Optical-Electro Neural Interface - from Invasive to Non-Invasive How AI can help?

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Edinburgh, 7th Dec 2022

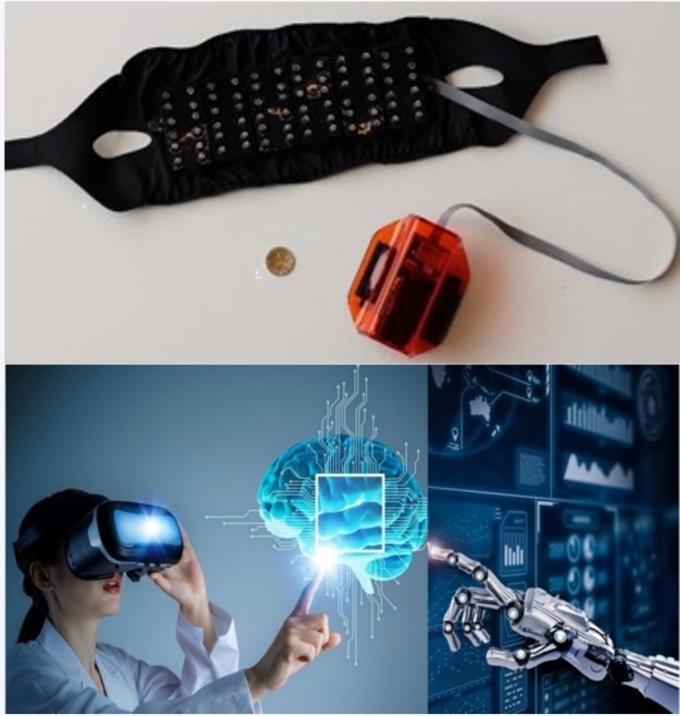
About HUBIN

Dr Hubin Zhao

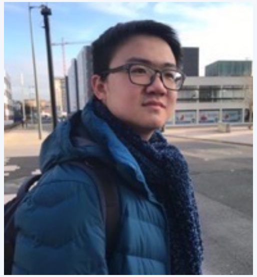
- Lecturer @ Division of Surgery & Interventional Science, UCL
- Co-PI of Centre for Rehabilitation Engineering & Assistive Tech, Faculty of Medical Sciences
- Co-PI of DOT-HUB, Faculty of Engineering Science

My Team: **HUB of Intelligent Neuroengineering (HUBIN)**

- Working at the intersection of Advanced Electronics, Neural Engineering, and Medical Technologies
- Particularly interested in wearable, intelligent, medical imaging, sensing and health monitoring technologies and their applications (inc. BCI, HRI, Rehabilitation, etc.)



