Electrowetting adaptive optical devices for LIDAR

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Abstract: Electrowetting devices are compact, low power, transmissive, and adaptable. We have demonstrated nonmechanical beam steering in a LIDAR system and imaging in a multiphoton microscope, with an electrowetting prism.

OCIS codes: (010.1080) Active or adaptive optics; (010.3640) Lidar; (170.0110) Imaging systems; (170.2520) Fluorescence microscopy; (180.5810) Scanning microscopy.

Beam scanning is critical for microscopy, LIDAR and free-space communications. While mechanical beam scanners are robust, they commonly suffer from drawbacks such as movable parts prone to failure, large power requirements, heavy weights, large sizes, and high costs. In contrast, nonmechanical beam scanners are attractive, as they are generally low weight, compact, low power, and are often inexpensive. One particularly attractive implementation of nonmechanical beam steering is offered by electrowetting-based devices. The electrowetting on dielectric (EWOD) [1] principle enables the control of the shape of a liquid droplet or liquid-liquid interface on a dielectric surface through an applied voltage. The result is an ultra-smooth, tunable liquid interface that is an ideal platform for tunable lenses and prisms. Devices based on the EWOD principle are appealing due to their low power consumption, large range of tunability, and absence of mechanical moving parts. Electrowetting is a versatile technology, and has been used for imaging, optical switching [2-4], and beam scanning [5-7]. Extending electrowetting devices to multiple electrodes enables the generation of a custom surface shape at the liquid-liquid interface [8-10].

We focus on applying electrowetting devices to beam scanning required for multiphoton microscopy and LIDAR. Both applications require devices with Hz-level response. The response time of the devices can be controlled with drive voltages, size, or choice of liquids. We have recently shown response tuning from under-damped to critical to overdamped by simply adjusting the input driving voltages to the devices [11]. Additionally, by selecting a liquid combination (de-ionized water and 1-phenyl-1-cyclohexene) with a large refractive index contrast (Δn: 0.23), low viscosity, and minimal density mismatch, we have shown liquid responses up to 800 Hz, with more than 26 degrees of beam steering [12].

Electrowetting devices with multiple electrodes can be used as a tunable prism. They can be used to replace the galvanometer scanners in multiphoton microscopes [11] or the motorized mechanical scanners, common in LIDAR systems [13]. For microscopy, only a few degrees of steering are required. On the other hand, scanning LIDAR systems require a large output beam and a large steering angle. As the devices operate on surface tension, density mismatch between two liquids constrains the device diameters to mm/cm-scale. We have demonstrated a LIDAR system with 180 degrees of scanning in one dimension, using an electrowetting device, triplet lens and miniature fisheye [13]. Scanning at 200 Hz has been achieved (Figure 1).

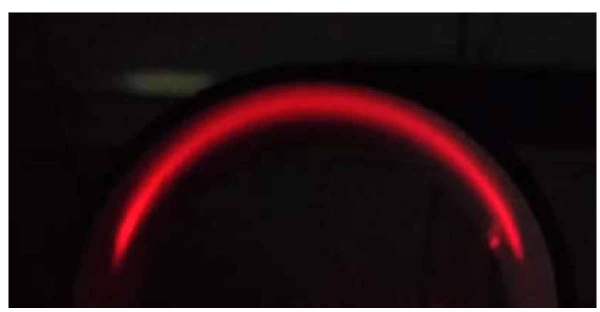

Figure 1. Beam scanning over 180º at 200 Hz, using an electrowetting prism that can be applied to LIDAR.

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