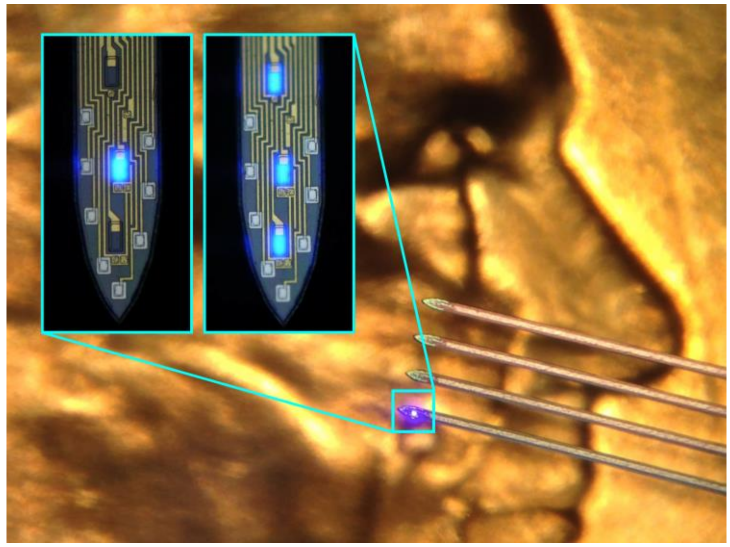
NeuroLight Technologies

Optoelectrode Datasheet



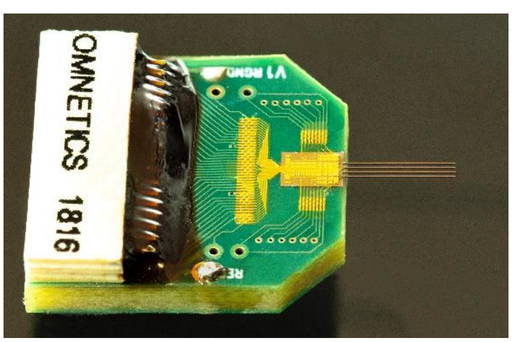
Features

- 12 µLEDs, 10 x 15 µm each, 3 per shank
  - Emission Peak λ = 460 nm and FWHM = 40 nm
  - Typical irradiance of 33 mW/mm^2 (@ max operating current of 100 µA)
- 32 recording channels, 8 per shank
  - Electrode impedance of 1000 - 1500 kΩ at 1 kHz
  - Noise floor ≤ 5 μV_{rms} using an Intan RHD2132 Amplifier Board
- < 50$\mu V_{pk\text{-}pk}$ stimulation artifact [1]
- 5 mm shank length, < 2g total weight
- Please direct questions or concerns to info@neurolighttech.com

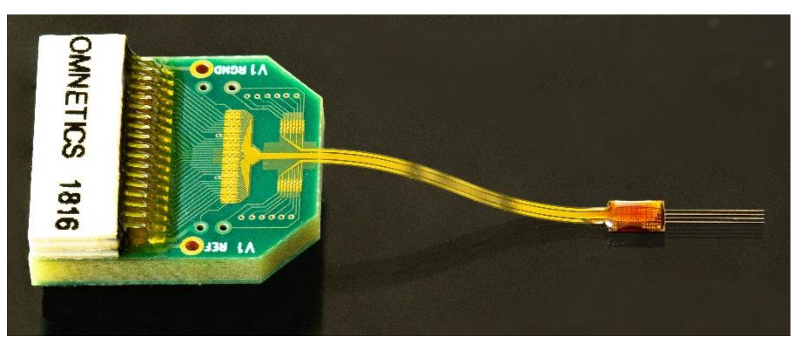
Description

The optoelectrodes are fabricated on a GaN-on-silicon substrate with recording sites and precisely defined µLEDs (10 x 15 µm), allowing **for simultaneous recording and local optogenetic stimulation with < 50$\mu V_{pk\text{-}pk}$ stimulation artifact**. For chronic experiments, the N1-F21-O36/18 (right, below) features an extremely durable, yet flexible cable allowing for light-weight stereotactic head fixtures. For acute experiments, we recommend the N1-A0-O36/18 (left, below).

N1-A0-O36/18 (Acute)

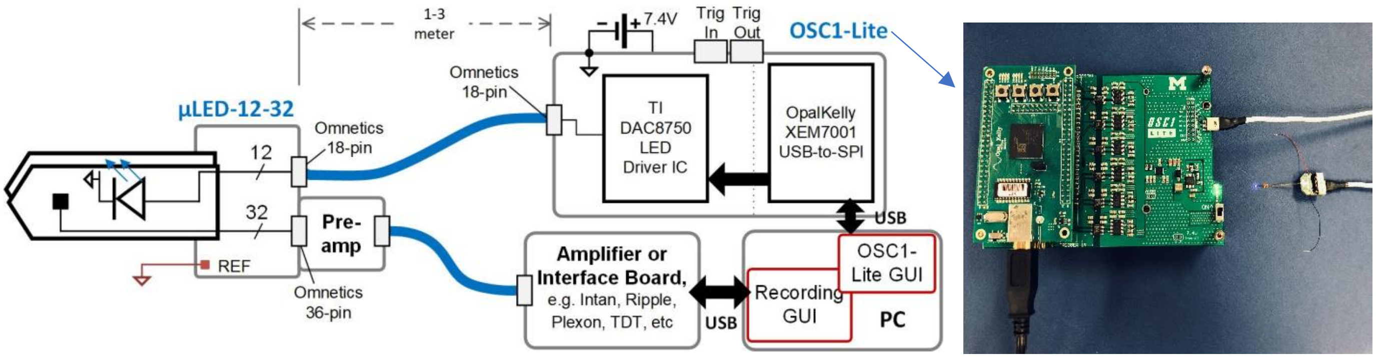


N1-F21-O36/18 (Chronic)



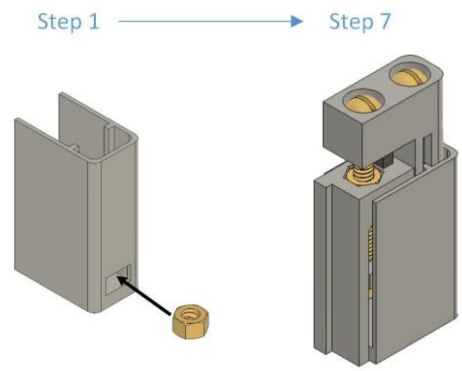
Warning: devices are not ESD protected

Typical System Configuration



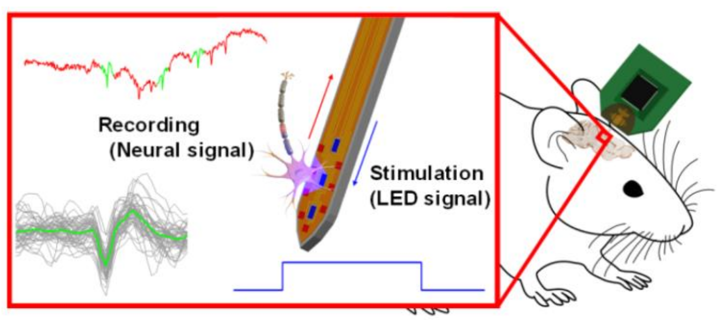
For recording from the 32 electrodes, we recommend an Intan RHD2132 pre-amp headstage and an RHD2000 interface board. For stimulation, we recommend an open-source µLED driver system, OSC1Lite, which provides everything required for independent channel stimulation with custom waveform (software, battery, usb cable, Omnetics cable, etc). For stereotactic insertion, we recommend our 3D printable microdrive. The 3D printable microdrive and an instructional surgery video can be found on GitHub.

