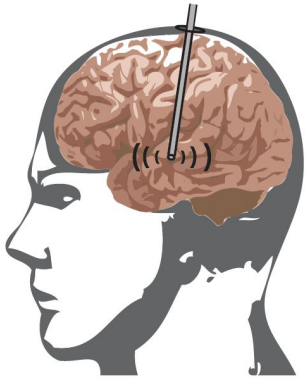
Microdisplays: Interfacing with the Brain

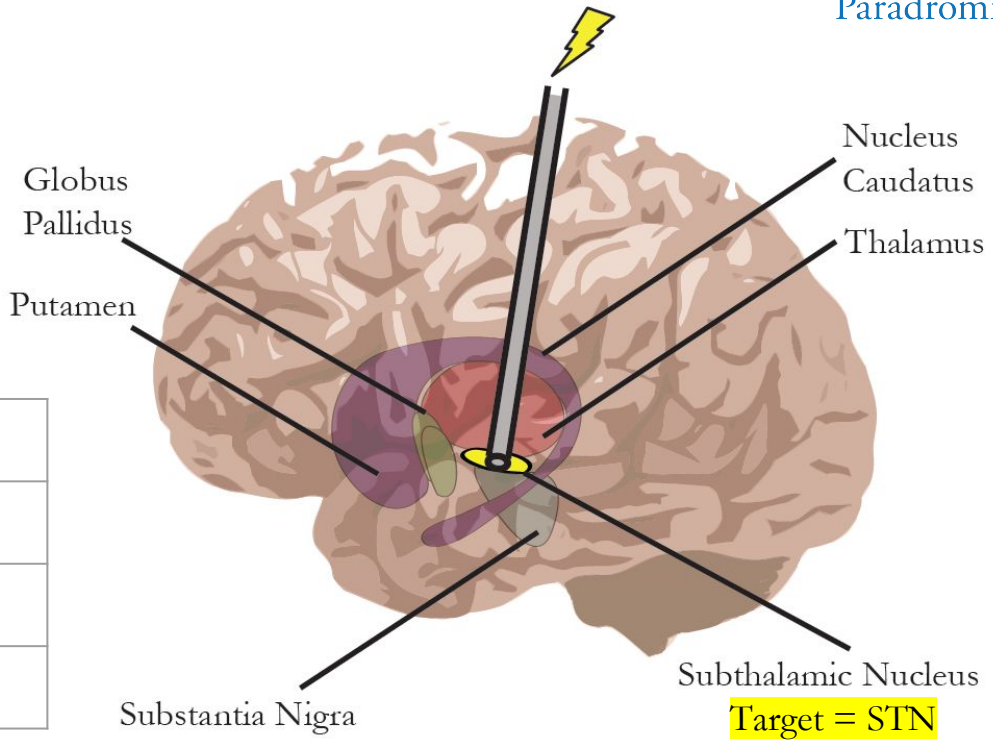
Mina Hanna, Yu Wei, Yifan Kong, Matt Angle, Mihaly Kollo, Andreas Schaeffer, Jun Ding & Nick Melosh

Stanford ENGINEERING | Melosh Lab
Materials Science & Engineering

Deep Brain Stimulation

Paradromics





FDA-approved application	Affected Persons in NA
Essential Tremor	7,000,000
OCD	5,000,000
Parkinson's Disease	1,000,000
Tourette Syndrome	300,000

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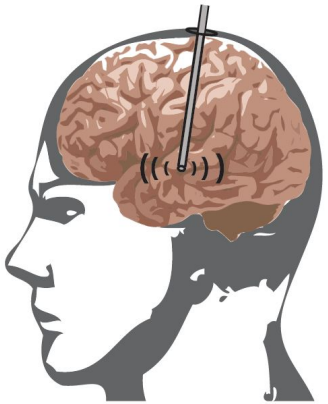
Deep Brain Stimulation - Cont.

Paradromics



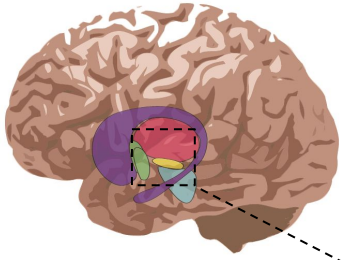
Current Market Size: $800M (QiG 2016 Estimate, all neurostimulation $4.5B)

2020 Projection: $3.21B (Transparency Market Research 2020 Estimate)

The Market is large and growing quickly.

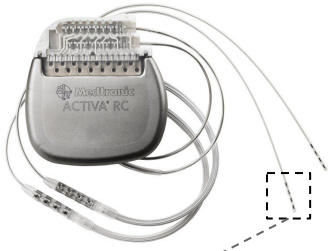
The Selectivity Problem

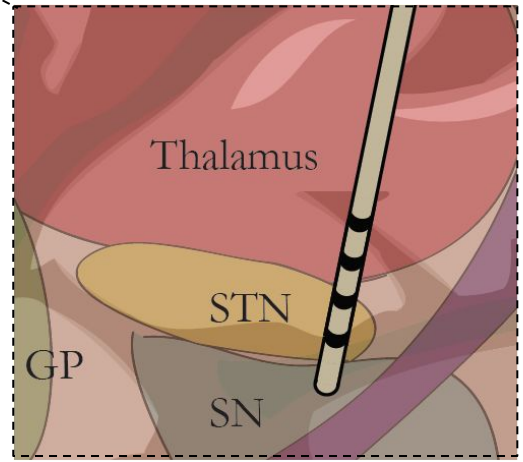
Paradromics

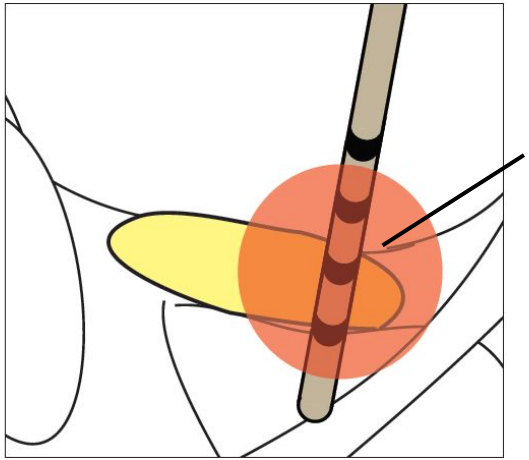


Today, DBS lacks the resolution to target therapeutic pathways without also activating other areas.

