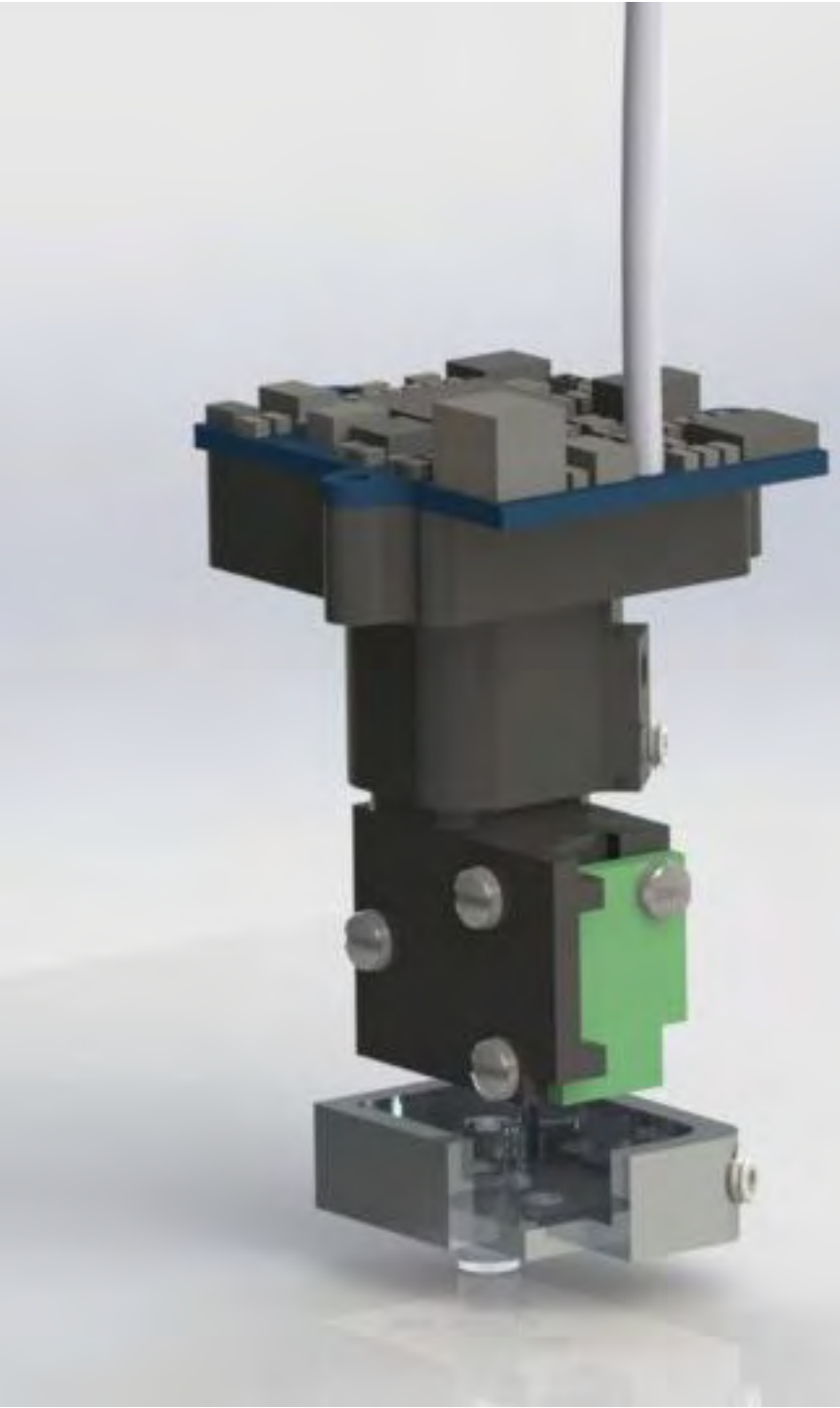
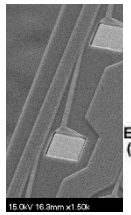


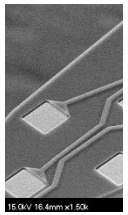
Miniature microscopes and the brain: Bridging the gap between neuroscience and technology

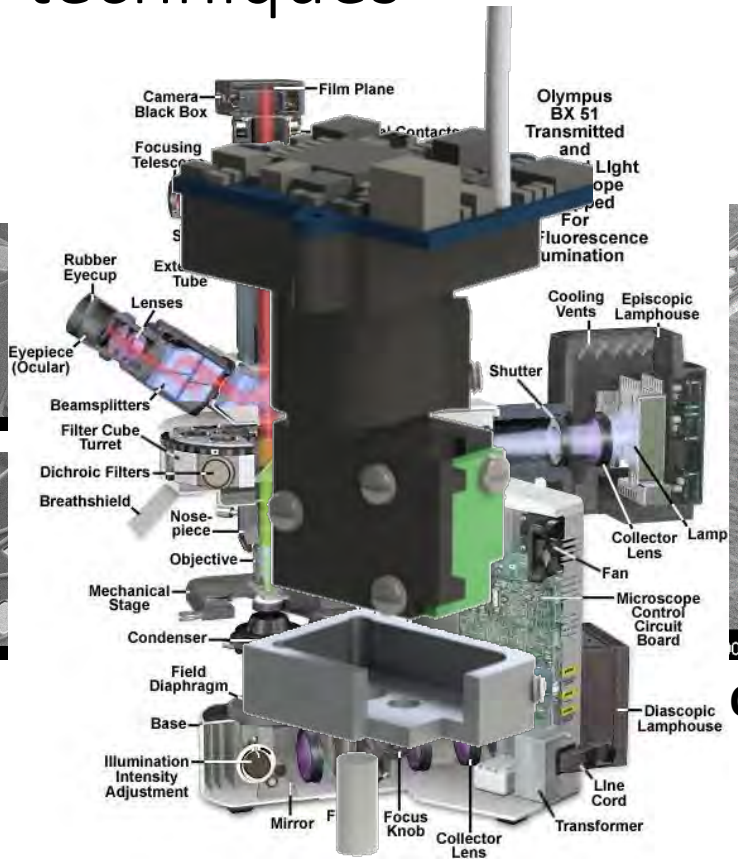
2019 Neuro Open-source Workshop

Daniel Aharoni, PhD
Department of Neurology, UCLA
January 15th, 2019

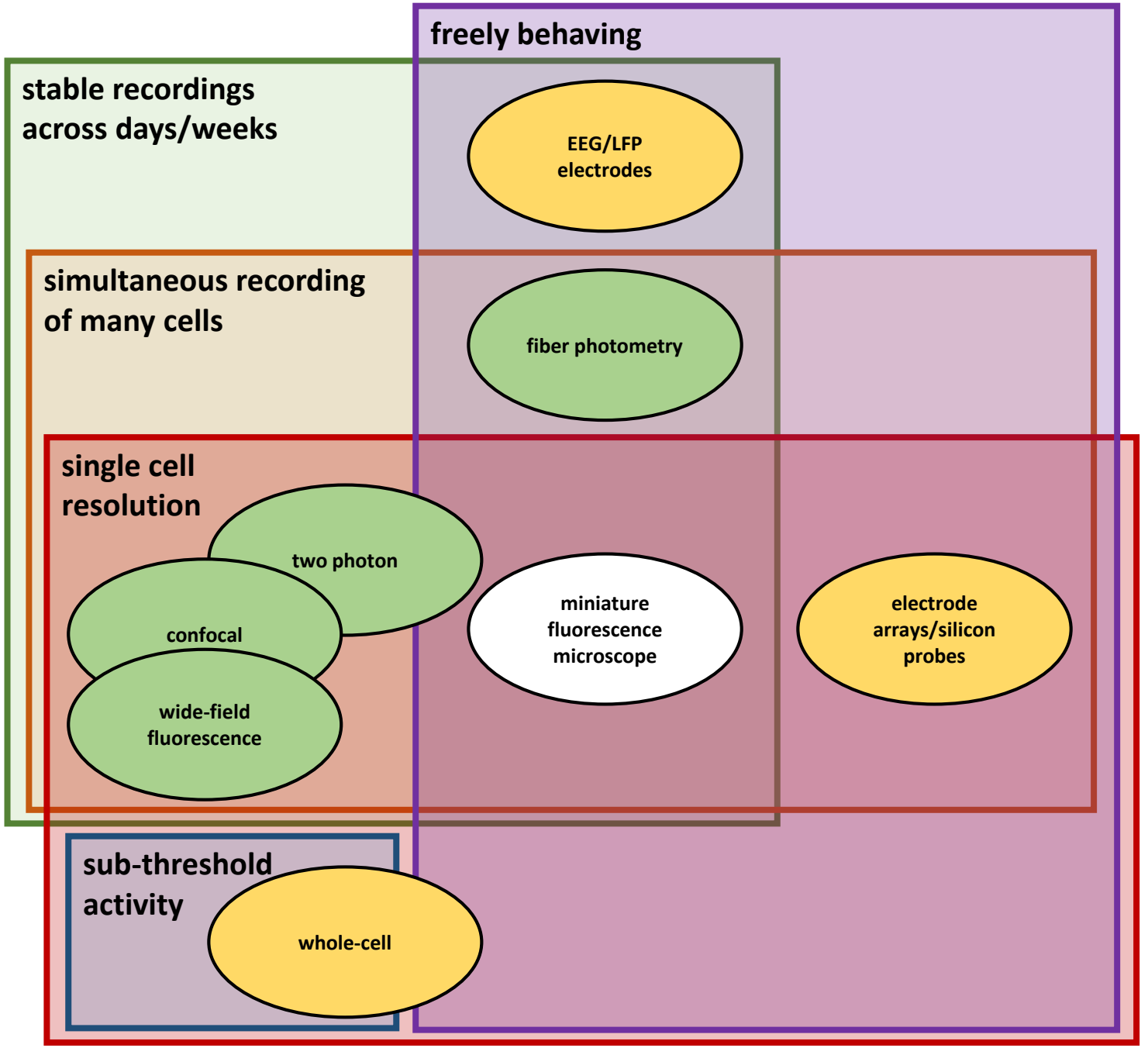
In vivo recording capabilities and techniques



