Gain saturation effects in BBO parametric amplifier

W.Hogervorst [a] , N.Kondratyuk [b], A.Shagov [b], V.Belyi [c]

In Laser Optics 2000: Solid State Lasers ,edited by V.Ustugov,
Proceedings of SPIE vol.43508(SPIE, Bellingham,WA,2001) p.136

.

ABSTRACT

In the present work the gain saturation effects in type-I BBO optical parametric amplifier (OPA) pumped by the 3-rd harmonic of multimode Nd:YAG laser are investigated. The OPA gain was measured as a function of input idler energy at 1064 nm with a constant pump energy at 355 nm and a beam divergence 0,3 mrad. In the 9 mm BBO crystal at pump intensity ~ 68 MW/cm^2 and input idler intensity ~ 18 MW/cm^2 the efficiency of energy extraction in the saturated gain regime ~ 31% was obtained. The ways of increase the efficiency of energy extraction in the two-crystal OPA configuration are discussed.

Keywords: optical parametric amplifier, BBO crystal

1. INTRODUCTION

Significant successes now are achieved in the field of creation of narrow-band pulsed optical parametric oscillator (OPO) on BBO crystals pumped by the 3-rd harmonic of Nd:YAG lasers [1-3]. For increase of pulses energy of a single and an idler waves the optical parametric amplifier (OPA) containing one or several consistently located BBO crystals was used [3,4]. At collinear phase-matching the angular acceptance in BBO crystal is very small and it is equal ~ 0,28 mrad·cm^{-1} [5]. In the present work the gain saturation effects in BBO parametric amplifier pumped by the 3-rd harmonic of Nd :YAG laser are investigated.

2. EXPERIMENT

We used a multimode Q-switched Nd:YAG laser with pulse energy up to 330 mJ, peak power density up to 250 MW/cm^2 and pulse width ~5 ns as a radiation source at 1064 nm. The output was multimode and had a flat-top intensity profile. For cascade third-harmonic generation (THG) we used a 3-mm-long type II KTP 1 crystal with AR coatings, cut at $\varphi_{pm} = 23,5°$ and 20-mm-long type II DKDP 2 crystal, cut at $\theta = 59°$. For space division of the fundamental and the third harmonics dichroic mirrors 4 and 5 were used. The diameters of the pump beam at 355 nm and the idler beam at 1064 nm were decreased by two hard apertures 4 mm in diameter. The divergence of the pump beam was ~ 0.3 mrad. The pump energy in the input of the OPA was ~ 43 mJ. The idler energy in the input of the OPA was attenuated from 0.2 mJ to 22 mJ using a waveplate 7 and two polarizes 6 and 8. The OPA gain medium was a 9-mm-long type I BBO crystal, cut at $\theta = 29°$ and coated with a protective AR coating. For space division of pump, signal and idler beams dichroic mirrors 4 and 5 were used.

The experimental set up is shown in Fig. 1.

---

[a] W.H.: e-mail: wh@nat.vu.nl
[b] N.K., A.Sh.: e-mail: solarls@infonet.by
[c] V.B.: e-mail: tol@dragon.bas-net.by

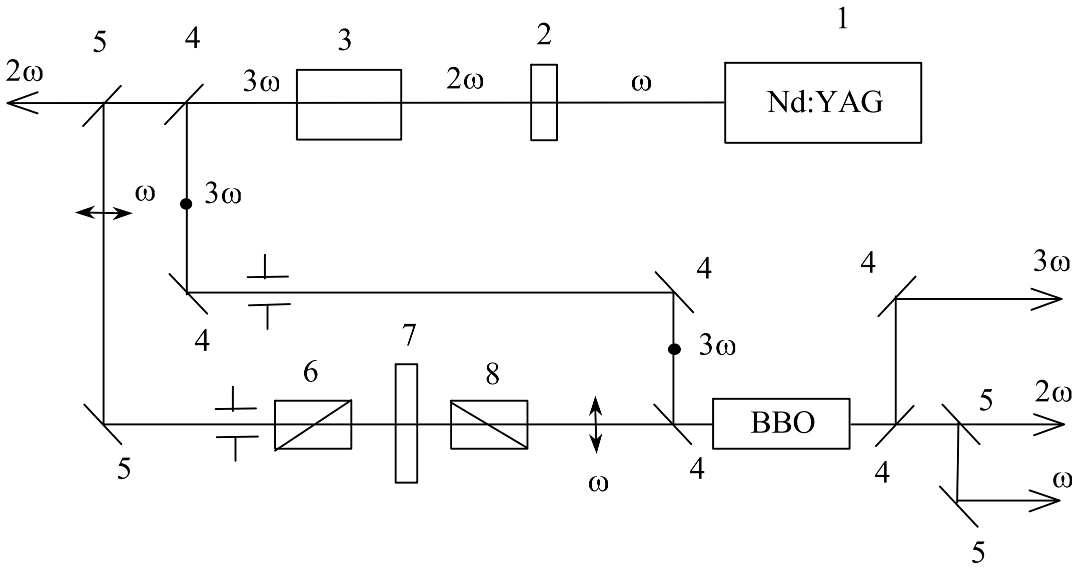

Fig.1 Experimental layout.

The experimentally obtained results of the OPA output energies with the input pump energy W_{30}~ 43 mJ is shown in Fig.2. It can be seen that the maximal extraction efficiency and the gain saturation effects were obtained at input idler energy W_{10} > 8 mJ. The OPA output energies of the signal and the pump waves where constant when input idler energy was varied from 8 mJ to 22 mJ.

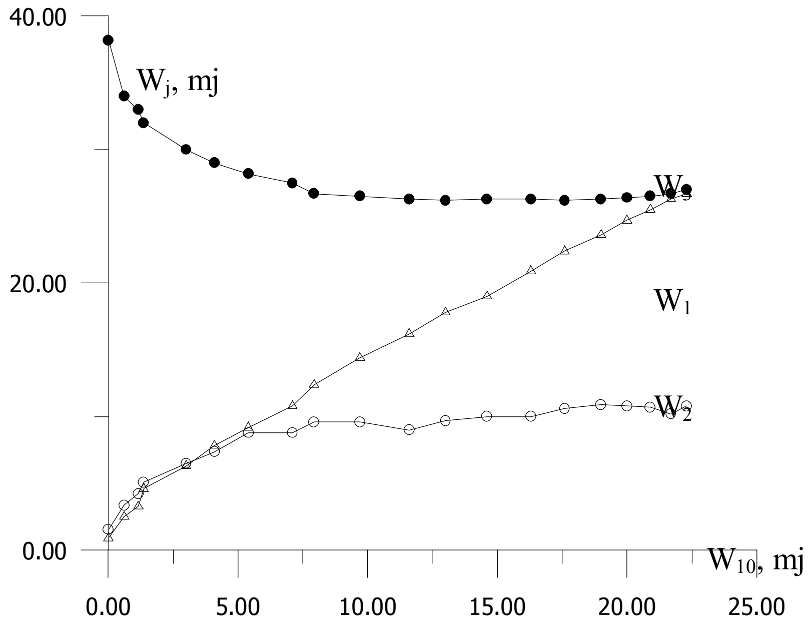

Fig.2. The OPA output pulse energies at λ_1, λ_2 and λ_3 with the constant input pump energy W_{30}~ 43 mJ versus input idler energy at λ_1.

From the Fig.2 the following characteristics of the OPA can be seen:

- the output energies of pulses

  at 355 nm - W_3~26,5 mJ,
  at 532 nm - W_2~10,0 mJ,
  at 1064 nm - W_1~11,5 mJ,

- the efficiency of OPA at the signal $\eta_2 \approx \dfrac{W_2}{W_{30}} \approx 0{,}23$,

- the efficiency of OPA at the idler $\eta_1 \approx \dfrac{W_1 - W_{10}}{W_{30}} \approx 0{,}08$,

- the total OPA efficiency $\eta_1 \approx \eta_2 + \eta_1 \approx 0{,}31$

We investigated the gain saturation effects when the input pump energy OPA was decreased down to ~ 29.3 mJ. The results are shown in Fig.3.