This causes speech defects, among other side-effects.







poor spatial selectivity

activates many brain areas

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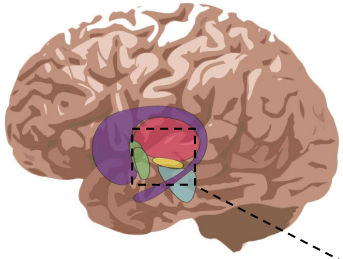
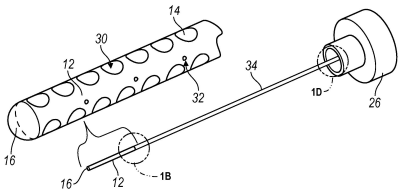
More Channels, More Precision

Paradromics

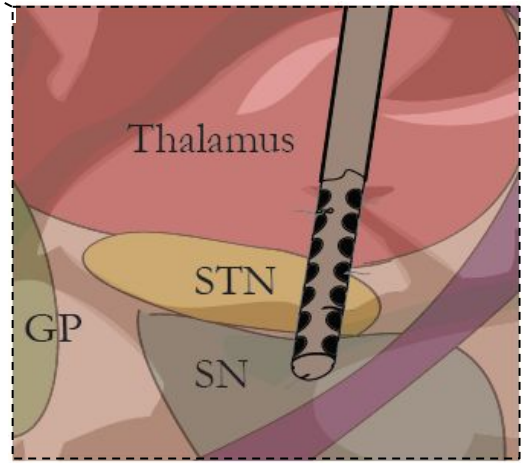


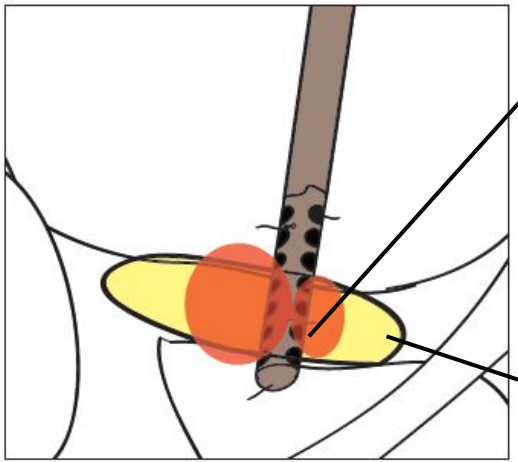
In 2014 Medtronic bought Sapiens DBS for **$200M** for a their DBS system that uses a 32-40 electrode stimulator.

Clinical trials have shown improved targeting over traditional DBS.



Sapiens Steering Brain Stimulation





improved spatial selectivity

….but still activates >10,000 neurons in bulk

The STN contains 560,000 neurons

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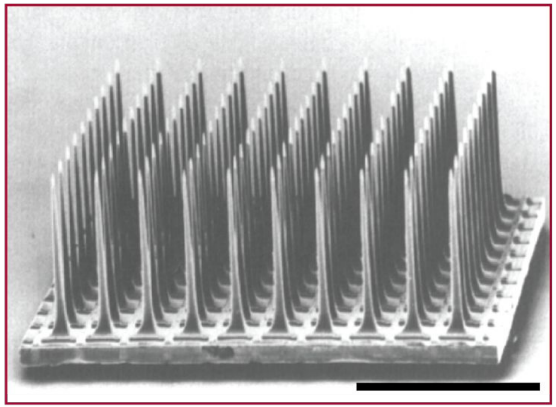
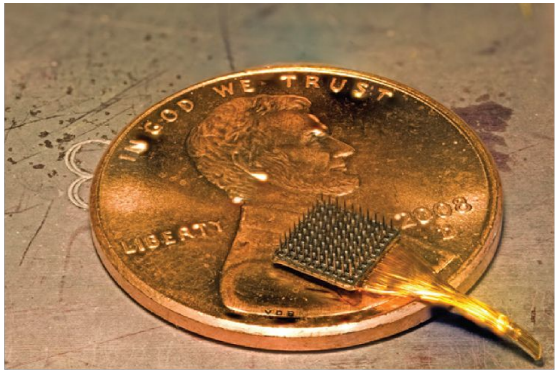
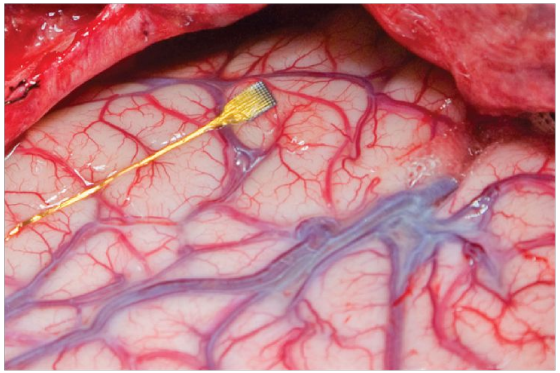
Current Research Technologies are Ill-Suited...

