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# NONLINEAR CONVERSION OF ND-GLASS LASER RADIATION INTO HARMONICS AND THEIR INTERACTION WITH PLASMA

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# NONLINEAR CONVERSION OF ND-GLASS LASER RADIATION INTO HARMONICS AND THEIR INTERACTION WITH PLASMA*

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In [1-3] the authors showed that a multimode laser radiation can be effectively transformed into the second harmonic with the help of nonlinear crystals. However, the question of the efficiency of harmonic generation in respect to the number of laser transverse modes at the fundamental frequency remained unanswered. The present report is devoted just to this problem.

As a source of radiation a multimode pulsed Nd-glass laser "KANAL-2" [4] was used. The laser allowed one to effectively vary both the number of transverse modes and the spectrum width. One should note that the improvement of radiation parameters in the laser system (a decrease in the number of transverse modes, placing of the polarizers at the system output, etc.) in order to reach highly effective energy conversion results in an essential drop of the output power. Here arises the problem of finding the optimal conditions in order to reach high output energy of the laser at the wavelength $\lambda = 0.53$ μm. For this purpose the dependence of conversion efficiency on the radiation power density $I \approx 0.2 \div 3$ GW/cm$^2$ in a KDP 60×60×30(length) mm$^3$ crystal with an ooe synchronism was studied at the radiation divergence of $2\alpha = 0.47 \div 3.5$ mrad and the number of transverse modes $n \approx 100 \div 1000$ for both the linearly-polarized and non-polarized radiation.

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At $n \approx 100$ and $2\alpha \approx 1.17$ mrad, the conversion efficiency makes about $K \approx 40\%$ within a wide range of the power density $I \approx 0.2 \div 3$ GW/cm$^2$ for the polarized, as well as for non-polarized radiation (see Fig.1 (1)). Note that the value $K \approx 40\%$ is twice as much as the conversion efficiency for multimode radiation given in [1]. The fact that approximately the same part of radiation at the fundamental frequency is conversed in both cases (the polarized and non-polarized radiation) is explained, most likely, by a much more homogeneous density distribution over the beam cross-section in non-polarized radiation (see Fig.2). The conversion efficiency dependence on the power density occurs at the divergence of non-polarized radiation $2\alpha \approx 0.47$ mrad, and reaches its maximum $K \approx 52\%$ at $I \approx 0.5$ GW/cm$^2$ (see Fig.1 (2)).

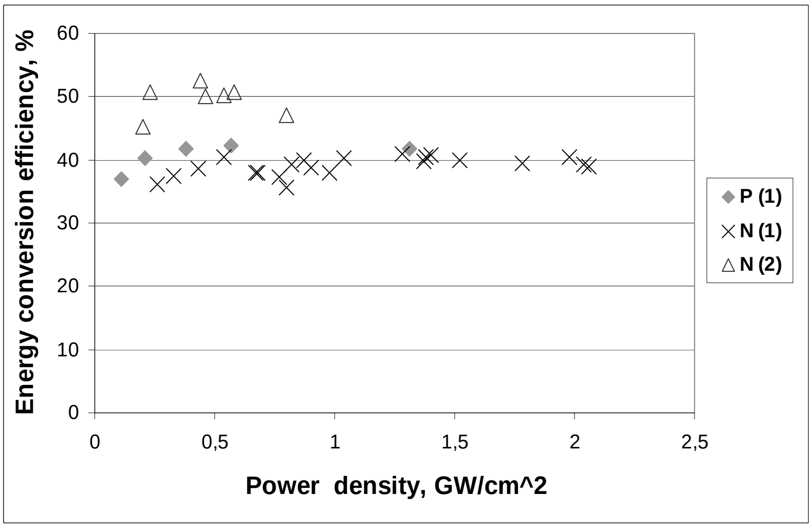



Fig.1. Efficiency of conversion. P, polarized radiation; N, non-polarized radiation. Number of transverse modes, $n \approx 1 \times 10^2$; divergence (1) $2\alpha = 1.17$ mrad, (2) $2\alpha = 0.47$ mrad.

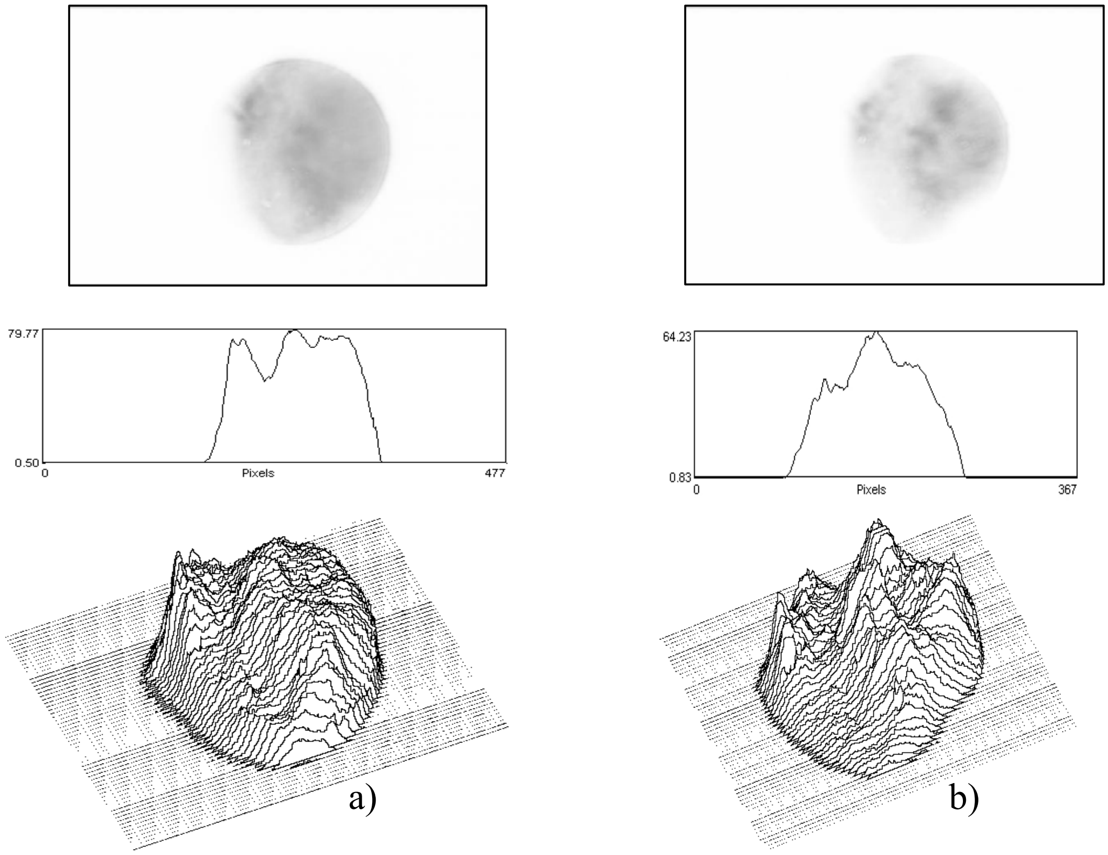



Fig.2. The near field of fundamental radiation. a) non polarized, b) polarized.

At $n \approx 1000$ and $2\alpha \approx 3.5$ mrad the conversion efficiency for the polarized and non-polarized radiation is also practically the same, and varies near 25%, changing insignificantly within the power density range $I \approx 0.2 \div 2.3$ GW/cm$^2$ (see Fig.3a (1)). However, for the non-polarized radiation and divergence being $2\alpha \approx 1.4$ mrad, one observes the conversion efficiency dependence on the power density. Starting from $I \approx$ 0.2 GW/cm$^2$, when $K \approx 32\%$, the conversion efficiency grows, and reaches the maximum of $K \approx 45\%$ at $I \approx 0.5$ GW/cm$^2$. Further the efficiency monotonically drops to $K \approx 17\%$ at $I \approx 2$ GW/cm$^2$ (see Fig.3a (2)). Investigation of the angular dependence of the efficiency of the second harmonic generation has shown that at 2.5 increase in the radiation divergence the angular dependence is widened by almost the same value (see Fig.3b).

