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# A study of resistance of absorbing centres in a $Pr^{2+}:CaF_2$ crystal to high-power laser radiation

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***Abstract*. A change in the absorption coefficient of $Pr^{2+}$::$CaF_2$ crystal in the spectral region from 530 to 1000 nm is found after irradiation by 30-mJ, 20-ns pulses from a repetitively pulsed 1.064-μm neodymium laser with a radiation power density of 500 MW $cm^{-2}$. After irradiation by $10^5$ pulses, the spectrum of the absorption coefficient variation $\Delta\alpha$ represents a broad band ($\sim$ 3000 $cm^{-1}$) centred at 710 nm with the maximum value of $\Delta\alpha = 1.1$ $cm^{-1}$.**

***Keywords***: *photochemical transformations, interaction of radiation with matter.*

This paper is devoted to the study of photochemical transformations in a fluorite crystal $CaF_2$ doped with $Pr^{2+}$ ions induced by a high-power IR radiation at 1.064 μm.

Due to their high transparency in a broad spectral range and good technological parameters, fluorite crystals were always treated as a promising laser material [1 – 4]. Fluorite crystals doped with special impurities are used as passive switches [5] and as apodising diaphragms [6]. In the latter case, $CaF_2$ crystals doped with $Pr^{2+}$ ions are used, and the resistance of these crystals to high-power laser radiation is an important characteristic of the material. Note that the characteristics of crystals of other types varied after high-power IR irradiation. For example, an irreversible change in the transmission of an LiF crystal with $F_2^-$ colour centres was observed in Ref. [7] after a high-power irradiation at 1.06 μm.

Photochemical transformations of colour centres in fluorite crystals were investigated earlier in a number of papers. For example, photochemical transformations induced by UV radiation were observed in Refs [8, 9]. The resistance of colloidal absorption bands to high-power IR irradiation was investigated in Ref. [9] by using the 1.064-μm radiation from a Nd laser. In this case, only an insignificant weakening of the colloidal absorption band with maxima in the region between 2 and 3 μm was observed. In Ref. [6], the $Pr^{+2}$:$CaF_2$-based apodising diaphragms were manufactured using an argon laser.

We present below the results of exposure of $Pr^{2+}:CaF_2$ crystals to high-power radiation at 1.064 μm, which demonstrate the appearance of a new broad absorption band with a maximum in the near-IR spectral region.

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A sample was irradiated by a focused beam from a repetitively pulsed Nd laser. After irradiation by a certain number of pulses, the transmission spectrum was measured in the irradiated region of the sample. The diameter of the irradiated region was 0.6 mm.

Because the measurements of the transmission of a sample irradiated by a focused laser beam with the help of commercial spectrophotometers involves difficulties, we assembled a special setup for transmission measurements (Fig. 1). Light from flashlamp (*1*) was coupled with the help of fibre (*2*) to the entrance slit of monochromator (*3*), from which radiation of the required wavelength was coupled to fibre (*4*). A 1:1 image of the fibre end was formed by objective (*6*) on sample (*7*). The size of the light spot on the sample was 0.3 mm. A part of the radiation incident on the sample was directed by beamsplitter (*5*) to photodiode (*9*) for measuring the energy of the radiation pulse incident on the sample. The energy transmitted through the sample was measured by photodiode (*8*). Signals from the photodiodes were registered by digital ATsP-14 voltmeters in the standard CAMAC configuration. An AGAT PC was used for controlling the monochromator, as well as for collection and preliminary processing of the experimental data.

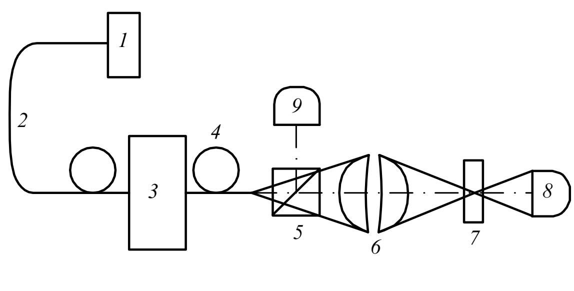


**Figure 1.** Experimental setup.

Samples were irradiated by 30-mJ, 20-ns IR pulses from a *Q*-switched Nd : YAG laser. The pulse repetition rate was 20 Hz and the radiation power density on the sample was about of 500 MW $cm^{-2}$. During irradiation, the photodiode was moved aside, and a screen was inserted between objective (*6*) and sample (*7*) to protect the objective from exposure to high-power radiation. After irradiation of the sample by a certain number of pulses, the transmission of the irradiated part of the sample was measured.