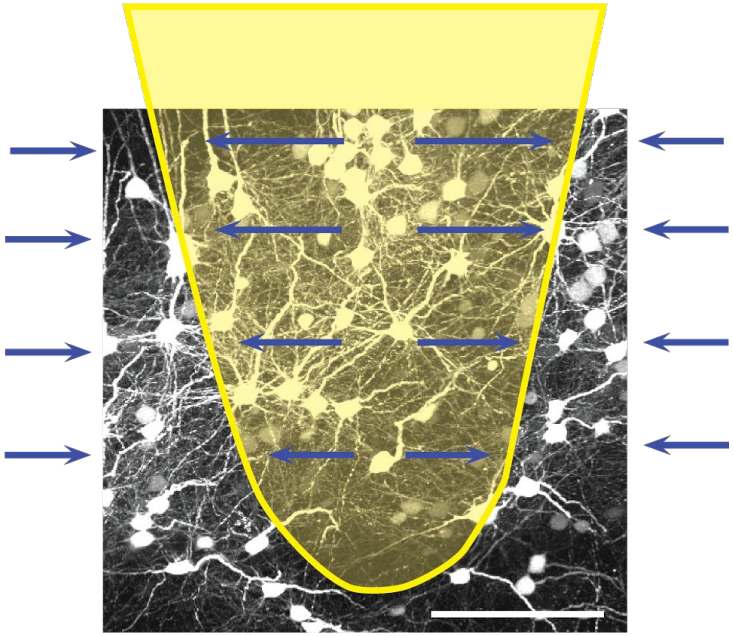
Blackrock Microsystems -
Utah Array



2 mm





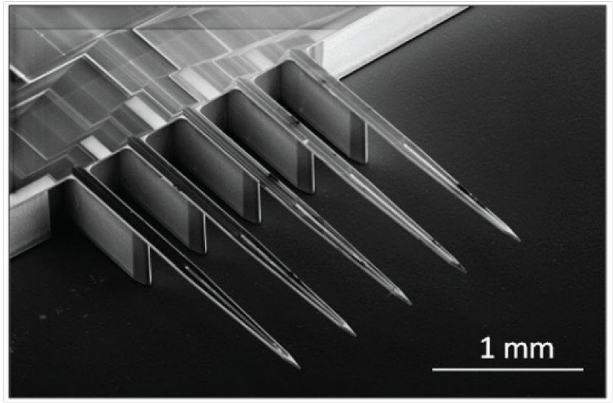


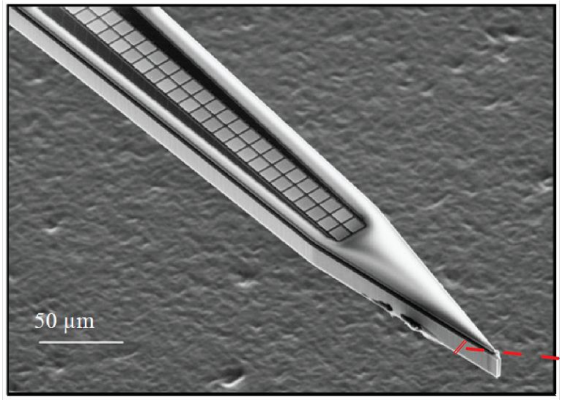
50 um

R. Tomer et al. Nat. Protocol, 2014

Current Research Technologies are Ill-Suited… - Cont.

High Density 'Michigan Style' Probes





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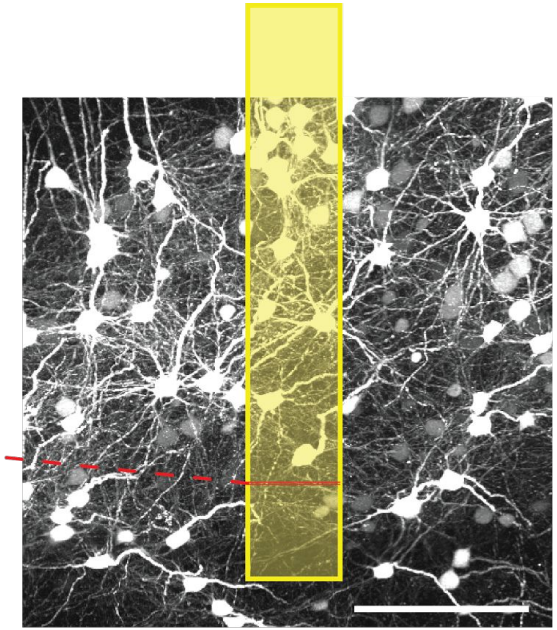
Sholvin et al. IEEE, 2015



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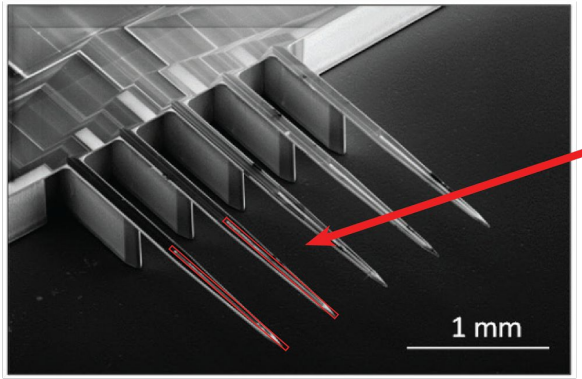
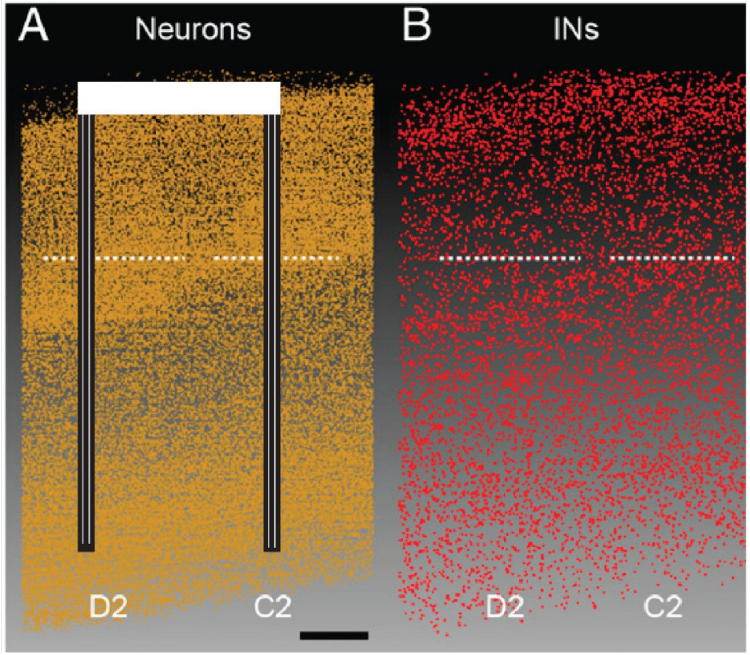
R. Tomer et al. Nat. Protocol, 2014

Current Research Technologies are Ill-Suited… - Cont.



