Impact of Self-Action Effects on Second Harmonic Generation Efficiency in KDP Crystals with Embedded Anatase Nanoparticles

A. Popov[1], V. Yatsyna[1], M. Kopylovsky[1], I. Pritula[2] and V. Gayvoronsky [1,*]

Abstract. *Second harmonic generation efficiency enhancement in KDP single crystals with embedded anatase nanoparticles was accomplished in comparison with nominally pure KDP crystal. The enhancement effect occurs due the self-focusing of laser pump pulses.*

Key words: KDP, anatase nanoparticles, nonlinear optical response, self-action phenomena, second harmonic generation.

I. Introduction

The single crystals of potassium dihydrogen phosphate (KDP, KH_2PO_4) family are widely used in modern optoelectronics and nonlinear optics. In particular, optical crystals with lower impurity and higher laser damage threshold are required in industrial laser systems. In fact, this type of crystals has low magnitude of d_{36} nonlinear coefficient which determines second harmonic generation (SHG) efficiency in comparison to borate crystals family. The basic method to improve properties of KDP crystals is organic/inorganic additions incorporation into pure matrix when the grow process is performed. The possibility of growing KDP crystals with embedded TiO_2 nanoparticles of anatase modification (KDP:TiO_2) was shown [1]. The presence of anatase nanoparticles in the matrix leads to the enhancement of cubic nonlinear optical (NLO) response and the sign change of photoinduced refractive index variation under picosecond pulses irradiation with a wavelength of 1064 nm [2]. This effect is caused by giant NLO response of anatase nanoparicles due to resonant excitation of surface states under picosecond laser pulses irradiation [3]. At present work the effect of anatase nanoparticles on the efficiency of SHG in KDP:TiO_2 single crystals under picosecond laser pulses was studied.

II. Experimental details

KDP:TiO_2 and nominally pure KDP single crystals were grown by temperature reduction method onto point seed (10×10×10 mm^3). Anatase nanoparticles were obtained by method of precipitation with subsequent microwave heating and calcination of resultant powder.

The samples with dimensions of 10×10×10 mm^3 cut along the type II of phase matching direction (oe-e interaction) for SHG at 1064 nm – the fundamental wavelength of Nd:YAG laser were investigated.

Measurements of SHG efficiency were carried out under phase-matching conditions. The laser beam of the mode-locked Nd:YAG laser with Gaussian spatial profile (42 ps pulse duration, repetition frequency 5 Hz) was used.

III. Results and discussion

The SHG efficiency increase was obtained in KDP:TiO_2 single crystals in comparison with KDP one. Most strongly the efficiency increasing effect is manifested at moderate excitation energies up to 40 μJ (peak laser intensity of up to 2 GW/cm^2).

To verify the impact of self-action effects on the SHG process, the transmitted laser beam profile was recorded at 6 cm behind the output face of the crystal. In the range of excitation energies up to 40 μJ a slight narrowing of the laser beam in a KDP crystal in comparison with freely propagating beam takes place. At the same time for a KDP:TiO_2 crystal the developed internal self-focusing effect and the formation of a narrow beam kern on the background of aberration pattern is observed. This effect is due to giant NLO response of anatase nanoparticles manifestation. It leads to the pump field concentration and the increase of pulse peak intensity. Therefore, the self-focusing of laser pump radiation leads to an increase of SH signal and efficiency of the process.

IV. Conclusions

Significant increase of SHG efficiency was obtained in KDP:TiO_2 single crystals in comparison with KDP one as a result of internal self-focusing effect.

It was shown that KDP crystals with incorporated nanoparticles are promising materials for efficient conversion of laser radiation.

Acknowledgment

The work was supported by the NASU 1.4.1 B/141 project and joint F40.2.098 RFBR-SFBR grant.

References

[1] I. Pritula, O. Bezkrovnaya, M. Kolybayeva, A. Kosinova, D. Sofronov, V. Tkachenko and V. Tsurikov, "Solution growth of KDP single crystals doped with titanium dioxide nanoparticles", *Materials Chemistry and Physics*, vol. 129, pp. 777-782, 2011.

[2] I. Pritula, V. Gayvoronsky, M. Kolybaeva, V. Puzikov, M. Brodyn, V. Tkachenko, A. Kosinova, M. Kopylovsky, V. Tsurikov and O. Bezkrovnaya, "Effect of incorporation of titanium dioxide nanocrystals on bulk properties of KDP crystals", *Optical Materials*, vol. 33, pp. 623-630, 2011.

[3] V. Gayvoronsky, A. Galas, E. Shepelyavyy, Th. Dittrich, V. Timoshenko, S. Nepijko, M. Brodyn and F. Koch, "Giant nonlinear optical response of nanoporus anatase layers", *Applied Physics B, vol.* 80, pp. 97-100, 2005.

[1] Institute of Physics NASU, Kyiv, Ukraine
[2] Institute for Single Crystals NASU, Kharkiv, Ukraine
[*] vlad@iop.kiev.ua