Dispersion Engineering via Nonlocal Transformation Optics

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Transformation optics (TO) is one of the most powerful and versatile frameworks for the systematic design of artificial media. Recently (G. Castaldi *et al.*, Phys. Rev. Lett., 108, 063902, 2012), we have proposed an extension of this approach that enables the manipulation and control of *nonlocal* light-matter interactions, which are becoming increasingly relevant in a variety of metamaterial applications, including artificial magnetism and ultrafast nonlinear optics. Instead of *spatially-changing* refractive properties, we introduced a framework of transformation media that can tailor the wave interaction in the *reciprocal* space of spatial wave-numbers, so as to induce desired nonlocal effects. This approach relies on the increased availability of nonlocal homogenization models, and admits a powerful geometrical interpretation in terms of direct manipulation of the equifrequency contours. Overall, it allows designing artificial materials with much broader degrees of freedom, including the possibility of nonlocal signal processing.

In this work, we further extend this framework, via the introduction of *frequency-dependent* wavenumber transformations, which enable the (local) tailoring of the dispersion surfaces. We then explore possible applications to selected scenarios of interest for dispersion engineering. For instance, we exploit non-centrosymmetric wavenumber transformations to engineer nonreciprocal effects such as unidirectional propagation. Furthermore, we address the design of exotic effects, such as the “frozen-mode” regime and Dirac-cone-type dispersion. For these examples, we also carry out the synthesis of multilayered metamaterials (based on realistic constituents) that suitably approximate the theoretical constitutive “blueprints” derived via our approach.

Overall, these new results provide further evidence of the systematic and versatile character of the nonlocal-TO framework, which may open intriguing venues in dispersion engineering of artificial materials.