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Book review

Crystal Optics with Spatial Dispersion, and Excitons

Second corrected and updated edition

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[pp. i–xi + 441, with 46 Figs.]

Spatial dispersion, i.e., the dependence of the dielectric constant tensor on the wave vector at a fixed frequency is physically explained by the fact that the electrical polarization at a given point in the medium is determined not only by the magnitude of the electric field at this point, but also by the field in a certain neighbourhood of this point. The amount of spatial dispersion is determined by the parameter ak (a – radius of the influence, k – wave vector). Since, in crystals $a \sim 10^{-9}-10^{-10}$ m, therefore, spatial dispersion in optical range can be regarded as being weak ($ak \ll 1$), and thus neglected. However, in crystal optics, there are some phenomena, such as natural optical activity (gyrotropy), optical anisotropy of cubic crystals, and additional light waves, which exist due to spatial dispersion. That makes the spatial dispersion theory important, especially in the field of excitation theory, closely connected with spatial dispersion. It is also of importance that crystal optics with spatial dispersion is a more general theory which includes all of ordinary crystal optics (called in the reviewed book classical optics) as its special case.

Although, Lorentz in his molecular theory of optical rotatory power (gyrotropy) had taken account of the wavelength-dependent terms more than 100 years ago, the attention to the possible existence of spatial dispersion was forcefully called by the scientists as late as in the 1950s. Since this time spatial dispersion has become the subject of increasing interest in electrodynamic and condensed matter optics, in crystal optics in particular. The authors of the reviewed book belong to the pioneers in the field of spatial dispersion and excitons. They made important and deep contributions to this subject of modern optics.

It may be said that the whole book is devoted to the response function in spatially dispersive media, i.e., to dielectric-constant tensor $\varepsilon_{ij}(\omega, k)$ and to the consequences resulting from the dependence of dielectric-constant on wave vector k. The book is a skillful comnation of the macroscopic and microscopic approaches to crystal optics with spatial dispersion and exciton theory. This second English edition, if compared with the first one (in 1966), is much enlarged. Quite numerous changes and substantial additions, made in this book, concern principally all the problems that have attracted much attention in the recent years. The nonlinear effects in crystals optics, however, are not contained in the book.

The *Introduction* includes the fundamental conceptions and a review of the book contents. It is followed by six successive chapters, i.e.:

– *The complex dielectric-constant tensor* $\varepsilon_{ij}(\omega, k)$ *and normal waves in a medium,*
– *The tensor* $\varepsilon_{ij}(\omega, k)$ *in crystals,*
– *Spatial dispersion in crystal optics,*
– *Surface excitons and polaritons,*
– *Microscopic theory,*
– *Conclusions.*

In Chapter 2 the general properties of the dielectric-constant tensor are discussed for spatially homogeneous anisotropic medium with spatial dispersion. It is shown how accounting for spatial dispersion leads to corrections in Maxwell's boundary conditions. Different types of excitons as the resonances of the dielectric function are considered. Chapter 3 is an application of the dielectric-constant tensor $\varepsilon_{ij}(\omega, k)$ to crystals. It is shown that both the formulation of this tensor and its use in macroscopic electrodynamic are possible if $ak \ll 1$. Hence, dielectric function and its reciprocal can be replaced by a series expansion in powers of ak. The properties of such an expansion are discussed.

The Chapter 4 is the largest one and concerns directly the description of the crystal optics with spatial dispersion in the macroscopic approach. It is obvious that the problems of propagation, reflection and refraction of various kinds of normal waves in crystal are discussed only in cases, when spatial dispersion leads to qualitatively new effects or yields nonnegligible corrections to the formulas of classical crystal optics. Thus, the dispersion of normal waves in gyrotropic and nongyrotropic crystals in the region of excitation resonances is, in particular, considered, when additional light waves are formed and when dissipation should be taken into account. A theory of optical anisotropy of cubic crystals is developed for the cases of dipole and quadrupole transitions. The next part of this chapter deals with the effects of mechanical stresses and external electric and magnetic fields. The concept of additional propagating modes involves the problem of additional boundary conditions, which is discussed in detail by using the model of isolated resonance in a number of examples. In the last part of this chapter experimental investigations of spatial dispersion in crystals, including the experiments with the new techniques such as picosecond spectroscopy or resonant laser light scattering spectroscopy, are reviewed. A detailed comparison of experimental and theoretical results has been made for semiconductor compounds (particularly for II–VI compounds, where spatial dispersion is pronounced). The majority of spatial dispersion effects are illustrated, using the results obtained for CdS and GaAs.

The very important and modern problem of surface spectroscopy, including spatial dispersion, is treated in Chapter 5. Spectra of surface polaritons in isotropic and anisotropic media and the effect of transition layers on these spectra are discussed. Different experimental investigations of surface polaritons using both classical (attenuated total reflection) and new techniques (Raman scattering, low energy electrons scattering) are reviewed.

Chapter 6 is a microscopic approach, i.e., it contains the calculation of the tensor $\varepsilon_{ij}(\omega, \boldsymbol{k})$ in the region of exciton resonances. The calculation procedure for molecular crystal is described in detail by the local field method, in particular. The theory of Raman scattering of light and X-rays with the production of excitons, and bulk and surface polaritons are considered. The final part of this chapter concerns the Cherenkov's and transition radiation in medium displaying spatial dispersion.

The last Chapter 7 contains some conclusions. One of them is that so many papers concerning spatial dispersion and excitons have been published in the recent years that the second edition of the book can be regarded to be only an introduction to the problem. The other conclusions concern the present and future trends in research in this field.

One more conclusion may be added to those made by the authors: this book in the assumed by them framework is an excellent and comprehensive monograph. It may be recommended to all the scientists working in the field of crystal optics.

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