LASER COMPONENTS

Lithium Triborate Crystal (LiB_3O_5,LBO)

Introduction

Lithium Triborate (LiB_3O_5 or LBO) is an excellent nonlinear optical crystal discovered and developed by the Chinese Academy of Sciences. Our partner has exclusive rights to **produce, manufacture and market** the patented LBO crystal and its NLO devices.

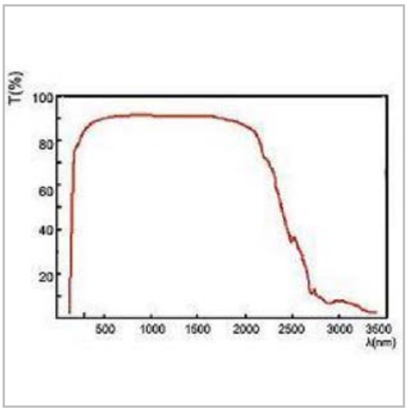

Figure 1:
Transparency curve of LBO

LBO is featured by:

- Broad transparency range from 160 nm to 2600 nm (see Figure 1);
- High optical homogeneity (ðn ≈10-6/cm) and being free of inclusion;
- Relatively large effective SHG coefficient (about three times that of KDP);
- High damage threshold;
- Wide acceptance angle and small walk-off;
- Type I and type II non-critical phase matching (NCPM) in a wide
- wavelength range;
- Spectral NCPM near 1300 nm.

LASER COMPONENTS offers:

- Strict quality control;
- Large crystal size up to 15x15x20 mm^3 and maximum length of 60 mm;
- AR-coating, mounts and repolishing services;
- A large quantity of crystals in stock (in China);
- Fast delivery (10 days for polished only, 15 days for AR-coated – plus transport from China).

08/19 / V02 / HW / diverse-laser-optics/laser-rods-crystals/lbo

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Crystal structure	orthorhombic, space group $Pna2_1$, point group mm^2
Lattice parameter	a = 8.4473 Å, b = 7.3788 Å , c = 5.1395 Å , Z = 2
Melting point	about 834 °C
Mohs hardness	6
Density	2.47 g/cm³
Thermal conductivity	3.5 W/m/K
Thermal expansion coefficient	α_x=10.8 x 10^{-5}/K, α_y= -8.8 x 10^{-5}/K, α_z=3.4 x10^{-5}/K

Table 1: Chemical and structural properties

Transparency range	160 – 2600 nm	
SHG phase matchable range	551~2600 nm (Type I) 790 – 2150 nm (Type II)	
Therm-optic coefficient (°C, l in µm)	$dn_x/d_T = -9.3x10^{-6}$ $dn_y/d_T = -13.6x10^{-6}$ $dn_z/d_T = (-6.3-2.1\lambda)x10^{-6}$	
Absorption coefficient	<0.1%/cm at 1064 nm <0.3%/cm at 532 nm	
Angle acceptance	6.54 mrad-cm (φ, Type I,1064 SHG) 15.27 mrad-cm (θ, Type II,1064 SHG)	
Temperature acceptance	4.7 °C-cm (Type I, 1064 SHG) 7.5 °C-cm (Type II,1064 SHG)	
Spectral acceptance	1.0 nm-cm (Type I, 1064 SHG) 1.3 nm-cm (Type II,1064 SHG)	
Walk-off angle	0.60° (Type I 1064 SHG) 0.12° (Type II 1064 SHG)	
NLO coefficient	$d_{eff}(I) = d_{32}\cos\phi$ $d_{eff}(I) = d_{31}\cos^2\theta+d_{32}\sin^2\theta$ $d_{eff}(II) = d_{31}\cos\theta$ $d_{eff}(II) = d_{31}\cos^2\theta+d32\sin^2\theta$	(Type I in XY plane) (Type I in XZ plane) (Type II in YZ plane) (Type II in XZ plane)
Non-vanished NLO susceptibilities	d_{31} = 1.05 ± 0.09 pm/V d_{32} = -0.98 ± 0.09 pm/V d_{33} = 0.05 ± 0.006 pm/V	
Sellmeier equations (λ in mm)	$n_x^2 = 2.454140+0.011249/(\lambda^2-0.011350) - 0.014591\lambda^2 - 6.60 \times 10^{-5}\lambda^4$ $n_y^2 = 2.539070+0.012711/(\lambda^2-0.012523) - 0.018540\lambda^2 + 2.00 \times 10^{-4}\lambda^4$ $n_z^2 = 2.586179+0.013099/(\lambda^2-0.011893) - 0.017968\lambda^2 - 2.26 \times 10^{-4}\lambda^4$	

Table 2: Optical and nonlinear optical properties

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

SHG and THG at Room Temperature

LBO is phase matchable for the SHG and THG of Nd:YAG and Nd:YLF lasers, using either type I or type II interaction. For the SHG at room temperature, type I phase matching can be reached and has the maximum effective SHG coefficient in the principal XY and XZ planes (see Fig. 2) in a wide wavelength range from 551 nm to about 2600 nm (the effective SHG coefficient see Table 2).