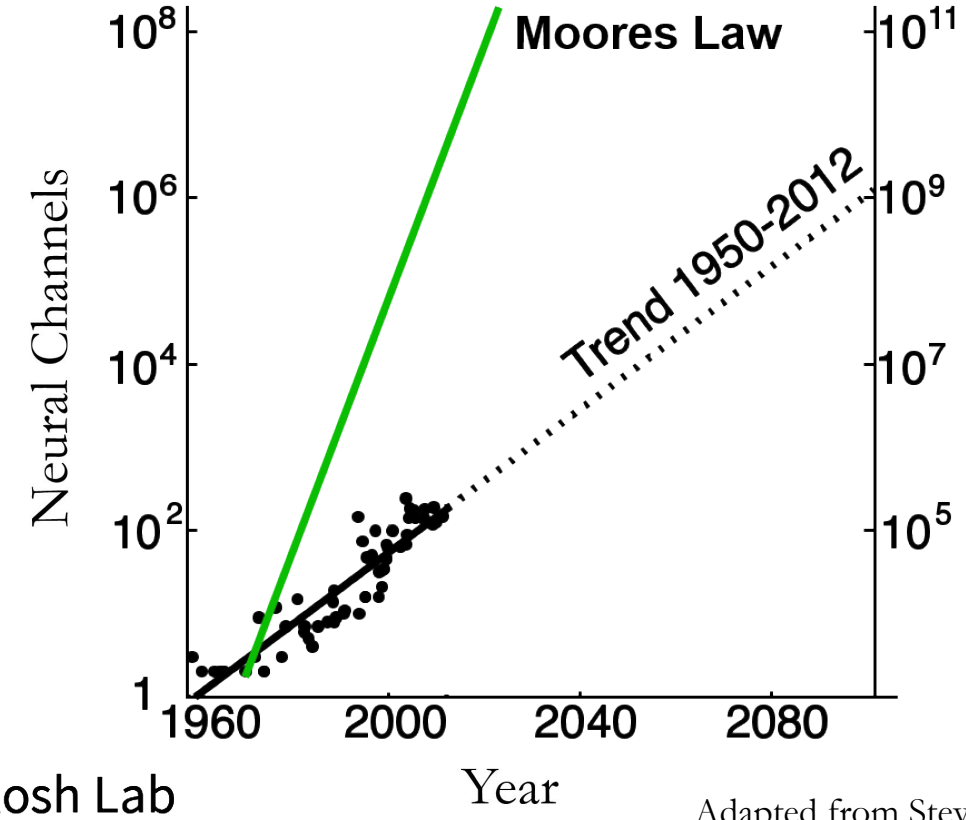
66,000 neurons



200 um

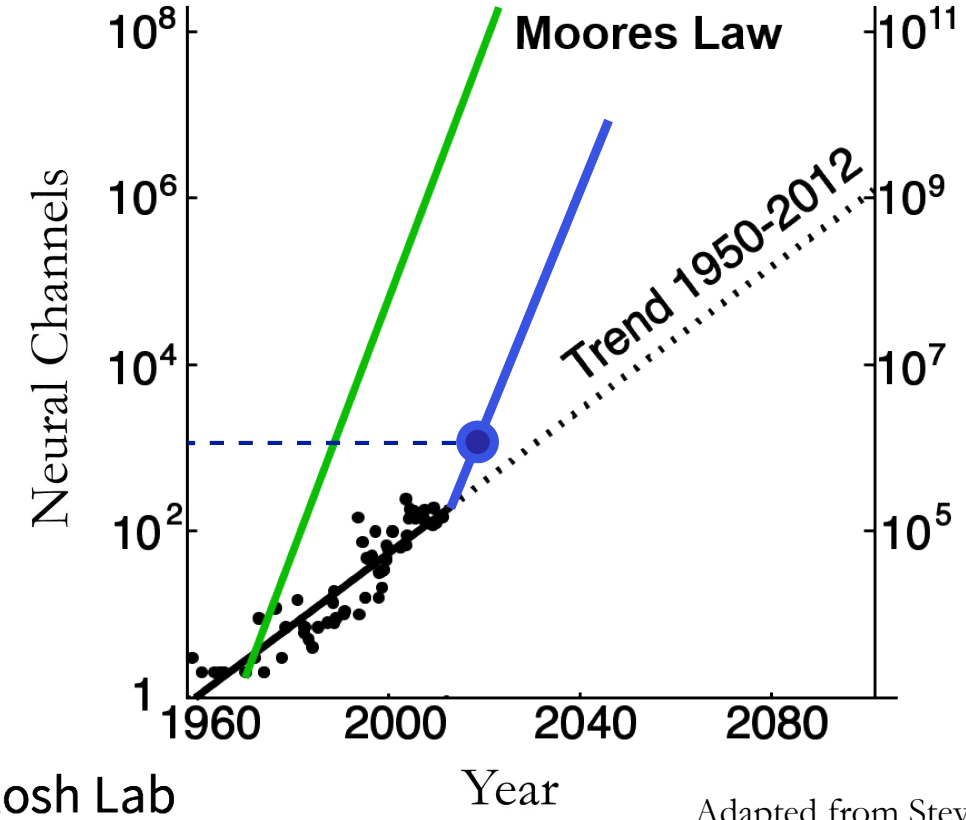
Inhibitory interneurons in a cortical column form hot zones of inhibition in layers 2 and 5A, Meyers et al. 2011

