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10th International Workshop on Technologies for Optogenetics and Neurophotonics

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PROGRAM AT A GLANCE

keynote talk | invited talk | industry talk | contributed talk

Tuesday, May 6 2025			
15:30-16:00		REGISTRATION	
16:00-16:15		**Opening**	
16:15- 17:00		**Mikhail Shapiro**	Talking to cells: biomolecular ultrasound to image and control cells deep inside the body
17:00-17:30		**Tommaso Fellin**	Aberration corrected microendoscopes for large field-of-view two-photon functional imaging in the deep brain
17:30-18:00		**Olivia Masseck**	Illuminating the Brain: New Tools to Decipher How Neuronal Circuits Generate Complex Behaviors
18:00-18:05		***NKT Photonics***	
18:05-18:10		***Hamamatsu***	
18:10-20:00		WELCOME RECEPTION	

Wednesday, May 7 2025			
8:15-8:45		REGISTRATION	
8:45-9:30		**Demetri Psaltis**	Imaging with multimode fibers
9:30-10:00		**Patrick Ruther**	Optical cochlear implants based on µLEDs and their hybrid combination with conventional electrodes
10:00-10:05		***Light Conversion***	
10:05-10:10		***TOPTICA Photonics***	
10:10-10:40		Coffee break	
10:40-11:10		**Steve Blair**	The Utah Optrode Array for large volume optogenetic manipulation in NHP brain
11:10-11:40		**Alina Pushkarev**	On the spectrum or off the spectrum? Shrimp Rhodopsins as far-red absorbing optogenetic tools
11:40-12:10		**Shy Shoham**	Multiscale interrogation of neural connectivity in vivo using precision optogenetics
12:10-12:15		***HOLOEYE***	
12:15-12:20		***DeepEn***	
12:20-13:50		Lunch	
13:50-14:20		**Filippo Pisano**	Towards deep brain multi-messenger neurophotonics
14:20-14:50		**Keith Mathieson**	Chronically implantable µLED arrays for optogenetic cortical surface stimulation in mice
14:50-14:55		***InnoLas Laser***	
14:55-15:00		***Mightex***	
15:00-17:30		Coffee break & Poster session	
18:00-20:00		Home of Carlsberg exhibition	
20:00-23:00		Dinner at Madklubben restaurant	

Thursday, May 8 2025			
8:45-9:30		**Valentina Emiliani**	All-optical manipulation at depth in head-restrained and freely moving mice
9:30-10:00		**Pau Gorostiza**	Controlling neuronal activity with photoswitchable drugs: from brain waves to single synapses
10:00-10:05		***Opto Biolabs***	
10:05-10:10		***OptogeniX***	
10:10-10:40		Coffee break	
10:40-11:10		**Ileana Hanganu Opatz**	Higher order cortices during development: a story of critical periods and innate behaviors
11:10-11:40		**Mariam Al-Masmudi**	Illuminating the brain to improve the diagnosis and treatment of brain metastasis
11:40-11:50		**Jiaming Ji**	Optogenetic Activation of Prefrontal Circuits via Upconversion Technology for Depression Treatment
11:50-12:00		**Marcello Meneghetti**	Implantable neural interfaces for the central nervous system based on multifunctional optical fibers
12:00-12:10		**Hoda Shamsnajafabadi**	Evaluation of AAV-Mediated Optogenetic Expression in Human Retinal Organoids
12:10-12:20		**Sabina Hillebrandt**	OLEDs: The Cornerstone for Next-Generation Neural Interfaces
12:20-12:25		***ATLAS Neuroengineering***	
12:25-12:30		***Ningaloo Biosystems***	
12:30-14:00		Lunch	
14:00-14:45		**Ofer Yizar**	OptoGPCRs: the new generation of inhibitory optogenetic actuators
14:45-15:15		**Tommaso Patriarchi** **EMBO Young Investigator Lecture**	Next-generation tools to visualize neuromodulators in the brain
15:15-15:45		**Vasiliki Giagka**	Graphene-based transparent neuroelectronics for multimodal neural interfacing
15:45-15:50		***Coherent***	
15:50-16:20		Coffee break	
16:20-16:30		**Johannes Vierock**	pHRoG: pH Regulating optoGenes for all-optical control of subcellular pH
16:30-16:40		**Emilija Boštogaitė**	*In vitro* stability of polymer fibers for optical interfaces
16:40-16:50		**Luisa Camerin**	Photoswitchable Carbamazepine Analogs for Non-Invasive Neuroinhibition *In Vivo*
16:50-17:00		**Jonas Wietek**	A bistable inhibitory OptoGPCR for multiplexed optogenetic control of neural circuits
17:00-17:10		**Nicole Byron**	Sleep-dependent microglial calcium dynamics in Alzheimer's disease mouse models
17:10-17:20		**Niklas Meyer**	CandOR – For strong light-induced Calcium-Influx without Depolarisation
17:20-17:30		**Mohammadrahim Kazemzadeh**	Physics-Informed Deep Learning for Digital Twin of Turbid Media
17:30-17:40		**Linda Piscopo**	Plasmonic Tapered Fiber Sensors for Ultra-Sensitive Neurotransmitter Detection via SERS
17:40-18:00		**Best Poster Award & CLOSING REMARKS**	

Friday, May 9 2025	
10:00-13:00	NKT Photonics headquarters visit

USEFUL INFO

OPTOGEN 2025 takes place at Tivoli Axelborg building in Copenhagen.
The complete **venue address** is *Vesterbrogade 4, 1620 København, Denmark*.

SOCIAL EVENTS

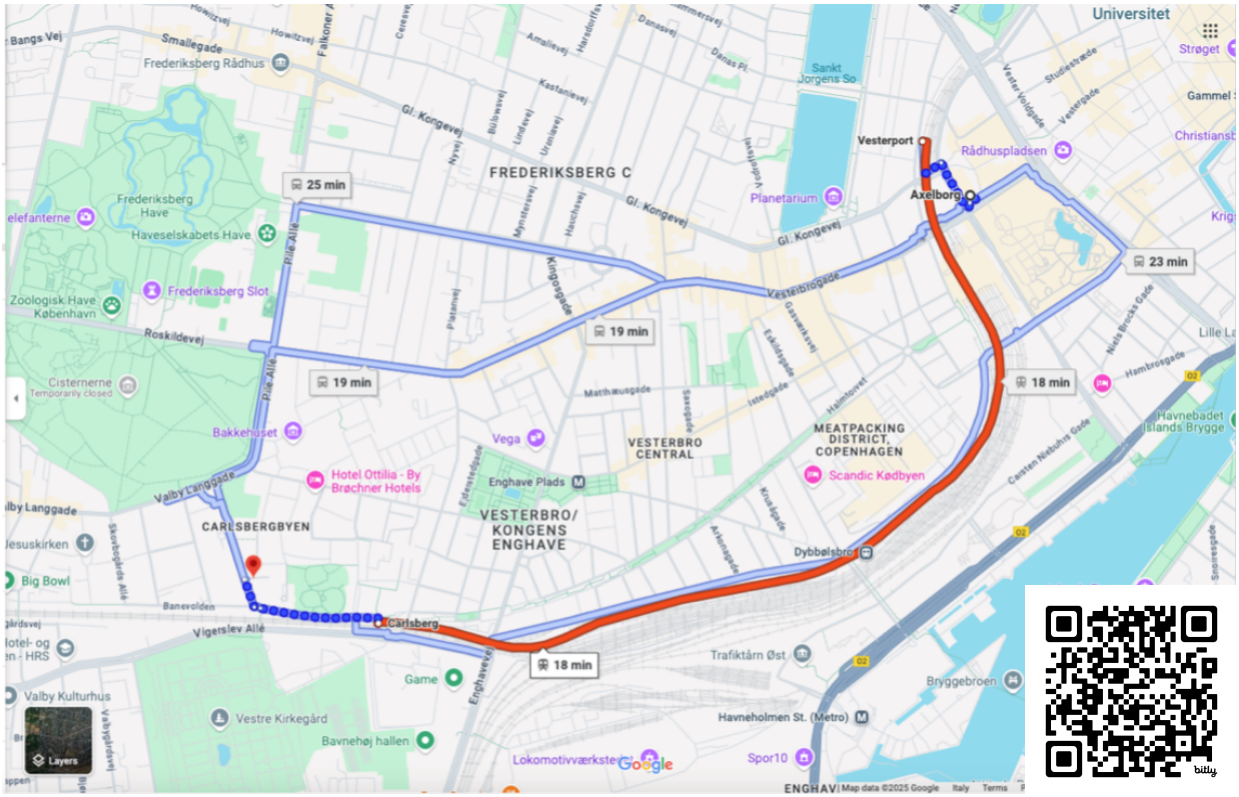
Welcome reception takes place Tuesday May 6th, 6:10 pm at the conference venue.

The social event will start Wednesday May 7th 2025 at 6:00 pm with a tour of **Home of Carlsberg Museum**, where you will have the chance to learn more about the historical Danish beer brand.
The complete **museum address** is *Gamle Carlsberg Vej 11, 1799 København V, Denmark*.
Guests will access the museum in two separate groups, starting respectively 6:00 pm and 6:15 pm from the Home of Carlsberg main entrance. The visit is included in the conference fee and will end with an included beer at the Carlsberg bar.

At 8:00 pm, guests will be chaperoned at **Madklubben Home of Carlsberg** restaurant which is located next to the museum. The complete **restaurant address** is *Gamle Carlsberg Vej 11, 1799 København, Denmark*.
The social dinner will be held from 8:00 pm to 11:00 pm.

DIRECTIONS

Tivoli Axelborg building and Home of Carlsberg Museum / Madklubben Restaurant are approximately 3 km (~1,86 miles) away from each other.
The best option to reach the Carlsberg museum and Madklubben restaurant is by using the H-line train (direction Ballerup St.). Take the train from the Vesterport Station and exit at the Carlsberg station. This normally takes about 18 minutes. Scanning the ***QR Code below***, you will get preset directions with Google Maps to depart from the Optogen2025 venue to the Home of Carlsberg on Wednesday 7th May, 5:30 pm.



INVITED TALKS

Tuesday, May 6th 16:15 - 17:00 **KEYNOTE TALK**

Talking to cells: biomolecular ultrasound to image and control cells deep inside the body

Mikhail G. Shapiro, PhD
Max Delbrück Professor of Chemical Engineering and Medical Engineering,
California Institute of Technology
Investigator, Howard Hughes Medical Institute
Fulbright-Tocqueville Distinguished Chair, ESPCI 2024-5
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Studying biological function in intact organisms and developing targeted cellular therapies requires methods to image and control the function of specific cells deep inside the body. Fluorescent proteins and optogenetics serve this purpose in small, translucent specimens, but are limited by the poor penetration of light into deeper tissues. In contrast, most non-invasive techniques such as ultrasound and magnetic resonance imaging – while based on energy forms that penetrate tissue – are not effectively coupled to cellular function. Our work attempts to bridge this gap by engineering biomolecules with the appropriate physical properties to interact with sound waves and magnetic fields. In this talk, I will describe our recent work on biomolecular reporters and actuators for ultrasound. The reporters are based on gas vesicles – a unique class of air-filled protein nanostructures derived from buoyant photosynthetic microbes. These proteins scatter sound waves, enabling their detection with ultrasound. I will describe our progress in understanding the biophysical and acoustic properties of these biomolecules, introducing them genetically into various cell types of interest for in vivo imaging, and turning them into dynamic sensors of intracellular molecular signals. In addition to their applications in imaging, gas vesicles can be used to control cellular location and function by serving as receivers of acoustic radiation force or seeding localized bubble cavitation. Additional control is provided by thermal bioswitches – biomolecules that provide switch-like control of gene expression in response to small changes in temperature. I will describe how these functionalities allow the development of remote-controlled cell therapies and diagnostics.

Tuesday, May 6th 17:00 - 17:30 **INVITED TALK**

Aberration corrected microendoscopes for large field-of-view two-photon functional imaging in the deep brain

Tommaso Fellin[1]*

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Neural population dynamics in ventral regions of the mammalian brain play fundamental roles in crucial brain functions such as decision making, the regulation of circadian rhythms, and the control of instinctive and motivational behavior. A fundamental prerequisite to understand how neuronal population dynamics in these ventral regions of the brain control such important behavioral processes is to sample large neuronal networks with high and homogeneous spatial resolution and minimal invasiveness. Current techniques based on two-photon microendoscopy are limited in achieving this main goal. Therefore, addressing questions related to how activity of specific neuronal cells in deep regions of the mammalian brain compares across space and whether activity is homogeneously or non-homogeneously distributed over large networks is challenging. In this talk, I will present the development of aberration corrected microendoscopes to perform two-photon functional imaging over extended field-of-views in the deep mammalian brain. I will describe several applications of corrected microendoscopes in both head fixed mice and freely moving animals performing ethologically relevant behavior.

Short bio: Tommaso Fellin graduated in Physics at the University of Padova in 1998 studying enzyme kinetics with time-resolved spectroscopy. From 1998 to 2003, he was a PhD student in the Dept. of Biomedical Sciences at University of Padova and he investigated the biophysical properties of voltage-gated calcium channels (supervisor, D. Pietrobon). During his first postdoctoral training period (2003-2004), he integrated electrophysiological and imaging techniques to study neuron-glia communication in brain slices (supervisors, G. Carmignoto and T. Pozzan). In 2005 he moved to the Dept. of Neuroscience at University of Pennsylvania School of Medicine as a senior postdoctoral researcher and continued his research on neuron-glia interaction (supervisor, P. Haydon). In 2008, he joined the Italian Institute of Technology (IIT) as a junior Principal Investigator. He is currently senior Principal Investigator at the IIT, head of the Optical Approaches to Brain Function Laboratory, co-head (together with Dr. S. Panzeri) of the Neural Coding Laboratory, and Associate Director for the Technologies for Life Sciences Research Domain.

Tuesday, May 6th 17:30 - 18:00 **INVITED TALK**

Illuminating the Brain: New Tools to Decipher How Neuronal Circuits Generate Complex Behaviors

Ryan Fink[1,2], Martin Kubitschke[2], Olivia Masseck[1,2*]

[1]University of Cologne, Neuromodulatory Circuits, Zülpicher Str.47b, 50674 Köln, Germany
[2]University of Bremen, Synthetic Biology, Leobener Str. 5, 28359 Bremen, Germany
*Corresponding author. E-mail: masseck@uni-bremen.de

Understanding how neuronal networks generate complex behavior is one of the central goals of neuroscience. Neurotransmitters and neuromodulators play a crucial role in information flow between neurons, and deciphering their dynamics as well as their effects on neuronal activity is key to understanding their behavioral relevance.
In this talk, I will introduce PinkyCaMP, a new red-shifted genetically encoded calcium indicator (GECI) based on mScarlet [1]. PinkyCaMP outperforms existing red-shifted calcium sensors in brightness, photostability, and optogenetic compatibility. It is well tolerated by neurons, showing no toxicity or aggregation, both in culture and in vivo. Additionally, I will present sDarken, a novel family of genetically encoded serotonin (5-HT) sensors based on the native 5-HT1A receptor and circularly permuted GFP (Kubitschke et al., 2022). sDarken sensors exhibit high fluorescence in the unbound state and decrease fluorescence upon 5-HT binding. Variants with different serotonin affinities enhance versatility in serotonin imaging. These sensors demonstrate excellent membrane expression, high specificity, and a superior signal-to-noise ratio, enabling detection of endogenous serotonin release and in vivo imaging. To overcome the limitations of intensity-based fluorescent measurements, we are now implementing fluorescence lifetime imaging (FLIM) as a novel readout for serotonin dynamics.

Short bio: Olivia earned her PhD in Neuroscience from the Ruhr University Bochum. Originally trained as an electrophysiologist, she later expanded her expertise to optogenetics, protein design, circuits neuroscience, behavior and machine learning methods. Olivia began her postdoctoral research in the lab of Stefan Herlitze and later became a junior group leader and assistant professor for advanced fluorescence microscopy at the Ruhr University. She then accepted in 2018 a position as an associate professor for Synthetic Biology at the University of Bremen. Now, Olivia leads the Neuromodulatory Circuits Lab at the University of Cologne.

References

[1] Fink R, Imai S, Gockel N, Lauer G, Renken K, Wietek J, Lamothe-Molina PJ, Fuhrmann F, Mittag M, Ziebarth T, Canziani A, Kubitschke M, Kistmacher V, Kretschmer A, Sebastian E, Schmitz D, Terai T, Gründemann J, Hassan S, Patriarchi T, Reiner A, Fuhrmann M, Campbell RE, Masseck OA. PinkyCaMP a mScarlet-based calcium sensor with exceptional brightness, photostability, and multiplexing capabilities. bioRxiv [Preprint]. 2025 Jan 11:2024.12.16.628673. doi: 10.1101/2024.12.16.628673. PMID: 39763884; PMCID: PMC11702558.
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Wednesday, May 7th 8:45 - 9:30 **KEYNOTE TALK**

Imaging with multimode fibers

Demetri Psaltis*

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*Corresponding author. E-mail: demetri.psaltis@epfl.ch

We tap into the large number of spatial modes (>10,000) available in multimode fibers (MMFs) for endoscopic imaging. We construct a database for training a neural network by experimentally recording input-output pairs from the MMF. The trained network reconstructs the input to the MMF from the light intensity measured at the output [2,3]. A neural network can also be trained to produce the input that will result in a desired pattern at the output of the fiber [4]. A spatial light modulator is used in this case to shape the input wavefront. The combination of the MMF and the digital processing at both ends of the fiber, converts the MMF to an imaging system with capabilities in many instances similar to a lens. For instance, light can be focused and digitally scanned at the far end of the fiber, a modality that has been used to demonstrate fluorescence microscopy, confocal microscopy, selective ablation and 3D printing through a fiber in an endoscope.

Short bio: Demetri Psaltis received his BSc, MSc, and PhD from Carnegie-Mellon University, Pittsburgh, Pennsylvania, USA. In 1980, he joined the faculty at the California Institute of Technology, Pasadena, California, USA. He moved to the Ecole Polytechnique Federale de Lausanne (EPFL) in 2006. His research interests include imaging, holography, biophotonics, nonlinear optics, and optofluidics. He has authored or coauthored over 400 publications in these areas. He is a fellow of the Optical Society of America, IEEE, the European Optical Society, and SPIE. He was the recipient of the International Commission of Optics Prize, the Humboldt Award, the Leith Medal, and the Gabor Prize.

References

[1] Demetri Psaltis and Christophe Moser, Imaging with multimode fibers, Optics and Photonics News, pp. 24-31, vol. 27, (2016).
[2] Navid Borhani, Eirini Kakkava, Christophe Moser, Demetri Psaltis, Learning to see through multimode fibers, Optica, Vol. 5, Issue 8, p. 960, (2018).
[3] Babak Rahmani, Damien Loterie, Georgia Konstantinou, Demetri Psaltis,
Christophe Moser, Multimode optical fiber transmission with a deep learning network,
Light Science and Applications, 7, Article number: 69 (2018)
[4] Babak Rahmani, Danien Loterie, Eirini Kakkava, Navid Borhani, Ugur Tegin, Demetri Psaltis, Christophe Moser, Actor neural networks for the robust control of partially measured nonlinear systems showcased for image propagation through diffuse media, , Nature Machine Intelligence, volume 2, pages403–410 (2020)

Wednesday, May 7th 9:30 - 10:00 **INVITED TALK**

Optical cochlear implants based on µLEDs and their hybrid combination with conventional electrodes

Patrick Ruther
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Cochlear implants (CIs) are the most successful neuroprostheses worldwide, with over one million patients benefiting from them. These implants suffer however from limited spectral selectivity due to current spread around each stimulating electrode. Optogenetic stimulation of the auditory nerve has demonstrated that this limitation can be overcome, as light from small light-emitting diodes (LEDs) or optical waveguides can be precisely confined in space [1,2]. This presentation will highlight recent advancements in the development and application of optical cochlear implants and explore the potential benefits of hybrid CIs that combine conventional electrical stimulation with micro-LEDs (µLEDs) [3].

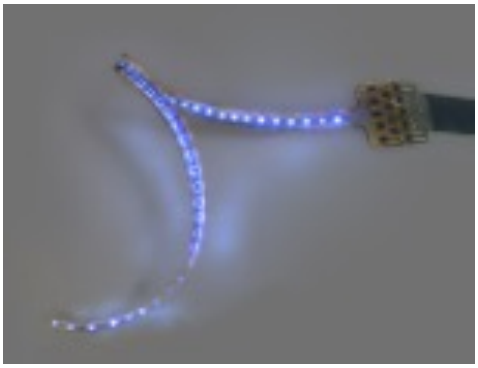

***Fig. 1**: Optical CI with 49 µLEDs integrated in an epoxide-based substrate (µLED size 50×50 µm).*

Short bio: Patrick Ruther received the Diploma degree in physics and the Ph.D. in mechanical engineering in 1993 and 1996, respectively. From 1996 to 1998, he held a post-doctoral position at the Research Center Karlsruhe, Germany, developing LIGA-based microoptical components. Since 1998, he has been a Senior Scientist at the Department of Microsystems Engineering (IMTEK), University of Freiburg. His focus is on the design, fabrication, and characterization of CMOS-compatible MEMS devices, including microoptical functionality for biomedical applications, such as neuroscience and optogenetics. He is a Co- Founder of the spin-off company ATLAS Neuroengineering, Belgium. Patrick Ruther serves as an elected member of the BrainLinks-Braintools Executive Board at the University of Freiburg.

References

[1] A. Dieter et al., "µLED-based optical cochlear implants for spectrally selective activation of the auditory nerve," EMBO Mol. Med., vol. 12, p. e12387 (12pp), 2020.
[2] D. Keppeler et al., "Multichannel optogenetic stimulation of the auditory pathway using microfabricated LED cochlear implants in rodents," Sci. Transl. Med., vol. 12, no. 553, p. eabb8086, 2020.
[3] A. A. Azees et al., "Spread of activation and interaction between channels with multi-channel optogenetic stimulation in the mouse cochlea," Hearing Research, vol. 440, p. 108911, 2023.

Wednesday, May 7th 10:40 - 11:10 **INVITED TALK**

The Utah Optrode Array for large volume optogenetic manipulation in NHP brain

Steve Blair[1]*, Christopher Reiche[1], Andrew Clark[1], Alessandra Angelucci[1], Niall McAlinden[2], Yunzhou Cheng[2], Keith Mathieson[2], Loren Rieth[3]

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[2]University of Strathclyde, Institute of Photonics, Glasgow, UK
[3]West Virginia University, Morgantown WV, USA
*Corresponding author. E-mail: blair@ece.utah.edu

Optogenetics studies in non-human primates (NHPs) are crucial for understanding neural circuit function and dysfunction in human brain disorders. NHP optogenetics has been hampered by the lack of devices for light delivery to deep neural tissue across large areas. We developed the Utah Optrode Array (UOA) [1], a 10x10 array of penetrating glass light-guides, tiling a 4x4mm2 area, bonded to interleaved 10x10 needle-aligned and 9x9 interstitial µLED arrays, for independent photostimulation of deep and superficial brain tissue. Extensive bench and in vivo testing in macaque primary visual cortex demonstrated that the UOA allows for spatiotemporally patterned photostimulation of deep cortical layers with sub-millimeter resolution, at the scale of single cortical layers and columns, over a large volume [2,3]. This selectivity can be scaled up to multiple layers and columns by varying the number of simultaneously activated µLEDs and/or the light irradiance, allowing for high experimental flexibility. The UOA will improve our understanding of neural circuit function in NHPs, and the circuit-level basis of human brain disorders, and offers great potential for clinical applications.

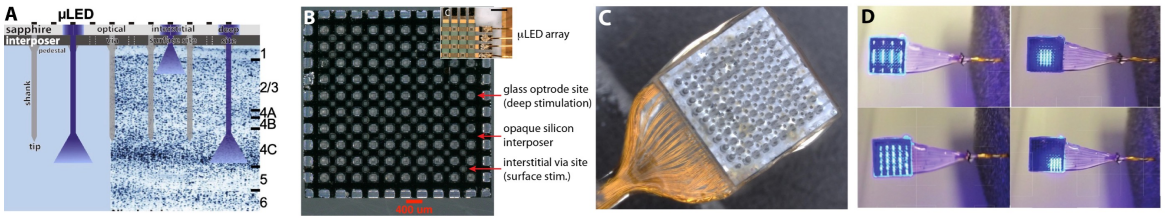

Fig. 1: A. Graphical side-view of UOA device showing surface and deep stimulation. B. Facing-view of UOA device. C. Facing-view after wirebonding and encapsulation. D. Example emission patterns.

Short bio: Steve Blair received BS and MS degrees from Rose-Hulman Institute of Technology in 1991 and 1993, respectively, and the PhD degree from the University of Colorado at Boulder in 1998. Since 1998, he has been with the Electrical and Computer Engineering Department at the University of Utah in Salt Lake City. Prof. Blair's research interests include photonic neural interfaces, plasmonics, slow-light nonlinear optics, photonic microsystems, and microarray technology.

References

[1] N. McAlinden, Y. Cheng, R. Scharf, E. Xie, E. Gu, CF Reiche, R. Sharma, P. Tathireddy, L. Rieth, S. Blair, K. Mathieson, "Multisite microLED optrode array for neural interfacing," Neurophotonics 6 (3), 035010 (2019)
[2] A. M. Clark, A. Ingold, C. F. Reiche, D. Cundy III, J. L. Balsor, F. Federer, N. McAlinden, Y. Cheng, J. D. Rolston, L. Rieth, M. D. Dawson, K. Mathieson, S. Blair, A. Angelucci "An optrode array for spatiotemporally-precise large-scale optogenetic stimulation of deep cortical layers in non-human primates," Communications Biology 7, 329 (2024)
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Wednesday, May 7th 11:10 - 11:40 **INVITED TALK**

On the spectrum or off the spectrum? Shrimp Rhodopsins as far-red absorbing optogenetic tools

Alina Pushkarev[1,2*], Camille Brouillon[1,5], Marjorie Lienard[3,4], Megan Porter[2], Moran Shalev Benami[5], Johannes Vierock[6], Sonja Kleinlogel[7], Peter Hegemann[1]

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[2]Technion - Israel Institute of Technology 3200003 Haifa, Israel
[3]University of Lund SE-221 00, Sweden
[4]University of Liège 4000, Belgium
[5]University of Bern 3012, Switzerland
[6]University of Hawai'i at 96822 Mānoa, USA
[7]Weizmann Institute of Science 7632706 Rehovot, Israel
*Corresponding author. E-mail: alinadrusilla@gmail.com

Although the Mantis Shrimp has intrigued the scientific world for a long time, the visual system of this animal just kept becoming more and more complicated. In order to show that animals such as the mantis shrimp indeed see beyond the human visible spectrum, absorption measurements were made directly on the eyes, complemented with behavioral studies, but no one was able to express and study the rhodopsins biophysically. In 2020, the most extensive sequencing attempt of the mantis shrimp's eye mRNA was published1, revealing an astonishing number of 33 rhodopsins. In this project, we attempted to express and characterize rhodopsins from mantis shrimp, find the red-shifted ones, and explore their potential as optogenetic tools. Far red-absorbing rhodopsins are useful since the red wavelengths penetrate the tissue and scatter more in the neuronal tissue. In a collaboration with Prof. Megan Porter in Hawaii, we received a collection of almost 600 crustacean rhodopsins. These rhodopsins were sorted through a phylogenetic tree, and 25 representatives were synthesized artificially and expressed in HEK293 cells, along with 16 proposed long-wave sensitive (LWS) opsins from *Neogonodactylus oerstedii*. During the project, we were able to characterize the spectrum and G protein sensitivity of these rhodopsins, uncovering that they have exceptional bistability. The middle-wave-sensitive ones are activated by blue light and deactivated by red light, while the long-wave-sensitive ones act in the opposite direction. In true Mantis Shrimp fashion, the more research is conducted, the more questions emerge about this intriguing and complex visual system.

Short bio: Dr. Alina Pushkarev studied bio-medical sciences in the Hebrew University of Jerusalem with a focus on microbiology. During her PhD she moved to the Israel Institute of Technology, where she discovered a completely new family of rhodopsins (Heliorhodopsins, Nature 2018) by using functional metagenomics. Later she moved to Berlin to work with Prof. Peter Hegemann on the expression of long wave sensitive rhodopsins from crustaceans.

References

[1] Porter, Megan L., et al. "Exceptional diversity of opsin expression patterns in Neogonodactylus oerstedii (Stomatopoda) retinas." Proceedings of the National Academy of Sciences 117.16 (2020): 8948-8957.

Wednesday, May 7th 11:40 - 12:10 **INVITED TALK**

Multiscale interrogation of neural connectivity in vivo using precision optogenetics

Mursel Karadas[1,†], Jonathan Gill[1,†], Darnel Theagene[2], Dmitry Rinberg[1], Shy Shoham[1,2*]

[1]Dept. of Neuroscience, NYU Grossman School of Medicine, NYC, NY, USA
[2]Dept. of Biomedical Engineering, NYU Tandon School of Engineering, NYC, NY, USA
*Corresponding author. E-mail: Shoham@nyu.edu

Neural circuits achieve their computational power through their connectivity. Behaviors linking sensation to action are governed by the interplay of neurons communicating over multiple spatial scales, as well as within local populations of neurons. Yet, circuit computations are usually only inferred by observing the activity of neurons, not their interconnections. Here, we describe a system based on a custom 2-photon microscope for multiscale optogenetic interrogation of the effective connectivity between neurons. This system combines large scale patterned illumination using a digital micromirror device (DMD) with precise holographic 2-photon stimulation at a fine spatial scale. Using this combined approach, we demonstrate the ability to identify neurons by their tuning to sensory stimuli as well as the effective input they receive from other circuits. We demonstrate this using two model systems: the mouse olfactory bulb and somatosensory cortex. In the olfactory bulb, we used DMD pattern stimulation to activate glomeruli expressing ChR2 and identify mitral and tufted cells receiving direct input from individual glomeruli. We then interrogated the effective connections between individual mitral cells using holographic stimulation and relate the sign and strength of cellular coupling to distances in odor tuning and differences in glomerular input. This new tool provides a unique window towards unraveling how local connectivity reshapes sensory representations.

Short bio: Shy Shoham is the co-director of the NYU Tech4Health institute and a Professor of Neuroscience and of Ophthalmology at NYU Grossman School of Medicine. His lab develops and applies photonic, acoustic and computational tools for bi-directional interfacing with neural circuits. He holds a Physics BSc from Tel-Aviv University, a PhD in Bioengineering from the University of Utah and was a Lewis-Thomas postdoctoral fellow at Princeton University. He serves on the editorial boards of SPIE Neurophotonics, Journal of Neural Engineering and Translational Vision Sci. & Technology, and has co-edited the Handbook of Neurophotonics.

Wednesday, May 7th 13:50 - 14:20 **INVITED TALK**

Towards deep brain multi-messenger neurophotonics

Filippo Pisano [1,2,*]

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Methods for optical recording of functional neuronal signals have transformed neuroscientific research. This advancement has been enabled by genetically targeted molecular reporters that translate neuronal dynamics into a modulation of fluorescence intensity in response to optical excitation [1]. However, these techniques remain limited in their ability to capture the complex interplay between neuronal function, metabolic activity, and variations in the molecular composition of the local microenvironment [2]. This limitation presents a compelling challenge in neuro-technology [3] and raises the question of how to increase the amount of information that can be extracted from optical neural recordings.
In this talk, I will present recent results that highlight opportunities offered by a broader outlook on the physical phenomenologies involved in light-brain interactions, drawing inspiration from multi-messenger strategies developed in the field of astronomy. Going beyond fluorescence, I will focus on emerging approaches using label-free Raman spectroscopy for biomolecular characterization of neuronal tissue, both in vivo and ex vivo, with particular emphasis on fiber-based configurations [4].

Short bio: Filippo Pisano is Associate Professor of Applied Physics at the Department of Physics and Astronomy 'G. Galilei', University of Padua. He received his PhD from the Institute of Photonics – University of Strathclyde in Glasgow (UK) and he previously held postdoctoral and researcher appointment at the Fondazione Istituto Italiano di Tecnologia – Center for Biomolecular Nanotechnologies in Lecce (IT). His research, recently supported by an ERC Starting grant (2024), focuses on the development of tools and methods for harnessing light-brain interactions to measure neural dynamics with label-free optical recordings.

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Wednesday, May 7th 14:20 - 14:50 **INVITED TALK**

Chronically implantable µLED arrays for optogenetic cortical surface stimulation in mice

Ryan Greer[1], Antonin Verdier[2], Emma Butt[1], Yunzhou Cheng[1], Ella Callas[2], Niall McAlinden[1], Martin D. Dawson[1], Brice Bathellier[2] & Keith Mathieson[1]*

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Optoelectronic devices for optogenetic control of neural activity are an enabling technology, helping to study brain circuits and relate their activity to behavioural metrics. However, developing chronically implantable devices that offer high-resolution neuromodulation remains a challenge, especially if they are to facilitate freely behaving experiments. Here we present a 100-element µLED array (200 µm pixel pitch, 2 × 2 mm² footprint) coupled into a miniaturised, flexible system suitable for chronic implantation and optogenetic stimulation of the surface of the mouse cortex [1]. The µLEDs can remain stable for over 300 hours continuous operation time in-vivo, allowing for months-long chronic experiments. Simultaneous electrophysiology recordings confirmed robust neuronal responses corresponding to low µLED drive currents (<5 mA), minimising thermal effects and supporting future wireless operation. The spatial resolution of neuronal responses was consistent with a simulated model of light scattering in the cortical layers, enabling device optimisation. Behavioural experiments with chronically implanted mice demonstrated robust learning during discrimination tasks using spatially distinct optogenetic stimulation patterns.

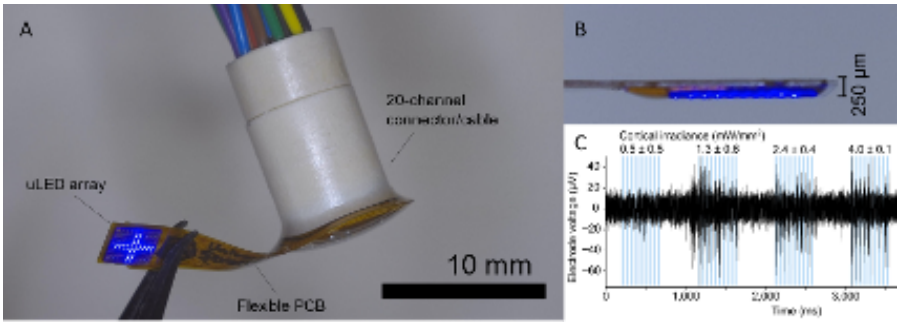

Fig. 1: A) µLED array integrated to a flexible, lightweight package for chronic implantation in mice. B) Cross-section of implantable section for stimulation of cortical surface. C)In vivo electrophysiology demonstrate low cortical surface irradiance can drive reliable multi-unit activity in layer 2/3 neurons.

Short bio: Professor Keith Mathieson is a physicist specialising in neural interfaces and is the Director of the Strathclyde Neurotechnology Centre. Earning his BSc and PhD degrees in Physics from the University of Glasgow in 1997 and 2001, he was elected a Fellow of the Royal Society of Edinburgh in 2024. He holds a Royal Academy of Engineering Chair in Emerging Technologies at the University of Strathclyde, a 10-year award focusing on the development of optoelectronic neural-interfacing technologies. He has contributed to the development of optoelectronic devices, such as retinal implants [2] to restore vision to patients with degenerative retinal conditions, which are now in clinical trials. His publication record includes research into photovoltaic retinal prostheses and optoelectronic devices for optogenetics.

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Thursday, May 8th 8:45 - 9:30 **KEYNOTE TALK**

All-optical manipulation at depth in head-restrained and freely moving mice

Valentina Emiliani

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The genetic targeting of neuronal cells with activity reporters, such as calcium or voltage indicators, has driven a paradigmatic shift in neuroscience, where photons have replaced electrons in reading large-scale brain activities at cellular resolution.
Simultaneously, optogenetics has shown that targeting neuronal cells with photosensitive microbial opsins enables the transduction of photons into electrical currents of opposing polarities. This allows for the activation or inhibition of neuronal signals in a minimally invasive manner. These advances have, in turn, spurred the development of sophisticated wavefront-shaping techniques, enabling 'all-optical' interrogation of deep brain circuits with high spatial and temporal resolution across large volumes [1].
In this presentation, we will discuss the most recent approaches we have proposed to push the frontiers of circuit optogenetics, enabling all-optical manipulation at depth in both head-restrained and freely moving mice.

Short bio: Valentina Emiliani is a CNRS Research Director at the Vision Institute in Paris, where she leads the Photonics Department and the Wavefront Engineering Microscopy group. She and her team have pioneered the use of wavefront-shaping approaches in neuroscience. Specifically, they have developed several light-shaping techniques, such as computer-generated holography and temporal focusing, to sculpt excitation volumes precisely tailored to selected targets. When combined with optogenetics and functional imaging, wavefront shaping enables all-optical control of neuronal activity with unprecedented spatiotemporal precision. Currently, her research focuses on further refining these all-optical techniques and applying them to study neural circuits involved in vision using mouse models.

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Thursday, May 8th 9:30 - 10:00 **INVITED TALK**

Controlling neuronal activity with photoswitchable drugs: from brain waves to single synapses

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The large number of photoswitchable biomolecules discovered and developed in recent years covers a great variety of cellular functions like catalysis of metabolic processes, cytoskeletal polymerization and motors, nucleic acids dynamics, intracellular signaling and perhaps most dazzlingly membrane excitability, which has been at the focus of photopharmacology and optogenetics to study neurobiology. The dream of precisely and remotely photocontrolling every aspect of neuronal activity in intact tissue appears within reach and offers the promise of understanding the underlying molecular mechanisms [1]. Recent and ongoing projects at IBEC focused on photopharmacology will be outlined, including the development and applications of photoswitchable ligands of ion channels and receptors to control neuronal activation and inhibition with one-, two-, and three-photon excitation [2]. These molecular tools allow spatiotemporal control of endogenous proteins in vivo [2-7] at multiple scales from emerging cortical waves in the brain [8, 9] to individual synapses [10, 11]. They also enable multiple applications, from sensory restoration [4] to noninvasive inhibition of pain [6].

References

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Thursday, May 8th 10:40 - 11:10 **INVITED TALK**

Higher order cortices during development: a story of critical periods and innate behaviors

Ileana L. Hanganu-Opatz

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Survival often depends on the ability to react swiftly to environmental challenges, even in the earliest stages of extra-uterine life. Consequently, behaviors that are crucial to survival are often innate, meaning that they occur without prior experience or learning. Such innate behaviors are traditionally thought to largely rely on lower order cortical areas, if not entirely on subcortical circuits that bypass sensory cortices. In contrast, higher order brain areas (HOAs) are considered to rather refine or adapt such instinctive behaviors and mainly account for higher cognitive processing. Among these areas, the prefrontal cortices act as a hub of cognitive processing indispensable for the daily life. Considering that HOAs have a protracted development, their contribution to behaviors early in life has been postulated to be even more limited, yet experimental evidence is still missing. Our recent data revealed how coordinated patterns of electrical activity during defined periods of neonatal development ("critical periods") shape the function of prefrontal circuits and the cognitive performance throughout life [1],[2]. Moreover, we provide experimental data that challenge the traditional view that HOAs develop too slowly to influence early behavior or sensory processing. Instead, we demonstrate that the neonatal OFC plays a critical role in orchestrating innate responses, revealing a level of complexity in neonatal brain circuits that was previously unrecognized.

Short bio: Ileana L. Hanganu-Opatz studied Biology and Biochemistry at University Bucharest, Romania and did her PhD at Heinrich Heine-University, Düsseldorf, Germany. After a postdoc at INSERM Marseille, France, she has been appointed as director of the Inst. Developmental Neurophysiology at University Medical Center Hamburg-Eppendorf. Ileana Hanganu-Opatz pioneered the dissection of developmental circuits and demonstrated the critical role of network activity early in life for adult brain function and behavior. She received Emmy Noether- and ERC Consolidator Grants and acts as speaker of several large national consortia. In recognition of her expertise, Ileana Hanganu-Opatz has received the Adolf Fick-Award of the German Society of Physiology in 2024 and been elected as speaker of the Hamburg Center of Neuroscience, member of the executive board of the German Neuroscience Society, member of the Academy of Sciences in Hamburg, and member of the Committee for Higher Education and Training of FENS. Ileana Hanganu-Opatz is funding member of the FENS-Kavli Network of Neuroscience.

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Thursday, May 8th 11:10 - 11:40 **INVITED TALK**

Illuminating the brain to improve the diagnosis and treatment of brain metastasis

Mariam Masmudi-Martín[1,*]

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Brain metastases or secondary brain tumors occur in approximately 10-30 % of cancer patients as a result of hematogenous dissemination of systemic cancer being the most common cancer in the brain. They remain as an unmet clinical need that recent therapeutic advances in oncology (i.e., targeted therapy or immunotherapy) have not been able to bend in spite of their major benefits on extracranial metastases. Brain colonization by metastatic cells requires the adaptation to a new microenvironment, implying rewiring of genomic, transcriptomic and metabolomic hallmarks, resulting in extremely dynamic tumors that are continuously evolving. Additionally, metastatic outgrowth in the brain frequently impairs patient neurocognition, which is a major contributor to the morbidity of this type of metastasis. This makes brain metastasis a unique emerging entity in oncology based on its particular biology and, consequently, the pharmacological approaches that should be considered. We have exploited the properties of light, avoiding highly invasive methodologies, to improve i) the diagnosis of brain metastases by applying Raman technology to characterize the complexity of the tumor itself and the surrounding microenvironment [1] and ii) the treatment of brain metastasis by modulating the permeability of the blood-brain barrier (BBB)/ blood-tumor barrier (BTB), increasing the permeability of T-cells lymphocytes to target metastatic cells more efficiently in the brain.

Short bio: Mariam obtained her bachelor degree in Biology (University of Malaga, 2009). She carried out her PhD studies at the laboratory of Dr. Zafaruddin Khan at the Centro de Investigaciones Medico Sanitarias (CIMES, Malaga, 2015) studying novel strategies to prevent memory loss in aging and in Alzheimer´s disease. In 2015, she joined the laboratory of Dr. David Fernández at the Autonomous University of Madrid to apply electrophysiological techniques ex vivo and in vivo. In July 2019, she joined the Brain Metastasis Group (PI: Manuel Valiente) leading a research line focused on dissecting the interaction between brain metastasis and neuronal circuits (Cancer Cell, 2023) [2] where she applies her previous background in neuroscience. She was part of the Nanobright consortium that implemented novel methods to better diagnose brain tumors using low-invasive optical approaches (Nature Methods, 2025) [1]. She has been awarded with an AECC postdoctoral fellowship.

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Thursday, May 8th 14:00 - 14:45 **KEYNOTE TALK**

OptoGPCRs: the new generation of inhibitory optogenetic actuators

Ofer Yizhar*

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Long-range communication between brain regions allows synchrony and coordination between distant neural circuits, and is the foundation for complex information processing and behavior. For example, outputs from the prefrontal cortex to diverse subcortical circuits are crucial for regulation of learning, decision-making, and social behavior. Optogenetics has allowed unprecedented advances in understanding the causal roles of distinct neural populations in behavior. However, while optogenetic tools have been widely used for the excitation of neuronal cell bodies and axons, optogenetic silencing of long-range transmission has posed significant challenges1. I will present our work developing several novel optogenetic tools for spatiotemporally-precise silencing of long-range axonal projections. To efficiently suppress synaptic transmission, we designed a new set of inhibitory bistable rhodopsins that couple to the Gi/o signaling pathway and can be used to suppress synaptic release in vitro and in vivo, in a spatially and temporally precise manner. For example, eOPN3 is a highly light-sensitive OptoGPCR that can suppress synaptic release with microwatt light sensitivity2. PdCO, a newly added tool in this family, couples to Go signaling in neurons and allows spectral multiplexing for combined imaging and optogenetic silencing3. These tools, along with new variants that we are currently developing, are opening up new avenues for the functional interrogation of long-range connectivity in neural circuits.

