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Published in:

Proceedings of 6th EOS Topical Meeting on Optical Microsystems.

Publication date:

2015

Document Version

Publisher's PDF, also known as Version of record

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Citation (APA):

Glückstad, J., Palima, D., Bañas, A. R., & Villangca, M. J. (2015). Novel light-driven micro-robotics - POSTDEADLINE. In *Proceedings of 6th EOS Topical Meeting on Optical Microsystems*.

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Novel light-driven micro-robotics

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SUMMARY

Modern micro- and nanoscopy demands functionalities, not only for observing micro-biologic phenomena, but also for reaching into and manipulating mesoscopic constituents. This post-deadline contribution describes our latest generation of light-crafted micro-tools for enabling all-optical light-activated robotics on microscopic scales.

Introduction

Optics is a key enabling technology for getting a grasp of the micro- and nano-world. Creatively combining complementary approaches can realize advanced optical modalities that integrate an increasing number of functionalities and augment not just passive observation but also active access and control over the sub-micron world [1-2]. Using a merger of light and matter sculpting, we have laser-fabricated free-floating waveguides that can be optically trapped and “remote-controlled” in a volume; hence coined Wave-guided Optical Waveguides (WOWs). Combining micro-fabrication with optical trapping and manipulation allows us to exploit these WOWs in versatile and dynamically reconfigurable architectures [3]. A plurality of counter-propagating beam-traps relayed to the trapping volume by low-NA microscope objectives on our Biophotonics Workstation (BWS) control the WOW-structures demonstrating the possibility for a structure-mediated paradigm where micron-sized tools are used to achieve optical near-field tip-size access. However, realizing the full potential of this new structure-mediated approach in challenging microscopic geometries requires a versatile 3D light coupling that can dynamically track a plurality of WOWs to ensure continuous optimal light coupling on the fly.

To maintain high light throughput for the WOWs, we have integrated real-time updated computer generated holography that can dynamically control the 3D focus position of the coupling beams. Our results show that we can simultaneously maneuver the WOWs in 3D space while dynamically coupling light through them (i.e. Figs. 1a and 1b). This structure-mediated approach enables a host of new microscopic functionalities. WOWs with metal-coated tips can exploit plasmonic effects to achieve extreme confinement for localized light excitation and acquisition. Nanowires that exhibit particular optical properties can be attached to the WOWs [4] to obtain tunable and fully maneuverable “nano-torches”. Another potential application is for advanced Tip-Enhanced Raman Spectroscopy in a full 3D-manuevable configuration. The micro-to-nano light coupling and the possibility of integrating material transport in the WOW-structures can be a new gate-way for life sciences at the sub-cellular level [5]. The design possibilities offered by

laser-fabricated WOWs, the augmented holographic light coupling combined with the advanced 3D micromanipulation opens the possibility for performing exciting precision engineered light-matter interaction where it is needed. Our latest experimental results will be demonstrated in this post-deadline presentation.

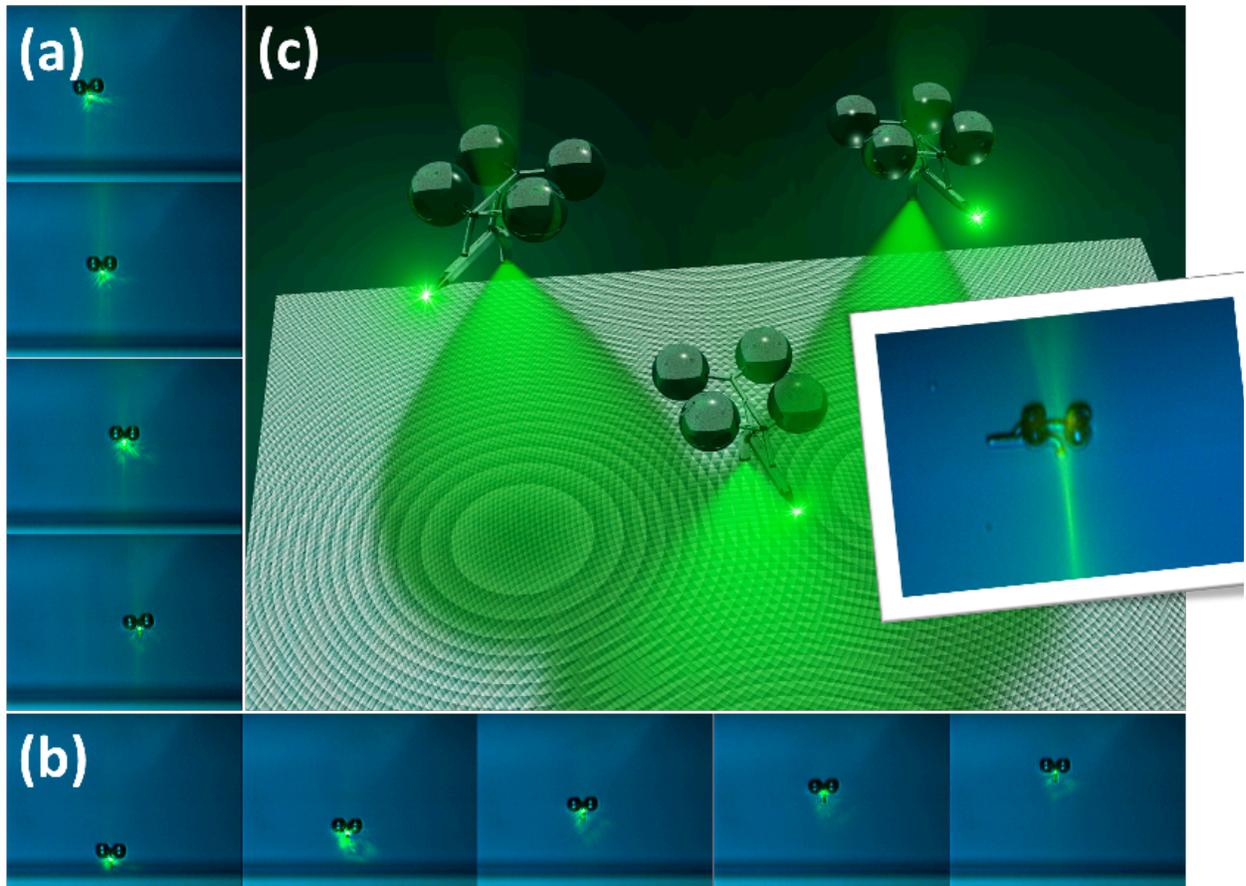


Figure 1. Real-time dynamic diffractive coupling of light to 3D-manipulated micro-tools. The experimental demonstrations show (a) lateral and (b) axial tracking of the coupling beams. (c) Concept art showing the diffractively-coupled micro-tools. Adapted from refs. [1-5].

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