Universal active metasurface modulation with ultimate performance in reflection

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Optical metasurfaces are becoming ubiquitous optical components to mold the amplitude, the phase and the polarization properties of light beams.

So far, most of these devices are passive in essence, that is, they cannot be arbitrarily reconfigured or optimized according to the user's interest and/or change in their surrounding environment. Here we propose an innovative design strategy relying on the position of topological singularities, namely zeros and poles of the reflection coefficient, to address full phase modulation of light reflecting off an active metasurface with almost unity efficiency.

The active metasurface unit cells, consisting of asymmetric Gires-Tournois resonators filled with electro-optics materials comprising either of Liquid crystal or multiple quantum wells, are able to modulate the reflected field from 0 to 2 associated with 100% reflection amplitude despite dealing with extremely low refractive index change on the order of 0.01. The second ingredient to achieve high efficiency modulation consists in optimizing the arrangement of the sub-wavelength unit-cells so as to account for local imperfection and near-field coupling between neighboring structures.

Consequently, an advanced optimization method accompanied with high-fidelity full-wave solver are required to identify the refractive index distribution.

In our case we rely on a statistical learning optimization technique. It is based on a surrogate model representation which provides a quick estimation to approximate the true function of interest to select the best candidates for the next simulation. Accordingly, programable beam steering configurations have been designed with ultimate performance in reflection. The realization of active beam splitter and active beam steering devices operating at GHz deflection frequency would open important applications in imaging microscopy, high resolution image projection, optical communication and 3D light detection and ranging (LiDAR).