High Density Optoelectrical Neural Interfaces for Direct Stimulation and Recording of Neural Activity

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Electrical & Computer ENGINEERING

Perception
Memory

Neural code

Collective action of **individual** neurons

Brain: a distributed processor

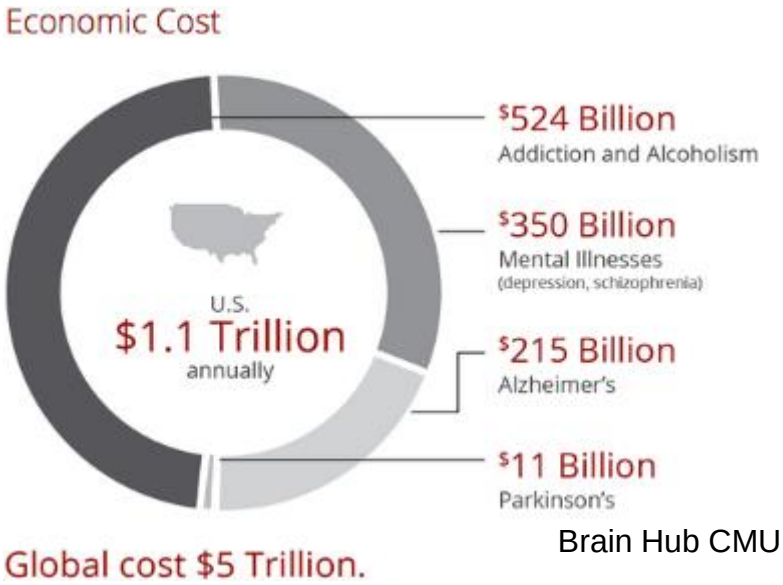
Rebecca Lee (Flicker)

Dynamic circuits-networks

Swirling Sandstone Paria Canyon Arizona

Neural Prostheses

Nervous System Disorders



Brain Hub CMU

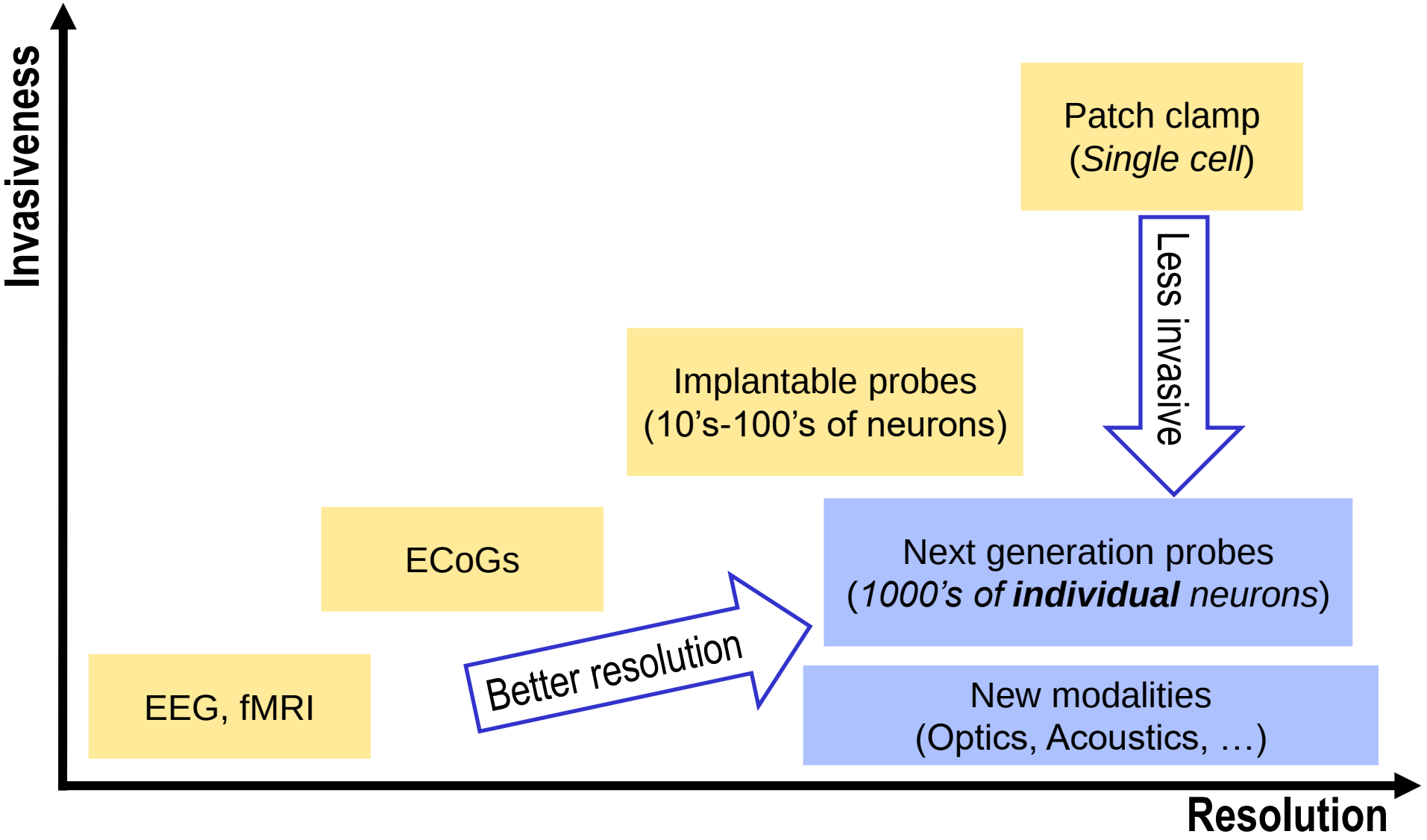
Brain-machine interfaces

University of Pittsburg-UPMC

Internet of things+ **brains**

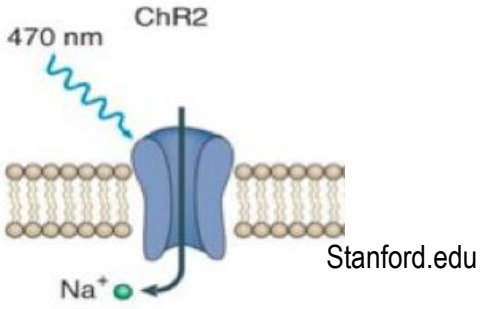
Terra Swarm UCB

What is Needed, What is Missing



Optical Stimulation (Optogenetics)

- Study of CNS disorders
- Cracking neural codes
- Isolating circuit elements of the network



If we can stimulate patterns of activity…

- Understand the neural code
- Identify critical neural circuits and pathways
- Direct writing of high-acuity sensory percepts into the cortex!

R. Pashaei, et al, 2014.

Optical Stimulation (Optogenetics)

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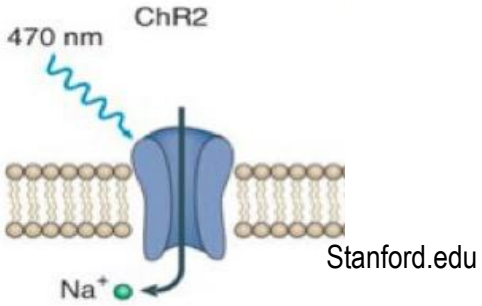


Evolution of light delivery mechanisms

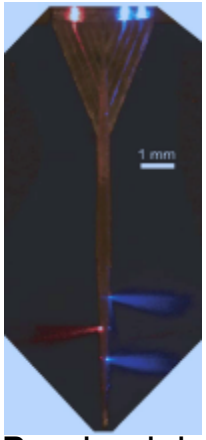
Fiber optics

Fibers glued to probe shanks

Neuronexus
(200 μm fiber)

