SPATIO-TEMPORAL CONTROL OF NEURONAL ACTIVITY WITH HOLOGRAPHIC PHOTOACTIVATION PATTERNS

M. Zahid, M. Velez-Fort, C. Ventalon, E. Papagiakoumou, MC. Angulo and V. Emiliani
Laboratory of Neurophysiology and New Microscopies, CNRS UMR 8154,
Inserm U603, University Paris Descartes
45, rue des Saints Pères, 75270 Paris Cedex 06, France
Email: cathie.ventalon@parisdescartes.fr

In recent years, the use of advanced optical techniques has been generating a growing interest in the field of neurobiology not only for visualizing neuronal structures and signaling processes, but also for controlling neuronal activity. This has been made possible by a rapidly expanding set of photosensitive tools that can be precisely controlled by light excitation [1]. In conjunction with spatiotemporally resolved photo-stimulation techniques, these photosensitive molecules represent the most promising alternative to electrical stimulation, providing ways to control precisely in space and time the activity of specific types of brain cells. These approaches require fast, flexible and precise illumination schemes, permitting a selective activation and imaging of sub-cellular regions or multi-cellular ensembles, with enough power to drive quick and fast gated reactions. We have recently obtained one successful solution to this problem in the form of a one-photon (1P) scan-less holographic microscope [1], where a liquid crystal spatial light modulator in the excitation path generates 2D and 3D multiple diffraction limited spots or, alternatively, shaped domains of excitation that accurately cover sub-cellular structures. We have shown that shaped holographic illumination for large excitation areas has a significant higher axial resolution than a Gaussian beam [2], and concentrates all the power of the laser on the desired region, thus providing the high intensity needed for fast uncaging or photostimulation. In previous studies, we have used holographic illumination to control glutamate uncaging on different neuronal cells in brain slices [2]. Here, we extend the use of holographic photolysis to multiple neurons excitation (Fig 1).

The system combines a liquid crystal device for holographic patterned photostimulation, high-resolution optical imaging, HiLo microscopy [3], to define the stimulated regions and a conventional Ca\(^{2+}\) imaging system to detect neural activity. By means of electrophysiological recordings and calcium imaging in acute hippocampal slices, we show that the use of excitation patterns precisely tailored to the shape of multiple neuronal somata represents a very efficient way for the simultaneous excitation of a group of neurons.

**Fig. 1: Holographic patterned light.**
a) A selected region from a fluorescence image recorded with HiLo microscopy showing OGB-loaded CA1 neurons of a hippocampal slice is used to calculate the phase profile to shape the excitation pattern in order to selectively excite b) the cell somata of or c), for a better defined uncaging-region, their contours. Adapted from Ref [4].

REFERENCES: