Metasurface Based Spectroscopy and Quantum Engineering Platform

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Relying on the local orientation of nanostructures, Pancharatnam–Berry (PB) metasurfaces are currently enabling a new generation of polarization sensitive optical devices. A systematical mesoscopic description of topological metasurfaces is developed, providing a deeper understanding of the physical mechanisms leading to the polarization-dependent breaking of translational symmetry in contrast with propagation phase effects.

We first demonstrate how to apply this mesoscopic theory to describe linear optical transmission for the arbitrary polarization dependent metasurfaces. Our theoretical model, which allows clear understanding of PB phase is proven in an experimental measurement involving Mach-Zehnder interferometric setup.

We next demonstrate that the reconstruction of a multidimensional nonlinear polarization response of a nanomaterial can be achieved in a single heterodyne measurement by active manipulation of the polarization states of incident light. Using multidimensional spectroscopy, we show the possibility to track both stationary and transient delocalized charge distributions via detecting plasmonic populations and coherences.

While the previous results encapsulate the both linear and nonlinear optical processes in metasurfaces with classical light, we further proceed with our studies involving quantum light properties. Leveraging on a pair of binary-pixel metasurfaces, we demonstrate direct measurement of all four polarization Bell states. Each metasurface is designed to produce two output modes that linearly superpose three Bell states in the coincidence counting measurement. By rotating the polarizers, the coincidence counting measurement achieves a tunable anticorrelation between one and the other two Bell states, achieving Bell state detection efficiency of 75% in a single measurement. Complete and deterministic Bell state measurement is further realized by performing two measurements. Our work shows the advantage of utilization of metasurfaces in quantum detection schemes and is of great applicative interest for quantum dense coding, entanglement swapping, quantum teleportation protocols and novel quantum information processing tasks.

References

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