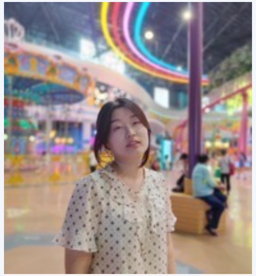
Current Team Members



Yunyi Zhao,
PhD Student

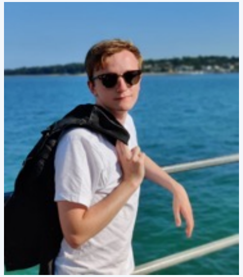
Xinkai Zhou,
PhD Student

Yunjia Xia,
PhD Student



Jianan Chen,
PhD Student

Ting Deng,
UG Student



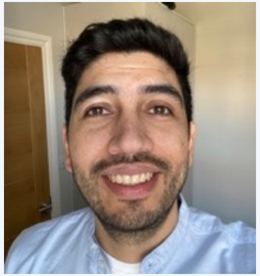
Alex Thomas,
UG Student
Co-Supervised

Renas Ercan,
Visiting PhD Student

Jingyu Lyu,
MRes Student

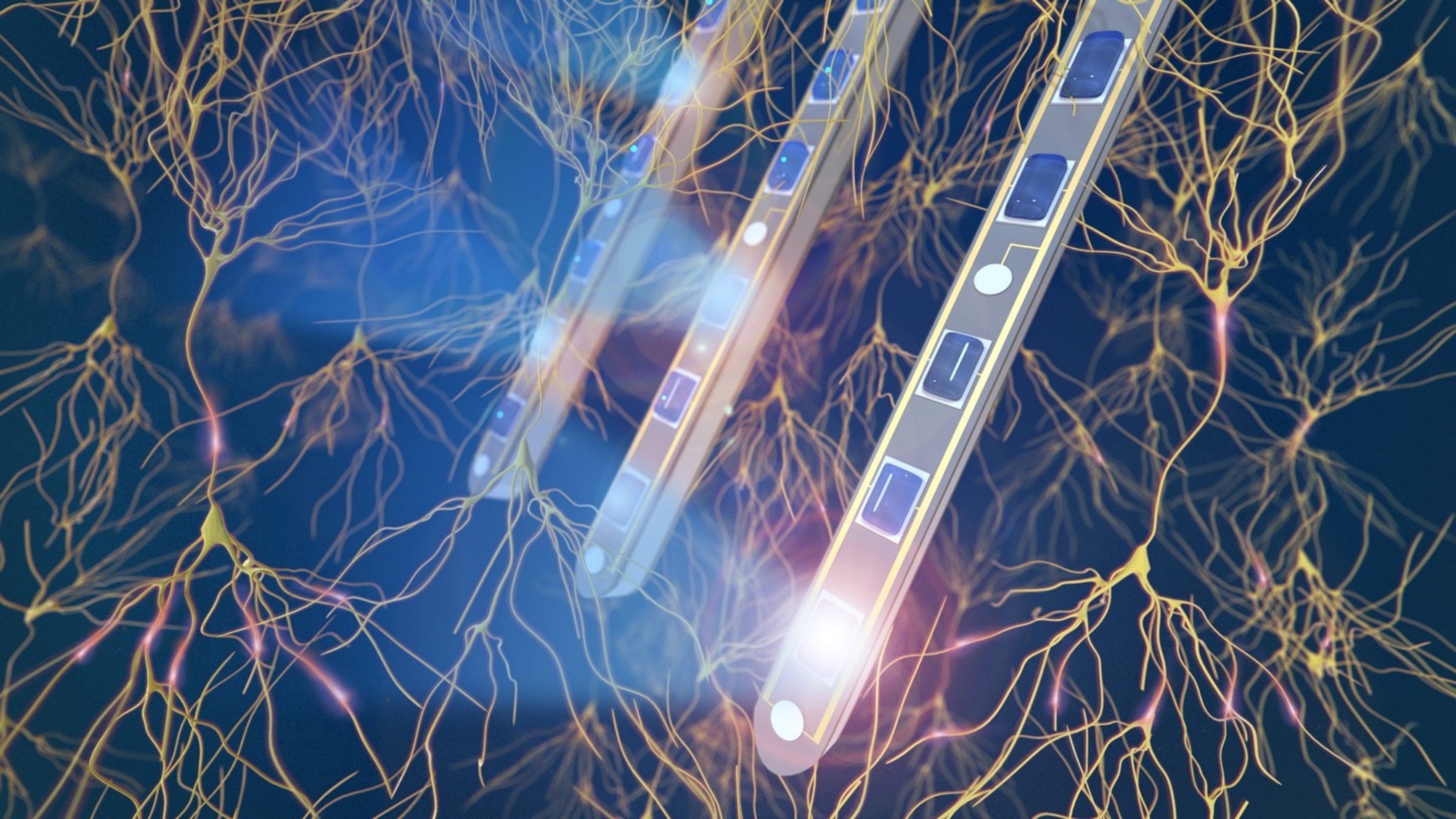
Sijian Pan,
MSc Student

Yuhan Li,
MSc Student

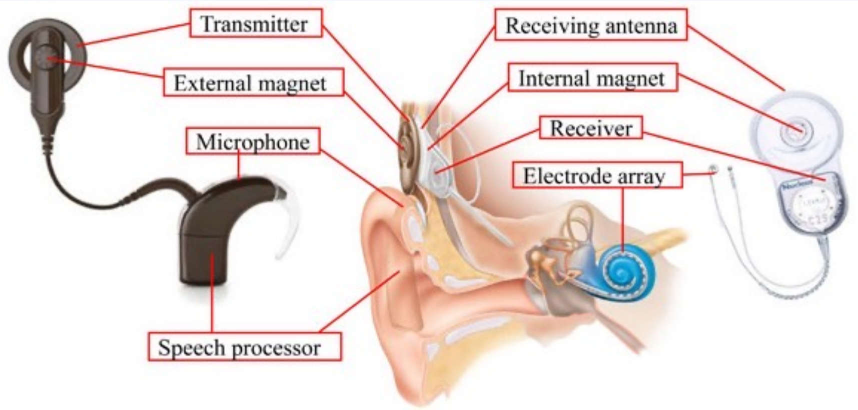


Rodrigo Leal,
PhD Student,
Co-Supervised

Gao Wang,
PhD Student,
Co-Supervised



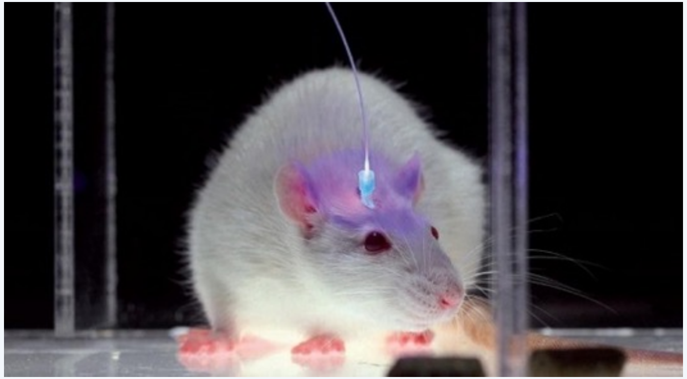
Electrical Neural Stimulation



