Preface

The focus of this field guide is largely on electromagnetic fields in linear materials. Even with the exclusion of nonlinearity (except in the last chapter), the panorama of electromagnetic properties within the ambit of this monograph is vast — a view which has been widely appreciated for the last 10 years.

An isotropic medium has electromagnetic properties which are the same in all directions. Such mediums provide the setting for introductory courses on electromagnetic theory, as encountered at high school or in early undergraduate classes. But isotropy is an abstraction which requires qualification when applied to real materials. For examples, liquids and random particulate composite mediums may be isotropic on a statistical basis, while cubic crystals are isotropic when viewed at macroscopic length–scales. In the frequency domain, electromagnetically isotropic mediums are characterized simply by scalar constitutive parameters which relate the induction field phasors $\underline{D}$ and $\underline{H}$ to the primitive field phasors $\underline{E}$ and $\underline{B}$.

Often, naturally occurring materials and artificially constructed mediums are more accurately described as anisotropic rather than isotropic. Anisotropic mediums exhibit directionally dependent electromagnetic properties, such that $\underline{D}$ is not aligned with $\underline{E}$ or $\underline{H}$ is not aligned with $\underline{B}$. Dyadics (i.e., second–rank Cartesian tensors) are needed to relate the primitive and the induction field phasors in anisotropic mediums. No wonder, these mediums exhibit a much more diverse range of phenomenons than isotropic mediums do. A visit to the mineralogical section of the local museum should impress upon the reader the array of dazzling optical effects that may be attributed to anisotropy in crystals.

Bianisotropy represents the natural generalization of anisotropy. In the electromagnetic description of a bianisotropic medium, *both* $\underline{D}$ and $\underline{H}$ are anisotropically coupled to *both* $\underline{E}$ and $\underline{B}$. Hence, in general, a linear bianisotropic medium is characterized by four 3×3 constitutive dyadics. Though seldom described in standard textbooks, bianisotropy is in fact a ubiquitous phenomenon. Suppose a certain medium is characterized as an isotropic dielectric medium by an observer in an inertial reference frame Σ. The same medium generally exhibits bianisotropic properties when viewed by an observer in another reference frame that translates at uniform velocity with respect to Σ. While naturally occurring materials with easily appreciable bianisotropic properties in normal environmental conditions are relatively rare (viewed from a stationary reference frame), bianisotropic mediums may be readily conceptualized through the process of homogenization of a composite of two or more constituent mediums. Bianisotropy looks set to play an increasingly important role in the rapidly burgeoning fields relating to complex mediums and metamaterials.

Our aim in this field guide is to extend and update the standard treatments of crystal optics found in classical textbooks such as Born & Wolf's *Principles of Optics*[3] and Nye's *Physical Properties of Crystals*[4]. We provide a broad overview of electromagnetic anisotropy and bianisotropy. The topics covered are constitutive relations (Chap. 1), examples of anisotropy and bianisotropy (Chap. 2), space–time symmetries (Chap. 3), planewave propagation (Chap. 4), dyadic Green functions including depolarization dyadics (Chap. 5), homogenization formalisms (Chap. 6), and nonlinear aspects (Chap. 7). The target audience comprises graduate students and researchers seeking an introductory survey of the electromagnetic theory of complex mediums. A familiarity with basic electromagnetic theory, and a commensurate level of mathematical expertise, is assumed. An appendix is provided to acquaint the reader with dyadic notation and algebra. SI units are adopted throughout.

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[3] M. Born and E. Wolf, *Principles of optics, 7th (expanded) ed*, Cambridge University Press, Cambridge, UK, 1999.
[4] J.F. Nye, *Physical properties of crystals*, Oxford University Press, Oxford, UK, 1985.