CRYSTAL CATALOG

High Quality Optical Materials

CASTECH®
福晶科技

GWU-Lasertechnik

CASTECH Inc.

NLO Crystals · Laser Crystals · Precision Optics · Laser Components

About Us

CASTECH Inc. is a worldwide leading manufacturer of LBO crystals, BBO crystals, Nd:YVO_4 crystals, TGG crystals, precision optical components, high-power isolators, acousto-optical and electro-optical devices, etc. We are mainly engaged in researching, manufacturing and selling nonlinear optical crystals, laser crystals, precision optics and a variety of laser components, which are widely used in laser, optical communication, medical equipment, testing, analysis instruments and many other fields. Our mission is to deliver innovative products and solutions to our customers in photonics industry, and help them to realize their full potential in business. Here at CASTECH, we value comity, integrity, honesty and innovation.

ISO 9001 · IATF 16949 · ISO 14001 · ISO 45001

- Founded in 1990 by FIRSM (Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences).
- A public company (2008, Shenzhen, China, Stock Code: 002222).
- Sales revenue over US$80 millions.
- Over 1,000 employees.
- 40,000 m^2 facility.
- The ratio of domestic and international markets stands at 5:5.

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WeChat Account

IMPORTANT MILESTONES OF CASTECH

In 2021	CASTECH obtained the Laboratory accreditation certificate of China National Accreditation Service for Conformity Assessment.
In 2020	CASTECH is IATF16949 certificated.
In 2019	CASTECH is ISO45001 certificated. CASTECH expanded its grating production capacity for both optical communication and ultrashort pulse laser applications.
In 2016	CASTECH completed company structural adjustment, and formed new crystals, optics and laser components divisions.
In 2013	CASETCH expanded its production lines for laser components including high power isolatiors, Acousto-Optic Devices, Electro-Optic Devices etc.
In 2012	CASTECH is ISO14001 certificated. CASTECH moved to the new facility.
In 2009	CASTECH began to build its new facility of total 40,000 m^2.
In 2008	Fujian CASTECH Crystals, Inc. was renamed as "CASTECH Inc." CASTECH completed IPO in China Shenzhen Stock Exchange (SSE: 002222).
In 2007	CASTECH expanded its production line of DPM crystals to 1 million pcs per year.
In 2006	CATECH increased its capacity of optics production line. CASTECH was restructured to a joint-stock company.
In 2004	CASTECH acquired 30% shares of Hangzhou Keting Optical Technology Inc., with registration capital of 21 millions RMB.
In 2002	CASTECH acquired 55% shares of Qingdao CRYSTECH Inc., with registration capital of 11 millions RMB.
In 2001	CASTECH passed ISO9001 international quality system authentication.
In 1996	CASTECH obtained Japan patent (Patent number 2023845) for the LBO crystal component and its applications.
In 1992	CASTECH succeeded in developing Nd:YVO_4 and YVO_4 crystals for the first time in China, and began the volume production.
In 1990	The LBO product from CASTECH was evaluated as one of ten most important laser products by American laser magazine. Fujian CASTECH Crystals, Inc. was licensed to be founded officially, which entire capital was own by FIRSM. FIRSM obtained China patent (Patent No. 88102084.2) for the LBO crystal component and its applications.
In 1989	FIRSM obtained U.S.A. patent (Patent No.4,826,283) for the LBO crystal component and its applications.
In 1987	The BBO product from FIRSM was evaluated as one of ten most important products by American laser magazine.
In 1986	FIRSM offered the first BBO crystal to the customer.
In 1981	FIRSM began to export PET, ADP, KDP and KAP crystals to the U.S.A. customers.

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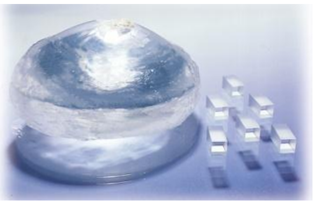

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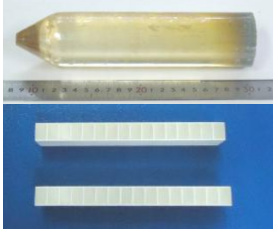


Accessories

LBO - Lithium Triborate (LiB_3O_5)

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). LBO crystal and its NLO devices now are produced, manufactured and marketed by CASTECH, Inc (CASTECH).

CASTECH's LBO is featured by

- Wide range of transparency (160-2600 nm, see Figure 1)
- High optical homogeneity ($\delta n \approx 10^{-6}$/cm), and being free of inclusion
- Relatively high SHG efficiency (about 3 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

CASTECH offers

- Strict quality control
- Large crystal size, aperture up to 40 x 40 mm^2 and length up to 60 mm
- AR-coating, mounts and re-working services
- A large quantity of crystals in stock
- Fast delivery (15 days for polished only, 20 days for AR-coated)

Basic Properties

Table 1. Chemical and Structural Properties

Crystal Structure	Orthorhombic, Space group $Pna2_1$, Point group mm2
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/cm^3
Thermal Conductivity	3.5 W/m/K
Thermal Expansion Coefficients	$\alpha_x = 10.8 \times 10^{-5}$/K, $\alpha_y = -8.8 \times 10^{-5}$/K, $\alpha_z = 3.4 \times 10^{-5}$/K

Table 2. Optical and Nonlinear Optical Properties

Transparency Range	160-2600 nm
SHG Phase Matchable Range	551-2600 nm (Type I) 790-2150 nm (Type II)
Therm-optic Coefficient (/°C, λ in μm)	$dn_x / dT = -9.3 \times 10^{-6}$ $dn_y / dT = -13.6 \times 10^{-6}$ $dn_z / dT = (-6.3 - 2.1\lambda) \times 10^{-6}$
Absorption Coefficients	<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 ℃·cm (Type I, 1064 SHG) 7.5 ℃·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 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	$d_{31} = 1.05 \pm 0.09$ pm/V $d_{32} = -0.98 \pm 0.09$ pm/V $d_{33} = 0.05 \pm 0.006$ pm/V
Sellmeier Equations (λ in μm)	$n_x^2 = 2.454140 + 0.011249 / (\lambda^2 - 0.011350) - 0.014591\lambda^2 - 6.60 \times 10^{-5}\lambda^4$ $n_y^2 = 2.539070 + 0.012711 / (\lambda^2 - 0.012523) - 0.018540\lambda^2 + 2.00 \times 10^{-4}\lambda^4$ $n_z^2 = 2.586179 + 0.013099 / (\lambda^2 - 0.011893) - 0.017968\lambda^2 - 2.26 \times 10^{-4}\lambda^4$

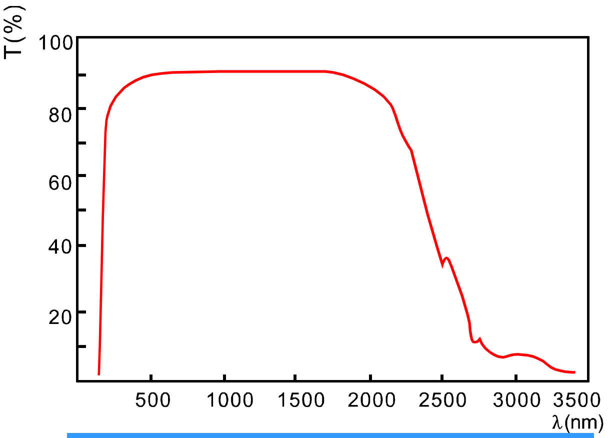


Figure 1. Transparency curve of LBO

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 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 CASTECH's LBO crystals.

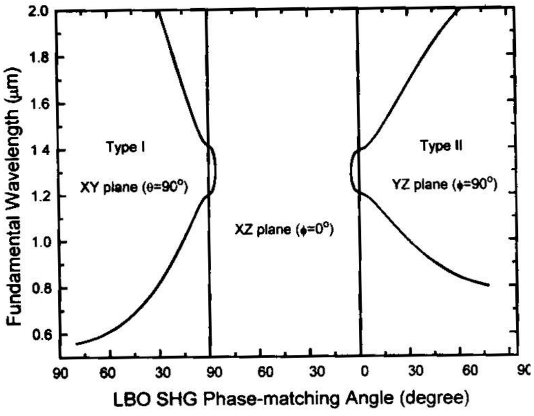


Figure 2. SHG tuning curves of LBO

Applications for SHG and THG at Room Temperature

- 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).
- 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 of LBO

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 efficiency 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 72 for more technical data.

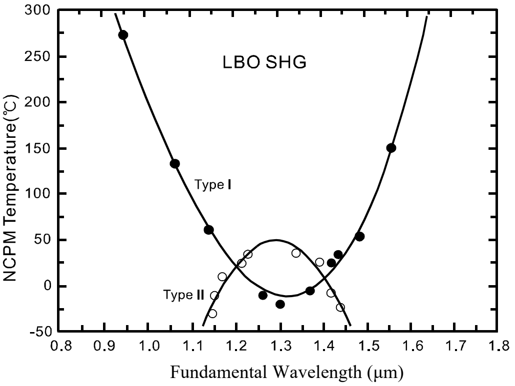


Figure 3. NCPM temperature tuning curves of LBO

Table 3. Properties of type I NCPM SHG at 1064 nm

NCPM Temperature	148 °C
Acceptance Angle	52 mrad·cm
Walk-off Angle	0
Temperature Bandwidth	4 °C·cm
Effective SHG Coefficient	2.69 × d_{36} (KDP)

Applications for NCPM

- Over 11 W of average power at 532 nm was obtained by extra-cavity 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. 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. The OPO and OPA which 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 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 FOHG 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.

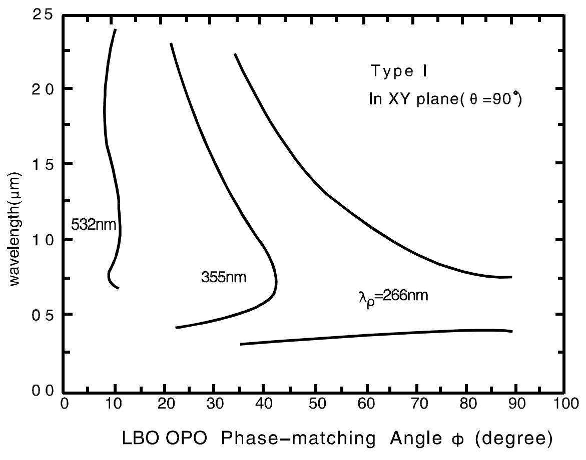


Figure 4. Type I OPO tuning curves of LBO

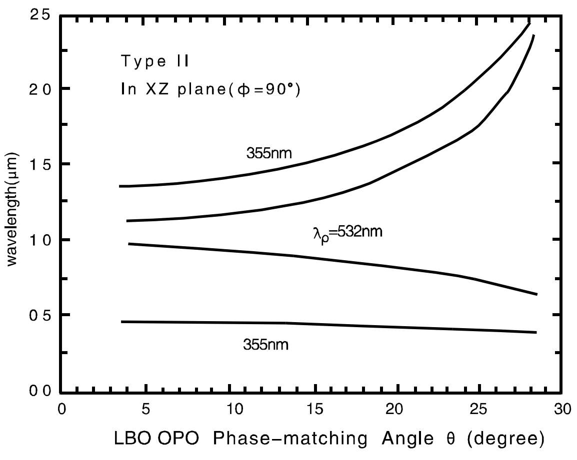


Figure 5. Type II OPO tuning curves of LBO

Applications for OPO and OPA

- 540-1030 nm tunable wavelength range with a quite high overall conversion efficiency has 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 ℃ to 148.5 ℃.
- By using type II NCPM LBO as an optical parametric generator (OPG) and type I critical phase-mateched BBO as an OPA, a narrow linewidth (0.15 nm) and high pump-to-signal energy conversion efficiency (32.7%) was 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 either by increasing the temperature of LBO or by rotating BBO.

LBO's Spectral NCPM

Not only the ordinary non-critical phase match (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 $\lambda_1 = 1.31$ µm with $\theta = 86.4$ °, $\Phi = 0$ °, for Type I and $\lambda_2 = 1.30$ µm with $\theta = 4.8$ °, $\Phi = 0$ °, for Type II. The phase matching at these position possess very large spectral acceptances $\Delta\lambda$ at λ_1 and λ_2, which are 57 nm·cm and 74 nm·cm respectively, 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-coating

CATECH provides the following AR-coatings:

- Dual Band AR-coating (DBAR) of LBO for SHG of 1064 nm;
  Frequency-tripled antireflection coating of LBO for THG of 1064 nm
- Low reflectance (R<0.2% @1064 nm, R<0.5% @532 nm, R<0.5% @355 nm) ;
  super low reflectivity of R<0.05% @1064 nm and R<0.1% @532 nm is available upon request
- Broad Band AR-coating (BBAR) of LBO for SHG of tunable lasers
- IBS, IAD coating methods are available upon request
- High damage threshold
- Long durability
- Other coating are available upon request

LBO's Parameters

Table 4. Specifications

Dimension Tolerance	(W±0.1 mm) × (H±0.1 mm) × (L+0.5/-0.1 mm) × (L≧2.5 mm) (W±0.1 mm) × (H±0.1 mm) × (L+0.1/-0.1 mm) × (L<2.5 mm)
Clear Aperture	Central 90% of the diameter
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/8 @633 nm
Transmitted Wave-front Distortion	≦λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	Δθ≦0.25°, ΔΦ≦0.25°
Chamfer	≦0.2 mm × 45°
Chip	≦0.1 mm
Damage Threshold	>10 GW/cm^2 @1064 nm, 10 ns, 10 Hz (polished only) >1 GW/cm^2 @1064 nm, 10 ns, 10 Hz (AR-coated) >0.5 GW/cm^2 @532 nm, 10 ns, 10 Hz (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 require 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 with free holders.

BBO - Beta-Barium Borate (β-BaB_2O_4)

Introduction

Beta-Barium Borate (β-BaB_2O_4 or BBO), discovered by FIRSM, CAS (Fujian Institute of Research on the Structure of Matter, Chinese Academy of Science), now is manufactured and marketed by CASTECH, Inc.

CASTECH's BBO is featured by

- Broad phase matchable range (409.6-3500 nm)
- Wide transmission region (190-3500 nm)
- Large effective second-harmonic-generation (SHG) coefficient about 6 times greater than that of KDP crystal
- High damage threshold
- High optical homogeneity with $\delta_n \approx 10^{-6}$ / cm
- Wide temperature-bandwidth of about 55 °C
- An efficient NLO crystal for the second, third, fourth, and even up to fifth harmonic generation of Nd doped lasers
- Widely applied in harmonic generation of ultrashort-pulse lasers

CASTECH Offers

- Strict quality control
- Crystal down to 0.005 mm thick, up to 25 mm long and size up to 15 × 15 × 15 mm^3
- P-coatings, AR-coating, mounts and re-working services
- A large quantity of crystals in stock
- Fast delivery (15 days for polished only, 20 days for AR-coated)

Basic Properties

Table 1. Chemical and Structural Properties

Crystal Structure	Trigonal, Space group R3c,
Lattice Parameter	a = b = 12.532 Å, c = 12.717 Å, Z = 6
Melting Point	About 1095 °C
Mohs Hardness	4
Density	3.85 g/cm^3
Thermal Conductivity	1.2 W/m/K($\perp$c); 1.6 W/m/K($\parallel$c)
Thermal Expansion Coefficients	$\alpha_{11} = 4 \times 10^{-6}$/K, $\alpha_{33} = 36 \times 10^{-6}$/K

Table 2. Optical and Nonlinear Optical Properties

Transparency Range	190-3500 nm
SHG Phase Matchable Range	409.6-3500 nm (Type I) 525-3500 nm (Type II)
Therm-optic Coefficient (/°C)	$dn_o/dT = -16.6 \times 10^{-6}$ $dn_e/dT = -9.3 \times 10^{-6}$
Absorption Coefficients	< 0.1% /cm at 1064 nm, < 1%/cm at 532 nm
Angle Acceptance	0.8 mrad·cm (θ, Type I, 1064 SHG) 1.27 mrad·cm (θ, Type II, 1064 SHG)
Temperature Acceptance	55 °C·cm
Spectral Acceptance	1.1 nm·cm
Walk-off Angle	2.7 ° (Type I, 1064 SHG) 3.2 ° (Type II, 1064 SHG)
NLO Coefficients	$d_{eff}(I) = d_{31}\sin\theta + (d_{11}\cos3\Phi - d_{22}\sin3\Phi)\cos\theta$ $d_{eff}(II) = (d_{11}\sin3\Phi + d_{22}\cos3\Phi)\cos^2\theta$
Non-vanished NLO Susceptibilities	$d_{11} = 5.8 \times d_{36}$ (KDP) $d_{31} = 0.05 \times d_{11}$ $d_{22} < 0.05 \times d_{11}$
Sellmeier Equations (λ in μm)	$n_o^2 = 2.7359 + 0.01878 / (\lambda^2 - 0.01822) - 0.01354\lambda^2$ $n_e^2 = 2.3753 + 0.01224 / (\lambda^2 - 0.01667) - 0.01516\lambda^2$
Electro-optic Coefficients	$\gamma_{22} = 2.7$ pm/V
Half-wave Voltage	7 KV（at 1064 nm, $3 \times 3 \times 20$ mm³）
Resistivity	$>10^{11}$ ohm·cm
Relative Dielectric Constant	$\varepsilon^s_{11}/\varepsilon_o$: 6.7 $\varepsilon^s_{33}/\varepsilon_o$: 8.1 Tanδ<0.001

BBO is a negative uniaxial crystal, with ordinary refractive index (n_o) larger than extraordinary refractive index (n_e). Both type I and type II phase matching can be reached by angle tuning. The phase matching angles of frequency doubling are shown in Fig. 2.

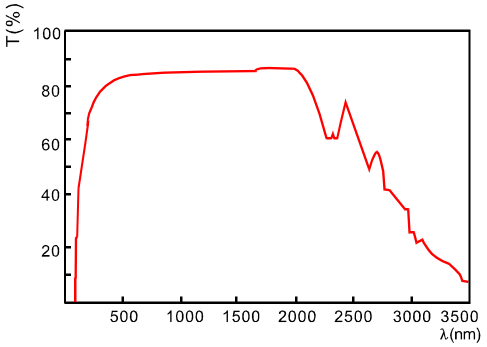


Figure 1. Transparency curve of BBO

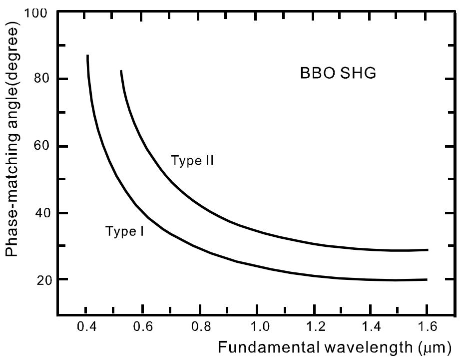


Figure 2. SHG tuning curves of BBO

Application in Nd:YAG Lasers

BBO is an efficient NLO crystal for the second, third and fourth harmonic generation of Nd:YAG lasers, and the best NLO crystal for the fifth harmonic generation at 213 nm. Conversion efficiency of more than 70% for SHG, 60% for THG and 50% for 4HG, and 200 mW output at 213 nm (5HG) have been obtained, respectively.
BBO is also an efficient crystal for the intracavity SHG of high power Nd:YAG lasers. For the intracavity SHG of an acousto-optic Q-switched Nd:YAG laser, more than 15W average power at 532 nm was generated in a CASTECH AR-coated BBO crystal. When it is pumped by the 600 mW SHG output of a mode-locked Nd:YLF laser, 66 mW output at 263 nm was produced from a Brewster-angle-cut BBO in an external enhanced resonant cavity.
Because of small acceptance angle and large walk-off, good laser beam quality (small divergence, good mode condition, etc.) is the key for BBO to obtain high conversion efficiency. Tightly focusing of laser beam is not recommended by CASTECH's engineers.

Applications in Tunable Lasers

1. Dye lasers

Efficient UV output (205-310 nm) with a SHG efficiency of over 10% at wavelength of ≧206 nm was obtained in type I BBO, and 36% conversion efficiency was achieved for a XeCl-laser pumped Dye laser with power 150KW which is about 4-6 times higher than that in ADP. The shortest SHG wavelength of 204.97 nm with efficiency of about 1% has been generated.
CASTECH's BBO is widely used in the Dye lasers. With type I sum-frequency of 780-950 nm and 248.5 nm (SHG output of 495 nm dye laser) in BBO, the shortest UV outputs ranging from 188.9 nm to 197 nm and the pulse energy of 95 mJ at 193 nm and 8 mJ at 189 nm have been obtained, respectively.

2. Ultrafast Pulse Laser

Frequency-doubling and -tripling of ultrashort-pulse lasers are the applications in which BBO shows superior properties to KDP and ADP crystals. Now, CASTECH can provide as thin as 0.005 mm BBO for this purpose. A laser pulse as short as 10 fs can be efficiently frequency-doubled with a thin BBO, in terms of both phase-velocity and group-velocity matching.

3. Ti:Sapphire and Alexandrite lasers

UV output in the region 360-390 nm with pulse energy of 105 mJ (31% SHG efficiency) at 378 nm, and output in the region 244-259 nm with 7.5 mJ (24% mixing efficiency) have been obtained for type I SHG and THG of an Alexandrite laser in BBO crystal.
More than 50% of SHG conversion efficiency in a Ti:Sapphire laser has been obtained. High conversion efficiencies have been also obtained for the THG and FOHG of Ti:Sapphire lasers.

4. Argon Ion and Copper-Vapor lasers

By employing the intracavity frequency-doubling technique in an Argon Ion laser with all lines output power of 2 W, maximum 33 mW at 250.4 nm and thirty-six lines of deep UV wavelengths ranging from 228.9 nm to 257.2 nm were generated in a Brewster-angle-cut BBO crystal.
Up to 230 mW average power in the UV at 255.3 nm with maximum 8.9% conversion efficiency was achieved for the SHG of a Copper-Vaper laser at 510.6 nm.

BBO's OPO and OPA

The OPO and OPA of BBO are powerful tools for generating a widely tunable coherent radiation from the UV to IR. The tuning angles of type I and type II BBO OPO and OPA have been calculated, with the results shown in Fig. 3 and Fig. 4, respectively.

1. OPO pumped at 532nm

An OPO output ranging from 680 nm to 2400 nm with the peak power of 1.6 MW and up to 30% energy conversion efficiency was obtained in a 7.2 mm long type I BBO. The input pump energy was 40 mJ at 532 nm with pulse-width 75 ps. With a longer crystal, higher conversion efficiency is expected.

2. OPO and OPA pumped at 355nm

Using CASTECH's BBO crystal, the OPO system covers a turning range from 400 nm to 3100 nm, and over the wavelength range from 430 nm to 2000 nm the OPO system's conversion efficiency reach 18%~30%.
Type II BBO can be used to decrease linewidth near the degenerated points. A linewidth as narrow as 0.05 nm and usable conversion efficiency of 12% were obtained. However, a longer (>15 mm) BBO should normally be used to decrease the oscillation threshold when employing the type II phase-matching scheme.
Pumping with a picosecond Nd:YAG at 355 nm, a narrow-band (<0.3 nm), high energy (>200 μJ) and wide tunable (400-2000 nm) pulse has been produced by BBO's OPAs. This OPA can reach as high as more than 50% conversion efficiency, and therefore is superior to common Dye lasers in many respects, including efficiency, tunable range, maintenance, and easiness in design and operation. Furthermore, coherent radiation from 205 nm to 3500 nm can be also generated by BBO's OPO or OPA plus a BBO for SHG.

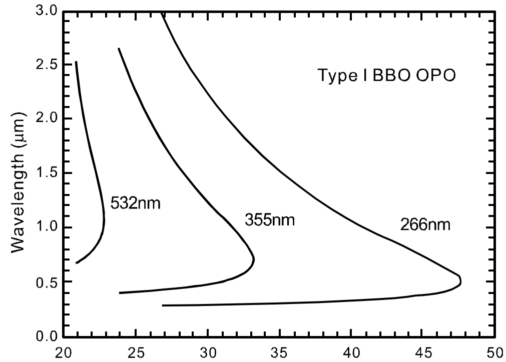


Figure 3. Type I OPO tuning curves of BBO

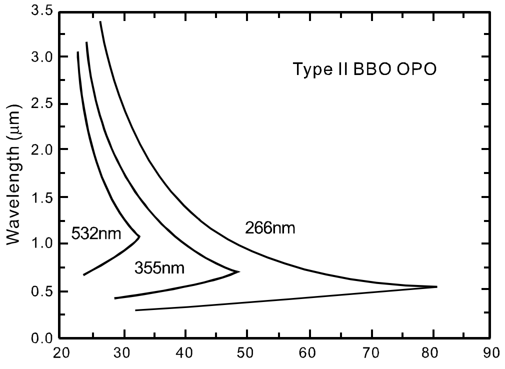


Figure 4. Type II OPO tuning curves of BBO

3. Others

A tunable OPO with signal wavelengths between 422 nm and 477 nm has been generated by angle tuning in a type I BBO crystal pumped with a XeCl excimer laser at 308 nm. And a BBO's OPO pumped by the fourth harmonic of a Nd:YAG laser (at 266 nm) has been observed to cover the whole range of output wavelengths 330-1370 nm.

When pumped by a 1 mJ, 80 fs Dye laser at 615 nm, the OPA with two BBO crystals yields more than 50 µJ (maximum 130 µJ), <200 fs ultrashort pulse, over 800 nm - 2000nm.

BBO's E-O Applications

BBO can also be used for E-O applications. It has wide transmission range from UV to about 3500 nm. And it has much higher damage threshold than KD*P and $LiNbO_3$. More than 100W output power and 1000 KHz repitition rate have been reached by using CASTECH's E-O BBO crystals and $Nd:YVO_4$ crystals as gain media. At 5 KHz, its pulse has width as short as 6.4 ns, and energy of 5.7 mJ or peak power of 900 KW. It has advantages over the commercial A-O Q-switched one, including very short pulse, high beam quality and size compact as well. Although it has a relative small electro-optic coefficient, and its half-wave voltage is high (7 KV at 1064 nm, $3 \times 3 \times 20$ mm^3), long and thin BBO can reduce the voltage requirements. CASTECH now can supply 25 mm long and 1 mm thin high optical quality of BBO crystal with Z-cut, AR-coated and Gold/Chrome plated on the side faces.

Coatings

CASTECH provides the following AR-coating for BBO:

- IBS, IAD coating methods are available upon request
- Low reflectance dual band and triple band AR-coating of BBO for SHG, THG and FOHG of 1064 nm
- Broad Band AR-coating (BBAR) of BBO for SHG of tunable lasers
- Broad Band P-coating of BBO for OPO applications
- High damage threshold
- Long durability
- Other coatings are available upon request

BBO's Parameters

Table 3. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) × (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0. 1 mm) × (L + 0.1/-0.1 mm) × (L＜2.5 mm)
Clear Aperture	Central 90% of the diameter
Internal Quality	No visible scattering paths or centers when inspected by a 50 mW green laser
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/8 @633 nm
Transmitted Wavefront Distortion	≦λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦0.25°
Chamfer	≦0.2 mm × 45°
Chip	≦0.1 mm
Damage Threshold	＞1.5 GW/cm^2 @1064 nm, 10 ns, 10 Hz (polished only) ＞1 GW/cm^2 @1064 nm, 10 ns, 10 Hz (AR-coated) ＞0.3 GW/cm^2 @532 nm, 10 ns, 10 Hz (AR-coated)
Quality Warranty Period	One year under proper use.

Notes

- BBO has a low susceptibility to the moisture. Users are advised to provide dry conditions for both application and preservation of BBO.
- BBO is relatively soft and therefore requires precautions to protect its polished surfaces.
- When angle adjusting is necessary, please keep in mind that the acceptance angle of BBO is small.
- CASTECH engineers can select and design the best crystal, 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.

BIBO - Bismuth Triborate (BiB_3O_6)

Introduction

Bismuth Triborate (BiB_3O_6 or BIBO) is a newly developed nonlinear optical crystal. It possesses large effective nonlinear coefficient, high damage threshold and inertness with respect to moisture. Its nonlinear coefficient is 3.5-4 times higher than that of LBO, 1.5-2 times higher than that of BBO. It is a promising doubling crystal to produce blue laser. The top-seeded solution growth (TSSG) technique is used at CASTECH for the growth of BIBO single crystals.

CASTECH offers

- Strict quality control;
- Large crystal size up to 10 × 10 × 15 mm^3;
- AR-coating mounts and re-working services;
- A large quantity of crystals in stock;
- Fast delivery (15 days for polished only, 20 days for AR-coated).

Basic Properties

Table 1. Chemical and Structural Properties

Crystal Structure	Monoclinic, Point group 2
Lattice Parameter	a = 7.116 Å, b = 4.993 Å, c = 6.508 Å, β = 105.62°, Z = 2
Melting Point	726 °C
Mohs Hardness	5-5.5
Density	5.033 g/cm^3
Thermal Expansion Coefficients	$\alpha_a = 4.8 \times 10^{-5}$ /K, $\alpha_b = 4.4 \times 10^{-6}$ /K, $\alpha_c = -2.69 \times 10^{-5}$ /K

Table 2. Optical and Nonlinear Optical Properties

Transparency Range		286 - 2500 nm
Absorption Coefficients		< 0.1%/cm at 1064 nm
Physical Axis		X // b, (Z, a) = 31.6°, (Y, c) = 47.2°
SHG of 1064/532 nm	Phase matching angle	168.9° from Z axis in YZ plane
	Deff	3.0 ± 0.1 pm/V
	Angular acceptance	2.32 mrad·cm
	Walk-off angle	25.6 mrad
	Temperature acceptance	2.17 °C·cm

Sellmeier coefficients	$n^2_i(\lambda) = A + B / (\lambda^2 - C) - D \lambda^2$ (λ in μm)			
	A	B	C	D
n_1	3.6545 (4)	0.0511 (2)	0.0371 (3)	0.0226 (1)
n_2	3.0740 (3)	0.0323 (1)	0.0316 (3)	0.01337 (6)
n_3	3.1685 (3)	0.0373 (1)	0.0346 (3)	0.01750 (8)

BIBO's Parameters

Table 3. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0. 1 mm) × (L + 0.1/-0.1 mm) (L<2.5 mm)
Clear Aperture	Central 90% of the diameter
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/8 @633 nm
Transmitted Wavefront Distortion	≦λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	Δθ≦0.25 °, ΔΦ≦0.25 °
Chamfer	≦0.2 mm × 45°
Chip	≦0.1 mm
Damage Threshold	>0.3 GW/cm^2 @1064 nm, 10 ns, 10 Hz (AR-Coated)
Quality Warranty Period	One year under proper use.

Coatings

- Dual or triple band AR-coatings of BIBO for SHG and THG applications
- Broad Band AR-coating (BBAR) and P-coating of BIBO for OPO applications
- Low reflectance
- Long durability
- Other coatings are available upon request

CLBO - Cesium Lithium Borate ($CsLiB_6O_{10}$)

Introduction

Cesium Lithium Borate ($CsLiB_6O_{10}$ or CLBO) is a newly developed crystal with excellent UV nonlinear feature, and widely used for semiconductor inspection, micro processing, bio-medical, UV-LiDAR, etc. Compared to BBO, it has larger spectral and temperature acceptance, larger angle tolerance and smaller walk-off angle (see Table 1). These advantages make CLBO obtain larger SHG conversion efficiency than BBO. Moreover, it is suitable for FOHG and FIHG of high-power Nd:YAG laser.

CASTECH'S CLBO is featured by

- Cut-off wavelength up to 180 nm
- Maximum FOHG and FIHG conversion efficiencies of Nd doped laser
- Relatively large effective NLO coefficient (about two times that of KDP)
- Wide acceptance angle and small walk-off angle
- The VUV output at 193 nm is available by phase matching
- No saturation for high-power generation
- Short grow cycle and large size

CASTECH offers

- Strict quality control
- Cutting angle and dimension upon request
- Sealed-housing or AR-coating/P-coating to prevent deliquescence
- AR-coating for fourth or fifth harmonic generations of 1064 nm
- Reworking services
- Fast delivery (15 working days for polished only, 20 working days for AR-coated)

Basic Properties

Table 1. Nonlinear Optical Properties of CLBO and BBO Crystal

Wavelength (nm)	NLO Crystal	Phase Matching Angle (deg)	Deff (pm/V)	Angle Tolerance (mrad·cm)	Walk-off Angle (deg)	Spectral Acceptance (nm·cm)	Temperature Acceptance (℃·cm)
532 + 532 = 266	CLBO	61.70	0.84	0.49	1.83	0.13	8.30
	BBO	47.70	1.32	0.17	4.80	0.07	4.50
1064 + 266 = 213	CLBO	68.40	0.87	0.42	1.69	0.16	4.60
	BBO	51.10	1.26	0.11	5.34	0.08	3.10

Table 2. Chemical and Structural Properties

Crystal Structure	Tetragonal, Space group I $\bar{4}2m$
Lattice Parameter	a = b = 10.494 Å, c = 8.939 Å
Symmetry	Z = 4
Melting Point	About 844.5 ℃

Table 3. Optical and Nonlinear Optical Properties

Transparency Range	180-2750 nm
Angle Acceptance	1.02 mrad·cm at 1064 nm, 0.49 mrad·cm at 532 nm， 0.84 mrad·cm at 488 nm.
Temperature Acceptance	9.4℃·cm
Spectral Acceptance	7.03 nm·cm at 1064 nm, 0.13 nm·cm at 532 nm, 0.09 nm·cm at 488 nm
Walk-off Angle	1.78 ° at 1064 nm, 1.83 ° at 532 nm, 0.98 ° at 488 nm
Effective NLO Coefficients	1.01 pm/V at 532 nm, 1.16 pm/V at 488 nm, 0.95 pm/V at 1064 nm
NLO Coefficients	$d_{eff}(I) = d_{36} \sin\theta_m \sin(2\Phi)$ $d_{eff}(II) = d_{36} \sin(2\theta_m) \sin(2\Phi)$
Sellmeier Equations (λ in μm)	CLBO at 20 ℃ $n_o^2 = 2.2104 + 0.01018 / (\lambda^2 - 0.01424) - 0.01258 \lambda^2$ $n_e^2 = 2.0588 + 0.00838 / (\lambda^2 - 0.01363) - 0.00607 \lambda^2$ (0.1914 μm<λ<2.09 μm)

CLBO's Parameters

Table 4. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) × (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0. 1 mm) × (L + 0.1/-0.1 mm) × (L＜2.5 mm)
Clear Aperture	Central 90% of the diameter
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/6 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	Δθ≦0.25 °, ΔΦ≦0.25 °
Chamfer	≦0.2 mm × 45 °
Chip	≦0.1 mm
Damage Threshold []	＞300 MW/cm² @532 nm, 10 ns, 10 Hz (AR-Coated); ＞150 MW/cm² @266 nm, 10 ns, 10 Hz (AR-Coated);
Quality Warranty Period	One year under proper use.

Coatings

- Dual or triple band AR-coating of CLBO for fourth and fifth harmonic generation of 1064 nm
- High damage threshold
- Long durability
- Other coatings are available upon request

Table 5. Reflectance of AR-coating

Base Material	AR-Coating	Reflectance
CLBO	AR-532 nm/266 nm	R<0.2% @532 nm R<1% @266 nm
CLBO	AR-1064 nm/266 nm/213 nm	R< 1% @1064 nm R< 3% @266 nm R< 3% @213 nm

Notes

CLBO crystal is very hygroscopic, and please use or keep it in dry and sealed environment.

KTP - Potassium Titanyl Phosphate ($KTiOPO_4$)

Introduction

Potassium Titanyl Phosphate ($KTiOPO_4$ or KTP) is widely used in both commercial and military lasers including laboratory and medical system, range-finders, LiDAR, optical communication and industrial systems.

CASTECH's KTP is featured by

- Large nonlinear optical coefficient
- Wide angular bandwidth and small walk-off angle
- Broad temperature and spectral bandwidth
- High electro-optic coefficient and low dielectric constant
- Large figure of merit
- Nonhydroscopic, chemically and mechanically stable.

CASTECH offers

- Strict quality control
- Large crystal size up to $20 \times 20 \times 40$ mm^3 and maximum length of 60 mm
- Quick delivery (15 working days for polished only, 20 working days for coated)
- Unbeatable price and quantity discount
- Technical support
- AR-coating, mounting and re-working service

Basic Properties

Table 1. Chemical and Structural Properties

Crystal Structure	Orthorhombic, Space group $Pna2_1$, Point group mm2
Lattice Parameter	a = 6.404 Å, b = 10.616 Å, c = 12.814 Å, Z = 8
Melting Point	About 1172 °C
Mohs Hardness	5
Density	3.01 g/cm^3
Thermal Conductivity	13 W/m/K
Thermal Expansion Coefficients	$\alpha_x = 11 \times 10^{-6}$ /°C, $\alpha_y = 9 \times 10^{-6}$ /°C, $\alpha_z = 0.6 \times 10^{-6}$ /°C

Table 2. Optical and Nonlinear Optical Properties

Transparency Range		350-4500 nm
SHG Phase Matchable Range		497-1800 nm (Type II)
Therm-optic Coefficient (λ in μm)		$dn_x/dT = 1.1 \times 10^{-5}$ /°C $dn_y/dT = 1.3 \times 10^{-5}$ /°C $dn_z/dT = 1.6 \times 10^{-5}$ /°C
Absorption Coefficients		<0.1% /cm at 1064 nm, <1% /cm at 532 nm
For Type II SHG of a Nd:YAG laser at 1064 nm	Temperature Acceptance	24 °C·cm
	Spectral Acceptance	0.56 nm·cm
	Angular Acceptance	14.2 mrad·cm (Φ); 55.3mrad·cm (θ)
	Walk-off Angle	0.55 °
NLO Coefficients		$d_{eff}(II) \approx (d_{24} - d_{15}) \sin 2\Phi \sin 2\theta - (d_{15} \sin^2\Phi + d_{24} \cos^2\Phi) \sin\theta$
Non-vanished NLO Susceptibilities		d_{31} = 6.5 pm/V d_{24} = 7.6 pm/V d_{32} = 5 pm/V d_{15} = 6.1 pm/V d_{33} = 13.7 pm/V
Sellmeier Equations (λ in μm)		$n_x^2 = 3.0065 + 0.03901 / (\lambda^2 - 0.04251) - 0.01327 \lambda^2$ $n_y^2 = 3.0333 + 0.04154 / (\lambda^2 - 0.04547) - 0.01408 \lambda^2$ $n_z^2 = 3.3134 + 0.05694 / (\lambda^2 - 0.05658) - 0.01682 \lambda^2$
Electro-optic Coefficients:		Low frequency (pm/V) / High frequency (pm/V)
r_{13}		9.5 / 8.8
r_{23}		15.7 / 13.8
r_{33}		36.3 / 35.0
r_{51}		7.3 / 6.9
r_{42}		9.3 / 8.8
Dielectric Constant		ε_{eff} = 13

Applications for SHG and SFG of Nd: Lasers

KTP is the most commonly used material for frequency doubling of Nd:YAG and other Nd-doped lasers, particularly when the power density is at a low or medium level. Up to now, Nd:lasers that use KTP for intra-cavity and extra-cavity frequency doubling have become a preferred pumping sources for visible dye lasers and tunable Ti:sapphire lasers as well as their amplifiers. They are also used as green sources for many research and industry applications.

- Close to 80% conversion efficiency and 700 mJ green laser were obtained with a 900 mJ injection-seeded Q-switch Nd:YAG lasers by using extra-cavity KTP.
- 8 W green laser was generated from a 15 W LD pumped $Nd:YVO_4$ with intra-cavity KTP.

KTP is also being used for intracavity mixing of 0.81 μm diode and 1.064 μm Nd:YAG laser to generate blue light and intracavity SHG of Nd:YAG or Nd:YAP lasers at 1.3 μm to produce red light.

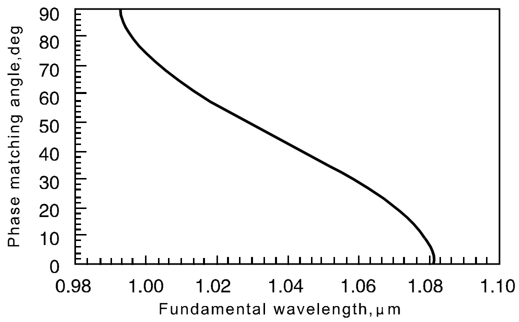


Fig. 1 Type II KTP SHG in XY Plane

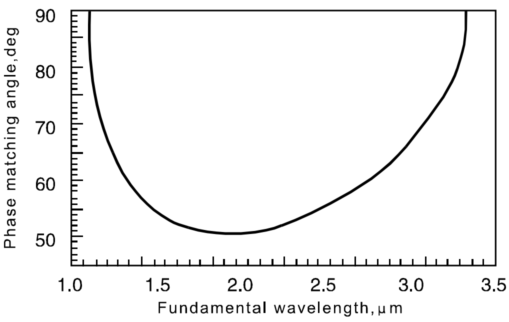


Fig.2 Type II SHG in XZ Plane

Applications for OPG, OPA and OPO

As an efficient OPO crystal pumped by a Nd:laser and its second harmonics, KTP plays an important role for parametric sources for tunable outputs from visible (600 nm) to mid-IR (4500 nm), as shown in Fig. 3 and Fig .4.

Generally, KTP's OPOs provide stable and continuous pulse outputs (signal and idler) in fs, with 10^8 Hz repetition rate and a miniwatt average power level. A KTP's OPO that are pumped by a 1064 nm Nd:YAG laser has generated as high as above 66% efficiency for degenerately converting to 2120 nm.

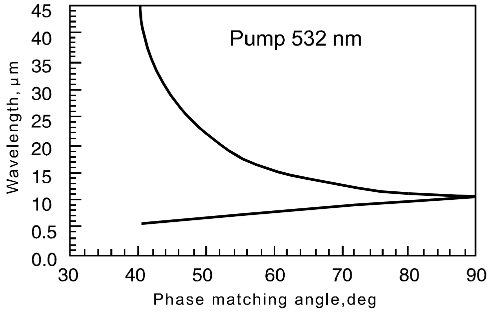


Fig.3 OPO pumped at 532 in X-Z plane

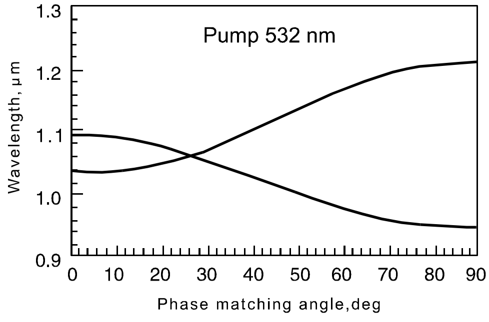


Fig.4 OPO pumped at 532 in X-Y plane

The novel developed application is the non-critical phase matched (NCPM) KTP's OPO/OPA. As shown in Fig.5, for pumping wavelength range from 0.7 μm to 1 μm, the output can cover from 1.04 μm to 1.45 μm (signal) and from 2.15 μm to 3.2 μm (idler). More than 45% conversion efficiency was obtained with narrow output bandwidth and good beam quality.

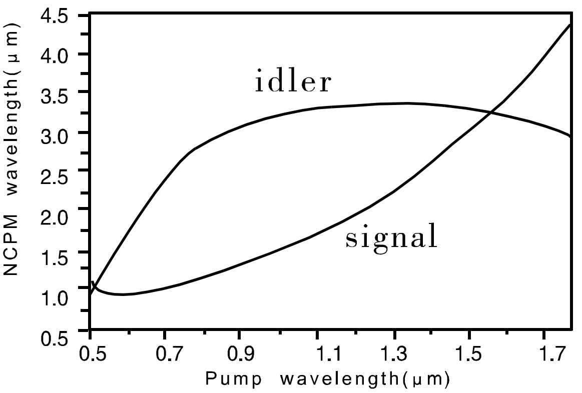


Fig.5 Type II NCPM OPO

Applications for E-O Devices

In addition to unique features, KTP also has promising E-O and dielectric properties that are comparable to $LiNbO_3$. These excellent properties make KTP extremely useful to various E-O devices. Table 1 is a comparison of KTP with other E-O modulator materials commonly used:

Table 3. Electro-Optic Modulator Materials

Materials	ε	N	Phase			Amplitude		
			R (pm/V)	K (10^{-6}/°C)	N^7r^2/ε $(pm/V)^2$	r (pm/V)	K (10^{-6}/°C)	n^7r^2/ε $(pm/V)^2$
KTP	15.42	1.80	35.0	31	6130	27.0	11.7	3650
$LiNbO_3$	27.90	2.20	8.8	82	7410	20.1	42.0	3500
KD*P	48.00	1.47	24.0	9	178	24.0	8.0	178
$LiIO_3$	5.90	1.74	6.4	24	335	1.2	15.0	124

From Table 1, clearly, KTP is expected to replace $LiNbO_3$ crystal in the considerable volume application of E-O modulators, when other merits of KTP are combined into account, such as high damage threshold, wide optical bandwidth (>15 GHZ), thermal and mechanical stability, and low loss, etc.

Applications for Optical Waveguides

Based on the ion-exchange process on KTP substrate, low loss optical waveguides developed for KTP have created novel applications in integrated optics. Table 2 gives a comparison of KTP with other optical waveguide materials. Recently, a type II SHG conversion efficiency of 20% $/W/cm^2$ was achieved by the balanced phase matching, in which the phase mismatch from one section was balanced against a phase mismatch in the opposite sign from the second. Furthermore, segmented KTP waveguide have been applied to the type I quasi-phase-matchable SHG of a tunable Ti:Sapphire laser in the range of 760-960 mm, and directly doubled diode lasers for the 400-430 nm outputs.

Table 4. Electro-Optic Waveguide Materials

Materials	r (pm/V)	n	$\varepsilon_{eff}(\varepsilon_{11}\varepsilon_{33})^{1/2}$	n^3r/ε_{eff} (pm/V)
KTP	35	1.86	13	17.30
$LiNbO_3$	29	2.20	37	8.30
$KNbO_3$	25	2.17	30	9.20
BNN	56	2.22	86	7.10
BN	56-1340	2.22	119-3400	5.1-0.14
GaAs	1.2	3.60	14	4.00
$BaTiO_3$	28	2.36	373	1.00

KTP's Parameters

Table 5. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) × (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.1/-0.1 mm) × (L＜2.5 mm)
Clear Aperture	Central 90% of the diameter
Internal Quality	No visible scattering paths or centers when inspected by a 50 mW green laser
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/8 @633 nm
Transmitted Wavefront Distortion	≦λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦0.25 °
Chamfer	≦0.2 mm × 45 °
Chip	≦0.1 mm
Damage Threshold	＞1 GW/cm² @1064 nm, 10 ns, 10 Hz (AR-coated) ＞0.3 GW/cm² @532 nm, 10 ns, 10 Hz (AR-coated)
Quality Warranty Period	One year under proper use.

AR-coatings

CASTECH provides the following AR-coatings:

- Dual Band AR-coating (DBAR) of KTP for SHG of 1064 nm; low reflectance (R<0.2% @1064 nm and R<0.5% @532 nm)
- High reflectivity coating: HR 1064 nm & HT 532 nm, R>99.8% @1064nm, T>90% @532 nm
- Broad Band AR-coating (BBAR) of KTP for OPO applications.
- High damage threshold (>300 MW/cm² at both wavelengths)
- Long durability
- Other coatings are available upon request.

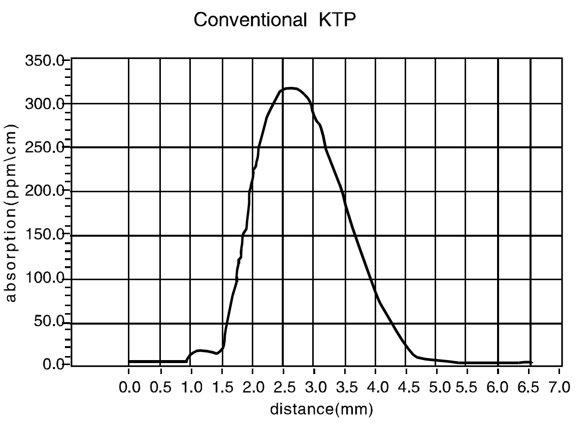
GTR-KTP

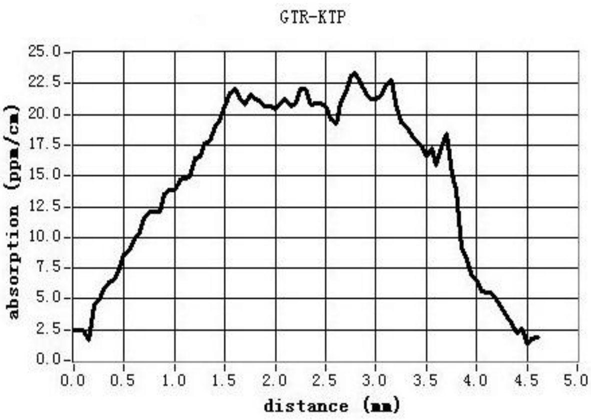
- Gray Tracking Resistance Potassium Titanyl Phosphate

Introduction

KTP is an excellent nonlinear crystal, but its gray tracking phenomena limits its use in high repetition rate and high power laser systems. CASTECH's **GTR-KTP crystal** has higher gray tracking resistance than the regular flux grown KTP crystal. Through Photo-thermal Common-path Interferometer, the occurrence of gray tracking can be measured by an increase of bulk absorption through a strong CW 532 nm green laser within several minutes.

1. Bulk absorption measurements before gray tracking testing:

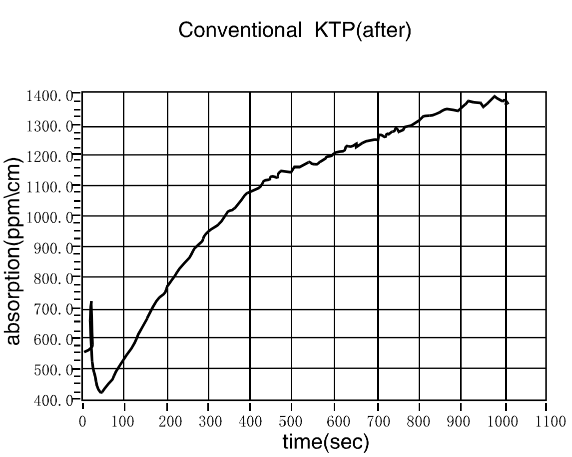


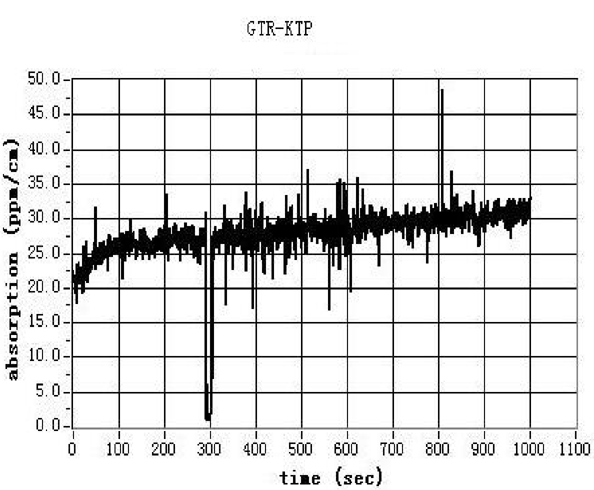


It appears that the absorption of CASTECH's GTR-KTP at 1064 nm is only 1/10 of conventional KTP.

