Characterization of optical microsystems designed to thermal control of the neural tissue

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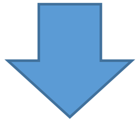
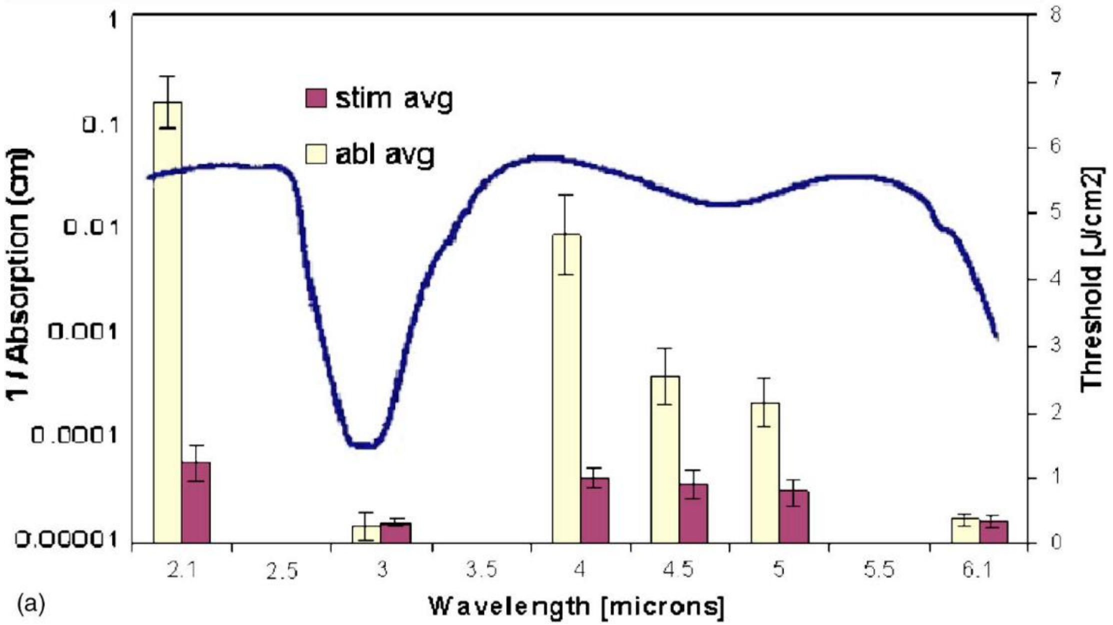
Interim report (semester 3) – 25 Jan, 2018

Neuroscientific motivations

- Effect of body temperature and brain temperature on neural activity
- Pulsed infrared neural stimulation (INS)
- Biological mechanism of INS?



- Precise, multimodal tool is needed
- Current INS is limited to cortical investigations



Wells et al., J. Biomed. Opt. 10 (2005)

→ My work: multimodal Si brain electrode = optrode

Multimodal brain electrode

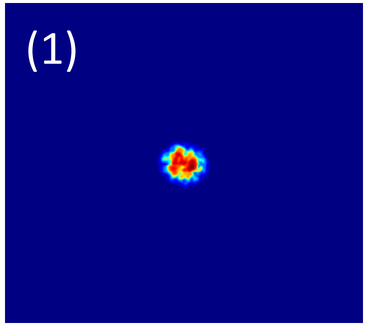
- Electrophysiology
  - Rectangular-shape Pt thinfilm
  - 30×30 μm^2 recording sites with 100 µm spacing
- Thermometer
  - Meander-shape Pt thinfilm
- Optical stimulation
  - Bulk Si: mechanical substrate and IR waveguide (2 in 1)

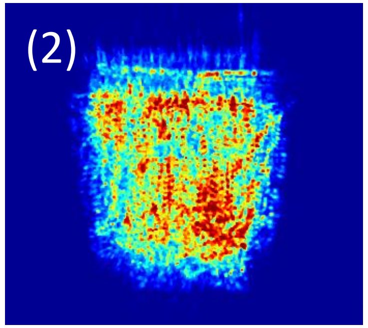
Modality 1 – Optical measurement

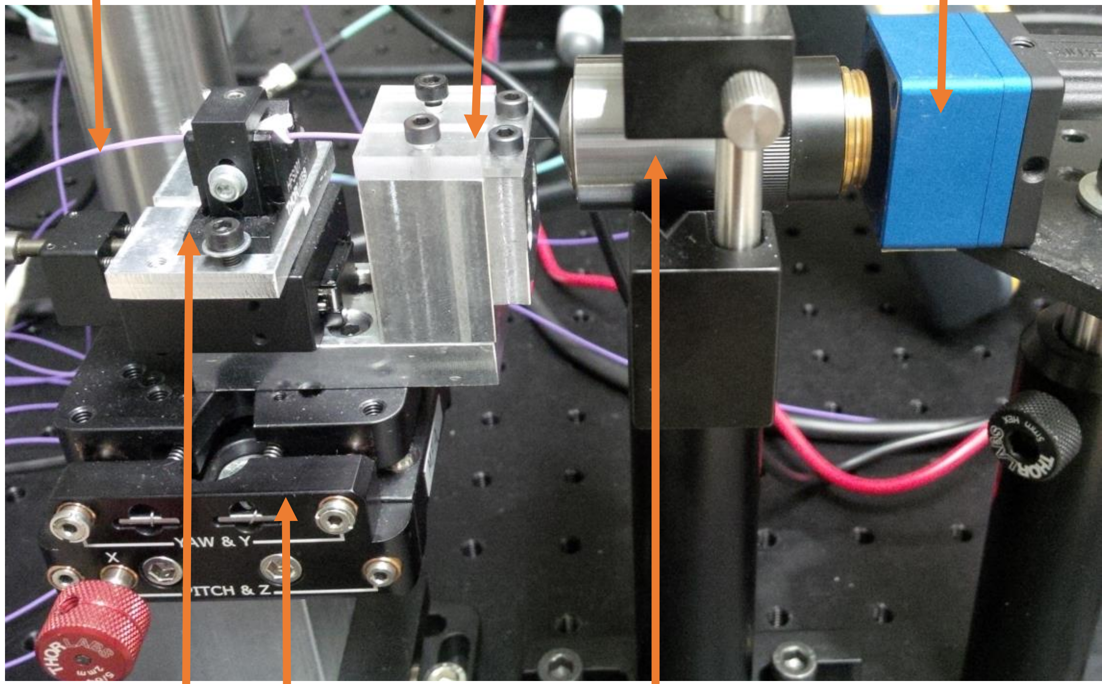
- Relative LASER beam power measurement

CMOS beam profiler (CINOGY Techn. GmbH)

1. Reference image: optical power coupled out from the optical fibre (max. 5 mW)
2. Electrode image: optical power coupled out from the blunt-type electrode tip (fiber inserted into the chip's fiber guide)
3. Overall coupling efficiency: ratio of (2) and (1)







Modality 1 – Measurement results

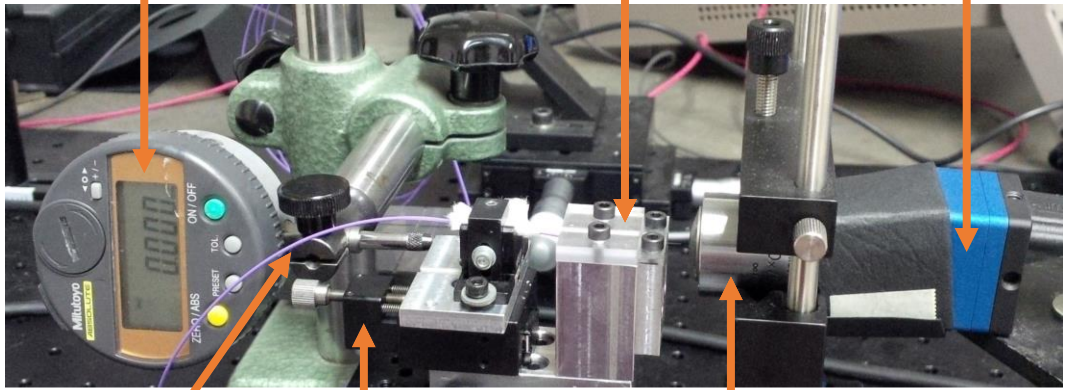
- Theoretical max. waveguiding eff.: 48%
- Device under test:
  - Individual optrode chips
  - Fully assembled optrode devices
- Packaging improved the measurement repeatability