Short bio: Ofer Yizhar is a professor of neurobiology at the Weizmann Institute of Science in Israel. He received his PhD from the Tel Aviv University and did his postdoctoral fellowship with Karl Deisseroth at Stanford University. He established his own research group at the Weizmann Institute in 2011. His lab develops new techniques for studying the brain and uses these techniques to understand the brain circuits involved in memory, decision making and social behavior.

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Thursday, May 8th 14:45 - 15:15 **INVITED TALK**

Next-generation tools to visualize neuromodulators in the brain

V. Rohner[1], S. Curreli[2], P.J. Lamothe Molina[1], Z. Kagiampaki[1], C. Nardin[2], A. Dieter[3], A. Yee[4], G. Foustoukos[5], L. Eschholz[3], P. Milanese[5], L. Banterle[5], T. Ziebarth[6], L. Ravotto[1], J. Dernic[1], M.A. Bhat[1], L. Sonmez[6], B. Weber[1], A. Reiner[6], A. Lüthi[5], S.J. Wiegert[3], C. Ford[4], T. Fellin[2], T. Patriarchi[1,*]

[1]University of Zurich, Institute of Pharmacology and Toxicology, Zurich, Switzerland, [2]Italian Institute of Technology, Genova, Italy, [3]University of Heidelberg, Mannheim, Germany, [4]University of Colorado Denver, Aurora, United States, [5]University of Lausanne, Department of Fundamental Neurosciences, Lausanne, Switzerland, [6]Bochum University, Bochum, Germany

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Genetically encoded sensors represent a rapidly advancing technology that is essential for visualizing extracellular neuromodulator dynamics [1-3]. These tools enable real-time monitoring of behaviorally relevant and task-specific neuromodulator fluctuations, providing insights into their release and uptake/diffusion kinetics, as well as the spatial organization of release events in the brain. Our lab is currently focusing on the development of highly sensitive and multicolor genetically encoded optical probes for norepinephrine [4]. In this talk, I will present our latest advancements in this direction. I will also share my perspective on new research directions, highlighting key areas for further technological development.

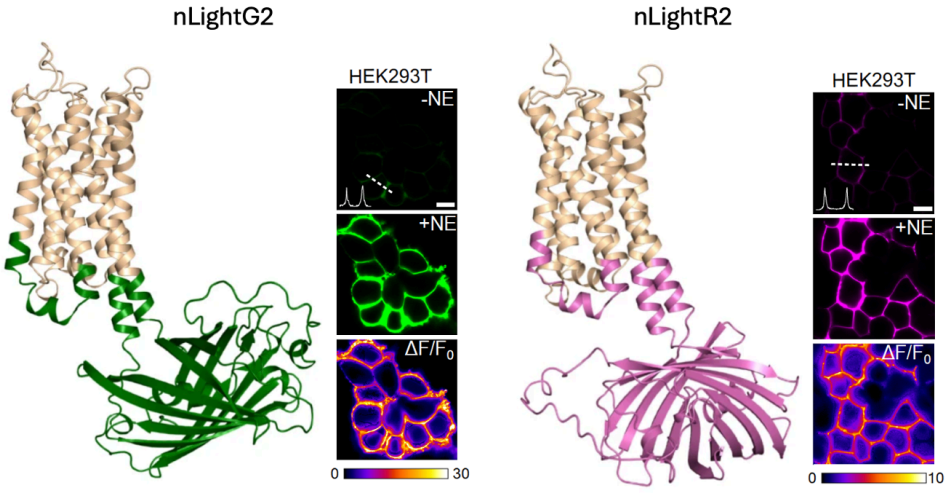

Fig. 1: Next-generation green and red norepinephrine indicators from our laboratory.

Short bio: Tommaso Patriarchi is Assistant Professor of Chemical Neuropharmacology at the University of Zurich since 2019. He obtained his PhD in 2015 from the University of Siena, Italy, and worked as a postdoctoral fellow at the University of California Davis. He developed dLight1, the first genetically encoded sensors that enabled high-resolution in vivo imaging of dopamine dynamics in living animals. Research in his lab focuses on developing next-generation optical tools for observing and controlling the action of neuromodulators in the brain. Tommaso is the recipient of several grants and awards, including an ERC Starting Grant 2020, a project grant from the Swiss National Science Foundation, the Young Scientist Lectureship Award by the International Society for Neurochemistry (2023) and is an EMBO Young Investigator since 2024.

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Thursday, May 8th 15:15 - 15:45 **INVITED TALK**

Graphene-based transparent neuroelectronics for multimodal neural interfacing

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Combining electrical and optical modalities within a single neural interface enables high-resolution, artifact-free interrogation of neural circuits—especially in the context of optogenetics and optical imaging. This talk will present our recent advances in the development of a novel class of optically transparent graphene-based neuroelectronic interfaces, designed for both in vitro and in vivo applications.
For in vitro studies, we have developed transparent microelectrode arrays on quartz substrates that enable high signal-to-noise ratio neural recordings while maintaining optical access for concurrent imaging or optogenetic stimulation. For in vivo use, we employ soft, medical-grade polymer substrates to achieve stable, biocompatible interfaces compatible with chronic implantation and imaging.
Our fabrication process is based on a transfer-free, wafer-level approach that produces multilayer graphene electrodes with excellent electrochemical performance. We introduce micro-corrugations on the electrode surface to reduce impedance while preserving transparency, and demonstrate graphene tracks with one of the lowest sheet resistances reported in the literature—a critical step toward scalable, high-density neural interfaces. By integrating optical transparency, high-density scalability, and excellent electrical performance, these interfaces open new possibilities for neuroscience experiments that require precise stimulation and recording, without compromising optical access, facilitating a more comprehensive view of neural activity across modalities.

Short bio: Vasiliki (Vasso) Giagka (Senior Member IEEE) was born in Athens, Greece. She received the M.Eng. degree in electronic and computer engineering from the Aristotle University of Thessaloniki, Thessaloniki, Greece. She received the Ph.D. degree in Electronic Engineering from University College London, UK. She was a postdoctoral researcher at the Implanted Devices Group at University College London, UK. She is now an Associate Professor of Bioelectronics at Delft University of Technology (NL) and a research group leader at Fraunhofer Institute for Reliability and Microintegration IZM, Berlin (DE). Her research focuses on the fabrication of soft active multimodal neural interfaces. In particular, she investigates new approaches to reduce their size and increase their spatial resolution to meet the challenges of bioelectronic medicines.

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P2	**Optogenetic Activation of Prefrontal Circuits via Upconversion Technology for Depression Treatment** *Jiaming Ji, Jinyan Guo, Weifeng Yao, Chaojin Chen*
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