Piezo-Modulation Method of the Elementary Oscillators Differentiation on the Type and the Orientation in Cubic Crystals

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Abstract – Authors have determined the form of sample and luminescence excitation and observation conditions which allow to determine the orientations of elementary oscillators by presence or absence of modulation in axial-periodic dependence of luminescence intensity. Also the multipolarity of oscillators are determined by typical peculiarities of axial dependence.

1. Introduction

The investigation of multipolarity and orientations elementary oscillators is actual for determination of the nature and structure of the color centers in crystals, as well as for applications (such as color center lasers, the creation of passive laser Q-switch, etc.). Usually the method of azimuthal dependences and the polarizing diagrams is applied to determination of type and orientations absorbing and radiating color centers oscillators in cubic crystals, the method suggested by P.P.Feofilov [1]. The essence of the given method is research of dependences of a measured degree of polarization of a luminescence from a direction of observation and electric and wave vectors of exciting light.

Earlier authors [2] had been offered a method to solve the same problem. It based on measurement of depth of modulation of axial-periodic dependence of color centers luminescence in cubic crystals with the induced anisotropy. It is known, that elementary oscillators, describing transitions in color centers in cubic crystals are orientated along rotary axes of symmetry of the second, third and fourth order [1]. Also it is known, that cubic crystals could be artificially transformed into crystals with lower symmetry, using one-axis compression or imposing of an electric field. Under mechanical or electrostatic forces there is a deformation of a crystal lattice, change a component of dielectric permeability and dielectric susceptibility tenzors, that accordingly results in occurrence of double refraction and double absorption. It is possible to allow, that the small deformation resulting in artificial anisotropy of a cubic crystal, does not result in appreciable change of orientations oscillators and to their distribution on orientations. In the given crystals under certain conditions excitation and observation of color centers luminescence the spatial – periodic picture (axial-periodic dependence) of luminescence is observed. Depth of modulation of axial-periodic dependence is various at orientations of oscillators on crystallografic axes $6C_2$, $4C_3$, $3C_4$ and depends on type of oscillator (linear dipole oscillator or rotator). Experimental validation of method of determination of multipolarity and orientations elementary oscillators based on this distinction is carried out in work [2] on crystals LiF with F_2 and F_3^+ – color centers. It is shown, that observable spatial – periodic dependences are well coordinated with settlement.

In the given work the problem of determination of optimum conditions of excitation and observation of color centers luminescence is put, also as a configuration of a sample and a direction of compression for increase of resolving opportunities of a method.

2. The scheme of measurements

For determination of elementary oscillators orientations it is enough to make simple procedure of measurements. It is possible to choose such form of sample, direction of compression, excitation and observation of luminescence, that on two photos of spatial – periodic pictures of luminescence it is unequivocally determined orientations of elementary oscillators. In Fig. 1. the scheme of experiment is shown.

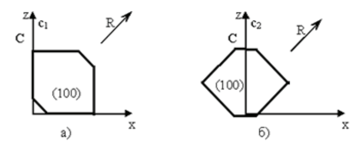

Fig. 1. The scheme of measurements, *a*- a direction of compression on axis C_4 (the optical axis c_1 is induced), *b* – a direction of compression on axis C_2 (the optical axis c_2 is induced)

The wave vector of exciting light **k** is normal to the crystallographic planes (100) (and planes in Fig. 1) on an axis y, compression of a crystal was made on axis C_4 (Fig. 1, *a*) or on axis C_2 (Fig. 1, *b*), the induced optical axes is c_1 and c_2, accordingly. Linearly polarized exciting light with vector **E** directed under an angle $+45^o$ to an axis z incident on crystal surface. Vector **R** shows a direction of observation of a spatial – periodic picture of luminescence.

