Multiple scattering and co-operative response in periodic and disordered metamaterials

Nikitas Papasimakis[1,*], Stewart Jenkins[2], Vassili A. Fedotov[1], Felipe A. Pinheiro[3], Janne Ruostekoski[2], Nikolay I. Zheludev[1,4]

[1] *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, Southampton, SO17 1BJ, UK*

[2] *Mathematical Sciences and Centre for Photonic Metamaterials, University of Southampton, Southampton, SO17 1BJ, UK*

[3] *Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro-RJ, 21941-972, Brazil*

[4] *Centre for Disruptive Photonic Technologies, Nanyang Technological University, Singapore 637371, Singapore*

The optical properties of metamaterials are prescribed not only by the properties of their constituting elements (termed meta-atoms or meta-molecules), but also by their interactions, which can result in an emergent behaviour dramatically different from the single metamolecule response. Strongly interacting metamolecules provide control over the radiative properties of metamaterials by resonantly suppressing scattering through the excitation of subradiant collective modes. Such metamaterials are also highly sensitive to disorder and, in fact, introducing disorder in the positions of the metamolecules leads to the appearance of localized excitations, which retain the multipole nature of the single metamolecule response.

Here, we will report on the engineering of metamaterials with strong inter-metamolecule interactions, targeting at enhancing metamaterial properties and enabling practical applications. In particular, we will present a framework for the analysis and design of light enhancement and confinement, as well as scattering properties in periodic and disordered metamaterials. We will discuss the role of strong interactions in polarisation sensitive light phenomena. Moreover, we will demonstrate that under excitation with prescribed spatial patterns of evanescent waves, the resonant modes supported by the metamaterial are directly linked to the wavevectors of the evanescent excitation field. It will be shown that by examining the far-field properties of the metamaterial response, information about the near-field excitation landscape can be obtained. Finally, we will discuss implications for sensing, imaging, and spectroscopy.