Analysis of energy budget for scattering of fields induced by nearby sources

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The frequency-domain volume integral equation (VIE) is a general framework for theoretical analyses and numerical simulations of scattering by particles of arbitrary shape and internal structure. The VIE has been known for more than 60 years, but a number of issues remained, which recently revived the interest in this subject. This led to a rigorous derivation of the VIE for a set of multilayered particles with sharp edges and corners [1], further extended to general incident fields, including those caused by sources located near the scatterer [2]. The only missing element is the energy budget for such general scattering problem. Optical cross sections (extinction, absorption, and scattering) are defined through the power rates (integrals of the Poynting vectors over the closed surfaces) in many textbooks on light-scattering theory. However, those definitions are incomplete and/or ambiguous in the case of source-induced fields.

We provide rigorous definitions of various components of the energy budget for scattering of source-induced electromagnetic fields by a finite non-magnetic object. We use the VIE framework and define power rates in terms of integrals of the Poynting vector over various surfaces, enclosing some or all of the impressed sources, the scatterer, and the environment (such as a planar multilayered substrate). Thus, we generalize the conventional cross sections and obtain new interrelations analogous to the well-known optical theorem. We rigorously treat the strong singularity of the VIE kernel, but keep derivations accessible to a wide audience. The defined power rates are further related to the decay-rate enhancement and apparent quantum yield of an arbitrary emitter, which are the core concepts in nanophotonics, surface-enhanced Raman scattering, and electron-energy-loss spectroscopy. We also discuss the practical calculation of the power rates and decay-rate enhancements in the framework of the discrete dipole approximation (DDA). In particular, we derive the volume-integral expression for the scattered power and use it to prove the automatic satisfaction of the optical theorem irrespective of the discretization level. Thus, the optical theorem cannot be used as an internal measure of the DDA accuracy. The details are given in Ref. [3].

References

[1] Yurkin, M. A., and M. I. Mishchenko, 2018: Volume integral equation for electromagnetic scattering: rigorous derivation and analysis for a set of multilayered particles with piecewise-smooth boundaries in a passive host medium. *Phys. Rev. A* **97**, 043824.

[2] Mishchenko, M. I., and M. A. Yurkin, 2018: Impressed sources and fields in the volume-integral-equation formulation of electromagnetic scattering by a finite object: a tutorial. *J. Quant. Spectrosc. Radiat. Transfer* **214**, 158–167.

[3] Moskalensky, A. E., and M. A. Yurkin, 2019: Energy budget and optical theorem for scattering of source-induced fields. *Phys. Rev. A*, submitted.

Preferred mode of presentation: Oral