Simple Implementation of Effective Permittivity at Dispersive Metal-Dielectric Tilt Interfaces for Open-Source FDTD Package

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In recent years, metamaterial has gained tremendous attention for its extraordinary properties and applications in both microwave and optical regime. It is categorized as a material with negative permittivity or permeability. At high THz frequency (such as optical communication band), metals possess negative epsilon as metamaterials. Due to the rapid growth of nanotechnology, sub-micron metal waveguides can confine optical fields at nano-scale (much smaller than signal wavelength) that cannot be achieved by pure dielectric. This kind of waveguide is also called plasmonic waveguide that guides wave in the form of surface plasmons, which is known as electron oscillation on metal surfaces.

Finite-Difference-Time-Domain (FDTD) method is widely used for the electromagnetic wave propagation in microwave and optical devices/systems for its intuitive algorithm and fast broad band simulation. However, for plasmonic devices, fields are confined around the metal-dielectric interface with regions that are much smaller than the signal wavelength; therefore in order to precisely describe the field behavior, the number of grids in the simulation has to be increased greatly. In the mean time, the stair casing error caused by the index contrast between the metal with negative real permittivity and dielectric with positive real permittivity will affect the numerical stability significantly. Under this situation, some sub-pixel smoothing techniques such as contour-path integral or effective permittivity method have to be imposed at material interfaces to obtain the numerical stability.

Currently, the powerful open-source FDTD package, Meep, developed by MIT has no sub-pixel smoothing function enabled for dispersive materials that can be utilized to model metals for plasmonic related problems. This somehow prevents users to simulate structures with large index contrast.

In this work, we will demonstrate the use of effective permittivity at metal-dielectric tilt interface in Meep without modifying the source code itself to reduce the stair-casing error for the simulation of plasmonic devices, which will help front-end users to utilize it to deal with more complex problems.