General Point Dipole Theory for Periodic Metasurfaces: Magnetoelectric Scattering Lattices Coupled to Planar Photonic Structures

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We study semi-analytically light emission and absorption properties of arbitrary stratified photonic structures with embedded two-dimensional magnetoelectric point scattering lattices, as used in recent plasmon-enhanced LEDs and solar cells. By employing dyadic Green's function for the layered structure in combination with Ewald lattice summation to deal with the particle lattice, we develop an efficient method to study the coupling between planar 2D scattering lattices of plasmonic, or metamaterial point particles, coupled to layered structures. Using the `array scanning method' we deal with localized sources. Firstly, we apply our method to light emission enhancement of dipole emitters in slab waveguides, mediated by plasmonic lattices.
We benchmark the array scanning method against a reciprocity-based approach to find that the calculated radiative rate enhancement in k-space below the light cone shows excellent agreement. Secondly, we apply our method to study absorption-enhanc ement in thin-film solar cells mediated by periodic Ag nanoparticle arrays. We study the emission distribution in k-space of a coupled waveguide-lattice system. In particular, we explore the dark mode excitation on the plasmonic lattice using the so-called Array Scanning Method. Our method could be useful for simulating a broad range of complex nanophotonic structures, i.e., metasurfaces, plasmon-enhanced light emitting systems and photovoltaics.