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PhotoMEA: a new optical biosensor for the study of the functional properties of neuronal networks

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Nano Photonic

Technological innovations in the fields of biomedical optics and electronics have lead to an extremely high level of miniaturization. These steps opened important perspectives to interface optoelectronic instruments with cellular systems. In this frame, a patent was registered for a novel optoelectronic technological solution, named PhotoMEA, for the study of the neuronal activity in culture, in order to understand the physiological and pathological functioning of neuronal networks.

At present, the neuronal functional properties are investigated either by a large-scale approach (i.e. MicroElectrode Array devices, MEAs) that enables the study of the general activity of a complex neuronal network, or alternatively by a micro-scale approach (i.e. intracellular or patch electrodes) suitable for the detailed analysis of the molecular mechanisms that actively contribute to the generation and modulation of the single neuron activity. Systems based on electrodes have yielded important results in neurophysiology, but now they start to show some severe limits, such as the possibility of inducing cellular damage in the case of intracellular electrodes and the poor spatial resolution in the case of MEAs.

The PhotoMEA device combines two optical tools for studying the functional properties of in-vitro neuronal networks. Light stimulation and optical recording of neuronal activity are promising approaches for investigating the molecular mechanisms at the basis of neuronal physiology. In particular, flash photolysis of caged compounds offers the unique advantage of allowing to quickly change the concentration of either intracellular or extracellular bioactive molecules, such as neurotransmitters or second messengers, for the stimulation or modulation of neuronal activity. Moreover, optical recordings of neuronal activity by Voltage-Sensitive Dyes (VSDs) allow to follow changes of neuronal membrane potential with high-spatial resolution. This enables the study of the sub-cellular responses and that of the entire network at the same time.

Combining these two optical methods the micro-scale approach (stimulation) meets the large-scale approach (recording). This methodology may be extremely useful for testing the ability of drugs to affect neuronal properties as well as alterations in inter- and intra-neuronal communication.