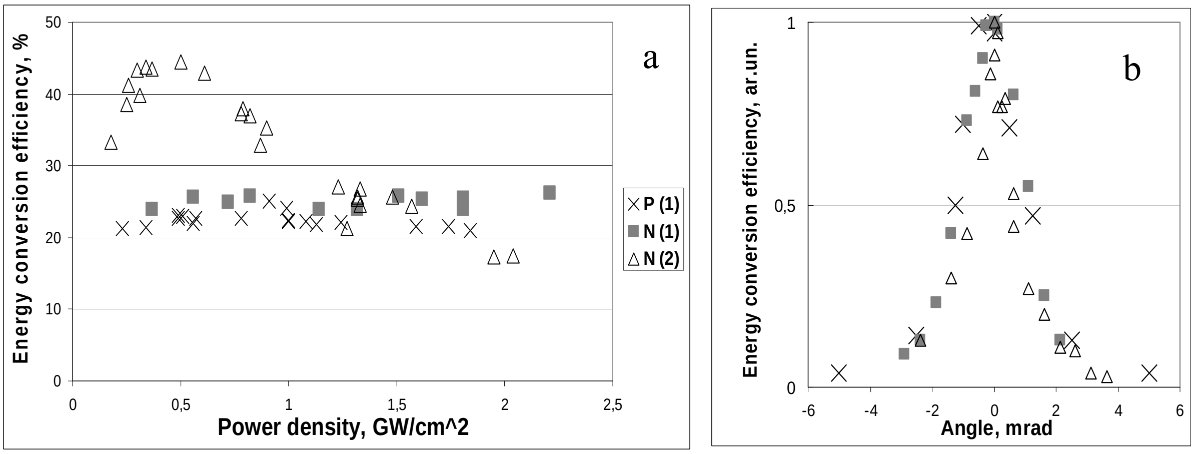



Fig.3. Efficiency of conversion.
P, polarized radiation; N, non polarized radiation;
$n \approx 1\times10^3$, divergence: (1) $2\alpha = 3.5$ mrad, (2) $2\alpha = 1.4$ mrad. a) Power dependence of second-harmonic conversion efficiency, b) Angular dependence of second-harmonic generation.

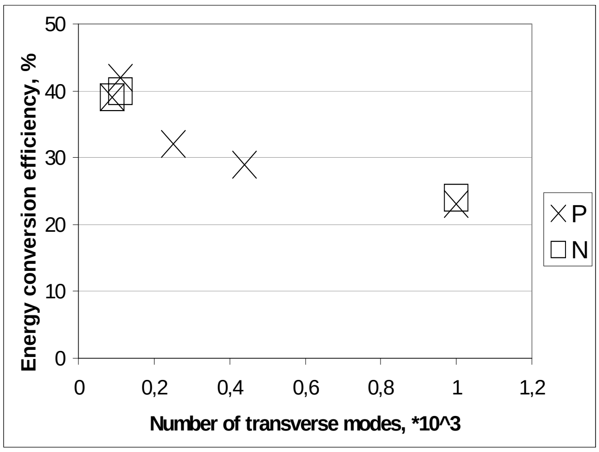



Fig.4. Transverse modes quantity dependence
of second-harmonic conversion efficiency.

