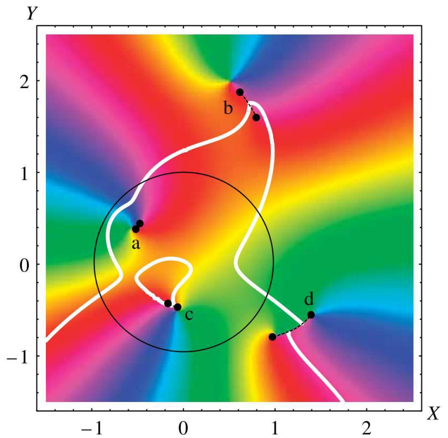
双各向异性 & 广义相对论 †

Bianisotropic & General Relativity

† Dedicated to Professor J. F. Nye, FRS, and Professor S. Ramaseshan on their 80th birthdays.



双各向异性晶体是最一般的线性局域电磁材料 (Kong 1975)，其中每个场矢量 E 和 H 张量耦合到相关矢量 D 和 B。

$$\begin{pmatrix} \mathbf{E} \\ \mathbf{H} \end{pmatrix} = \begin{pmatrix} \dfrac{\boldsymbol{\eta}_{\mathrm{e}}^{(3)}}{\varepsilon_0} & \dfrac{\boldsymbol{\eta}_{\mathrm{em}}^{(3)}}{\sqrt{\varepsilon_0\mu_0}} \\ \dfrac{\boldsymbol{\eta}_{\mathrm{me}}^{(3)}}{\sqrt{\varepsilon_0\mu_0}} & \dfrac{\boldsymbol{\eta}_{\mathrm{m}}^{(3)}}{\mu_0} \end{pmatrix} \begin{pmatrix} \mathbf{D} \\ \mathbf{B} \end{pmatrix}$$

一般的双各向异性耦合包含了许多不同的偏振现象，包括真正的电磁交叉耦合效应、传统的电和磁双轴各向异性、法拉第效应和自然光学活性，以及如果材料中存在耗散，所有这些的吸收对应物。

作为基本场，我们选择 D 和 B，而不是 E 和 H 或 E 和 B，因为 D 和 B 总是横向于波方向 s，所以，众所周知（Kong 1974 ），6 × 6 矩阵形式可以简化为 4 × 4 (§ 3).

D 和 B 可以用单个四分量向量表示，但我们选择分别考虑 D 和 B 的奇点。

这种对洛伦兹对称性的忽视是适当的，在洛伦兹对称中，惯性参考系的变化将混合 D 和 B 的分量，因为我们正在考虑均匀介质中的单hromatic 平面波，提供自然静止系，因此相对性是无关紧要的（尽管我们注意到一个有趣的事实，即运动可以引起双各向同性，甚至负折射率；见 Mackay&Lakhtakia 2004 ）。

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As the fundamental fields we choose $\mathbf{D}$ and $\mathbf{B}$, rather than $\mathbf{E}$ and $\mathbf{H}$ or $\mathbf{E}$ and $\mathbf{B}$, because $\mathbf{D}$ and $\mathbf{B}$ are always transverse to the wave direction $\mathbf{s}$, so, as is well known (Kong 1974), the 6×6 matrix formalism can be reduced to 4×4 (§3). $\mathbf{D}$ and $\mathbf{B}$ can be represented by a single four-component vector, but we choose to consider the singularities of $\mathbf{D}$ and $\mathbf{B}$ separately. This neglect of the Lorentz symmetry, in which a change of inertial reference frame would mix the components of $\mathbf{D}$ and $\mathbf{B}$, is appropriate because we are considering monochromatic plane waves in a uniform medium, providing a natural rest frame, so relativity is irrelevant (although we note the interesting fact that motion can induce bianisotropy and even a negative refractive index; see Mackay & Lakhtakia 2004).

2005 - The optical singularities of bianisotropic crystals
- XXXX - Berry

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Naturally occurring materials which exhibit appreciable bianisotropic effects, under normal environmental conditions, are relatively scarce. However, artificial materials with substantial bianisotropic effects may be readily realized. Such materials can be conceptualized as homogenized composite materials (HCMs), arising from constituent materials which are not themselves bianisotropic (or even anisotropic in some cases), as is discussed in section 6.4.

Far from being an esoteric property, bianisotropy is actually a ubiquitous one [15]. From the perspective of special relativity, the classifications of isotropy and bianisotropy are not covariant under the Lorentz transformation.

For example, a material which is an isotropic dielectric material with respect to one inertial reference frame is a bianisotropic material with respect to another inertial reference frame [11]. Furthermore, from the perspective of general relativity, free space subjected to a gravitational field is electromagnetically equivalent to a nonhomogeneous bianisotropic material [29, 30].

在正常环境条件下表现出明显的双各向同性效应的天然材料相对稀缺。

然而，具有实质性双各向同性效应的人造材料可能很容易实现。

这种材料可以被概念化为均质复合材料 (HCMs)，如第 6.4 节所讨论的，由本身不是各向异性 (甚至在某些情况下是各向异性) 的组成材料产生。

双各向同性并不是一个深奥的性质，实际上是一个普遍存在的性质 [15]。

从狭义相对论的角度来看，各向同性和各向异性的分类在洛伦兹变换下并不是协变的。

例如，相对于一个惯性参考系为各向同性介电材料的材料相对于另一惯性参考系是双各向同性材料 [11]。

此外，从广义相对论的角度来看，受到引力场作用的自由空间在电磁上等效于非均匀的双各向同性材料 [29 ， 30]。

2020 - Modern Analytical Electromagnetic Homogenization with Mathematica (Second Edition)
- IOP Publishing Ltd - Mackay