Advanced Research and Technology Symposium 2018

Revolutions in Biotechnology

Microelectronics Interfacing Neural Devices (MIND)

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6 March 2018

This material is based upon work supported by the Assistant Secretary of Defense for Research and Engineering under Air Force Contract No. FA8721-05-C-0002 and/or FA8702-15-D-0001. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Assistant Secretary of Defense for Research and Engineering.

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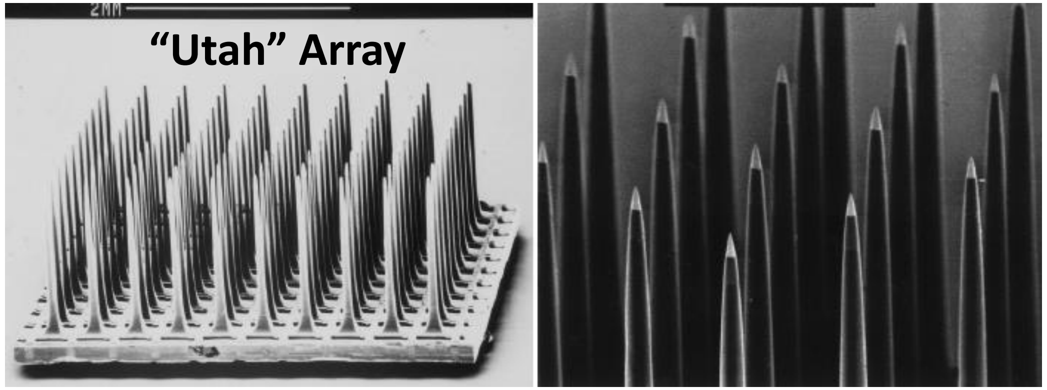
Motivation

State of the Art

Current *in vivo* electrical neurophysiology understanding is based on grossly invasive, bulky, <u>necessarily cannulated</u> technology platforms

"Utah" Array



"Michigan" Probes

Surgical installation

Internalization and deactivation

Glial scarring and chronic inflammation

Poor device performance

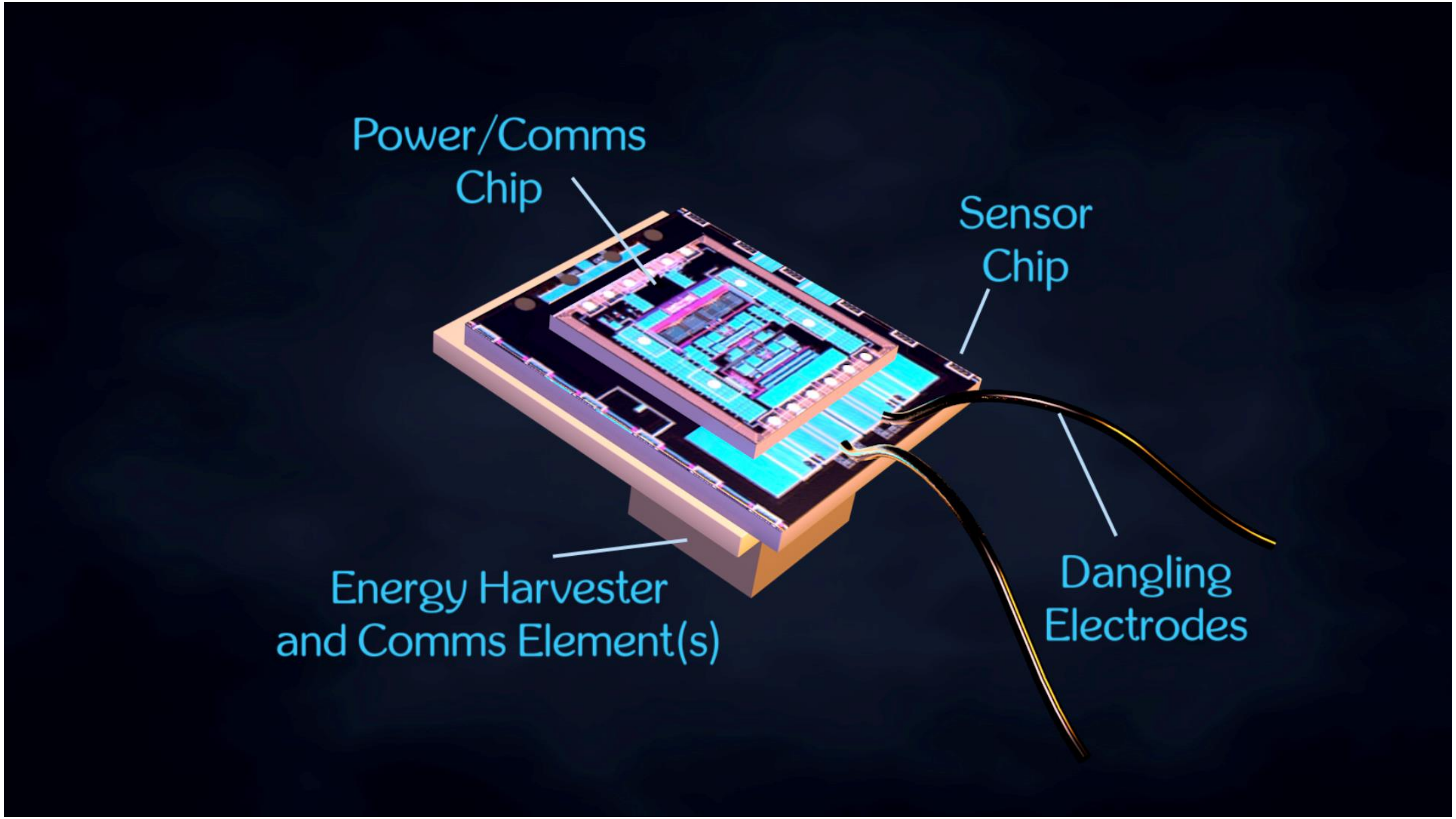
All of these technologies are subject to a strong observer effect:

