3D Dynamic Tuning of Metasurfaces

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Dielectric metasurfaces have proven to be a versatile platform for planar optical devices due to their unique capability for light manipulation. Advances in designing and creating such metasurfaces have led to realizing compact optical metadevices, including holograms, flat lenses, beam converters and deflectors. To date, most functional dielectric metasurfaces are based on static structures defined by geometric parameters such as the shape and size of meta-atoms and their arrangement. However, it is crucial to enable dynamic tunability of the metasurfaces in order to achieve their practical functionality. Integrating optical metasurfaces into liquid crystal (LC) cells has proven to be a successful strategy for realizing pronounced metasurface resonance tuning. Due to the anisotropy of liquid crystals, the positions of the resonances can be dynamically controlled by an external stimulus, such as temperature [1], voltage [2] or magnetic field [3]. However, a fully three-dimensional (3D) tuning of dielectric metasurfaces was never considered so far.

Here, for the first-time, we introduce a fully controllable 3D active tuning of dielectric metasurfaces in bulk LCs, where the application of an external magnetic field effectively controls the molecular reorientation. To illustrate this concept, we present experimental and theoretical study where the magnetic field in such bulk configuration provides fully controllable 3D molecular orientation entailing extra flexibility for spectral tuning of electric and magnetic resonances of dielectric metasurfaces. This is possible because the magnetic-field tuning approach does not require pre-alignment of LC through special surface treatment, such as surface rubbing, which is commonly used for other liquid crystal tuning methods. Our results open important opportunities for realizing dynamically reconfigurable metadevices and offer a unique opportunity for observation of novel physical effects without the usual limitations imposed by boundary conditions of LC cells and external voltage.

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