ERC Project BACKUP

Unveiling the relationship between
brain connectivity and function by integrated photonics

The biological approach

BACKUP neuromorphic photonics and the brain

European Research Council
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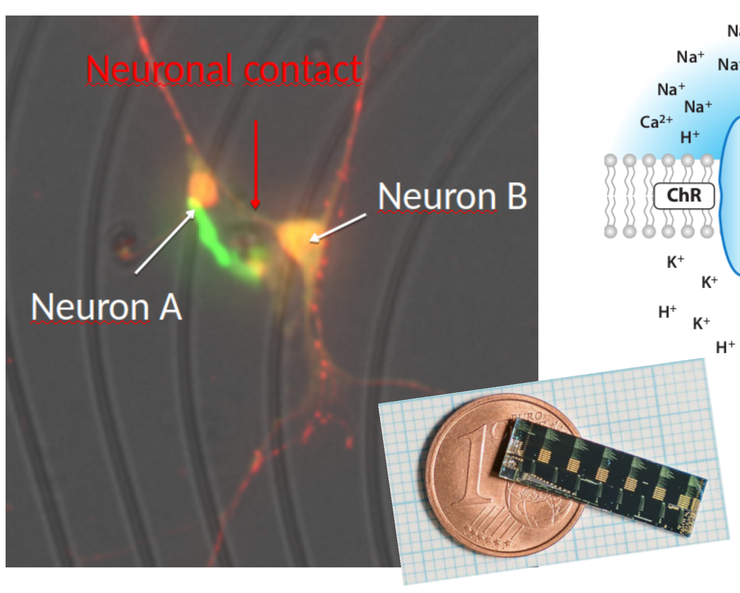
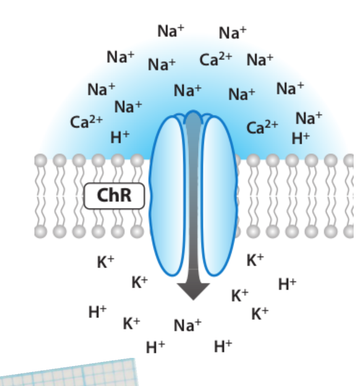
UNIVERSITÀ DI TRENTO
Dipartimento di Fisica

"BACKUP" Project

The idea is to realize an hybrid neuromorphic computing platform in which integrated photonic circuits and a neuronal network are able to compute jointly, in order to emulate brain processes and develop schemes able to supplement neuronal functions. We will take advantage of this to study the process of memory formation and to suppress epilepsy seizures.





Optogenetics

Optogenetic will provide the signal transduction between photonic chip and neurons. Embryonic E17 cortical neurons are transfected with DNA constructs expressing channelrhodopsin and are plated on the surface of the integrated photonic chip. Transfected neurons beacome active when illuminated through the photonic chip..

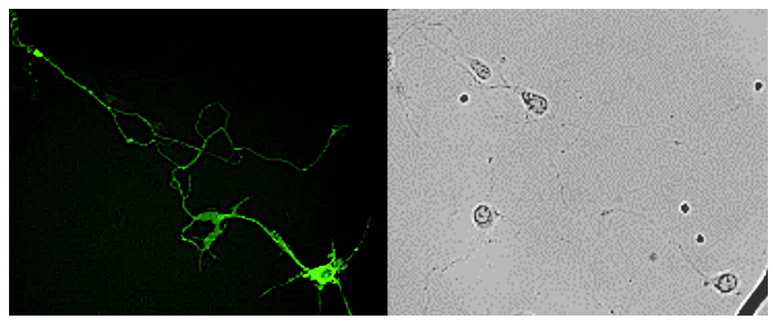


Fig.1: ChR2 transfected neurons.

Signal detection

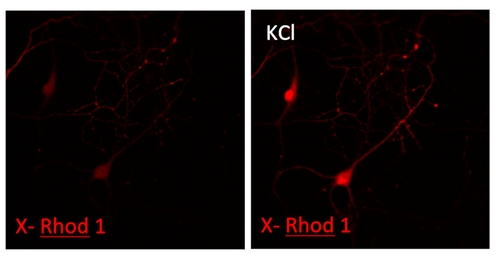


Fig. 2: Cultured cortical neurons labelled with calcium indicator X-Rhod1.

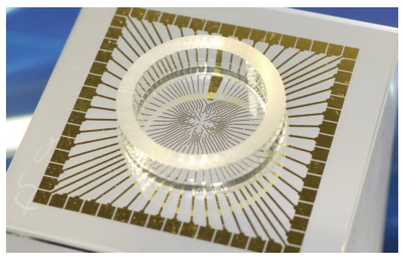


Fig. 3: Multichannel MEA2100 Multi Electrode Array (MEA).

