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CRYSTAL CATALOG

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GWU-Lasertechnik

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福建福晶科技股份有限公司
CASTECH INC.

Lithium Triborate (LiB_3O_5, LBO)

Introduction

Lithium Triborate (LiB_3O_5 or LBO) is an excellent nonlinear optical crystal discovered and developed by FIRSM, CAS (Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences). Fujian CASTECH Crystals, Inc. **(CASTECH)** has the exclusive rights to produce, manufacture and market the patented LBO crystal and its NLO devices. **The patent number is 4,826,283 in USA, 2023845 in Japan and 88 1 02084.2 in China.**

CASTECH's LBO is featured by

- Broad transparency range from 160nm to 2600nm (see Figure 1);
- High optical homogeneity ($\delta n \approx 10^{-6}$/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 1300nm.

CASTECH offers

- Strict quality control;
- Large crystal size up to 30x30x30mm^3 and maximum length of 60mm;
- AR-coating, mounts and re-polishing services;
- A large quantity of crystals in stock;
- Fast delivery(10 days for polished only, 15 days for AR-coated).

Table 1. Chemical and Structural Properties

Crystal Structure	Orthorhombic, Space group $Pna2_1$, Point group mm2
Lattice Parameter	a=8.4473Å, b=7.3788Å, c=5.1395Å, Z=2
Melting Point	About 834°C
Mohs Hardness	6
Density	2.47 g/cm^3
Thermal Conductivity	3.5W/m/K
Thermal Expansion Coefficients	α_x=10.8x10^{-5}/K, α_y= -8.8x10^{-5}/K, α_z=3.4x10^{-5}/K

Table 2. Optical and Nonlinear Optical Properties

Transparency Range	160-2600nm
SHG Phase Matchable Range	551-2600nm (Type I) 790-2150nm (Type II)
Therm-optic Coefficient (/ °C, λ in μm)	$dn_x/dT=-9.3\times10^{-6}$ $dn_y/dT=-13.6\times10^{-6}$ $dn_z/dT=(-6.3-2.1\lambda)\times10^{-6}$
Absorption Coefficients	<0.1%/cm at 1064nm <0.3%/cm at 532nm
Angle Acceptance	6.54mrad·cm (φ, Type I,1064 SHG) 15.27mrad·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	1.0nm·cm (Type I, 1064 SHG) 1.3nm·cm (Type II,1064 SHG)
Walk-off Angle	0.60° (Type I 1064 SHG) 0.12° (Type II 1064 SHG)
NLO Coefficients	$d_{eff}(I)=d_{32}\cos\phi$ (Type I in XY plane) $d_{eff}(I)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ (Type I in XZ plane) $d_{eff}(II)=d_{31}\cos\theta$ (Type II in YZ plane) $d_{eff}(II)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ (Type II in XZ plane)
Non-vanished NLO Susceptibilities	$d_{31}=1.05\pm0.09$ pm/V $d_{32}=-0.98\pm0.09$ pm/V $d_{33}=0.05\pm0.006$ pm/V
Sellmeier Equations (λ in μm)	$n_x^2=2.454140+0.011249/(\lambda^2-0.011350)-0.014591\lambda^2-6.60\times10^{-5}\lambda^4$ $n_y^2=2.539070+0.012711/(\lambda^2-0.012523)-0.018540\lambda^2+2.00\times10^{-5}\lambda^4$ $n_z^2=2.586179+0.013099/(\lambda^2-0.011893)-0.017968\lambda^2-2.26\times10^{-5}\lambda^4$

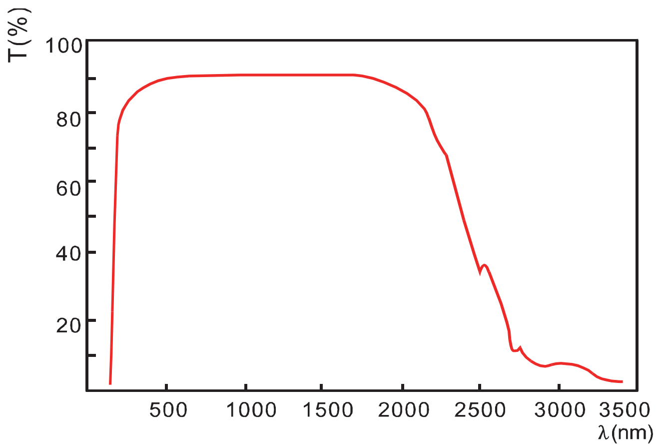

Figure 1. Transparency curve of LBO

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 551nm to about 2600nm (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 CASTECH's LBO crystals.

