Neural Stimulation from an Implantable Optogenetics System

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Introduction

Optogenetics uses light to manipulate neural activity with millisecond precision[1].

It involves transfecting targeted cells with opsin (photosensitive protein) and exciting/silencing them with pulses of visible light.

Advantages:

- Specific cell-type targeting
- Simultaneous stimulation
- Harmless to tissue

Clinical Applications[2]:

- Parkinson's Disease[3], Epilepsy
- Activating heart muscle
- Restoring hearing

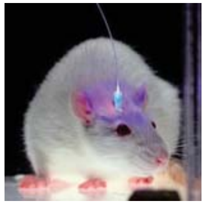
State-of-the-art:

(A) Bench-top fibre-optic system – readily available[4]

New approaches:

(B) Wirelessly powered device

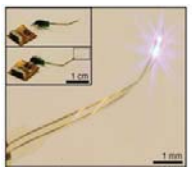
(C) Integrate µLEDs in neuro-probe[5]



(A)

(B)

(C)

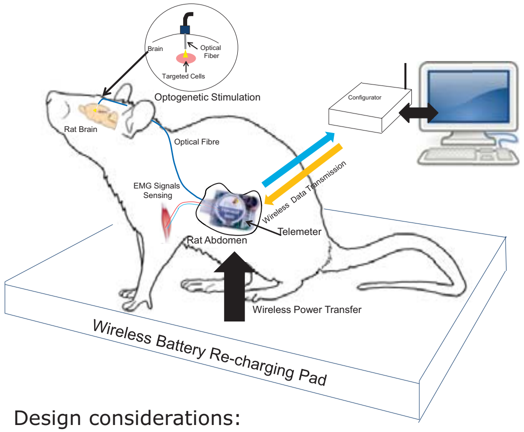


Aim of this Study

Eliminate risk of infection by implementing a fully implantable optogenetics stimulation system for chronic studies.

Design Concept

Placing the light source and electronics in rat abdomen and delivering light to deep brain via optical fibre.



Design considerations:

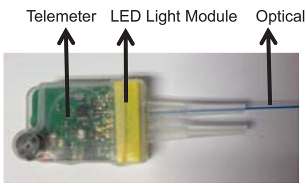
- Small for implantation in rat.
- Low heat dissipation.
- Robust and precise light delivery.
- Remote control of light stimulation.

Light Generation & Delivery

Light source: 280µm x 280µm Blue (465nm) LED – suitable for activating ChR2 expressed neuron.

Light delivery: a 200µm (core) optical fibre.

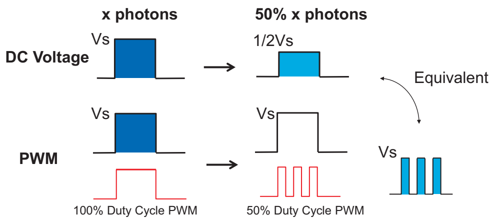
Prototype:



- Optical power at the tip of fibre is 100µW – sufficient to activate a ChR2 expressed neuron.
- Light module power consumption is 6.4mW.

Optical Power Regulation

- LED Optical power can be regulated by (a) current or (b) Pulse-Width Modulation (PWM).
- PWM easily implemented in microprocessor, a huge advantage for implantation.
- PWM technique: at high frequency, the amount of photons emitted can be perceived as an integration of the pulses.
- We want to validate whether PWM can achieve equivalent light stimulation as DC voltage regulation.

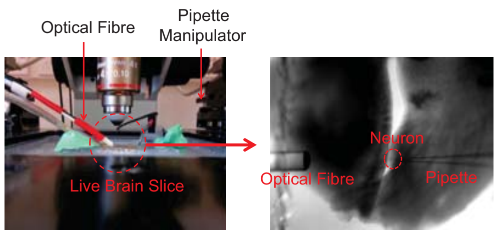


Mouse Brain Slices Validation Experiment

To validate our implantable optogenetics system, whole-cell recordings of neuron from transgenic mouse brain slices using photocurrent patch clamp was performed.

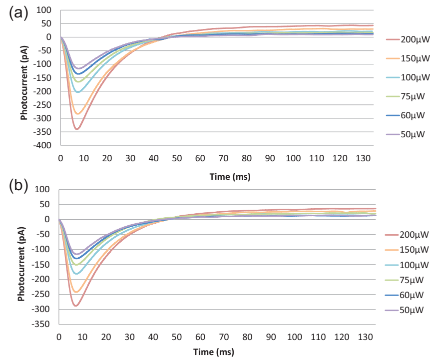
Intention:

- Show LED light source is able to evoke photocurrent response
- PWM is a good technique to regulate optical power

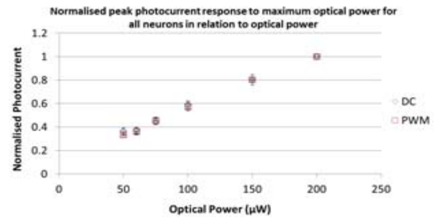


Results

Photocurrents evoked by a series of optical power levels with 4ms light pulse using (a) DC voltage and (b) PWM technique



Both DC voltage and PWM techniques evoked equal drops in photocurrent for a given reduction in power.



Conclusion

Our LED optogenetics system is implantable:

- Small and robust light delivery system.
- Sufficient optical power to evoke photocurrent in neuron with low power consumption.
- PWM is a feasible method for controlling light power.

References

1. E. S. Boyden, *et al.*, "Millisecond-timescale, genetically targeted optical control of neural activity," *Nat Neurosci*, vol. 8, pp. 1263-1268, 2005.
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