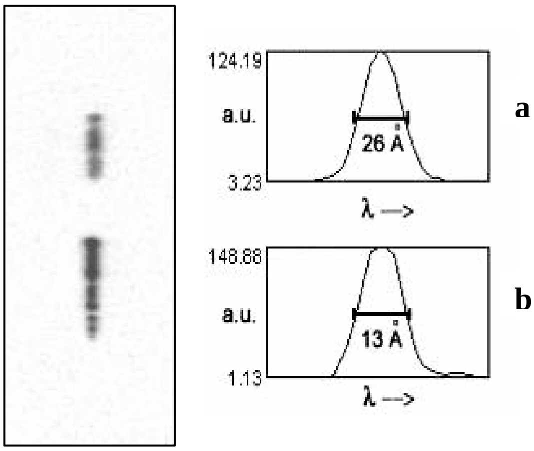
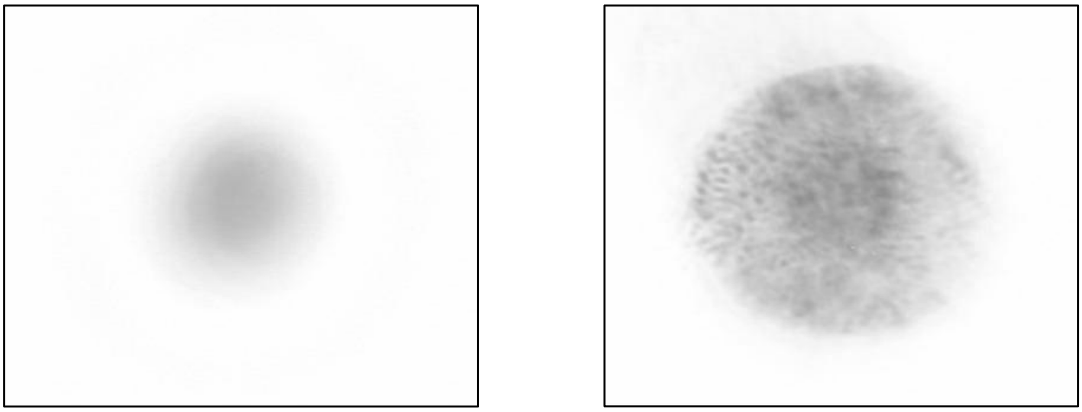



Fig.5. Spectra of a fundamental wave (a) and a second-harmonic wave (b).

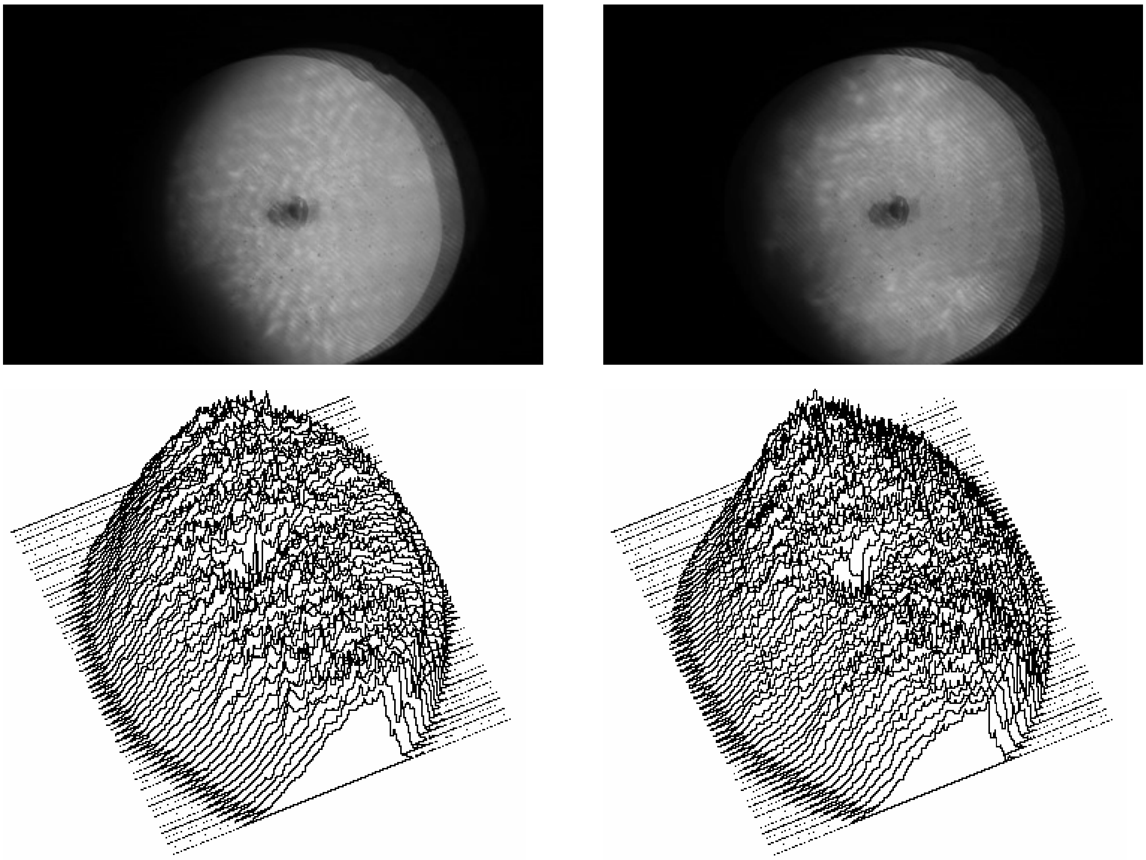
Fig. 4 illustrates the efficiency of radiation conversion into the second harmonic for the number of transverse modes $n \approx 10^2 \div 10^3$. The presented results were obtained for practically the same values of radiation divergence: $2\alpha \approx 1.05 \div 1.4$ mrad. It should be noted that the inaccuracy of measurements of the radiation energy was smaller than 5% of the maximum value. The second harmonic spectrum width is two times smaller than that for the fundamental radiation, and does not vary with the change in the transverse mode number (see Fig.5).