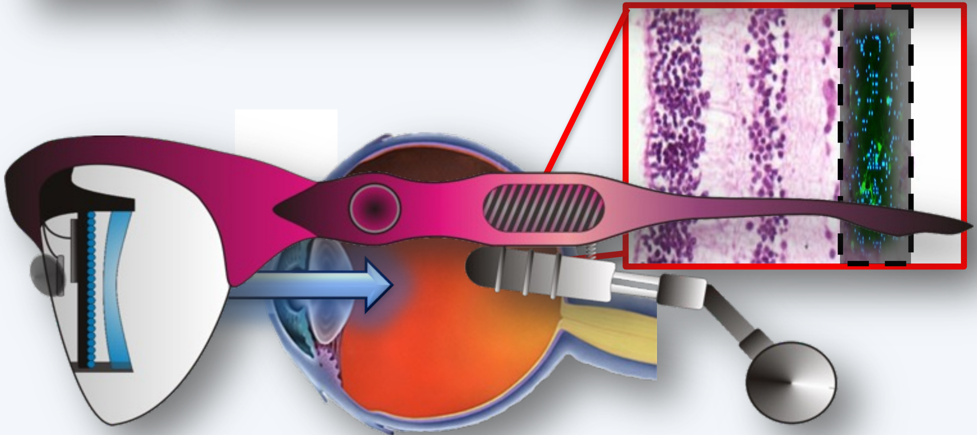
Cochlear Implant

Deep Brain Stimulation

Optogenetics

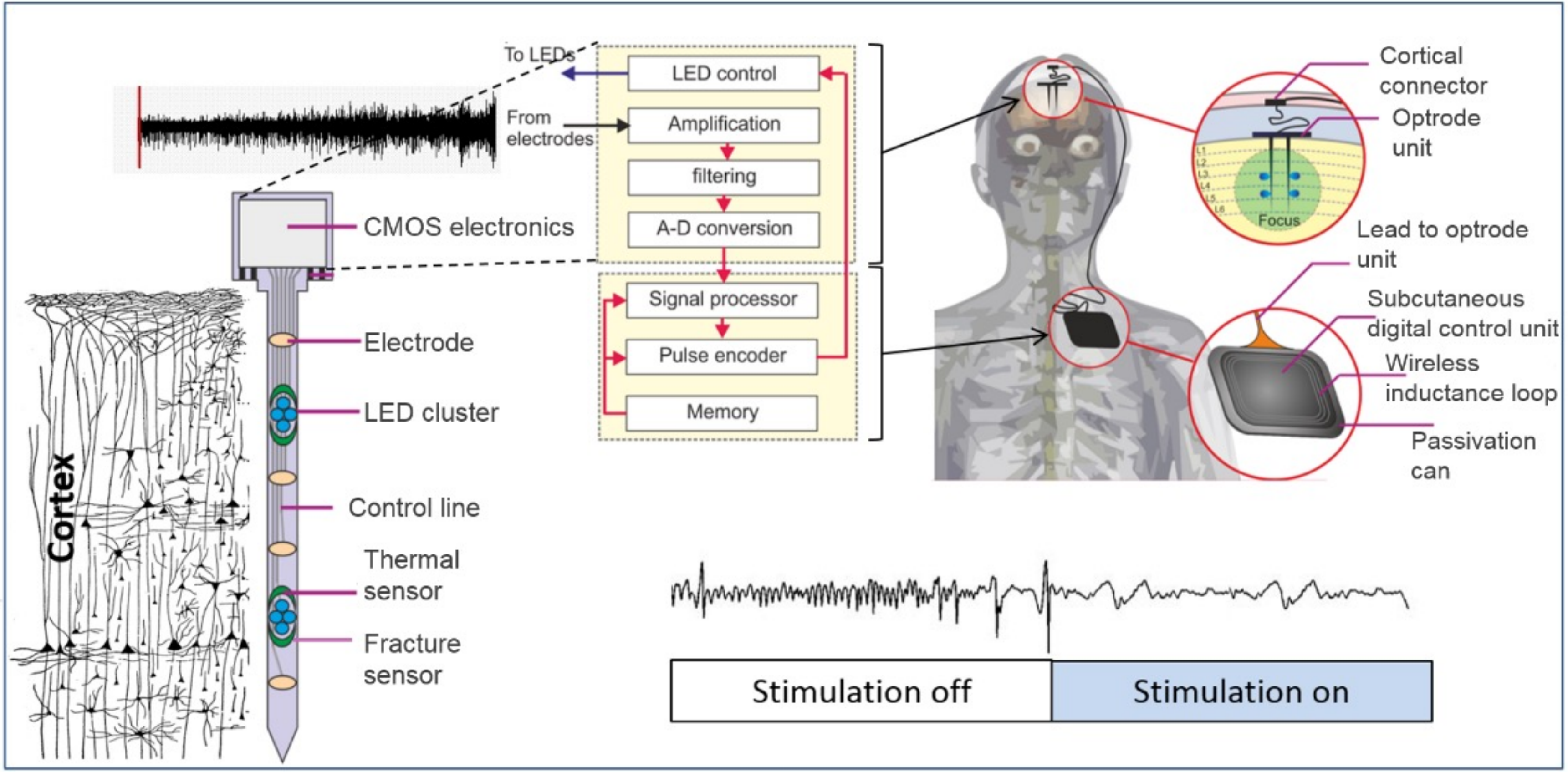


Optogenetics

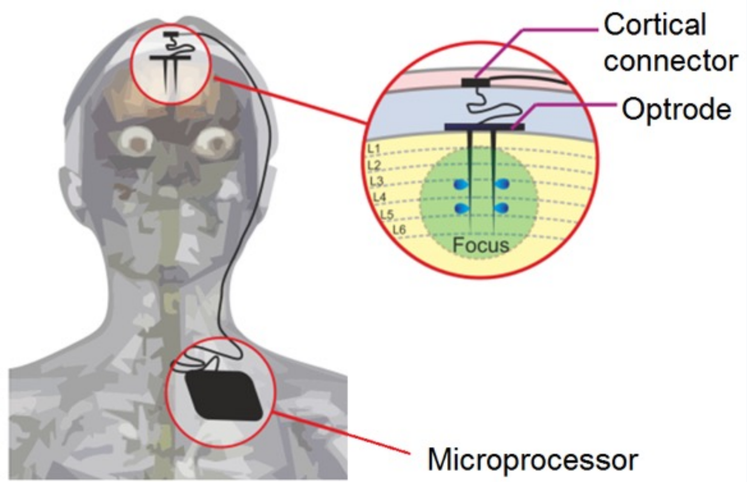


Retinal Prosthesis

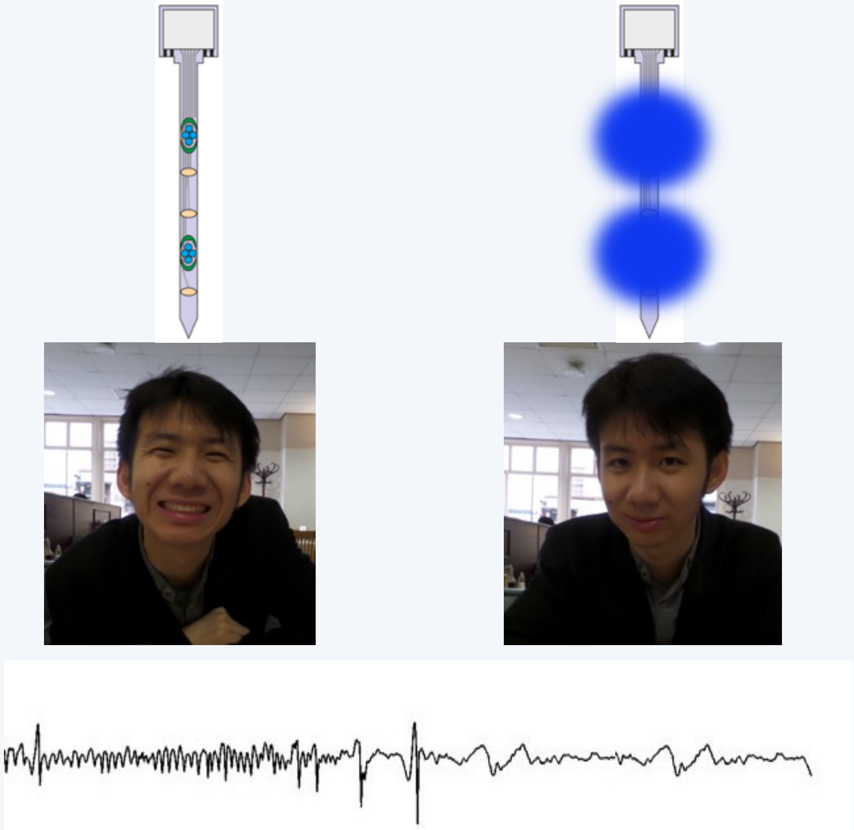
Active Implantable Optrode



Optogenetic Implant

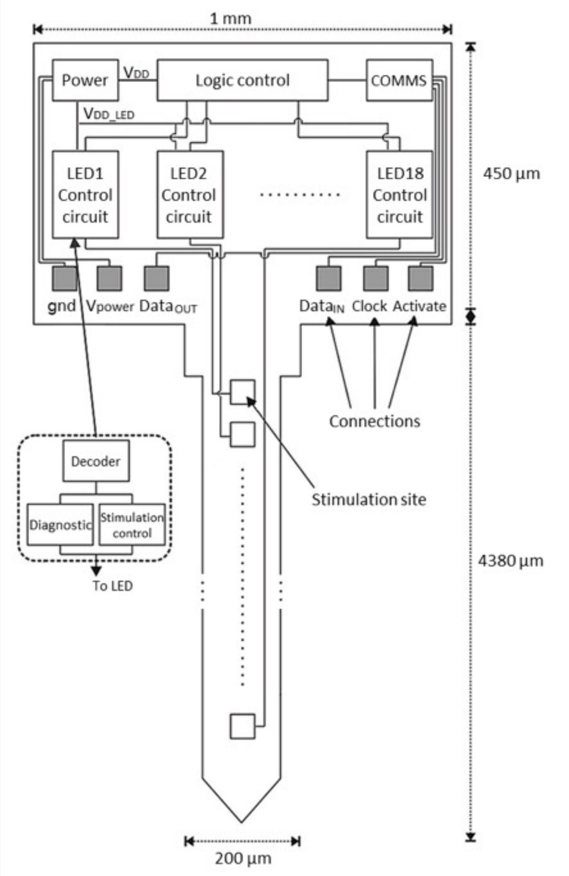


Proposed Optrode



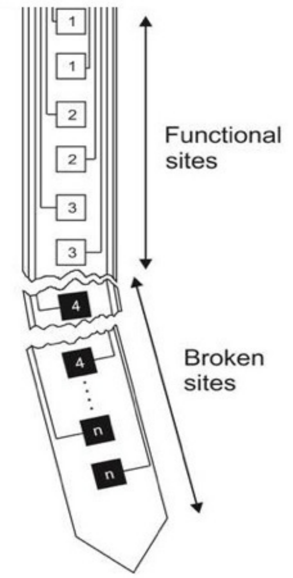
Stimulation off	Stimulation on

Chip Design & Implementation

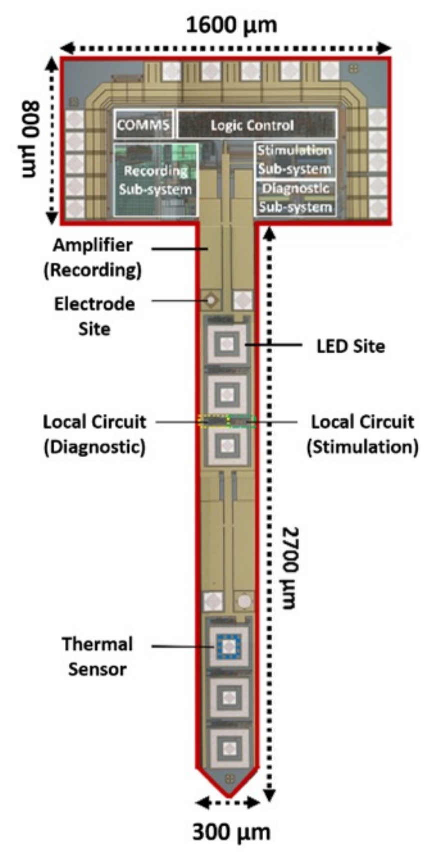


Open Loop

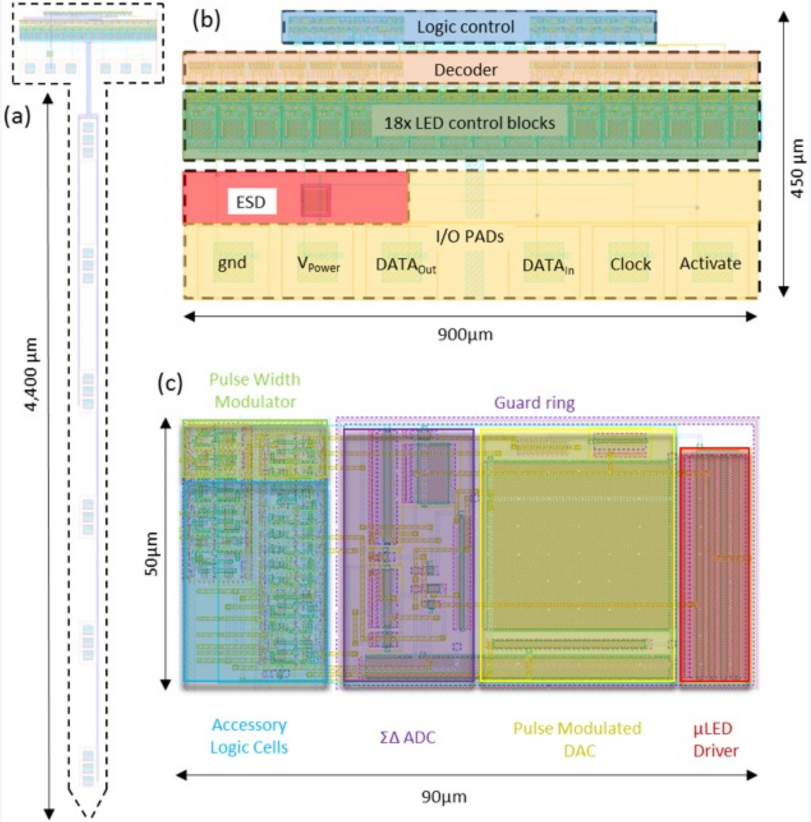
Self-Diagnosis Strategy

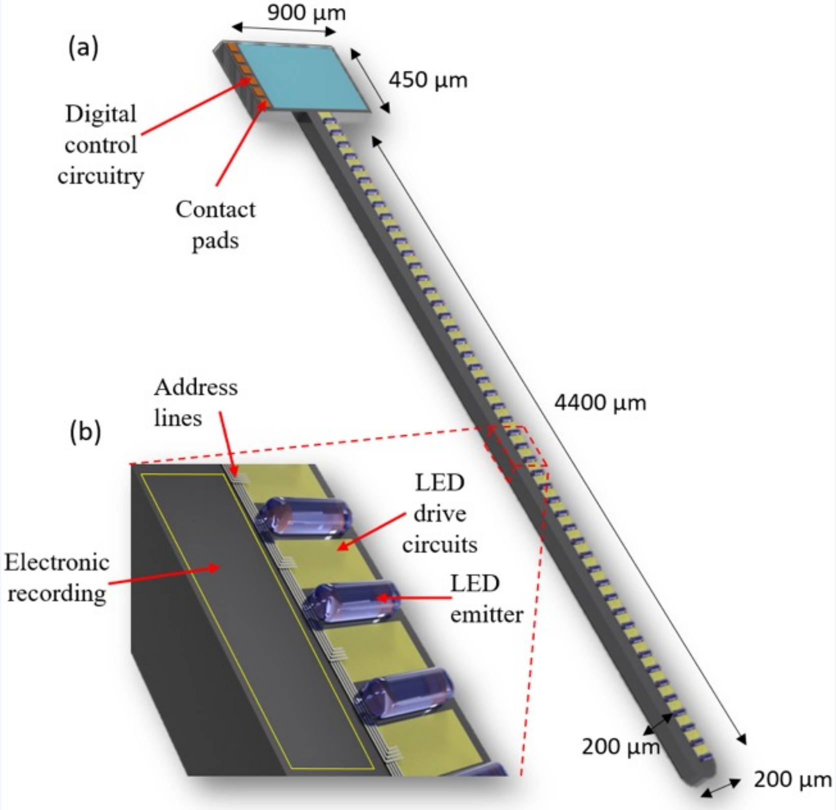


Closed Loop