Observation affects the system!

Higher spatio-temporal resolution than ever before, with fewer biological issues

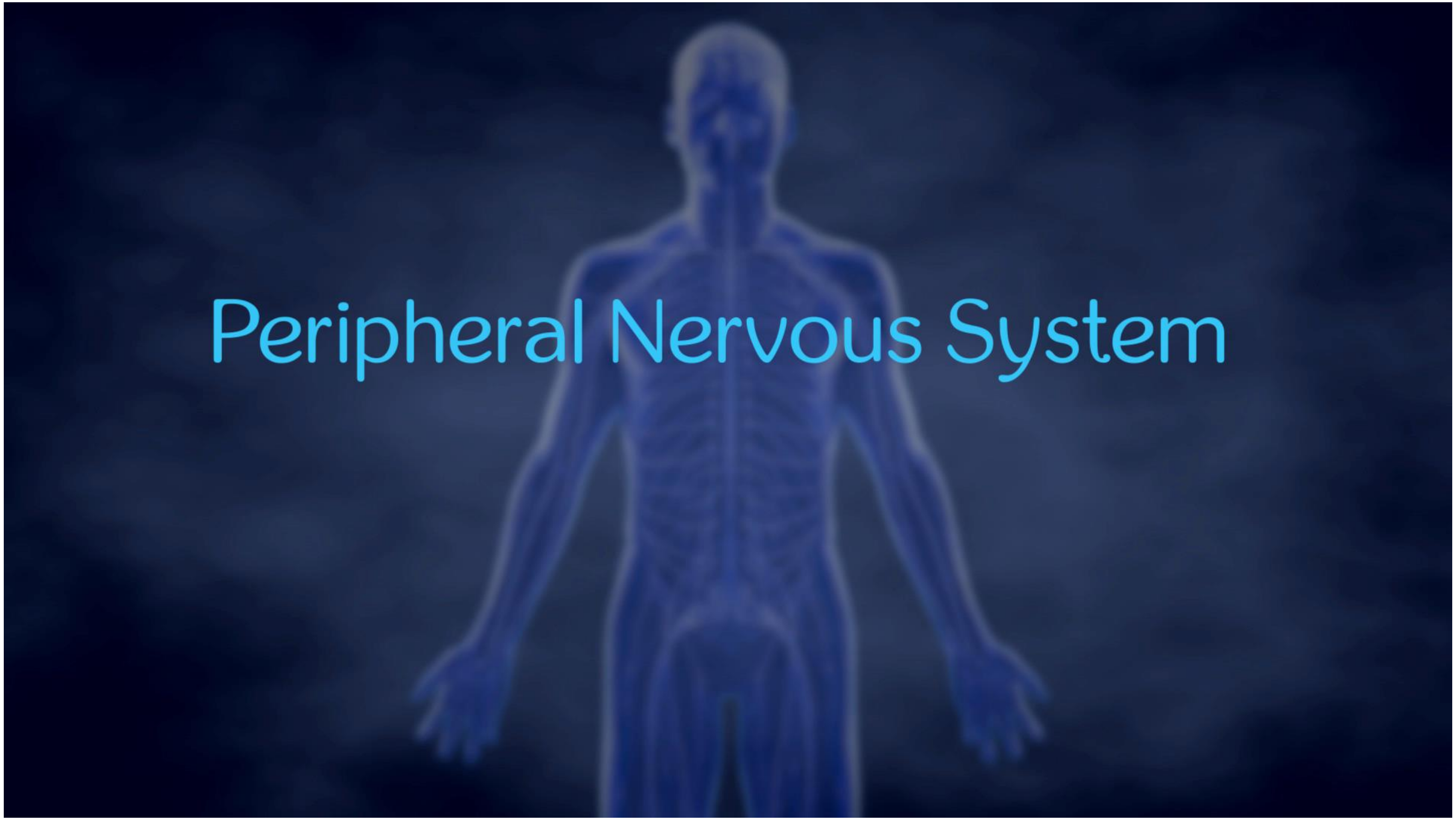
Review paper: Fattahi et al, *Adv. Mater.* 26, pp1846, 2014

The Vision



Power/Comms Chip
Sensor Chip
Energy Harvester and Comms Element(s)
Dangling Electrodes

How It Works



Sensor Interface ASIC Tapeout

	Single Channel Size (µm)	Power (µW)	Analog Front-End	ADC (ENOB)	Spike Detector	Amp Noise (µVrms) (Hz)
MIT LL MIND	330 × 270	~4*	Y	9.4 *	Y	4.25 (1–10e3)*
Seo 2016	750 × 750	N/A	Y	N	N	180
Shulyzki 2015	200 × 200	12.9	Y	5	N	7.99 (10–5e3)
Biederman 2015	160 × 160	3.02	Y	8.2	N	7.5 (100–10e3)

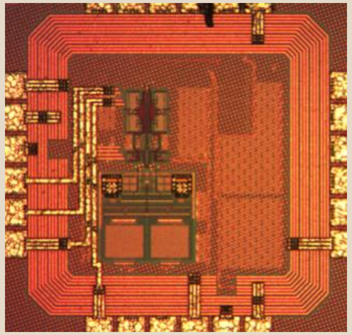
* Simulated results

- Total system power requirement <10 µW
  - Based on published values of ultrasound power harvesting for given volume
- Combines small size, mixed-signal (analog + digital), ultralow-power, low-noise sensor into one ASIC chip
- Further size and power reduction planned

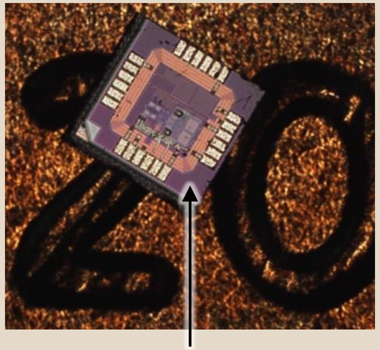
- Neural sensor custom ASIC: low-noise neural amplifier, 10-bit ADC, digital spike detector
- Size: 330 µm × 270 µm
- Average power consumption <4 µW*

