

ULTRAVIOLET-INDUCED TRANSIENT ABSORPTION IN BBO AND LBO CRYSTALS AND ITS INFLUENCE ON FREQUENCY CONVERSION

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ABSTRACT

In the present paper we represent the results of investigations of an ultraviolet (266nm) – induced nonlinear absorption in BBO and LBO crystals and its influence on frequency conversion. We determined that in BBO and LBO crystals at two-photon absorption of low intensive $< 100 \text{ MW/cm}^2$ nanosecond pulses at 266nm transient defects are generated. With the help of computational modeling it was defined that the absorption cross section of transient defects at 266nm in BBO and LBO crystals are equal to $\sim 8 \cdot 10^{-17} \text{ cm}^2$ and $\sim 2 \cdot 10^{-16} \text{ cm}^2$, respectively. We've measured the BBO and LBO OPOs efficiency and found out that LBO OPO efficiency depends on the pump pulses repetition rate.

Keywords: transient absorption, optical parametric oscillator, BBO, LBO crystals.

1. INTRODUCTION.

BBO and LBO crystals are very useful material for optical parametric oscillators (OPOs). BBO OPO pumped at 266nm was tuned in the range from 300nm to 2340nm¹. At pump intensity of $\sim 46 \text{ MW/cm}^2$ the signal conversion at $\lambda_s=340\text{nm}$ is $\sim 15\%$ at 2 times above threshold. The only work on LBO OPO utilizing 12ns 266nm pump employs a 16 mm long crystal cut along z-axis (interaction type II)². The change of the crystal temperature from 20°C to 70°C leads to the slight tuning of the signal and idler wavelengths in the range $313,8\text{nm} \rightarrow 311,5\text{nm}$ and $1,751\mu\text{m} \rightarrow 1,826\mu\text{m}$, respectively. The threshold intensity is about $\sim 10 \text{ MW/cm}^2$, the total conversion is $\sim 10\%$ at 3,5 times above the threshold.

It was known that in KDP and DKDP crystals at two-photon absorption of high intensive UV radiation the transient defects are generated³. These transient defects absorbed in the wide range from 200nm to 700nm. The transient defect absorption cross section at 532nm and 266nm are equal to $\sim 4,6 \cdot 10^{-18} \text{ cm}^2$ and $\sim 2,7 \cdot 10^{-18} \text{ cm}^2$, respectively. The intensity-dependent loss properties of KDP, BBO and LBO crystals pumped by sub-picosecond laser pulses at 264nm and 211nm were investigated⁴. It was found that two-photon absorption coefficients for KDP, BBO and LBO crystals at 264nm are equal to $\sim 0,26 \text{ cm/GW}$, $\sim 0,93 \text{ cm/GW}$ and $\sim 0,15 \text{ cm/GW}$, respectively.

In the formerly published article it was shown that in BBO crystal at two-photon absorption of low intensive $< 100 \text{ MW/cm}^2$ nanosecond pulses at 266nm dynamic transient defects are generated, the transient defect absorption cross section at 266nm is equal to $\sim 8 \cdot 10^{-17} \text{ cm}^2$, the nonlinear losses in BBO crystal decreased in the conditions of strong energy exchange between interaction wave in BBO optical parametric amplifier (OPA)⁵. In this work we present the new results of the measurements of intensity-dependent loss properties of BBO and LBO crystals at 266nm and their influence on BBO and LBO OPOs efficiency.

2. EXPERIMENT.

In our experiments we investigated critically the type-I BBO OPO and non-critically type-II LBO OPO. The OPO were pumped by the fourth harmonic (266nm) of a 10 Hz Q-switched Nd:YAG laser (the LQ-727 model from "Solar LS" Co.) which provided pump pulses with a duration $\sim 4,5 \text{ ns}$ and energies up to 65mJ. The pump beam $\sim 5 \text{ mm}$ in diameter had a divergence $\sim 0,8\text{mrad}$. The pump beam was polarized in the vertical plane and had a nearby square spatial intensity profile. We used Frenel attenuator for varying the pump intensity from 4MW/cm^2 up to 70MW/cm^2 .

The OPO was operated in the spectral ranges from 310nm to 350nm (signal wave) by using AR-coated type-I 10 mm-long BBO crystal cut at the angle of $\theta=38,7^\circ$ and type-II 20 mm –long LBO crystal cut at the angles of $\varphi=0^\circ$ and $\theta=7^\circ$. The OPO resonator is shown in Fig.1. It is a flat/flat cavity type of design and is singly resonant at the signal wave. The output mirror has a HR coating at 266nm and

~40% reflection in the range 310...350 nm. The pump beam is reflected off the output mirror, and makes a round trip inside the OPO resonator. The cavity length is ~100 mm.

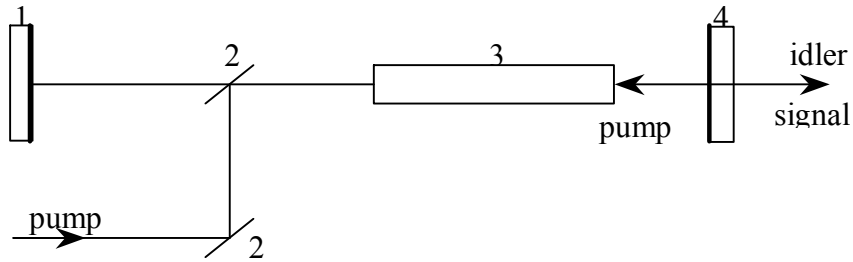


Fig.1 The layout of the OPO resonator.

1 – HR rear mirror, 2 - 45° HR at 266 nm mirror which is transparent for the OPO wavelengths, 3 – nonlinear crystal, 4 – output mirror.

The OPO output energies at pump intensity ~62 MW/cm² and repetition rate 10 Hz were measured. At normal incidence the BBO OPO output energies were ~10mJ at 341nm. The LBO OPO output energies were ~0,5mJ at 314nm.

We determined that LBO OPO efficiency depends on repetition rate. At repetition rate 0,2 Hz the output energies of LBO OPO increased up to 5mJ (Fig.2). It should be noted, that the BBO OPO output was constant, when the repetition rate was varied from 0,2 Hz to 10 Hz.

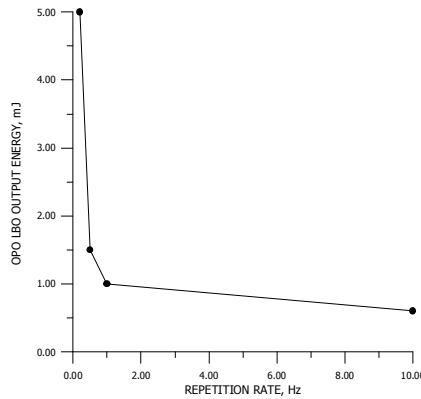


Fig.2 LBO OPO output energies as a function of repetition rate.

On the basis of experimental investigations we assumed that the main factors restricting the BBO and LBO OPOs efficiency were nonlinear absorption at 266 nm and effects of thermal self-actions. We've measured the intensity-dependent transmission curves at 266nm for BBO – a) and LBO – b) crystals, Fig.3. We measured the transmission of LBO crystal at 266nm versus repetition rate. It was determined that transmission of 20-mm LBO crystal at 266nm was increased from 0,71 at 10 Hz to 0,73 at 0,2 Hz. It should be noted, that transmission of 10-mm BBO crystal at 266nm was constant, when the repetition rate was varied from 0,2 Hz to 10 Hz. We measured the transmission of BBO and LBO crystals at 532nm versus pump intensity at 266nm. It was determined that the induced absorption by transient defects in 10-mm BBO crystal at 532nm was ~ 2,6 %. The induced absorption by transient defects in LBO crystal at 532nm was not observed.

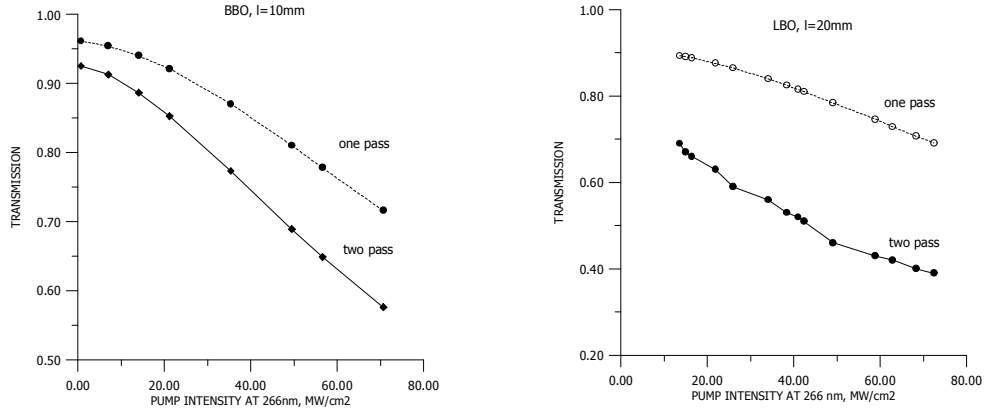


Fig.3 Intensity-dependent transmission curves for BBO – a) and LBO – b) crystals measured at 266nm and repetition rate 10 Hz.

3. NUMERICAL MODELING.

To determine the transient defect density and absorption cross-section at 266nm and 532nm we have numerically modeled transient defect absorption strength in nonlinear crystals. Model of Marshall et al was used for numerical analysis³. They hypothesized that the defects are created by two-photon absorption of 266nm light, the induced absorption builds up during the laser pulse and is directly related to the time-integrated UV intensity that has traversed a given point in the crystal. In our model we assumed that defects is not beaching by subsequent 266nm irradiation. The three general equation governing the defect density N , the pump intensity $I_{4\omega}$ and the probe intensity I_p are then expressed as:

$$\frac{dN(z,t)}{dt} = \frac{\beta \cdot I_{4\omega}^2(z,t)}{8\hbar\omega}, \quad (1)$$

$$\frac{dI_{4\omega}(z,t)}{dz} = -\alpha_{4\omega} \cdot I_{4\omega}(z,t) - N(z,t) \cdot \sigma_{4\omega} \cdot I_{4\omega}(z,t) - \beta \cdot I_{4\omega}^2(z,t), \quad (2)$$

$$\frac{dI_p(z,t)}{dz} = -\alpha_p \cdot I_p(z,t) - N(z,t) \cdot \sigma_p \cdot I_p(z,t), \quad (3)$$

with an initial conditions $N(z,t=0)=0$, where z , β , α , σ and $\hbar\omega$ are depth in the crystal, the two-photon absorption constant, the linear absorption coefficient, the defect absorption cross section and the fundamental photon energy of Nd:YAG, respectively. In Eq.1 the defect formation by two-photon absorption 4ω irradiation is describe. The terms in braces on the right hand side of Eq.2 and Eq.5 arise from the intrinsic linear and transient defect linear absorption, respectively. The input intensity of pump and probe pulses with a Gaussian temporal profile are defined as

$$I_{4\omega}(0,t) = I_{4\omega}^{\max} \cdot \exp\left\{-\left[2\sqrt{\ln 2} \cdot \left(\frac{t}{t_p} - 1,29\right)\right]^2\right\},$$

$$I_p(0,t) = I_p^{\max} \cdot \exp\left\{-\left[2\sqrt{\ln 2} \cdot \left(\frac{t}{t_p} - 1,29\right)\right]^2\right\},$$

where t_p is the pulse width, $I_{4\omega}^{\max} = 0,94 \cdot \frac{4 \cdot E_{4\omega}(0)}{\pi \cdot \varnothing^2 t_p}$ - the maximum intensity of the pump pulses,

$I_p^{\max} = 0,94 \cdot \frac{4 \cdot E_p(0)}{\pi \cdot \varnothing^2 t_p}$ - the maximum intensity of probe pulses,

$E_{4\omega}$ and E_p - the energies of the pump and probe respectively, \varnothing - the beam diameter.

The pump intensity $I_{4\omega}(0, t)$ was approximated by a step-wise function with Δt step-width and constant intensity inside the each step $I_{4\omega}(0, t_n)$, where $t_n = n \cdot \Delta t$. For each step Eq.1 has explicit solution and transient defect density

$$N(z, t_n) = N(z, t_{n-1}) + \frac{\beta \cdot I_{4\omega}^2(z, t_n)}{8\hbar\omega} \cdot \Delta t, \quad (4)$$

where $N(z, t_{n-1})$ is the defects density for previous time interval of $[0, t_{n-1}]$.

The Eq.2 and Eq.3 are then solved with a Runge-Kutta numerical routine for each spatial slice in the crystal. With this assumptions the transient defect absorption cross section at 266nm and 532nm can be determined from the shape of intensity-dependent transmission curves, Fig.3.

Based on numerically calculations we determined that the defect absorption cross section at 266nm in BBO and LBO crystals are equal to $\sim 8 \cdot 10^{-17} \text{cm}^2$ and $\sim 2 \cdot 10^{-16} \text{cm}^2$ respectively, and at 532nm in BBO crystal is equal to $\sim 8 \cdot 10^{-18} \text{cm}^2$. We calculated that the average values of transient defect density N in BBO and LBO crystals are equal to $\sim 6 \cdot 10^{15} \text{cm}^{-3}$ and $\sim 1 \cdot 10^{15} \text{cm}^{-3}$, respectively at pump intensity of 70 MW/cm² at 266nm.

These data could be helpful for the optimization of UV nonlinear-frequency converters on BBO and LBO crystals.

4. REFERENCES

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