Superbackscattering Nanoparticle Architectures

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Any spectroscopy, communication, remote sensing, manipulation and/or imaging system composed of an individual emitter/receiver device is ultimately based on a backscattering measurement. Therefore, nanoantennas and nanoparticle architectures with exceptionally large backscattering cross-sections are of general interest for a wide range of technological applications. Naturally, superbackscattering nanoantennas must be understood as scatterers/obstacles in regards to electromagnetic fields and, therefore, their design must inevitably differ from the design of conventional antenna/radiators. In essence, nanoantennas must not only re-radiate (scatter) the incident field along a desired direction, but they must also extract the energy from it via destructive interference. The intrinsically different physics of this process is inevitably associated with a new set of design strategies and fundamental limitations yet to be discovered.

In a recent work, the authors have derived an upper bound for the backscattering cross-section of a passive nanoparticle (Liberal *et al* IEEE Trans. Antennas Propag., vol. 62, no. 12, pp. 6344-6353, 2014). This bound establishes that the backscattering cross-section of a passive nanoparticle is uniquely limited by its forward-backward scattering directivity product. Thus, the design of superbackscattering nanoparticle architectures can be aligned with superdirective and beamforming techniques studied in classic antenna theory. For example, Uzkov demonstrated that the maximal directivity of an electrically small linear array of N isotropic radiators is N^2. On the other hand, Harrington demonstrated that the maximal directivity of an antenna efficiently exciting N_p multipoles is $N_p^2+2N_p$. The backscattering counterparts of these theorems can be derived, and they demonstrate that the maximal backscattering cross-section of a linear array of N isotropic scatterers is $\sigma_{back} \leq \frac{1}{4\pi}N^2\left(N+1\right)^2$, whereas the maximal backscattering cross-section of a scatterer efficiently exciting N_p multipoles is $\sigma_{back} \leq \frac{1}{4\pi}(N_p^2+2N_p)^2$.

These theoretical results also suggest useful guidelines that enable the straightforward design of superbackscattering nanoparticle architectures. Several designs of nanoparticle arrays and higher order mode nanoresonators that approach these theoretical limits will be reported in our presentation.