CONCERNING THE SELECTION RULES IN MANDEL'SHTAM-BRILLOUIN SCATTERING IN CRYSTALS

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Measurement of the intensities of the Mandel'shtam-Brillouin (MB) components in crystals having large optical anisotropy is of considerable interest because recently Nelson and Lax [1] have pointed out the error of the customary idea that the photoelasticity tensor of optically anisotropy crystals is symmetrical. It follows from [1] that when account is taken of the antisymmetrical deformation tensor, which describes the rotation of the volume element of the crystal, the photoelasticity tensor $p'_{ijk\ell}$ is represented in the form of a sum of parts that are symmetrical and antisymmetrical with respect to the acoustic indices, $p'_{ijk\ell} = p_{ij(k\ell)} + p_{ij[k\ell]}$. The antisymmetrical photoelasticity tensor $p_{ij[k\ell]}$ is determined only by the dielectric tensor. Our calculations have shown that when $p_{ij[k\ell]}$ is taken into account an appreciable change (in some cases $\sim 10^3$) takes place in the values of the scattering coefficients of calcite.

We have investigated the thermal MB scattering in calcite single crystals. Light from an He-Ne laser with $\lambda = 0.63\ \mu$, scattered through 90°, was analyzed with a Fabry-Perot interferometer, and the interference patterns were registered photographically. The relative intensities of the MB components were measured by photographic photometry. The intensity of the incident light was calibrated with density scales that were photographed simultaneously with the scattering spectrum in the light of the same laser. The exact setting of the crystal during the photography of the spectra was effected by the conoscopic picture. The reproducibility of the experimental data was $\sim 20\%$. A microphotograph of one of the spectra is shown in the figure. The experimental data and the scattering coefficients calculated in accordance with the Motulevich formulas [2] are summarized in the table, where $\tilde{R}^{rs}_{pq}$ and R^{rs}_{pq} are the values of the scattering coefficients calculated without and with allowance for $p_{ij[k\ell]}$, respectively, p and q are the propagation directions, r and s denote the polarizations of the incident and scattered light, and $\vec{\kappa}$ and $\vec{\gamma}$ are unit vectors of the propagation direction and phonon polarization corresponding to the given MB component.

Microphotogram of the scattering spectrum for the case $\vec{\kappa}(0; 0.67; -0.744)$. The dispersion range of the interferometer is 1.663 cm^{-1}.

As seen from the table, the most significant changes in the calculated scattering coefficients occur for components corresponding to quasitransverse phonons polarized in the scattering plane. To explain such changes of the scattering coefficients, let us examine the expressions for the components of the tensor describing the change of the dielectric constant ϕ_{ij}, the squares of which determine the intensities of the corresponding MB components.

Without allowance for $p_{ij[k\ell]}$ we have

	${}_{III}R^{xx}_{zy}$	${}_{I}R^{xx}_{zy}$	${}_{I}R^{yz}_{zy}$	${}_{III}R^{yz}_{zy}$	${}_{II}R^{yz}_{-zy}$
κ	0; 0,706; – 0,706	0; 0,706; – 0,706	0; 0,67; – 0,744	0; 0,67; – 0,744	0; 0,67; 0,744
γ	0; 0,67; – 0,65	0; 0,65; 0,76	0; 0,7; 0,715	0; 0,715; – 0,7	0; 0,56; – 0,83
$v_{calc} \cdot 10^5$ cm/sec	6.02	3,42	3,24	5,97	3,14
$v_{exp} \cdot 10^5$ cm/sec	6.01	3,38	3,31	6,05	3,10
$\tilde{R}^{rs}_{pq}$	100	6,5	0.006	12,6	0,49
R^{rs}_{pq}	100	6,5	12,5	11,7	17,4
R^{rs}_{pq} exp	100	8	7,5	14	19

$$\tilde{\phi}_{yz} = n_y^2 n_z^2 [p_{41}(\kappa_x \gamma_x - \kappa_y \gamma_y) + p_{44}(\kappa_z \gamma_y + \kappa_y \gamma_z)]. \quad (1)$$

