Nanophotonics Application of 3D Spectral Discontinuous Galerkin Method and Enlarged Cell Technique

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Computational electromagnetics is finding many applications in nanophotonics where phenomena of electromagnetic waves interacting with nanoscale structures are studied. In this work, we are mainly concerned with optical waves interacting with nano-metallic objects. Surface plasmon waves, one type of surface electromagnetic waves in the optical frequency, can be supported along the boundary between two materials with opposite signs of dielectric constants, such as a metal and a dielectric. These surface plasmon waves are free electron oscillations on metal surfaces under optical excitations. The oscillation and propagation of free charge density near the surface create a surface electromagnetic wave near the boundary between the two materials. Surface plasmon waves decay exponentially into the dielectric material and the metal with characteristic lengths shorter than the wavelength. They also attenuate in the propagation direction due to the Ohmic loss in metals. The bulk characteristics of nano-metallic objects are often described by macroscopic dispersion relations between the dielectric constant and frequency, for example the widely used Drude model.

One important design objective in nanophotonics is to determine an optimal structure that can support surface plasmon waves with minimum propagation loss along the waveguide direction. In order to perform optimal design of such nanophotonic devices involving metallic objects, we adopt two time-domain computational electromagnetic algorithms, the spectral discontinuous Galerkin method (DGM) and the enlarged cell technique (ECT). The DGM has spectral accuracy and is ideal for large structures, while the ECT, as a further improvement over the conformal FDTD method, has second-order accuracy and is ideal for sub-wavelength structures. Using these two methods, we can accurately and efficiently model electromagnetic waves propagating in nano-photonic structures with dispersive media. We have used these methods to design several interesting surface plasmon waveguides with small attenuation. Results will be shown to demonstrate the effectiveness of our approach.