Sapienza University of Rome
School of Pharmacy and Medicine
Department of Physiology and Pharmacology

PhD program in Behavioral Neuroscience

Luca Berdondini

Neuroscience and Brain Technologies
Istituto Italiano di Tecnologia - Genova

Network electrophysiology with high-resolution neuroelectronic devices

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Aula Luciani
(University Campus – Building CU027)

for info: stefano.ferraina@uniroma1.it; 06 49910306

Dynamics of visual perception and collective neural activity

Abstract

The challenge of establishing access to large brain areas at the scale of single neurons has occupied neuroscientists and engineers for decades, but current methods, based on optical approaches, magnetic resonance or microelectrodes, are still limited with respect to the accessible spatial and/or temporal scale. Among these techniques, microelectrodes remain the most precise transducers of electrophysiological signals from single neurons, but they are typically limited in the number of accessible neurons.
During this seminar, I will present an emerging approach based on the design of microelectronic circuits that is used to realize new generations of devices and probes able to record electrophysiological signals at sub-millisecond temporal resolution, from several thousands of closely spaced microelectrodes. While introducing the technological concepts behind these probes, I will focus on the experimental results achieved so far on increasingly complex neuronal systems, ranging from cultured neuronal networks, brain slices and retinal whole mounts. These case-studies will highlight the capabilities of these devices to literally image extracellular electrical signals and how to exploit them for studying the properties and responses of neuronal networks and brain circuits. Finally, I will introduce an emerging approach based on plasmonic nanostructures that allows to establish intracellular couplings and that can be combined with these high-resolution electrode array devices. This is a promising approach that might enable to perform multiscale monitoring at single-cell resolution of molecular and electrical signals within networks.

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Short Biography

Luca Berdondini was born in 1974, in Locarno (Switzerland). He received the M.Sc. degree in microengineering from the Swiss Federal Institute of Technology of Lausanne in 1999 with a Master Thesis at Caltech (USA). After a short working experience in robotics, he began his Ph.D. studies in the field of bio-electrochemical sensor arrays at the Sensors Actuators and Microsystems Laboratory of the Institute of Microtechnology, University of Neuchâtel. He received his Ph.D in 2003 with a thesis on micro- and nano-fabricated interfaces for in-vitro electrophysiology, introducing an innovative concept for high-resolution CMOS based microelectrode arrays (MEAs). Post-doctoral R&D (2003 – 2007) was oriented on the development of chip integrated solutions for in-vitro neurophysiology and bio-sensor applications, contributing to EC and industrial funded projects. Currently, Luca Berdondini leads the NETs[3] Laboratory at the Fondazione Istituto Italiano di Tecnologia (IIT), in the department of Neuroscience and Brain Technologies (Genova, Italy). His current research focuses on the development and experimental application of high-resolution neuroelectronic platforms based on CMOS-technology enabling recordings from thousands of micro-/nano-electrodes for electrophysiology and neuroscience.