Electronic Supplementary Information

Field strength and frequency tunable, two-way rotation of liquid crystal micro-particles dispersed in a liquid crystal host

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Supplementary Figure 1: Incident angle dependence of cross-polarized transmittance of the anti-paralleled cell containing 5CB at 640 nm. The pretilt angle is determined as $\theta_0 = 1.8^{\circ}$ by crystal rotation method,^[1] with taking $n_e = 1.717$ and $n_o = 1.529$ for 5CB at room temperature.^[2] Note that experiments were performed using an anti-parallel cell with a gap of ~34 µm composed of two glass substrates containing 5CB, and the cross-polarized transmittance was measured with different incident angle of light (with a wavelength of 640 nm) between cross polarizers. After the measurement, the carve-fitting is carried out according to the theoretical formula.



Supplementary Figure 2: Applied voltage dependence of cross-polarized transmittance of a (a) planar alignment and (b) twisted nematic cell at 589 nm. Best fits are obtained when $K_{11} = 6.3$ pN, $K_{22} = 4.5$ pN, and $K_{33} = 9.9$ pN with taking $\Delta \varepsilon_{LC} = 13.6$, $\Delta n = 0.180$ and $\theta_0 = 1.8^\circ$ (red lines). The blue curves calculated with different elastic constants are also shown for comparison. Note that the measurement was performed by using 5CB at 25 °C.



Supplementary Figure 3: (a) Applied voltage and (b) effective electric field (E_{eff}) dependence of cross-polarized transmittance of a pure host LC in the absence of particles at 540 nm. The solid circles and lines are experimental and theoretical values, respectively. Theoretical calculation is performed with taking the experimentally obtained birefringence of the host as $\Delta n = 0.141$ (at 540 nm).



Supplementary Figure 4: (a) Measured real and imaginary parts of the complex dielectric constant of the host LC at 30 °C. (b) Dielectric anisotropy of the host LC with various temperature. (c) Temperature dependence of the crossover frequency (f_c) and its fit according to the Arrhenius equation ($f_c = \exp(-E_{act}/k_BT)$, where E_{act} is the activation energy, k_B is the Boltzmann constant and *T* is the temparature).^[3] A best fit is obtained when $E_{act} = 937$ meV.



Supplementary Figure 5: Contour plot of local deviation angle distribution between the host director with and without the particle at 10 kHz (a) in the in-plane direction at the middle of the cell and (b) in a plane parallel to the long axis of the particle throughout cell-thickness at the center of the particle ($E_{eff} = 1.0 \text{ V/}\mu\text{m}$). The shaded region in the middle indicates the position of the particle.



Supplementary Figure 6: Lateral deviation angle between the host and particle along the long axis at the middle of the cell at (a) 10 kHz, (b) 15 kHz, (c) 17.5 kHz and (d) 20 kHz. Dotted lines shows exponential function fits.



Supplementary Figure 7: (a) Depth director deviation profiles between the host director with and without the particle throughout the cell-thickness at the center of the particle with various fields (the shaded region indicates the position of the particle), and (b) their exponential function fits (dotted lines).

References:

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