Buzsaki lab

Waveguides

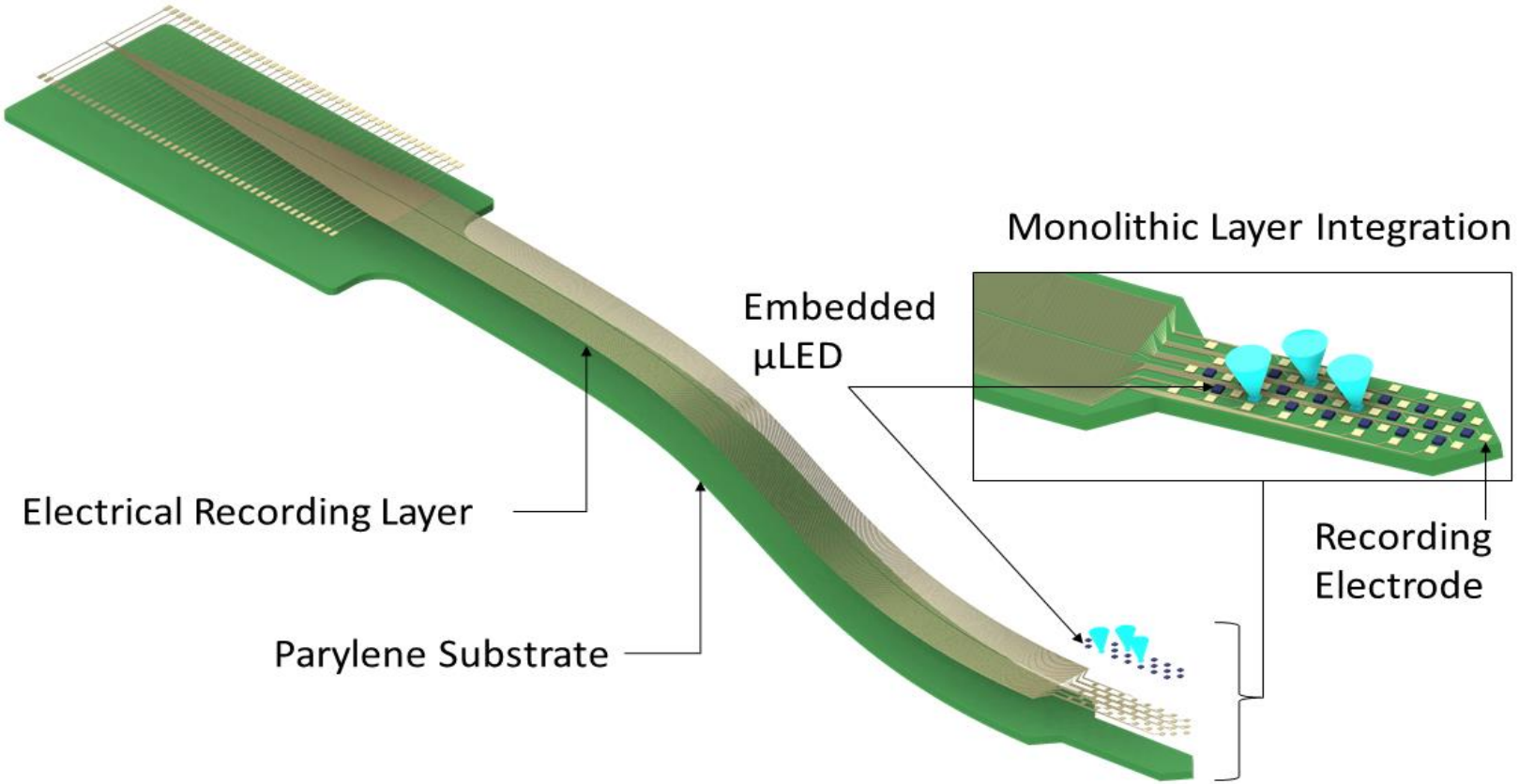


Boyden lab
(~20 μm waveguides)

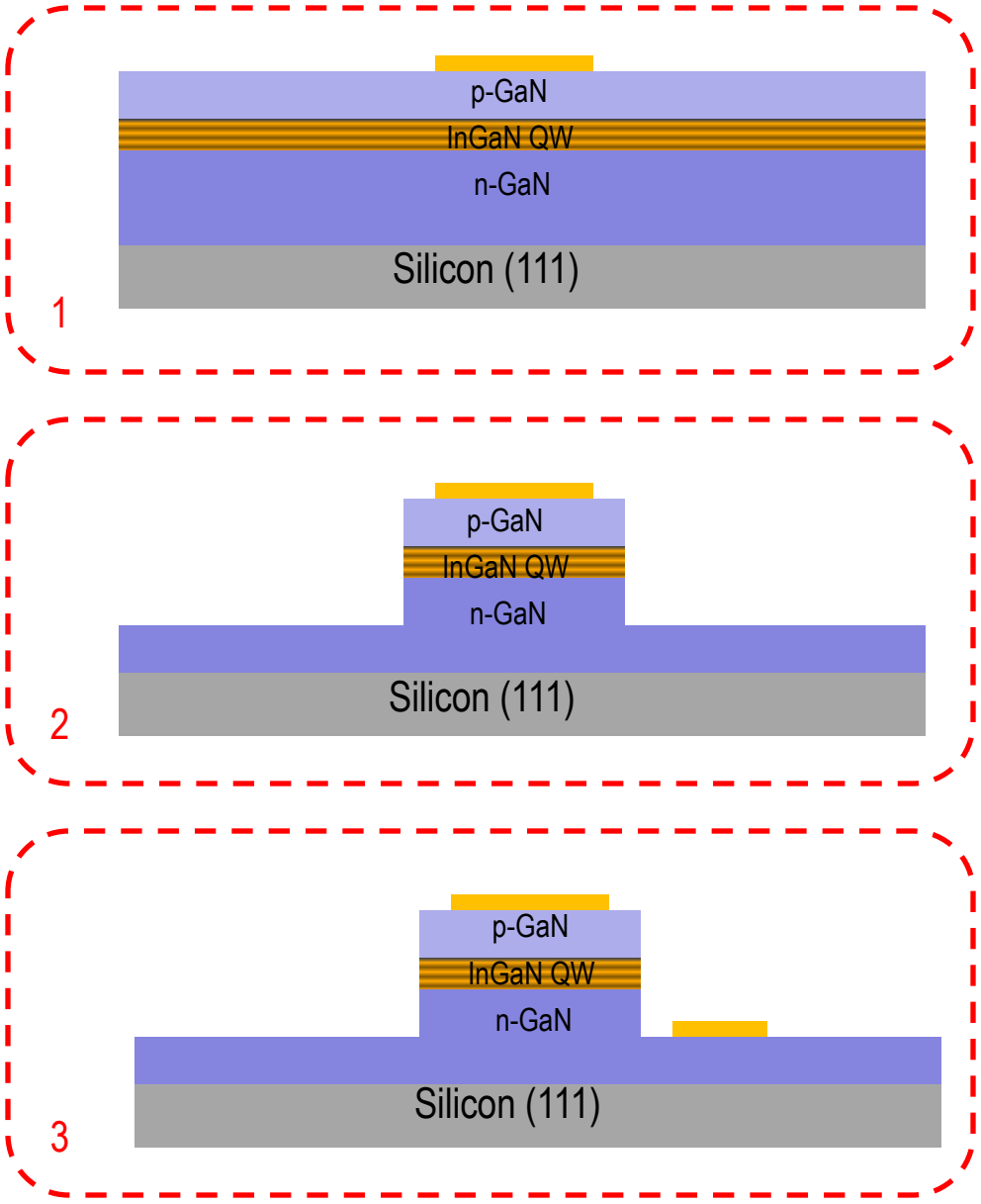
R. Pashaei, et al, 2014.

Our Solution

- Flexible implantable μ-LEDs



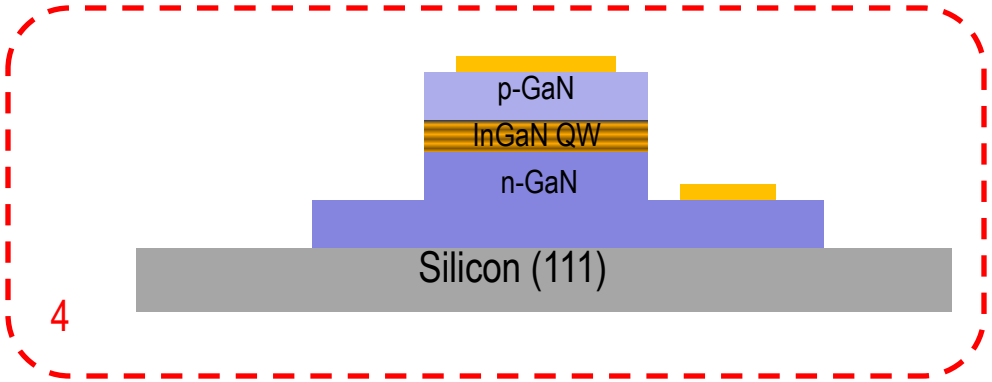
Fabrication Process Design



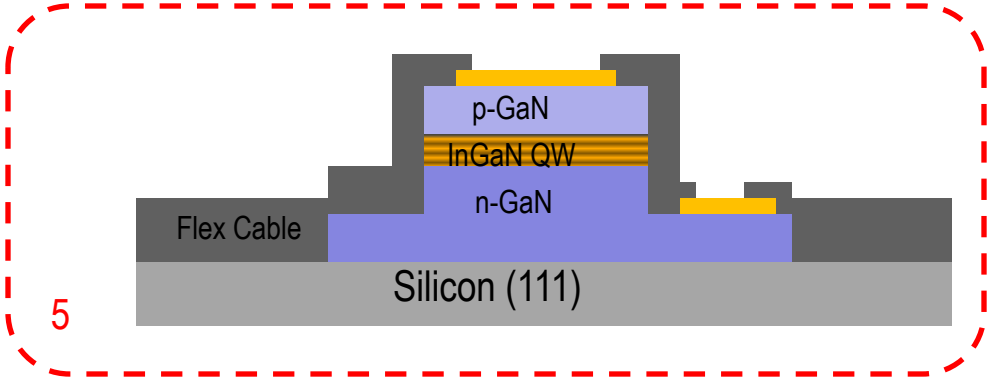
Deposit p+ contact
(Lithography -> Metal Deposition -> Lift-off)

n+ layer etch
(Lithography -> RIE etch)

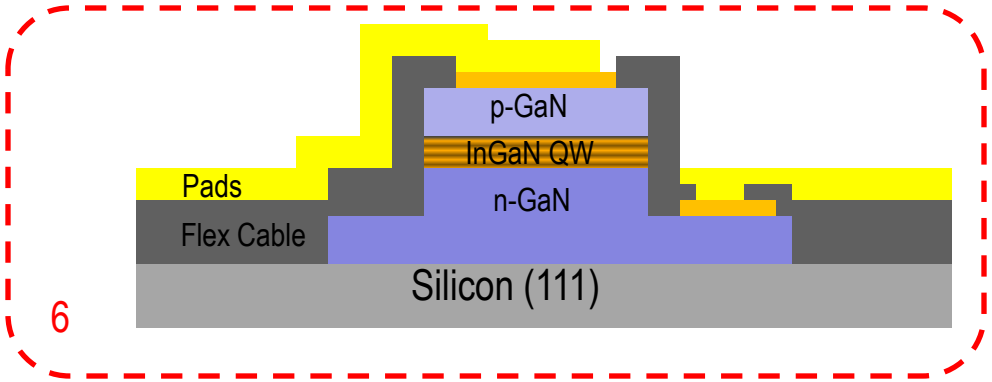
Deposit n+ contact
(Lithography -> Metal Deposition -> Lift-off)



Mesa Etch
(Lithography -> Etch)



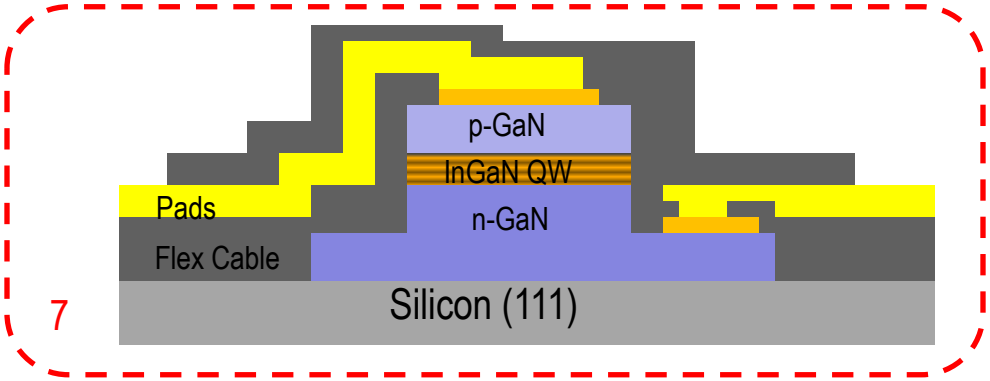
Flex cable bottom (Parylene C)
(Deposition -> Lithography -> Etch)



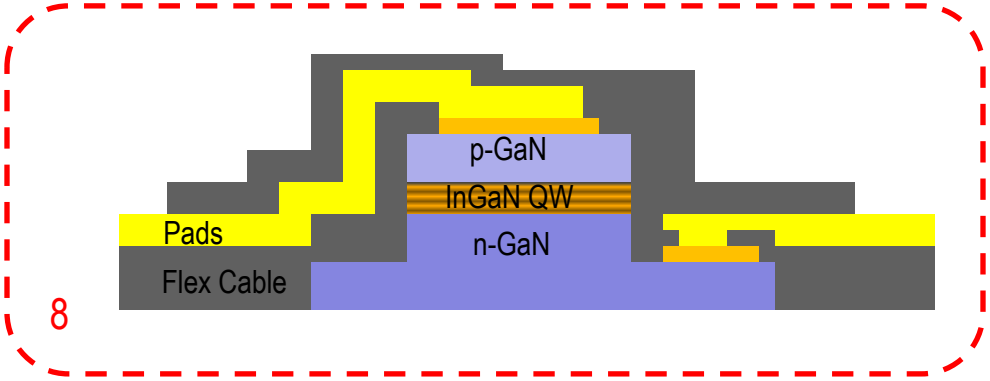
Pad deposition
(Lithography -> Deposit -> Liftoff)

Monolithic Process Design

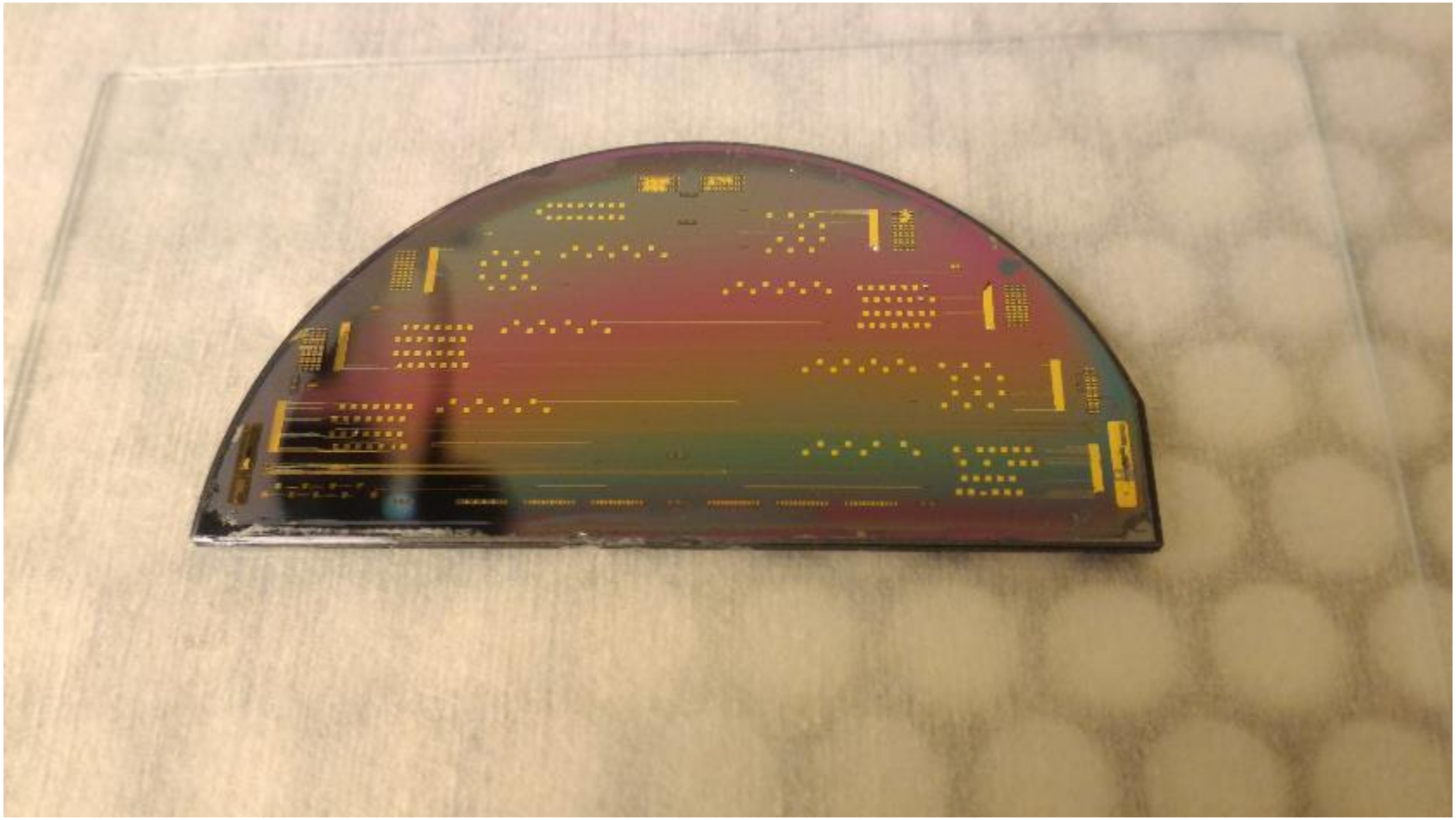
- Monolithic cable design ➡ No need for postfab bonding!



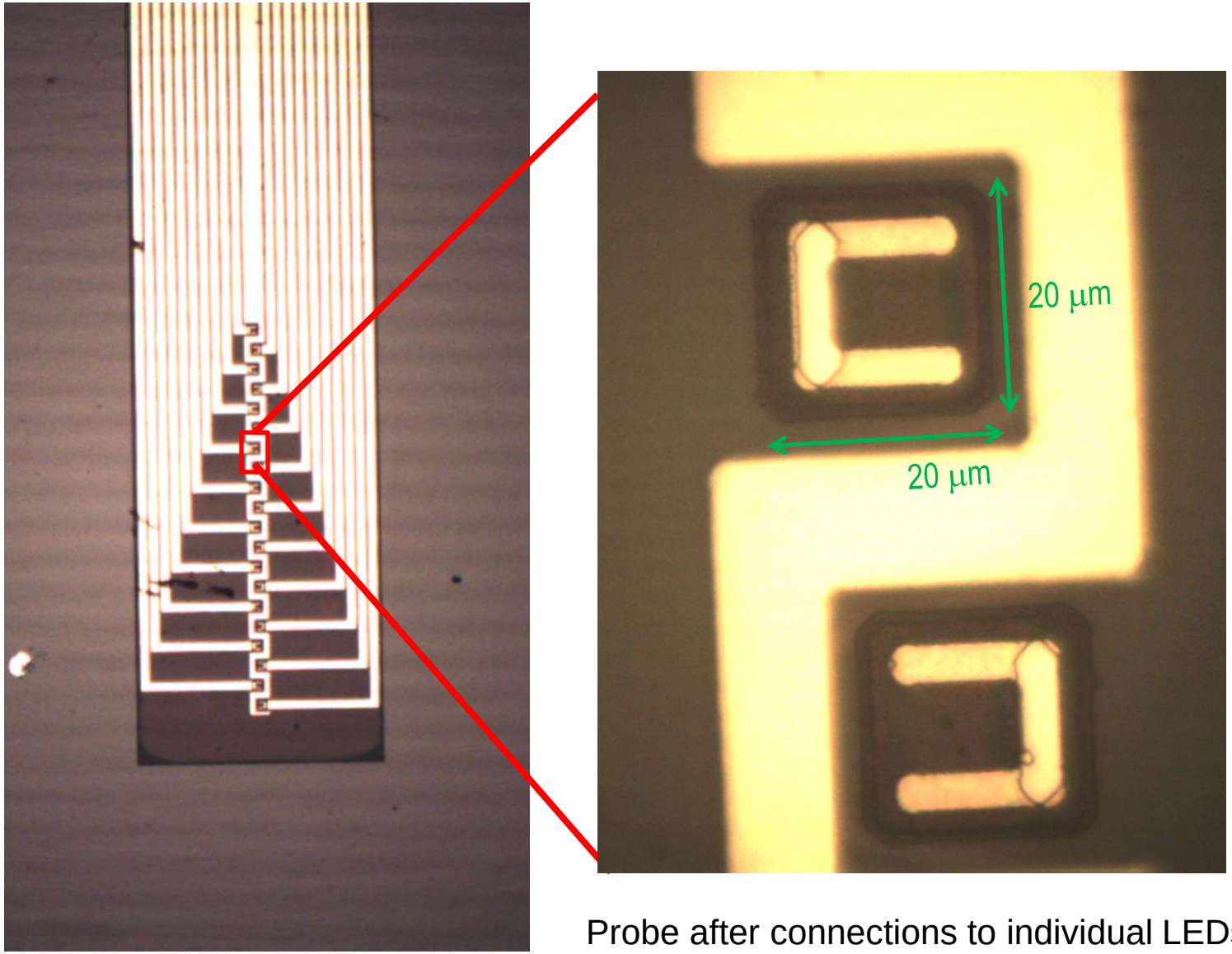
Flex Cable Top (Parylene C)
(Deposit -> Lithography -> Etch)



