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

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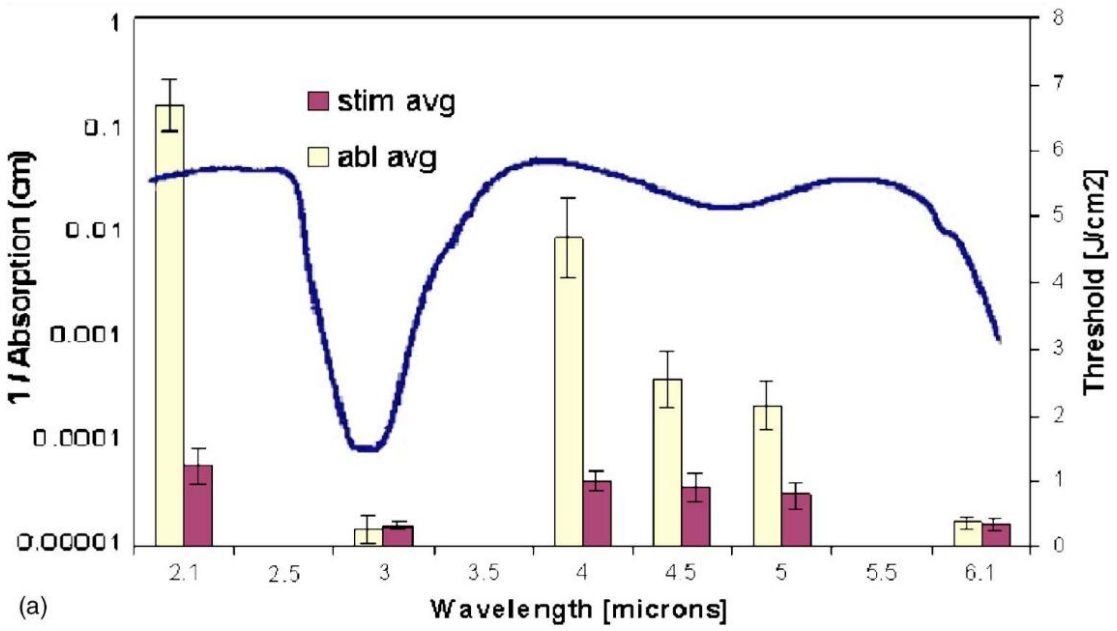
Research Group for Implantable Microsystems

Interim report (semester 6) – 20. June 2019

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

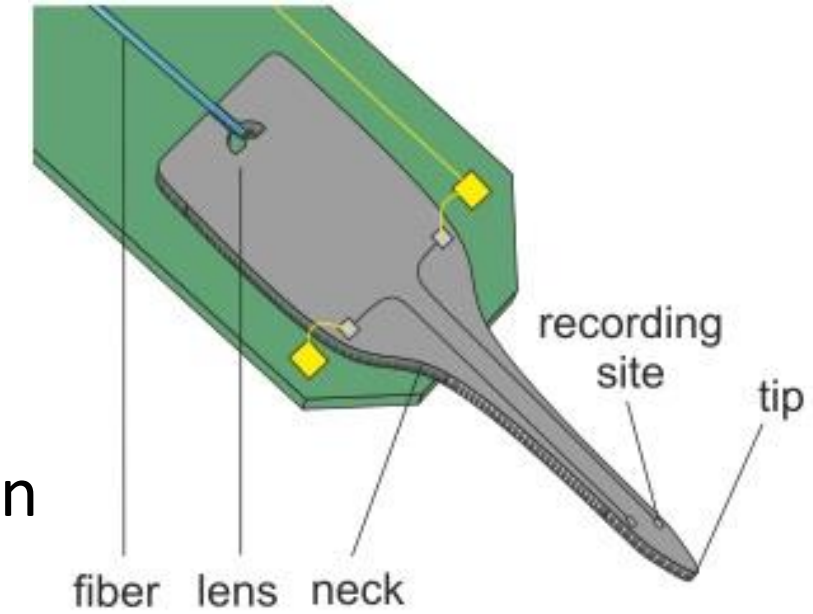


Wells et al., J. Biomed. Opt. 10 (2005)

