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Numerically exact solvers of macroscopic Maxwell equations

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Different approaches exist for solving the macroscopic Maxwell equations numerically for electromagnetic scattering problems. The most direct way is based on discretizing the temporal and spatial partial derivatives by use of central difference approximations. This method is known as the finite-difference time-domain method. The solution to the scattering problem is computed by iterating over time.

Another approach is obtained by deriving from Maxwell-Faraday's law in conjunction with Maxwell-Ampère's law (with Maxwell's additional displacement-field term) the frequency-domain vector wave equation (assuming time-harmonic fields). Allowing the dielectric properties to vary inside the particle, one derives a volume-integral equation solution, which makes use of the wave equation's Green's function. Volume-integral equation methods, such as the discrete dipole approximation (DDA), are based on discretizing the integration domain of the volume-integral equation solution.

If the dielectric properties can be assumed to be constant or, at least, piecewise constant inside the scatterer, then the frequency-domain wave equation can be further simplified to the vector Helmholtz equation. Separation of variables leads to a set of general solution functions, in which one can expand the incident, scattered, and internal fields. The remaining problem is then to determine the unknown expansion coefficients of the scattered and internal fields in terms of the known coefficients of the incident field. Different numerical approaches have been devised, such as the point-matching method, which enforces the boundary condition in a set of matching points on the surface of the scatterer. Another approach is the extended boundary condition method (EBCM), which yields a T-matrix solution to the scattering problem. Other methods for computing a T-matrix solution have been developed, such as the superposition T-matrix method (STM) for aggregates and general multiple-sphere systems.

The most widely used methods at the moment seem to be the EBCM, STM, and DDA. We can observe that numerically exact methods are gradually displacing the use of approximate methods. For instance, until the 1990's the Rayleigh-Debye-Gans approximation was commonly used to compute light scattering by aggregated particles; nowadays such computations are almost exclusively done by use of the STM. The increasing popularity of numerically exact methods has been spurred by the development of improved methods and algorithms, as well as the widespread availability of user-friendly, open-source computer programs.