Remove Silicon Substrate
(Etch)

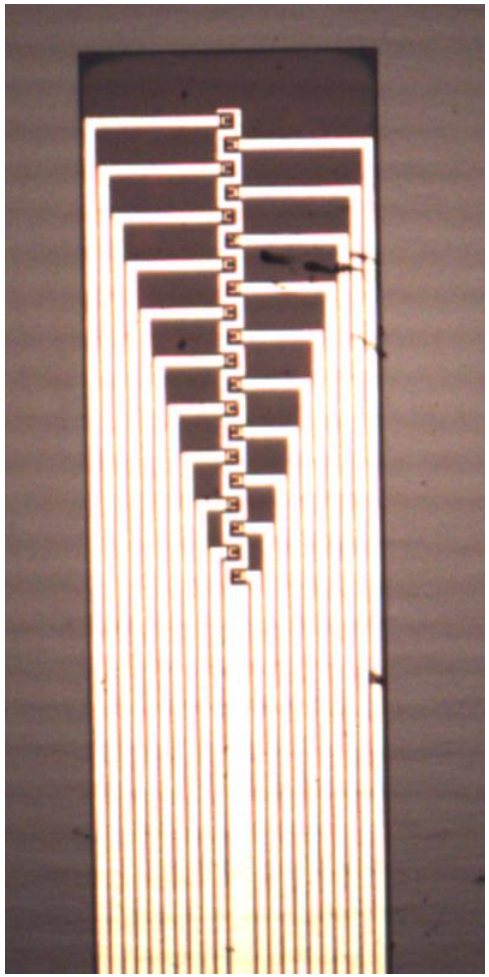


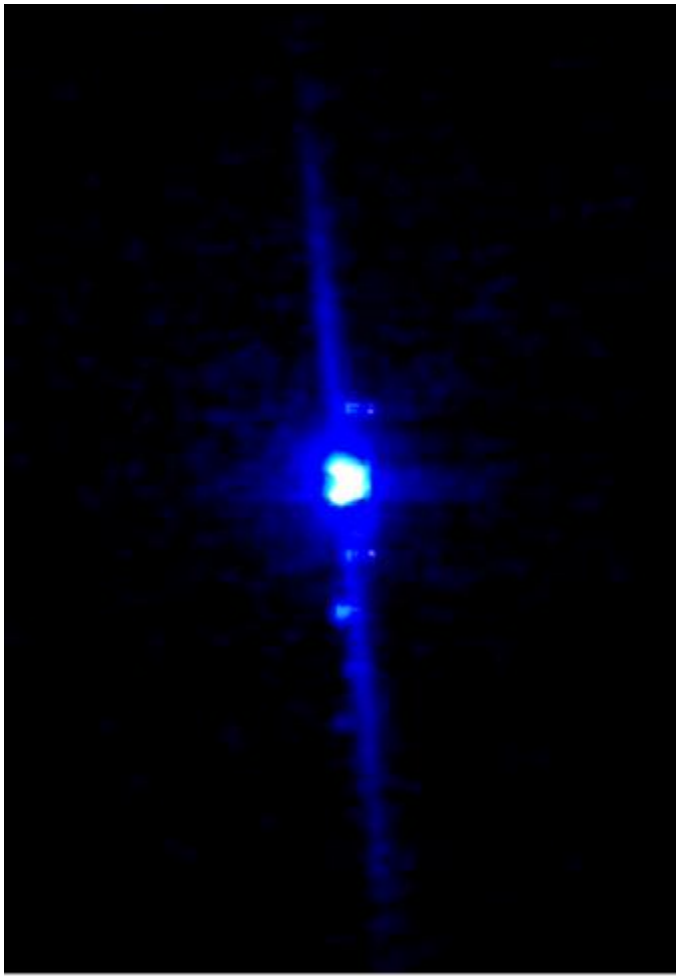
Linear Array Design



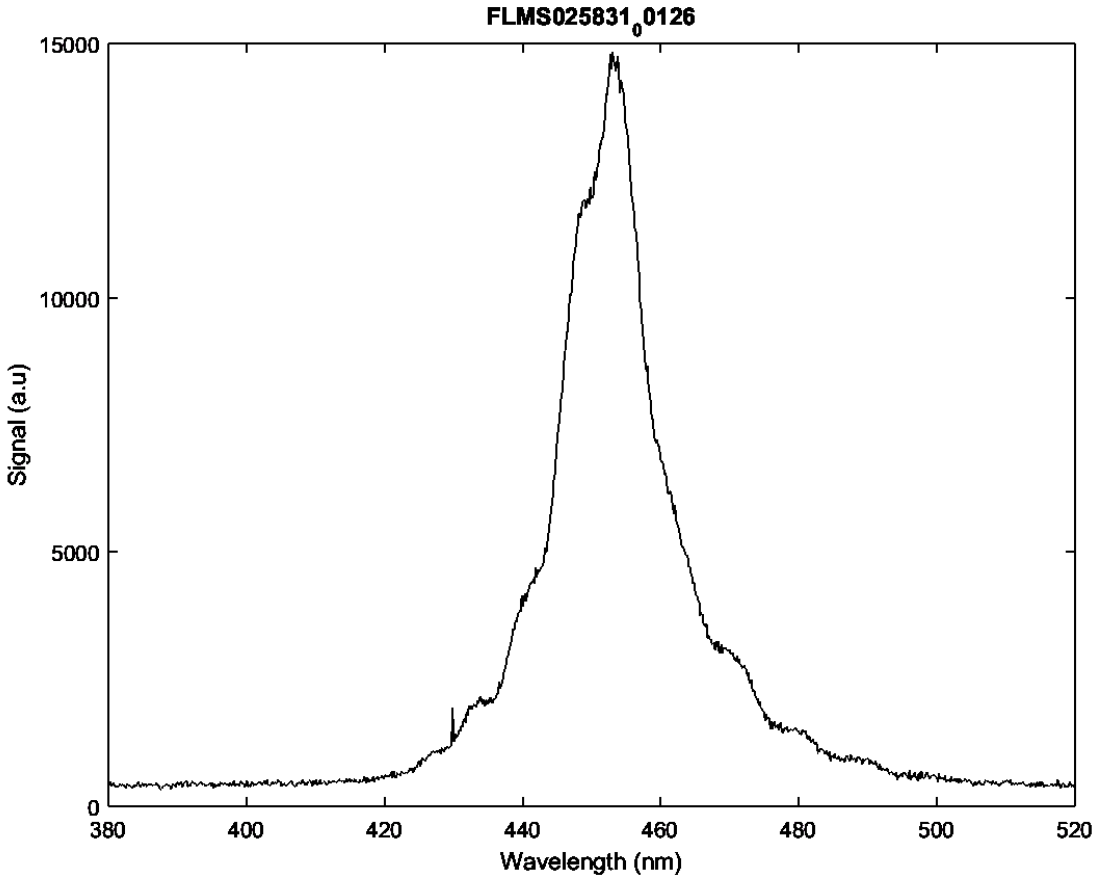
Probe after connections to individual LEDs are realized

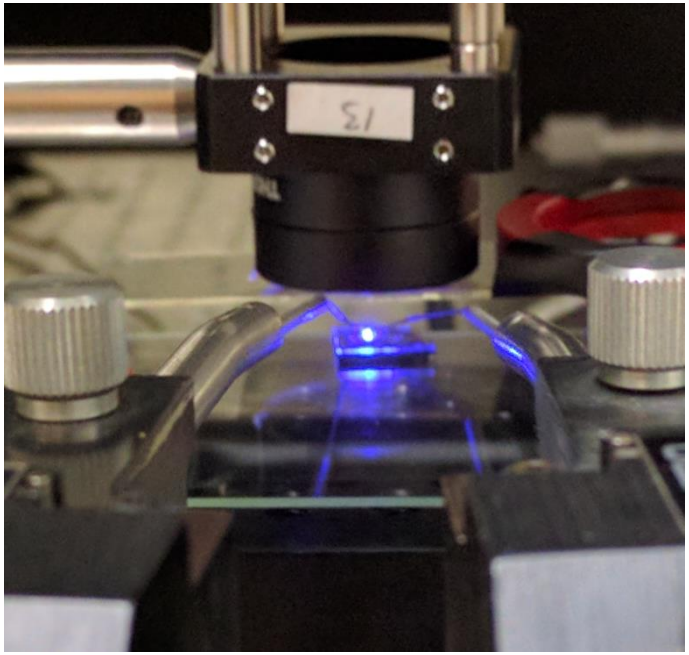
Bright Light Emission Possible!





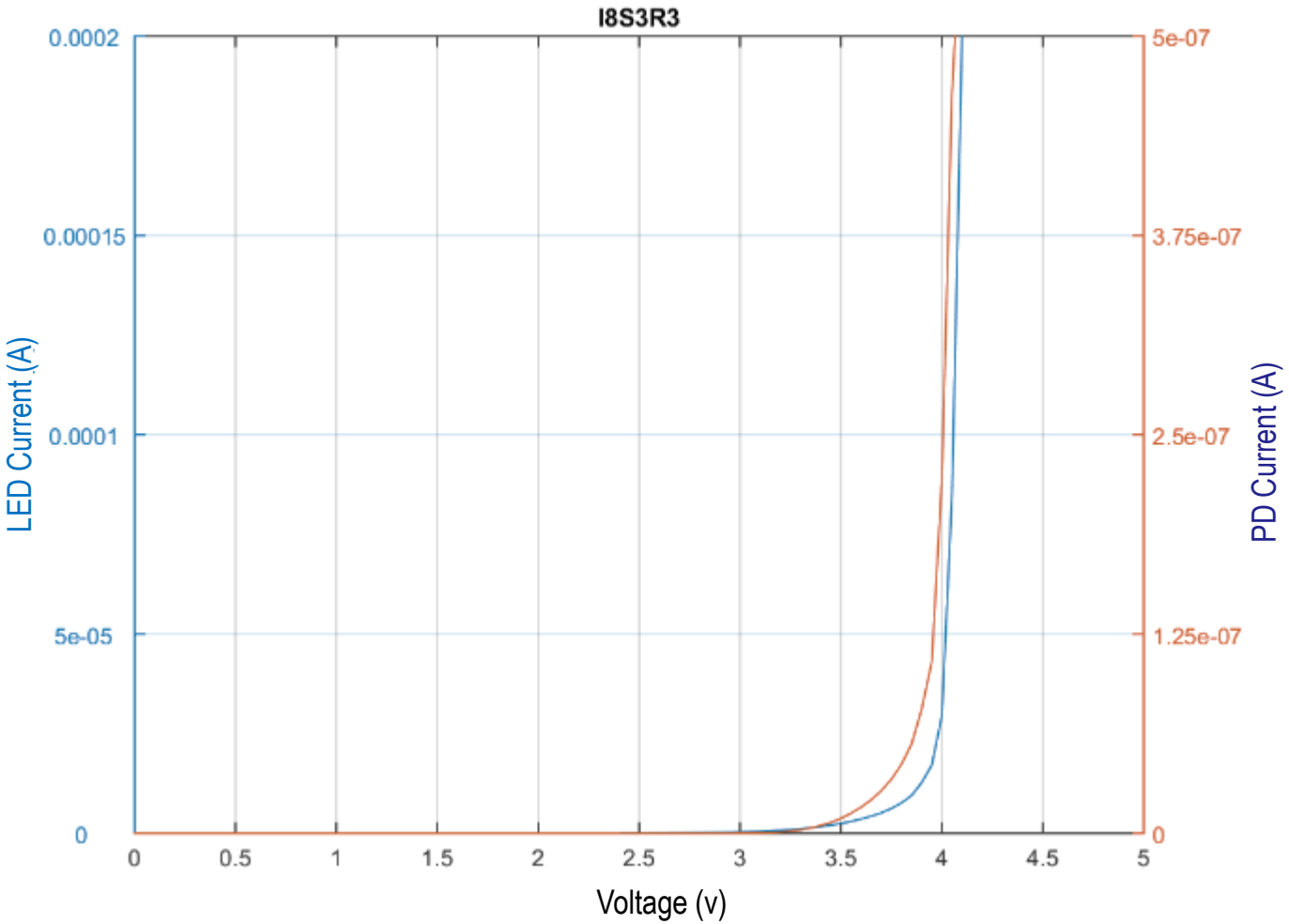
Emission Spectrum



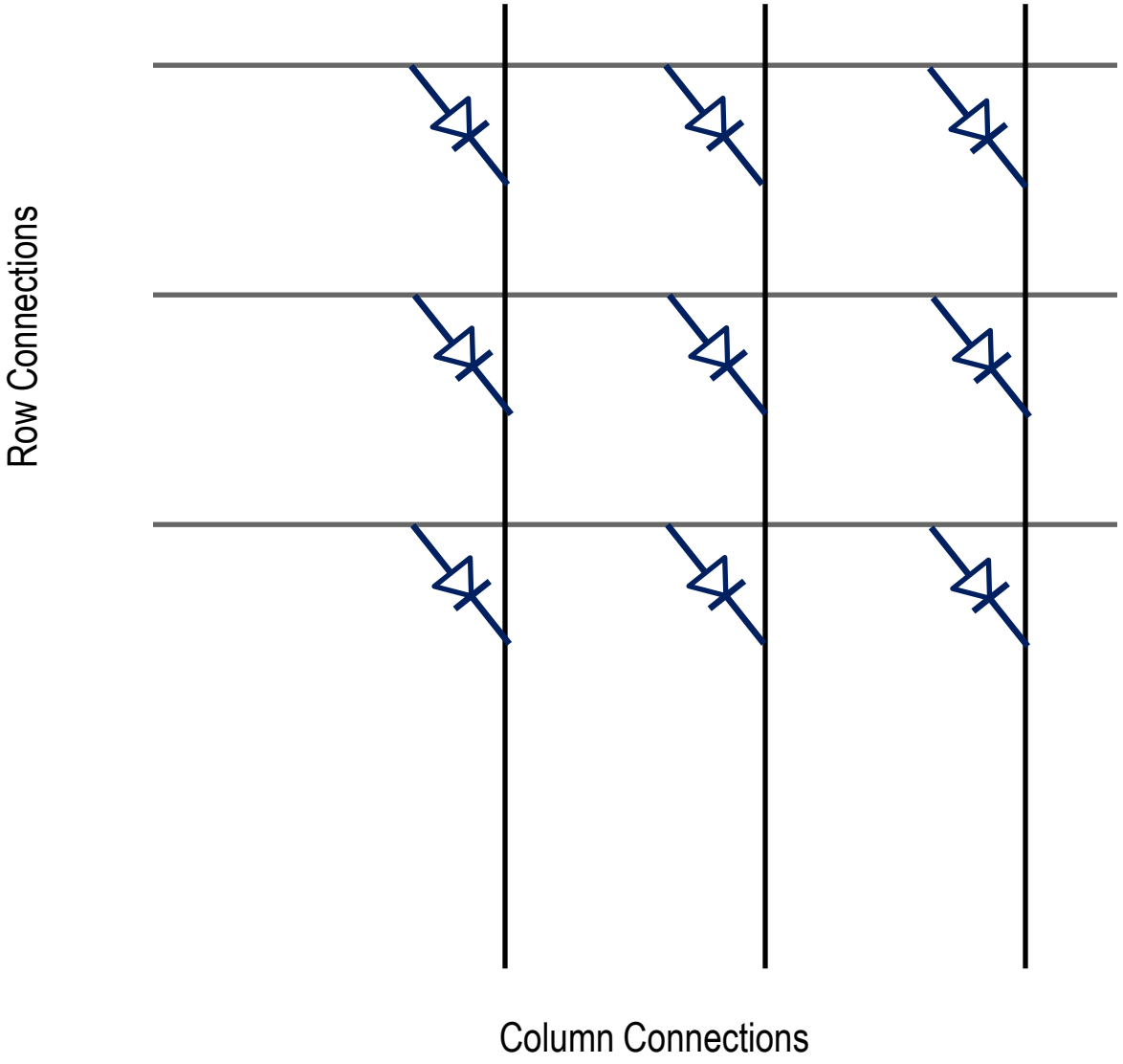


λ= 453 nm FWHM ~ 14 nm

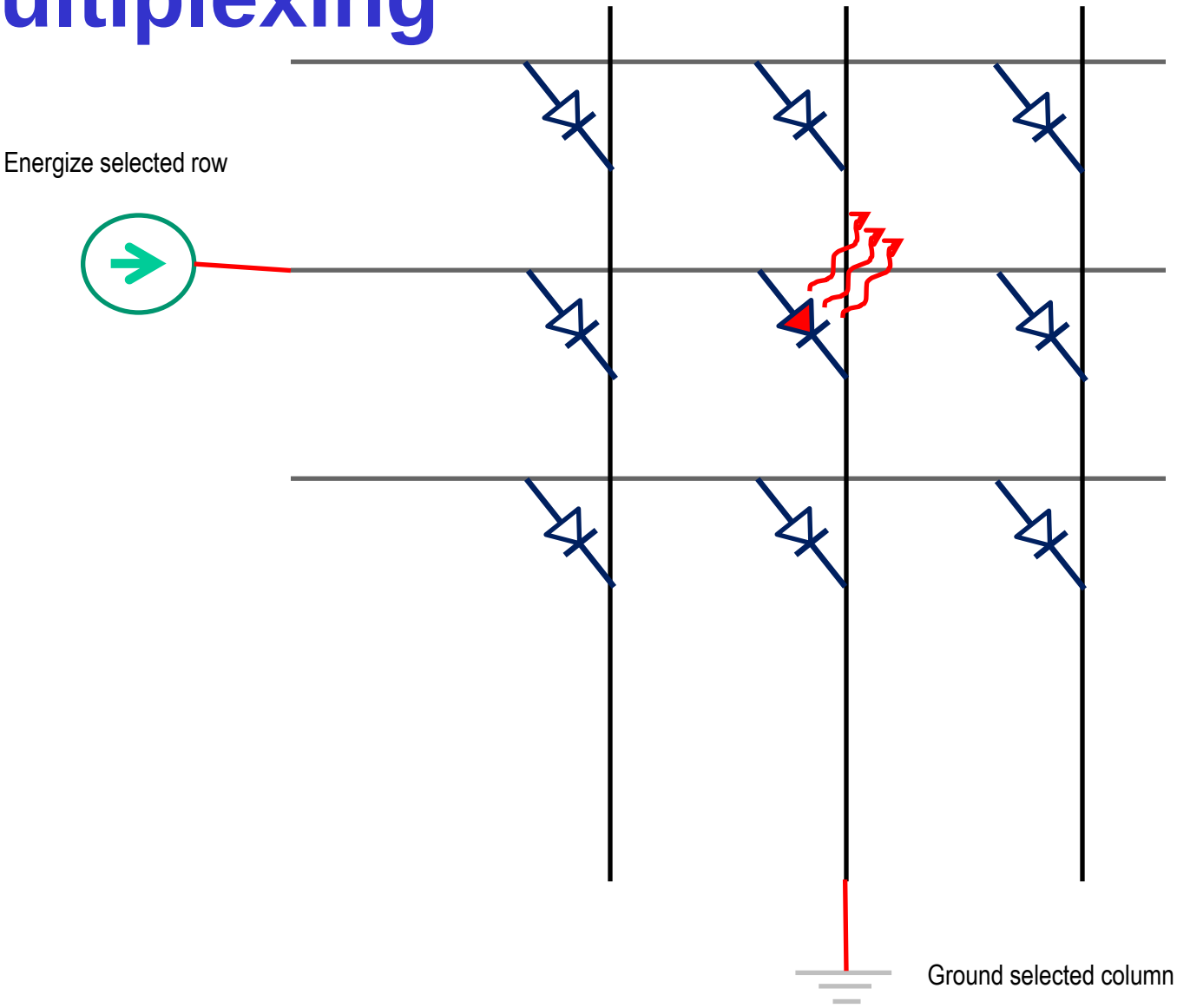
I-V and Optical Power Characterization



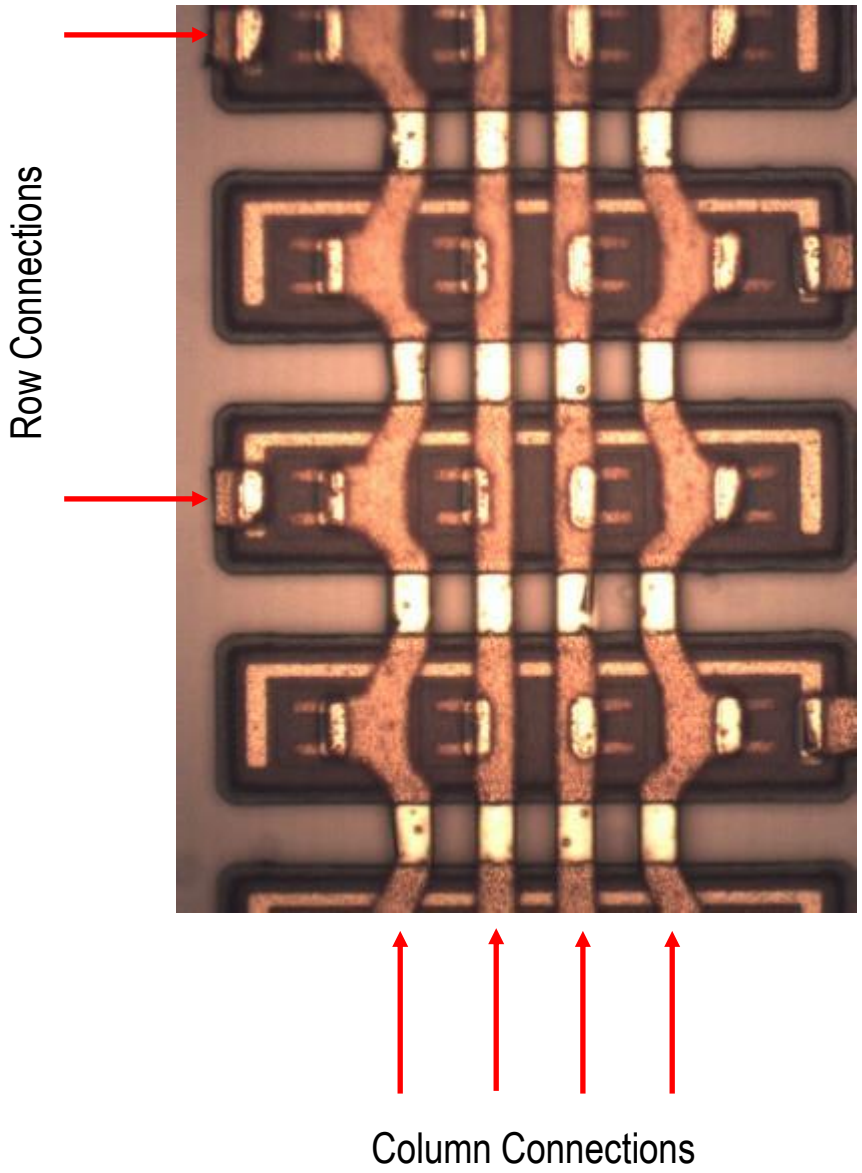