The optimum type II phase matching falls in the principal YZ and XZ planes (see Fig. 2 - the effective SHG coefficient see Table 2).

SHG conversion efficiencies of more than 70% for pulse and 30% for cw Nd:YAG lasers, and THG conversion efficiency over 60% for pulse Nd:YAG laser have been observed by using LBO crystals.

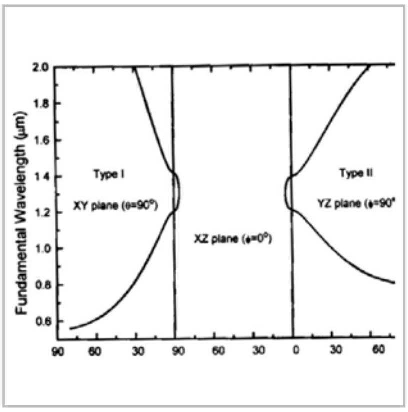

Figure 2:
SHG tuning curves of LBO

Applications

- More than 480 mW output at 395 nm is generated by frequency doubling a 2 W mode-locked.
  Ti:Sapphire laser (<2 ps, 82 MHz). The wavelength range of 700 – 900 nm is covered by a 5x3x8 mm 3 LBO crystal.
- Over 80 W green output is obtained by SHG of a Q-switched Nd:YAG laser in a type II 18 mm long LBO crystal.
- The frequency doubling of a diode pumped Nd:YLF laser (>500 µJ @ 1047 nm, <7 ns, 0 –10 kHz) reaches over 40% conversion efficiency in a 9 mm long LBO crystal.
- The VUV output at 187.7 nm is obtained by sum-frequency generation.
- 2 mJ/pulse diffraction-limited beam at 355 nm is obtained by intracavity frequency tripling a Q-switched Nd:YAG laser.

Non-critical Phase-Matching

As shown in table 3, Non-Critical Phase-Matching (NCPM) of LBO is featured by no walk-off, very wide acceptance angle and maximum effective coefficient. It promotes LBO to work in its optimal condition. SHG conversion efficiencies of more than 70% for pulse and 30% for cw Nd:YAG lasers have been obtained, with good output stability and beam quality.

08/19 / V02 / HW / diverse-laser-optics/laser-rods-crystals/lbo

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

NCPM temperature	148 °C
Acceptance angle	52 mrad-cm$^{1/2}$
Walk-off angle	0
Temperature bandwidth	4 °C-cm
Effective SHG coefficient	2.69 d_{36}(KDP)

Table 3: Properties of type 1 NCPM GHG at 1064 nm

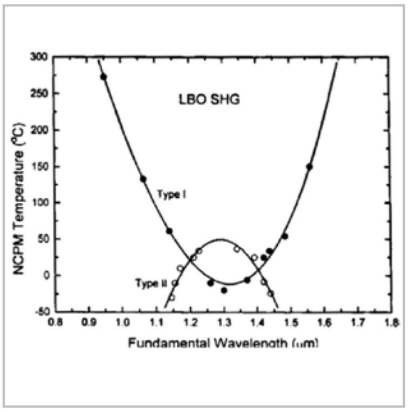

Figure 3:
NCPM temperature tuning curves of LBO

As shown in Fig.3, type I and type II non-critical phase-matching can be reached along x-axis and z-axis at room temperature, respectively. (We offer an assembly of oven and temperature controller for NCPM applications.)

Applications

- Over 11 W of average power at 532 nm was obtained by extracavity SHG of a 25 W Antares mode-locked Nd:YAG laser (76 MHz, 80 ps).
- 20 W green output was generated by frequency doubling a medical, multi-mode Q-switched Nd:YAG laser. Much higher green output is expected with higher input.

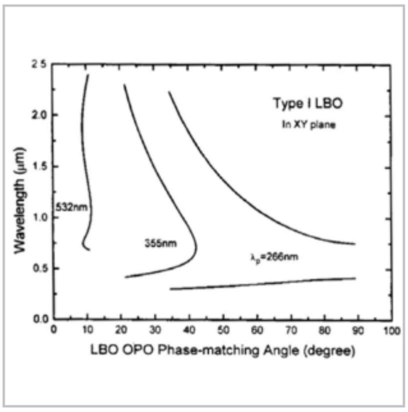

Figure 4:
Type I OPO tuning curves of LBO

LBO´s OPO AND OPA

LBO is an excellent NLO crystal for OPOs and OPAs with a widely tunable wavelength range and high powers. These OPO and OPA that are pumped by the SHG and THG of Nd:YAG laser and XeCl excimer laser at 308 nm have been reported. The unique properties of type I and type II phase matching as well as the NCPM leave a big room in the research and applications of LBO's OPO and OPA.

Fig.4 shows the calculated type I OPO tuning curves of LBO pumped by the SHG, THG and 4HG of Nd:YAG laser in XY plane at the room temperature.

