Ultra high-speed variable focus optics for novel applications in advanced microscopy

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The ability to rapidly change the focal plane of an optical system or rapidly change the intensity distribution in a given focal plane has many important applications in real-world imaging systems. In such cases, a fast, tunable optical element with low aberration and high transmission coefficient is necessary, yet few viable systems exist. Here we present an alternative adaptive lens technology that uses sound to create varying index of refraction in a fluid. Known as a tunable acoustic gradient index of refraction (TAG) lens, this device has the ability to provide rapidly tunable focal lengths at microsecond time scales while maintaining high optical throughput and low aberration. We will first introduce the fundamental principles of operation and the unique approach to high-speed focal length scanning with this resonating device as it applies to light sheet, multiphoton, and confocal imaging methods. We will then highlight a simple but powerful imaging technique in which multiple focal planes can be acquired from the volume of a sample in real-time without the need for image processing, complex illumination or mechanical translation of the optics or sample. We apply this method to a number of applications including 3D particle tracking in microfluidic flows to illuminate vorticity and other 3D flow phenomena that cannot be observed using standard fixed optical systems [1,2].

[1] T.-H. Chen, J. T. Ault, H.A. Stone, C. B. Arnold, "High-speed axial-scanning wide-field microscopy for volumetric particle tracking velocimetry," Exp. Fluids, 58, 41 (2017)

[2] S. Kang, E. Dotsenko, D. Amrhein, C. Theriault, and C. B. Arnold, "Ultra-high-speed variable focus optics for novel applications in advanced imaging," Proc. SPIE., 10539, 1053902 (2018)