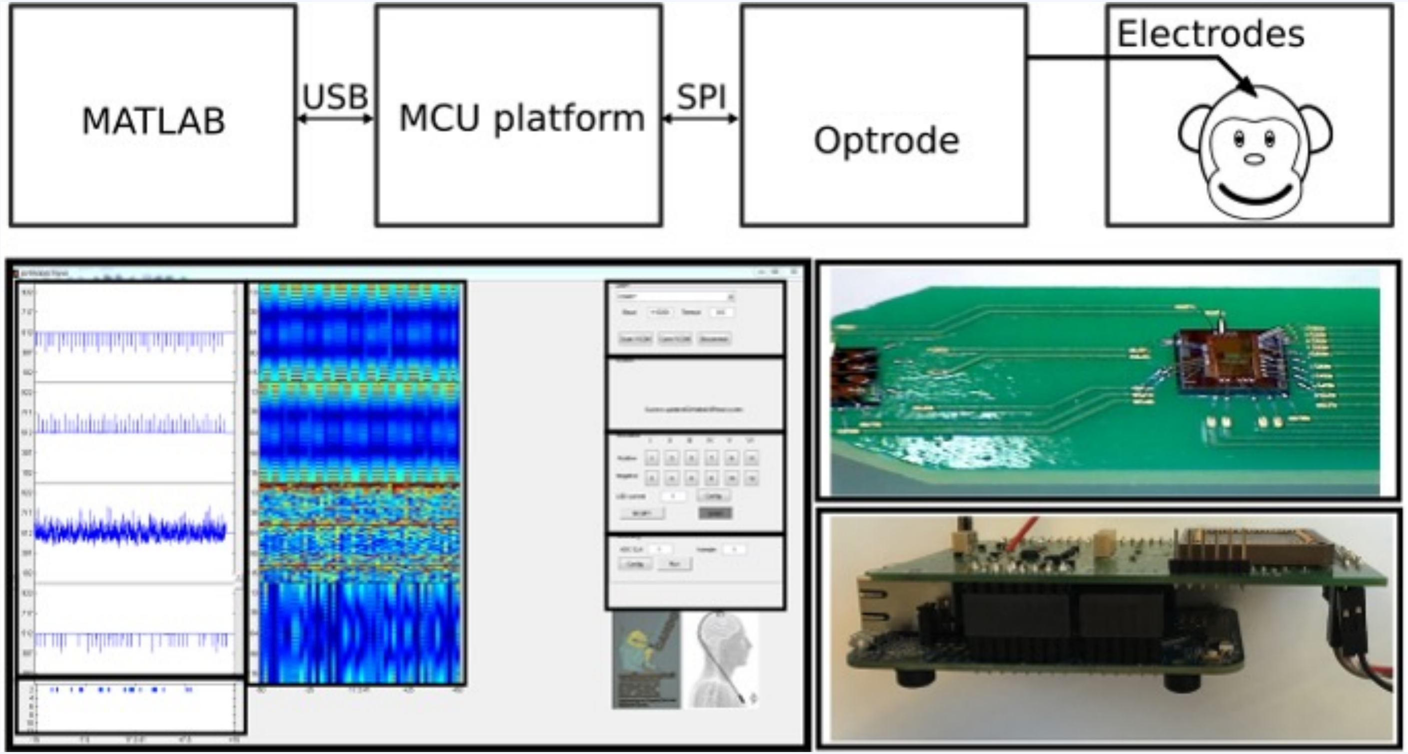


Chip Design & Implementation

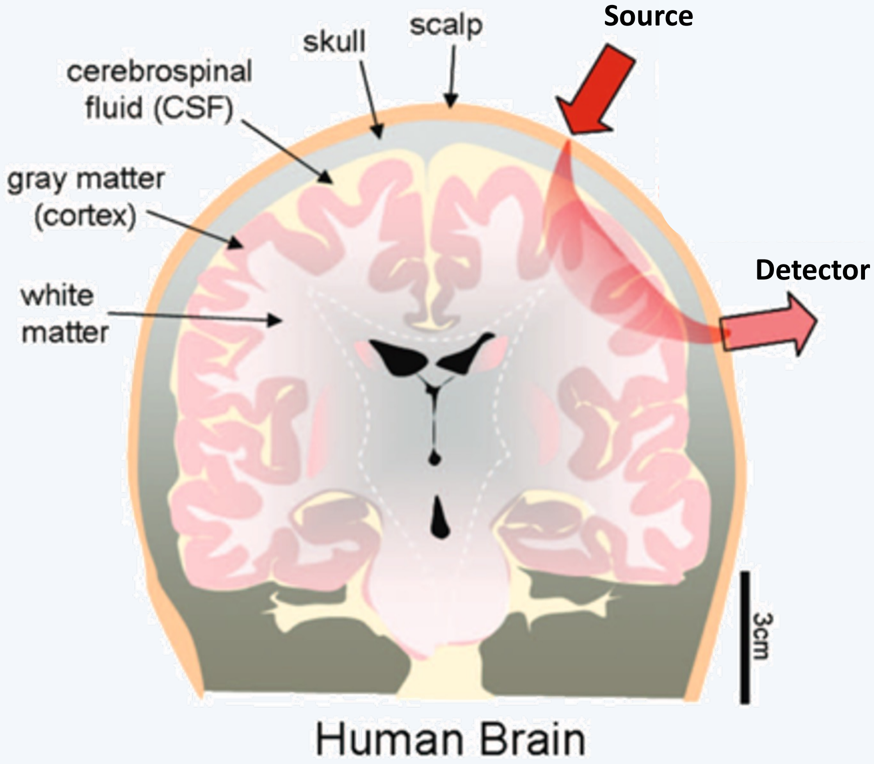




Animal Experiment Test Platform



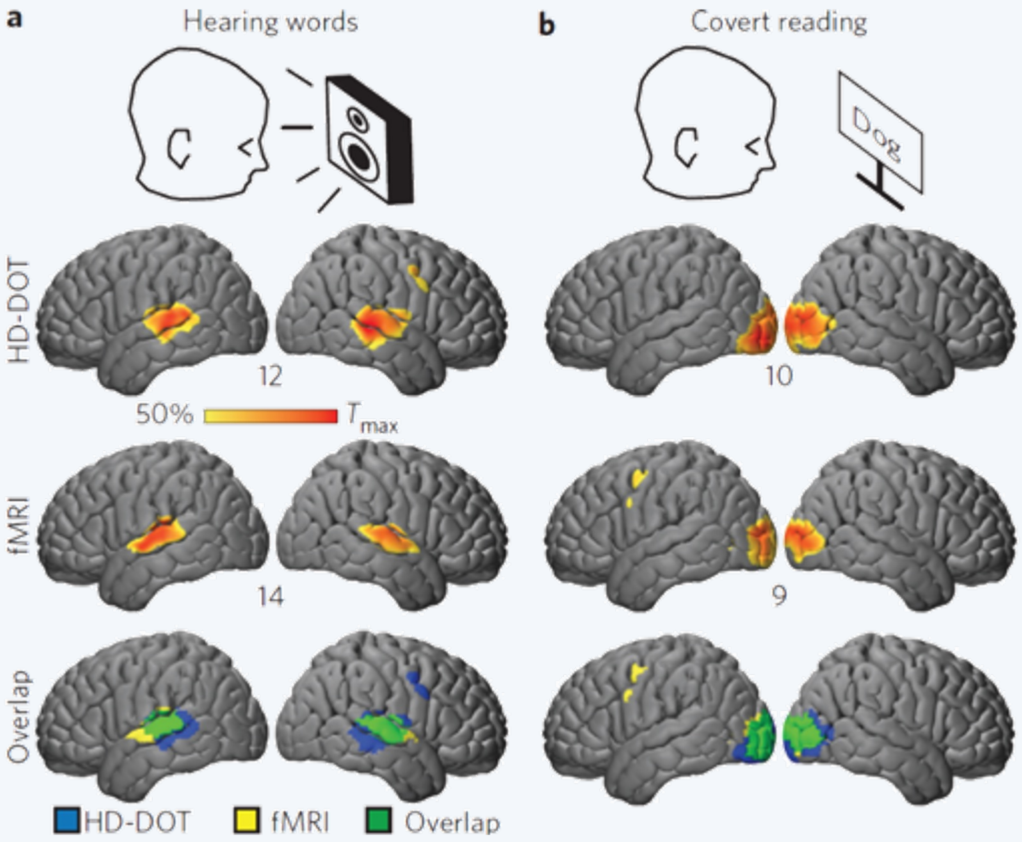
Near-infrared spectroscopy



- Tissue is relatively transparent to red and near-infrared (NIR) light
- NIR light can be transmitted through the scalp and skull to the brain and back again
- The principle absorbers of light in biological tissue are the haemoglobins, so NIRS is sensitive to brain oxygenation
- Brain oxygenation is linked closely to brain function
- Functional near-infrared spectroscopy (fNIRS) - the application of near-infrared spectroscopy to study brain function

