Superscattering from individual subwavelength dielectric structures

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Abstract: Superscattering corresponds to the scenario when the scattering cross-section (σ_{sca}) of a scatterer is significantly larger than its single-channel limit. Theories have shown that although cross sections in each individual scattering channel are bounded, one can realize superscattering by leveraging contributions from several channels (resonances). Based on dispersion engineering of surface plasmons, plasmonic/dielectric layered structures have been used to demonstrate superscattering phenomena at optical frequencies. Considering the Ohmic loss in plasmonic materials, pure dielectric subwavelength structures can be good candidates for the superscattering effect. On the other hand, to create multiple resonances at a given frequency, subwavelength structures with higher structural and material complexity are in general required, which presents a challenging design task. In this work, combining a mode analysis of cylindrical systems and an electromagnetic optimization method, we numerically study superscattering from individual multilayered dielectric cylinders illuminated by a TM^z incident plane wave. We show that a maximum normalized σ_{sca} of ~5 can be achieved based on resonances associated with the lowest five angular momentum channels (0, ±1, and ±2). The optimized design is referred to as the "pure" mode configuration, which simultaneously results in high directivity along the propagation direction of the incident wave. Furthermore, by changing the optimization objective to maximizing the value of σ_{sca} with more channels involved (referred to as the "complex" mode configuration), we also obtained an optimized σ_{sca} as large as ~ 6.46 and ~ 6.71 for two- and three-layer cylinders, respectively. Our results reveal that a judicious combination of mode analysis and a custom optimization method can enable efficient designs of complex dielectric structures capable of exhibiting exotic scattering responses.