Microdrive



- Optional for chronic use where position control is desired
- Total travel –
  - Mouse – 2.6 mm
  - Rat – 5.7 or 8.9 mm
- Resolution, distance per turn – 280 µm
- 3D printable CAD files are available for download at this GitHub page

Applications

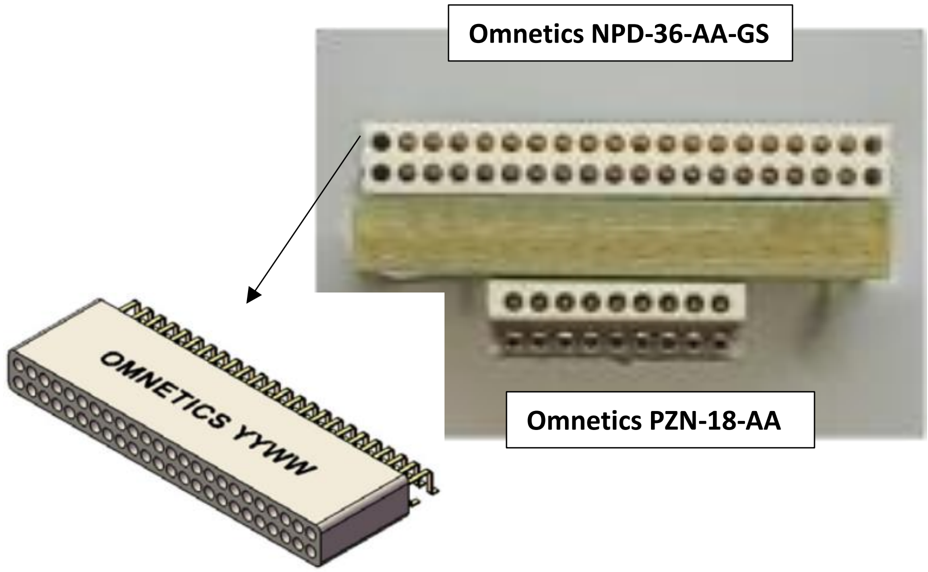


- Optogenetic-control of local neural circuits in awake, behaving studies
- Square-wave excitation for precise timing control
- Sine-wave excitation for graded modulation
- Chronic optogenetics where a microdrive is used for fine-tune positioning

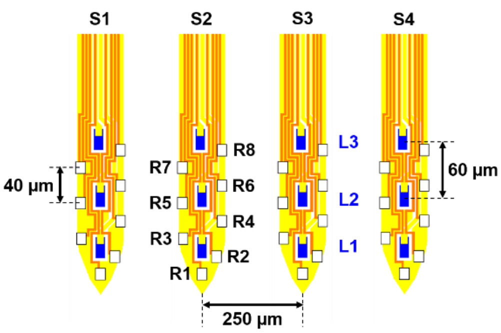
Warning: devices are not ESD protected

Connectors & Mapping

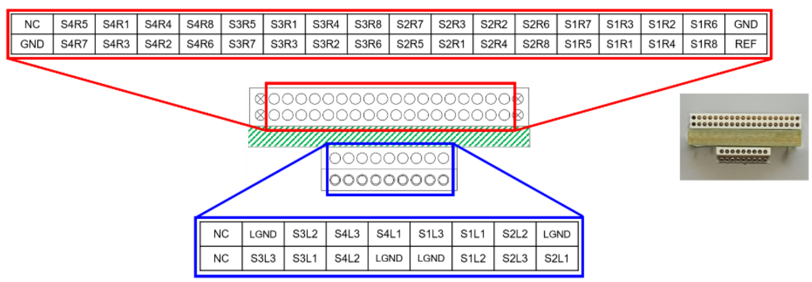
- Recording connector: 36-pin Omnetics (NPD-36-AA-GS, top)
- Stimulation connector: 18-pin polarized Omnetics (PZN-18-AA, bottom)



