Transdimensional Meta-Photonics
Alexandra Boltasseva and Vladimir M. Shalaev

In all areas of science ranging from mathematics and physics to data analysis and computation, moving from one dimensionality to the other reveals new phenomena and brings remarkable performance changes. Historic examples from surface science and the very recent area of optical metamaterials and metasurfaces have shown that transitioning from bulk, three-dimensional (3D) structures to two-dimensional (2D) counterparts uncovered truly new physics unattainable with 3D systems and enabled novel applications. However, the “transdimensional” regime that by the definition relates to in-between dimensionalities and contains components of different dimensions, remains somewhat that might be overlooked.

In the highly dynamic fields of nanophotonics and plasmonics – or metal-based nanoscale optics – extensive research has focused on utilizing either conventional materials in the form of thin films or nanoparticles with bulk material properties, or 2D structures including metal-dielectric interfaces and novel 2D materials. Yet, the material optical properties’ evolution in the transitional – transdimensional – regime between 3D and 2D is still underexplored. In such transdimensional materials (TDMs) that have thickness of only a few atomic layers, the material’s optical and electronic properties are expected to show unprecedented tailorability including unusually strong dependences on structural parameters such as thickness (number of atomic monolayers), composition (stoichiometry, doping), strain and surface termination compared to their 3D counterparts and conventional thin films (that are usually described by the bulk material properties). Similar to truly 2D materials such as graphene, transdimensional materials are also expected to show extreme sensitivity to external optical and electrical stimuli. With the recent discovery of 2D and quasi-2D materials as well as the development of novel plasmonic materials that can be grown as ultra-thin layers (down to few atomic layers) one can now probe the exciting properties of TDMs as they evolve from a single atomic layer to a larger number N when the properties become similar to those of the bulk material.