APPLICATIONS OF LITHIUM TRIBORATE LIB_3O_5 (LBO) CRYSTAL

1. Generation of harmonics of Nd:YAG and Nd:YLF laser radiation

Due to the very high threshold of surface damage, high nonlinearity, large acceptance angle and low birefringence, the LBO crystal is very suitable for harmonic generation of high-intensity laser radiation.

1.1 SHG nanosecond Nd:YAG laser

In comparison with BBO, LBO-based second harmonic generation (SHG) of nanosecond Nd:YAG laser radiation (λ = 1064 nm, τ_p = 8 – 10 ns) shows better efficiency. The most optimal for SHG of nanosecond Nd:YAG laser radiation is the LBO crystal with a length of 14 mm (θ = 90 deg., φ = 12 deg.), which gives more than 70% energy conversion efficiency for pump radiation intensity in the range of $0.5 – 0.8\times10^{13}$ W/m^2.

1.2 SHG picosecond Nd:YAG and Nd:YLF lasers

The highly efficient SHG of picosecond Nd:YAG laser radiation (λ = 1064 nm, τ_p = 35 ps) is obtained by the 15 mm long LBO crystal (θ = 90 deg., φ = 0 deg.) heated to 148.5°C; with an energy conversion efficiency of 60-65% for the pump intensities of $1.5 – 4\times10^{13}$ W/m^2.

The SHG of picosecond Nd:YLF laser radiation (λ = 1047 nm, τ_p = 55 ps) is achieved in a 12 mm long LBO crystal cut for the none-critical phase-matching along the x-axis with an energy conversion efficiency of more than 60 %.

1.3 CW and flash-lamp pumped Nd:YAG lasers

The external resonant frequency doubling of a CW Nd:YAG laser (λ = 1064 nm, P_{pump} = 18 W) in a 6 mm long LBO crystal (θ = 90 deg., φ = 0 deg.) is obtained with a conversion efficiency of 36%.

High-efficiency intracavity frequency doubling of a flash-lamp pumped Nd:YAG laser (λ = 1064 nm, Δ_f = 250 Hz, pumping energy 1.25 J) is reported using a 6 mm long LBO crystal cut for Type I interaction in the xy plane.

1.4 THG nanosecond Nd:YAG laser

The efficiency of third-harmonic generation (THG) of nanosecond Nd:YAG laser radiation (λ = 1064 nm, τ_p = 8 – 10 ns) based on LBO crystals exceeds that based on BBO or DKDP at high intensities of pump radiation. The overall (IR → UV) energy conversion efficiency is more than 30 % for a 15 mm long LBO crystal cut for Type II (yz plane, *oe* → *o*) and 1013 W/m2 pump intensity; and about 22 % for 12 mm long LBO crystal cut for Type I (xy plane *oo* → *e*) and 2×10^{12} W/m^2 pump intensity.

The efficient THG of picosecond Nd:YAG laser radiation (λ = 1064 nm, τ_p = 25 ps) in two sequential LBO crystals (SHG in a 6.5 mm long crystal cut for *oo* → *e* interaction in the xy plane, SFG in a 6 mm long crystal cut for *oeo* interaction in the yz plane) is shown to have the overall energy conversion efficiency (IR → UV) of 50 % at a pump intensity of 3.3×10^{13} W/m^2.

2. Generation of harmonics of Ti:Sapphire Laser Radiation

2.1 SHG nanosecond Ti:Sapphire laser

The comparison between LBO and $LiIO_3$ crystals used for SHG of ns Ti:Sapphire laser radiation shows the superiority of LBO for this purpose. With the 5 mm long LBO crystal cut for *oo* → *e* - type interaction (θ = 90 deg., φ = 30 deg.) at λ = 390 nm it is obtained pulses with an energy of 8 mJ which corresponds to 30 % efficiency when pumping with an intensity of 9×10^{12} W/m^2 (pulse duration at the fundamental frequency is 12 ns).

2.2 SHG picosecond Ti:Sapphire laser

The efficient SHG of picosecond Ti:Sapphire laser radiation (tuning range 720 – 850 nm, repetition rate 82 MHz, pulse duration 1.5 ps, mean power 1.75 W at $\lambda = 790$ nm) is obtained in a 8 mm long LBO crystal ($\theta = 90$ deg., $\varphi = 32$ deg.).

When pumping at $\lambda = 790$ nm with an intensity of about 8×10^{13} W/m^2, 21 % energy conversion efficiency (internal) exists.

In comparison with $LiIO_3$ (or BBO) LBO produces 2 (or 1.3) times less power at the doubled frequency, but due to the very low walk-off angle LBO shows much better beam profile, which is very important for subsequent THG, FHG and SFG processes.

2.3 SHG femtosecond Ti:Sapphire laser

The internal energy conversion efficiency is 50 % for SHG of femtosecond Ti:Sapphire (tuning range 720 – 850 nm, repetition rate 82 MHz, pulse duration 100 fs, mean power 1.1 W at $\lambda = 800$ nm) is achieved in a 8 mm long LBO crystal.

