

An Efficient Numerical Method to Analyze Nanoplasmonic Structures

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There is a growing interest to use plasmonic nanostructures for many applications including clean energy (e.g., solar cells), biological and chemical sensing. The optical behavior of metals is completely different from that observed at low frequencies. While at RF, metal behaves like a perfect electric conductor (with a negligible surface impedance) which is modeled by a surface electric current, at optical frequencies, the penetration of the waves cannot be ignored. Capturing this effect requires volumetric discretization of the structure. A plasmonic material has a complex permittivity with a negative real and positive imaginary parts (assuming $e^{-i\omega t}$ time convention). This results in a penetration depth of $1/k_0 n_i$, where k_0 is the wavevector of the background material and n_i is the imaginary part of the refractive index of the plasmonic object. In optical wavelengths where the wavevector is very large, penetration depth becomes very small. Consequently, to model and consider the evanescent waves inside the plasmonic structures, a numerical method with a **very fine meshing strategy** near the plasmon-dielectric interface is required. Existing modeling numerical methods can be classified into differential equation methods (e.g., Finite Element Method (FEM) and Finite Difference Time Domain (FDTD)) and integral equation (IE) methods (e.g., method of moments or MoM). In differential equation methods, the whole space should be discretized which will result in a large number of unknowns. In contrast, the integral equation methods only discretize the desired objects. Hence, if there is a large white space between objects, integral equation methods are preferred over differential equation methods. However, as soon as the size of the problem increases, and consequently the number of unknowns rises, traditional IE methods such as MoM will consume a huge memory and calculation time increases drastically. Also, these methods have serious problem dealing with multiscale multiphysics problems. Equivalence principle algorithm (EPA), as an efficient domain decomposition method, invokes equivalence principle to decompose the solution domain into subdomains and then solve each of them independently. Later, it stitches them together to calculate the solution for the original problem. The entire procedure can be accelerated by application of fast techniques such as the multilevel fast multipole algorithm (MLFMA). It provides a level of parallelization and also alleviates the need to build and save large matrices. Therefore, EPA (relatively) needs lesser amount of memory and it provides more robust solution for multiscale multiphysics problems. Although EPA has been used for several applications, but its application for modeling and analyzing nanoplasmonic structures has not been reported before and it will be presented in here.