URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Polarizability of Nonstationary Particles

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One of the key concepts in the investigation of electromagnetic wave interactions with a subwavelength particle is the notion of "polarizability", which is simply the ratio between the induced electric dipole moment and the external electric field (assume that the particle under study has only an isotropic electric response) [1]:

$$\mathbf{p} = \alpha \cdot \mathbf{E}. \tag{1}$$

Here, $\mathbf{p}$ represents the induced electric dipole moment, α is the electric polarizability, and $\mathbf{E}$ denotes the excitation electric field. By contemplating analytical expressions written for the polarizability, we indeed achieve considerable amount of information, such as possible resonances, the time-averaged power exerted on the particle, radiated from the particle, and absorbed by the particle (see e.g. Refs. [1, 2]).

However, Eq. (1) written in the frequency domain is valid only for an immutable (or stationary) particle in which the geometry of the particle and the optical properties of the material from which the particle is made do not change in time. This is a basic assumption that we always consider in mind without mentioning it. From this point of view, the thought-provoking question then arises, "if the particle is nonstationary, what will be the expression that accurately describes the relation between the electric field as the action and the dipole moment as the reaction?" Also, "how is the polarizability derived for such a particle?" To answer these questions, we need to consider the particle response in the time domain and revisit the very definition of the polarizability [3]. In this talk, first, we briefly discuss this time-domain definition and describe the linear, causal, and nonstationary relation which links the induced electric dipole moment to the electric field. To find the polarizability of nonstationary particles we consider the equation of motion of a charged particle. This linear differential equation with time-dependent coefficients determines the induced dipole moment. By this way, we develop a systematic approach for calculating the polarizability of nonstationary particles (see Ref. [3]).

We hope that our work has a prodigious potential to influence researchers who are active in nanophotonics and metamaterials (metasurfaces) communities, because temporal modulation of individual particles or particles immersed in an array is an additional degree of freedom (in addition to the use of spatial inhomogeneities) for creating exotic wave phenomena and controlling light in desired ways [4].

References

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