2.4 CW Ti:Sapphire laser

The SHG of CW Ti:Sapphire laser radiation using a 10 mm long LBO crystal cut for Type I interaction $oo \rightarrow e$ has 22 % of external energy conversion efficiency.

3. Generation of Tunable Radiation in Deep UV

With SHG in a BBO crystal possesses a very large birefringence it is possible to obtain tunable UV radiation up to 204.8 nm; in LBO the shortest UV wavelength generated by SHG in the xy plane near the y-axis ($oo \rightarrow e$) is about 277.3 nm. On the other hand, LBO has a much better transmission in the UV than BBO (up to 155 nm and up to 189 nm, respectively). This allows obtaining tunable UV and VUV radiation by SFG in LBO.

When mixing the fourth harmonic of a Nd:YAG laser ($\lambda = 266.1$ nm) with the IR radiation ($\lambda_1 = 1.37 – 2.5$ μm), it is possible to obtain UV radiation in the 223 – 241 nm range.

When mixing 212.8 nm (or 190 nm) radiation with the IR radiation in the range 1.43–2.5 μm (or 1.54 – 2.5 μm), it is possible to produce tunable UV output in the range 185–196 nm (or 169 – 177 nm). In all cases the shortest UV wavelength produced corresponds to Type I interaction along the y-axis.

The generation of tunable UV radiation below 188 nm in LBO requires a subsequent employment of one or two additional SFG procedures, which at present is the only method to obtain deep-UV radiation using three-wave interactions in nonlinear optical crystals.

4. Optical Parametric Oscillators and Amplifiers

532.1 and 523.5 nm pumping

Most of LBO-based optical parametric oscillators (OPO) and amplifiers (OPA) with 532.1 nm (or 523.5 nm) pump use the Type I temperature-tuned none-critical phase-matching along the x-axis. The degeneracy point ($\lambda_s = \lambda_i$) corresponds to the temperature of 148.5°C (in the case of 532.1 nm pumping) and 180°C (in the case of 523.5 nm pumping).

The threshold intensity for LBO-based singly resonant OPO (SROPO) with synchronous pumping at $\lambda_s = 532$ nm or 523.5 nm lies in the range (1.5 – 2.5) $\times10^{13}$ W/m^2 for the crystals of 12–15 mm length. The same parameter for the doubly resonant OPO (DROPO) with synchronous pumping at 523.5 nm is equal to 1.1×10^{13} W/m^2 for a 12 mm long LBO crystal. For ns LBO-based DROPO this parameter is even lower — 2.2×10^{12} W/m^2 (crystal length 15 mm).

For LBO-based SROPO with the synchronous pumping at $\lambda = 532$ nm at ~ 3 times above threshold it is a 30 % signal energy conversion efficiency and 47 % total energy conversion efficiency; for DROPO with synchronous pumping at 523.5 nm at ~5 times above threshold it is found a 46 % total energy conversion efficiency.

354.7 nm pumping

LBO-based OPO with the 355 nm pump use the Type I angle-tuned phase-matching in the xy plane or the Type II temperature-tuned noncritical phase matching along the z-axis.

For SROPO schemes with ns 355 nm pump utilizing Type I and Type II phase-matching the threshold pumping intensity varies in the range from 1.5×10^{11} W/m^2 to 4×10^{11} W/m^2 (the length of LBO crystals is 11 – 16 mm). A pump-to-signal energy conversion efficiency of 22% and a total energy conversion efficiency of 35 % for 16 mm long LBO crystal are at ~3 times above the SROPO threshold. For single-pass traveling-wave OPO (TWOPO) with ps 355 nm pump the highest pump-to-signal energy conversion efficiency value is 38 % for 10 mm long LBO crystal; pump intensity of 1.8×10^{14} W/m^2.

307.8 nm pumping

In LBO-based ns SROPO using XeCl excimer laser radiation as a pump an LBO crystal of 16 mm length cut along the z-axis (Type II none-critical phase-matching) is employed and both temperature and angular tuning are used.

The threshold intensity of SROPO with 10 ns 308 nm pump lies between 1.8×10^{11} W/m^2 and 3.6×10^{11} W/m^2 (using 15 – 16 mm long LBO crystals). The external total energy conversion efficiency is about 20 – 30 % at 3.5 times above the threshold.

266.1 nm pumping

LBO-based SROPO utilizing 12 ns 266 nm pump employs a 16 mm long crystal cut along the z-axis (interaction Type II). The threshold intensity is about 10^{11} W/m^2, the total energy conversion efficiency is ~10 % at 3.5 times above the threshold.

CW Pump Sources

To the LBO-based continuous-wave optical parametric oscillator the CW radiation of an argon-ion laser at λ = 364 nm or 514.5 nm is used as a pump.

The threshold pump power is 250 mW in the case of the 514.5 nm pump and 115 mW in the case of 364 nm pump; 10 % total external efficiency is achieved at 3.6 and 9.6 times above threshold, respectively.