Homogenization of random particulate media in regimes of near-resonant cooperative scattering

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The description of disordered composite materials through an effective refractive index is a topic that has a long history and in which some of the more famous scientists have had an involvement (e.g. Poisson, Faraday, Maxwell, Rayleigh, etc). Today, the interest in homogenization is still persistent, mainly because of two reasons : (i) useful optical properties can emerge from inhomogeneous media, (ii) fundamental questions regarding the cooperative scattering of light have not yet encountered satisfactory responses.

In practice, the value of the effective index is often predicted by means of one of the existing effective-medium theories. Let us mention two of them : those of Maxwell-Garnett and Bruggeman, which typically have had the widest use. However, even though other more elaborated models are often more accurate (e.g., Lichteneker, Felderhof, etc.), no effective-medium theory can fully described all configurations, with versatility and generality.

In this talk, the focus will be on the calculation of an effective refractive index for a system of randomly distributed particles that interact resonantly. Several features will be presented. 1) Statistical considerations about the calculation of a representative mean field, ensuring no bias in the extracted effective index, will be analyzed. 2) I will emphasize that the obtained value is only valid through the concept of restricted homogenization, stating that the effective index of an inhomogeneous medium has not necessarily the same range of validity as that of a homogeneous medium. 3) A large part of the talk will be dedicated to Bergman's representation of the effective index via a spectral density function, which carries structural information about the composite : it will be shown how one can take advantage of regimes where homogenization is restricted to construct the spectral density function. 4) Finally, an insight into the mechanisms at play in resonant interactions will be provided through the eigenmodes analysis of particulate agglomerates with different shapes.