2D Array



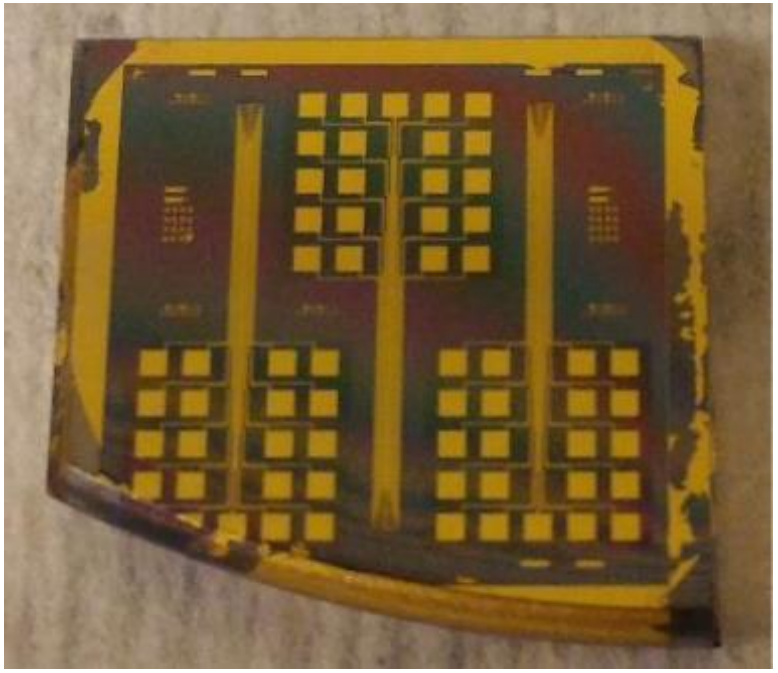
Reducing the number of wires: Multiplexing

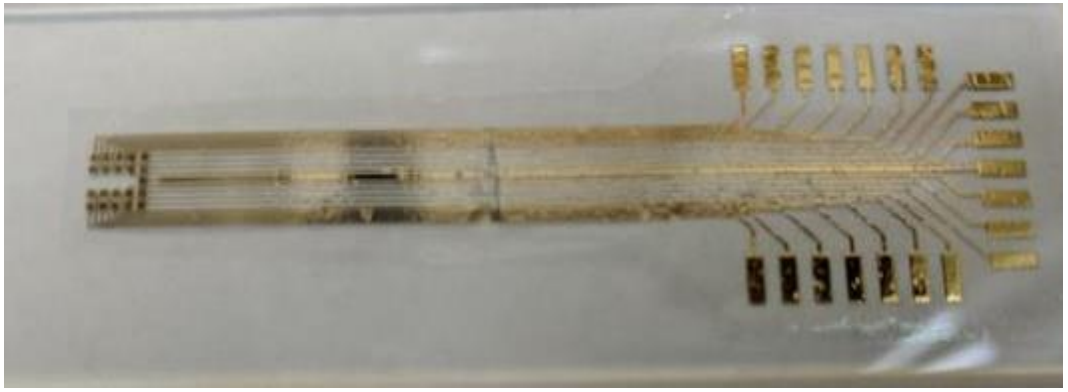


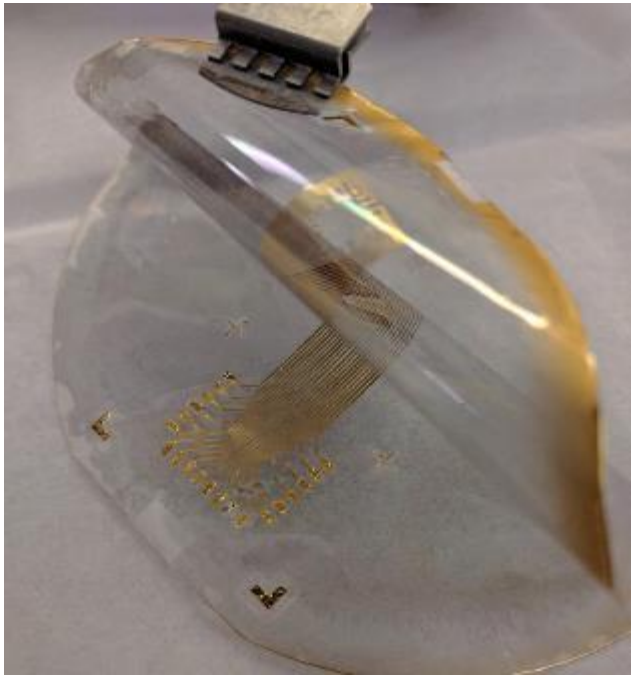
Architecture of the Probes (2D MUX)



