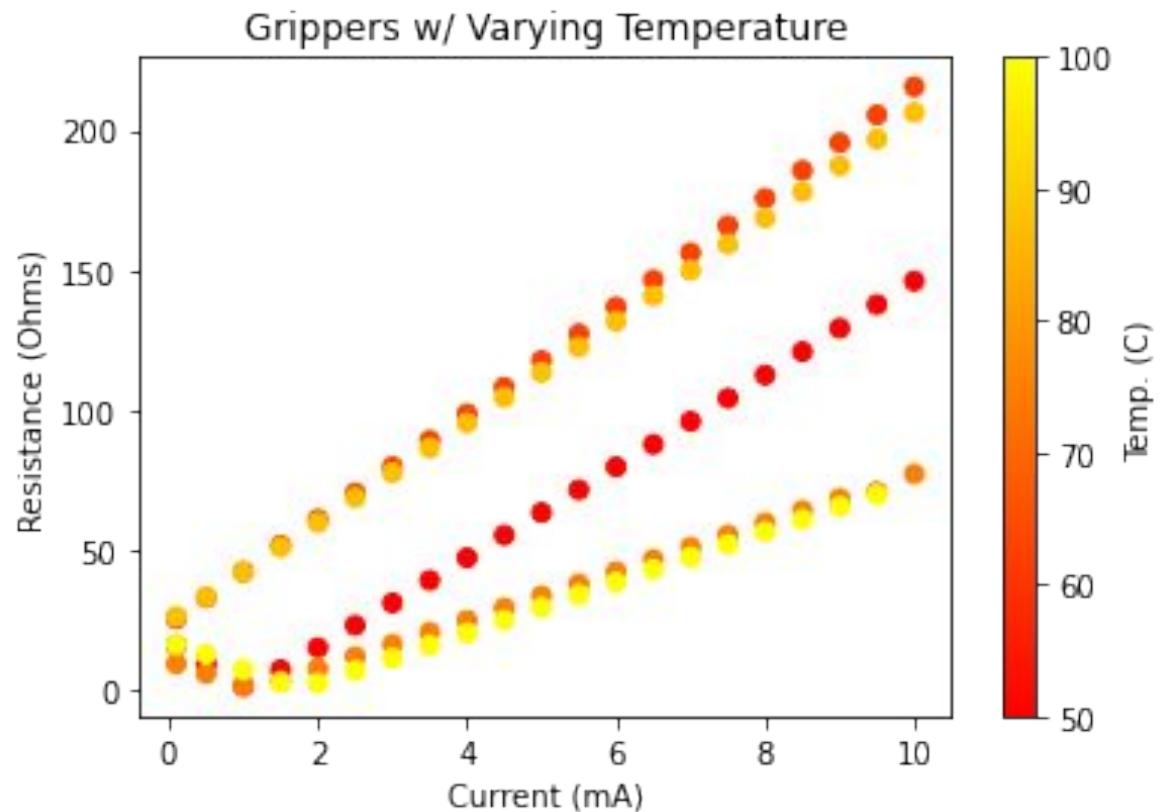
Gripper Success % By Distance from wire



Most reliable when distance from end to wire is:

$< 425 \mu\text{m}$ or $> 675 \mu\text{m}$

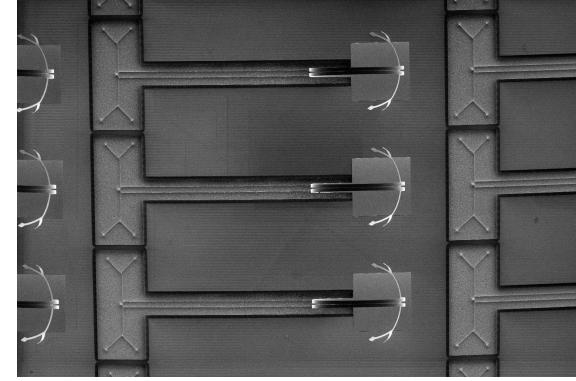
Part 1: Gripper Characterization



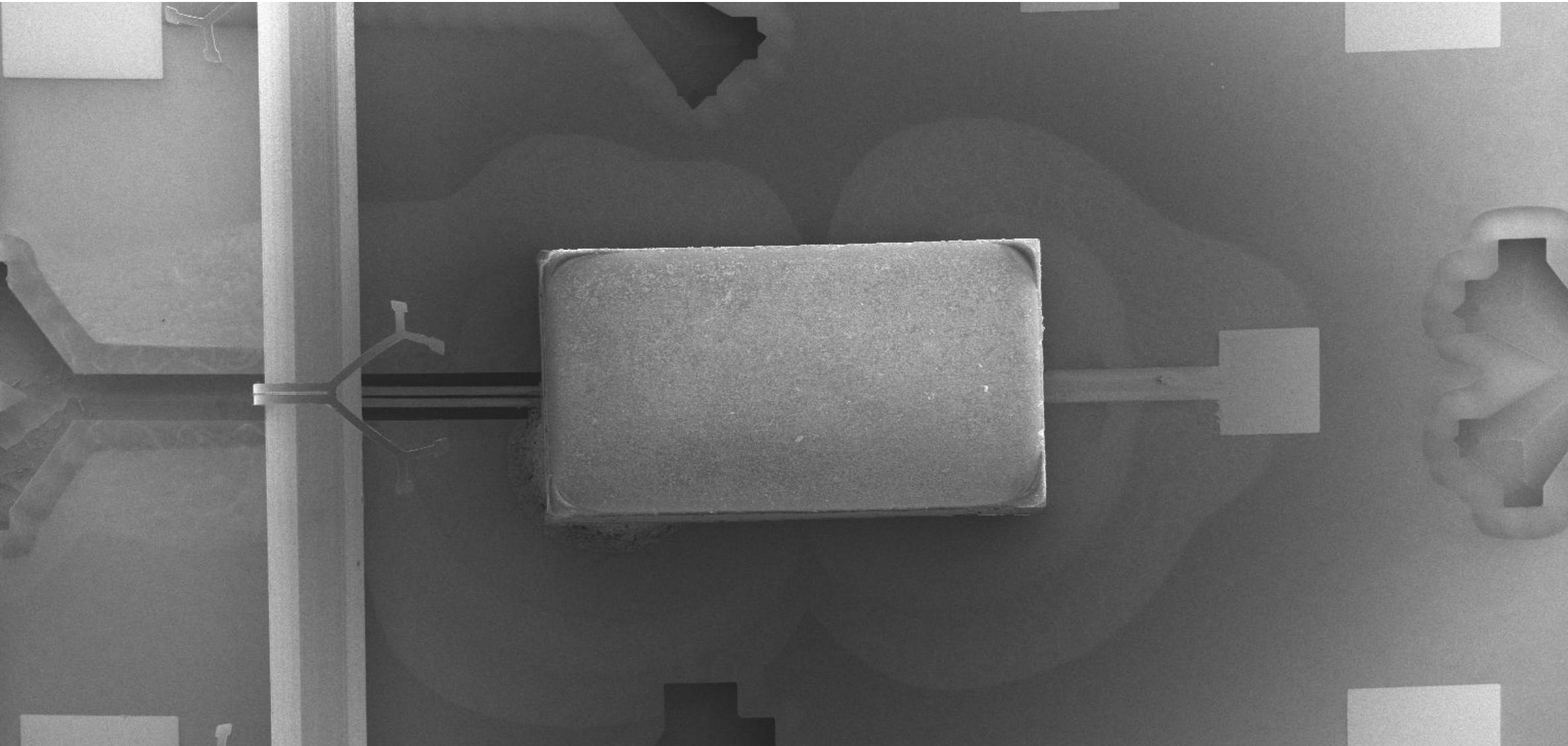
- Lowest resistance point shifts with temperature
- Slope decreases with temperature
- Minimal resistances between $0.5 \Omega \sim 10 \Omega$

Gripper #	Before Ω	After Ω
1-1	770	8.353
1-2	14.27	14.07
1-3	466.7	15.63
1-4	10.2	9.76
1-5	17.8k	13.28

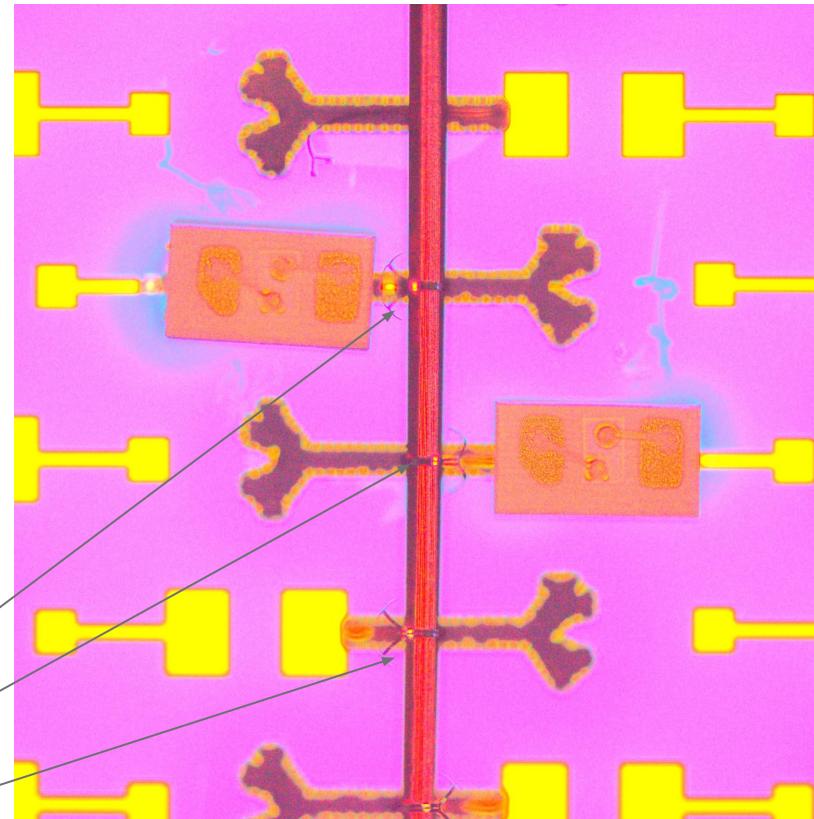
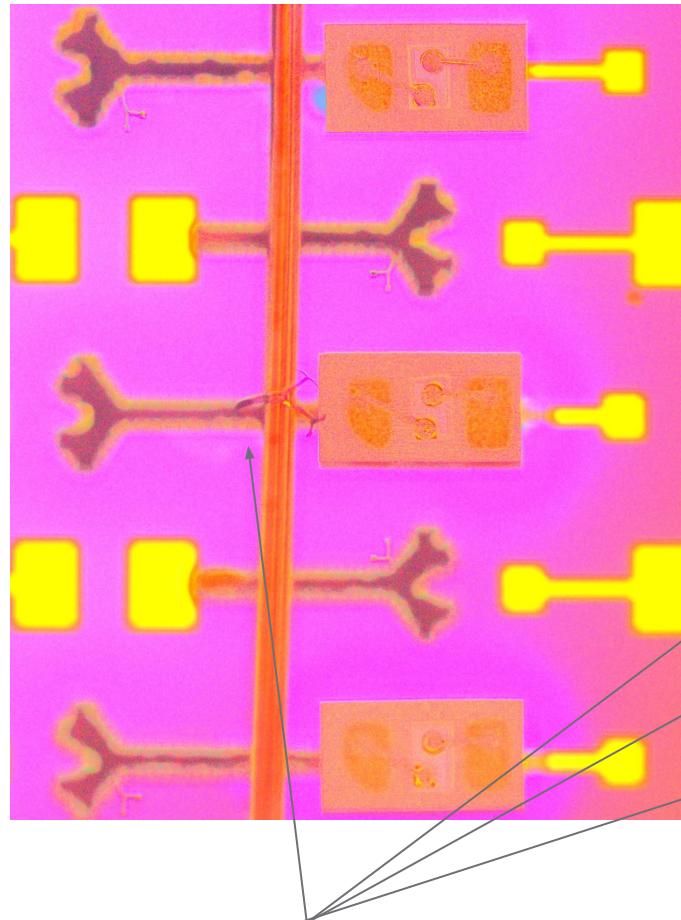
“Juicing” grippers with large currents (~ 20 mA) and returning to normal currents ($\sim 0.1\text{-}5$ mA) stabilized performance



