A Semi-Analytical Theory for Four-Dimensional Photonic Materials

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Four-dimensional photonic materials consist of spatially structured unit cells made from time-varying materials. We may think of them as isolated structures, but periodic arrangements in 2D or 3D, leading to metasurfaces and metamaterials, are also currently at stake. Besides intellectual curiosity, these novel materials sustain interesting effects with technological relevance. However, a reliable framework for modelling and design needs to be available to explore such opportunities.
This work presents an overview of our efforts to establish such a framework. Starting from the description of the interaction of light with an individual object made from a time-varying and dispersive material in terms of a T-matrix, we study the optical response of much more advanced photonic material, as mentioned above, made from such basic building blocks. From the study of the permissible eigenmodes for light in these media, observable quantities such as reflection and transmission from structured time-varying photonic materials can be investigated. We emphasize the interplay between dispersive and parametric effects in the considered materials and disentangle effects emerging from the spatial and temporal structure. While much of our work currently relies on spheres as the basic building block, the theory can be easily extended to arbitrarily shaped objects.

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