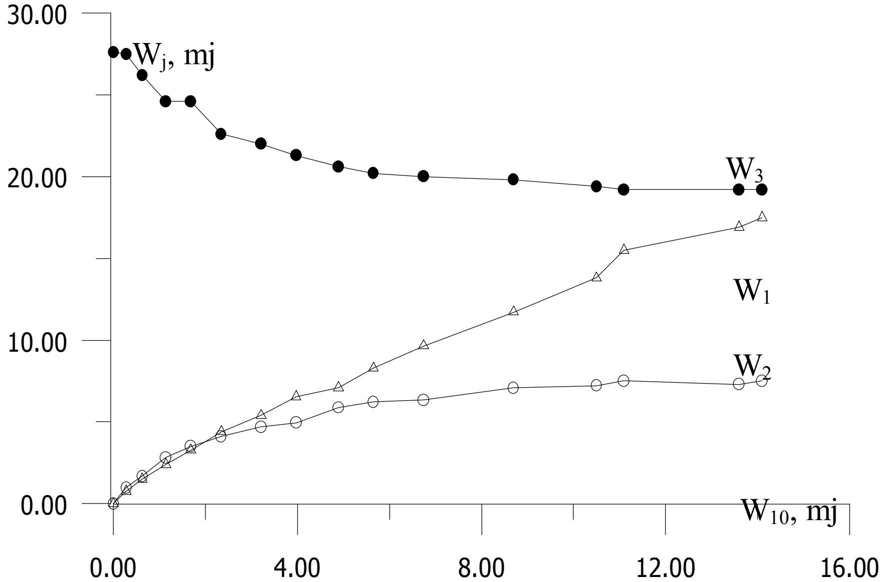

Fig.3. The OPA output pulse energies at λ_1, λ_2 and λ_3 with the constant input pump energy W_{30}~ 29.3 mJ versus input idler energy at λ_1.

In this case the maximal extraction efficiency and the gain saturation effects were obtained at input idler energy $W_{10} > 5$ mJ which is less than in the previous case.

On the base of the obtained experimental data the OPO scheme consisting 2 consistently located BBO crystals with a mirror between them with a high reflection coefficient for signal wave and a high transmission for the pump and idler waves is proposed. In the two-crystal OPA configuration efficient energy extraction may be increased. In this case both of the BBO crystals work in the gain saturation regime and:

- the crystal-1 provides the maximum signal gain,
- the crystal-2 provides the maximum idler gain.

Comparing the measured values of OPA output energies (Fig. 2, Fig.3) it is possible to make an estimation of extraction energy efficiency in the two-crystal OPA configuration:

- for crystal-1: input $W'_{10} = 4mJ$, $W'_{30} = 43mJ$

  output $W'_1 = 6,8mJ$, $W'_2 = 7,5mJ$, $W'_3 = 29mJ$;

- for crystal-2: input $W''_{10} = 6,8mJ$, $W''_{30} = 29mJ$

  output $W''_1 = 8,4mJ$, $W''_2 = 6,3mJ$, $W''_3 = 20mJ$

- total OPA efficiency at signal $W_2 = W'_2 + W''_2 = 13,8mJ$ ($\eta_2 = 0,32$);

- total OPA efficiency at idler $\Delta W_1 = W''_1 - W'_{10} = 4,4mJ$ ($\eta_1 = 0,10$);

- total OPA efficiency $\eta_1 \approx \eta_2 + \eta_1 \approx 0,42$

3. CONCLUSION

Gain saturation effects were studied using a constant pump intensity and variable input idler intensity. In the one-crystal OPA configuration at pump intensity ~ 68 MW/cm^2 and input idler intensity ~ 18 MW/cm^2 the efficiency of energy extraction in the saturated gain regime ~ 31% was obtained. On the basis of experimental data we made the conclusion, that in the two-crystal OPA configuration with the same input parameters the efficiency of energy extraction up to 42% is possible.

4. REFERENCES

1. J.M.Boon-Engering, L.A.W.Gloster, W.E.van der Veer, I.T.McKinnie, T.A.King, W.Hogervorst, "Highly efficient single-longitudinal-mode β-BaB_2O_4 optical parametric oscillator with a new cavity design ", Optics Letters, 20, pp. 2087 -2089, 1995.
2. J.M.Boon-Engering, W.E.van der Veer, E.A.J.M.Bente, W.Hogervorst, " Scanning and locking of a single longitudinal mode β-BaB_2O_4 OPO in grasing incidence configuration" , Optics Communications, 136, pp. 261-266, 1997.
3. A.Umbrasas, J.Jacob, " Widely tunable stable single longitudinal mode BBO OPO ", OSA TOPS on Advanced Solid State Lasers, 10, pp. 86-89, 1997.
4. .S.Wu, V.Kapinus, G.Blake, " A nanosecond optical parametric generator/amplifier seeded by an external cavity diode laser", Optics Communications, 159, pp. 74-79, 1999.
5. V.Dmitriev, G. Gurzadyan, D.Nikogosyan ,"Handbook of Nonlinear Optical crystals" (Berlin: Springer-Verlag, 1997).