Fig. 2 shows the transmission and the absorption coefficient of the $Pr^{2+}:CaF_2$ crystal measured before and after irradiation by $10^5$ pulses from a Nd:YAG laser. One can see that the transmission of the sample decreases after irradiation, the change in transmission depending on the wavelength. Fig. 3 shows the dependence of the absorption coefficient variation on the wavelength obtained by processing the data of Fig. 2. The spectrum of the absorption coefficient variation represents a broad band of width about of 3000 $cm^{-1}$ centred at 710 nm. After irradiation of the sample by $10^5$ pulses, the absorption coefficient at the maximum was $\sim 1.1$ $cm^{-1}$.

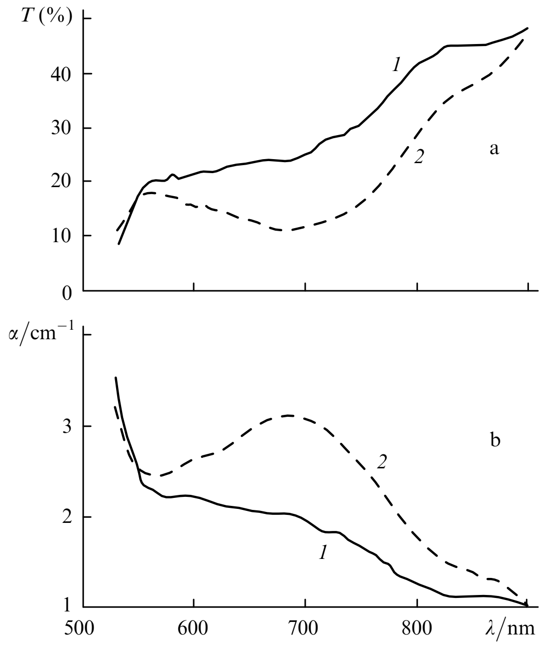


**Figure 2.** (a) Transmission and (b) the absorption coefficient of the sample before (curve *1*) and after (curve *2*) irradiation by $10^5$ pulses.

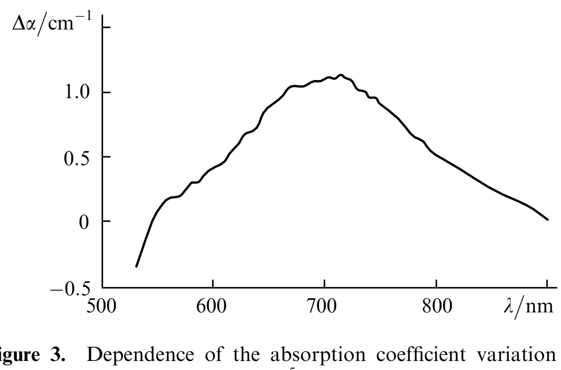


**Figure 3.** Dependence of the absorption coefficient variation on the wavelength after irradiation by $10^5$ pulses.

The dependence of the absorption coefficient variation at 710 nm on the number of radiation pulses is shown in Fig. 4. The solid curve in the figure corresponds to the approximation by the formula $f(n) = \alpha_0[1 - \exp(-\beta n)]$, where $\alpha_0 = 1.13$ $cm^{-1}$, $\beta = 0.046$, and $n$ is the number of pulses used.

We can assume that a new 710-nm absorption band is related to *M* centres produced in the sample by high-power IR irradiation [1, 4]. To understand the nature of this absorption band, further studies are required.

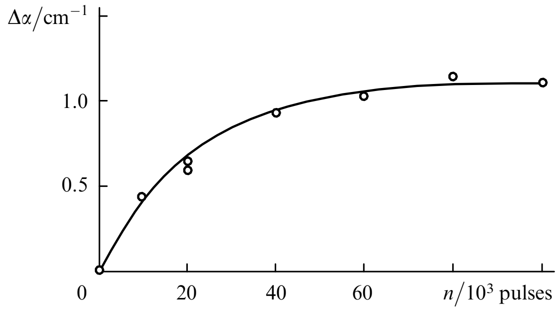


**Figure 4.** Dependence of the absorption coefficient variation at 710 nm on the number *n* of radiation pulses.

Thus, we have found the change in the absorption coefficient of a $Pr^{2+}:CaF_2$ crystal after its irradiation by a high-power laser pulses at 1.06 μm. The spectrum of the absorption coefficient variation represents a broad band of width $\sim 3000$ $cm^{-1}$ centred at 710 nm.

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