

LETTERS

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Comparison of the optical parameters of a CaF_2 single crystal and optical ceramics

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***Abstract*. Single crystal and optical ceramic CaF_2 samples are studied by the method of thermally induced depolarisation of laser radiation at 1076 nm. The absorption coefficients of the single crystal and ceramics are estimated as $\alpha < 4.5\times 10^{-4}$ cm^{-1} and $\alpha < 1.33\times 10^{-3}$ cm^{-1}, respectively.**

Keywords: *thermally induced depolarisation, optical ceramics, optical absorption, fluorite.*

Optical ceramic materials, in particular, active laser elements have aroused considerable interest in recent years [1, 2]. The spectral and lasing parameters achieved for ceramic samples compare well with those of single crystals. Of interest is also the development of manufacturing technology of fluoride laser ceramics [3].

The aim of this paper is to compare the optical characteristics of single crystal fluorite and transparent ceramics of the same chemical composition by the method of thermally induced depolarisation of laser radiation. We studied two CaF_2 samples of almost identical sizes (9 mm × 13 mm × 45 mm). One sample was cut from a single-crystal boule grown by the method of vertically directed crystallisation (the [001] orientation), another – from a piece of artificial optical ceramics synthesised and studied in [3].

Figure 1 shows the scheme of measurements. Linearly polarised laser (*1*) radiation is incident on spar wedge (*2*) providing ideal linear polarisation. Spar wedge (*3*) is oriented so that minimum of radiation is incident on CCD camera (*4*). The contrast of spar wedges was no worse than 10^{-6}. The radiation propagated through a sample became depolarised. Objective (*6*) transferred the image from the exit face of the sample on the CCD camera.

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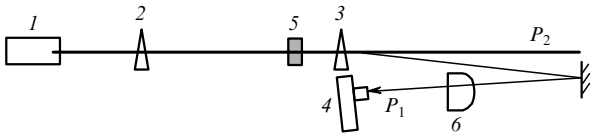

Figure 1. Scheme for measuring depolarisation in ceramic and crystal CaF_2 samples: (*1*) 1076-nm laser; (*2*, *3*) spar wedges; (*4*) CCD camera; (*5*) sample; (*6*) objective.

Depolarisation γ is described by the ratio $P_1/(P_1+P_2)$, where P_1 and P_2 are the radiation powers of the depolarised and polarised components, respectively. The obtained results are presented in Figs 2 and 3.

One can see from Fig. 2 that depolarisation in both samples is mainly localised in aperture angles, which is probably caused by stresses produced during cutting or machining. Depolarisation in ceramics is negligible (10^{-3} in better regions), although it is somewhat higher than in the single crystal.

Absorption in samples was determined by measuring depolarisation at a high power (Fig. 3) by the following method. Any cubic crystal is initially optically isotropic. The absorption of radiation in it is accompanied by the heat release, which produces temperature gradients resulting in mechanical stresses. Due to the photoelastic effect, such mechanical stresses cause the thermally induced depolarisation γ_T, which has the distribution in the form of the 'Maltese cross'. In the case of weak thermal releases in a crystal with the [001] orientation [4] and ceramics [5, 6], γ_T for a Gaussian beam is determined by the expressions

$$\gamma_{T[001]} = 0.137\,\frac{p^2}{8}\left[1+\left(\xi^2-1\right)\cos^2(2\theta)\right],$$

$$\gamma_{T\mathrm{cer}} = 0.137\,\frac{p^2}{8}\left(\frac{1+2\xi_{\mathrm{eff}}}{3}\right)^2,$$

where

$$p=\frac{Q\alpha L(P_1+P_2)}{\lambda\kappa};\quad Q=\alpha_T\,\frac{n_0^3}{4}\,\frac{1+\nu}{1-\nu}\,(p_{11}-p_{12});$$

$$\xi=\frac{2p_{44}}{p_{11}-p_{12}};\quad \xi_{\mathrm{eff}}=1+(\xi-1)\,\frac{225}{256};$$

α is the absorption coefficient of a sample; λ is the wavelength; θ is the angle between polarisation and one of the crystallographic axes; $p_{11}=0.056$, $p_{12}=0.228$, $p_{44}=$