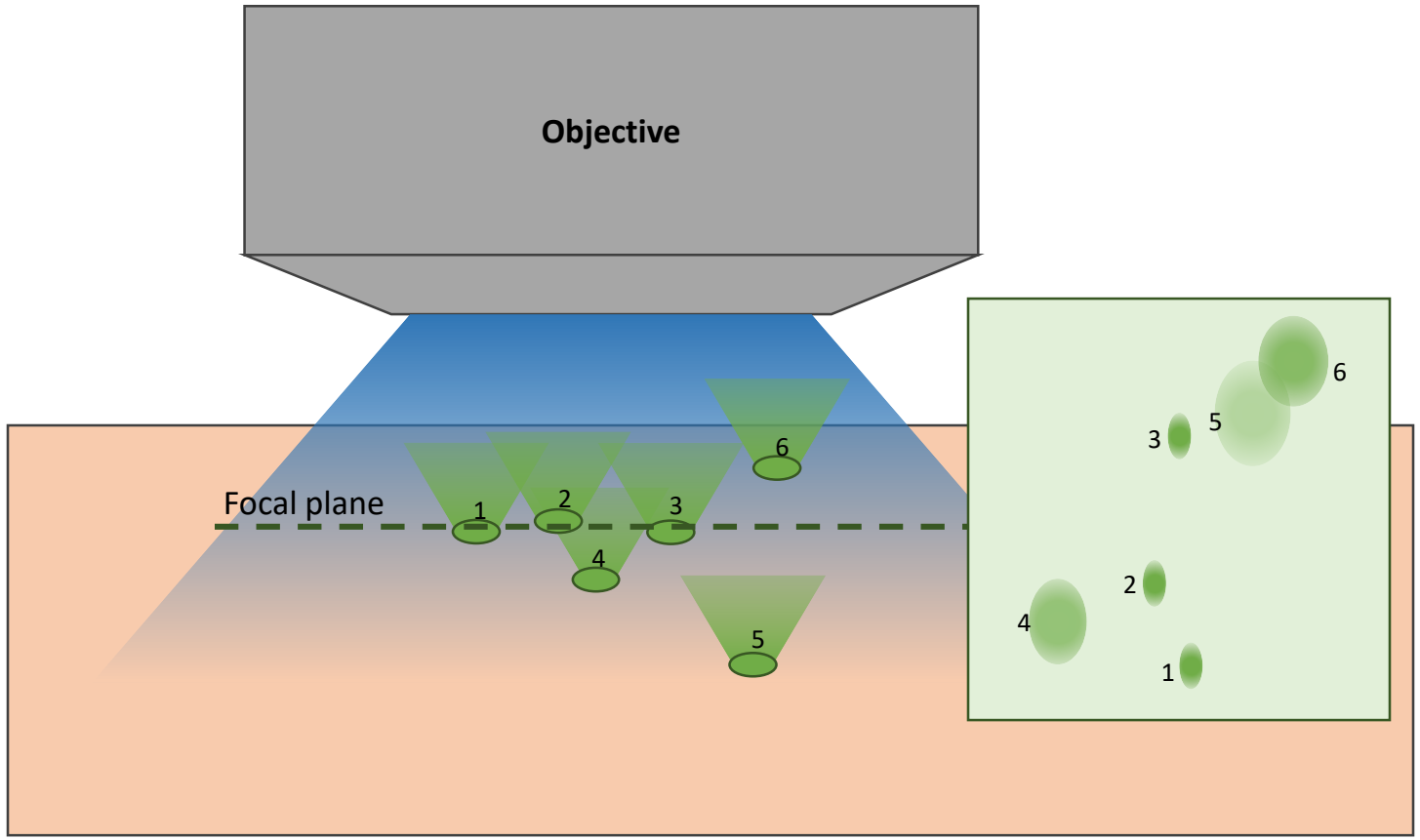




UCLA Miniscope **Olympus BX51** **CLA**

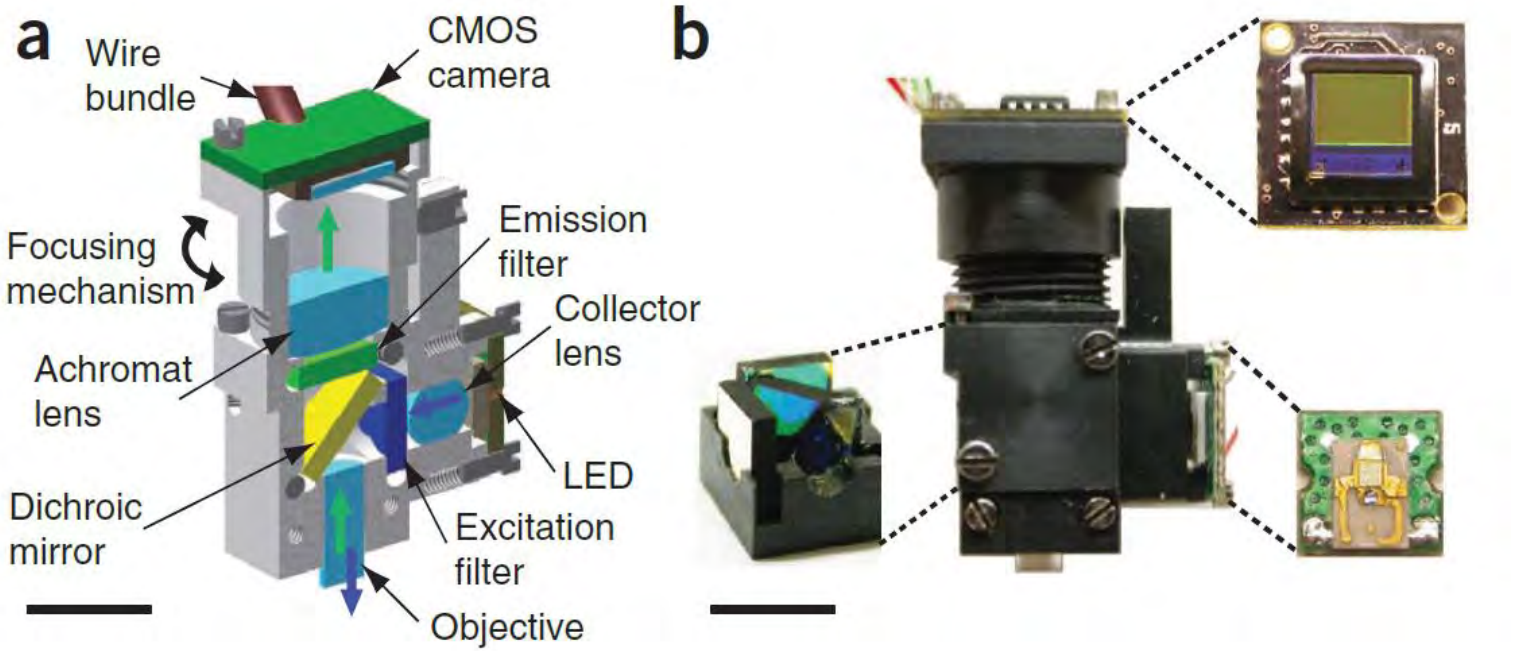


Wide-field fluorescence microscopy

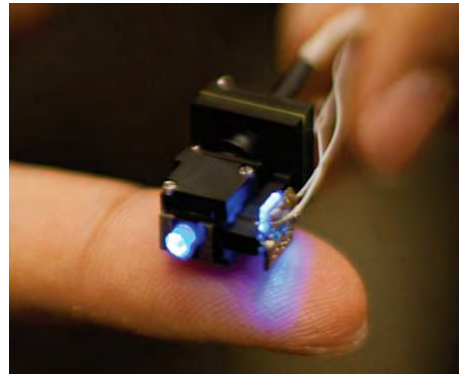


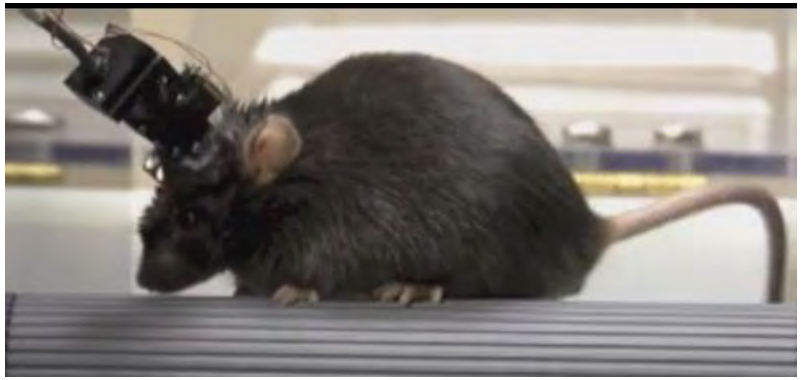
Miniaturized integration of a fluorescence microscope

Kunal K Ghosh[1,2,5], Laurie D Burns[2,5], Eric D Cocker[2,5], Axel Nimmerjahn[2], Yaniv Ziv[2], Abbas El Gamal[1] & Mark J Schnitzer[2–4]



Nature Methods, 2011





UCLA Miniscope

System

Miniscope

Head Mounted Scope

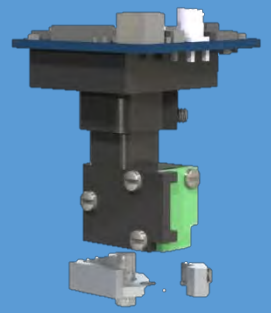
50Ω Coax

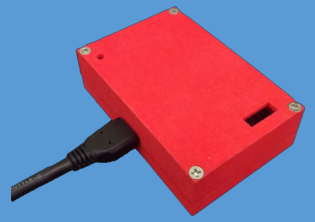
DAQ Hardware

USB3.0

Computer

Behavior Camera





Resource

Gerbers ← Circuit Schematics and Layouts

Compiled Software and Firmware ← Source Code

Machining Files ← 3D Design Files

Guides and Tutorials
Discussion Board

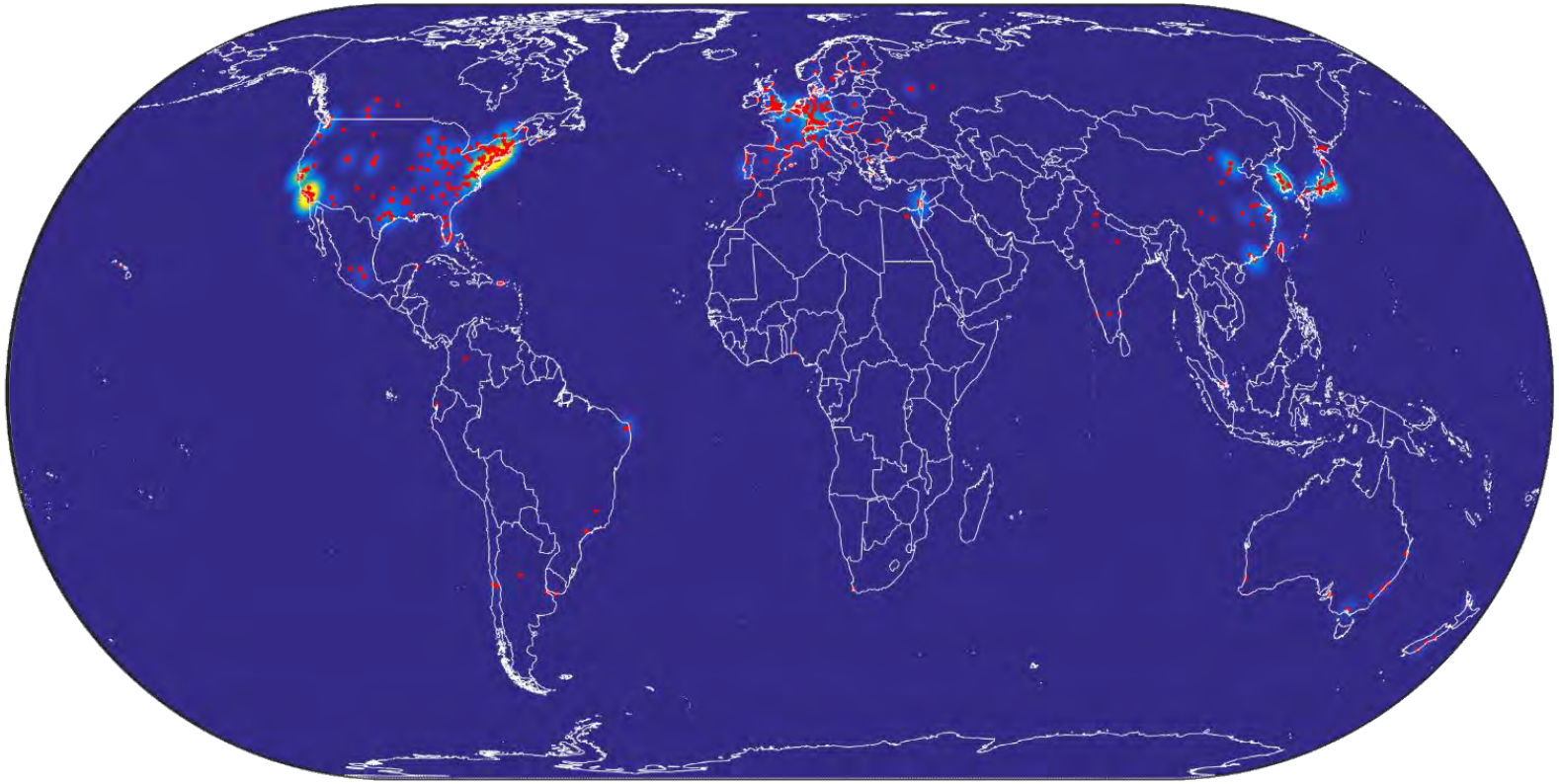
Users

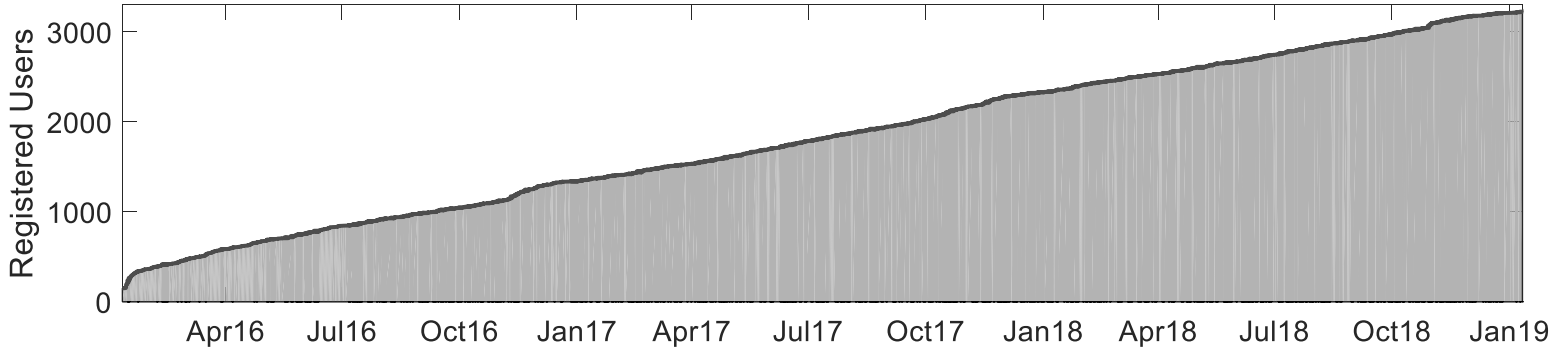
Developers

Miniscope.org

Miniscope.org resource

- Opened January 2016
- MediaWiki backbone for collaborative sharing
- 3200+ registered users
- 450+ labs build/using Miniscopes
- 1800+ Miniscopes built





Miniscope.org resource

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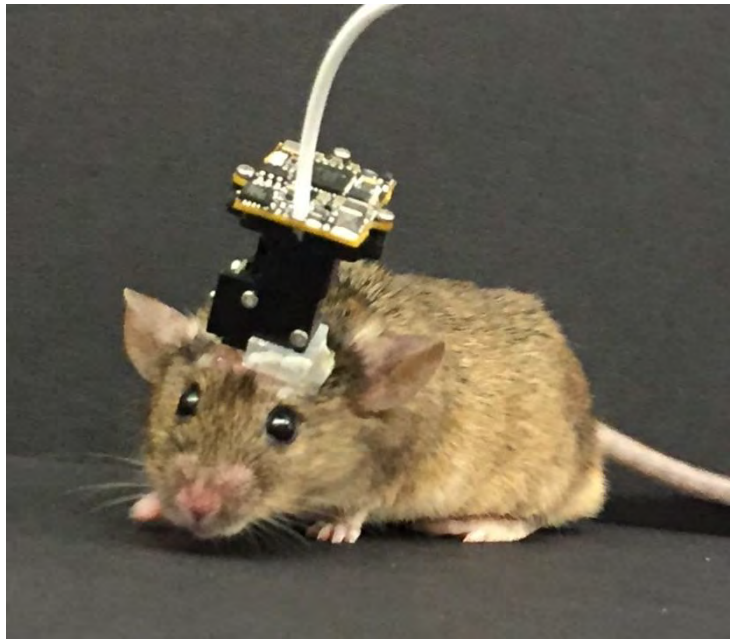
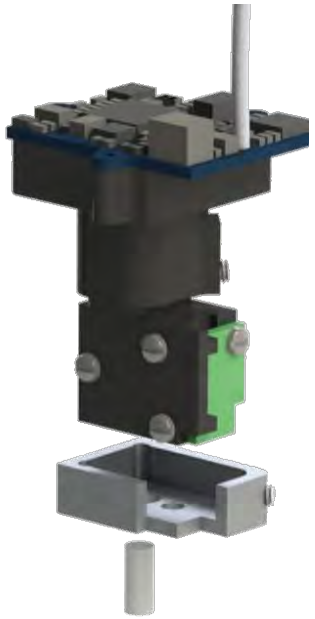
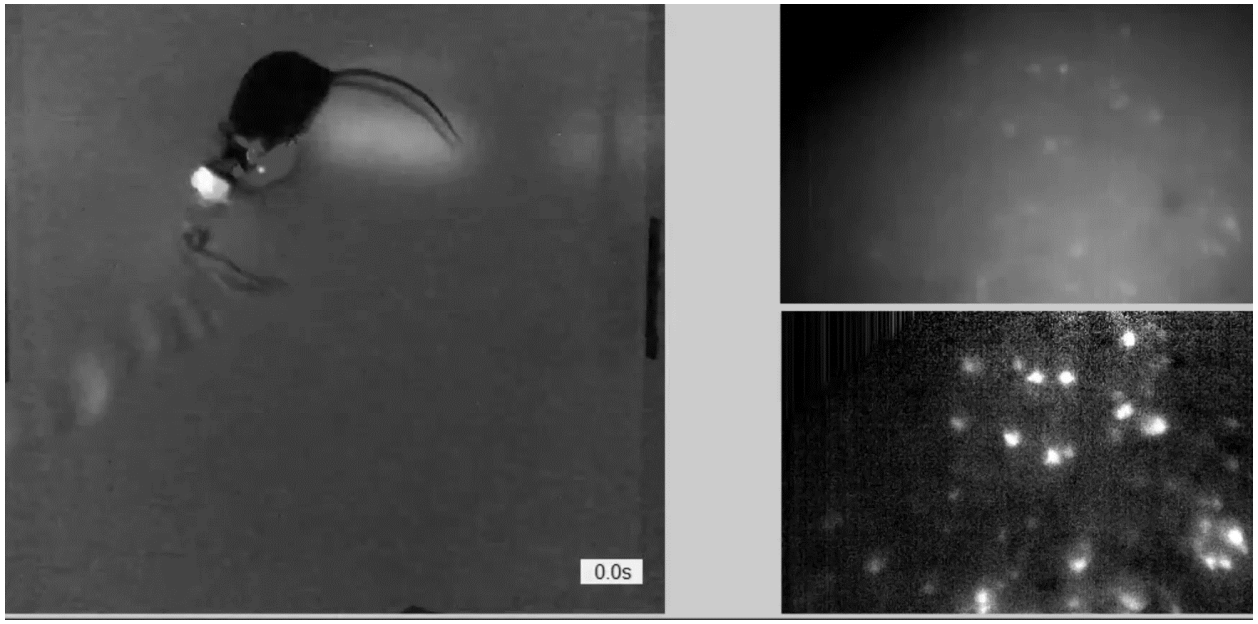
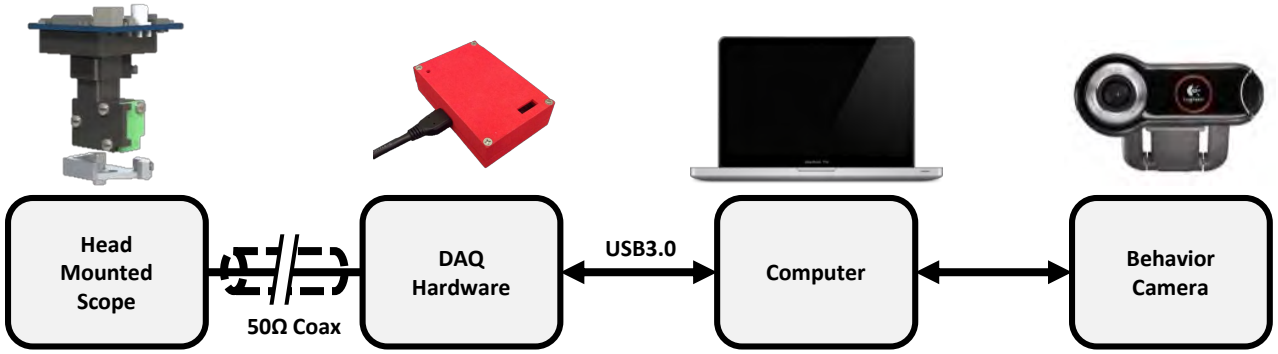
System overview









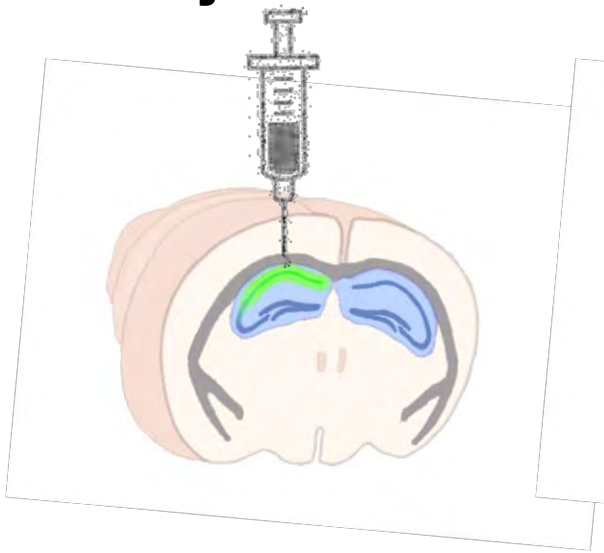
Mass: 3 grams
Dimensions: 6mm x 10mm x 20mm
Field of view: 700µm x 400µm
Focal depth: Down to 300µm
Features:

- Magnetic latching to baseplate
- Slider for Z-depth adjustment
- Single coaxial cable for power & data
- Commutator compatible

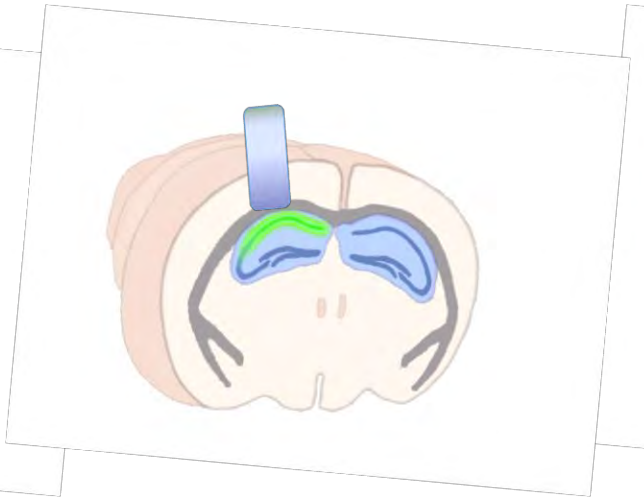
Cost: DAQ Hardware + 2 scopes < $1,500

Surgery overview

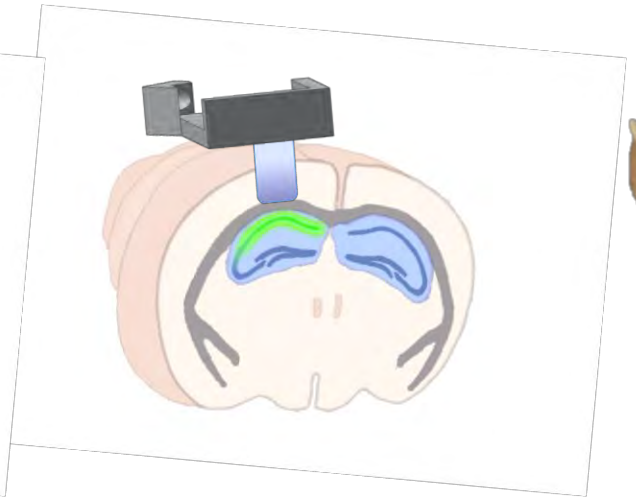
Virus injection



Implant lens

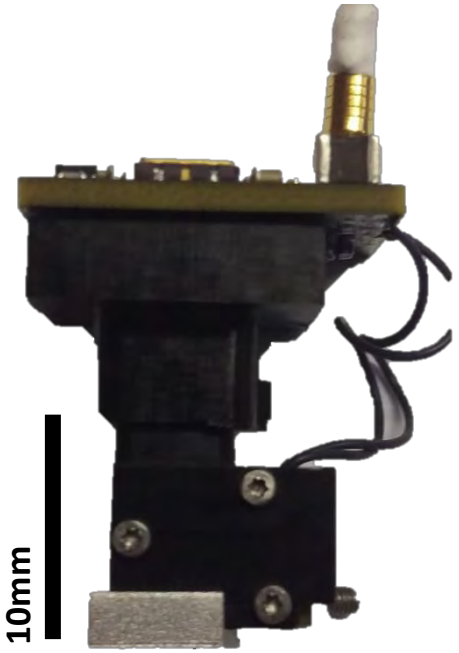


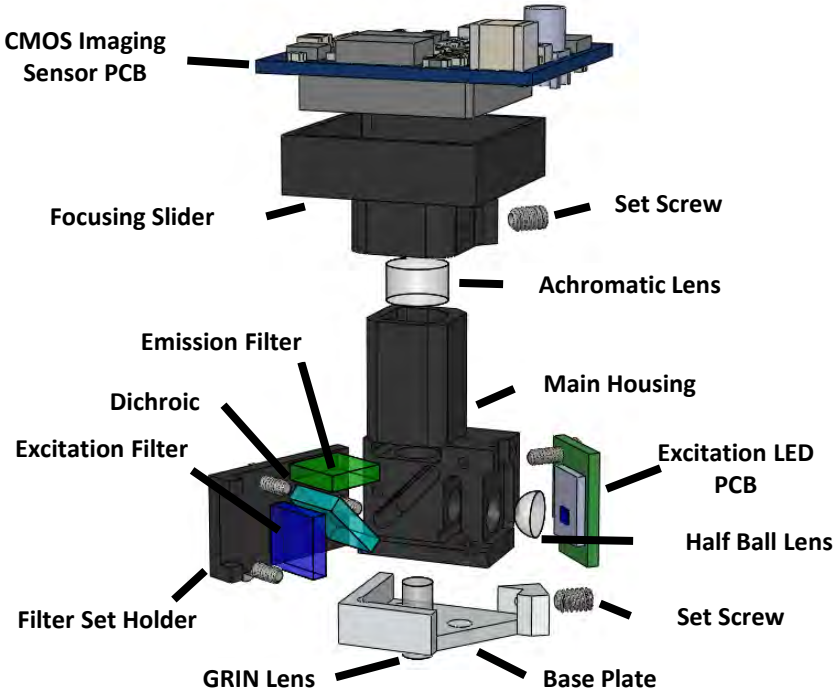
Cement baseplate

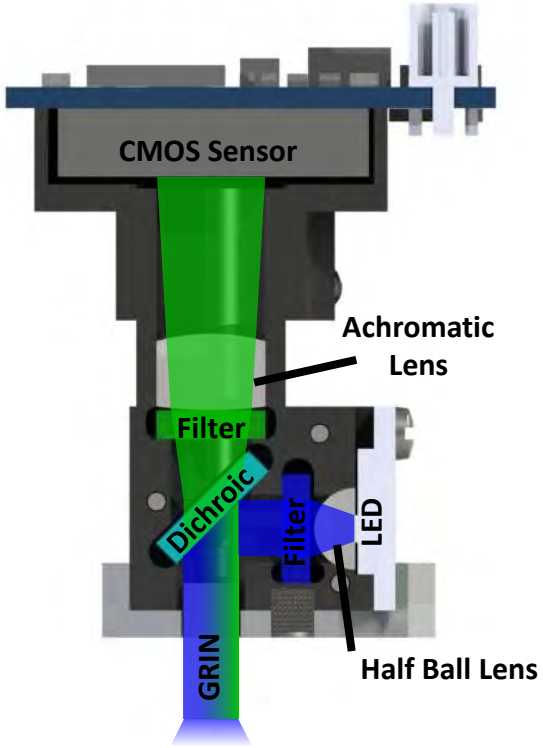


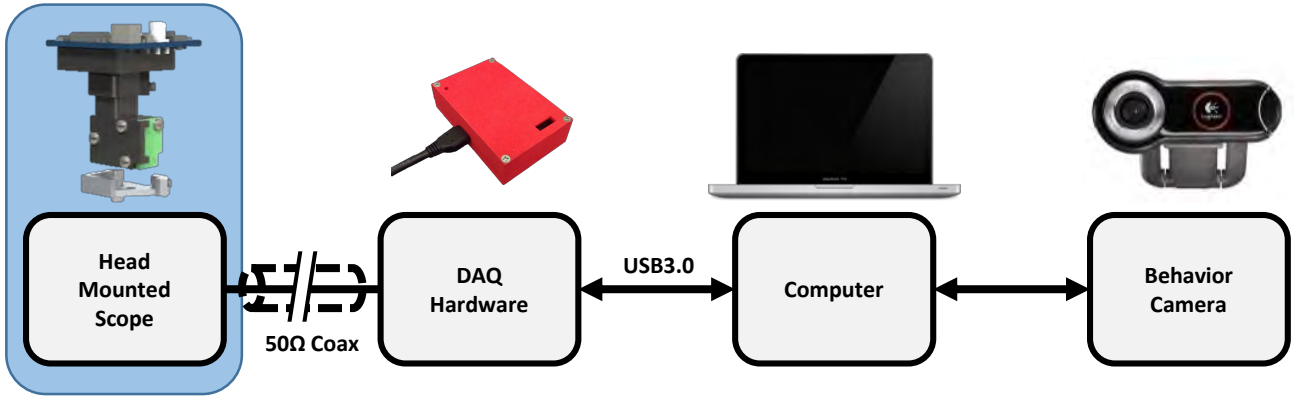
In vivo image

Head mounted scope









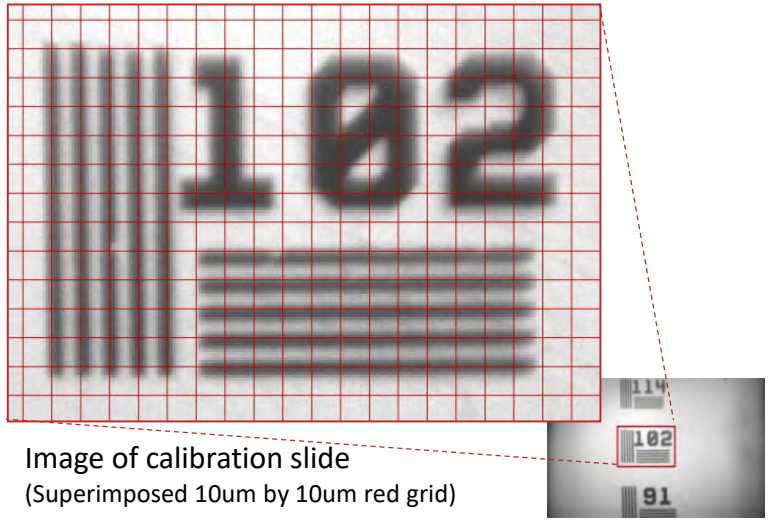


Image of calibration slide
(Superimposed 10um by 10um red grid)

Coaxial cabling

Power (x2)
I²C (x2)
Data (x15)
GPO (x4)

Power (x2)
I²C (x2)
Data (x15)
GPO (x4)

Head Mounted Scope

50Ω Coax

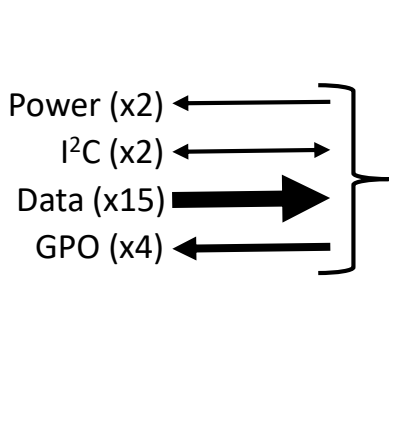
DAQ Hardware

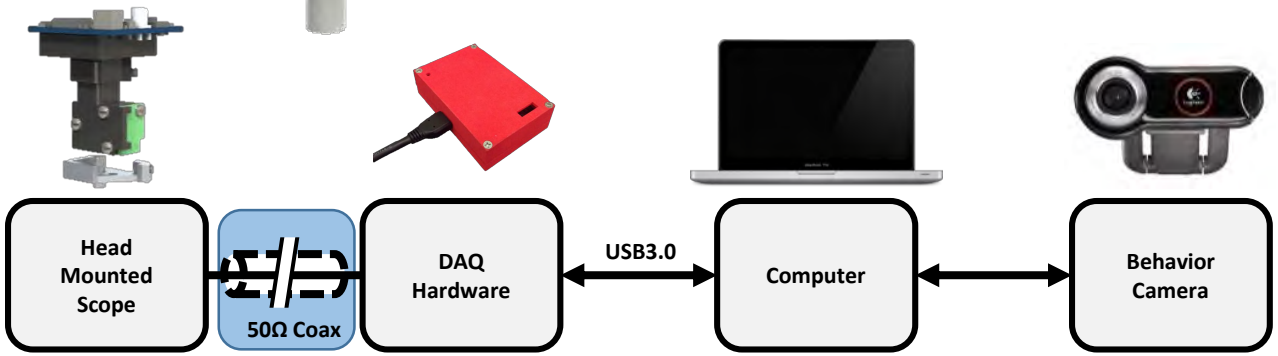
USB3.0

Computer

Behavior Camera

Coaxial cabling





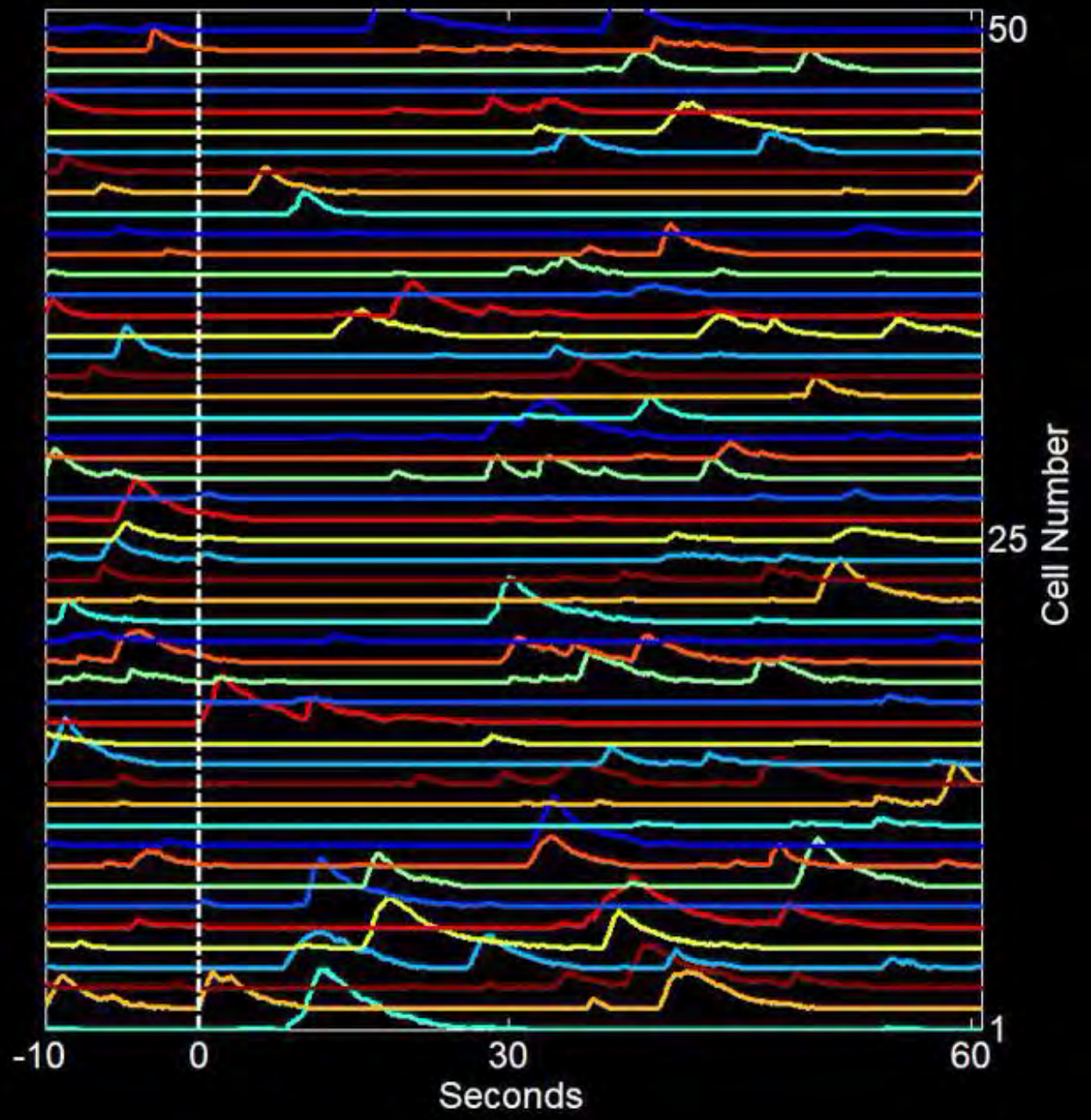
50Ω Coaxial Cable

- Down to 0.3mm diameter
- Up to 15m long
- Commutator compatible
- Up to 1.4Gbps (Mono 4K @ 18FPS)

Miniscope | 2m Linear Track

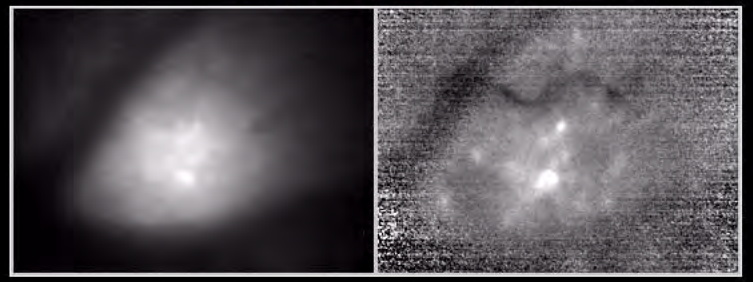
Mouse CA-1 | GCaMP6f | CNMF Output

Example ΔF/F

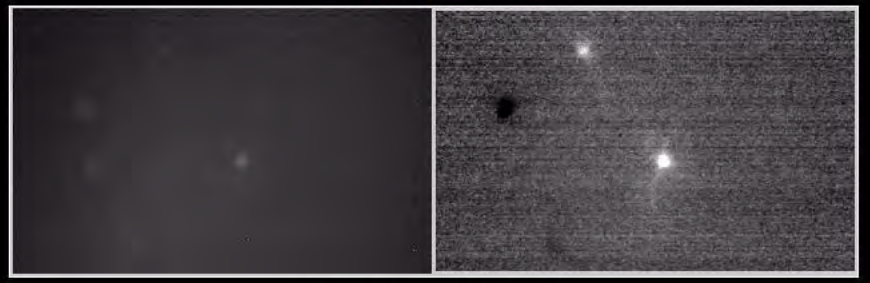


Hippocampal CA1

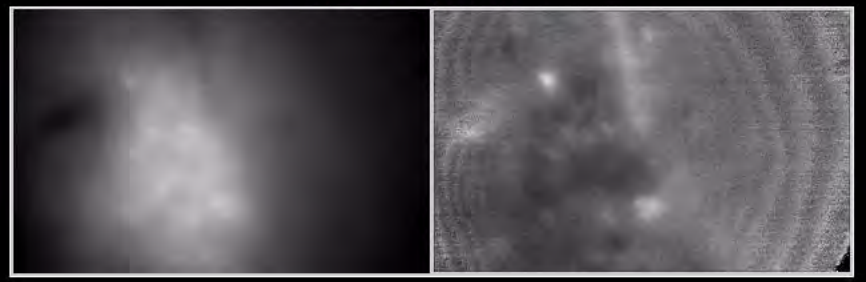
Parietal Cortex



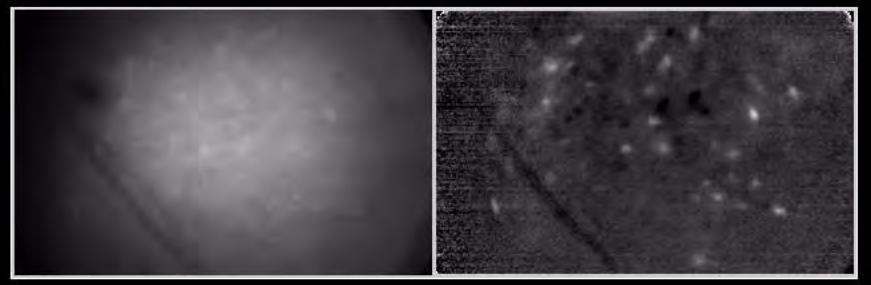
Subiculum



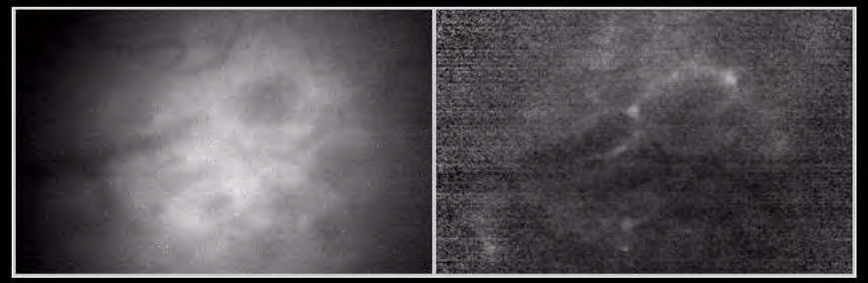
Retrosplenial



mPFC

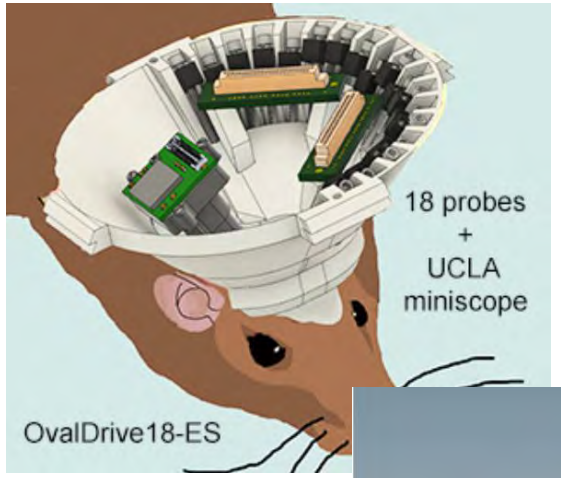


Striatum

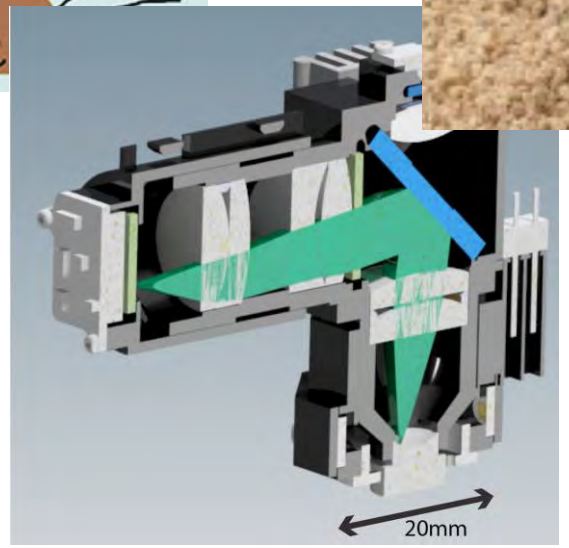


Visual Cortex

Related projects

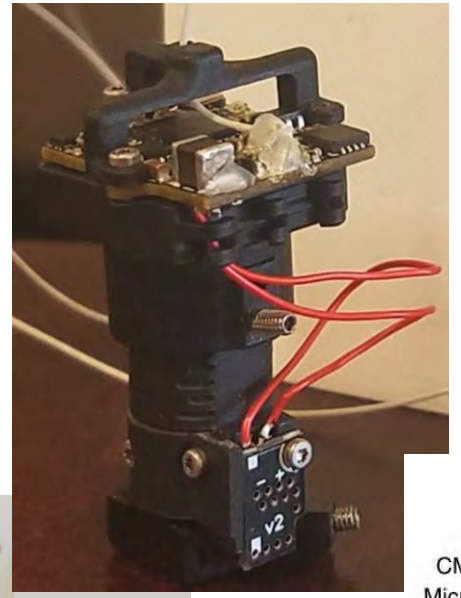


Blair Lab, UCLA

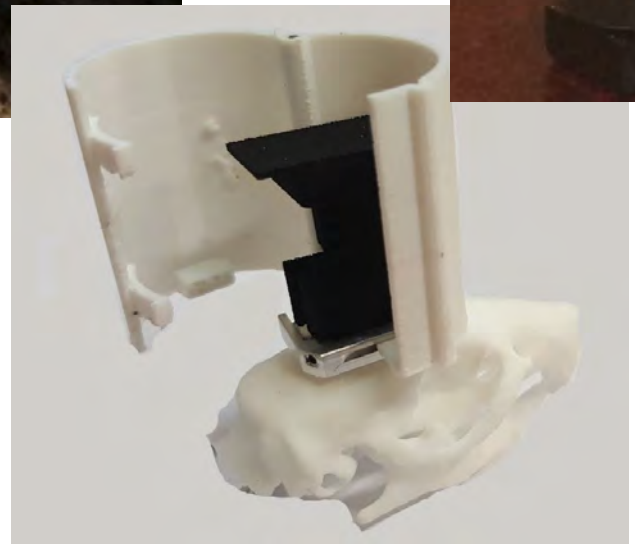


Tank Lab, Princeton

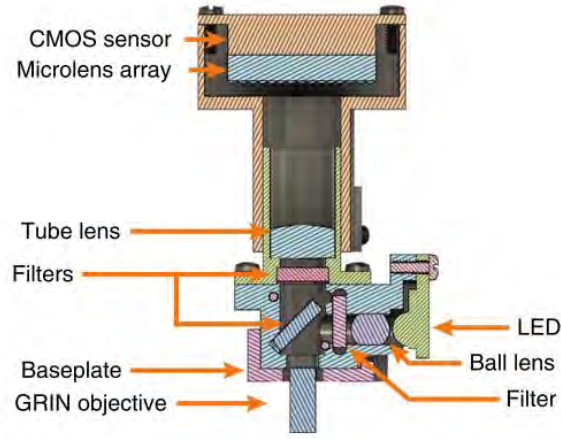
Hoogland Lab, NIN



Bastijn van den Boom, NIN

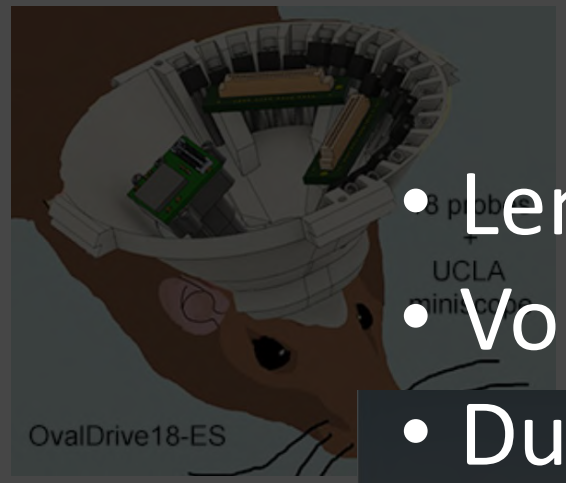


Vaziri Lab, Rockefeller

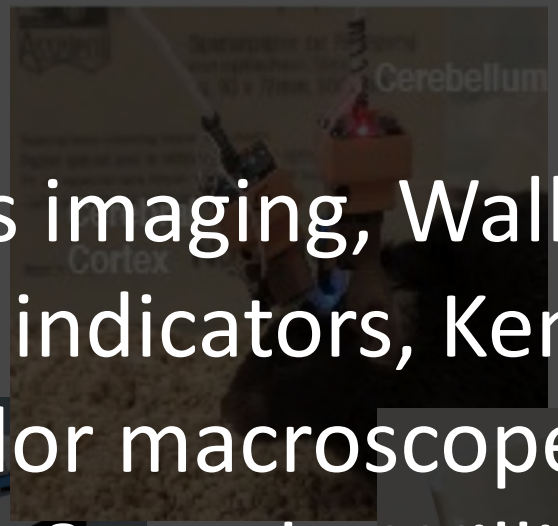


ONE Core, U of Colorodo

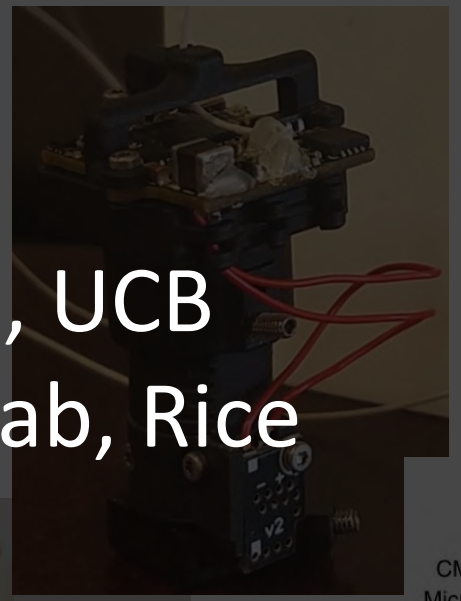
Related projects



Blair Lab, UCLA



Tank Lab, Princeton

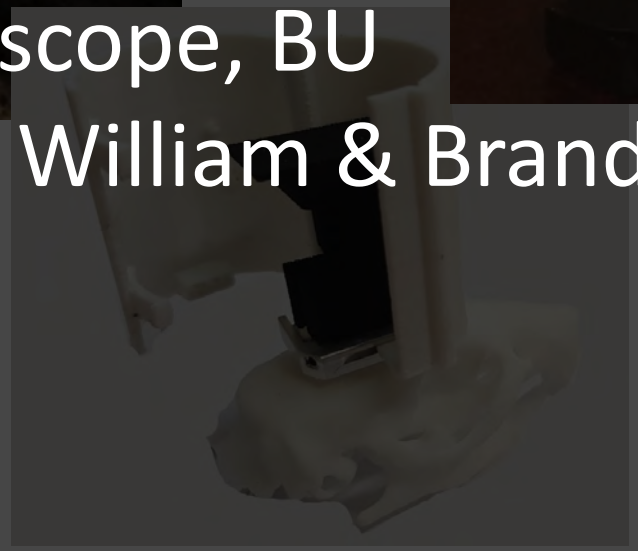


Bastijn van den Boom, NIN

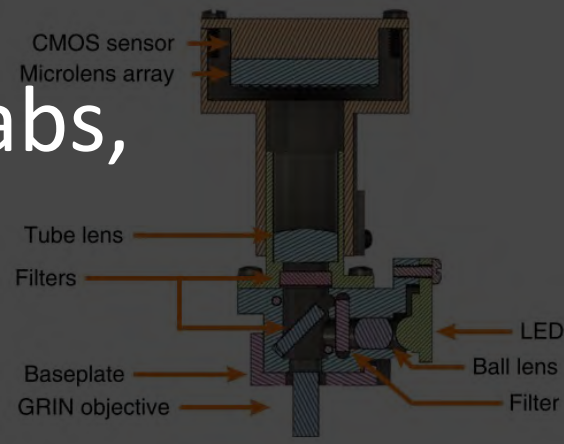
Vaziri Lab, Rockefeller

- Lensless imaging, Waller Lab, UCB
- Voltage indicators, Kemere Lab, Rice
- Dual color macroscope, BU
- Analysis & mods, William & Brandon Labs, McGill

Lab, NIN



U of Colorodo



Current development

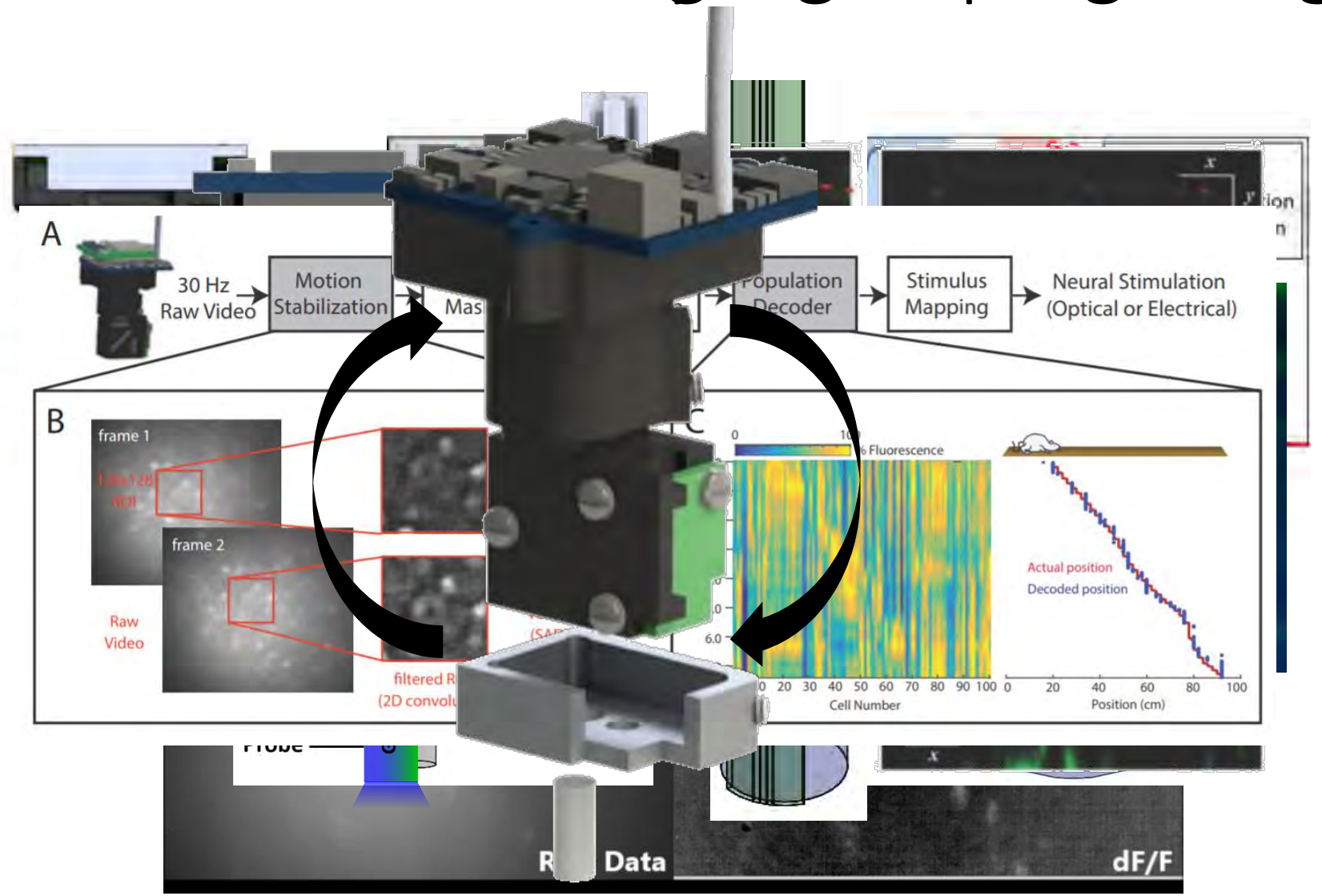
Using the open-source Miniscope platform as a foundation for innovation

Current development:

Optogenetics
(U01 BRAIN Initiative)

Multi-channel Imaging
(U01 BRAIN Initiative)

Microfluidics
(CSORDA Evans grant)



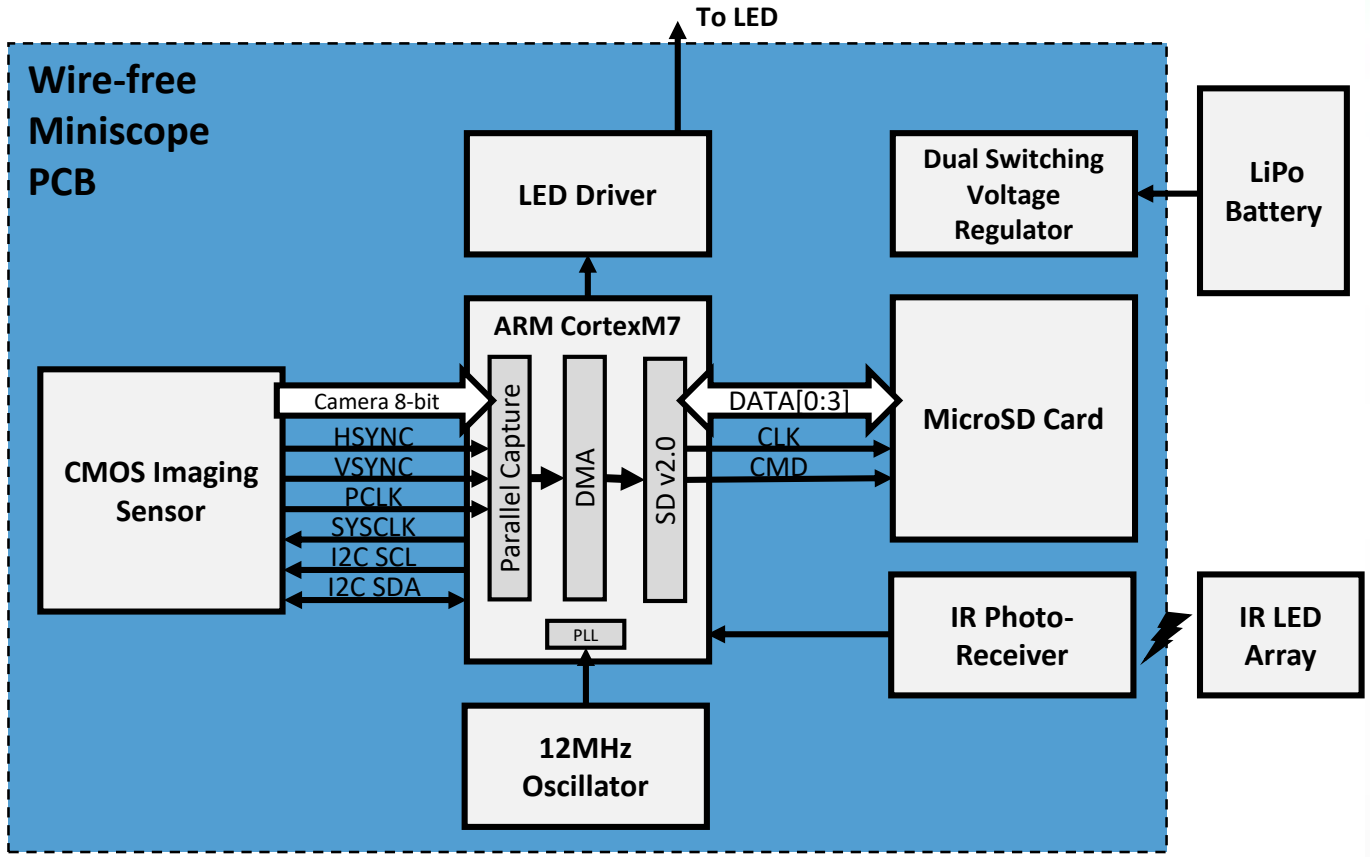
Light-field Vaziri Lab
(NSF Neurotech Hub)

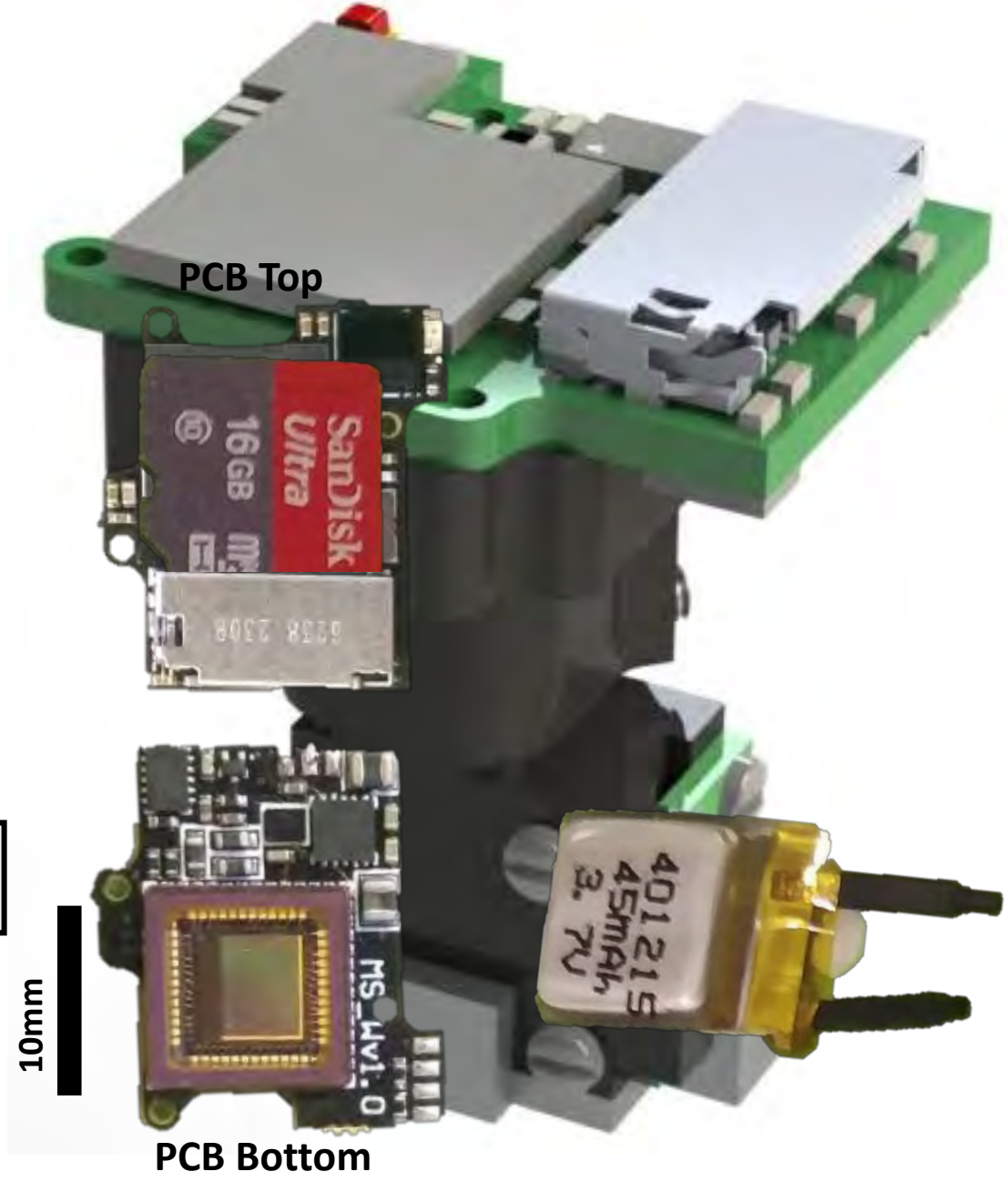
Hardware acc. Real-time head and Realtime processing position tracking
(NSF Neurotech Hub)

Wire-free Miniscope

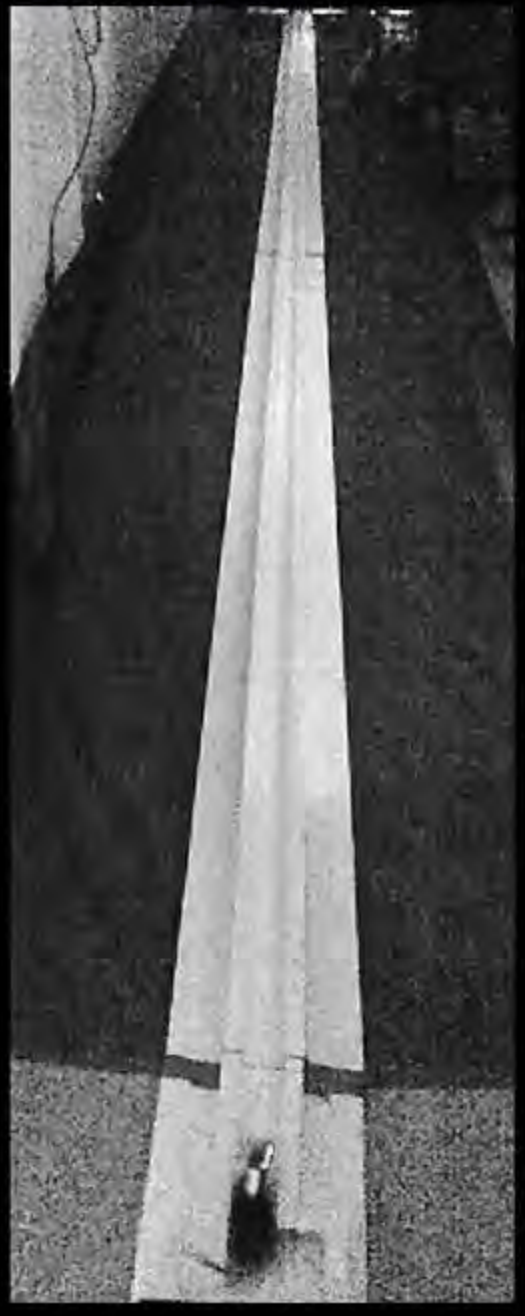
Battery powered, data logging, miniature microscope

Wire-free Miniscope



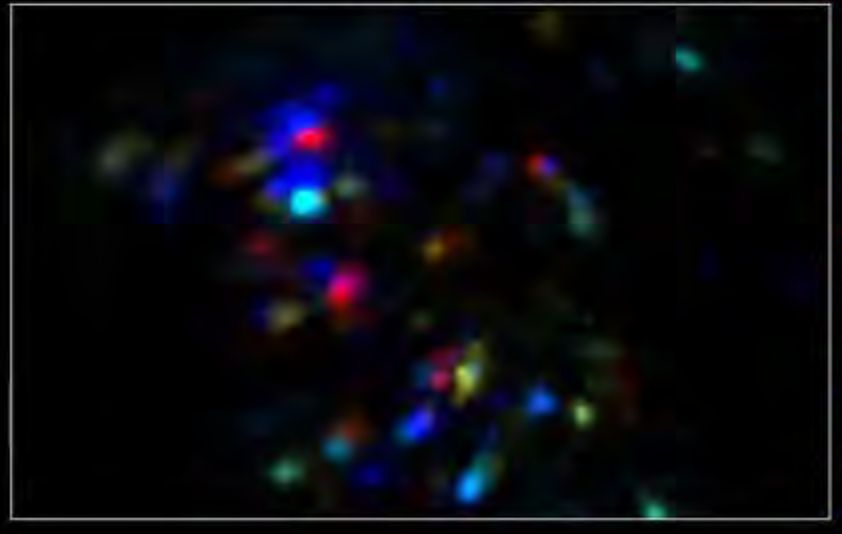


25 Foot Long Track. Camera 1

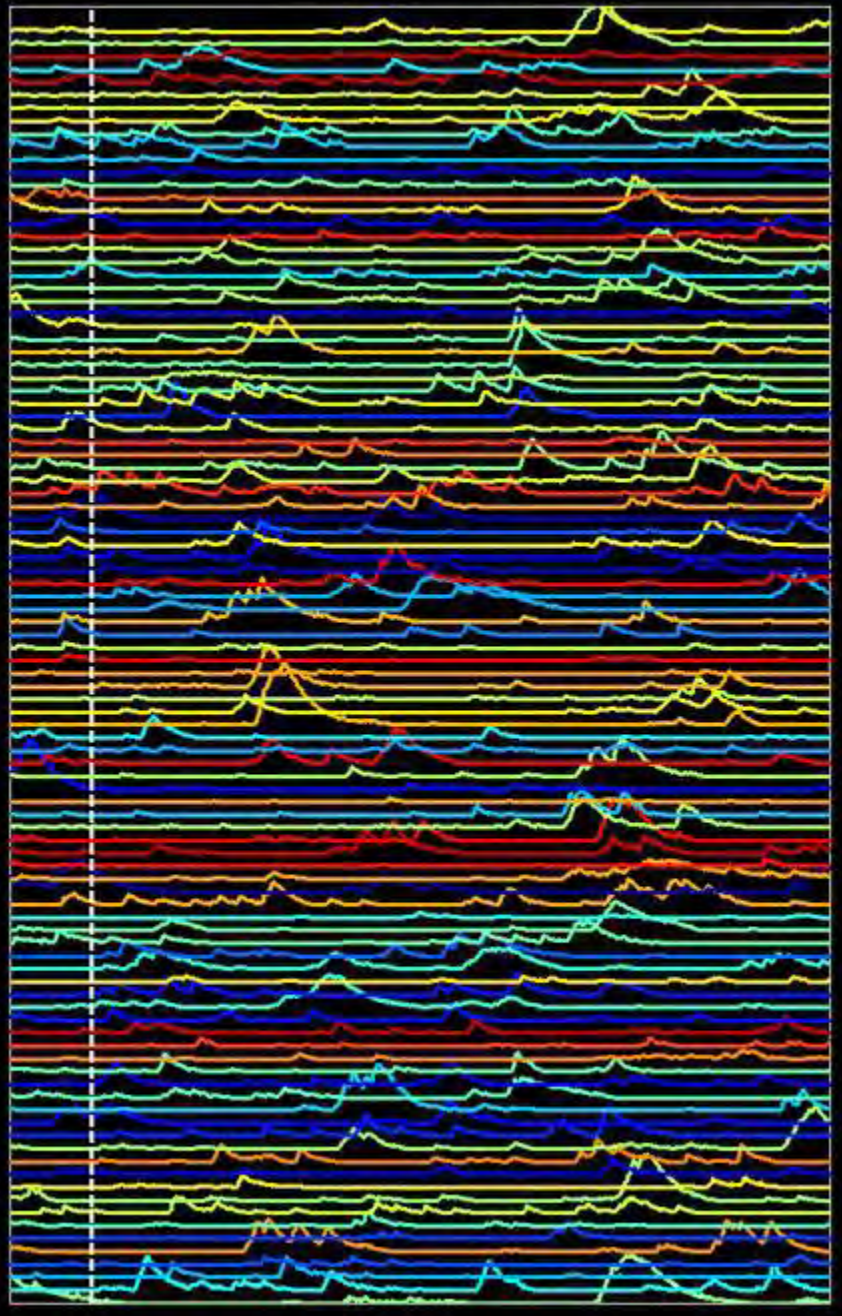


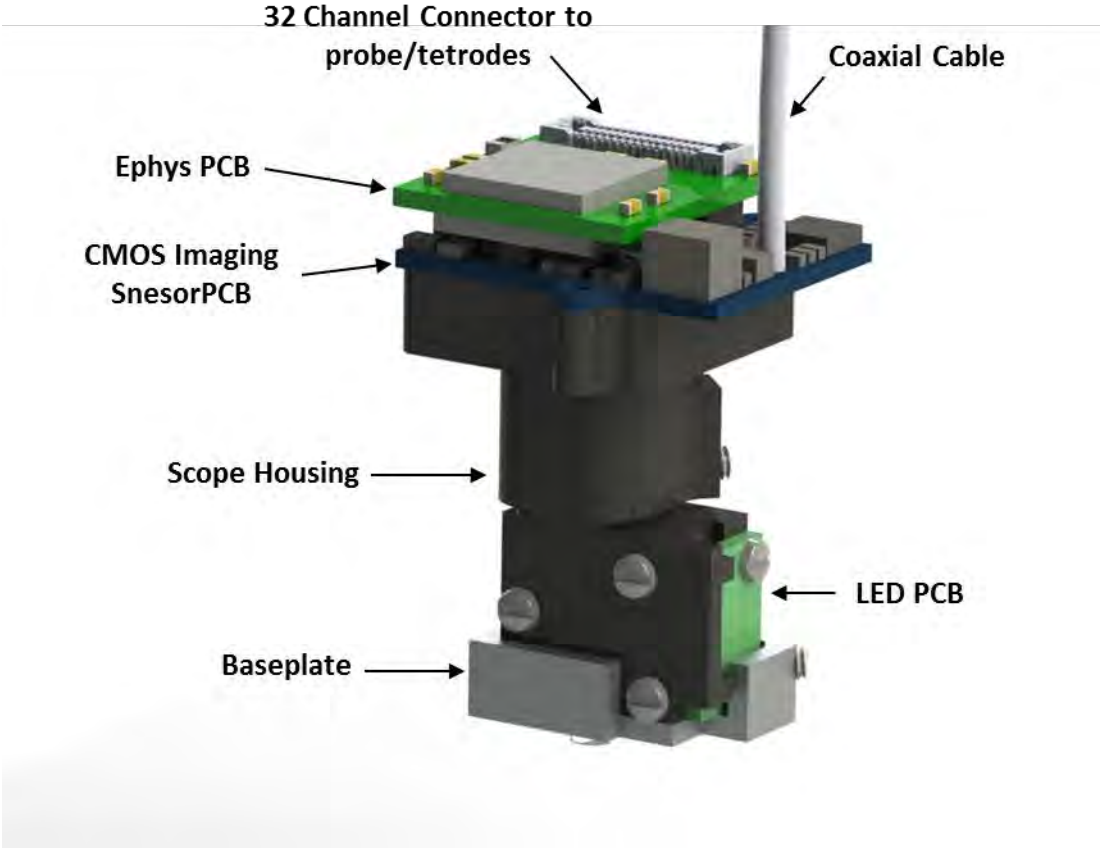
25 Foot Long Track. Camera 2

561 Neurons



Example ΔF/F

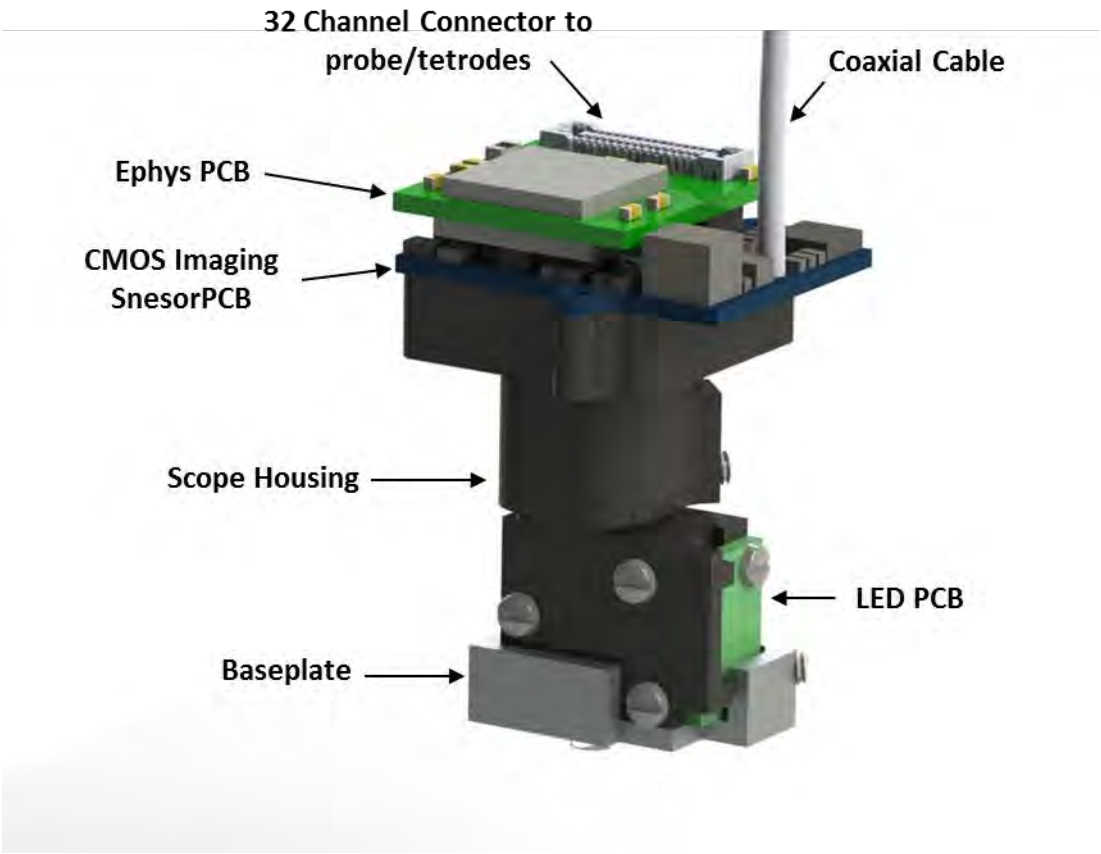


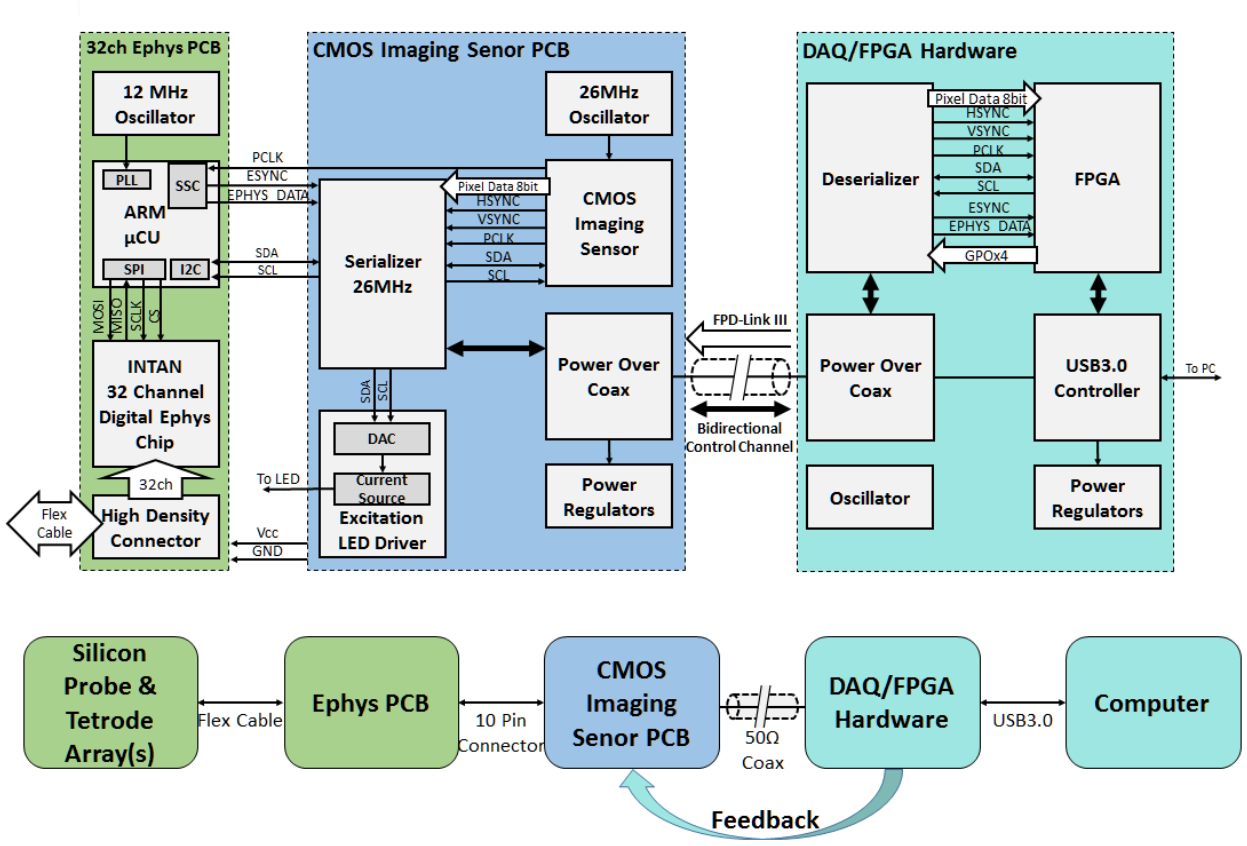


Electrophysiology Miniscope "E-Scope"

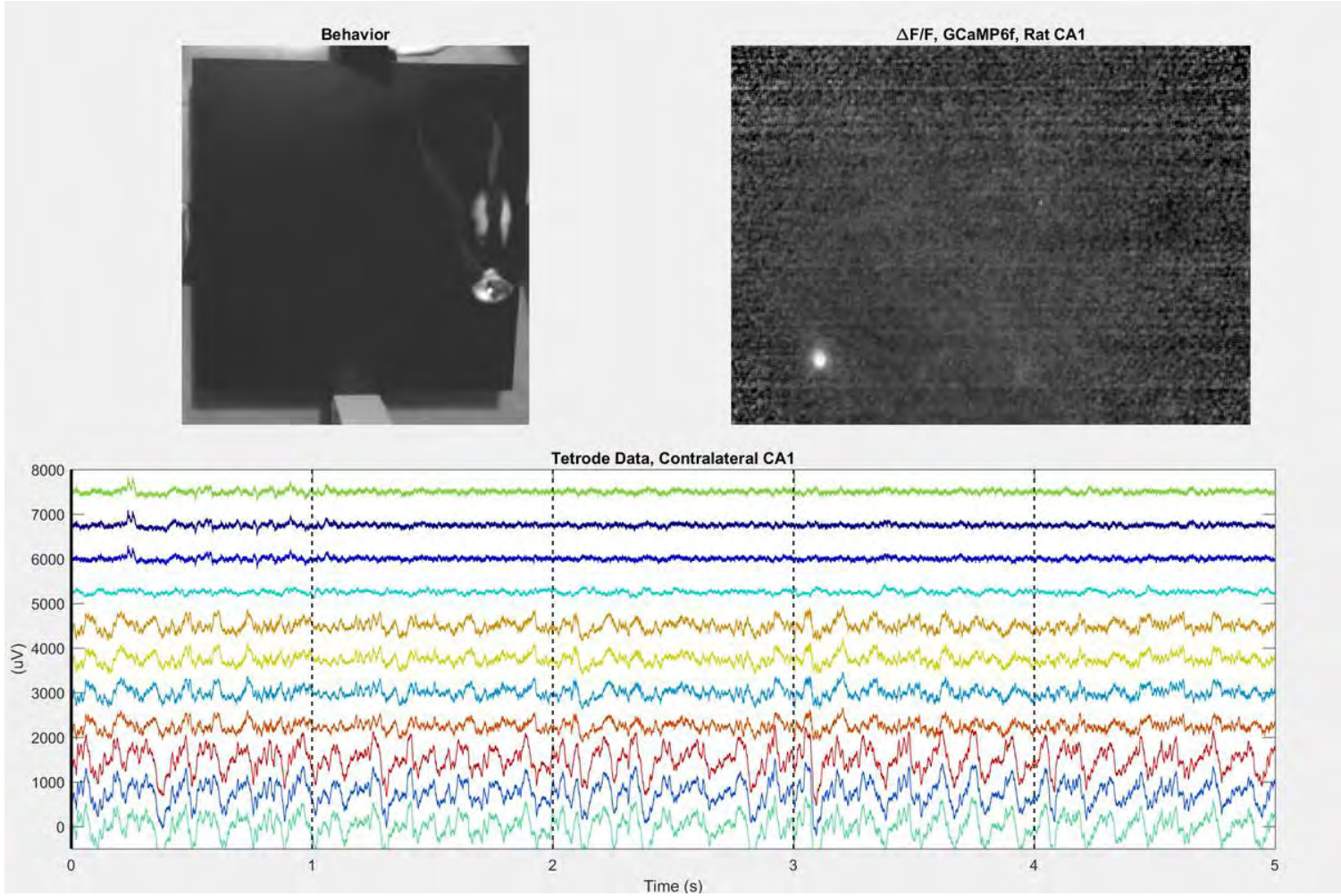
Simultaneous calcium imaging and ephys recording

Electrophysiology Minsicope “E-Scope”

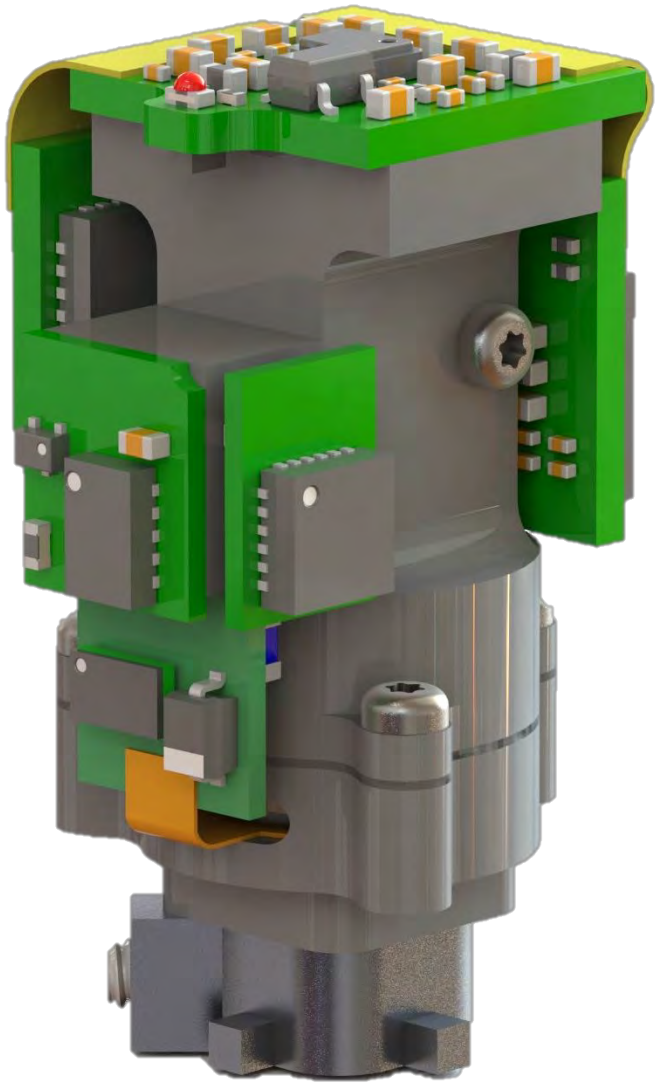




Electrophysiology Minsicope. Blair Lab

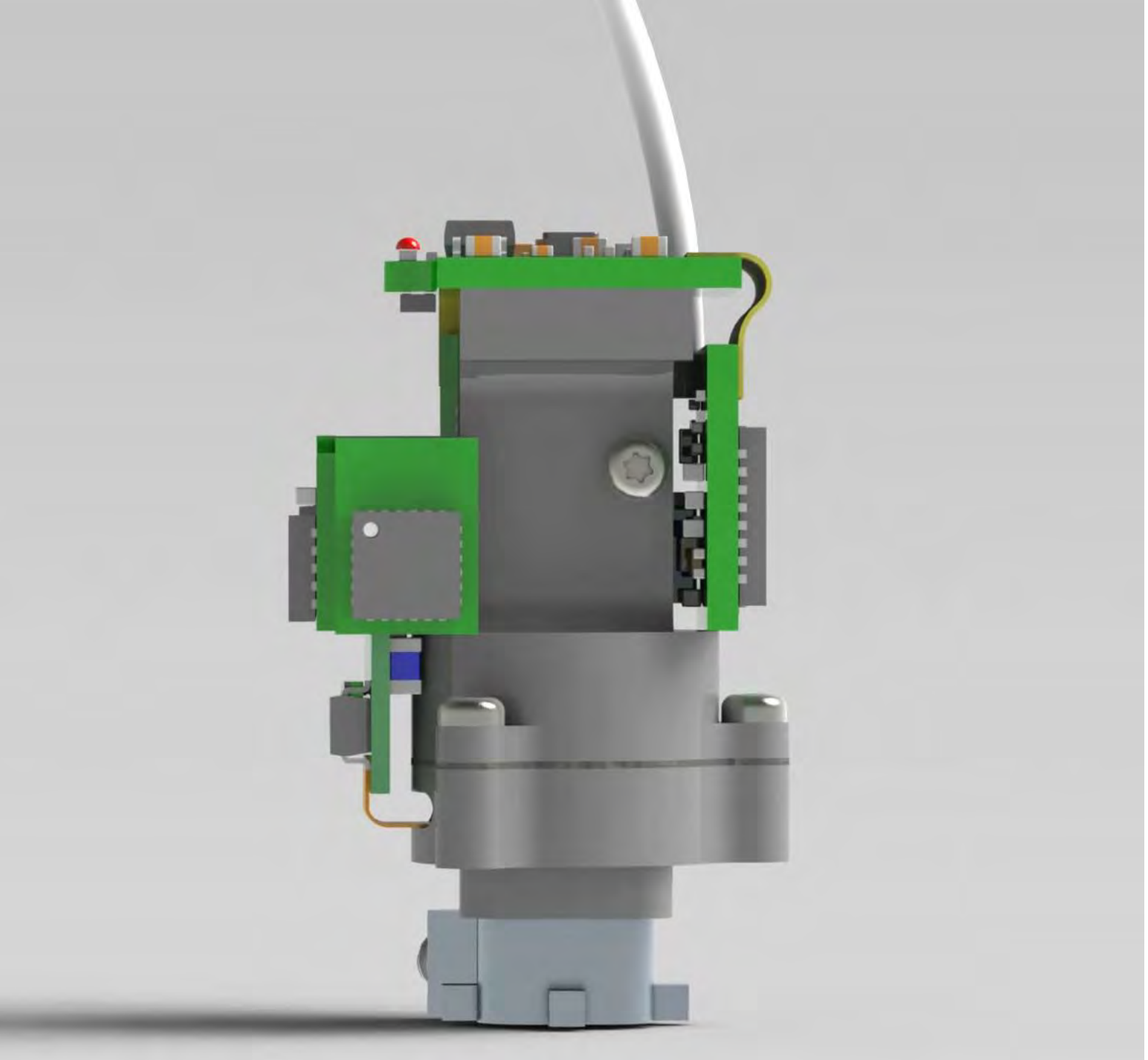


In collaboration with the Blair and Masmanidis Lab, UCLA



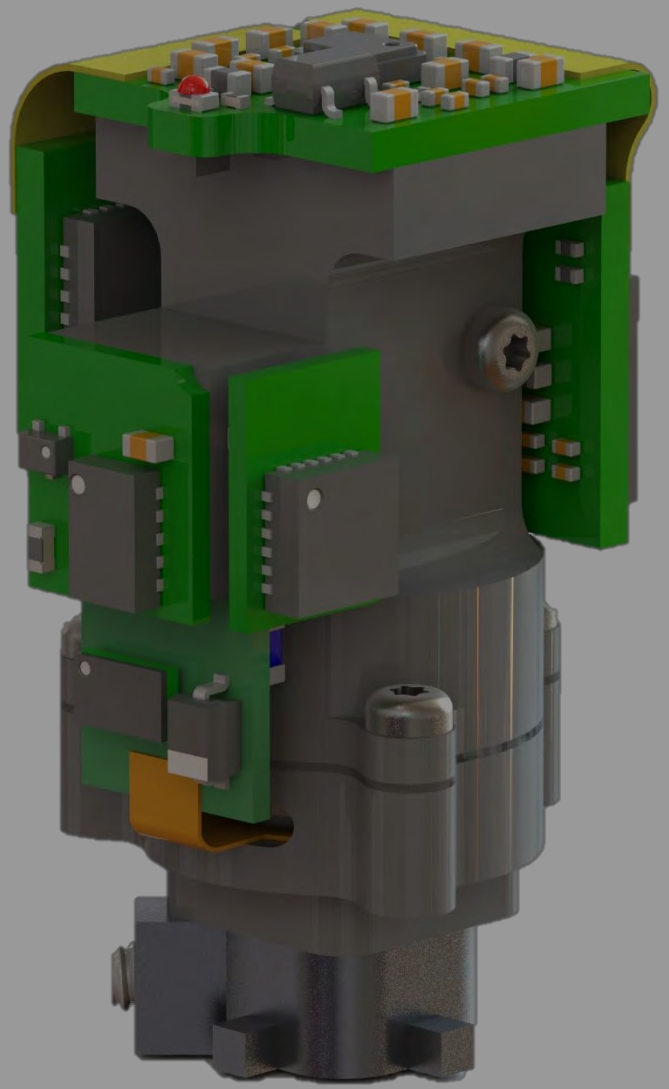
Next-Gen Miniscope Platform

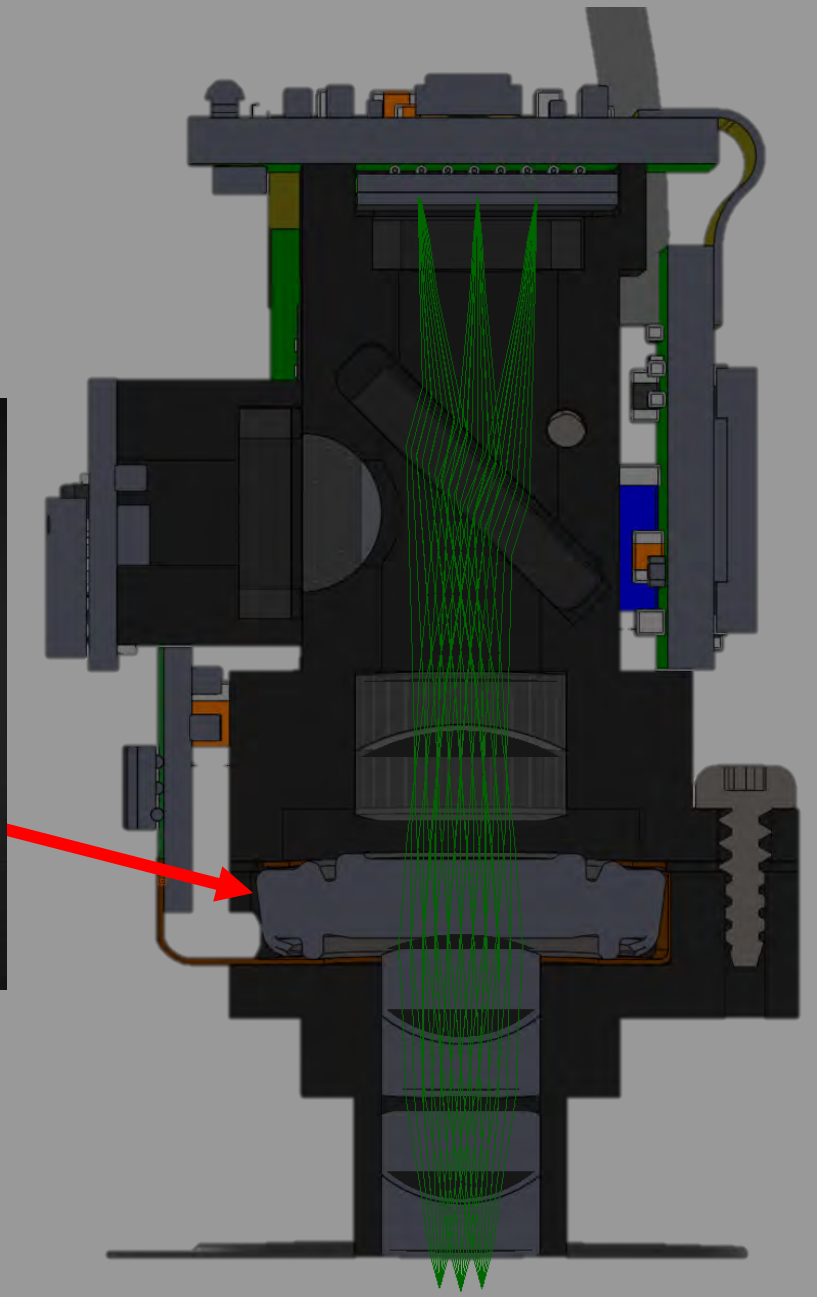
Rebuilding the Miniscope platform from the ground up



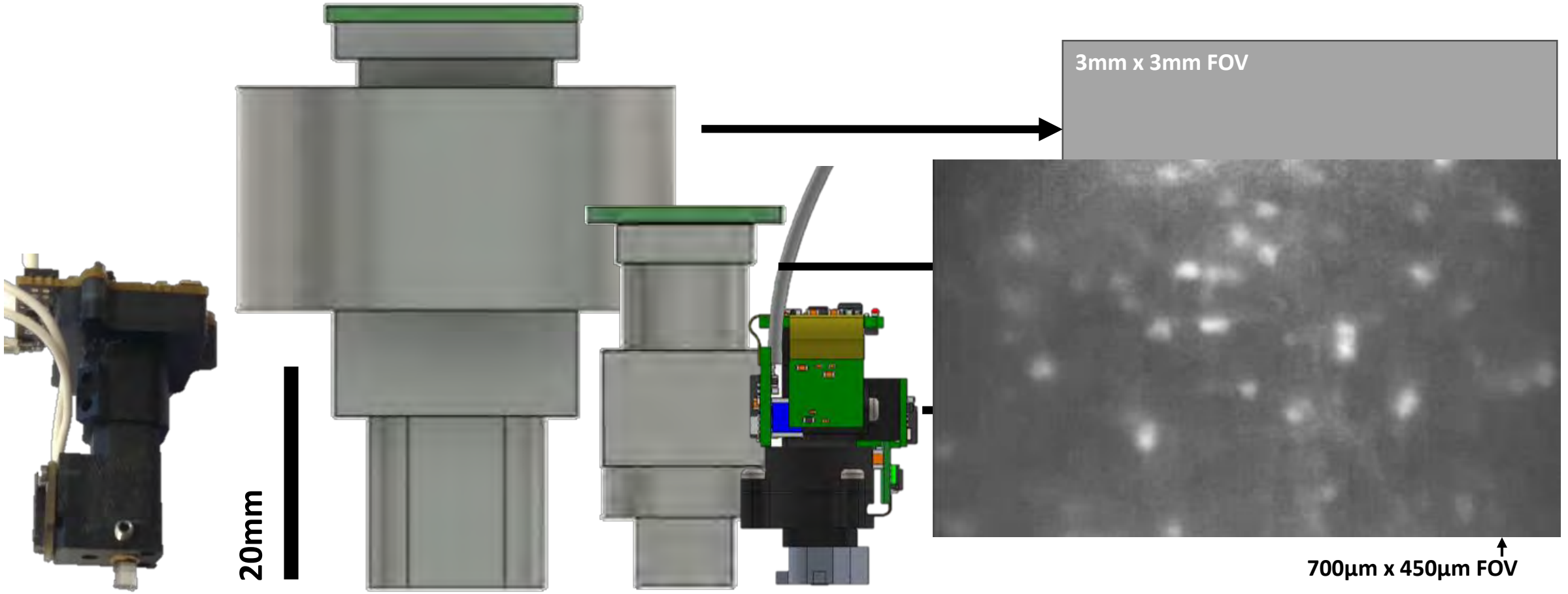
Specifications	Current Miniscope	Next-gen Miniscope
Height	22mm minimum	20mm maximum
Mass	3g	2.3g
Data cable	>5m coaxial cable	>5m coaxial cable
Maximum FPS @ full resoltuion	60FPS	120FPS
Field-of-view	0.4mm^2	0.8mm^2 to 3mm^2
Magnification	6x to 7x	2x to 3x
Mid working distance	~125µm	0.8mm to 2mm
Working distance adjustment	+/-125µm	+/-300µm
Footprint on skull	~75mm^2	25mm^2
Imaging + optogenetics		✓
Commutator	✓	✓
Wire-free option	✓	✓
Automated focus		✓
Fully achromatic		✓
Support for multiple photo-detectors		✓
Structured illumination capable		✓

Electrowetting Lens



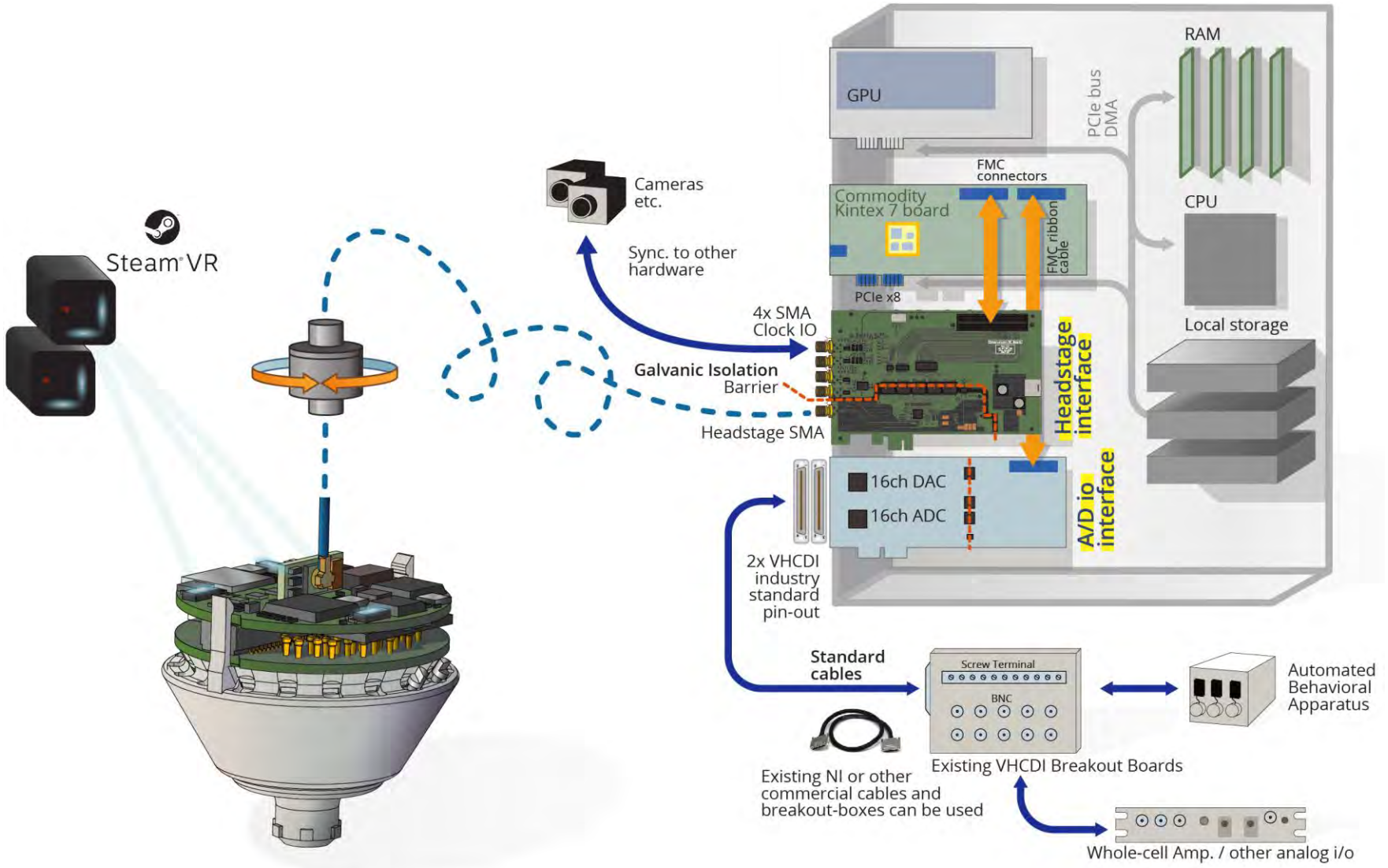


Field of view comparison

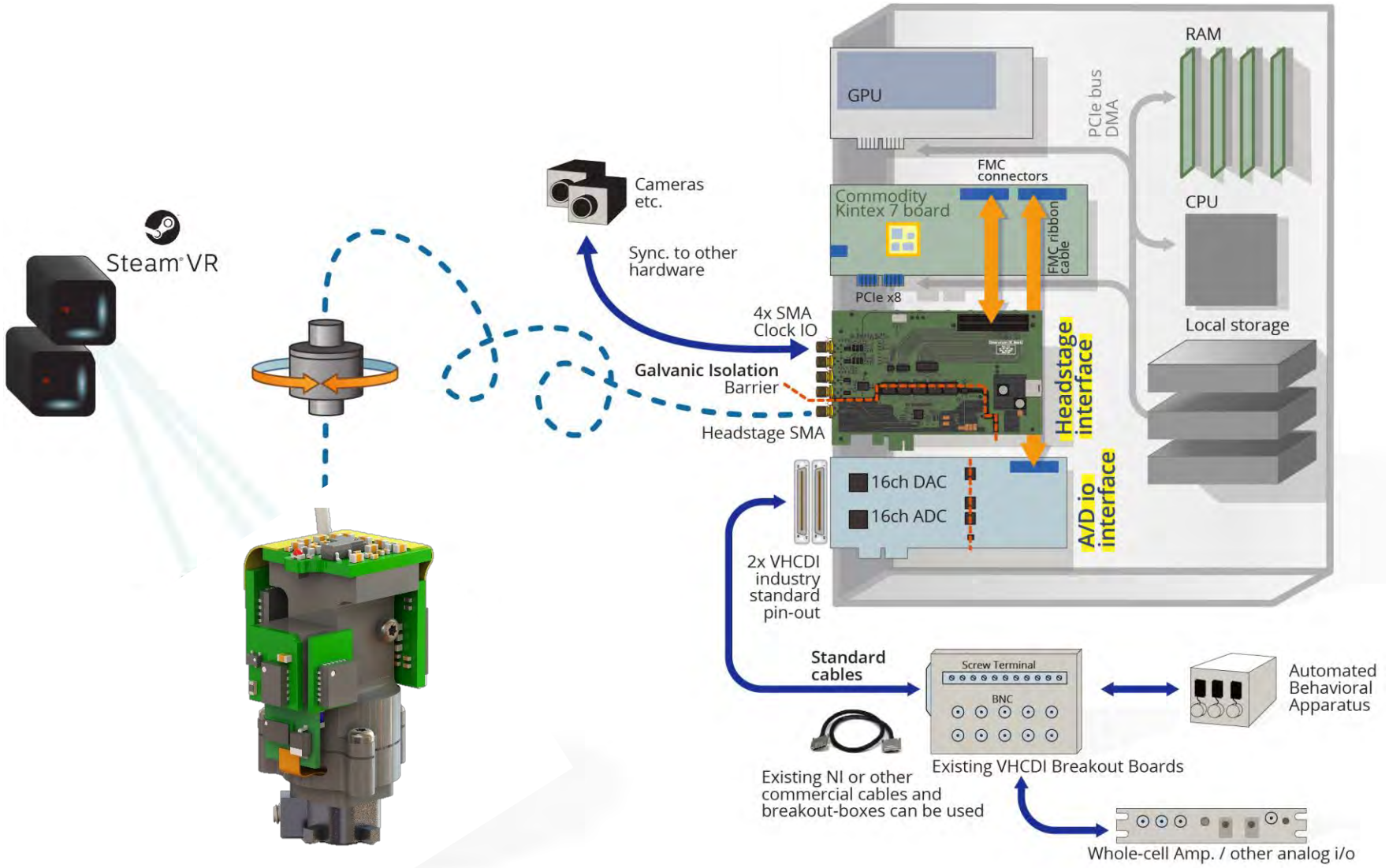


In collaboration with the Basso Lab, UCLA

Integration with Open Ephys



Integration with Open Ephys



SCOPE

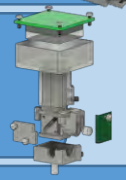
Miniscope v3
- MT9V032 Sensor (0.3MP @ 60FPS)
- Manual focus slider
- Objective GRIN lens

Miniscope v4
- PYTHON480 sensor (0.5MP @ 120FPS)
- Liquid tunable lens
- Achromatic objective

Miniscope v5
- Additional behavior sensors
- On-board FPGA
- Steam VR head/position tracking

Wire-free Miniscope
- Battery powered
- Data logging onto microSD card

Light-field Miniscope (MiniLFM)
- Volume imaging at video framerates



Large FOV Miniscopes (Siminiscope)
- High-end imaging sensors
- Possibility of wireless data transmission

EPHYS

32Ch Ephys
- Intan 32ch IC (RHD2132)
- Uses extra 2 parallel lines on the coax serializer

64 to 192Ch Ephys
- Intan ICs
- FPGA generic packaging of data

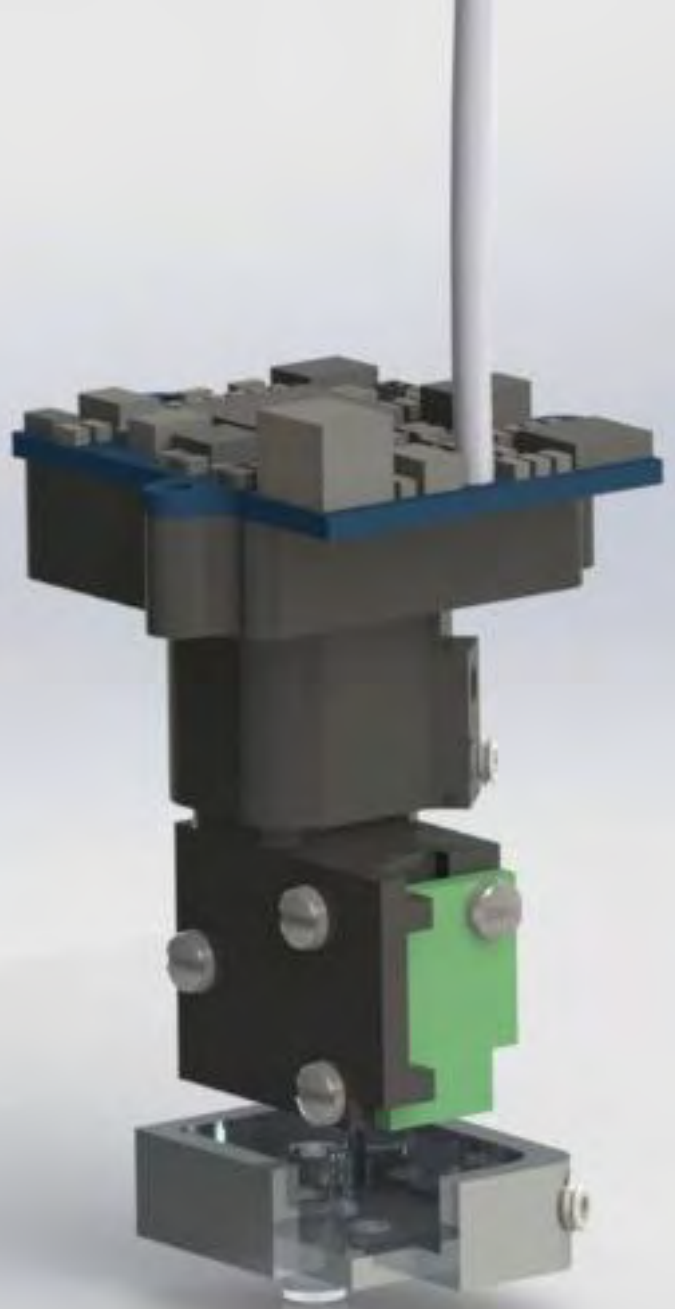
DAQ

USB Video Class (UVC) DAQ System
- Custom PCB based around a USB3.0 Host Controller
- USB drivers only support UVC
- A bit hacky to pull out ephys along with imaging data

Opal Kelly FPGA DAQ System
- Backward compatible
- Bulk USB3 transfer with individual buffers for each data source

Real-time Processing Capable

Next Gen FPGA DAQ System



Thank you

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