→ My work: multimodal Si brain electrode = optrode

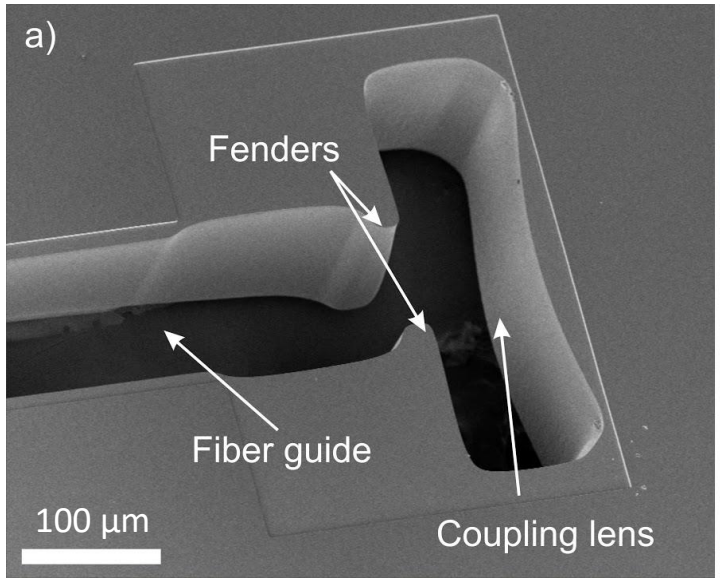
Multimodal brain electrode

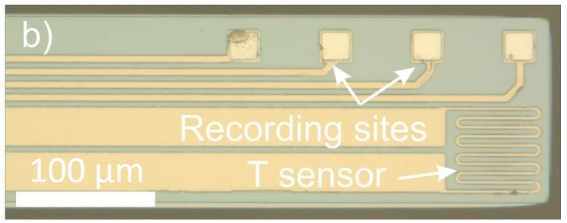
- Modality 1: Optical stimulation
  - Bulk Si: mechanical carrier and IR waveguide (2 in 1)
- Modality 2: Monitoring heat accumulation
  - Pt thinfilm thermometer (100 x 100 µm^2) at tip
- Modality 3: Electrophysiology
  - 900 µm^2 Pt recording sites with 100 µm spacing

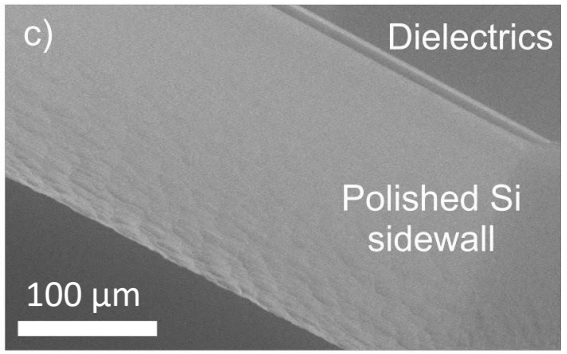


Kiss et al., S&A B: Chemical (2016) 676

[www.shklinika.hu]