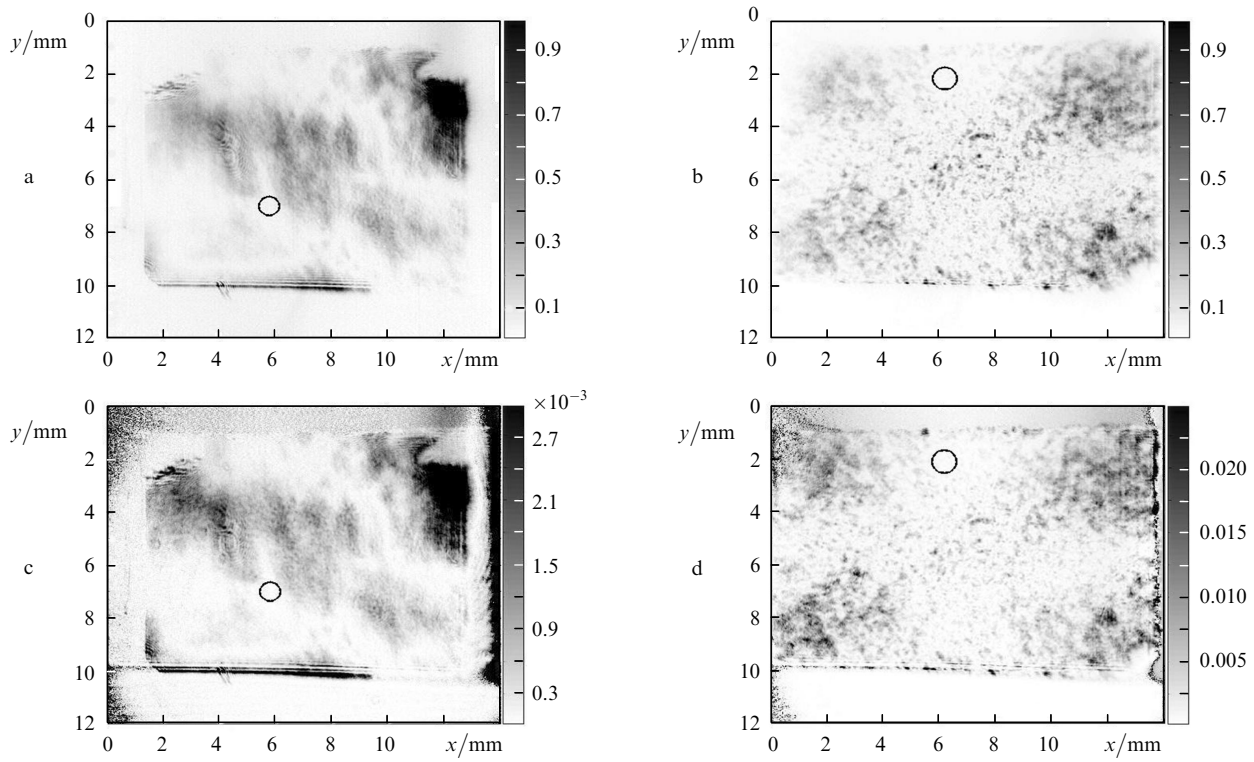

Figure 2. Spatial distributions of the depolarised component (a, b) and depolarisation (c, d) in the single crystal (a, c) and ceramics (b, d) for a radiation power of 1 W.

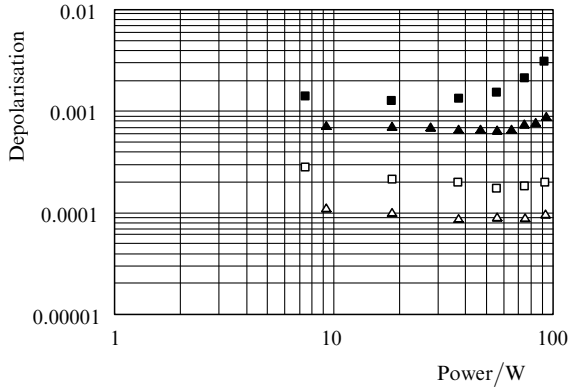

Figure 3. Dependences of depolarisation in regions indicated by circles in Fig. 2 on the radiation power for ceramics (dark squares and triangles) and single crystal (open squares and triangles) for $\theta = 45^\circ$ (squares) and $\theta = 0$ (triangles).

-0.024 are photoelastic coefficients; $\kappa = 10.3$ W m^{-1} K^{-1} is the heat conduction; $v = 0.24$ is the Poisson coefficient; $n_0 = 1.428$ is the refractive index; $\alpha_T = 18 \times 10^{-6}$ K^{-1} is the linear expansion coefficient; and $L = 45$ mm is the sample length. Thus, if the value of thermally induced depolarisation γ_T and constants of the medium are known, the absorption coefficient α can be easily calculated.

One can see from Fig. 3 that thermally induced polarisation in the crystal for powers up to 100 W is lower than 'cold' polarisation. Therefore, we cannot calculate absorption accurately. However, we can assert that it does not reach 4.5×10^{-4} cm^{-1}. In ceramics, we also did not observe thermally induced depolarisation ('Maltese cross'); however, the beginning of the rise in Fig. 3 demonstrates that absorption in ceramics is higher than in the crystal. According to our estimates, it does not exceed 1.33×10^{-3} cm^{-1}.

Thus, the calcium fluoride ceramics synthesised in [3] has the optical quality and low absorption.

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