Brillouin Light Scattering by Single Spherical Particles: An Exact Analytical Approach

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Brillouin light scattering (BLS) is a powerful non-destructive technique utilizing inelastic light scattering, due to phonon-induced spatiotemporal variations of the refractive index of a material, in order to monitor its frequency response in the hypersonic (GHz) regime. The recorded spectra contain rich information for the eigenmodes of the system under study and, in the last decade, have been used for the characterization of periodic self-assembled colloidal structures, revealing their dispersion relation. However, the lack of an exact, rigorous theoretical formulation, that would take into account the interaction of light with the elastic field inside the nanoparticles as well as in the interstitial region, has led to indirect explanations either in terms of the eigenmodes, the scattering cross section and the density of states of the individual particles or the frequency band structure of the colloidal crystal, solely in the framework of an elastodynamic description. It is nevertheless clear that only a rigorous full elasto-optic theoretical approach can give the correct relative intensities of the scattered light. For this purpose, we develop such a theoretical formulation of BLS by single spherical particles in vacuum, based on Green's functions, and derive analytical expressions for the BLS intensities, thus improving the computational efficiency and accuracy of previous calculations. The case of a solid particle embedded in an index-matching liquid is also discussed. This case, though more difficult to treat, is of interest since the acoustic field is not exclusively confined inside the particle, thus leading to a continuous spectrum and not to a discrete one as for the particle in vacuum. The above analytical considerations provide, also, the theoretical foundations for a rigorous description of the effect as well as the extension of BLS calculations to periodic structures (hypersonic phononic crystals).