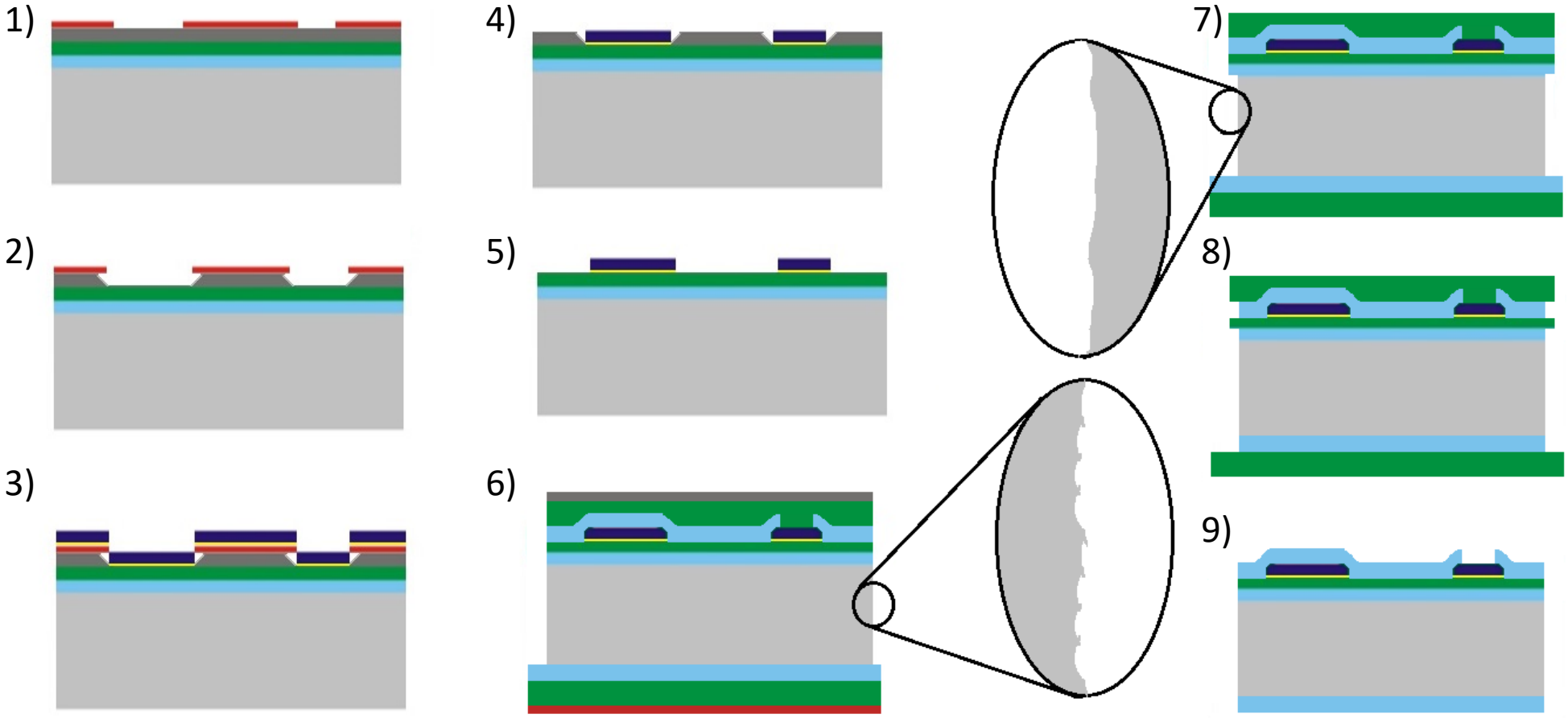






Microfabrication

+3 additional steps



Wet chemical polishing:

$HF:HNO_3:H_3PO_4$

1 : 8 : 1

Oxide etching:

NH_4F & HF

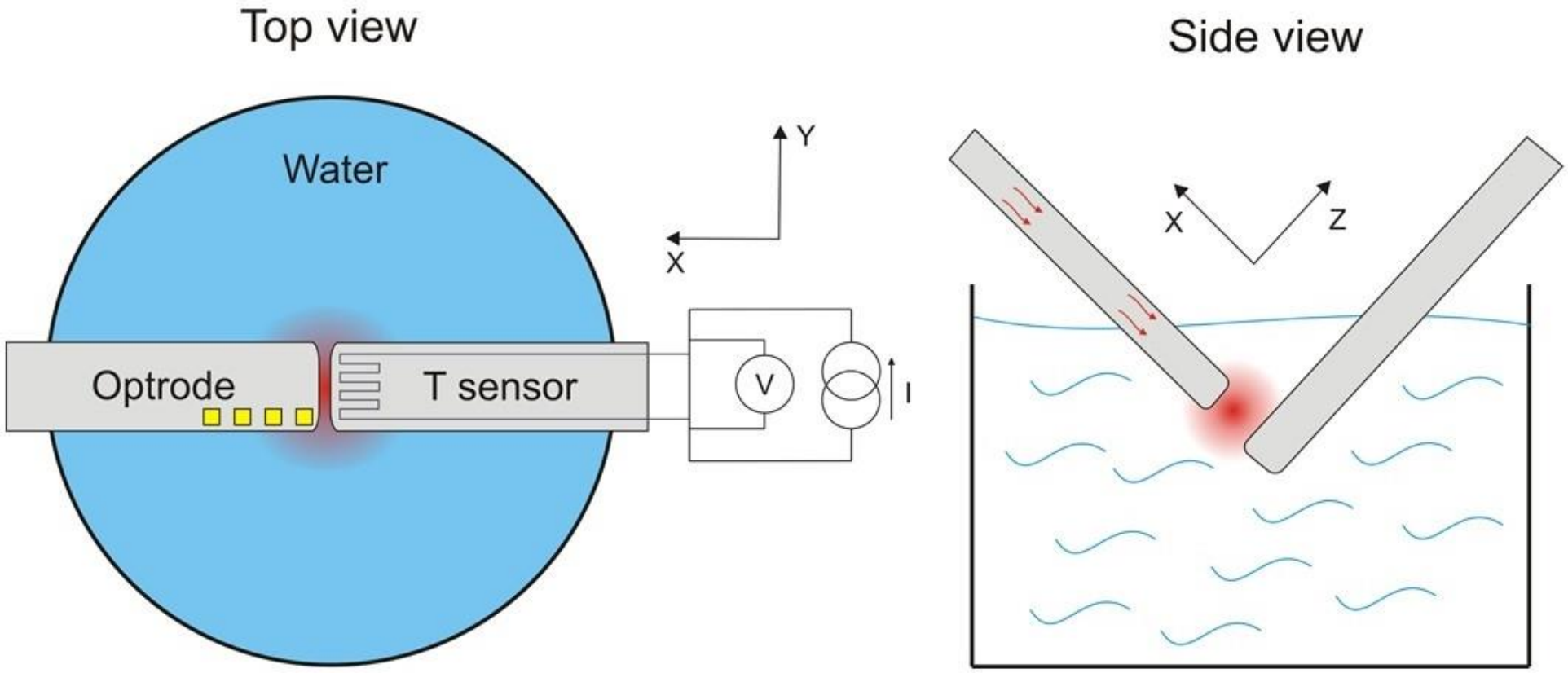
Nitride etching:

H_3PO_4

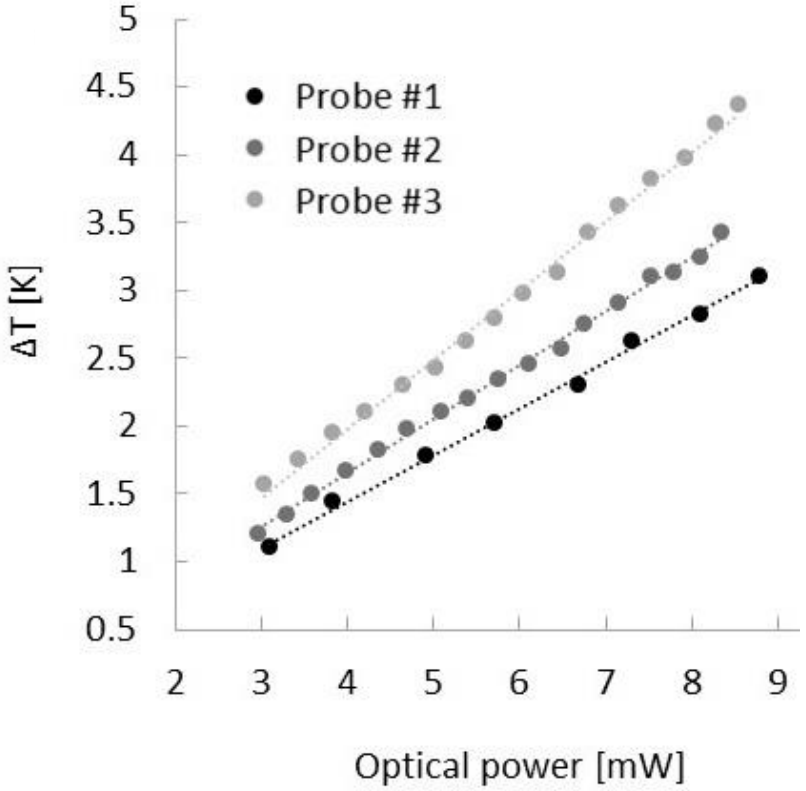
Characterization of modalities

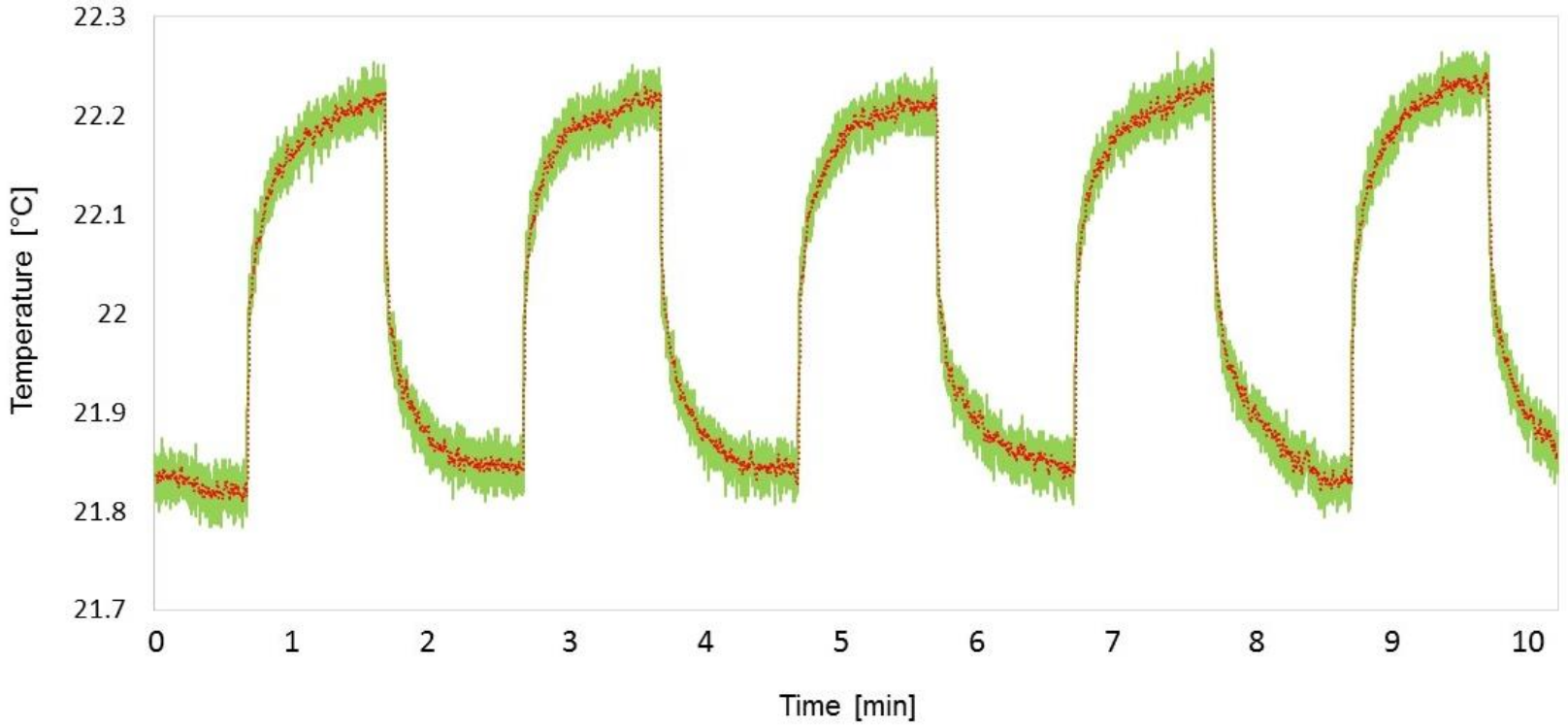
- The optrode device has 3 modalities:
  - Temperature sensor → thermometer calibration (in earlier semesters)
  - IR waveguiding → optical characterization:
    - Waveguiding efficiency
    - Optical power
    - Beam size, beam divergence
    - Optical heating: spatial distribution
  - Electrophysiological recording → reduction of the recording sites' impedance

