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Biomedical Optics Express Feature Issue Introduction: Optical Manipulation and Its Applications (OMA) 2023

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Abstract: The feature issue of Biomedical Optics Express presents studies that were the focus of the Optical Manipulation and its Applications (OMA) meeting that was held on 24 - 27 April 2022 in Vancouver, Canada.

A Topical Meeting on Optical Manipulation and its Applications (OMA) was conducted by OPTICA in April 2022 in conjunction with the Optica Biophotonics Congress in Vancouver, Canada. The authors presented their ground-breaking research across a wide variety of topics, all related to optical trapping applications, during three full days of technical sessions. The papers published in this issue of Biomedical Optics Express are a collection of contributions by authors who presented their work at the OMA meeting.

Included in this issue are two papers that use optical tweezers to measure the deformability of red blood cells. In the first, by Liu et al., an efficient and cost-effective method for creating a dynamic scanning dual-trap optical tweezers system is demonstrated [1]. In this method a motor-driven glass plate is placed in the path of one of the two laser beams external to the microscope. Rotations of the plate produce small displacements of the focal spot in the trapping plane, thereby changing the separation of the two traps. This technique is used to stretch red blood cells demonstrating a change in the deformability of cells with different morphologies that occurs when they are stored *in vitro*. Stilgoe et al. report similar red blood cell stiffness measurements performed using holographic optical tweezers to generate the dynamic dual optical traps required for stretching [2]. Significantly in these experiments they quantify the stiffness of the cells as a function of the duration of cold storage up to 50 days, finding that the stiffness of discocytes tended toward that of echinocytes after approximately 30 days.

The identification of pathogens in blood serum is the subject of the contribution by Vaculík et al. Their method uses optical tweezers Raman spectroscopy of an optically trapped bacterium followed by a spectral unmixing analysis of the Raman signal to identify four bacteria types in blood serum [3]. This study paves the way for rapid microbe identification directly in blood serum without the intervention and influence of a human data analyst. Raman spectroscopy for the identification of bacteria is also the goal of the work presented by Kotsifaki et al., where the problem of the weak Raman signal and poor signal-to-noise ratio from bacteria is surmounted through the use of a novel metamaterial nanostructure that exhibits a Fano resonance to enhance the signal [4]. The authors demonstrate that this method of Fano-Resonant Enhanced Raman Spectroscopy can detect and identify the signature peaks of *Escherichia coli* even at relatively low concentrations, paving the way for the realization of ultrasensitive bacterial identification.

Bacteria are also the subject of study in the work of Camba et al. who have contributed to a paper that shows the impact of optical trapping at different wavelengths on bacterial aggregation

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and biofilm formation [5]. According to the authors, the ideal cluster of bacteria for optical manipulation contains three to fifteen cells, when the bacteria will have undergone changes and will have secreted glue-like substances. However, the clusters will still be able to move when optical forces are applied. By using a laser with a wavelength range of 820-830 nm, biofilm clusters were trapped optically for a prolonged period while minimizing photodamage. This work offers alternative methods for manipulating and controlling biofilm growth using optical methods.

Accurate calibration of optical tweezers is fundamental to their ability to derive quantitative force data, and is typically derived from an analysis of the trajectory of a trapped particle. Pérez-García et al. have developed an approach to derive analytical solutions for the stiffness and diffusion constants in optical trapping by incorporating the integration time and sampling frequency of the trapped particle position measurements [6]. The authors noted that their approach provides accurate and precise results independent of each optical trapping calibration method, with errors that are less than 10% for a few seconds, a few thousand data points sampled under experimental conditions leading to a very good estimation of the stiffness. With this work, common calibration methods can be extended to contexts where the experimental conditions or limitations of the setup prevent them from being used in deal conditions, i.e., obtaining fast and reliable information about stiffness and diffusion in optical trapping with short integration times, high-frequency sampling and large amounts of data. A significant challenge for particle tracking that is highly relevant to the topical meeting is that of tracking a particle in the complex environment that exists inside a cell, that is both spatially and temporally inhomogeneous. To address this, Nakul et al. investigated the stochastic trajectories of a passive microparticle inside a cell using both experiments and theory [7]. In their work presented in this Feature Issue they have show that the contents of the power spectral density (PSD) measurements fall into two distinct frequency regimes: high-frequency fluctuations are associated with the (passive) mechanical properties of the cytoplasm while the low-frequency behaviour reveals the active forces that the microparticle feels from, e.g. motor protein or mechano-enzyme dynamics.

The work of Boateng et al. also addresses a difficulty encountered in particle tracking, whereby even high-speed cameras may not operate at frame rates sufficient to acquire the full trajectory particularly of nanometre sized particles is stiff optical traps. Their approach as reported here uses a residual neural network (ResNet) for morphological characterization of optically trapped nanoparticles on a single-particle level, even with temporally under-sampled trajectories acquired by a camera with a limited detection bandwidth [8]. The algorithm was validated using dielectric particles and extracellular vesicles.

Finally, a review paper on optical trapping with optical nanofibers has been contributed to this issue by Praveen Kamath et al. [9]. Since optical nanofibers have an evanescent field extending outside the surface of the fiber, they are ideal candidates for optical manipulation. The authors highlight some challenges and future potentials associated with optical nanofiber-based trapping.

Disclosures. The authors declare that there are no conflicts of interest related to this article.

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