Experimental investigation of the photoconductivity of wide-band insulators excited by ultraviolet laser radiation

B. G. Gorshkov, A. S. Epifanov, A. A. Manenkov, and A. A. Panov

P. N. Lebedev Physics Institute, Academy of Sciences of the USSR, Moscow
(Submitted 13 April 1981)
Zh. Eksp. Teor. Fiz. **81**, 1423–1434 (October 1981)

An investigation was made of the photoconductivity σ of wide-band insulators subjected to high-power ultraviolet ($\lambda = 0.27$ and $0.35\ \mu$) laser radiation. The dependence of σ on the laser radiation intensity I were determined. An irreversible increase in the photoconductivity of alkali halide crystals was observed at the wavelength $\lambda = 0.27\ \mu$ when the dependence $\sigma(I)$ was recorded by reducing the intensity. A study was made of the influence of heating and of high-temperature annealing of σ. Possible mechanisms of the photoconductivity of the investigated crystals were analyzed. The experimental data on the photoconductivity of KDP at the $\lambda = 0.27\ \mu$ wavelength were used to estimate the two-photon absorption coefficient β.

PACS numbers: 72.40. + w, 72.80.Jc

INTRODUCTION

Detection and investigation of the photoconductivity excited by laser radiation[1)] in transparent solids is of considerable interest in various aspects of the physics of the interaction of high-power electromagnetic radiation with matter. Such investigations can give, in particular, direct information on the ionization processes and they can be decisive in the determination of the dominant laser damage mechanism.

Several recent experimental and theoretical investigations[1-5] have established some characteristics of the optical strength of transport insulators subjected to laser radiation. In these investigations the laser damage mechanism was determined by indirect methods: the temperature and frequency dependences of the damage threshold regarded as a function of the intensity of the incident radiation were found experimentally and were then compared with the corresponding theoretical dependences, which made it possible to study the damage morphology, influence of heat treatment on the optical strength, etc. However, in order to identify the mechanism responsible for the damage to transparent insulators by laser radiation, it is preferable to employ methods involving direct detection of nonequilibrium carriers in the region of the interaction between laser radiation and matter. Investigations of the laser photoconductivity can give direct information on the nonequilibrium carrier density and can be used to determine the correlation between the photoconductivity kinetics and the laser damage dynamics. Investigations of this kind have been carried out already (see, for example, Refs. 6–8). The role of seed electrons in laser damage is considered in Refs. 9–13. Studies of the laser photoconductivity of wide-band insulators can also help to determine the mechanisms of nonlinear absorption in optical materials.

We studied the photoconductivity of alkali halide crystals and of transparent insulators used widely as optical materials in lasers ($Al_2O_3:Cr^{3+}$, KDP, DKDP, CaF_2). These materials were excited by ultraviolet radiation representing the third and fourth harmonics of a neodymium laser whose wavelengths were 0.35 and 0.27 μ, respectively. In these investigations our aim was to identify the mechanisms of the photoexcitation of nonequilibrium carriers by a detailed study of the dependences of the photoconductivity signal amplitude σ on the intensity I of the exciting laser radiation.

APPARATUS AND PHOTOCONDUCTIVITY MEASUREMENT METHOD

We used a Q-switched YAG:Nd^{3+} laser whose 1.06 μ radiation was converted, depending on the experiment, into the second, third, or fourth harmonics by doubling and mixing the frequencies of the fundamental and second harmonics in nonlinear KDP and DKDP crystals. Transverse and longitudinal modes were selected by standard methods so as to obtain single-frequency emission of the dominant TEM_{00} oscillation. A sufficiently high radiation power was achieved at all frequencies by amplifying the radiation from a master oscillator in three YAG:Nd^{3+} stages. The output energy of the radiation at the fundamental frequency (1.06 μ) of this system reached 1 J and the energies of the radiation at the second, third, and fourth harmonics of the fundamental frequency were 0.2, 0.05, and 0.01 J, respectively. The duration of the ultraviolet radiation pulses (of the wavelengths 0.35 and 0.27 μ) used in our experiments was 8 nsec at half-maximum and the shape of the pulses was close to Gaussian. When necessary, the radiation was attenuated stepwise by filters and the power could be reduced continuously by altering the output energy if the pump lamps in the laser amplification stages. A special feature of the apparatus was the absence of noise and strays during a laser pulse, which was important in recording weak photoconductivity signals. The diameter of a collimated or a weakly focused (by a long-focus KU fused quartz lens) laser beam was 0.15–2 mm on the surface of an investigated sample. This made it possible to measure the photoresponse in a wide range of intensities of the laser radiation ranging from values limited by the sensitivity of the apparatus to those close to the surface optical strength of crystals ($\sim 10^8$ W/cm^2).

The investigated transparent insulator samples were parallelepipeds of 4×4 mm cross section and 20 mm

 0038-5646/81/100755-06$02.40

long; the surfaces were either natural cleavage planes or were polished. The laser photoconductivity signal was recorded using a widely employed circuit with a capacitative coupling of the electrodes to a crystal (see, for example, Ref. 14).

Since the diameter of a laser beam on the surface of a sample did not exceed 2 mm, the radiation did not reach the electrodes directly. These electrodes were thin platinum plates of 2×10 mm dimensions. These platinum electrodes had the highest values of the work function (about 5.3 eV) among the tested metals (copper, nickel, silver, etc.) and this value exceeded the photon energy of the fourth harmonic of the neodymium laser (approximately 4.7 eV). Therefore, platinum was practically the only electrode material which allowed us to avoid stray signals resulting from the photoelectric effect of the electrodes encountered in studies of the photoconductivity of insulators at such very high radiation frequencies. The absence of stray signals due to the illumination of the electrodes was checked in a special experiment in which a scattering quartz plate was inserted in a laser beam: there was no photoconductivity signal due to the scattered radiation reaching the electrodes (a comparison was made with the case when the electrodes were screened completely from the scattered radiation). The contribution of the surface conductivity was suppressed by ensuring that the end surfaces of the samples were outside the electric field and by avoiding illumination of the lateral surfaces of the samples.

A high-voltage generator consisting of a pulsed high-voltage transformer and a rectifier, together with a triggering circuit for the pump lamps, produced electric pulses of amplitude up to 12 kV and duration of about 2×10^{-3} sec. These parameters made it possible to avoid creation of a space charge in the samples during the time between the laser pulses (~10–15 sec), because the majority of the investigated insulators were characterized by a fairly high room-temperature value of the bulk conductivity (for example, of the order of $10^{-13}\Omega^{-1}\cdot\text{cm}^{-1}$ in the case of NaCl) and a correspondingly short dielectric relaxation time (about 1 sec for NaCl). In the case of the processes occurring in times comparable with the laser pulse duration ($t_p\sim10^{-8}$ sec), the high voltage applied to the sample could be regarded as constant.

A set of parameters was selected so that the voltage across the charging capacitor reached its maximum value at the moment of generation of a giant laser pulse. The photoconductivity signal of a sample was recorded from a load resistance R_l and it was applied to an oscilloscope whose input capacitance was C_{in} and input resistance was R_{in}; the signal reached the oscilloscope either directly or via a wide-band amplifier. The system for recording the laser photoconductivity allowed us to study the photoresponse under signal integration and time resolution conditions. When the conditions $R_l \ll R_{in}$ and $R_l C_{in} \gg t_p$ were satisfied (carrier recombination time in the insulators[15] was $\tau_{rec}\sim10^{-11}$ sec, and therefore, $\tau_{rec} < t_p$), then the integration regime was obtained and this made it possible to increase the sensitivity of the detection system to small signals, i.e., to extend the dynamic range of the laser photoconductivity investigation. In this case the signal had a steep leading edge and an exponential decay characterized by a time constant $R_l C_{in}$.

Allowing for the coefficient representing the occupancy of the interelectrode space by radiation, $k=S/af$ (where S is the cross-sectional area of the laser beam, a and l are the electrode width and length, and f is the distance between the electrodes), we could express the signal amplitude in the form

$$u=USt_p\sigma l/f^2C_{in}, \tag{1}$$

where U is the voltage across the sample ($U \gg u$) and σ is the photoconductivity.

For $R_l C_{in} \ll t_p$ the regime of high time resolution was obtained. In this case the photoconductivity signal amplitude was

$$u=USl\sigma R_l/f^2. \tag{2}$$

EXPERIMENTAL RESULTS

The photoconductivity at 0.27 μ was observed for NaCl, KCl, KBr, KI, KDP, DKDP, $Al_2O_3:Cr^{3+}$, and CaF_2 crystals: for a given intensity of the laser radiation, the photoconductivity signal of alkali halide crystals was approximately an order of magnitude higher. The duration of the photocurrent pulses generated in all our crystals was equal to the duration of the laser pulses. Longer (~30 nsec) signals were exhibited only by KDP and DKDP.

Figure 1 shows the dependence $\sigma(I)$ of the laser photoconductivity at the wavelength 0.27 μ on the intensity of the laser radiation recorded for KDP and DKDP crystals. This dependence clearly consisted of a linear region in the range of low (~10^3–10^5 W/cm^2) laser radiation intensities, followed by a quadratic region. At 0.35 μ wavelength there was no photoconductivity in the case of KDP and DKDP.

The dependence $\sigma(I)$ was more complex in the case of alkali halide crystals. At the wavelength 0.27 μ an increase of the laser radiation intensity revealed three regions: a linear one at low laser radiation intensities, a superlinear one with a power exponent 1.4–2.1 at moderate intensities (~10^5–10^6 W/cm^2), and another

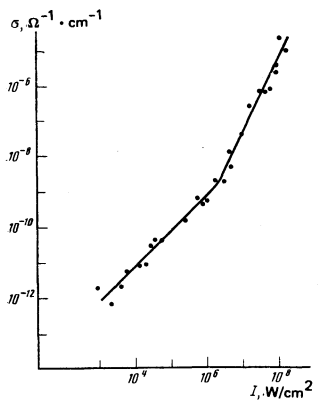

FIG. 1. Dependence $\sigma(I)$ for KDP and DKDP at $\lambda = 0.27\,\mu$.

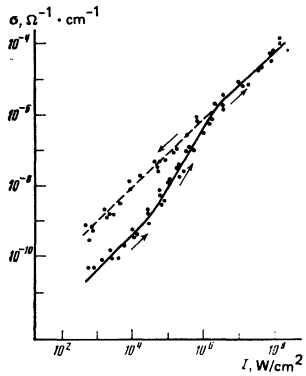

FIG. 2. Dependence $\sigma(I)$ for KCl at $\lambda = 0.27\,\mu$. The dashed curve shows the irreversible increase in σ when I is varied from high to low values (the directions of changes in I are denoted by arrows).

linear region at high intensities ($\sim 10^7$–10^8 W/cm^2). Typical results obtained for KCl are plotted in Fig. 2. One should point out that in the super-linear region of $\sigma(I)$ the power exponent of the laser radiation intensity varied not only with the nature of the alkali halide crystal, but also (within a certain range) from sample to sample. The absolute value of the signal varied within one order of magnitude.

All the $\sigma(I)$ dependences were recorded in the presence of strong additional illumination of the samples corresponding to the absorption band of the F centers; this illumination was provided by a halogen incandescent lamp of 100 W power. Without this additional illumination the photoconductivity signal was 3–5 times greater and the nature of the dependence $\sigma(I)$ was the same. Moreover, a special experiment carried out at the wavelengths of 0.27 and 0.53 μ established that a strong additional illumination suppressed the F centers generated by ultraviolet radiation during the ~10–15 sec intervals between the laser pulses. In this experiment we found that the action of the 0.27 μ laser radiation created the F centers, as deduced from the characteristic coloration of that part of a sample which was subjected to laser radiation (in this case the F-center concentration was at least 10^{15}–10^{16} cm^{-3}, as estimated from the absorption of light). Next, laser radiation of the 0.53 μ wavelength was directed to the same part of the sample. In the absence of a strong additional illumination the first 0.53 μ pulses produced clearly a photoconductivity signal (which should be attributed to the presence of the F centers because without a preliminary illumination at the 0.27 μ wavelength there was no photoconductivity signal at 0.53 μ). This signal could be used to estimate the F-center concentration.

When the samples were illuminated strongly with additional light from a halogen lamp, the photoconductivity signal at the 0.53 μ wavelength (after a preliminary illumination at 0.27 μ) was no longer observed, indicating that the F centers disappeared.

In the case of alkali halide crystals illuminated with the 0.27 μ wavelength it was found that when the dependence of the photoconductivity on the illumination intensity was recorded by reducing this intensity from high to low values, the photoconductivity did not return to the superlinear part of the dependence but remained a practically linear function of the intensity right down to low values of the latter (dashed line in Fig. 2). We thus established that illumination of alkali halide crystals with laser radiation of the 0.27 μ wavelength increased irreversibly the photoconductivity. This increase was stable and was retained for a long time (in excess of 100 h) even when the samples were subjected to prolonged bleaching with light from a high-power quartz lamp emitting in a wide range of frequencies.

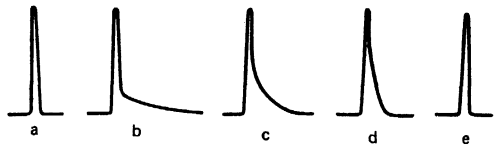

FIG. 3. Form of the photoconductivity signal observed on heating alkali halide crystals to the following temperatures: a) $T \approx 800$°K; b) 820°K ($\tau_1 \sim 10^{-7}$ sec, $\tau_2 \sim 2\times 10^{-6}$ sec); c) 840°K; d) 860°K; e) 900°K ($\tau_1 \sim 10^{-7}$ sec, $\tau_2 \sim 3\times 10^{-7}$ sec), where τ_1 and τ_2 are the time constants of the first and second exponential functions.

In a study of the influence of heating on the photoconductivity of alkali halides at the wavelength 0.27 μ it was established that when the temperature of the samples was about 700 °K the photoconductivity signal decreased by a factor of 7–10 compared with the room-temperature value. At about 850 °K the photoconductivity signal was in the form of two exponential functions and a further increase in temperature reduced rapidly the time constant of the second function (Fig. 3). The second function could be attributed to thermal ionization of lattice defects or traps of different kind whose energy levels were filled during a laser pulse.

Annealing in air at a temperature close to the melting point of a crystal, followed by rapid cooling, again reduced the photoconductivity signal (compared with that exhibited by a nonannealed sample). For example, in the case of KCl the signal fell by a factor of 8.

The laser photoconductivity of NaCl and KCl at the

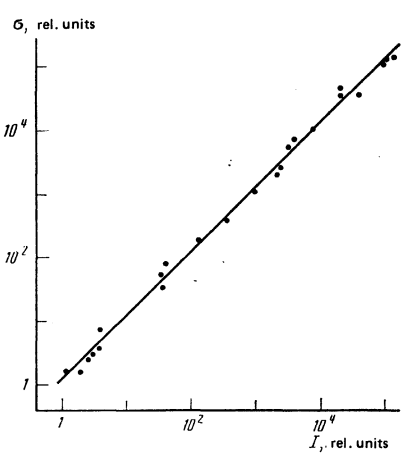

FIG. 4. Dependence $\sigma(I)$ for NaCl and KCl at $\lambda = 0.35\,\mu$ (after preliminary illumination at $\lambda = 0.27\,\mu$).

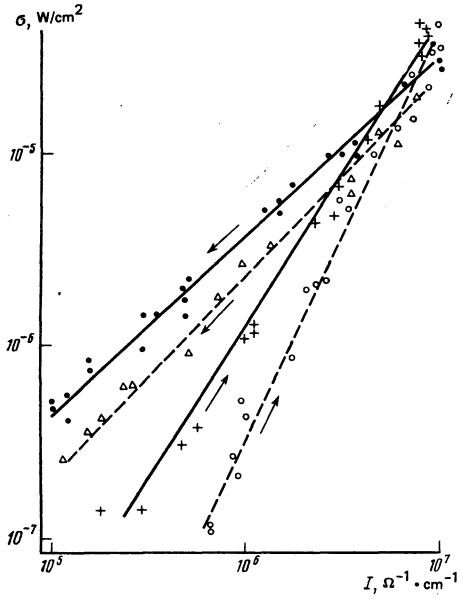

FIG. 5. Influence of high-temperature annealing on the dependence $\sigma(I)$ for KBr. The dashed lines show $\sigma(I)$ for the annealed crystals. The arrows indicate the direction of changes in the intensity of $\lambda = 0.35\,\mu$ laser radiation.

wavelength 0.35 μ was 2–3 orders of magnitude less than at 0.27 μ. A strong photoconductivity of NaCl and KCl at the 0.35 μ wavelength appeared only after preliminary illumination at 0.27 μ. The dependence $\sigma(I)$ at the wavelength of 0.35 μ was in this case linear for the "forward" and "reverse" intensity dependences (Fig. 4), and the absolute photoconductivity signal was approximately equal to the signal exhibited by KBr and KI at 0.35 μ.

In the case of KBr and KI illuminated with the 0.35 μ wavelength the nature of the dependence $\sigma(I)$ was the same as that obtained for 0.27 μ (Fig. 2). High-temperature annealing reduced by a factor of 2–5 the absolute photoconductivity signal at low and moderate illumination intensities, and had practically no influence at higher intensities (see Fig. 5 for KBr).

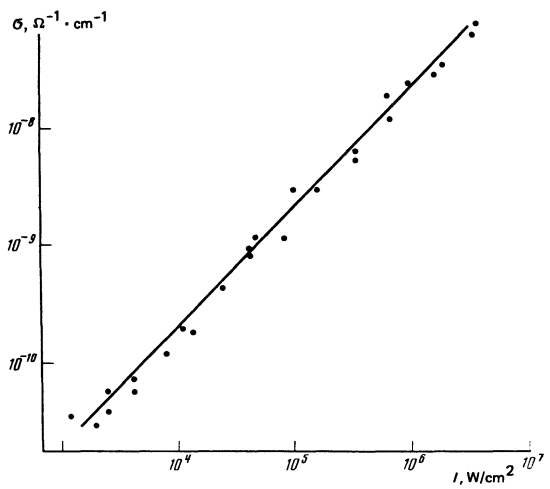

FIG. 6. Dependence $\sigma(I)$ for ruby at $\lambda = 0.27\,\mu$.

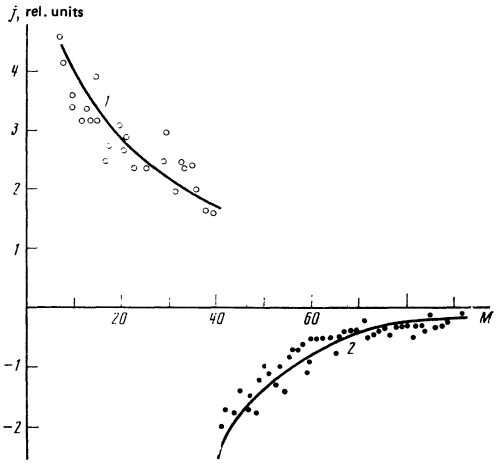

FIG. 7. Reduction in the photocurrent j of ruby as a result of formation of a space charge inside a crystal (1) and the photocurrent in ruby due to the presence of a space charge (2). Here, M is the number of laser pulses.

In the case of CaF_2 crystals the laser photoconductivity at the 0.27 μ wavelength was observed only at very high intensities (~10^8 W/cm² or higher). The range of the laser radiation intensities exciting the photoconductivity was found to be very narrow, because it was limited from above by the optical strength of the CaF_2 samples.

The dependence $\sigma(I)$ of ruby crystals was linear (Fig. 6) throughout the investigated range of laser radiation intensities (wavelength 0.27 μ). However, repeated illumination of ruby samples with ultraviolet radiation of constant intensity at the 0.27 μ wavelength revealed a reduction in the photoconductivity with time. When an external electric field applied to a sample was switched off, the polarity of the photoconductivity signal became reversed and eventually decreased to zero on increase in the number of laser pulses (Fig. 7). Bearing in mind the relatively low ionic conductivity of ruby at room temperature (~$10^{-16}\Omega^{-1} \cdot \text{cm}^{-1}$–Ref. 16) and the long dielectric relaxation time (~10^3 sec), the observed effect could be attributed to the formation of a space charge under the influence of ultraviolet photons and the field of such a charge was directed opposite to the external field. The effect allowed us to determine experimentally the conductivity of ruby from the rate of relaxation of the space charge (when the external field was switched off, this was achieved by occasional probing of a sample with light pulses and the process of relaxation of the space charge was governed by the internal bulk conductivity of a crystal and not by the photoconductivity). It should also be pointed out that neglect of this effect could distort greatly the investigated dependences $\sigma(I)$ of crystals with a low bulk conductivity. On the other hand, the effect was unimportant in the laser photoconductivity of alkali halide and KDP (or DKDP) crystals, because they were characterized by a considerably higher ionic conductivity (~$10^{-13}\Omega^{-1} \cdot \text{cm}^{-1}$) than ruby and by a much shorter (~1 sec) dielectric relaxation time.

DISCUSSION OF RESULTS

The photoconductivity of alkali halides at the 0.27 μ wavelength (its typical intensity dependence is shown in Fig. 5) can be explained if we assume that the carrier recombination time τ_{rec} is independent of the carrier density: the effect can be attributed to multistage excitation of carriers by transitions from the valence to the conduction band via stable intermediate energy levels of impurity states.

Multistage transitions account, in particular, for the observed difference (within the range 1.4–2.1) between the power exponents in the superlinear part of the dependence $\sigma(I)$. At high (~10^7 W/cm^2) laser radiation intensities the intermediate energy levels clearly become saturated. The linear nature of the dependence $\sigma(I)$ at low intensities (~10^3–10^4 W/cm^2) may be attributed to one-photon ionization of impurities or defects.

The irreversible increase in the photoconductivity observed when the dependence $\sigma(I)$ is recorded by reducing the intensity (which can be regarded as a characteristic optical hysteresis of linear nature) is due to the presence of filled intermediate energy levels. The same explanation accounts for the linear intensity dependence of the photoconductivity at the 0.35 μ wavelength exhibited by NaCl and KCl samples subjected previously to illumination at 0.27 μ (Fig. 4).

The reduction in the photoconductivity of alkali halides at the 0.27 μ wavelength observed on increase in the temperature and the reduction after high-temperature annealing, as well as the reduction at low and moderate intensities of the 0.35 μ radiation in the case of annealed crystals (Fig. 5), all indicate emptying of the intermediate levels as a result of their thermal ionization. It is probable that a process of this type is also observed in the study of the high-temperature photoconductivity (Fig. 3).

The major part of the experimental results on alkali halides, particularly those obtained at high laser radiation intensities, can be explained by the "activation" at carrier densities $N \sim 10^{11}$ cm^{-3} of quadratic recombination processes characterized by $\tau_{rec} \propto N^{-1}$. In this case the superlinear part of the dependence $\sigma(I)$ can be explained by multistage transitions and also by two-photon ionization, and the change to linearity at $I > 10^7$ W/cm^2 may be explained by quadratic recombination of carriers.[17] However, it should be pointed out that this model fails to account for the irreversible increase in the photoconductivity in the case when the dependence is recorded by reducing the intensity; moreover, it does not explain optical hysteresis as well as other features observed at low intensities. Clearly, these features are associated with the dynamics of the filling and emptying of the intermediate energy levels located in the band gap and with a possible change in the recombination time of nonequilibrium carriers after laser irradiation creating high carrier densities. For example, the reduction in the photoconductivity signal after high-temperature annealing (Fig. 5) may be associated with the emptying of traps or with a reduction in the carrier recombination time. At high laser radiation intensities the curves for the annealed and nonannealed samples approach one another (Fig. 5) and this can easily be explained by the onset of quadratic recombination at these intensities when the individual features of the samples are no longer important.

In the case of DKP and DKDP crystals the initial linear part of the dependence $\sigma(I)$ (observed at low laser radiation intensities also in the case of alkali halides) can be explained by one-photon ionization of impurities or defects. The following quadratic region ($I > 10^5$ W/cm^2) can be attributed to two-photon energy absorption processes. A simple analysis makes it possible to find the two-phonon absorption coefficient β from the experimentally determined photoconductivity.

Since $\sigma = eN\mu$, where N is the electron density, e is the electron charge, μ is the carrier mobility, $\mu = e\tau_{rel}/m^*$, τ_{rel} is the relaxation time between electron–phonon collisions, and m^* is the effective electron mass, it follows that

$$N = \sigma m^*/e^2\tau_{rel}. \tag{3}$$

If we substitute $n = 2$ in the general formula for many-photon processes $\alpha = \alpha_0 + \beta I^{n-1}$, where α is the absorption coefficient, α_0 is the linear part of the absorption coefficient, and n is the number of absorbed photons, we find the two-photon absorption coefficient

$$\beta = 2N\hbar\omega/I^2\tau_i, \tag{4}$$

where $2\hbar\omega$ is the energy absorbed by one electron in a two-photon process and τ_i is the limiting time of the process, which is the shorter of the two times: the laser pulse duration t_p and the carrier recombination time τ_{rec}. Finally, using Eqs. (1) and (3), we obtain

$$\beta = \frac{2\hbar\omega m^* u C_{in} f^2}{I^2\tau_i e^2\tau_{rel} U\tau_2 Sl}. \tag{5}$$

In Eq. (5) the symbol τ_2 denotes the photoconductivity lifetime, i.e., the longer of the times t_p and τ_{rec}.

If we assume that in the case of KDP the recombination time obeys $\tau_{rec} > t_p$ (this hypothesis is supported by the experimentally determined duration of the photoresponse of KDP amounting to 30 nsec) and if we postulate that the carrier mobility[2)] is $\mu = 10$ cm$^2 \cdot$ V$^{-1} \cdot$ sec^{-1}, we find that an estimate based on Eq. (5) yields $\beta \sim 10^{-9}$ cm/MW. This is five orders of magnitude less than the value given in Ref. 18, where the two-photon absorption coefficient was determined by measuring nonlinear absorption of light and its value was found to be 2.7×10^{-4} cm/MW.

In the case of ruby the linear nature of the dependence $\sigma(I)$ observed over several orders of magnitude of the intensity of the 0.27 μ radiation could be explained by one-photon ionization of impurity levels. These levels were clearly due to the Cr^{3+} ions which should be located at ~4.5 eV in ruby.

CONCLUSIONS

The reported investigation of the laser photoconductivity revealed the main features of the ultraviolet photoexcitation of nonequilibrium carriers. Of special interest were the dependences of the photoconductivity

on the intensity of laser radiation $\sigma(I)$, which were very characteristic and made it possible to find the nonequilibrium carrier density N from the experimental values of the photoconductivity. We shall now list the most important experimental results.

1. In the case of alkali halide crystals the photoconductivity observed at the wavelength $\lambda = 0.27\ \mu$ is characterized by a dependence $\sigma(I)$ with three clearly differentiated regions: a linear one in the range $I \sim 10^3$–10^4 W/cm^2, a superlinear one at $I \sim 10^4$–10^6 W/cm^2, and another linear one at $I \sim 10^6$–10^7 W/cm^2.

2. The photoconductivity of alkali halides at the $\lambda = 0.27\ \mu$ wavelength recorded by lowering the intensity of the laser radiation produces an irreversible stable increase in the photoconductivity, which is a form of optical hysteresis. The $\sigma(I)$ dependence is then linear.

3. Crystals of KDP and DKDP exhibit at $\lambda = 0.27\ \mu$ a dependence $\sigma(I)$ with two regions: a linear one at $I \sim 10^3$–10^4 W/cm^2 and a quadratic one at $I > 10^5$ W/cm^2. There is no hysteresis in this case.

4. The photoconductivity of ruby ($\lambda = 0.27\ \mu$) is characterized by a $\sigma(I)$ dependence linear over four orders of magnitude of the intensity. No hysteresis is observed. However, ruby exhibits a reduction in the laser photoconductivity after a large number (a few tens) of ultraviolet excitation pulses of constant intensity. This effect can be used to estimate experimentally the bulk conductivity of ruby.

The experimental results on the laser photoconductivity of the investigated alkali halide crystals taken as a whole lead to the hypothesis that in the absence of the dependence of the carrier recombination time τ_{rec} on the carrier density N the photoconductivity of alkali halide crystals at $\lambda = 0.27\ \mu$ (for $I \sim 10^5$–10^7 W/cm^2 and, correspondingly, $N \sim 10^9$–10^{11} cm^{-3}) is governed by multistage excitation of carriers as a result of interband transitions. If, however, $\tau_{rec} \propto N^{-1}$, the dependence $\sigma(I)$ for alkali halide crystals with $N \sim 10^{11}$ cm^{-3} can be interpreted as two-photon ionization of carriers in the presence of quadratic recombination.

Crystals of KDP and DKDP investigated in the range $I > 10^5$ W/cm^2 ($\lambda = 0.27\ \mu$) exhibit two-photon absorption of energy. The experimentally determined photoconductivity of KDP (DKDP) can be used to estimate the two-photon absorption coefficient β. If we assume that the carrier mobility in KDP is 10 cm$^2 \cdot V^{-1} \cdot$ sec^{-1}, we find that $\beta \sim 10^{-9}$ cm/MW.

[1)] The photoconductivity excited by laser radiation will be called the "laser photoconductivity."

[2)] We found no published information on the carrier mobility in KDP crystals but the value $\mu = 10$ cm$^2 \cdot V^{-1} \cdot$ sec^{-1} seems to be quite reasonable if we assume that $m^*/m_e \sim 1$ and $\tau_{rel} \sim 10^{-15}$ sec. Moreover, the measured value of the mobility in alkali halide crystals amounts to 10 cm$^2 \cdot V^{-1} \cdot$ sec^{-1} (Ref. 19). If we use the experimental mobility of electrons in sapphire, which is $\mu = 5.2 \times 10^{-2}$ cm$^2 \cdot V^{-1} \cdot$ sec^{-1} (Ref. 20), we find that an estimate of β yields $\sim 10^{-6}$ cm/MW, which is still two orders of magnitude less than the value given in Ref. 18.

[1]A. S. Epifanov, Zh. Eksp. Theor. Fiz. **67**, 1805 (1974) [Sov. Phys. JETP **40**, 897 (1975)].

[2]A. S. Epifanov, A. A. Manenkov and A. M. Prokhorov, Zh. Eksp. Teor. Fiz. **70**, 728 (1976) [Sov. Phys. JETP **43**, 377 (1976)].

[3]B. G. Gorshkov, Yu. K. Danileĭko, A. S. Epifanov, V. A. Lobachev, A. A. Manenkov, and A. V. Sidorin, Zh. Eksp. Teor. Fiz. **72**, 1171 (1977) [Sov. Phys. JETP **45**, 612 (1977)].

[4]B. G. Gorshkov, A. S. Epifanov, and A. A. Manenkov, Zh. Eksp. Teor. Fiz. **76**, 617 (1979) [Sov. Phys. JETP **49**, 309 (1979)].

[5]B. G. Gorshkov, A. S. Epifanov, A. A. Manenkov, and A. A. Panov, Kvantovaya Elektron. (Moscow) **6**, 2415 (1979) [Sov. J. Quantum Electron. **9**, 1420 (1979)].

[6]T. P. Belikova, A. N. Savchenko, and É. A. Sviridenkov, Zh. Eksp. Teor. Fiz. **54**, 37 (1968) [Sov. Phys. JETP **27**, 19 (1968)].

[7]V. I. Bredikhin, V. N. Genkin, A. M. Miller, and L. V. Soustov, Zh. Eksp. Teor. Fiz. **75**, 1763 (1978) [Sov. Phys. JETP **48**, 888 (1978)].

[8]V. N. Genkin, A. M. Miller, and L. V. Soustov, Zh. Eksp. Teor. Fiz. **79**, 1880 (1980) [Sov. Phys. JETP **52**, 949 (1980)].

[9]M. Mitropol'skiĭ, V. A. Khoteenkov, and G. S. Khodakov, Opt. Mekh. Promst. No. 6, 18 (1976) [Sov. J. Opt. Technol. **43**, 350 (1976)].

[10]B. G. Gorshkov, A. S. Epifanov, A. A. Manenkov, and A. A. Panov, Izv. Akad. Nauk SSSR Ser. Fiz. **44**, 2062 (1980).

[11]G. V. Gomelauri, A. S Epifanov, A. A. Manenkov, and A. M. Prokhorov, Zh. Eksp. Teor. Fiz. **79**, 2356 (1980) [Sov. Phys. JETP **52**, 1193 (1980)].

[12]B. G. Gorshkov, Yu. K. Danileĭko, A. A. Manenkov, A. M. Prokhorov, and A. V. Sidorin, Kvantovaya Elektron. (Moscow) **8**, 148 (1981) [Sov. J. Quantum Electron. **11**, 81 (1981)].

[13]B. G. Gorshkov, Yu. K. Danileĭko, A. S. Epifanov, A. A. Manenkov, A. M. Prokhorov, and A. V. Sidorin, Kvantovaya Elektron. (Moscow) **8**, 155 (1981) [Sov. J. Quantum Electron. **11**, 85 (1981)].

[14]R. G. Kepler, Phys. Rev. **119**, 1226 (1960).

[15]J. N. Bradford, R. T. Williams, and W. L. Faust, Phys. Rev. Lett. **35**, 300 (1975).

[16]I. K. Kikoin (ed.), (Tablitsy fizicheskikh Velichin: Spravochnik) (Tables of Physical Quantities: Handbook) Atomizdat, Moscow (1976), p. 321.

[17]R. T. Williams, P. H. Klein, and C. L. Marquardt, Proc. Symp. on Laser-Induced Damage in Optical Materials, Boulder, Colorado, 1977, NBS Spec. Publ. No. 509, 481 (1977).

[18]P. Liu, W. Lee Smith, H. Lotem, J. H. Bechtel, N. Bloembergen, and R. S. Adhav, Phys. Rev. B **17**, 4620 (1978).

[19]R. K. Ahrenkiel and F. C. Brown, Phys. Rev. **136**, A223 (1964).

[20]U. E. Hochuli, Phys. Rev. **133**, A468 (1964).

Translated by A. Tybulewicz