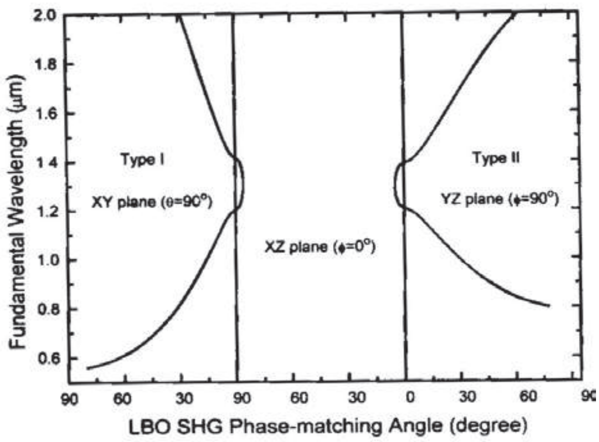

Figure 2. SHG tuning curves of LBO

Applications

- More than 480mW output at 395nm is generated by frequency doubling a 2W mode-locked Ti:Sapphire laser (<2ps, 82MHz). The wavelength range of 700-900nm is covered by a 5x3x8mm^3 LBO crystal.
- Over 80W green output is obtained by SHG of a Q-switched Nd:YAG laser in a type II 18mm long LBO crystal.
- The frequency doubling of a diode pumped Nd:YLF laser (>500µJ @ 1047nm, <7ns, 0–10KHz) reaches over 40% conversion efficiency in a 9mm long LBO crystal.
- The VUV output at 187.7 nm is obtained by sum-frequency generation.
- 2mJ/pulse diffraction-limited beam at 355nm 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.

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.

(CASTECH develops an assembly of oven and temperature controller for NCPM applications. Please refer to Page 69 for more technical data.)

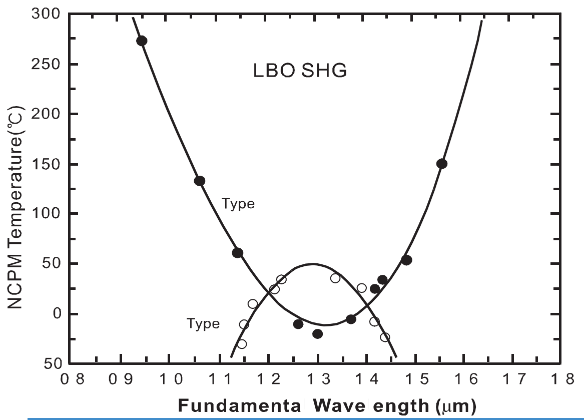

Figure 3. NCPM temperature tuning curves of LBO

Table 3. Properties of type I NCPM SHG at 1064nm	
NCPM Temperature	148°C
Acceptance Angle	52 mrad·cm
Walk-off Angle	0
Temperature Bandwidth	4°C·cm
Effective SHG Coefficient	2.69 x d_{36}(KDP)

Applications

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

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 which are pumped by the SHG and THG of Nd:YAG laser and XeCl excimer laser at 308nm have been reported. The unique properties of type I and type II phase matching as well as the NCPM leave a large 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. And Fig. 5 illustrates type II OPO tuning curves of LBO pumped by the SHG and THG of Nd:YAG laser in XZ plane.

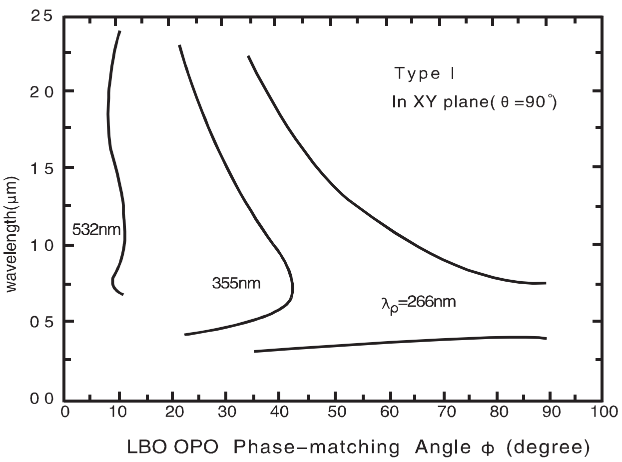

Figure 4. Type I OPO tuning curves of LBO

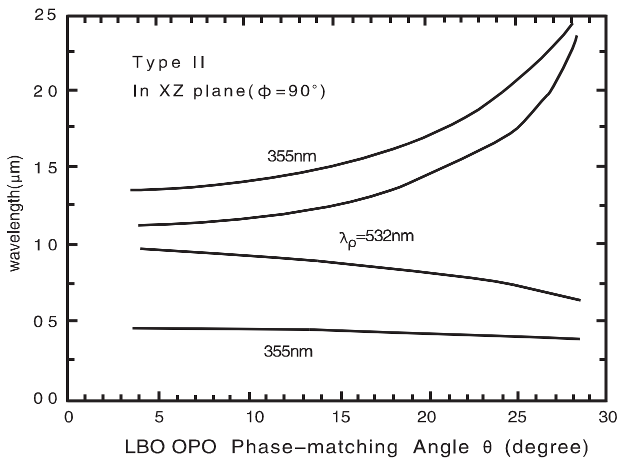

Figure 5. Type II OPO tuning curves of LBO

Applications

- A quite high overall conversion efficiency and 540-1030nm tunable wavelength range were obtained with OPO pumped at 355nm.
- Type I OPA pumped at 355nm with the pump-to-signal energy conversion efficiency of 30% has been reported.
- Type II NCPM OPO pumped by a XeCl excimer laser at 308nm 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 532nm was also observed to cover a wide tunable range from 750nm to 1800nm 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 (0.15nm) and high pump-to-signal energy conversion efficiency (32.7%) were obtained when it is pumped by a 4.8mJ, 30ps laser at 354.7nm. Wavelength tuning range from 482.6nm to 415.9nm was covered either by increasing the temperature of LBO or by 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 µm with θ =86.4°, φ=0° for Type I and λ_2=1.30 µm with θ =4.8°, φ=0° for Type II. The phase matching at these positions possess very large spectral acceptances Δλ. The calculated Δλ at λ_1 and λ_2 are 57nm·cm and 74nm·cm respectively, which are much larger than that of other NLO crystals. These spectral characteristics are very suitable for doubling broadband coherent radiations near 1.3 µm, such as those from some diode lasers, and some OPA/OPO output without linewidth-narrowing components.

AR-coatings

CASTECH provides the following AR-coatings:

- Dual Band AR-coating (DBAR) of LBO for SHG of 1064nm.
  low reflectance (R<0.2% at 1064nm and R<0.5% at 532nm), super low reflectivity of R<0.05% at 1064nm and R<0.1% at 532nm is available upon request; high damage threshold (>500MW/cm^2 at both wavelengths); long durability.
- Broad Band AR-coating (BBAR) of LBO for SHG of tunable lasers.
- Other coatings are available upon request.

CASTECH's Warranty on LBO Specifications

- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L≥2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50mW green laser
- Flatness: less than λ/8 @ 633nm
- Transmitting wavefront distortion: less than λ/8 @ 633nm
- Chamfer: ≤0.2mm x 45°
- Chip: ≤0.1mm
- Scratch/Dig code: better than 10/ 5 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: Δθ≤0.25°, Δϕ≤0.25°
- Damage threshold[GW/cm^2]: >10 for 1064nm, TEM00, 10ns, 10HZ (polished only)
  >1 for 1064nm, TEM00, 10ns, 10HZ (AR-coated)
  >0.5 for 532nm, TEM00, 10ns, 10HZ (AR-coated)
- Quality Warranty Period: one year under proper use.

Notes

- LBO has a low susceptibility to moisture. Users are advised to provide dry conditions for both the use and preservation of LBO.
- Polished surfaces of LBO requires precautions to prevent any damage.
- CASTECH engineers can select and design the best crystal for you, based on the main parameters of your laser, 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.
- For thin crystals, CASTECH can provide free holders for you.

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