Metasurfaces with Engineered Reflection and Transmission Properties Based on Asymmetric Resonators

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Metasurfaces have become a topic of extensive research, due to the unique opportunities they offer over wave-front manipulation, including arbitrary transmission/reflection steering and beam shaping. So far, the approaches taken for the design of such metasurfaces predominantly consist in engineering the local reflection coefficient or the impedance of the metasurface, leading to graded impedance profiles. This technique leads to a continuous profile for the metasurface characteristics, usually spanning over a wide range of values, which may require fine discretization in order to implement it in practice. This subsequently leads to small constituent elements and complicates the fabrication. Another problem with the local design approach is that it is limited by a fundamental upper bound regarding the power that can be transmitted in a particular direction, which decreases as the difference between the incident and transmitted directions increases. This problem can be partially overcome by adding bianisotropy to the metasurface, but the problem related to the need of using small elements in order to achieve a fine discretization of the continuous metasurface profile remains.

Here, we present a different approach that allows designing metasurfaces with arbitrary reflection and transmission properties, by using discrete resonant elements. We start from the simplest case of reflection in an arbitrary direction and show that this functionality can be achieved with perfect efficiency through a periodic array of simple dielectric resonators on the surface of an opaque metallic plane. For more complicated functionalities involving a larger number of diffraction orders, as in the case of incidence from the normal direction (in this case, since the periodicity is larger than a wavelength, there can be three or even more diffraction orders), an additional degree of freedom is necessary, either in the form of bianisotropic particles or an additional particle in each unit cell. This approach can be extended to an arbitrary number of particles per unit cell, in order to obtain transmission in any direction or even simultaneous transmission in multiple directions with ideal desired efficiencies. Our technique does not pose a limitation on the minimum size of the metasurface particles and significantly relaxes fabrication requirements, without restricting the obtainable functionalities or compromising the efficiency.