High-density Flexible Probes

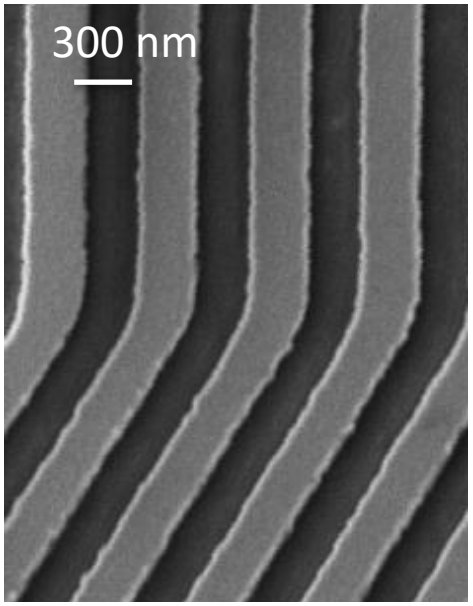




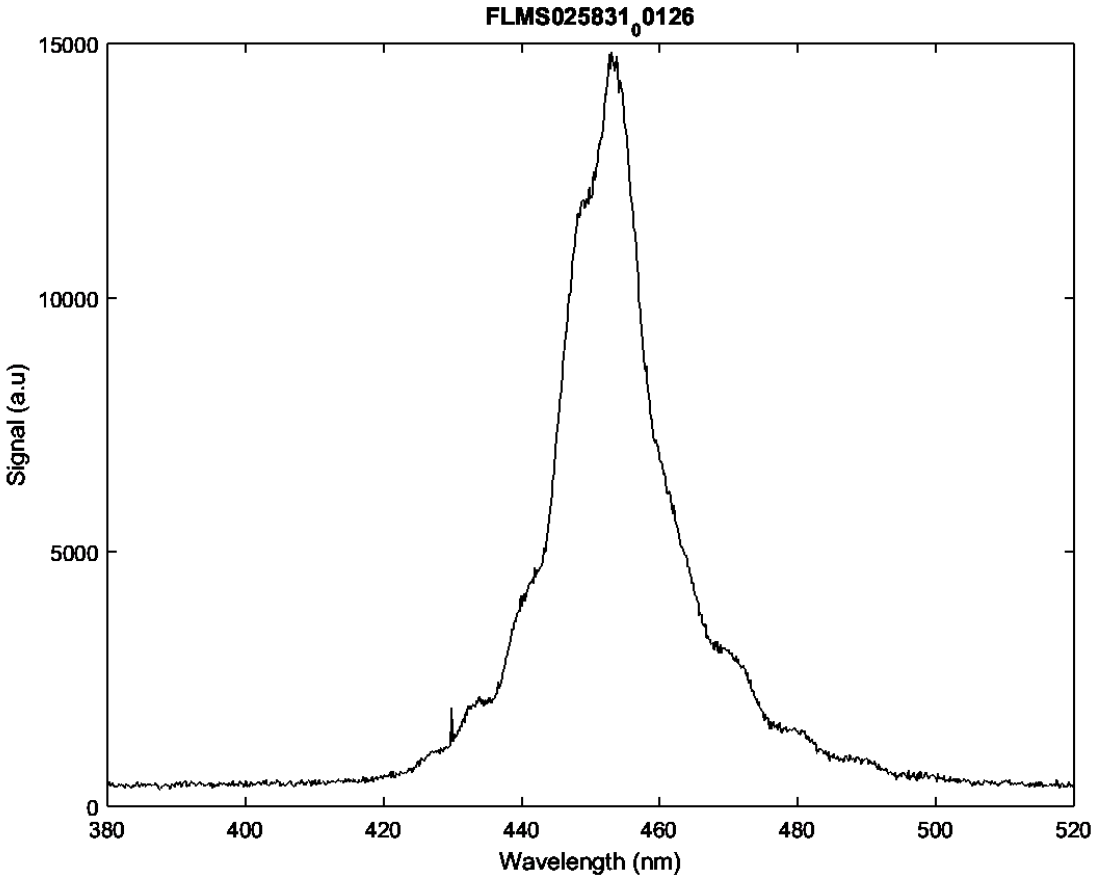


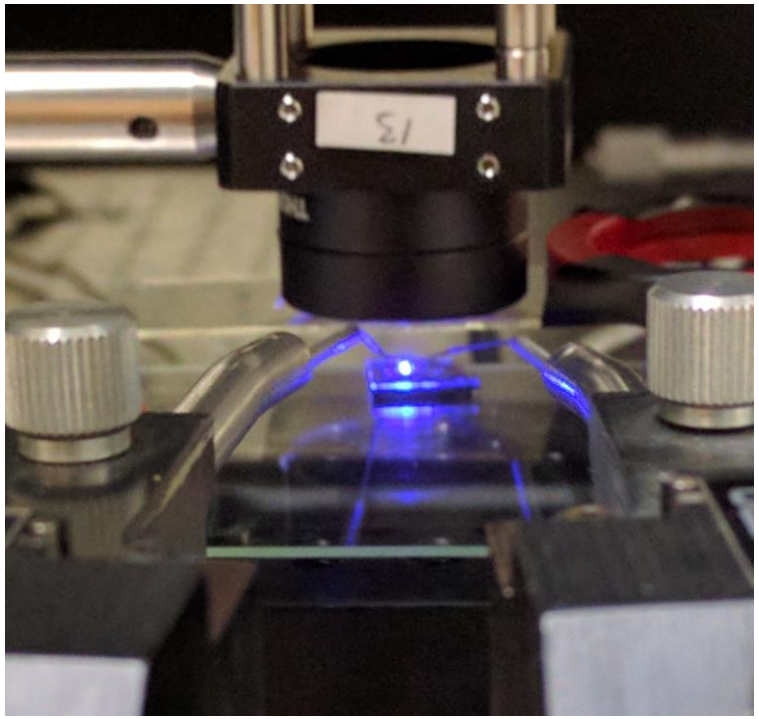
Flexible Cable

- Minimizing tethering force on the brain tissue
- High-density interconnects (280 nm!)
- Material: Parylene C
    - Biocompatible
    - Compliant
    - CVD at room temperature
    - Can be micromachined



Characterization





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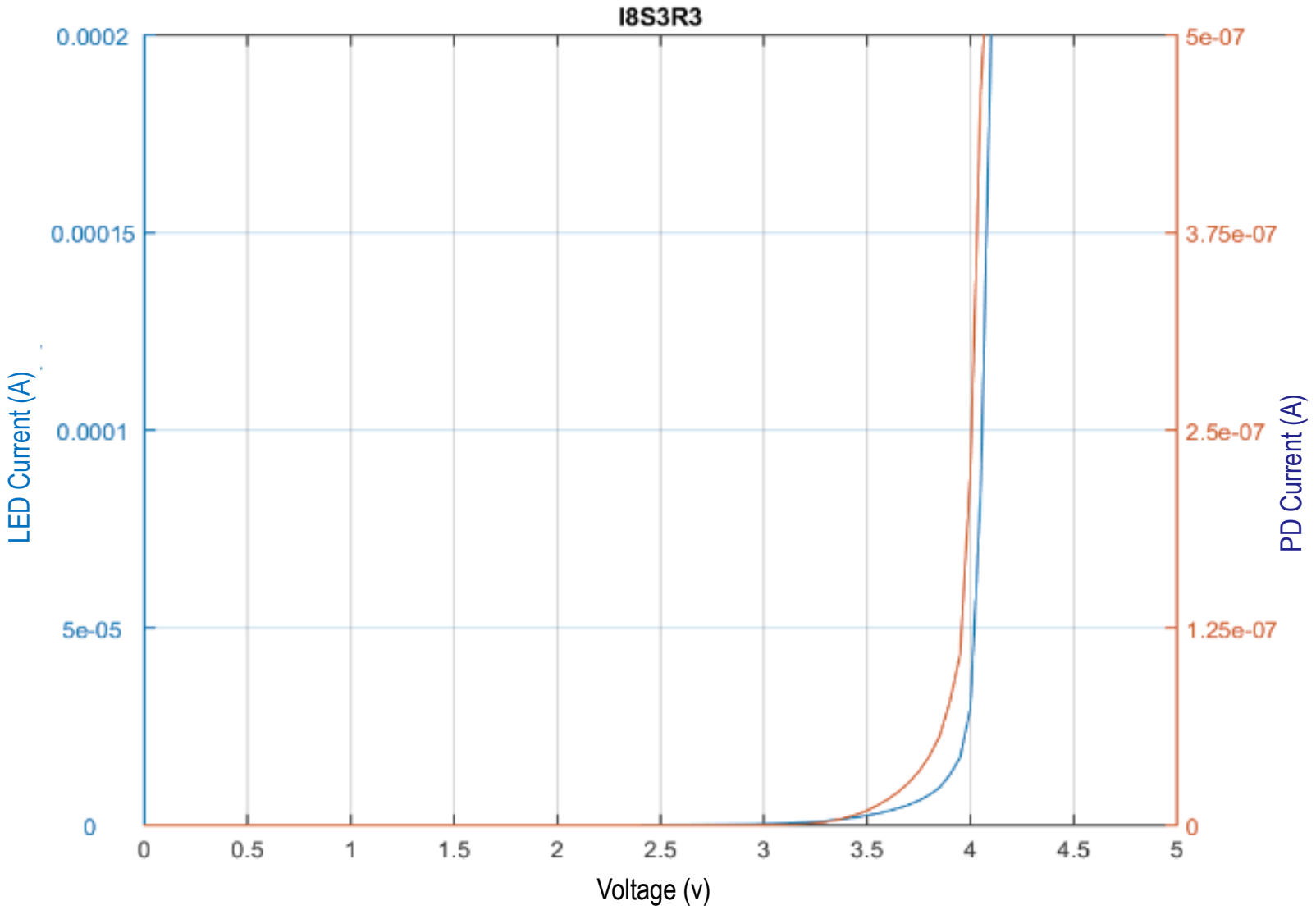
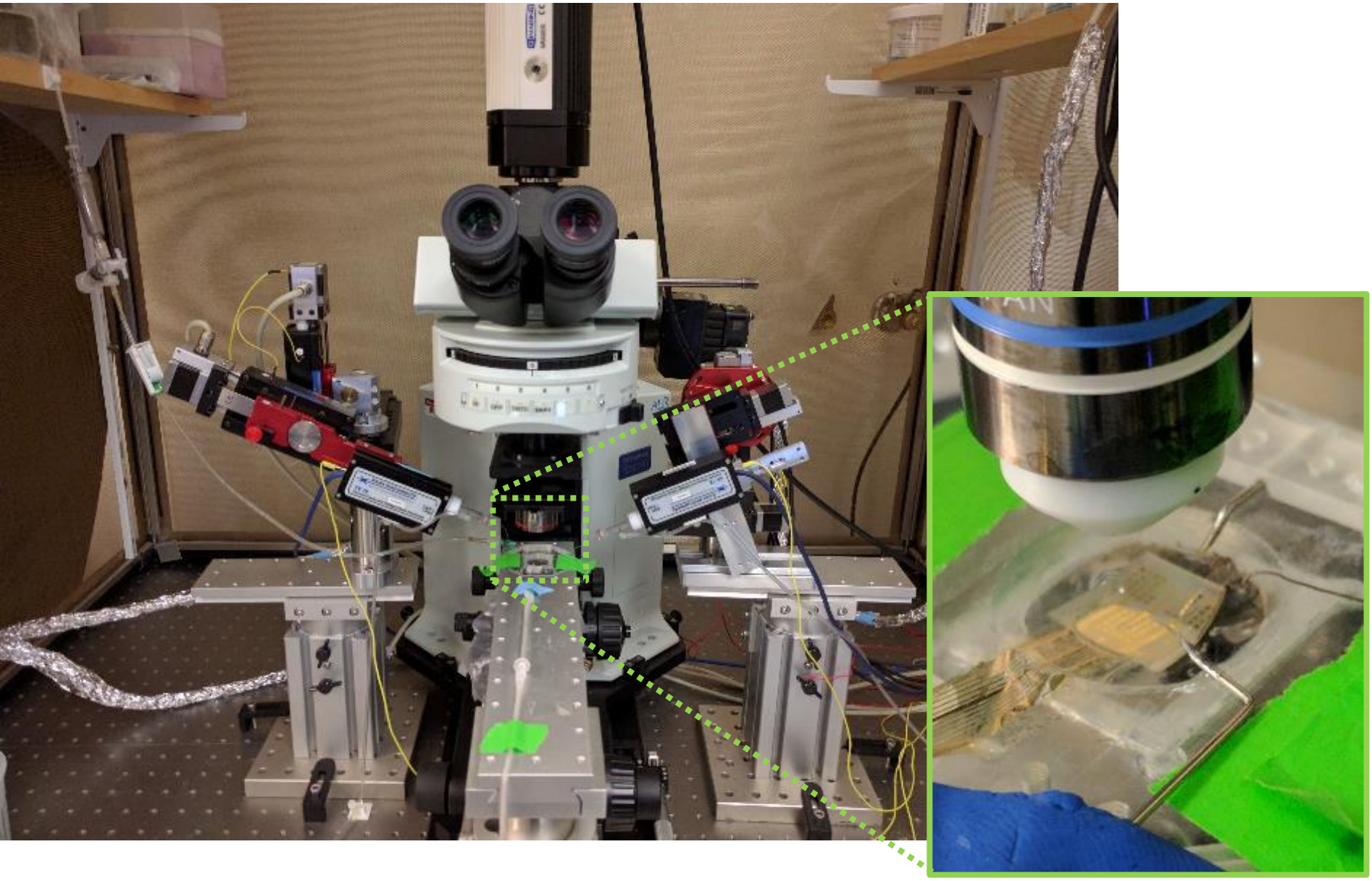
IV-Characteristic and Optical Power Measurement

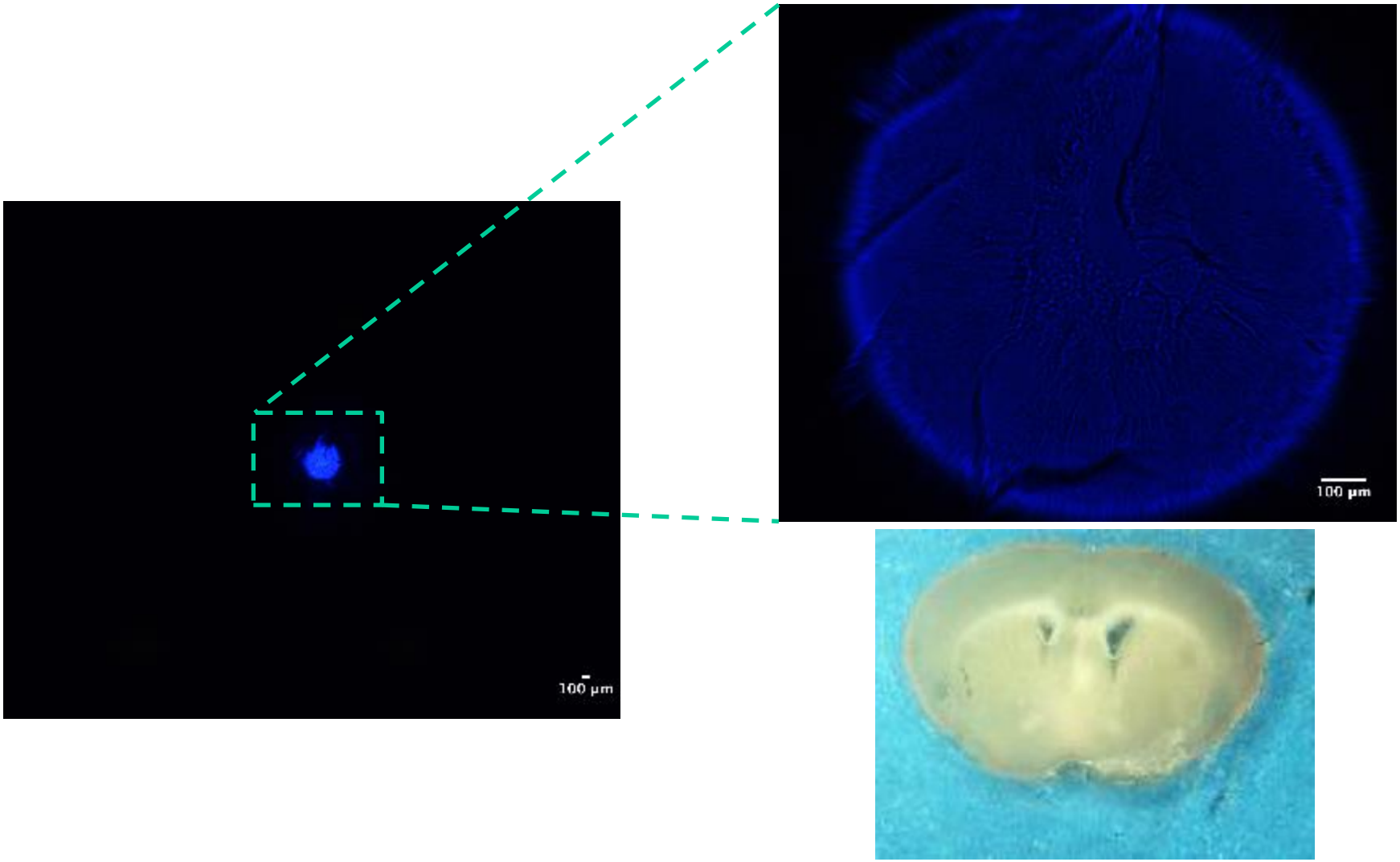


Optogenetic Experiments



Bright-field Image of a Brain Slice

- A μ-LED on a brain slice



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