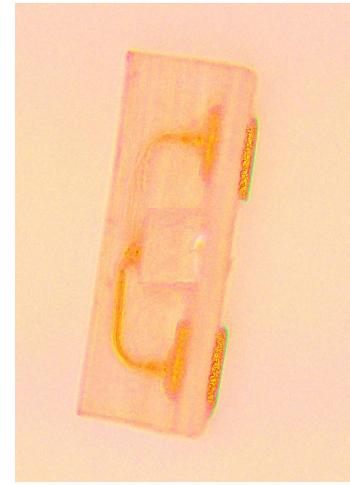
Part 2: Single-Grip on LEDs



PArt1: LED-Carrying Grippers



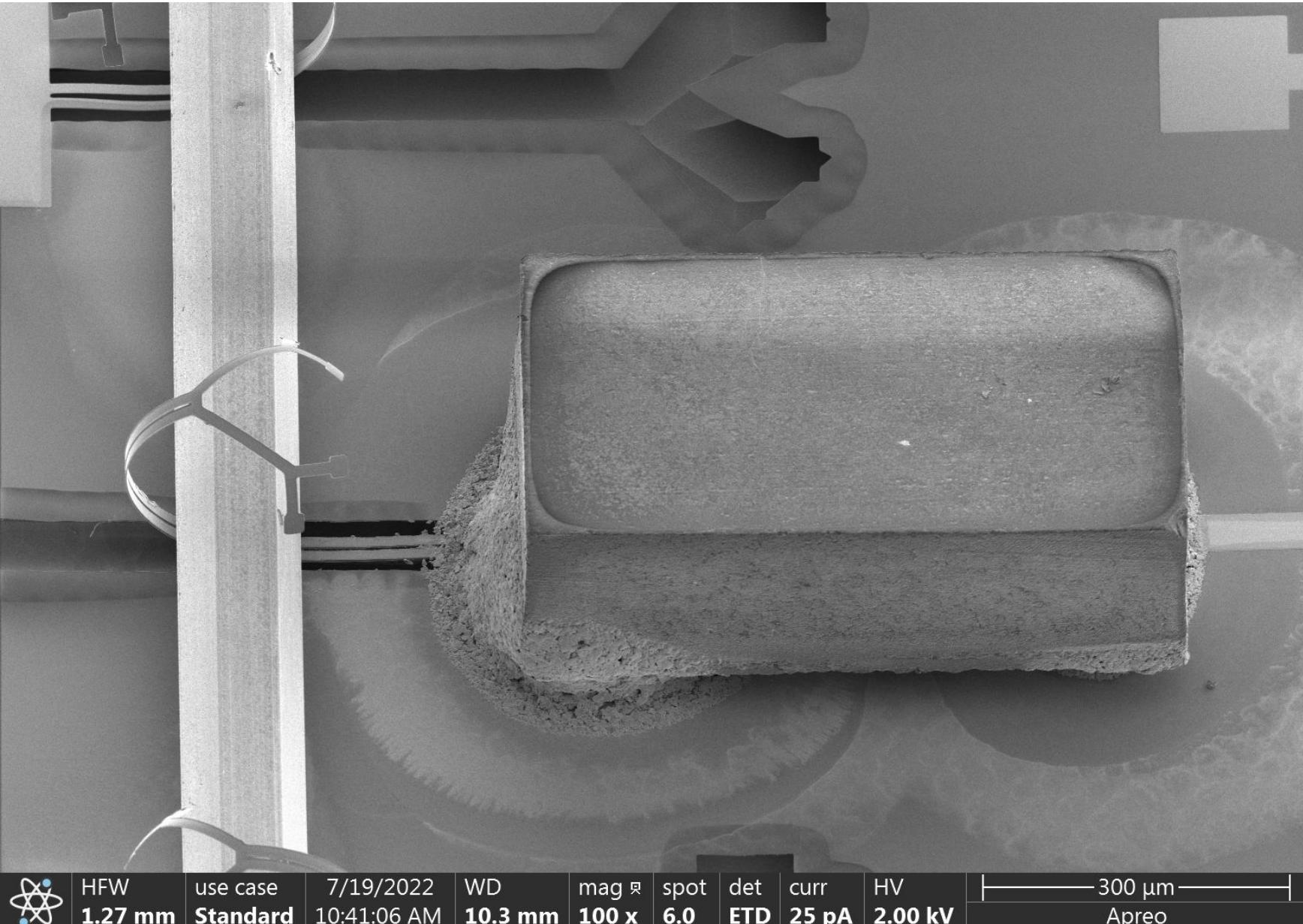
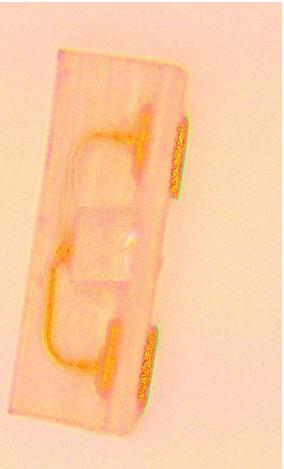
Successful Connection



Part 2: Single-Grip LED

- Successful Release
- Wire was manually shifted to left for secure grip during experiment

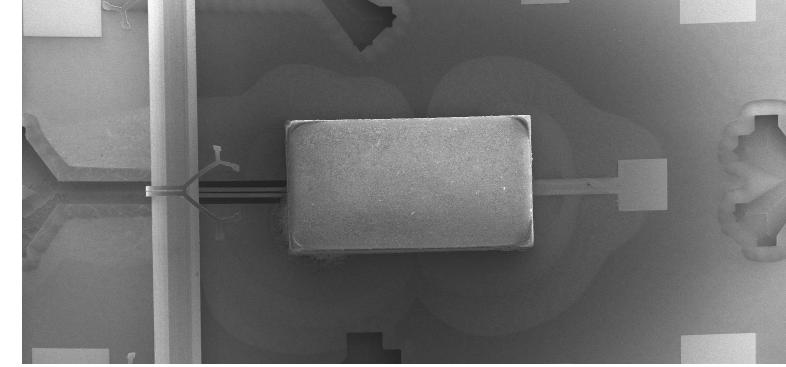
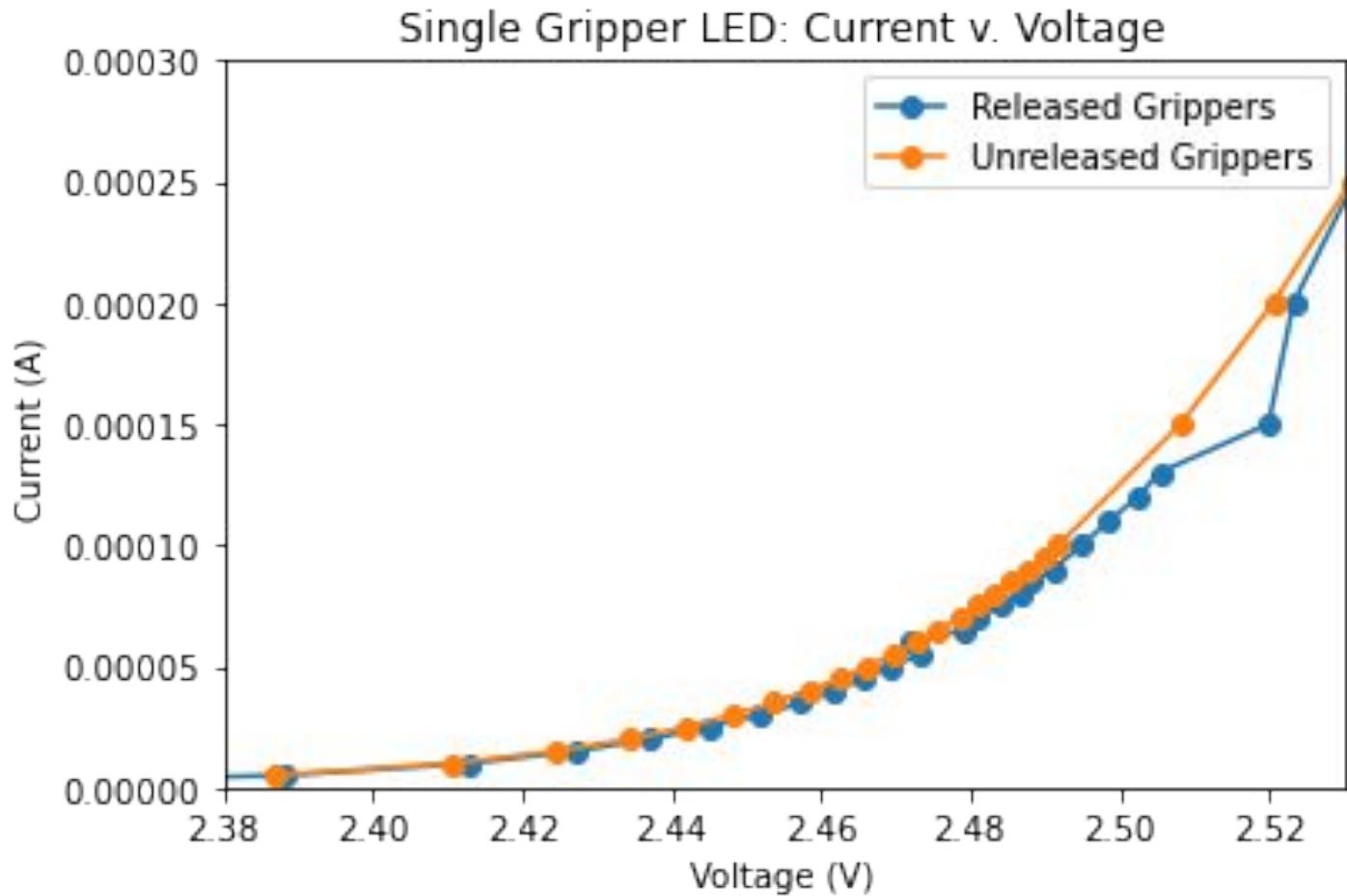
LED



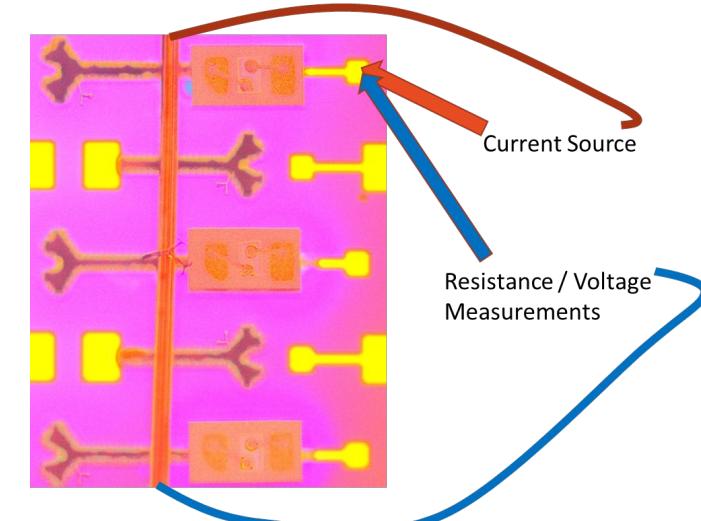
14

Atom icon	HFW 1.27 mm	use case Standard	7/19/2022 10:41:06 AM	WD 10.3 mm	mag 100 x	spot 6.0	det ETD	curr 25 pA	HV 2.00 kV	300 µm
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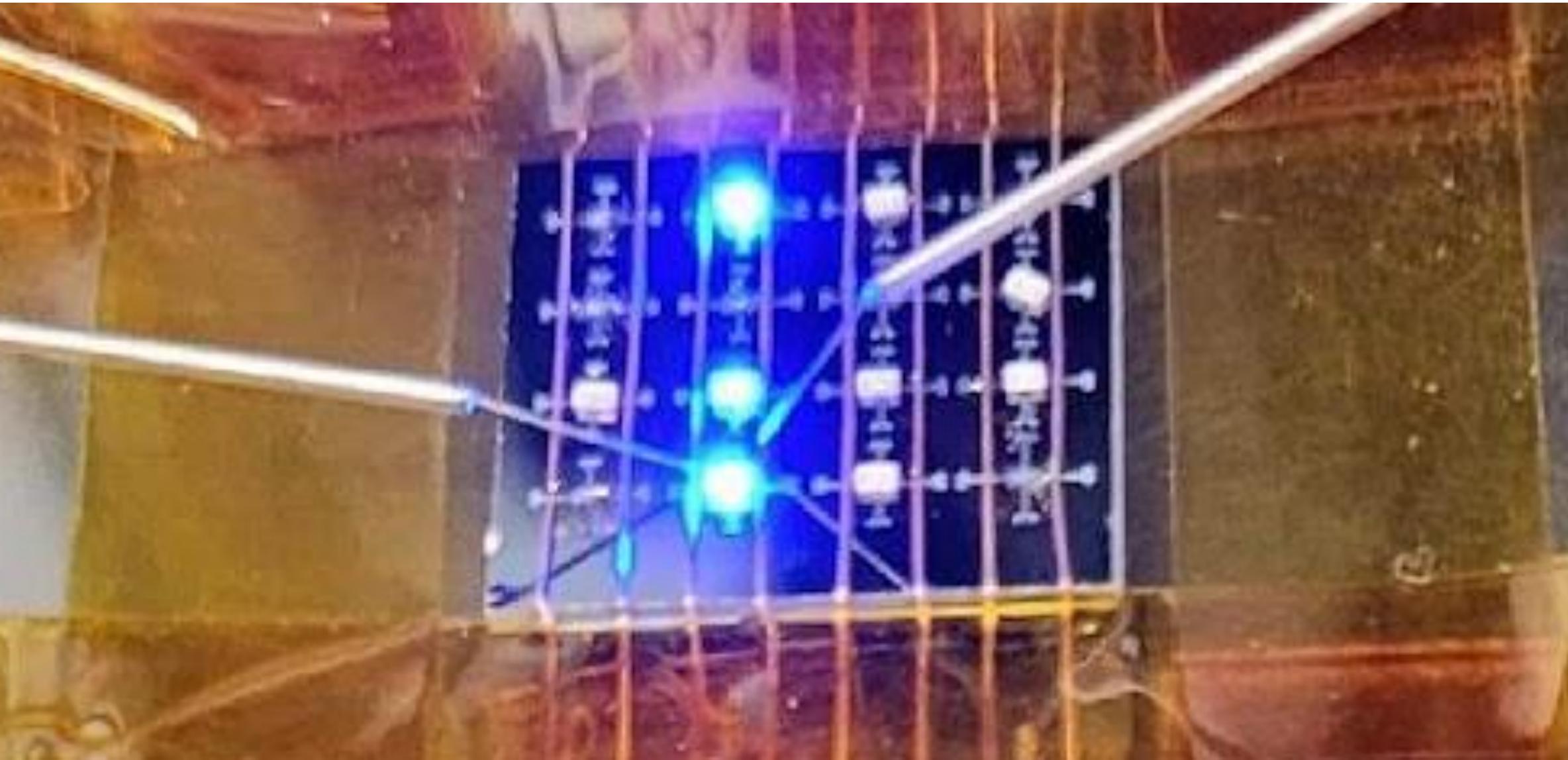
Part 2: Single-Grip on LEDs



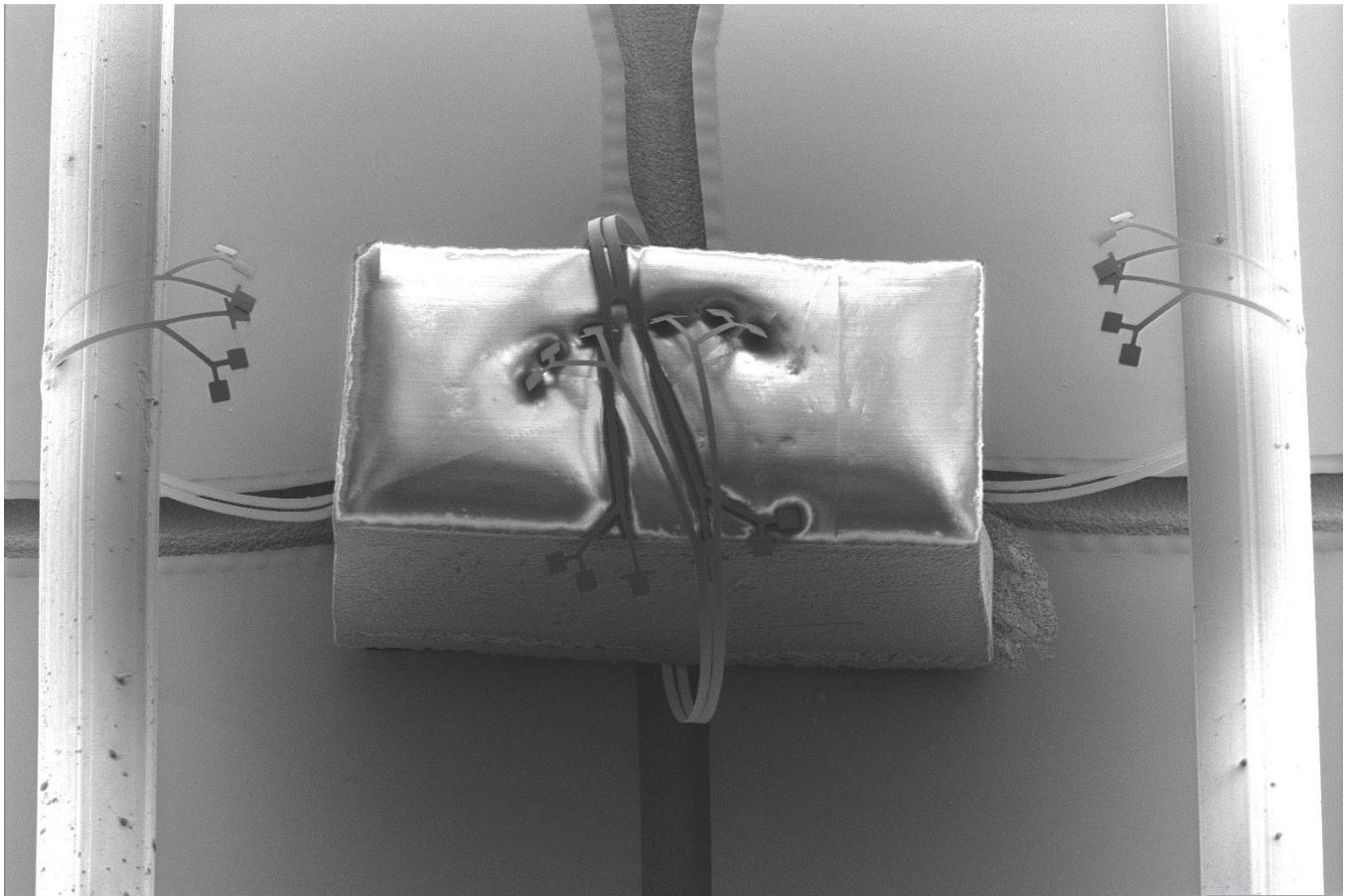
Released grippers have minimal effect on LED performance



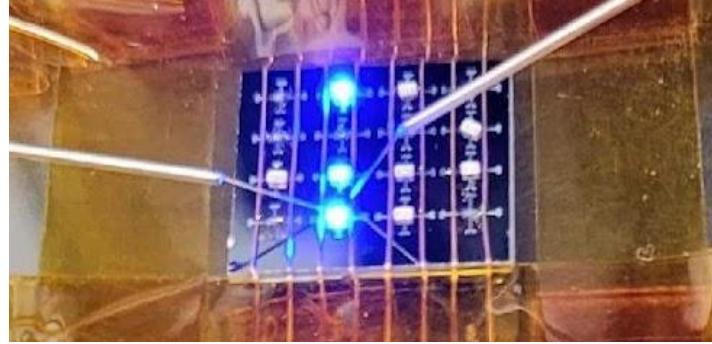
Part 3: Double-Grip on LEDs



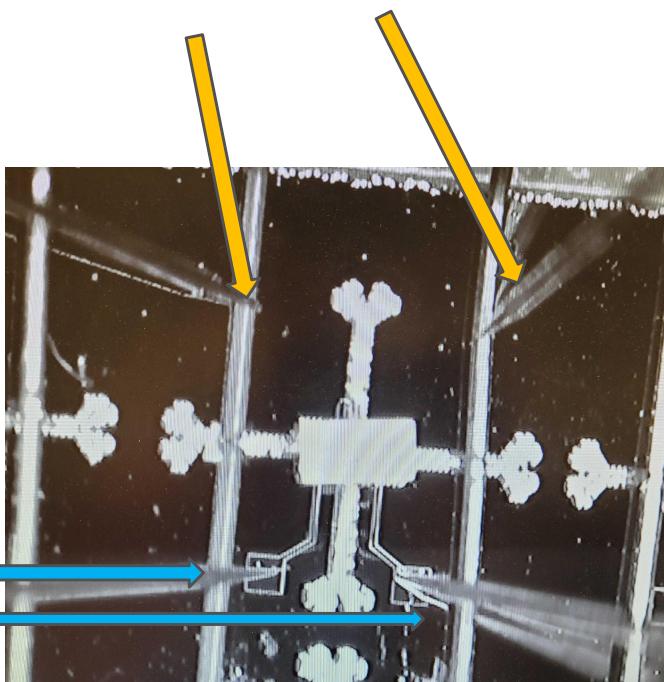
Part 3: Double-Grip on LEDs



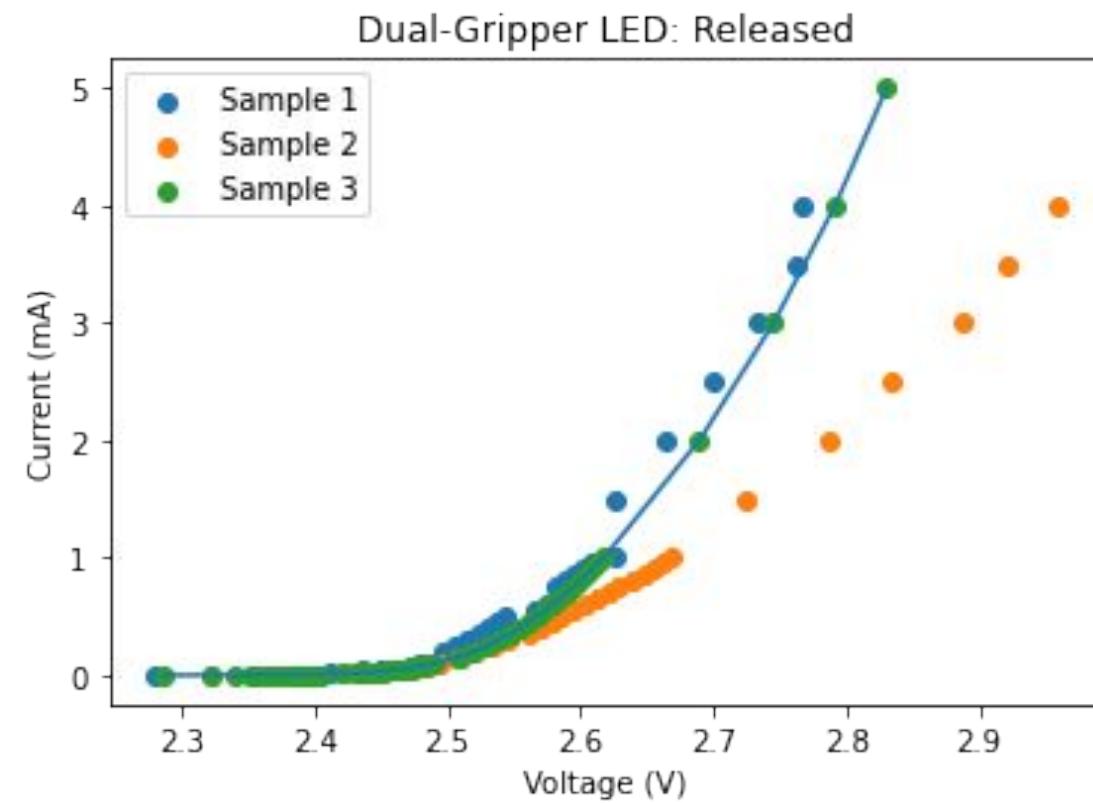
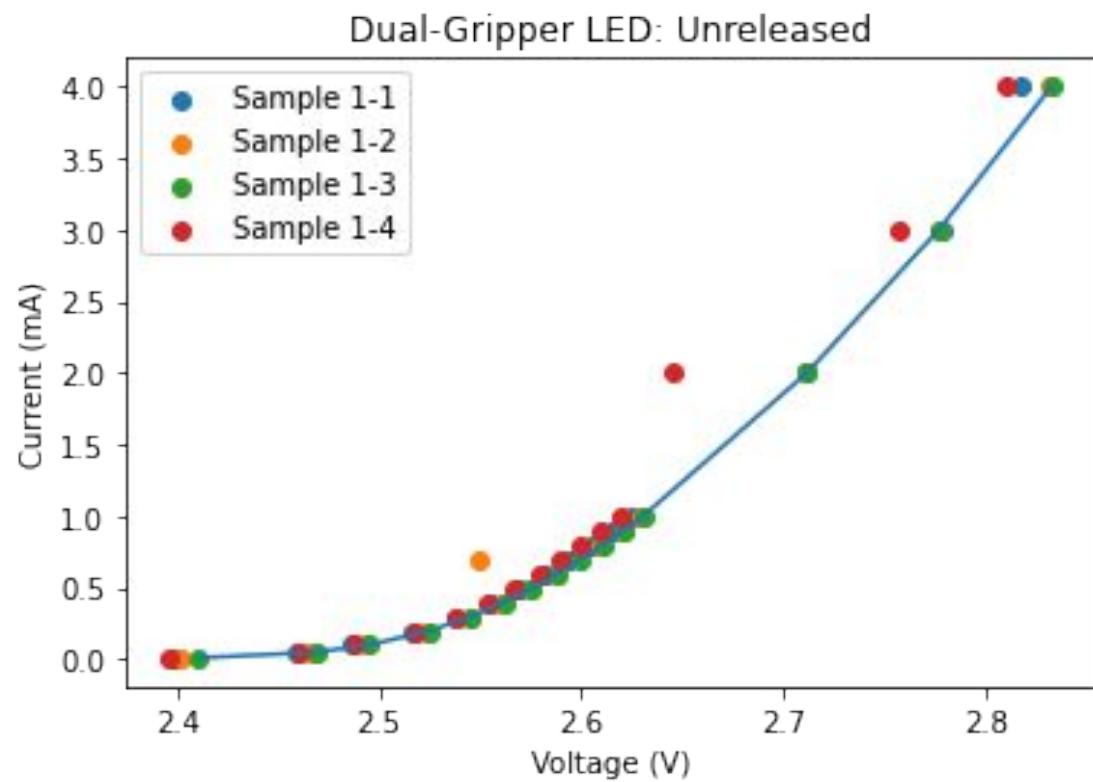
Resistance
Measurements



Sourcemeter
-Provides variable
current



Part 3: Double-Grip on LEDs



Final Remarks

- Gripper structures can efficiently, reliably power circuit systems
- Grippers hold potential as temperature / current overflow sensors
- Grippers, under correct conditions, have acceptable resistances ($10\ \Omega \sim 150\ \Omega$)

Acknowledgements

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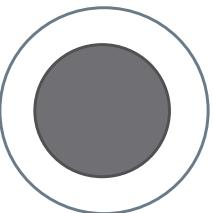
Dr. Evgenia Moiseeva

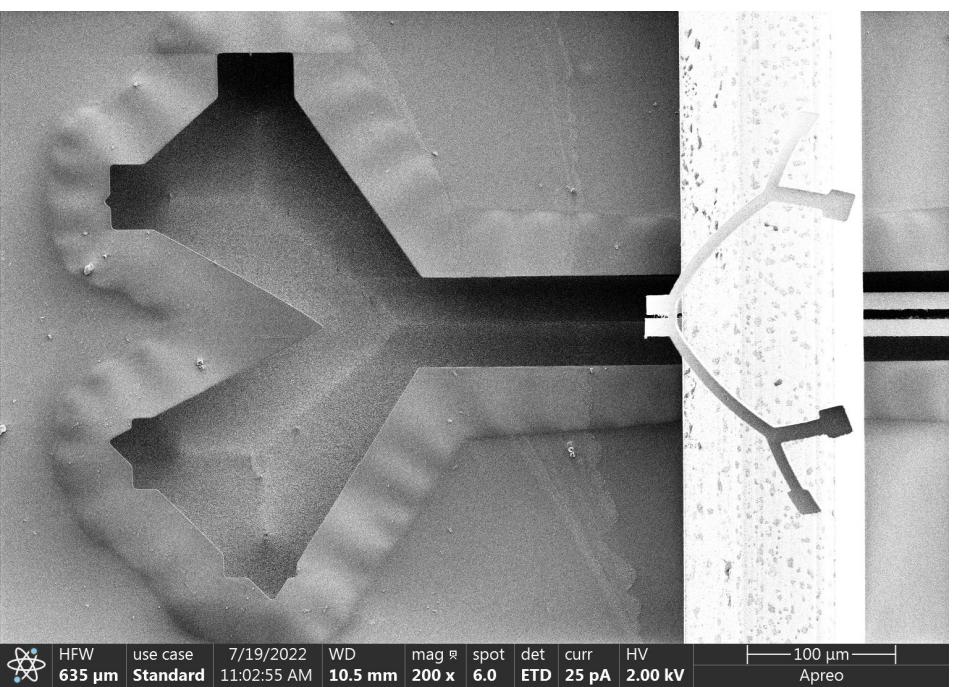
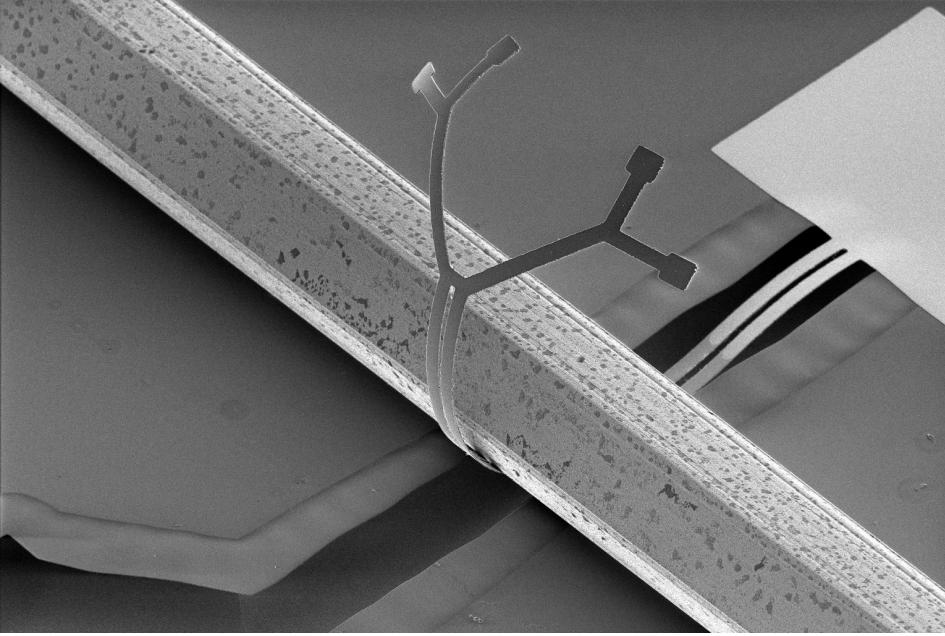