$TEM_{00}$ Multimode case $n \approx 10^3$

Fig.6. Far-field zone in $\lambda = 1.06$ μm (transverse modes).

A study has been made into the spatial distribution of the mode structure of the radiation coming from the generator in the far zone. The photos are presented for the case of one spatial mode $TEM_{00}$, and $n \approx 10^3$ (see Fig.6). The photographs' scale is different: the diameter of $TEM_{00}$ in the far zone is $d_{TEMoo} \approx 1.1$ mm, and $d_{n \approx 10^3} \approx 10$ mm. Note that for $n \approx 10^3$ the picture was very bright and with a homogeneous distribution over the beam cross section.



Before target After target

Fig.7. Distribution of the $\lambda = 0.53$ μm radiation intensity in near-field zone.

The experiments on interaction of second harmonic radiation with microstructured targets have been conducted. The photos of near-field zone of the second harmonic radiation before and after the interaction with triacetate cellulose target (the thickness 100 μm, and density 50 mg/cm$^3$) are presented on Fig.7. The intensity redistribution on the beam cross-section after the interaction of second harmonic radiation with microstructured target in not found.

Conclusion

A reduction in the number of transverse modes from c $10^3$ to $10^2$ results in a 2.5 times increase of the conversion efficiency. However, here one observes a three-fold reduction of the maximum energy at the laser output. Under the beam collimation at the laser output the divergence grows by 2.5 times thus reducing the conversion efficiency from 50% to 40% at $n \approx 100$, and from 45% to 25% at $n \approx 1000$. The beam collimation makes it possible to essentially increase the radiation power density and the homogeneity of fundamental frequency radiation distribution over the beam cross-section. The second harmonic spectrum width is two times smaller than that for the fundamental radiation, and does not vary with the change in the transverse mode number. The investigation of the second harmonic radiation angular dependence has shown that under the increase of the radiation divergence from $2\alpha$=1.4 mrad to $2\alpha$=3.5 mrad the angular dependence is widened approximately by the same value.

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**References**

[1] V.D. Volosov, V.V. Dedushkevich, V.N. Krylov, A.V. Tolstoshev, Izvestiya AN USSR, Ser. Fiz., 1979, vol. 48, p. 1643.

[2] S.I. Fedotov, Yu.V. Korobkin, M.V. Osipov, V.N. Puzyrev, A.T. Sahakyan, A.N. Starodub, V.B. Studenov, B.L. Vasin, "Nonlinear conversion of laser radiation with controllable coherence into second harmonic". XXIX ECLIM, Madrid, June 2006, p. 274.

[3] S.I. Fedotov, Yu.V. Korobkin, M.V. Osipov, V.N. Puzyrev, A.T. Sahakyan, A.N. Starodub, V.B. Studenov, B.L. Vasin. "Conversion of the Nd-laser partially coherent nanosecond pulses into the second harmonic". LGS'06, Vyatichi, October 2006, p. 23, http://lgs2006.ilc.edu.ru/en.

[4] S.I. Fedotov, L.P. Feoktistov, M.V. Osipov, A.N. Starodub, J. Russian Laser Research, 2004, vol. 25, p. 79.