Optical heating



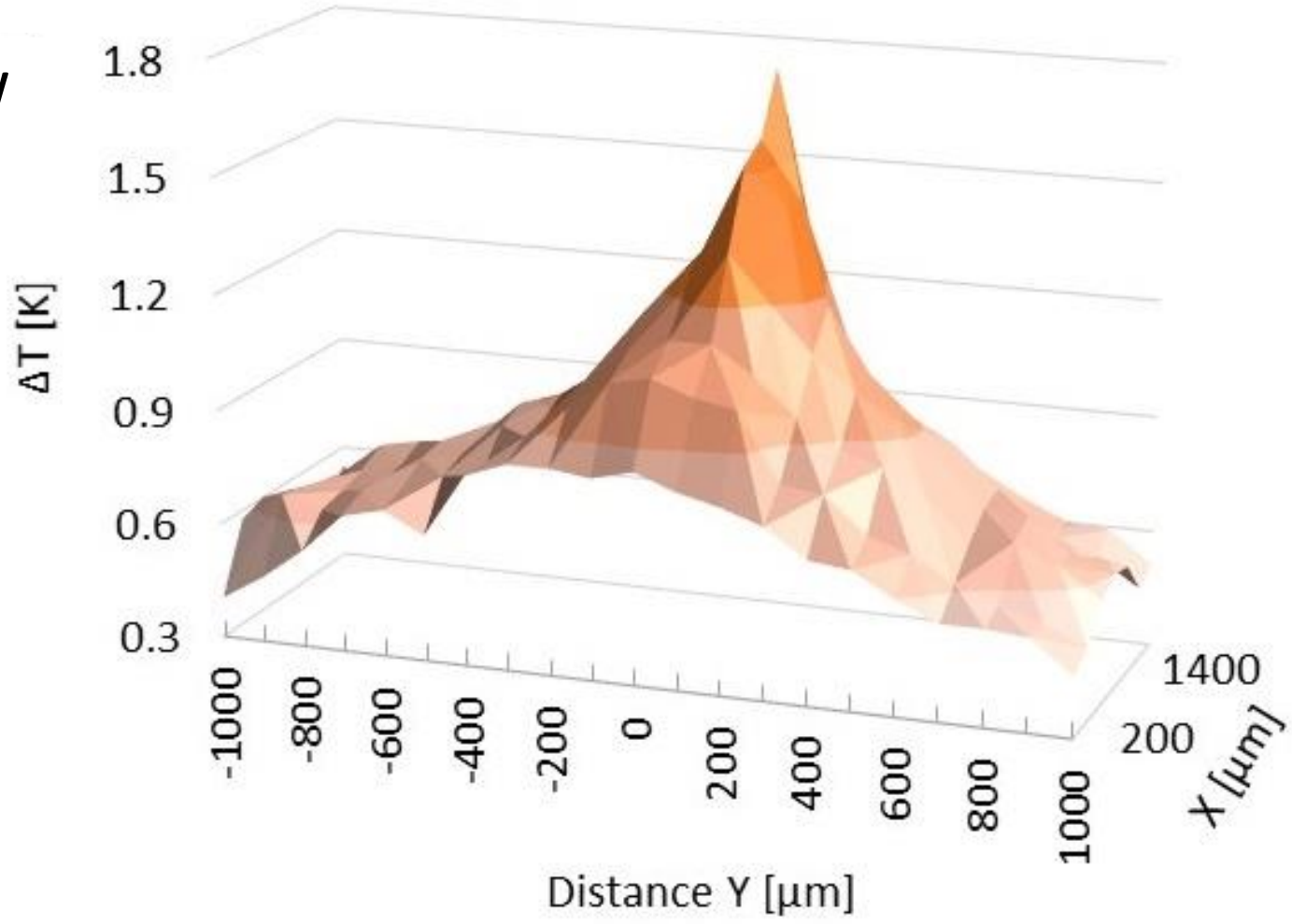
Optical heating





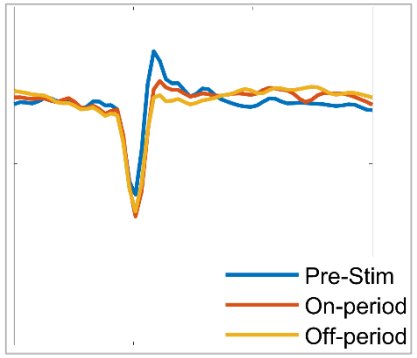
Optical heating – spatial distribution

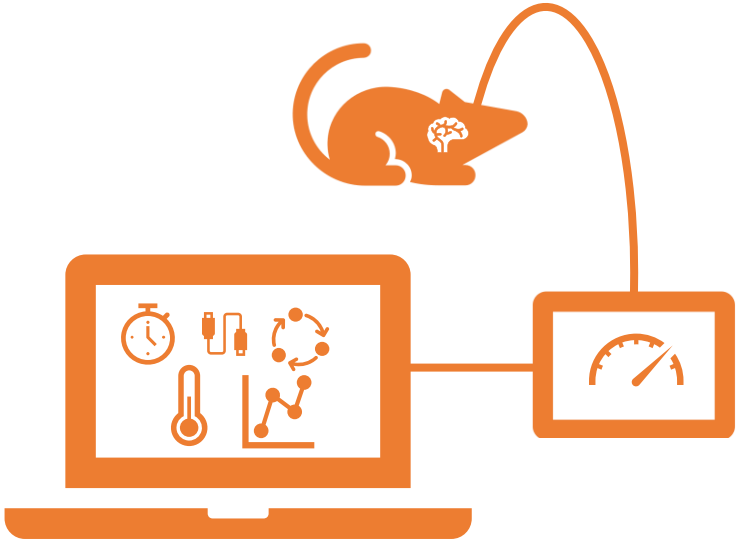
- P_{opt}= 7.88 mW



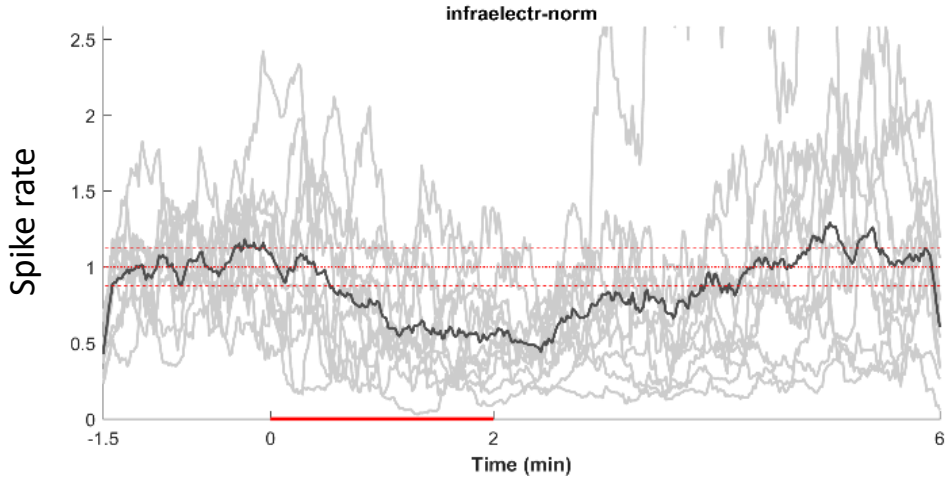
In vivo validation of the optrode device

- Reversible stimulation
- Effect of IR illumination depends on:
  - Observed brain region (type of stimulated neuron)
  - Optical heating power (ΔT [°C])

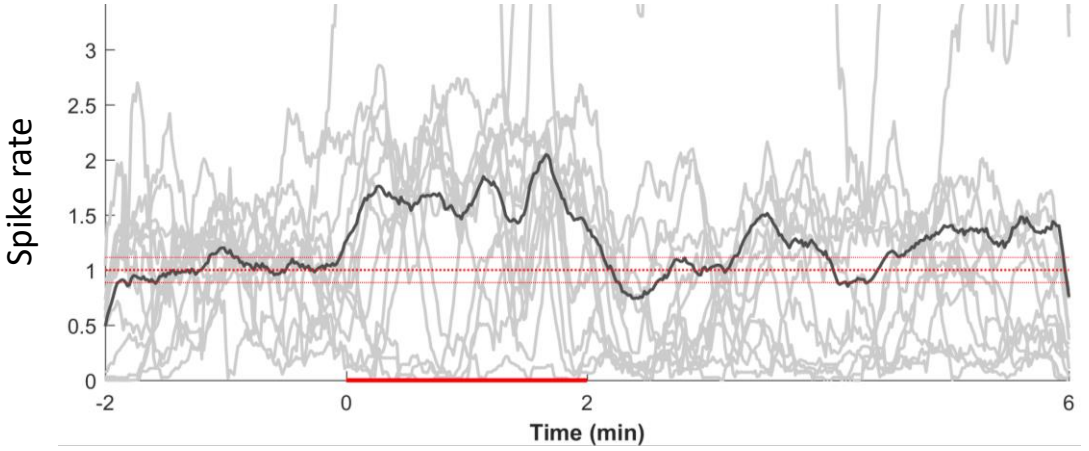




ΔT < 2°C, inhibition in rat cortex



ΔT > 4°C, excitation in rat hippocampus



Summary

- Multimodal MEMS brain electrode development
  - 3 integrated modalities: electrical recording, thermal measurement, IR wave guiding
- Measurements
  - Characterization of the spatial distribution of the optical heating
  - In vivo validation of the optrode device
- Further aims:
  - Redesign the layout of the optrode chips: optimization and development
  - Compare the old and the new versions
  - Second language exam
  - Begin to write my thesis

Summary

- Publications – completed & in prep.
  - Ö. C. Boros, Á. C. Horváth, S .Beleznai, Ö. Sepsi, D. Csősz, Z. Fekete, and P. Koppa, Optimization of an optrode microdevice for infrared neural stimulation, *Applied Optics* **58** (14) pp. 3870-3876 (2019)
  - Ágoston C. Horváth, Sándor Borbély, Örs C. Boros, Lili Komáromi, Pál Koppa, Péter Barthó, Zoltán Fekete, Infrared neural stimulation and inhibition using an implantable silicon photonic microdevice, *article under review*

➢ New National Excellence Foundation (ÚNKP): I was awarded a 10 months scholarship and already registered again to continue

Új Nemzeti Kiválóság Program