All-Fiber Beam Shaping for Precise Optical Manipulation within a Single Droplet

Kyunghwan Oh, Hyeonwoo Lee, Junbum Park, Juwon Yoon, Hyeungjoo Lee

Photonic Device Physics Laboratory, Department of Physics, Yonsei University, Korea
E-mail: koh@yonsei.ac.kr

1. Introduction

Optical manipulation of dielectric particles has been rapidly developed to cope with the increasing need for various applications such as optofluidics, optomechanics, and biophotonics. Commercially available optical trapping units are being widely used for both education and research purposes, which are based on focusing a laser light with a high numerical lens to provide a light intensity gradient [1]. Spatial light modulators are also being widely employed in optical trapping to manipulate the light intensity on a transverse plane [2]. However, current beam shaping technologies are using bulk optics, which cannot be used in a microscopic environment. Fiber optic beam shaping has been recently developed [3] and it can take advantage of the inherent small form factor and flexible configuration of the optical fibers.

In this talk, we will review Bessel-like beam generation using optical fibers and discuss how it can be applied to manipulate particles within a single droplet which cannot be achieved by bulk optics.

2. All-fiber Bessel beam generators

There have been two schemes to generate Bessel-like beams; 1) Fourier transformation of micro ring core at the facet of hollow optical fiber (HOF) and 2) Multimode interference along a coreless silica fiber (CSF) [3]. The principles of these methods are illustrated in Fig. 1.

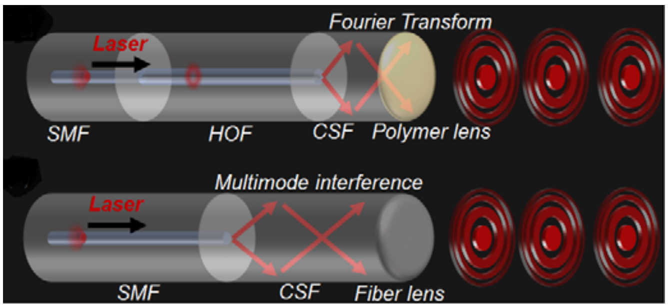

Figure 1. Priniciples of fiber optic Bessel-like beam generation. Top: Fourier transformation of ring core of hollow optical fiber Bottom: Multimode interference along the coreless silica fiber (CSF). Here SMF is single mode fiber.

Fiber optic Bessel-like beams generated by these schemes had the central peak with the full-width at half-maximum of 5~8μm, and the non-diffracting length of 600~900μm. Note that the optical fibers in the devices had the seamless connections and the outer diameter was commonly 125 μm. In contrast to previous bulk optic methods, these fiber optic Bessel-beam generators (FOBG) can be directly fed into a microscopic environment. In Figure 2, applications of FOBGs are shown.

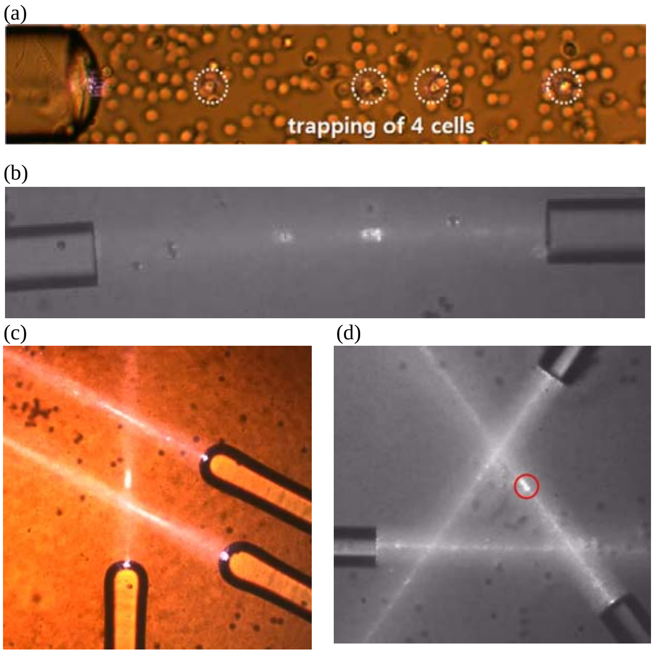

Figure 2. (a) single FOBG trapping 4 cells. (b) particle collider using two counter-propagating FOBGs. (c) three FOBGs to form an open loop (d) three FOBGs to form a closed triangle.

Here we used single FOBG, two of them, and three to manipulate dielectric particles and cells within a single droplet.

3. Conclusions

We successfully developed microscopic Bessel-like beam generators, where segments of optical fibers were seamlessly spliced. Due to their small form factor, multiple Bessel beams were multiplexed or crossed to allow a new degree of freedom in optical manipulation

Acknowledgments

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References

[1] A. Ashkin, et al. Opt. Lett. **11**, (1986) 288
[2] D. G. Grier, Nature, **424**, (2003) 810 (2003)
[3] H. Lee, et al. J. Lightwave Techno. **37** (2019) 2590.