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Keynote lecture

SINGLE, MULTIPLE, INDEPENDENT, AND DEPENDENT SCATTERING: A FIRST-PRINCIPLES PERSPECTIVE

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Ever since the publication of the classical treatise by Hendrik C. van de Hulst in 1957, the notions of "independent" and "dependent" scattering have permeated applied publications dealing with frequency-domain electromagnetic scattering by particulate media. However, the majority of definitions of these notions are quite vague and often range from being inconsequential to being outright wrong (a typical example is the invocation by Milton Kerker in his celebrated 1969 book of a scenario wherein "the scattering particle is unaffected by the presence of neighboring particles"). The common trait of such definitions is that they are based on qualitative *ad hoc* arguments rather than emerge as direct corollaries of macroscopic Maxwell's electromagnetics. It is therefore essential to perform a first-principles analysis of these notions starting from an explicit formulation of the frequency-domain Maxwell equations for a morphologically complex scattering object in the form of a group of *N* non-overlapping volumes called particles.

It is not the purpose of this lecture to discuss specifically all the numerous definitions of independent and dependent scattering regimes encountered in the literature. Indeed, that would largely amount to deciphering what the authors may have wanted to say rather than analyzing what they have stated explicitly. Instead, the main objective of this paper is to advance the premise according to which scattering by a multi-particle group is *independent* if certain optical observables (i.e., appropriately defined second moments in the electromagnetic field) for the entire group can be expressed (explicitly or implicitly) in appropriate single-particle observables. Otherwise the scattering by the multi-particle group is *dependent*. The purpose of the lecture is to give a systematic and self-consistent justification of this premise and give examples of independent and dependent scattering scenarios.

In lieu of using the standard differential-equation formalism of electromagnetic scattering, we build our analysis on the mathematically equivalent volume integral equation formulation. The unique advantage of the latter is that it naturally leads to the introduction of mutually independent individual-particle transition operators and yields a rigorous expression of the field scattered by an *N*-particle group in terms of the *N* single-particle transition operators. As such, this formalism allows one to bring the notion of individual-particle scattering into the consideration of electromagnetic scattering by the entire multi-particle object. Furthermore, it applies to a very wide range of particle morphologies.