Under the given conditions of excitation and observation, calculations of axial-periodic dependences of a luminescence of elementary radiators for oscillators orientations on crystallographic axes $6C_2$, $4C_3$ and $3C_4$ have been carried out. There were considered the cases when absorbs linear oscillator – radiates linear oscillator ($\pi - \pi$), absorbs rotator – radiates linear dipole ($\sigma - \pi$), absorbs dipole – radiates rotator ($\pi - \sigma$), absorb and radiate rotators ($\sigma - \sigma$). The received axial-periodic dependences of luminescence intensity on coordinate y are resulted in Fig. 2–5 (in figures the spatial coordinate y is replaced with a dimensionless variable $y = \frac{2\pi y}{\Lambda}$ where $\Lambda = \lambda/\Delta n$ – the period of change of stimulating light polarization condition, $\Delta n = |n_0 - n_e|$ – size of two-refraction of a crystal). Initial condition of polarization of stimulating light–plane polarizated, vector **E** is directed under an angle $+45^{\circ}$ to an axis z.

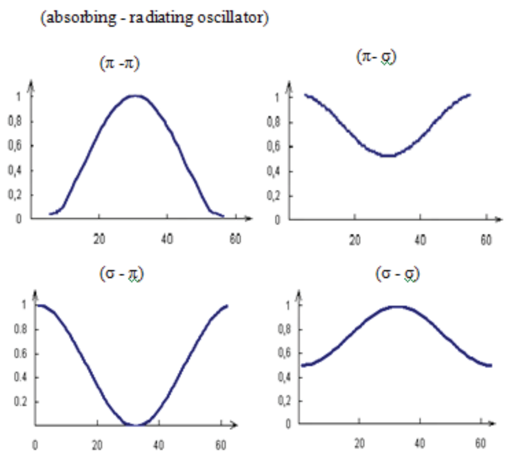

Fig. 2. Axial dependences of luminescence intensity. Absorbing and radiating oscillators (π, σ) are orientated on crystallographic axes $3C_4$, an optical axis c_2 (Fig. 1*б*). I – relative unit, I_{max} – normalize on 1, a scale $(2\pi y)/\Lambda$ in 0.1

Appeared, that for the given form of sample irrespective of types absorbing and radiating oscillators for oscillators orientation on axes $4C_3$ and $3C_4$ at measurements shown in Fig. 1*b* and Fig. 1*a*, accordingly, the spatial – periodic picture of a luminescence is absent (i.e. I(y) = const).

For oscillators orientations on axes $6C_2$ (irrespective of oscillator type) the spatial – periodic picture of a luminescence takes place both in measurement 1*a*, and in 1*b*. In the Table results of calculation for possible types absorbing and radiating oscillators are shown, the badge (+) designates presence of a spatial – periodic picture of a luminescence, by a badge (-) its absence.

From the Table it will obvious that presence or absence of modulation in a luminescence allows to determine unequivocally oscillators orientations. On prominent features of axial dependences (position of maxima and minima) could be determined the type (π or σ) of the oscillators (Fig. 2–5).

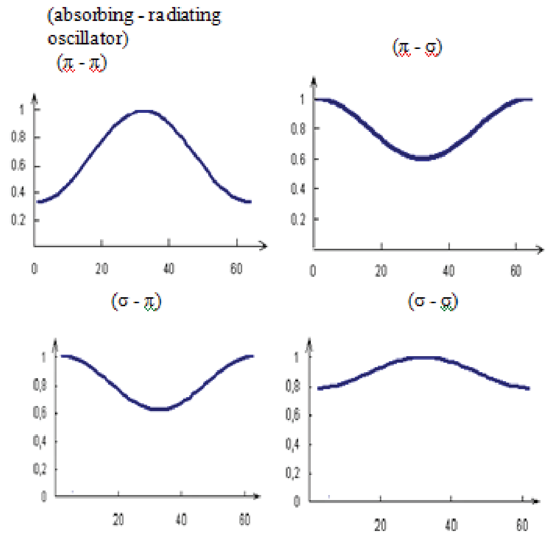

Fig. 3. Axial dependences of luminescence intensity. Absorbing and radiating oscillators (π, σ) are orientated on crystallographic axes $4C_3$, an optical axis c_1 (Fig. 1*a*)

