Light-printed, light-driven and light-coupling micro-tools for contemporary nano-biophotonics.

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Publication date:
2014

Document Version
Early version, also known as pre-print

Light-printed, light-driven and light-coupling micro-tools for contemporary nano-biophotonics

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At the Technical University of Denmark (DTU), we have previously proposed and demonstrated micro-targeted light-delivery and the opto-mechanical capabilities of so-called wave-guided optical wave-guides (WOWs). As the microscopic WOWs are optically trapped and maneuvered in 3D-space, it is important to maintain efficient light-coupling through these free-standing waveguides within their operating volume. We propose the use of dynamic diffractive techniques to create focal spots that will track and couple to the WOWs during full volume operation and with six-degrees-of-freedom. This is done by using a Hamamatsu Photonics LCoS-SLM to encode the necessary diffractive phase patterns to generate the multiple and dynamic coupling spots. The method is initially tested for a single WOW and we have demonstrated dynamic tracking and coupling for both lateral and axial displacements on our proprietary Biophotonics Workstation.

The work is based on a recent feature article in Nature Photonics where we promote the idea of fabricating a new class of so-called Topology Optimised microstructures via two-photon polymerization (2PP) and pioneering their use in nano-biophotonics to interact with and probe reconfigurable micro-environments. In this research the aim is to combine 2PP micro-fabrication and optical manipulation to demonstrate a structure-mediated micro-to-nano coupling paradigm for controlled manipulation of subdiffraction-limited nano-tools. The three-dimensional structures and resolution realizable in 2PP light-fabrication can already today create nano-tools fused into larger microstructures that, in turn, are steerable by dynamic light beams that are oblivious to the diffraction barrier. Applying multiple independently controllable beam traps on these microstructures using our proprietary BioPhotonics Workstation platform enables real-time "light robotic" manipulation with six degrees of freedom. This sets the stage for advanced studies using calibrated steering of optimally shaped and functionalized tools for biophotonics at the cellular level not available at the scientific arena as of today.

Two-photon spatio-temporal light engineering can also be used to expand the microscopic imaging modalities available to assist this light-driven nano-manipulation approach. Featured in a recent issue of Nature Methods we were pioneering research in neuro-photonics and optogenetics highly useful for future biophotonics undertakings on the smallest cellular scales. This research promises a powerful approach for controlling light-gated ion channels and pumps that makes it possible to probe intact neural circuits by manipulating the activity of groups of genetically similar neurons. This makes it possible to precisely aim space-time sculpted light at single neuronal processes, neurons or groups of neurons. The underlying light-engineering is currently being scientifically refined in a strong international context to address - for the first time - arbitrary and speckle-free parallel spatial and temporal two-photon light-sculpting.

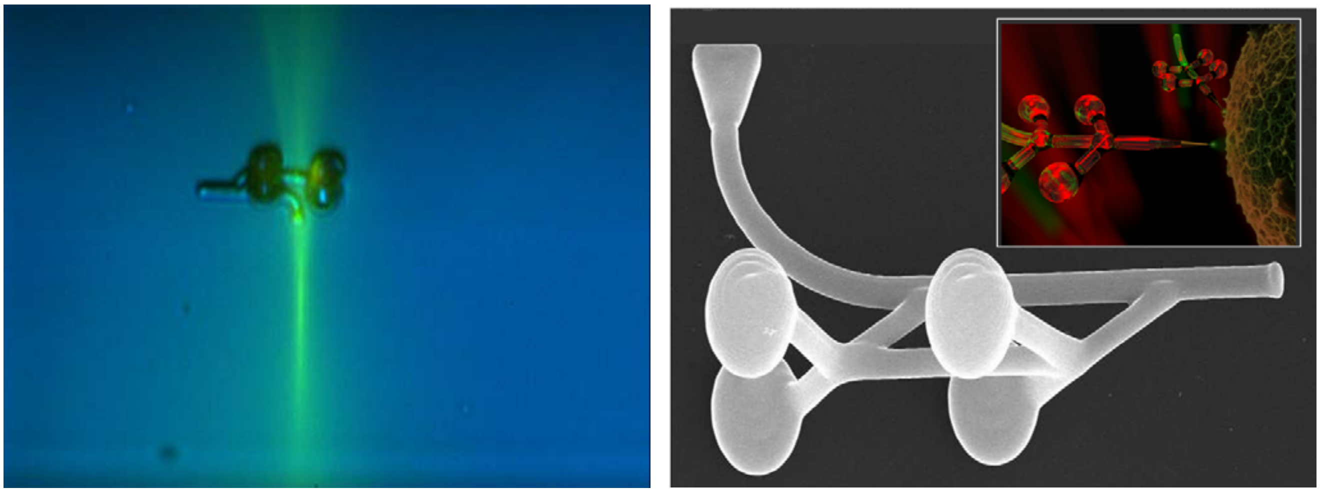

Figure 1: Advanced light sculpting, light manipulation and optical nanobio-probing. Adapted from refs [1-8].

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