Diffuse optical tomography

- Diffuse optical tomography (DOT) is a more-advanced offshoot of near-infrared spectroscopy (NIRS)
- To produce 3D brain imaging
- Resolution of high-density DOT approaches to fMRI
- How to achieve a fibreless, truly wearable technology which can provide high-quality 3D brain images?



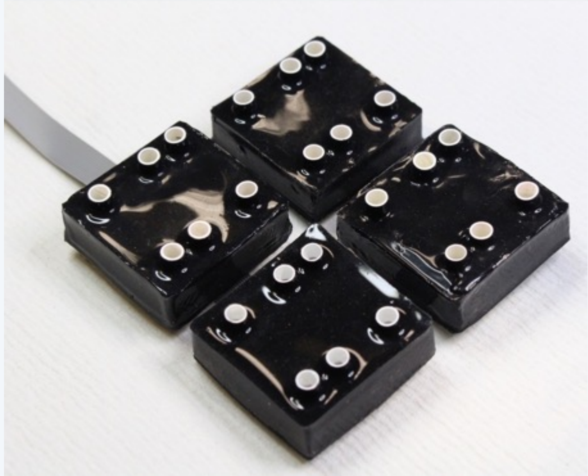
Fibre-based fNIRS/DOT systems

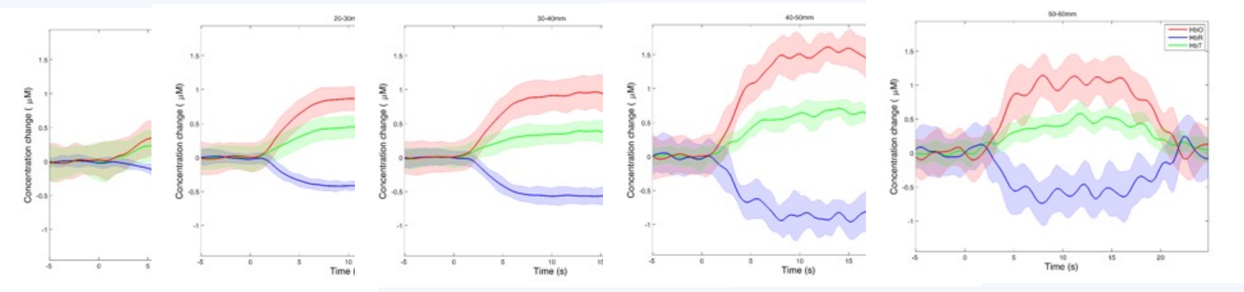
A fibre-less, high-density CW-DOT system?

REQUIREMENTS:

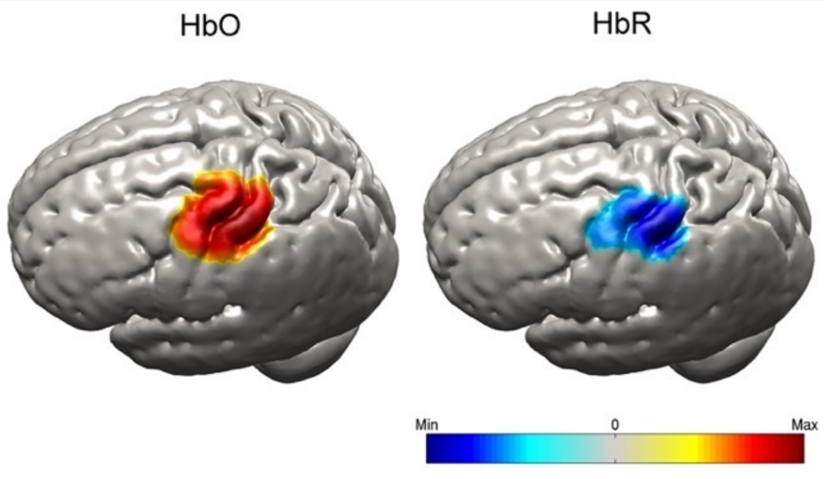
- Scalable
- Highest possible detection sensitivity
- Dynamic range sufficient to allow measurements from ~10 to > 35 mm
- Low power consumption
- Can conform to the curved scalp
- As little wiring as possible
- Lightweight

The uNTS Mark 1



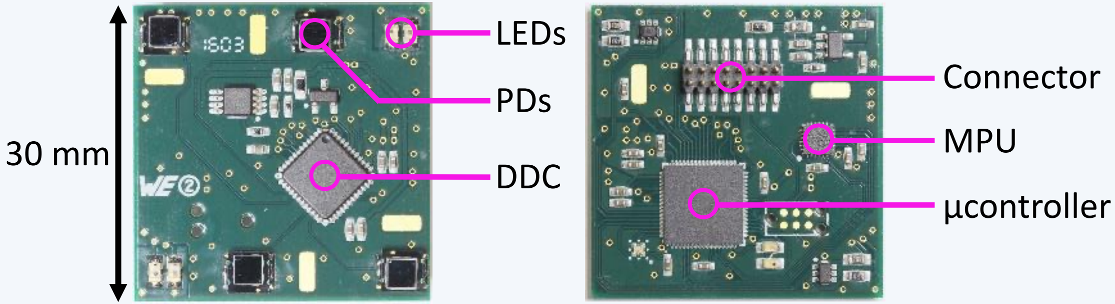


~20 mm 20-30 mm 30-40 mm 40-50 mm 50-60 mm



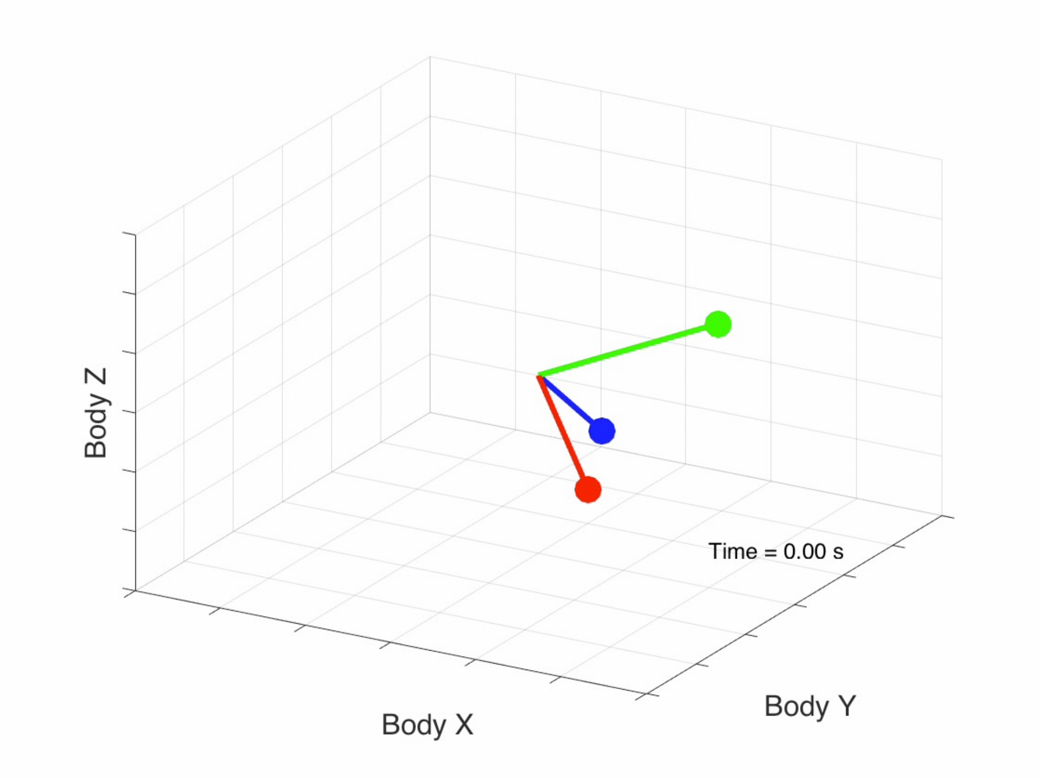
Chitnis et al. 2016

The µNTS Mark 2.1: A modular , fibreless DOT system

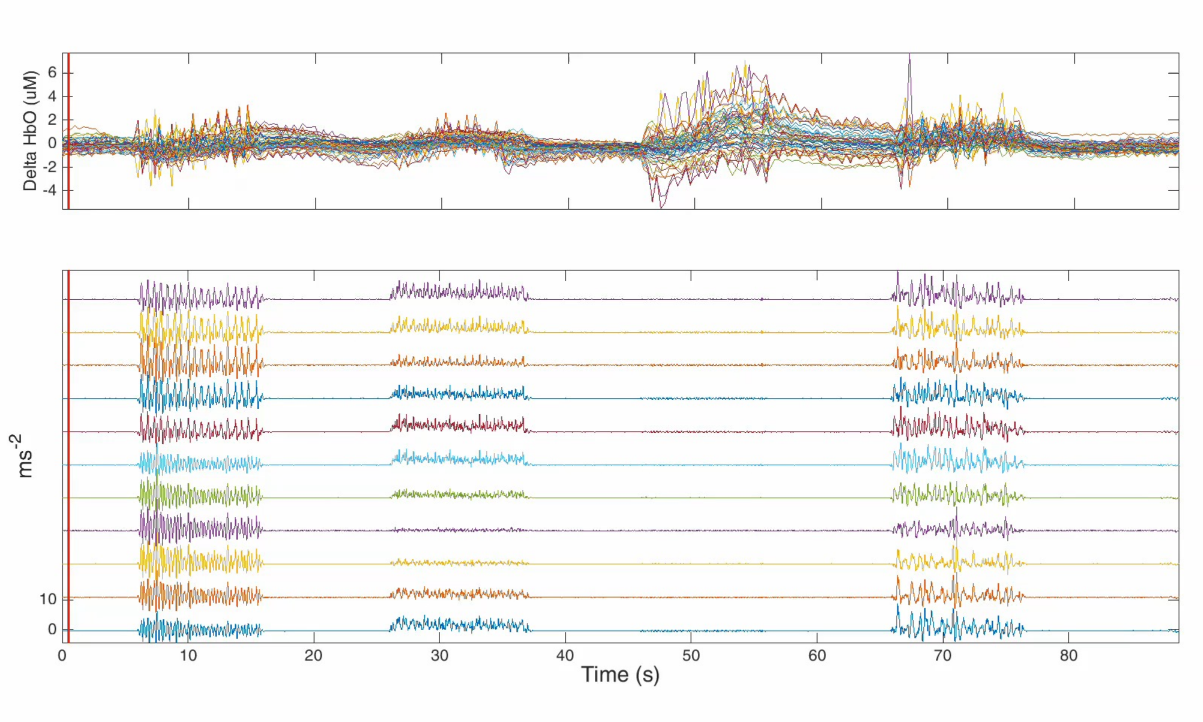


- A DOT system formed from a network of independent modules
- 24 source and 48 detector locations
- Provides 1152 source-detector channels per wavelength
- Highest sensitivity
- Each module integrates motion sensing
- Total weight ~300g

Motion Sensing



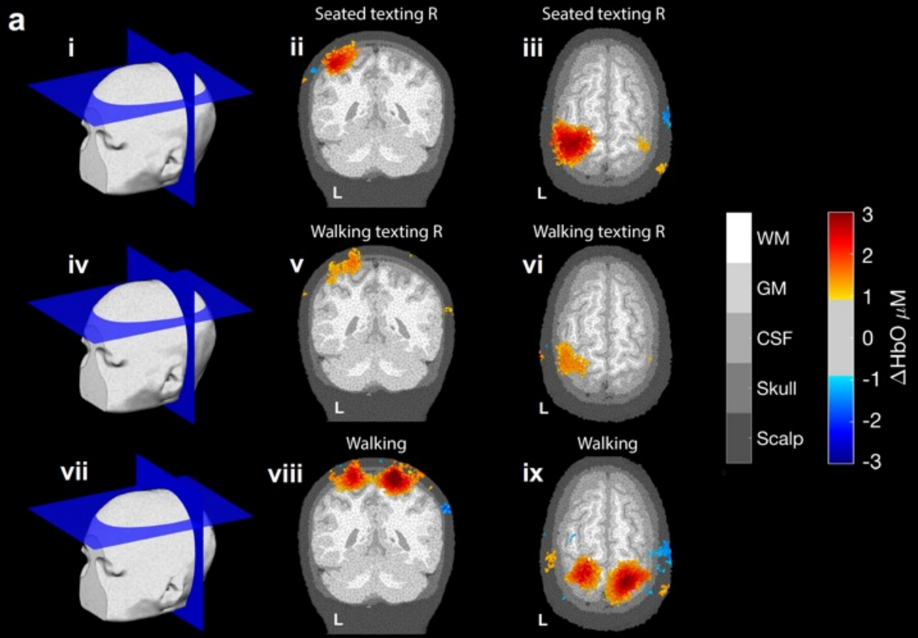
Motion Sensing

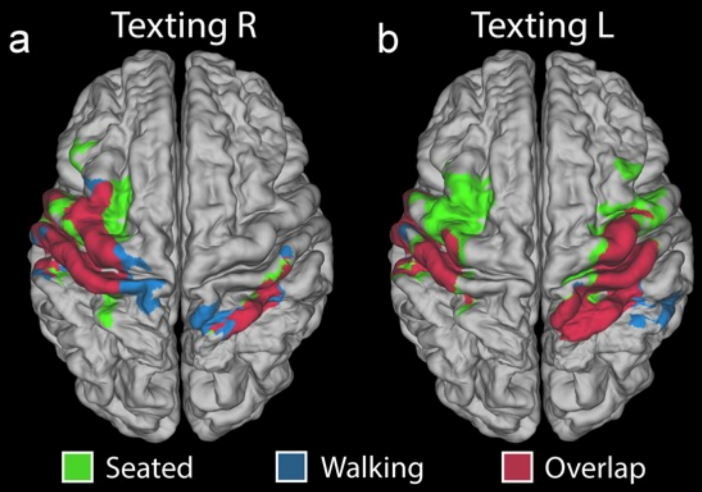


The uNTS: 3D functional imaging during overt movement

❖ Multiple conditions:

> Unimanual texting while seated,
> Unimanual texting while walking,
> Walking





The ANIMATE project

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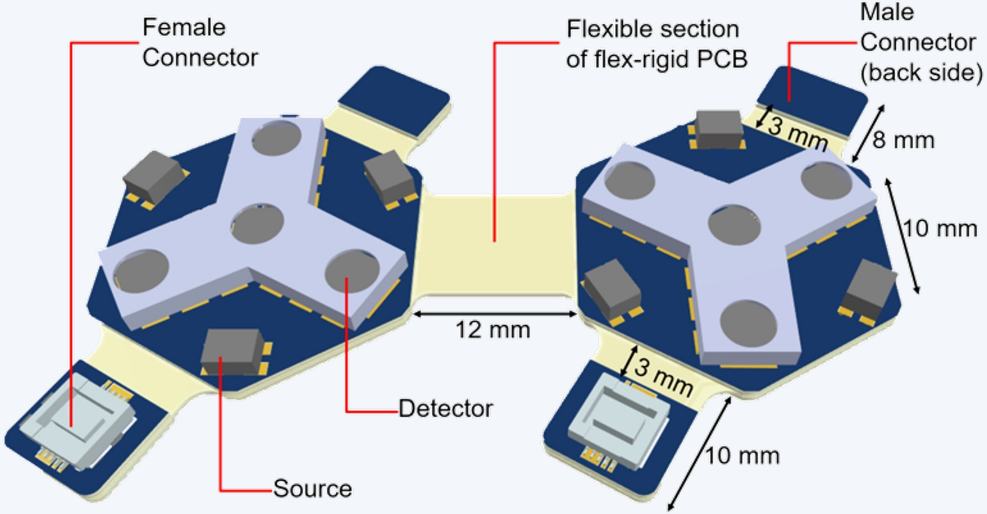
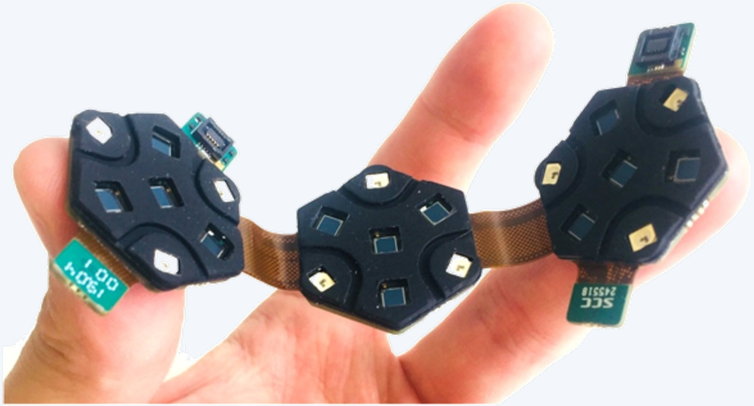
ANIMATE

