MAP-fis Essay Proposal, 2015-2016

(*please write in English*)

Supervisor

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Title

Opportunities of Micro and Nano Optical Fiber Tools in Neuroscience

Area

(*Materials, Optics, Condensed Theory, High Energy Theory,....*);

Optics, Neuroscience, Near-field Optics, Optogenetics, Optical Fibers, Optical tools, Neurodegerative diseases

Summary of Proposal

The development of optical tools for imaging, manipulating, trapping, guiding and collecting light onto biological structures has been having a significant impact in the study of intrinsic human neural mechanisms, as well as of the neural pathways characterizing neurological diseases. These achievements are being reached due to recent developments in Photonics applied to Biology and Medicine, and with the help of contributions by the Near-Field Optics.

Near-Field Optics is a promising research field that was recently developed, triggered by the constant need to measure, fabricate and manipulate individual structures on the nanometer scale. By allowing the investigation of individual nanometer-sized structures through the confinement of relevant radiation to sufficiently small extensions, Near-Field Optics allows structures characterization with high spatial resolution, challenging the optical diffraction limit. The development of such concept gave origin to nano up to micro optical probes, which have been applied for sensing purposes, having also a remarkable impact in the development of *optical tweezers*. Those are structures that, based on the effects of the forces that are exerted by a strongly focused optical beam on a given particle with dimensions between nano and micrometers, are able to trap and manipulate single cells and cellular organelles. In addition to this wide field of applications, fiber probes are being also successfully applicated in optogenetic experiments, guiding light over light-sensitive genetically modified cells.

Optogenetics is a very recent field in which optical and genetic principles are applied in order to manipulate neuronal activity (by switching on and off several types of neurons merely by using light at different wavelengths). This new technology therefore reveals to be a very promising

method for *in vivo* experiments for achieving new insights about the causal role of several cells of neural circuits. Taking into account its temporal resolution (it allows biological optical control in a millisecond scale), and its precision (being highly cell-specific), optogenetics has opened doors for developing new strategies to study cellular biological behaviour, having impact in both health and disease and being considered the method of the year by Nature in 2010. In the past few years, both the fields of targeted genetic techniques and photonics are being developed to be used together for allowing light-induced modulation of neural activity in living tissues and for creating optotools - hybrid systems that can both stimulate or inhibit firing action potentials in neurons. The standard approach for delivering light over the target neuron or cell, in order to modulate its physiological activity, is based on an optical fiber implanted into the skull of a animal brain – rat/mice - coupled to a light source - a laser -, through an optical fiber. Specific cells can be therefore manipulated by the light transmitted by the optical fiber probe tip, by forcing the expression of microbial proteins that are light-sensible - opsins - in those cells. Therefore, by precisely measuring the effects of those manipulations in real-time, optogenetics is revolutionizing neuroscientists' capacity to understand how defined neural circuit elements contribute to normal and pathological brain functions, having light guidance optical probes a remarkable role in the whole system. Since 2007 that special hybrids of fiberoptics and electrodes ('optrodes') have allowed high-speed simultaneous readouts that kept pace with the high-speed inputs of optogenetics. Novel devices and systems are now required to advance this vision.

In this essay proposal we aim at to explore and envision possible novel synergies of these crossing areas and fetch for new applications for these and future optical tools and sensors in neuroscience. The student is expected to perform the following tasks:

Prepare state-of-the-art about optical fiber tools applied to Neurosciences (to trap, manipulate, guiding/collecting light, onto normal/genetically modified cells) – historical background, characterization, fabrication methods, current applications, new trends;

Have a first contact with optical fiber fabrication methods and optical tools;

Be exposed to neuro-biology and neuroscience optogenetics experiments (@INESC TEC and in cooperation with I3S and FMUP).

Prepare a project plan in new optical tools applied to neuroscience challenges;

(*continue if necessary*)

References

(t*o allow students first look at topic*)

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