Part 3: Double-Grip on LEDs – Solder and Parylene Effects

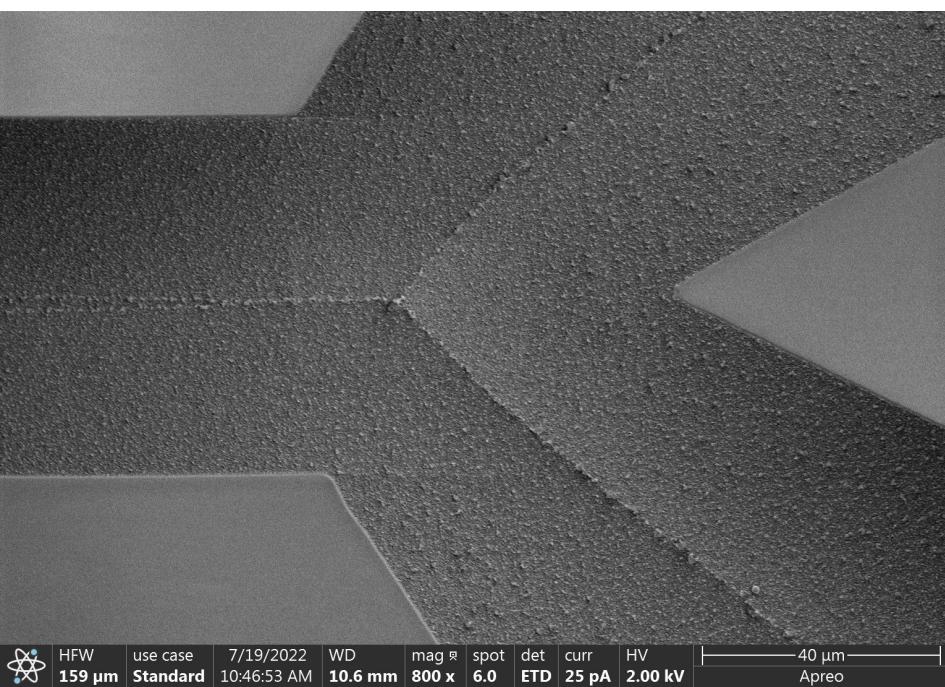
Etch Process

Parylene Coating
~10 microns (not to scale)

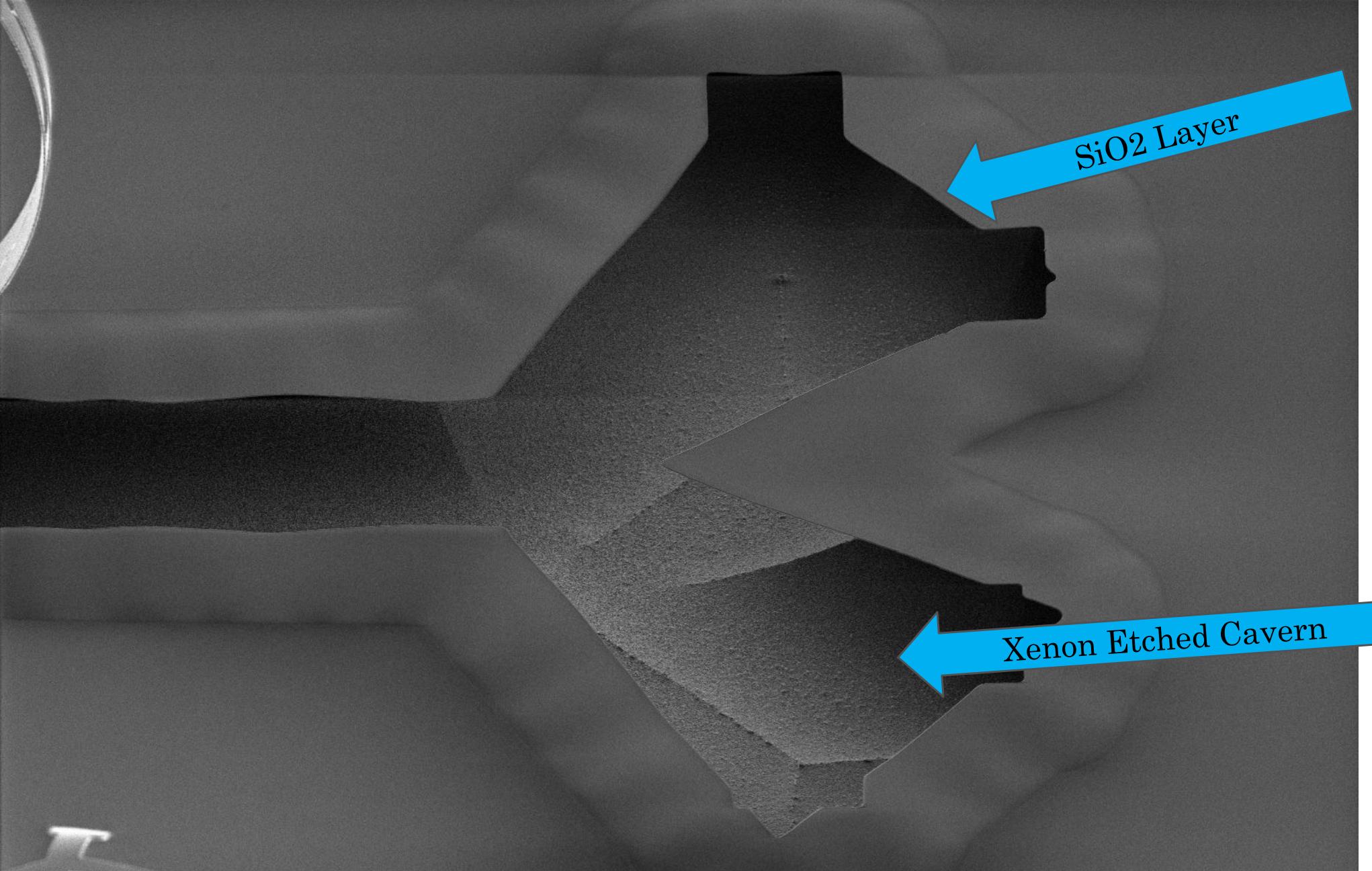




HFW use case 7/19/2022 WD mag spot det curr HV
635 μm Standard 11:02:55 AM 10.5 mm 200 x 6.0 ETD 25 pA 2.00 kV
100 μm
Apreo



HFW use case 7/19/2022 WD mag spot det curr HV
159 μm Standard 10:46:53 AM 10.6 mm 800 x 6.0 ETD 25 pA 2.00 kV
40 μm
Apreo



HFW
508 µm

use case
Standard

7/19/2022
10:53:21 AM

WD
10.7 mm

mag
250 x

spot
6.0

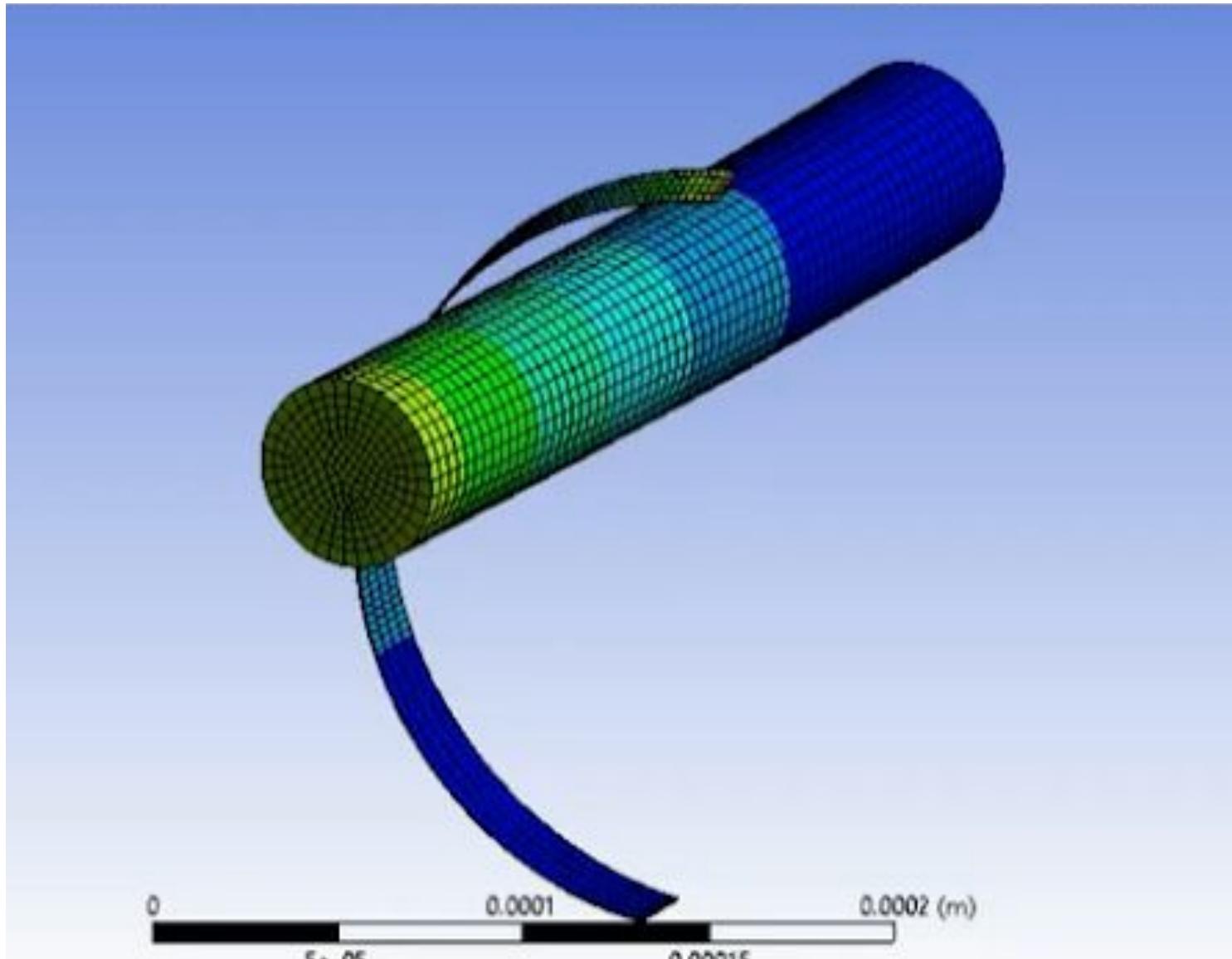
det
ETD

curr
25 pA

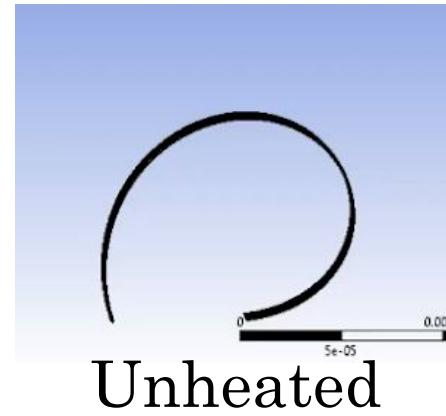
HV
2.00 kV

100 µm

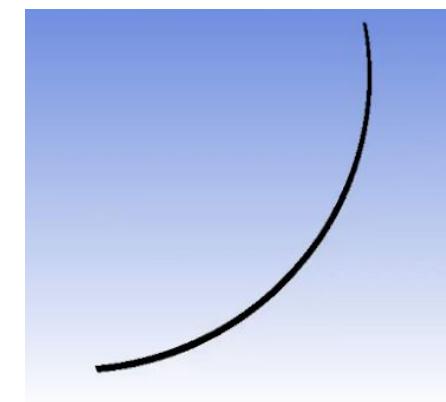
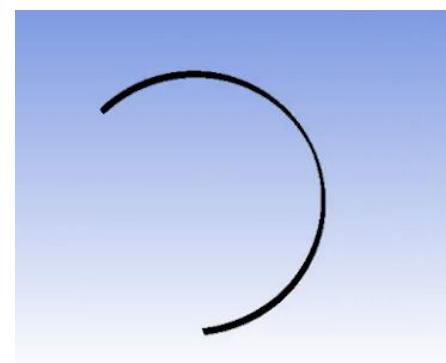
Apreo



Cantilever

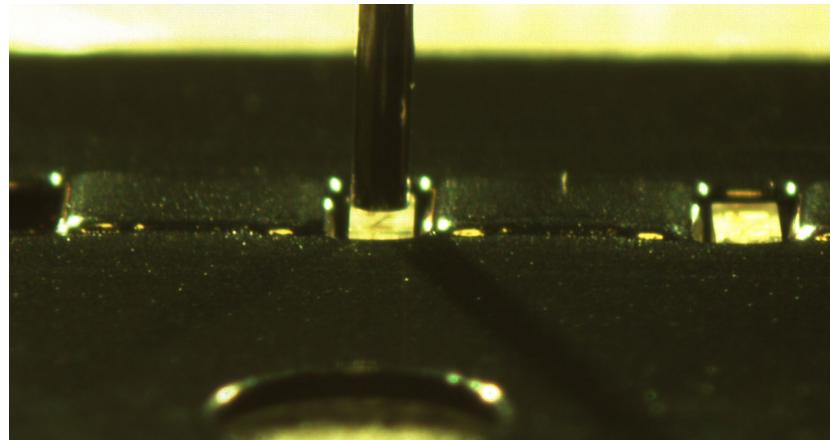


Unheated



Heated

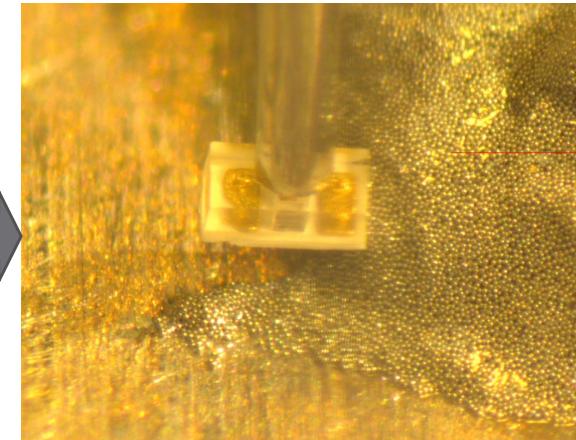
Exp. 1 (&2,3): Manufacturing



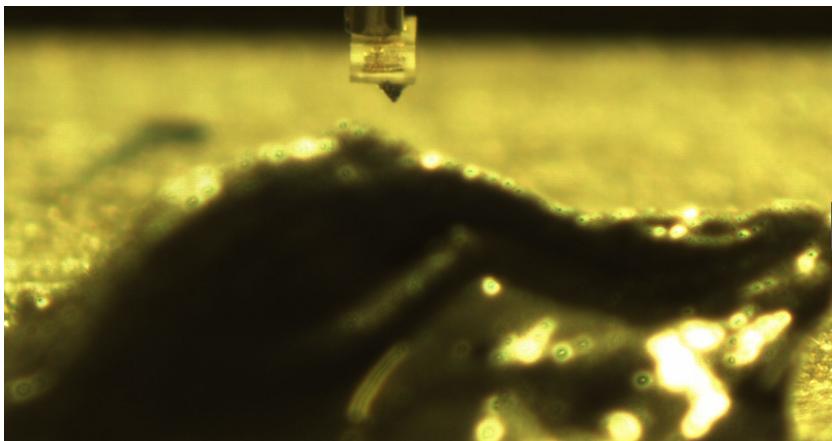
Vacuum grabs LED



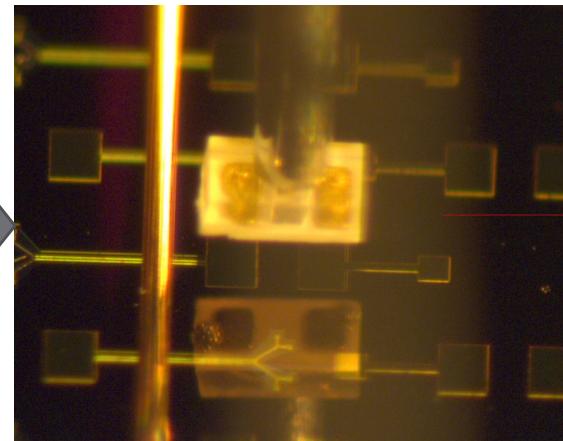
LED brought to solder



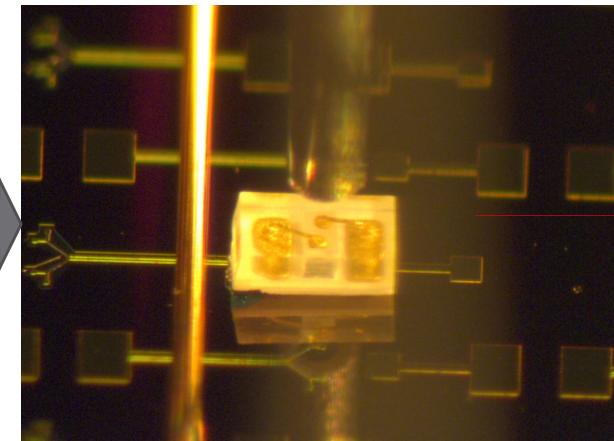
LED dipped in solder



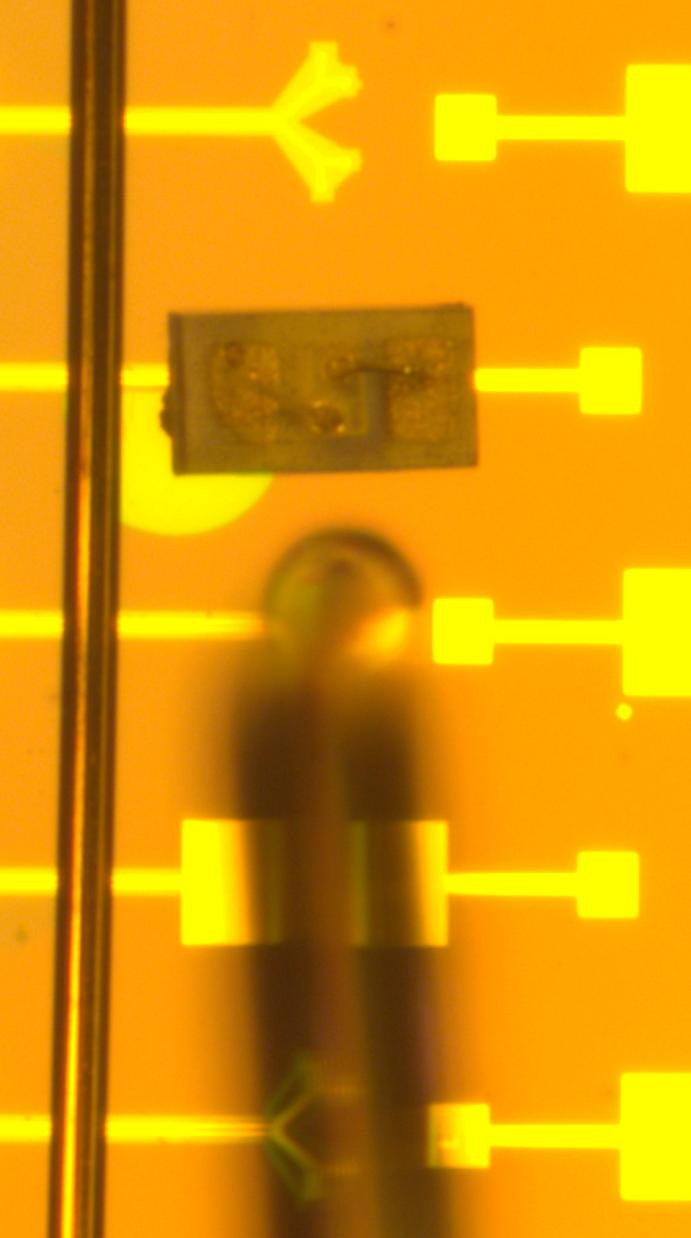
Verify solder is on LED



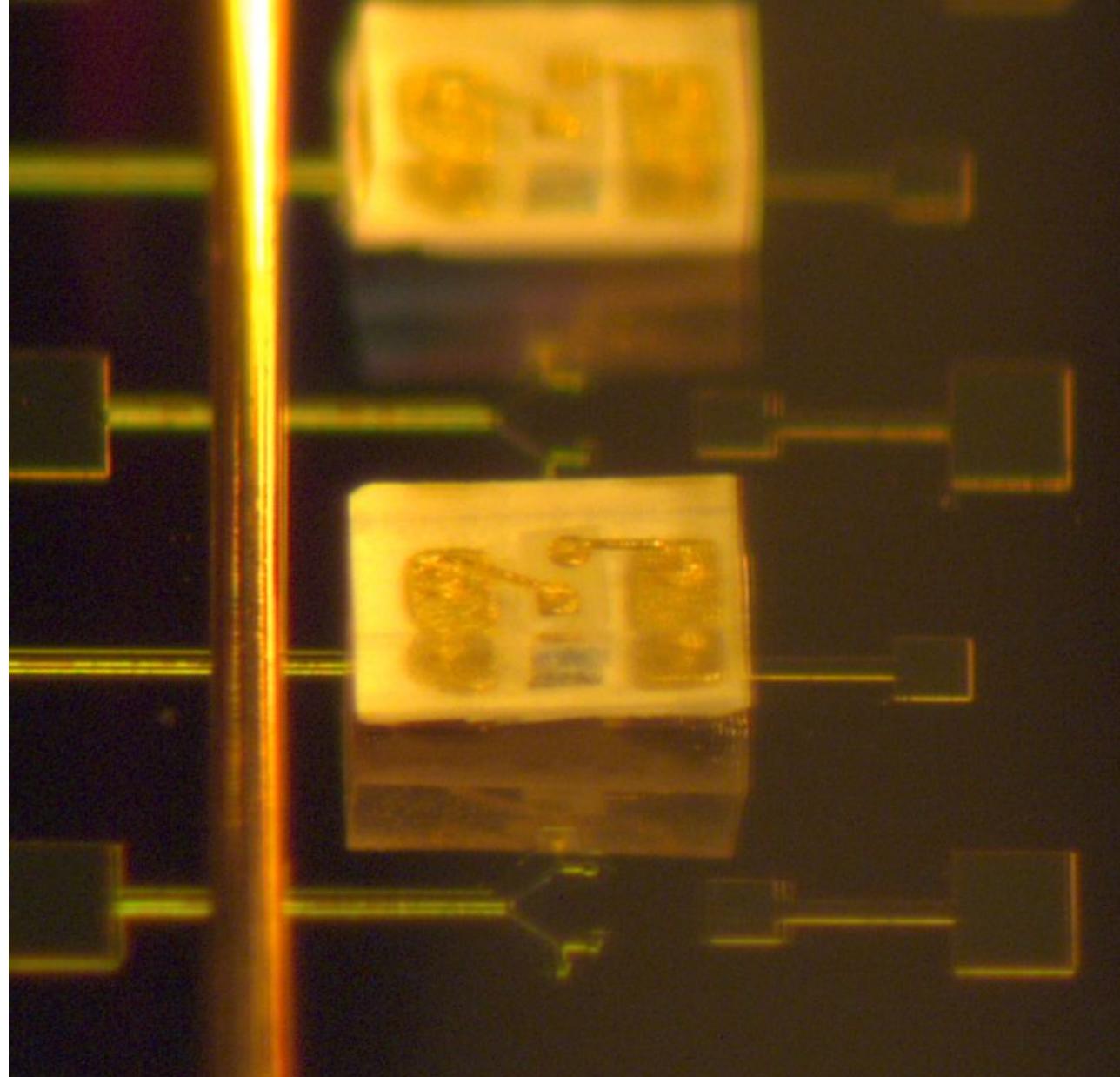
LED to contact pads



LED detached

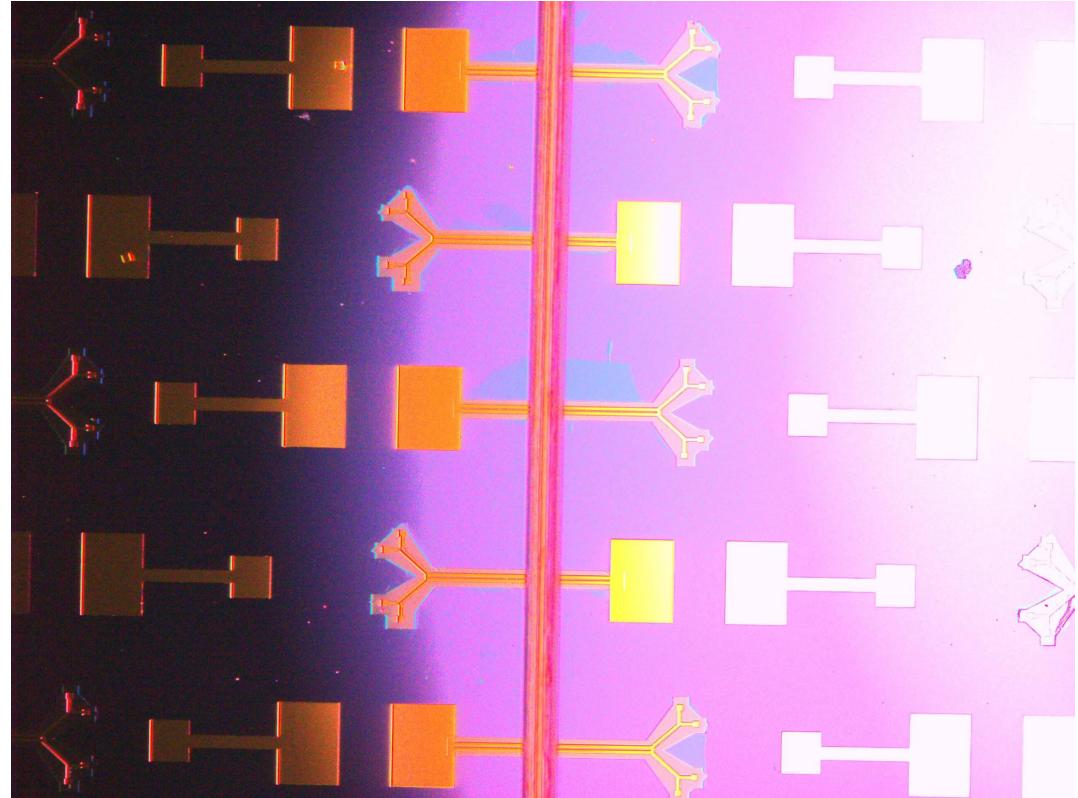
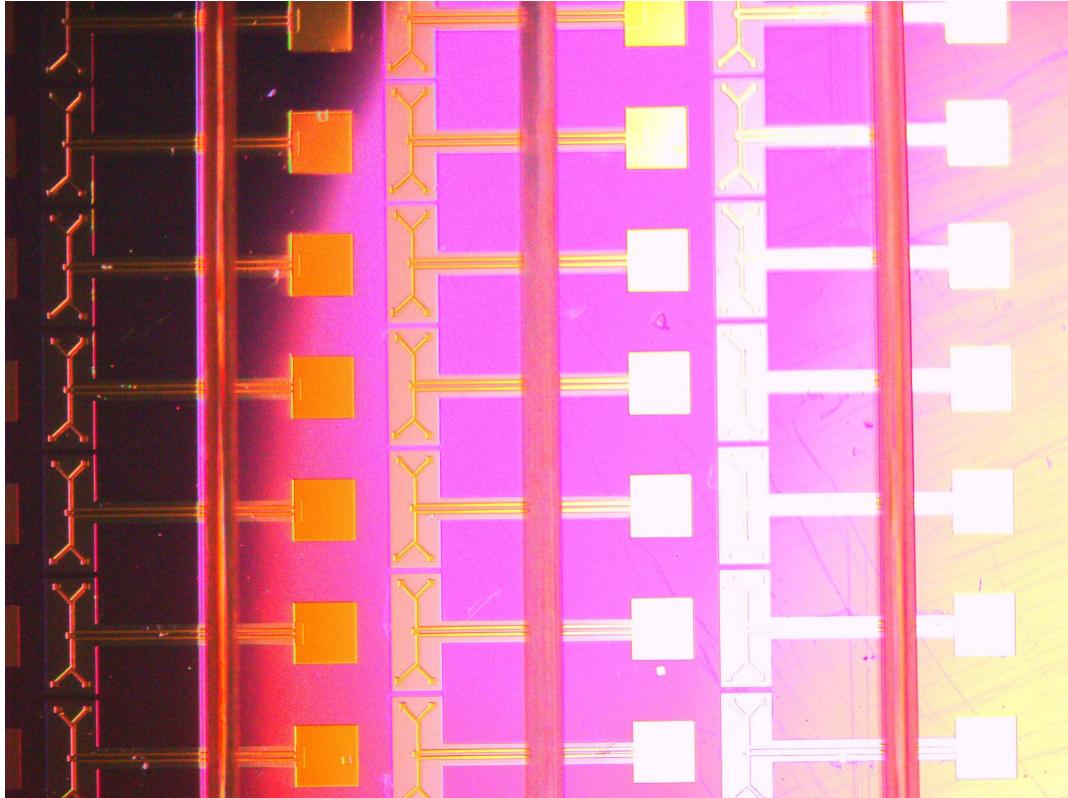