Modality 1 – Impact of fibre facet position from coupling lens (D)

4-digit digital micrometer

Custom designed sample holder

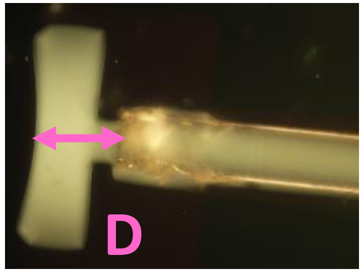
CMOS beam profiler



Multimode fibre

1D translation stage

Microscope objective as imaging optic (50×, NA=0.8)



- Average of D was calculated in case of max. waveguiding efficiency

Modality 1 – Laser beam divergence

- Far-field IR images by a CMOS beam profiler
- Spatial positions of diffraction maxima were observed along the horizontal and the vertical axes
- Two characteristic measures: inner and outer neighbours

Modality 2 – Thermal measurement

- Pt thin film resistance thermometer
- Calibration:
  - Simultaneous measurement with a NTC thermistor (±0.14 °C) as reference
  - 0.5 dl physiological saline
  - Various immersion depths
  - Control and recording: custom-developed Matlab code

Summary

- Multimodal MEMS brain electrode development
  - 3 integrated modalities: electrical recording, thermal measurement, IR wave guiding
- Test measurements
  - Relative beam power measurement
  - Impact of fibre facet position from coupling lens
  - Beam divergence measurement
  - Thermometer calibration in 3 different immersion depth
- Further aims:
  - Optical measurement: impact of core/cladding diameter on waveguiding behaviour
  - Simultaneous testing of the three modalities on packaged devices
  - In vivo validation

Publications – completed

- **Á. Cs. Horváth**, Ö. Sepsi, Cs. Ö. Boros, Sz. Beleznai, Pál Koppa, Z. Fekete: Multimodal neuroimaging microtool for infrared optical stimulation, thermal measurements and recording of neuronal activity in the deep tissue, *oral presentation at the 31st Eurosensors conf. in Sept. 2017.*
  Citation*: Proceedings* 2017; 1(4): 494.
- **Horváth ÁCs**, Sepsi Ö, Boros CsÖ, Beleznai Sz, Koppa P, Fekete Z: Multimodal neuroimaging microtool for infrared optical stimulation, thermal measurements and recording of neuronal activity in the deep tissue, *poster presentation at FENS Regional Meeting in Sept. 2017.*
- **Horváth Á. Cs.**: About the technology of deep brain implants with flexible carrier, *oral presentation at the 33rd Kandó conf. in Nov. 2017.*
- **Horváth Á. Cs.**: About the technology of deep brain implants containing waveguide, *oral presentation at the 33rd Kandó conf. in Nov. 2017.*

Publications – soon

- **Á. Cs. Horváth**, Ö. Sepsi, Sz. Beleznai, Cs. Ö. Boros, P. Koppa, Z. Fekete: A multimodal microtool for spatially controlled infrared neural stimulation in the deep brain tissue, *article under review.*
- **Á. Cs. Horváth**, Cs. Ö. Boros, Ö. Sepsi, Sz. Beleznai, P. Koppa, Z. Fekete: Micro-optrode with integrated thermal and electrophysiological recording sites and infrared waveguide for monitoring and stimulation of the neural tissue, *submitted abstract to 20th IEEE DTIP conf. in May. 2018*

Thank You for Your attention!