* Simulated results

First MIND Chip Received December 2016



MIND Chip



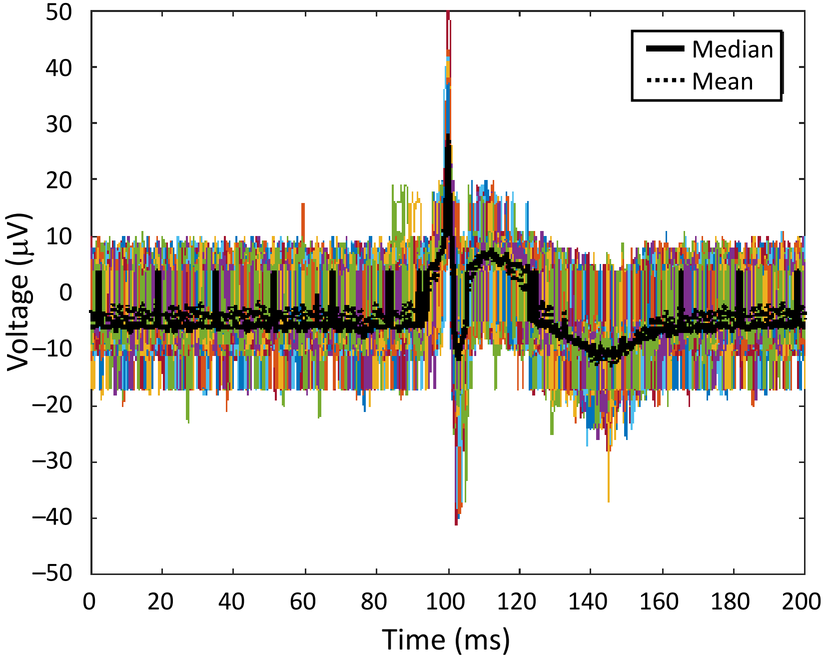
MIND Chip on the Surface of a Penny

Action Potentials in Heart Cells

Use easily cultured heart cells for first experiments

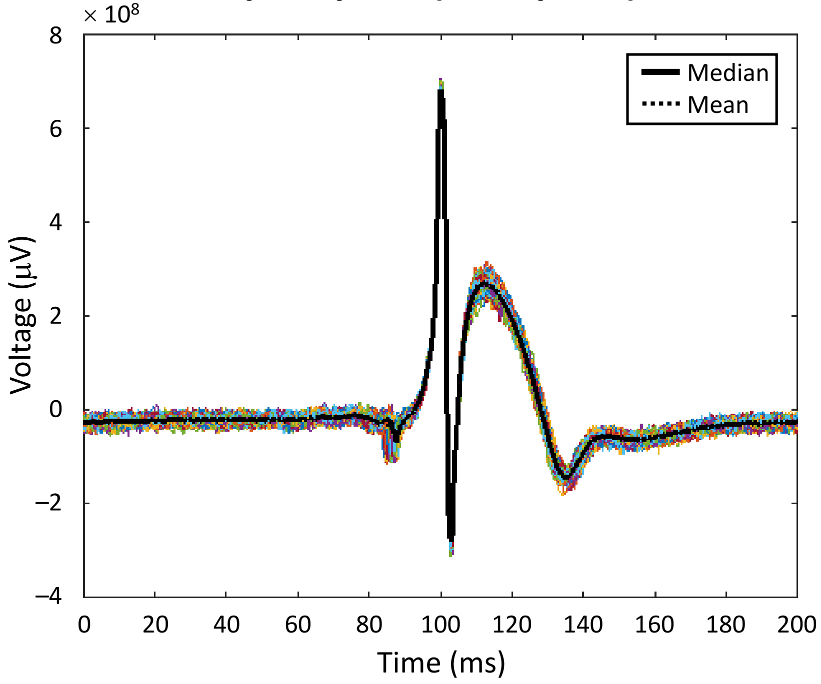
MIT LL MIND

Average Spike per Epoch (110 spikes)



COTS Measurement

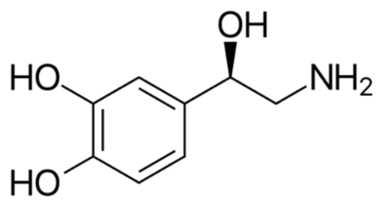
Average Spike per Epoch (153 spikes)

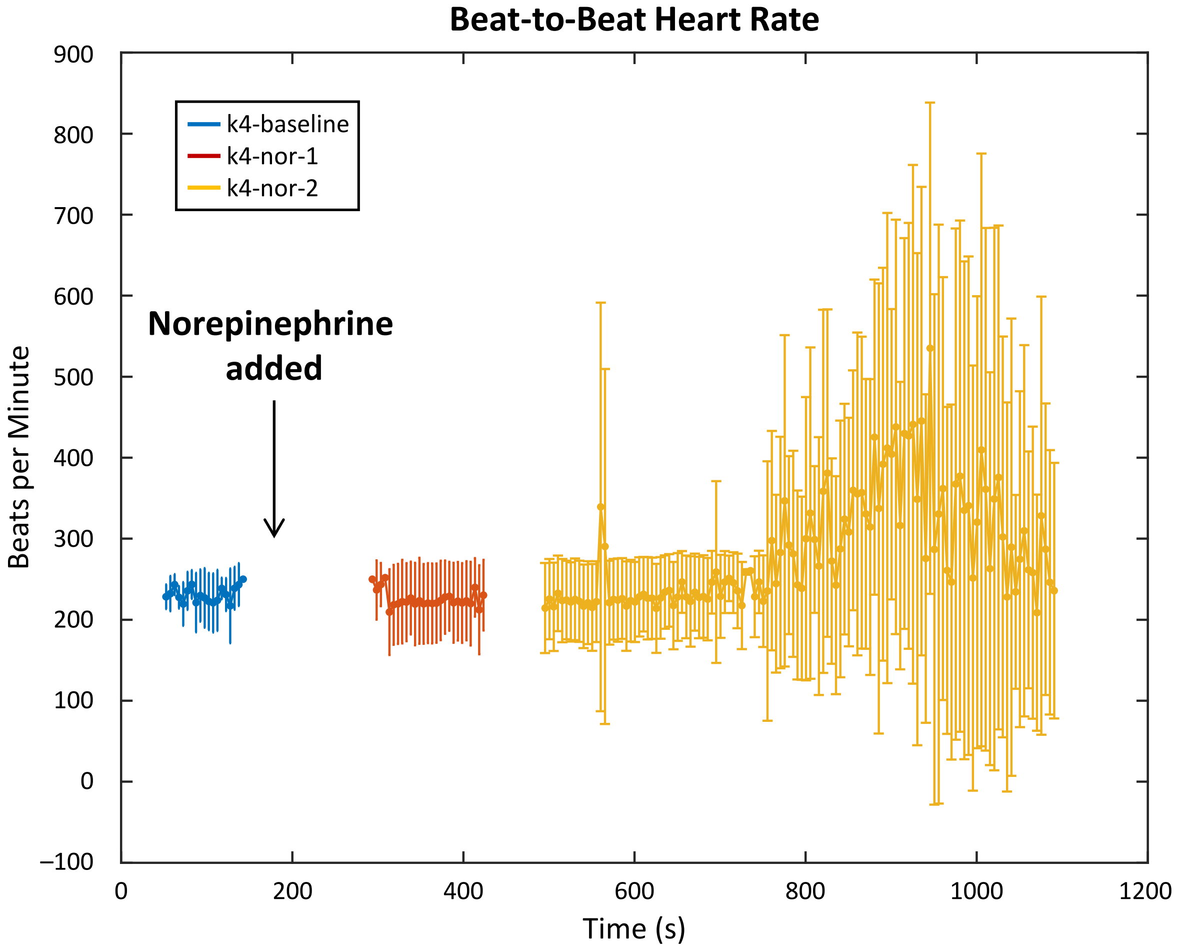


Morphologically similar waveforms, easily detect firing

Biological Activity: Effect of Norepinephrine

Neurotransmitter/drug used to raise heart rate



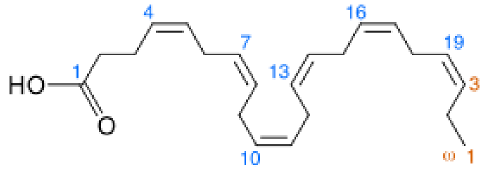


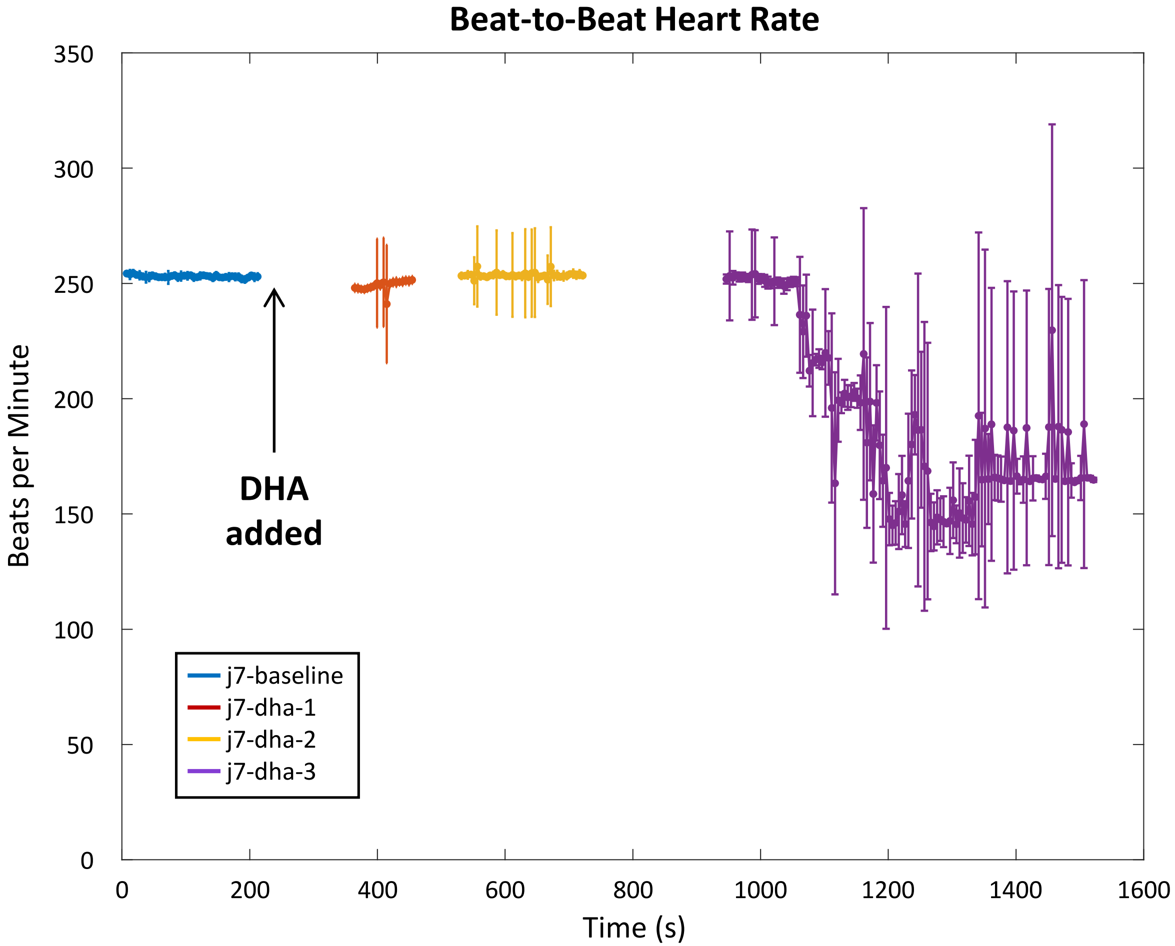
5 s window mean/stdev

Stable sensor able to detect biological events

Biological Activity: DHA (Fish Oil)

Drug used to lower heart rate





5 s window mean/stdev

Stable sensor able to detect biological events

Summary

- MIND is trying to revolutionize how we observe the nervous system
- Wireless, tiny, trivially introduced into body
- MIND chips are able to observe cell behavior *in vitro*
- Next Steps
  - Leverage advances in metamaterials of optical comms
  - *In vivo* testing in rodents