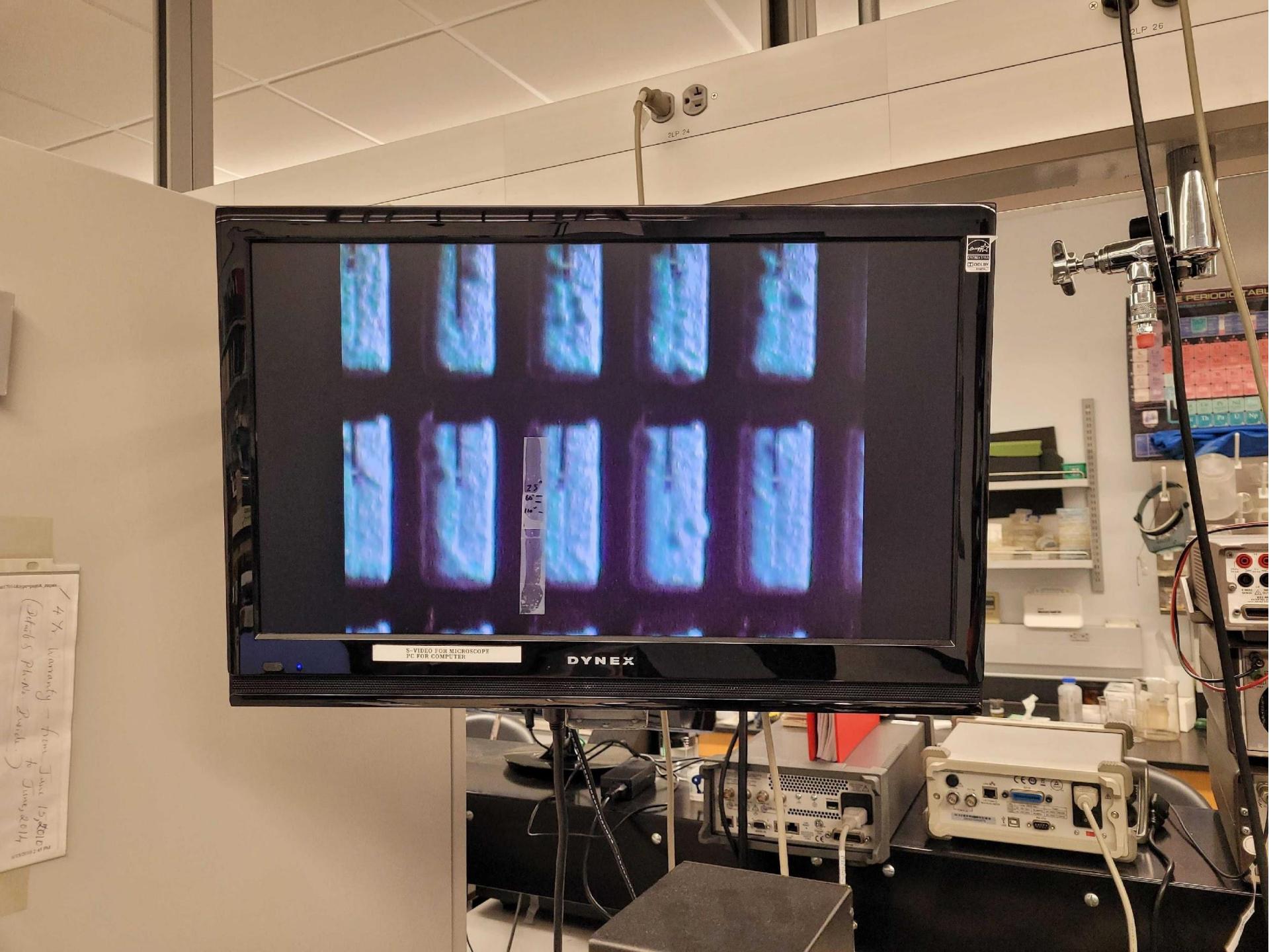
Top View

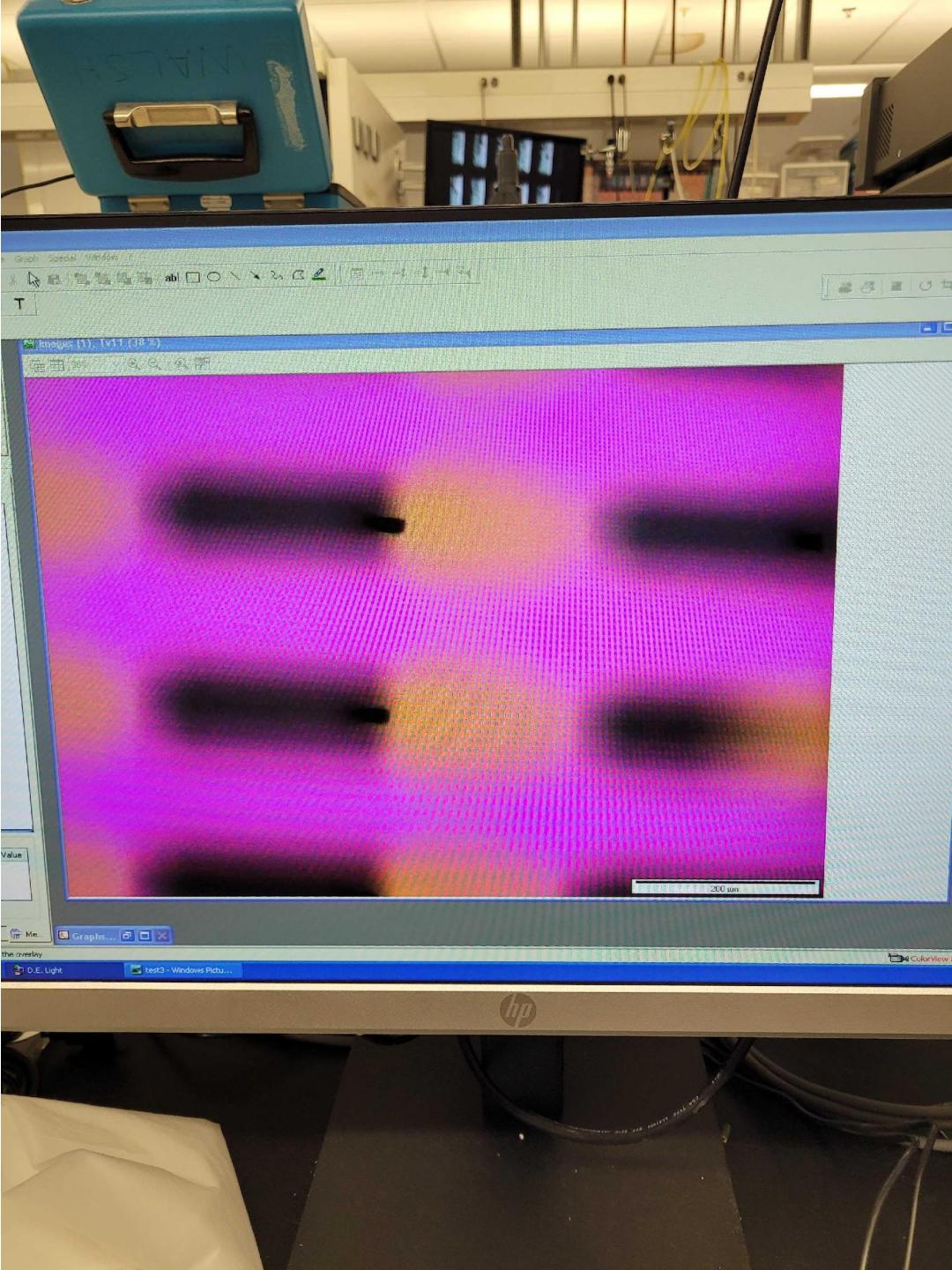
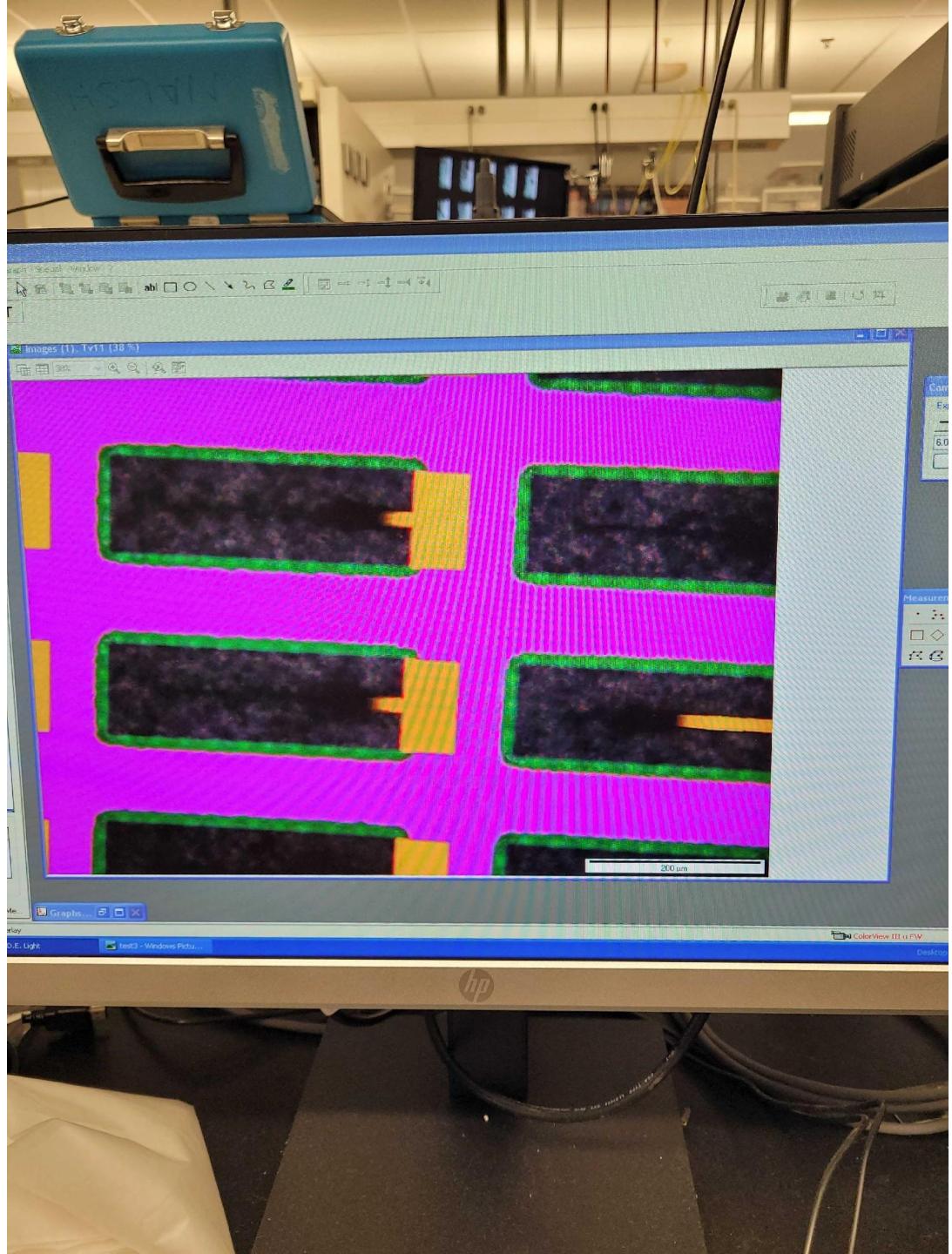


Side View

Setup – Wires on LEDs







Attachment Data

Wires -> ~150 microns away from contact pads

680	680	730	730	780	780	830	830
1	0	1	1	1	0	0	1
1	0	0	1	0	1	0	1
1	1	0	1	1	0	1	1
1	1	0	1	1	1	1	0
0	0	0	1	0	1	0	0
0	1	1	1	1	0	0	1
0	1	0	1	1	0	0	0
0	1	1	1	0	1	0	1
1	0	1	1	1	0	1	1