- The aim - to develop a new wearable functional brain imaging technology to investigate the emergence of cerebral palsy in infants at the cot-side
- Newborn infants vulnerable to brain injury and often go on to develop cerebral palsy
- The early diagnosis of cerebral palsy is critical

The ANIMATE system V1

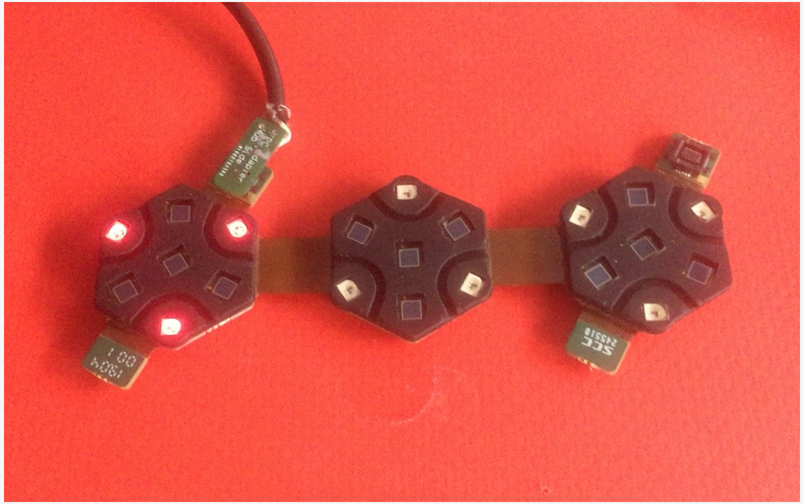
- Applications in the neonatal and pre-term populations require these wearable DOT technologies to be miniaturized further still
- We have developed a neonatal-specific wearable HD-DOT module as part of the ANIMATE project
- Exploits new PCB technology to produce ultra-low profile, lightweight sensors that can be directly interconnected to form imaging arrays

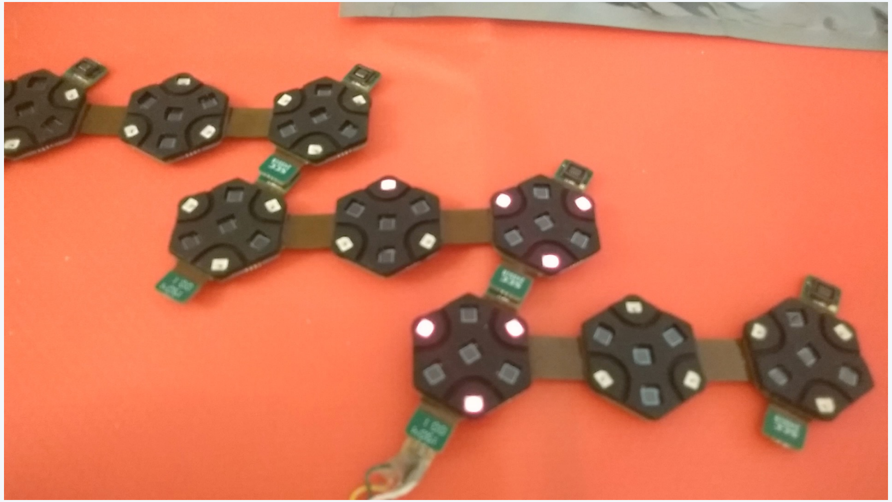




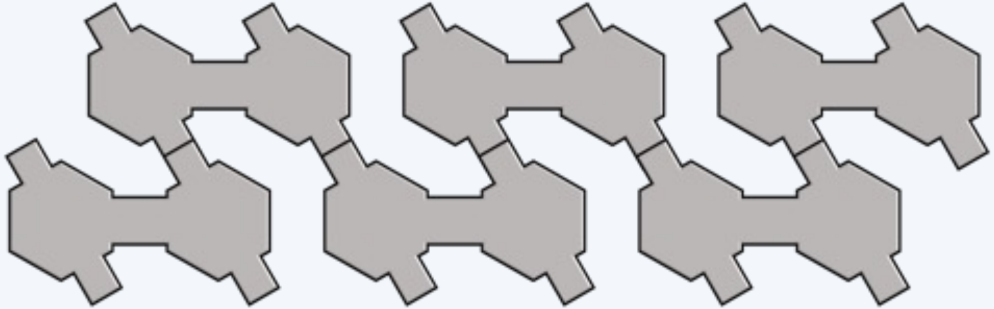
The ANIMATE system V1

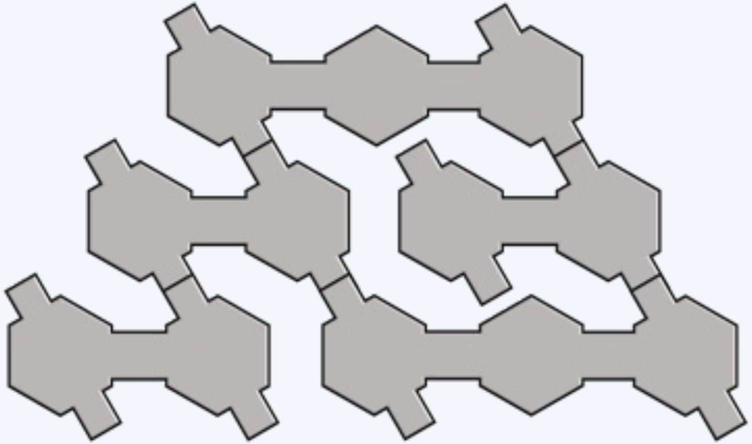
- To use flexible electronics to construct a miniaturized imaging array
- By combining dual- and triple-hex modules together, to create wide-range of ultra-lightweight, flexible HD-DOT imaging arrays
- This incorporates hundreds of emitters and detectors of near-infrared light to safely image the whole cortex of infant brain