Fig. 5 illustrates type II OPO tuning curves of LBO pumped by the SHG and THG of Nd:YAG laser in XZ plane.

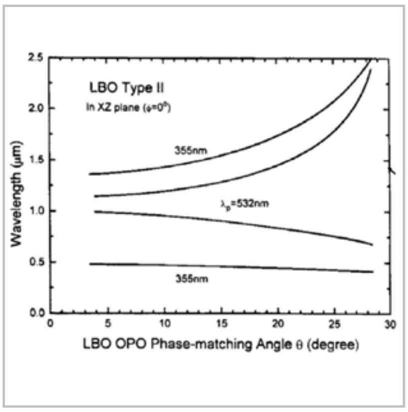

Figure 5:
Type II OPO tuning curves of LBO

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Applications

- A quite high overall conversion efficiency and 540 – 1030 nm tunable wavelength range were obtained with OPO pumped at 355 nm.
- Type I OPA pumped at 355 nm with the pump-to-signal energy conversion efficiency of 30% has been reported.
- Type II NCPM OPO pumped by a XeCl excimer laser at 308 nm has achieved 16.5% conversion efficiency, and moderate tunable wavelength ranges can be obtained with different pumping sources and temperature tuning.
- By using the NCPM technique, type I OPA pumped by the SHG of a Nd:YAG laser at 532 nm was also observed to cover a wide tunable range from 750 nm to 1800 nm by temperature tuning from 106.5 °C to 148.5 °C.
- By using type II NCPM LBO as an optical parametric generator (OPG) and type I critical phase-matched BBO as an OPA, a narrow linewidth (0.15 nm) and high pump-to-signal energy conversion efficiency (32.7%) were obtained when it is pumped by a 4.8 mJ, 30 ps laser at 354.7 nm. Wavelength tuning range from 482.6 nm to 415.9 nm was covered by increasing the temperature of LBO or rotating BBO.

LBO´S Spectral NCPM

Not only the ordinary non-critical phase matching (NCPM) for angular variation but also the non-critical phase matching for spectral variation (SNCPM) can be achieved in the LBO crystal.

As shown in Fig.2, the phase matching retracing positions are λ_1=1.31 mm with q =86.4°, φ=0° for Type I and λ_2=1.30 mm with θ =4.8°, φ =0° for Type II. The phase matching at these positions possess very large spectral acceptances $\Delta\lambda$. The calculated $\Delta\lambda$ at λ_1 and λ_2 are 57 nm-cm$^{-1/2}$ and 74 nm-cm$^{-1/2}$ respectively, which are much larger than the other NLO crystals. These spectral characteristics are very suitable for doubling broadband coherent radiations near 1.3 mm, such as those from some diode lasers, and some OPA/OPO output without linewidth-narrowing components.

AR-Coating

LASER COMPONENTS provides the following AR-coatings:

- Dual Band AR-coating (DBAR) of LBO for SHG of 1064 nm.
  - low reflectance (R<0.2% at 1064 nm and R<1.0% at 532 nm);
  - high damage threshold (>500 MW/cm2 at both wavelengths);
  - long durability.
- Broad Band AR-coating (BBAR) of LBO for SHG of tunable lasers.
- Other coatings are available upon request.

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

LASER COMPONENTS

Warranty on LBO Specification

- Dimension tolerance: (W±0.1 mm) x (H±0.1 mm) x (L+0.5/-0.1 mm) (L≥2.5 mm)
  (W±0.1 mm) x (H±0.1 mm) x (L+0.1/-0.1 mm) (L<2.5 mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50 mW green laser
- Flatness: less than l/8 @ 633 nm
- Transmitting wavefront distortion: less than l/8 @ 633 nm
- Chamfer: ≤0.2 mm@45°
- Chip: ≥0.1 mm
- Scratch/dig code: better than 10/5 to MIL-O-13830A
- Parallelism: better than 20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: $\Delta\theta \leq 0.25°$, $\Delta\Phi < 0.25°$
- Damage threshold [GW/cm²]: >10 for 1064 nm, TEM00, 10 ns, 10 Hz (polished only)
  > 1 for 1064 nm, TEM00, 10 ns, 10 Hz (AR-coated)
  > 0.5 for 532 nm, TEM00, 10 ns, 10 Hz (AR-coated)
- Quality warranty period: one year under proper use.

Note

1. LBO has a very low susceptibility to moisture. Users are advised to provide dry conditions for both the use and preservation of LBO.
2. Polished surfaces of LBO requires precautions to prevent any damage.
3. LASER COMPONENTS engineers can select and design the best crystal for you, if the main parameters of your laser are provided, such as energy per pulse, pulse width and repetition rate for a pulsed laser, power for a cw laser, laser beam diameter, mode condition, divergence, wavelength tuning range, etc.
4. For thin crystal, LASER COMPONENTS can provide free holder for you.

08/19 / V02 / HW / diverse-laser-optics/laser-rods-crystals/lbo

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk