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# Optically induced electrokinetic patterning and manipulation of particles

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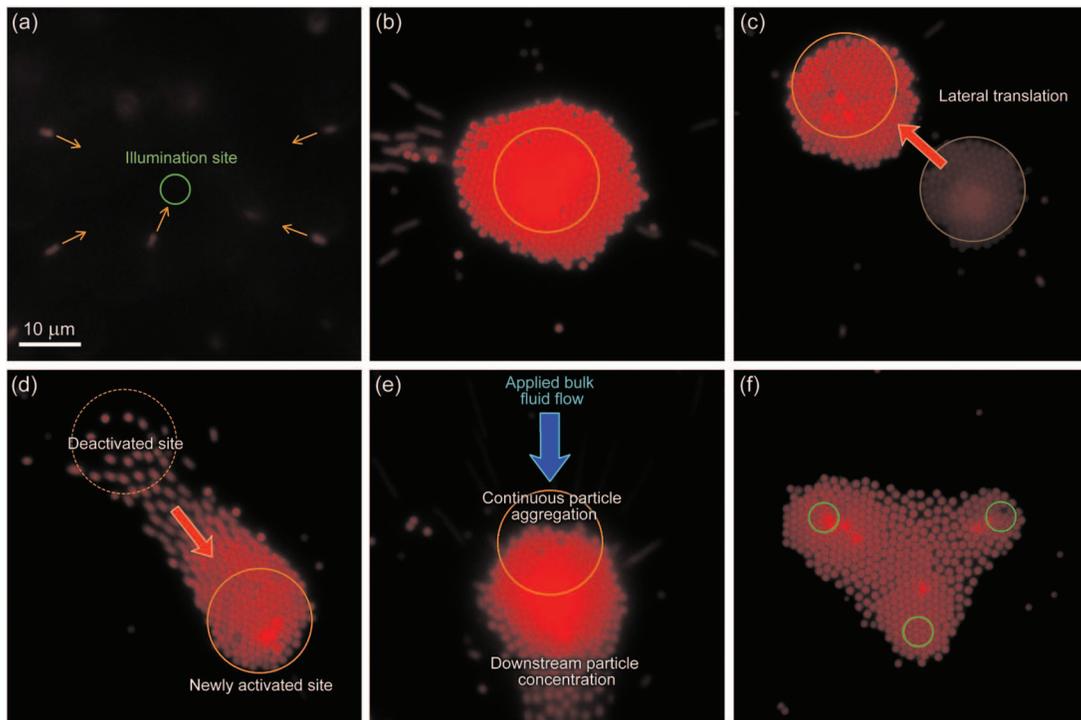


FIG. 1. (Color) (a) Particles (1.0  $\mu\text{m}$ ) are carried by the microfluidic vortex towards the center of the illumination site (b) where they aggregate at low ac frequencies ( $<150$  kHz). Particle aggregations can be translated by (c) dynamically translating the illumination site or (d) deactivating the illumination while simultaneously activating a nearby site. (e) Particles are continuously concentrated while bulk fluid motion is introduced. (f) Multiple illumination sites were used to pattern the particle aggregation (enhanced online). [URL: <http://dx.doi.org/10.1063/1.3200938.1>]

## Optically induced electrokinetic patterning and manipulation of particles

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The ability to easily and dynamically control fluid motion as well as manipulate particles in suspension is important for the development and characterization of a variety of lab-on-a-chip processes. Recently, we have introduced an optically induced electrokinetic technique termed rapid electrokinetic patterning (REP) that can rapidly concentrate, translate, and pattern colloids of many different sizes and compositions. We have tested polystyrene, latex, and silica beads in sizes ranging from 49 nm to 3.0  $\mu\text{m}$ .<sup>1,2</sup>

For our experiments REP was implemented with a highly focused beam of near-infrared light (1064 nm,  $<100$  mW) applied to a liquid sample injected between parallel-plate electrodes separated by 50  $\mu\text{m}$ . The illumination generated sharp thermal gradients in the liquid, yet the overall heating was not enough to induce natural convection due to the small size of the device. An applied alternating-current (ac) field acts upon these gradients resulting in electrothermal fluid motion.<sup>3</sup> A microfluidic vortex results, carrying particles towards its center [Fig. 1(a)].

At low ac frequencies ( $<150$  kHz), the colloids will become attracted to the surface of the electrode. The microfluidic vortex will compact these particles into a crystalline aggregation [Fig. 1(b)]. This aggregation can be translated by moving the location of the illumination [Fig. 1(c)] or deactivating the illumination while simultaneously activating a nearby site [Fig. 1(d)]. The microfluidic vortex continually introduces particles into the trapping region. When bulk fluid motion was applied, the particles were not trapped but rather concentrated for potential downstream processing [Fig. 1(e)]. Various complex illumination patterns have been applied to generate different patterns of particle aggregations [Fig. 1(f)].

Simultaneous application of the focused optical illumination and electric field were necessary for REP. The liquid can be heated directly with the applied highly focused beam of light or indirectly with the electrode or substrate absorbing the illumination. This dynamic electrokinetic technique could be utilized for a variety of microfluidic and colloidal manipulation schemes.

<sup>1</sup>S. J. Williams, A. Kumar, and S. T. Wereley, "Electrokinetic patterning of colloidal particles with optical landscapes," *Lab Chip* **8**, 1879 (2008).

<sup>2</sup>S. J. Williams, A. Kumar, N. G. Green, and S. T. Wereley, "A simple, optically induced electrokinetic method to concentrate and pattern nanoparticles," *Nanoscale* (in press).

<sup>3</sup>A. Kumar, S. J. Williams, and S. T. Wereley, "Experiments on optoelectrically generated vortices," *Microfluid. Nanofluid.* **6**, 637 (2009).