Moore's Law & Neurobiology



Adapted from Stevenson and Kording, 2011

Moore's Law & Neurobiology



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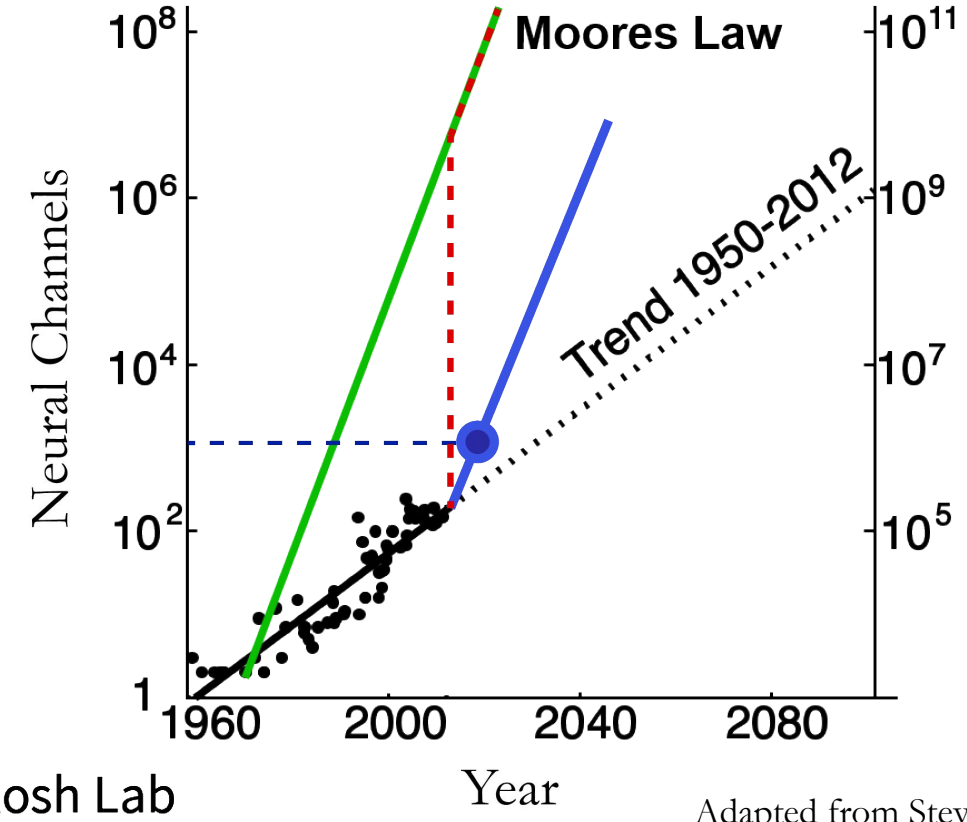


Adapted from Stevenson and Kording, 2011

What we need?

Well insulated

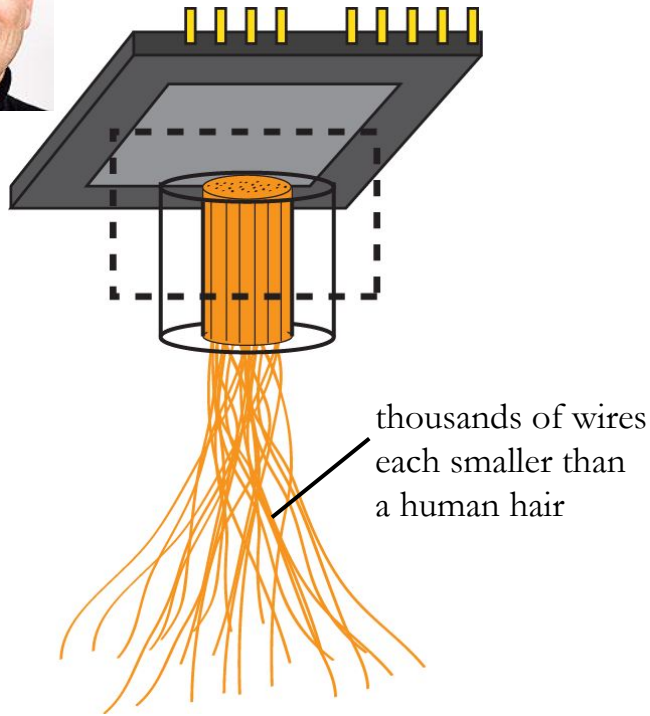
High Aspect Ratio (um diameter for millimeter - centimeter length)

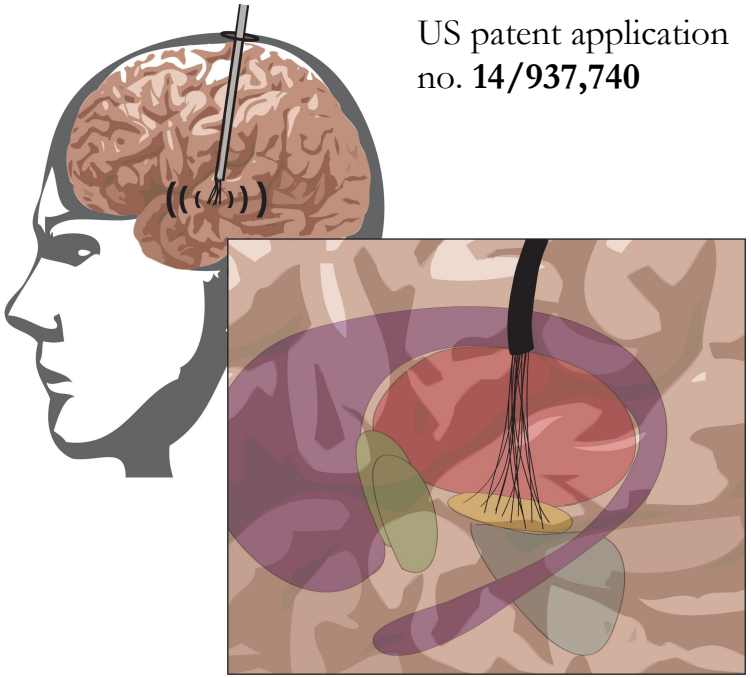
Can be densely packed

Can be produced at Scale (in excess of 10,000 individual channels)

And can sample densely from a three-dimensional area

Microwire bundles for DBS





US patent application
no. **14/937,740**

Paradromics

Microwire bundles will allow cellular and circuit-level targeting.

