ELECTROMAGNETIC WAVES IN CRYSTALS: THE PRESENCE OF EXCEPTIONAL POINTS

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In recent years, a growing interest in the fundamental physical properties of exceptional points (EP) and their use in applications has led to a significant increase in research activities in this area. At an EP, at least two eigenmodes are degenerate in their eigenvalue and eigenstate. The existence of such points was first reported by W. Voigt in 1902 for orthorhombic materials [1], who realized that in these materials at certain propagation directions, the propagation properties (complex refractive index) and the polarization of the two eigenmodes are simultaneously degenerated. Only a wave, either left or right circular polarized, can propagate along such a direction without changing its state. He therefore named these direction “Windungsachsen” (“winding axis”), which is now often called singular optic axis. It took almost 100 years, that the general case was discussed by Berry and Dennis in 2003 [2].

Here we present on overview on the EP in optically anisotropic materials and show that these points occur naturally in these systems. The results are illustrated by using the optical properties of real materials, which are used in current research, e.g., ZnO, KTP and β- Ga2O3 (Fig. 1). In bulk materials the properties of the EPs and their spatial distribution are determined by the dielectric function and the crystal symmetry of the material, respectively, which allows to distinguish between optically biaxial materials with triclinic, monoclinic or orthorhombic crystal symmetry. If the case that the phase front and amplitude front do not coincide with each other, EPs can also occur even in optically uniaxial materials and their properties and the corresponding waves can be tuned. This is of particular interest for technical applications, since this situation occurs for example in thin films and microresonators [3,4].

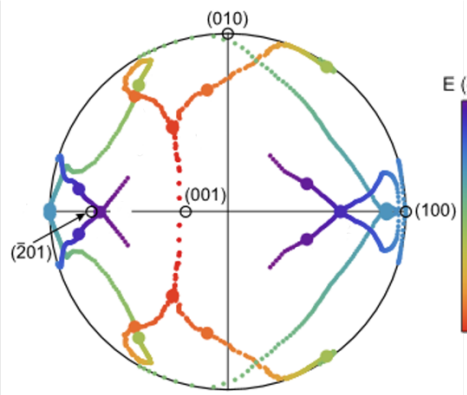

Fig. 1: Angular position of the exceptional points in $\boldsymbol{\beta} - Ga_2O_3$ as a function of the photon energy in the stereographic projection (upper hemisphere, taken from Ref. [5])

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