# PERSPECTIVES OF CREATING POWERFUL SOLID-STATE OPTICAL AMPLIFIERS BASED ON A $Ce^{3+}$:$LiCaAlF_6$ CRYSTAL

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*Pump-induced photodynamic processes in $Ce^{3+}$:$LiCaAlF_6$ (Ce:LiCAF) UV active media were studied by pump-probe technique. The modelling of a multipass optical amplifier testify the opportunity to design high-power UV laser system based on Ce:LiCAF media.*

**Introduction.** Today the actual problem of quantum electronics is obtaining powerful (>100 mJ) radiation in the UV spectral range with a pulse duration range from 10 ns to several fs. Existing systems offer obtaining radiation in the infrared spectrum and then converting to UV with nonlinear media. However, radiation resistance and degradation of nonlinear media makes it impossible to use them for high-power level. Using the 4*f*–5*d* transitions allows amplify pulses with duration up to 3 fs at spectra range 281–333 nm. This paper deals with perspectives of the creation of a powerful amplifier based on $Ce^{3+}$:$LiCaAlF_6$.

The $Ce^{3+}$:$LiCaAlF_6$ crystal has a unique resistance to photochemical reactions at relatively low pump and laser output power. However, in case of high-power pumping condition together with high-power amplified UV radiation the photodynamic processes in active medium and associated with them extra losses can be became extremely important. Therefore, it is necessary to know the parameters of photodynamic processes in order to use them to carry out modeling of high-power UV solid-state laser systems.

**Experiments and photodynamic processes model.** The 1 at.% in the melt $Ce^{3+}$ ions doped $LiCaAlF_6$ crystal was grown by Bridgman technique in Kazan federal university. The active element was 6 mm in diameter and 5 mm in the length. The pump-probe experiments were carried out for π-polarized pump and probe beams. The results are presented in Fig.1.

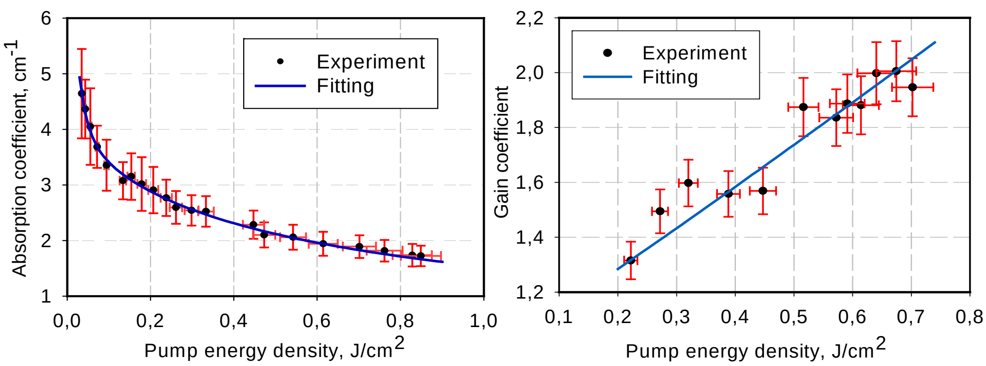


Fig. 1. Absorption coefficient of pump radiation at λ = 266 nm (a) and gain coefficient at λ = 290 nm (b) depending on the pumping radiation energy density with the fitting results.

Model of photodynamic processes described in [1] and shown in Fig. 2. The model included four levels scheme of laser oscillator (levels 1–4), transitions from excited states to the localized states in the conduction band (cross-sections $\sigma_{35}$ at the wavelength of 266 (pump) and 290 nm (probe)), recombination processes ($P_{51}$ and $P_{53}$ probabilities) as one of the type of free charges relaxation channels and the processes of formation of color centers ($P_{56}$ probability) as another one. The system also includes destruction of color centers channel both due to thermalization ($P_{65}$ probability) and due to absorption of pump and/or laser radiations (cross-sections $\sigma_{65}$ at the wavelength of 266 and 290 nm, respectively). Then, the interaction between radiation and media described by appropriated system of rate equations and radiative transfer equations for pump and probe radiations through the sample. We compared the two approaches for the solution – single pass amplifier model and grid methods [2]. With the single pass amplifier model first, we found photodynamic parameters associated with the pumping while interpreting nonlinear absorption at the pump wavelength (266 nm), in the second we got parameters associated with the probing while interpreting second experiment. The result shown on the Fig. 1 as the solid line and in the Table 1. The single pass amplifier model describes the experiments data with satisfactory accuracy, but it cannot describe the multi-pass of radiation in media. The grid method has been used to interpret the multy-pass of radiation.

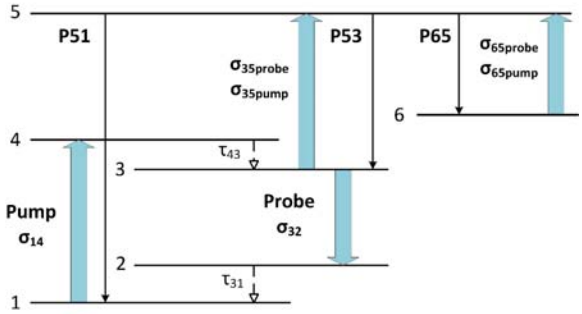


Fig. 2. Model of photodynamic processes in Ce:LiCAF active medium.

TABLE 1. Parameters of Photodynamic Processes in $LiCaAlF_6:Ce^{3+}$ Resulting from Computer Simulation

| Absorption cross-sections, $cm^2$ | | Probabilities, $s^{-1}$ | | Concentration, $cm^{-3}$ | |
|---|---|---|---|---|---|
| $\sigma_{35pump}$ | $(5.5\pm2)\cdot10^{-18}$ | $P_{51}$ | $(1\pm0.5)\cdot10^{8}$ | $Ce^{3+}$ ions | $(6\pm1.5)\cdot10^{17}$ |
| $\sigma_{65pump}$ | $(5\pm2)\cdot10^{-18}$ | $P_{54}$ | $(25\pm10)\cdot10^{8}$ | Color centers | $(3\pm1.5)\cdot10^{16}$ |
| $\sigma_{35probe}$ | $(1\pm0.5)\cdot10^{-18}$ | $P_{56}$ | $(7\pm3)\cdot10^{8}$ | | |
| $\sigma_{65probe}$ | $(3\pm1)\cdot10^{-20}$ | | | | |

**Conclusion.** In this work the key parameters of photodynamical processes in $Ce^{3+}:LiCaAlF_6$ crystal active media were estimated for the first time. There are the 5d-excited-state photoionization cross-sections of $Ce^{3+}$ ions and pump-induced color centers at pumping and probe beams wavelength together with rates of recombination processes of free charge carriers.Obtained parameters allow to produce calculations of powerful laser systems based on $Ce^{3+}:LiCaAlF_6$ crystal.

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1. V. V. Semashko, *Phys. Solid State*, **47**, 1507–1511 (2005).
2. I. Laukaityte, R. Čiegis, *Mathem. Model. Analysis*, **13**, 211–222 (2008).