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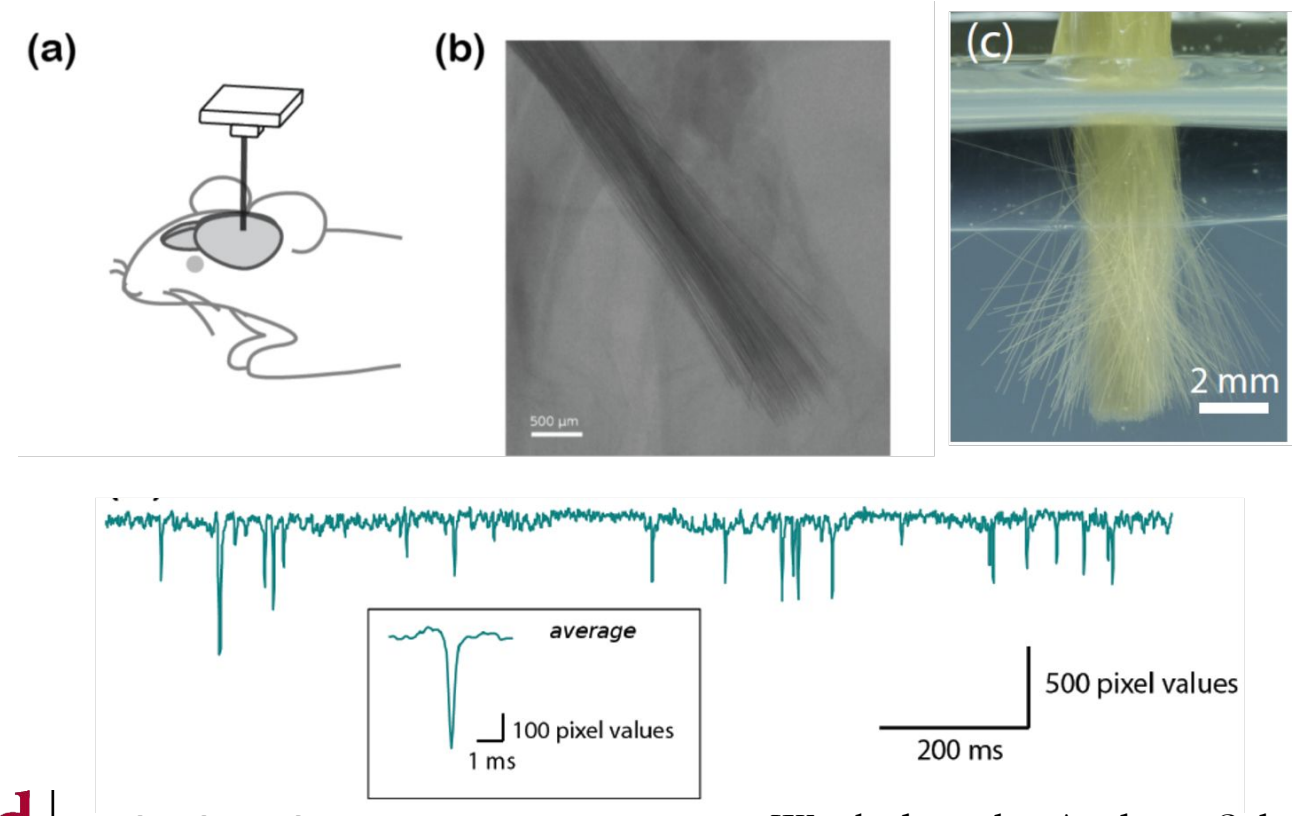
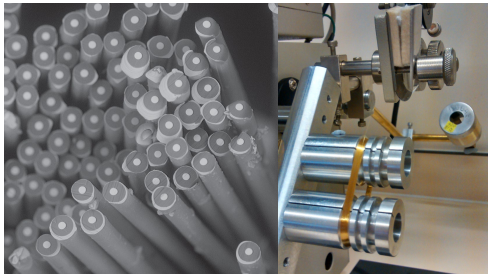
Neural Recordings



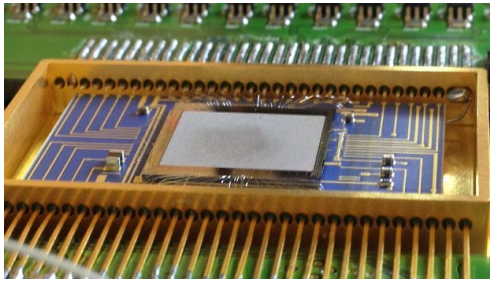
Work done by Andreas Schaefer, Crick

We achieve this massive parallelism by using proven, scalable components

Paradromics

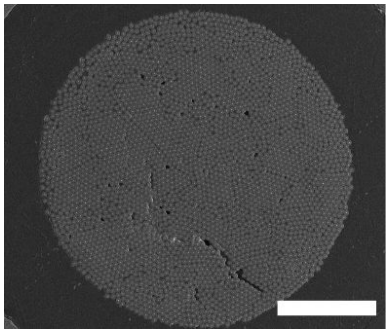


The probes can be easily produced at scale using simple manufacturing techniques, and with much greater electrode density, compared to existing technology.

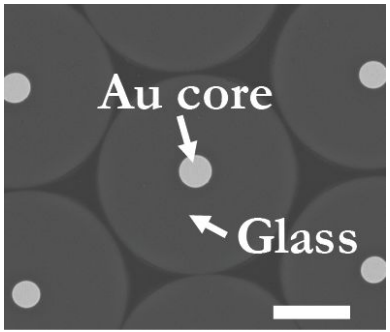


CMOS sensor technology is widely available and has benefited from billions of dollars and hundreds of person-years worth of development.

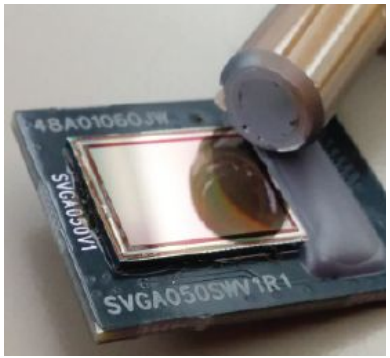
Using Microdisplays to Individually Control Microwires