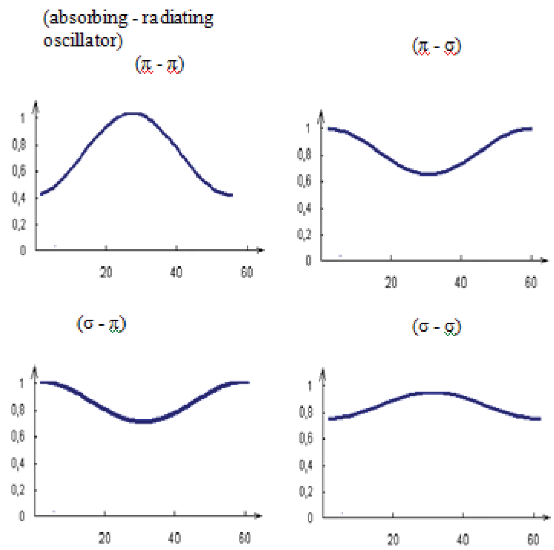

Fig. 4. Axial dependences of luminescence intensity. Absorbing and radiating oscillators (π, σ) are orientated on crystallografic axes $6C_2$, an optical axis c_1 (Fig. 1*a*)

Table 1. Observation of a spatial – periodic picture

Oscillators orientation	$6C_2$	$4C_3$	$3C_4$
Optical axis c1	(+)	(+)	(-)
Optical axis c2	(+)	(-)	(+)

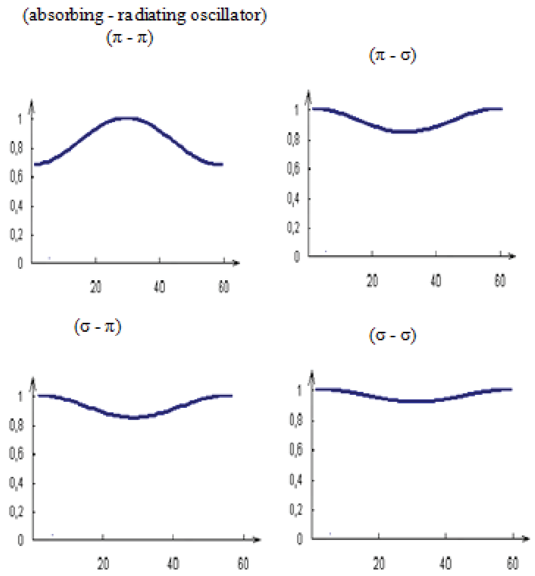

Fig. 5. Axial dependences of luminescence intensity. Absorbing and radiating oscillators (π, σ) are orientated on crystallographic axes $6C_2$, an optical axis c_1 (Fig. 1*b*)

3. Conclusion

In the given work the new method of determination of orientations and multipolarity of the color centers oscillators in cubic crystals (suggested by authors earlier) on axial-periodic dependence of intensity of the color centers luminescence is advanced. If earlier the method was based on measurement of depth of modulation of axial-periodic dependence, now the conditions of excitation and observation of a luminescence and form of sample which allow to apply simple procedure for determination of orientations and oscillators type are found. In the given updating a method on presence or absence of modulation in two spatial – periodic pictures of a luminescence of the centers the oscillators orientations are determined, and on position of maxima and minima type absorbing and radiating oscillators are unequivocally determined. The method is experimentally approved on F_2 and F_3^+ – color centers in crystals LiF with the induced anisotropy. The offered method supplements known methods of azimuthal dependences and polarizing diagrams, however has a number of advantages. For example, cases of oscillators orientation on four crystallographic axes C_3 and oscillators orientation on six axes C_2 by traditional method in experiment are frequently poorly distinct (as have similar dependences), these cases are well resolved by the suggested method.

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