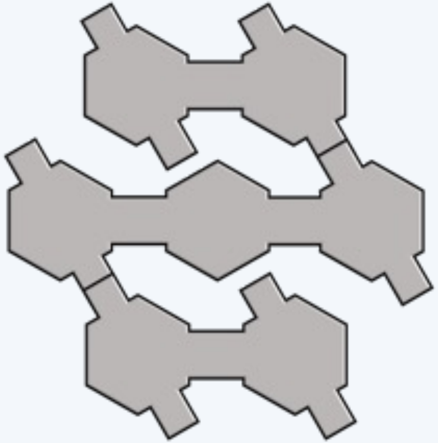




The ANIMATE system V1


(a) Imaging band

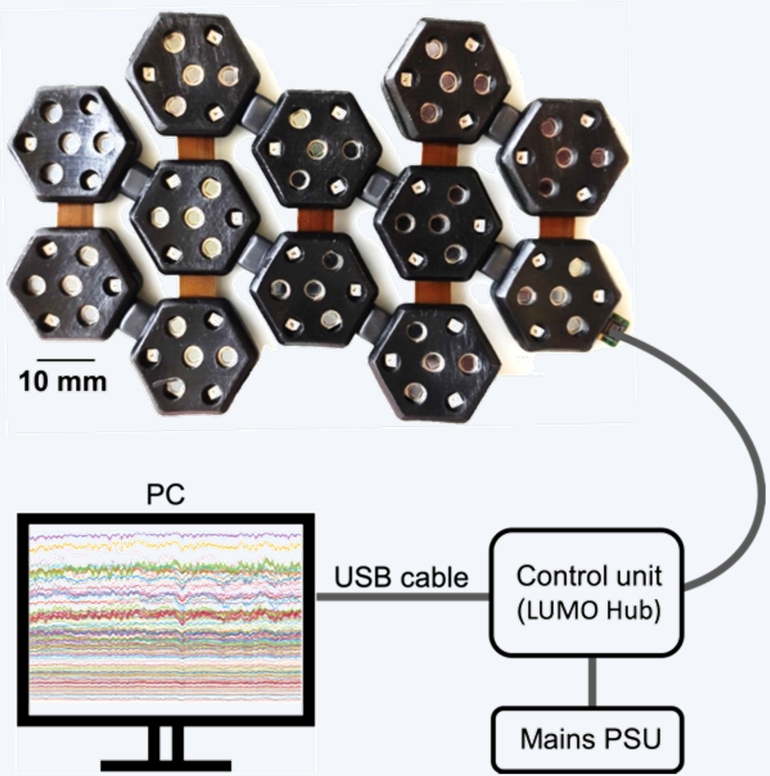

(b) Block


(c) Patch

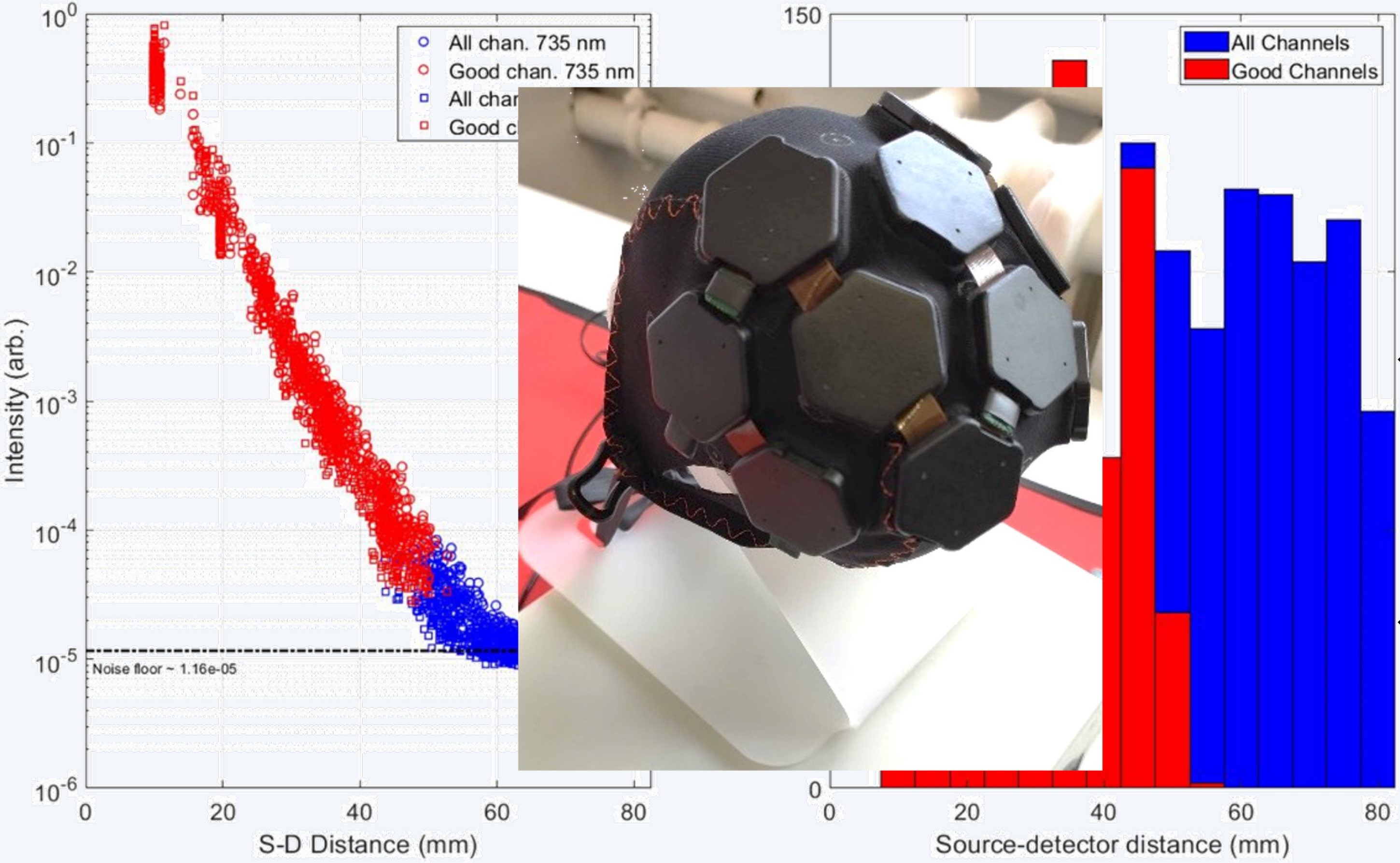
The ANIMATE system V1

The ANIMATE system V1

- 3 dual-hex and 2 tri-hex modules
- 36 source and 48 detector locations
- a 2-3-2-3-2 layout that can provide appropriate coverage for the motor cortex of neonates
- Total weight ~70 g with full encapsulation



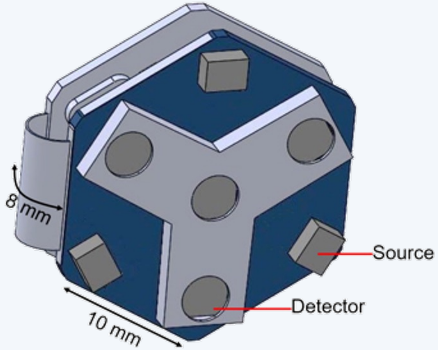
The ANIMATE system V1

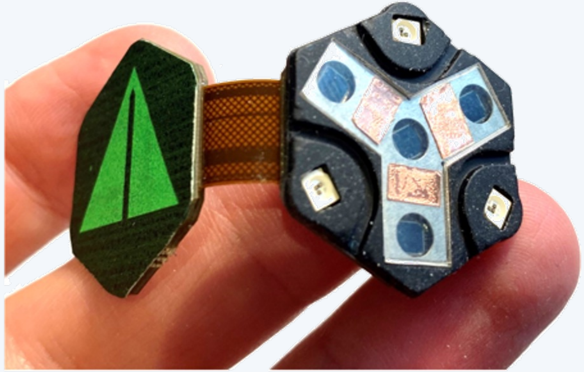


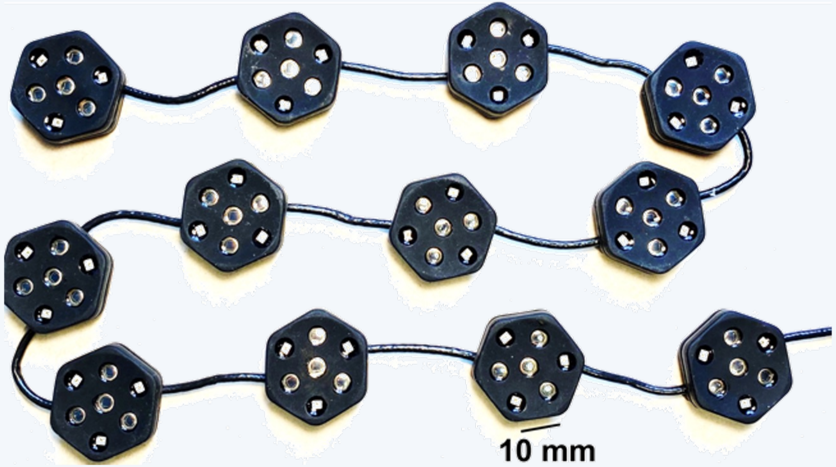
- ❖ 1728 DOT channels per wavelength (including 717 good channels, i.e. SDS <= 45 mm)
- ❖ Dynamic range: 106.6 dB

The ANIMATE system V2

- ANIMATE v2) implemented using the same individual hexagon. However, a second rigid hexagon is folded back to produce a stacked board pattern.
- To allow us to add connectors that permit the use of short lengths of cabling so as to build a stable daisy-chain of modules.
- To provide a more robust mechanical design, while the shielded cabling and stacked board pattern will provide additional noise isolation.







HUBIN @ UCL

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Our primary research interests including (but not limited to):

- **Wearable, Implantable, & Non-Contact Intelligent Imaging, Sensing & Health Monitoring Technologies**
- **AI Hardware for Medical Imaging and Healthcare**
- **Technology Developments & Applications for Neural Interface, Human-Robot Interaction**
- **Advanced Medical Electronics, Microelectronics & Optoelectronics for Healthcare**

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Acknowledgements

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EPSRC

erc European Research Council

THE ROYAL SOCIETY

UCL DIV OF SURGERY

HUBIN @ UCL

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