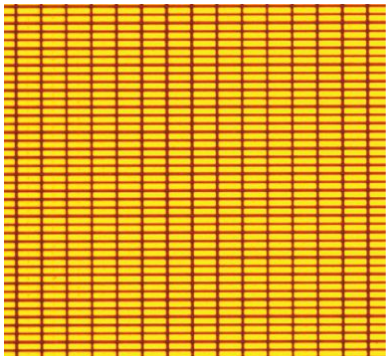


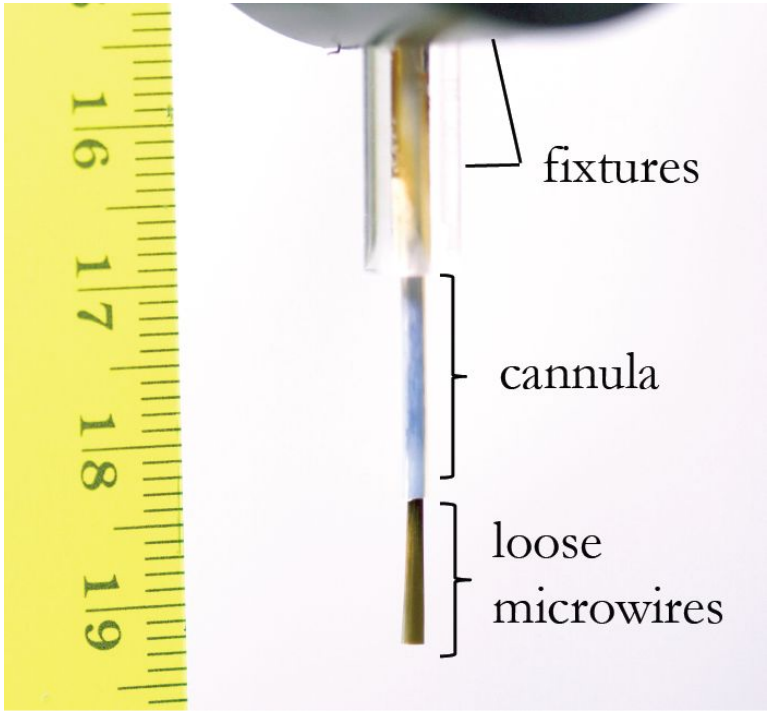
500 um



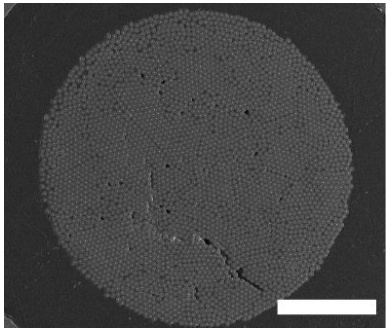
10 um







Using Microdisplays to Individually Control Microwires



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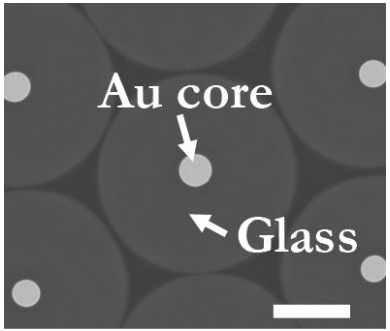

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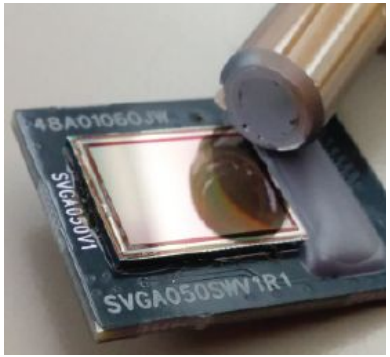
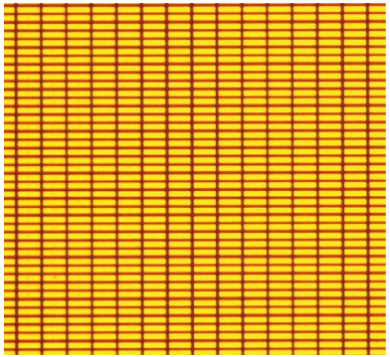
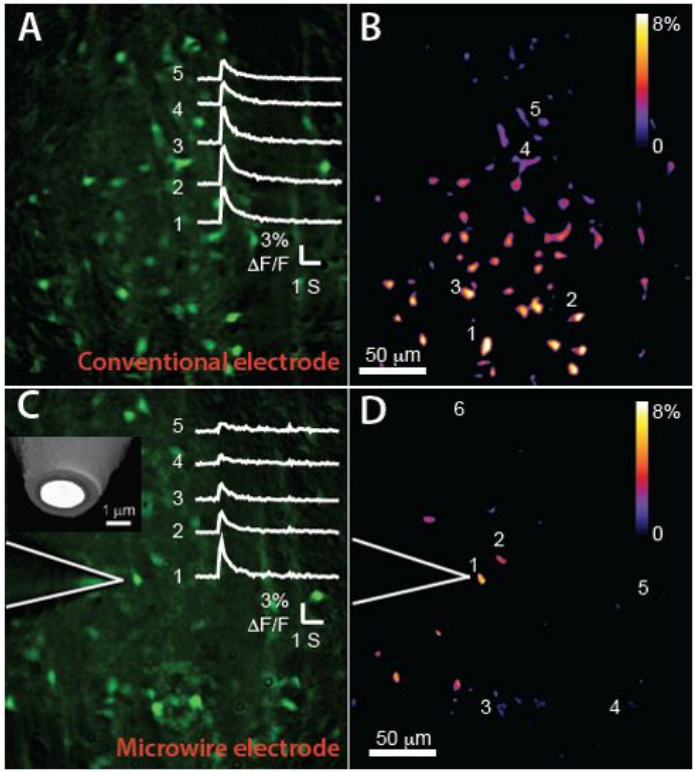




Fiber-based brain machine interface (BMI) technology to provide ultra-high resolution simulation and recording

Highest resolution & highest number of independent electrodes ever developed for BMI