The neuronal activity of neurons will be recorded using both optical and electrical detection: the optical one will be provided by Ca2+ indicators and voltage sensitive dyes, while the electrical one by a MEA system. The activation map of the network will be used to study its dynamics and to implement artificial photonic neurons.

Memory formation

The formation of memory is induced by selective activation of a specific subset of neurons in the network. These interconnected neurons form an engram. Patterned light illumination via a specific designed chip will allow the study of the engram formation.

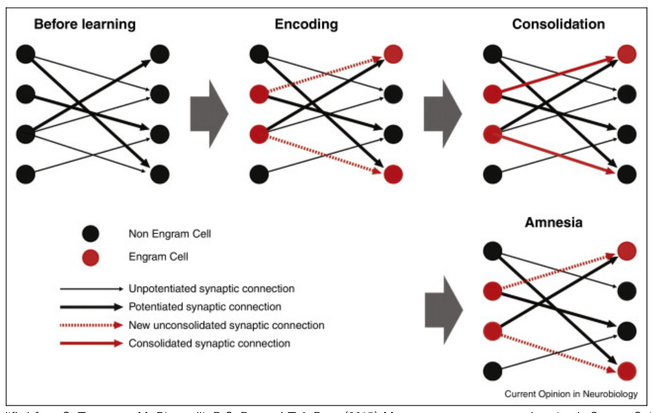
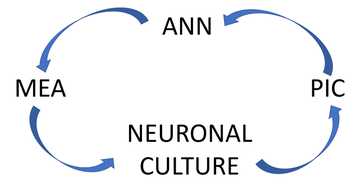


Fig. 4: in retrograde amnesia. Modified from S. Tonegawa, M. Pignatelli, D.S. Roy and T.J. Ryan (2015) Memory engram storage and retrieval. Current Opinion in Neu-robiology, 35:101–109

Epilepsy detection and suppression

Epilepsy is a chronic disease, characterized by spontaneous and recurrent bursts of neuronal hyperactivity (seizures). In vitro, seizures can be induced by the administration of convulsant agents which alter ionic properties of neuronal membrane, leading to hyperexcitability.



BACKUP will experiment the continuous recording of the neuronal activity, the recognition of the seizure by the opportunely trained RCN and the depression of the neuronal activity via optical excitation of selected channel-rhodopsin proteins. This will suppress seizure activity in neuronal networks in vitro.

Photonic chip

A photonic chip was designed in order to be able to address the single neurons with light.
Si3N4 waveguides ending with grating scatterers create a spotted light pattern on the neuronal culture.

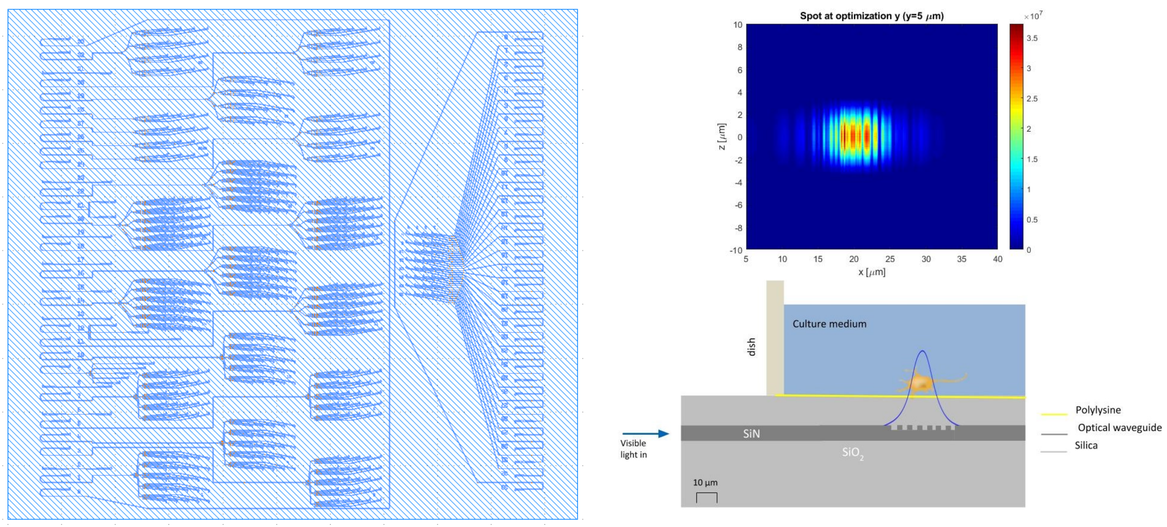


Fig. 5: (Left) The photonic chip designed to create a spotted light pattern on the neuronal network. (Top Right) Spot created on the surface of the chip by the designed scattering gratings. (Bottom Right) Cross section of the system and working principle of the scattering grating.

The Bio BACKUP Team