With allowance for $p_{ij[k\ell]}$ we have

$$\phi_{yz} = n_y^2 n_z^2 [p'_{41}(\kappa_x \gamma_x - \kappa_y \gamma_y) + p'_{44}\kappa_z \gamma_y + p'_{44} - \kappa_y \gamma_z], \quad (2)$$

where $p_{41} = p'_{41} = 0.01$, $p_{44} = 0.09$, and for the new tensor elements, using the Pockels data [3] for the symmetrical photoelasticity tensor $p_{ij(k\ell)}$, we obtain $p'_{2323} = p'_{44} = p'_{3113} = p'_{55} = -0.045$ and $p'_{2332} = p'_{4\bar{4}} = p'_{3131} = p'_{55} = -0.135$ for $\lambda = 0.63\ \mu$. In the case (1), for a quasitransverse phonon polarized in the scattering plane yz, we have $\kappa_z\gamma_y \simeq -\kappa_y\gamma_z$, and ${}_{I}\tilde{R}^{yz}_{zy}$ and ${}_{II}\tilde{R}^{yz}_{zy}$ are small by virtue of the smallness of the coefficient of p_{44} (see the table). On the other hand, for the quasitransverse phonon in the case (2), the last two terms in the expression for ϕ_{yx} can be represented approximately in the form $\kappa_z\gamma_y(p'_{44} - p'_{4\bar{4}}) = \kappa_z\gamma_y 2p_{23[2,3]}$, where $p_{23[2,3]} = 0.045$, meaning that ϕ_{yz} is now determined mainly by the value of the corresponding component of the antisymmetrical photoelasticity tensor, which leads to an appreciable change in the values of the scattering coefficients for the corresponding MB components. For the longitudinal MB components, allowance for $p_{ij[k\ell]}$, as expected, had no noticeable influence on the value of the scattering coefficient. The experimental data agree much better with the case (2), i.e., they indicate the need for taking into account the antisymmetrical deformation tensor in the analysis of the photoelasticity of optically anisotropic crystals. It should be noted that the experimental data cannot be attributed to changes only in the photoelasticity tensor components if this tensor is originally symmetrical, i.e., the system of three equations determining the experimental values of the component intensities ${}_{I}R^{yz}_{zy}$, ${}_{III}R^{yz}_{zy}$, and ${}_{II}R^{yz}_{-zy}$ is not compatible for all values of the components p_{41} and p_{44} of a photoelasticity tensor that is symmetrical in the acoustical indices. It follows from our data that one of the selection rules obtained by Gammon [4] is not satisfied for MB scattering in calcite.

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EXCITATION OF SRS USING A LOW-POWER LASER[1)]

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It is known that placement of a Raman-active substance inside a laser resonator makes it possible to greatly reduce the laser threshold power both as a result of formation of a resonator for the emission of stimulated Raman scattering (SRS) and as a result of the large laser-radiation fluxes inside the resonator [1, 2]. At a given laser power, i.e., the power released by the working medium of the laser, the laser radiation flux power in the resonator is determined by the losses introduced by the active element, by the mirrors, by the optical parts in the resonator, and by the cell with the Raman-active substance. These losses cannot be made very small. For example, using a ruby laser, the total loss amounts to 20 - 50% per pass and more. Consequently, in this case the exciting-radiation power in the resonator is only several times larger than the laser power.

We propose here a method for exciting SRS, whereby the exciting-radiation power can be made 100 times the laser power and more. The method is based on excitation of SRS in a confocal resonator of short length placed inside the laser resonator and filled with the Raman-active substance. Generation in the laser resonator is accompanied by much stronger radiation in the interior of the confocal resonator. In conjunction with the high Q of the confocal resonator for the radiation of the first Stokes component, this ensures excitation of SRS at relatively low power of the exciting laser[2)].

Figure 1 shows a diagram of the experimental setup with a confocal resonator, used to excite SRS in methane. Here 1 and 9 - mirrors forming a ruby-laser resonator 150 cm long, 2 - ruby rod, 6, 7 - mirrors of confocal resonator of 22 mm radius, 4 - cell with methane at a pressure of 70 atm, 5, 8 - cell windows, 3 - beam-splitting glass plate. The confocal-resonator mirror reflection coefficient was 90% at the laser wavelength and 96% at the wavelength 8708 Å of the first Stokes component.

If the incident radiation beam corresponding to some transverse mode of the laser, and having a frequency lying within the resonance band of the confocal resonator, is not matched to the confocal resonator, a two-beam annular mode is established in the confocal resonator (see Fig. 2). The radiation flux $P_2^{\dagger}$ in the confocal resonator is connected with the flux $P^{\dagger}$ incident on the resonator by the relation

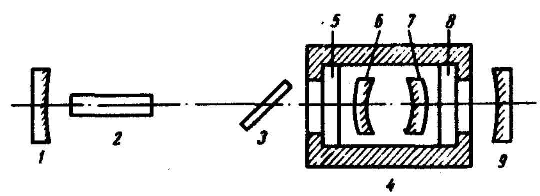

Fig. 1. Diagram of experimental setup.

1)Invention Disclosure No. 1467771/26-25, Priority 30 July 1970.

2)It is possible to use in lieu of a confocal resonator also a resonator of the Fox-Smith interferometer type, but in this case it becomes necessary to match the modes. In addition, it is possible to use different degenerate resonant systems [3].