Optoelectrode tip top view

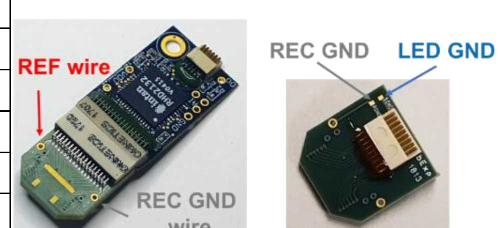


PCB rear view



Channel	Electrode	Channel	Electrode	Channel	Electrode	Channel	Electrode
in0	S2R7	in8	S1R8	in16	S3R6	in24	S4R5
in1	S2R3	in9	S1R4	in17	S3R2	in25	S4R1
in2	S2R2	in10	S1R1	in18	S3R3	in26	S4R4
in3	S2R6	in11	S1R5	in19	S3R7	in27	S4R8
in4	S1R7	in12	S2R8	in20	S4R6	in28	S3R5
in5	S1R3	in13	S2R4	in21	S4R2	in29	S3R1
in6	S1R2	in14	S2R1	in22	S4R3	in30	S3R4
in7	S1R6	in15	S2R5	in23	S4R7	in31	S3R8

Suggested connection w/ Intan headstage



Depending on your setup, you can tie REC and LED GNDs or not

Warning: devices are not ESD protected

Frequently Asked Questions

Q: I am seeing a stimulation artifact whenever I pulse the LEDs. Can this be avoided?

Stimulation artifacts can occur in the recordings at the beginning (stimulation onset) and the end (stimulation end) of the voltage / current pulse to the micro-LEDs in a shape of high-frequency, high-amplitude swing of the signal. Stimulation artifact is typically observed on the recording channels on the same shank of the LED being stimulated, but it is possible that it occurs on all the recording channels. The artifact amplitude and pulsewidth varies depending on position relative to the LED and the impedance of the given electrode.

The cause is mostly dominated by the photovoltaic effect for which we hope to have a solution available in 2019. A manuscript on these findings and our methods to effectively eliminate artifact has been submitted. Fortunately, there are ways to deal with it even in the current uLED versions, namely pulse shaping and subtraction methods.

Pulse shaping, i.e. slowing the slew rate (or rate of change) of the pulse signal provided to the LEDs, will reduce the artifact amplitude. Driving your LED with a sine wave is an extreme form of pulse shaping. In standard CMOS drivers, the turn-on period is in nanoseconds. It has been observed that sinusoidal or gaussian off-to-on and on-to-off transitions exhibit stimulation artifacts of smaller amplitudes than that of (high-speed) ramp. It has also been observed that ramp transitions with rise (and fall) times as long as a few milliseconds can also greatly reduce the stimulation artifact.

Another pulse shaping method to reduce the artifact is to reduce the total step change in the voltage required to drive the LED. Choose a low voltage where current is effectively zero, usually 2V works well, and program that to be off state for the LED. The ON state would be as it was before but in this situation the dV/dt is reduced and so is the artifact. Similar argument works for a current driver but this requires very high resolution, e.g. choose 100 nA.

The artifact can also be subtracted out before your spike sorting/PCA analysis. Given your timestamps for each ON and OFF event, remove the signal recorded for a 1 ms period at the stimulation onset. This should be repeated at the stimulation OFF event. The missing signal is then replaced with a linear interpolation. This has been done in English, McKenzie, et al., "Pyramidal cell-interneuron circuit architecture and dynamics in hippocampal networks", Neuron, 2017.

Q: I am wondering if my LEDs are still working properly. What is the best way to test them?

Micro-LEDs can be damaged due to extended exposure to high current. It is recommended that the micro-LEDs are not exposed to current higher than 100 µA for multiple stimulation cycles. If suspicious about proper operation, you can measure the current-to-voltage (I vs. V) characteristics of the potentially damaged micro-LED and compare that to the original characteristics as that can be used as a good indicator for the operation of the micro-LED. You can also measure the optical power output using an optical power meter (although measurement using optical power meters is not as accurate as the integrating sphere we use internally). This allows you to compare the radiant flux-to-voltage (E vs. V) or the radiant flux-to-current (E vs. I).

For current measurement, you can use a sourcemeter or a combination of a DC voltage source and a multimeter (with microampere resolution). For optical power measurement, you can use an optical power meter which uses calibrated silicon-based sensor and set the wavelength at 470 nm.

Q: Are the micro-LEDs ESD protected?