The Need for Precision

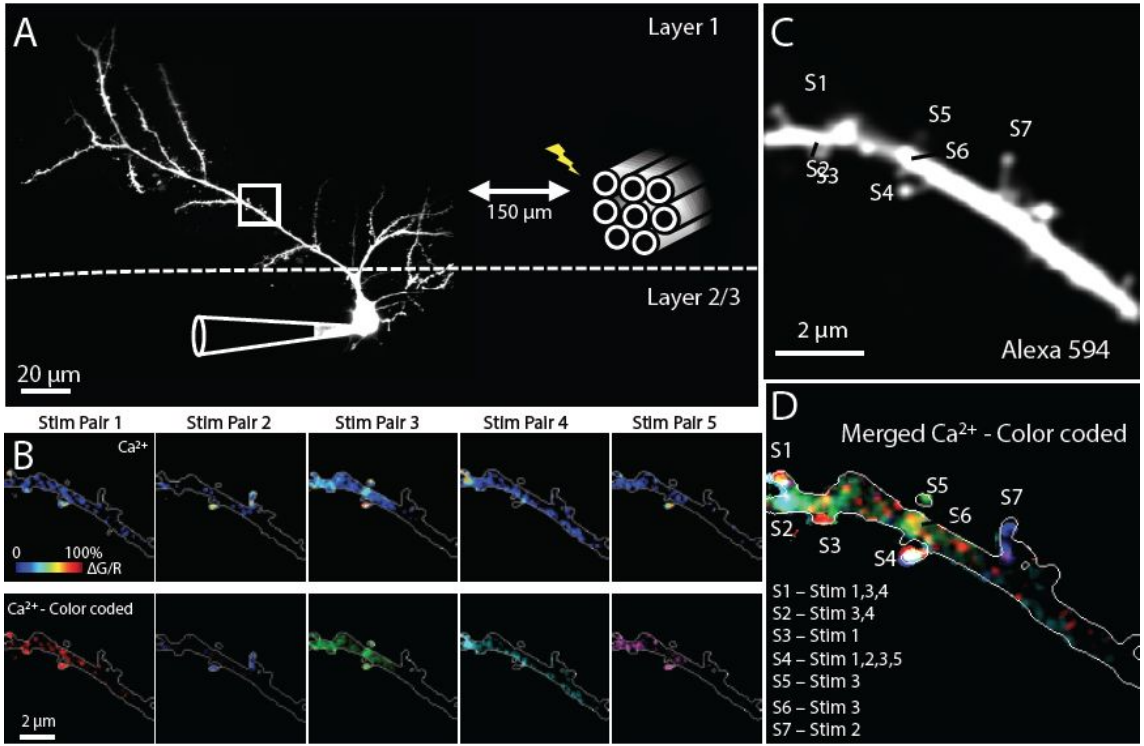


Conventional 125 um electrode stimulates a large field

Single microelectrode stimulates only a few cells

With Jun Ding, Stanford Neurosurgery, Dr. Yu Wei Wu

Stimulation of Individual Neurons and/or Axons



High spatial precision, activating only a few neuron or axon fibers

Creating different spatial and temporal patterns, and allow adjusting stimulation amplitude and frequency between stimulation leads

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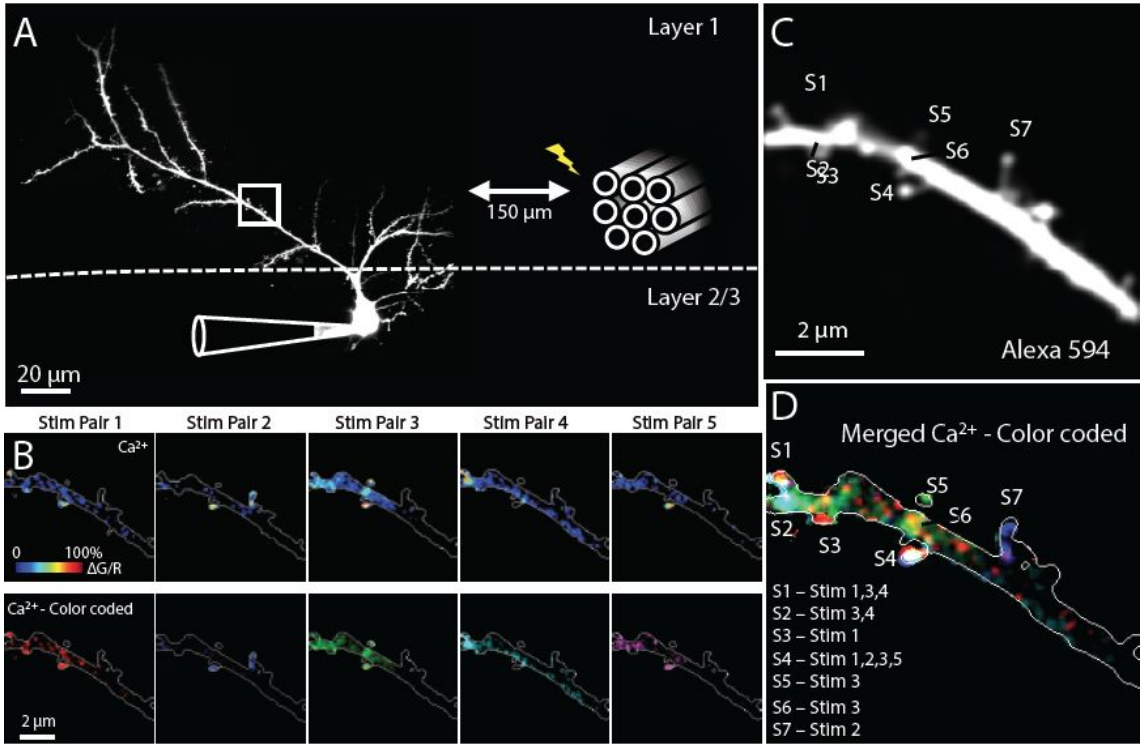
Stimulation of Individual Neurons and/or Axons



Will be the first demonstration of large stimulation devices that are capable of modulating the activity of hundreds to tens of thousands with high spatial precision

May allow precise parsing of components is responsible for therapeutic effects

With Jun Ding, Stanford Neurosurgery, Dr. Yu Wei Wu

Acknowledgements

Professor Nicholas Melosh
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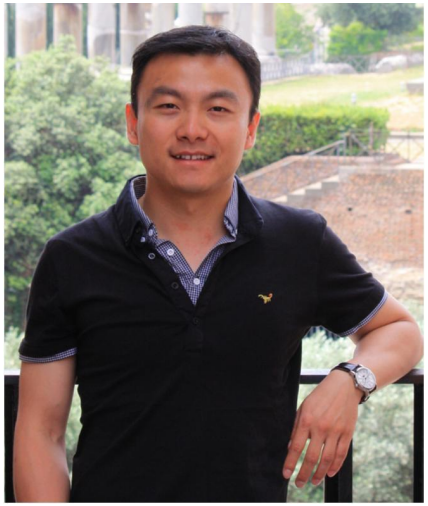

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Neuroscientist
Paradromics Inc.

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