ESD can permanently damage the micro-LEDs. Currently, there is no ESD protection circuitry integrated to the PCBs to protect the micro-LEDs on the optoelectrode. It is important that you discharge yourself before handling the micro-LED optoelectrode PCBs, especially when handling them in dry environment. It is also recommended that you use ESD protection equipment (e.g. ESD-safe mats and wrist straps) and ESD-safe (dissipative) tools for handling if available.

Q: Can I drive the LEDs with voltage driver instead of a current driver?

Current drivers are generally a safer way to use your µLEDs but if you choose to use a voltage driver follow the I-V curve carefully and consider placing a high precision resistor in series and monitor current as well. Any oscilloscope or voltmeter would work well across your resistor in this case and ensure you know the current. This is also a simple way to make your own I-V curve if you want to evaluate the µLEDs on your own.

Q: Can you recommend commercial current drivers for the uLEDs?

Plexon has begun testing our µLEDs with their system. We will share that information in the Google Group forum and encourage EVERYONE to share their own experience so the community can learn. **BUT each system must be carefully tested to ensure there are no voltage surges when the system is turned on or off.**

Q: How do I interpret the I-V curves for the micro-LEDs?

A turn-on voltage between 2.8V and 7V is considered usable, although near 3V is typical. If the I-V curve is flat, i.e. there is no current at any voltage, then the LED is open. Please do not use. If the turn-on is higher than 7V, it is also considered damaged. If the I-V curve is linear (I=a*V) then there is a short and that too is faulty.

Q: What is a normal working range for impedance values at 1 kHz frequency?

A normal working range is 100 kΩ to 1.5 MΩ. Outside of that, you are not likely to see spiking activity.

New Questions?

Contact info@neurolighttech.com.

Useful Links

- Video hosted on GoogleDrive showing surgical techniques for implanting the uLED array with a microdrive and even re-using the array.
- Github link where you can find our code for the OSC1 software and microdrive information.

References

[1] Kim, K., Vöröslakos, M., Seymour, J. P., Wise, K. D., Buzsáki, G., & Yoon, E. (2020). Artifact-free and high-temporal-resolution in vivo opto-electrophysiology with microLED optoelectrodes. *Nature Communications*, *11*(1), 1-12.

[2] Mendrela, A. E., Kim, K., English, D., McKenzie, S., Seymour, J. P., Buzsáki, G., & Yoon, E. (2018). A high-resolution opto-electrophysiology system with a miniature integrated headstage. *IEEE transactions on biomedical circuits and systems*, *12*(5), 1065-1075.

[3] Navas-Olive, A., Valero, M., Jurado-Parras, T., de Salas-Quiroga, A., Averkin, R.G., Gambino, G., Cid, E. and Liset, M. (2020). Multimodal determinants of phase-locked dynamics across deep-superficial hippocampal sublayers during theta oscillations. *Nature Communications*, *11*(1), pp.1-14.

[4] English, D. F., McKenzie, S., Evans, T., Kim, K., Yoon, E., & Buzsáki, G. (2017). Pyramidal cell-interneuron circuit architecture and dynamics in hippocampal networks. *Neuron*, *96*(2), 505-520.

[5] Wu, F., Stark, E., Ku, P. C., Wise, K. D., Buzsáki, G., & Yoon, E. (2015). Monolithically integrated μLEDs on silicon neural probes for high-resolution optogenetic studies in behaving animals. *Neuron*, *88*(6), 1136-1148.

[6] K. Kim, M. Vöröslakos, J. P. Seymour, K. D. Wise, G. Buzsáki, and E. Yoon, “Artifact-free and High-temporal-resolution *in vivo* Opto-electrophysiology with MicroLED Optoelectrodes,” *Nature Communications,* 11:2063, 2020.

[7] A. Navas-Olive, M. Valero, T. Jurado-Parras, A. de Salas-Quiroga, R. G. Averkin, G. Gamino, E. Cid and L. M. de la Prida, “Multimodal determinants of phase-locked dynamics across deep-superficial hippocampal sublayers during theta oscillations,” *Nature Communications,* 11:2217, 2020.