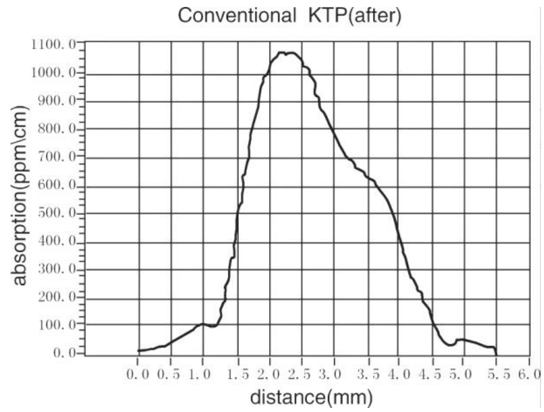
2. Gray Tracking Testing:

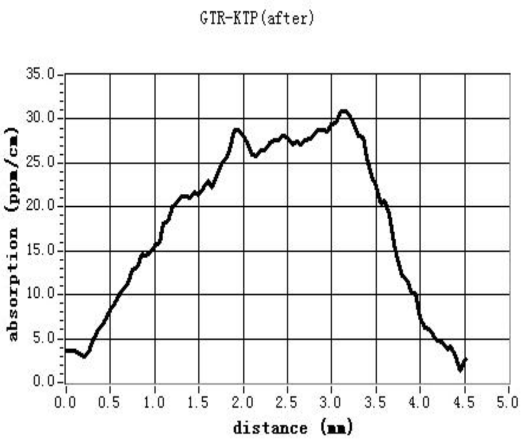
When a green laser beam (400 mW, beam diameter 0.07 mm, power density 10 KW/cm^2) goes through the crystal, it causes an increase in the IR absorption of the crystal. This phenomenon is correlated with "gray tracking effect". The following graphs show the absorption level changes over time at 1064 nm for CASTECH's GTR-KTP and the conventional KTP separately.



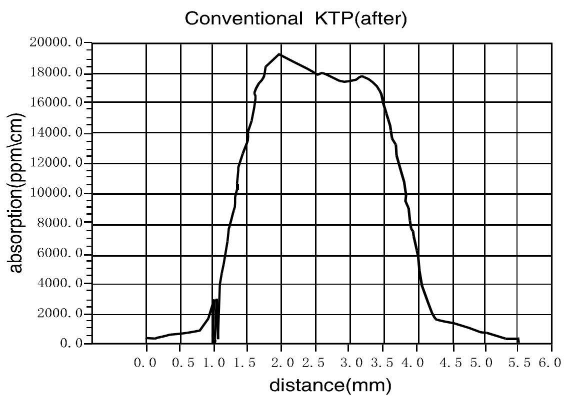


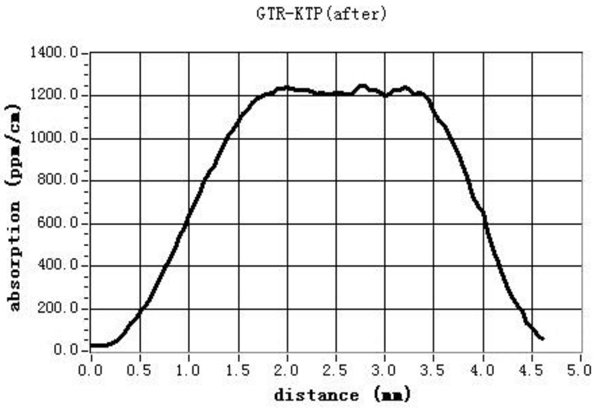
3. Bulk absorption measurements at 1064 nm after gray tracking testing





4. Bulk absorption measurements at 532 nm after gray tracking testing

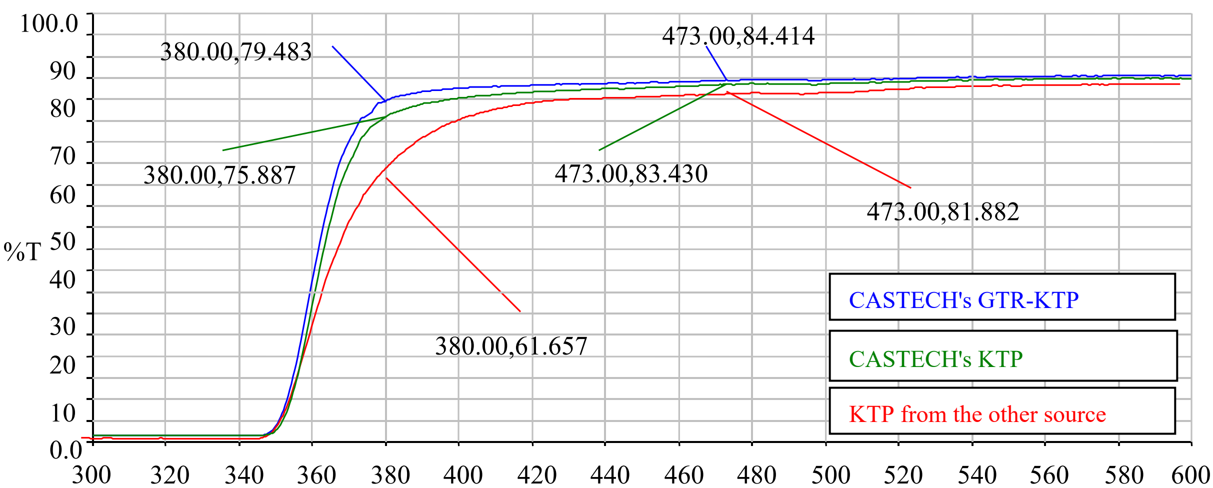




5. Damage threshold testing:

After testing a group of GTR-KTP and the conventional KTP crystals (polished only) with laser condition of 10 ns, 1 Hz, we found that CASTECH's GTR-KTP has laser damage threshold around 1.8 GW/cm^2 at 1064 nm, which is much higher than the conventional KTP (450 MW/cm^2 in the same condition).

6. Transmission curves in visible and UV region:



Apparently CASTECH's GTR-KTP has lower absorption than the conventional KTP in the range of 350-550 nm. We can conclude that CASTECH's GTR-KTP is expected to have a higher gray tracking resistance than the regular flux grown KTP crystals.

CASTECH offers GTR-KTP with

- Strict quality control
- Large crystal size up to 7 × 7 × 20 mm^3
- Quick delivery (3 weeks for polished only, 4 weeks for coated)
- Unbeatable price and quantity discount
- Technical support
- AR, HR-coating, mounting and re-working service

GTR-KTP's Parameters

Table 1. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) × (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.1/-0.1 mm) × (L＜2.5 mm)
Clear Aperture	Central 90% of the diameter
Internal Quality	No visible scattering paths or centers when inspected by a 50 mW green laser
Flatness	≦λ/8 @633 nm
Transmitted Wavefront Distortion	≦λ/8 @633 nm
Surface Quality (Scratch/Dig)	10/5 (Polished) to MIL-PRF-13830B 20/10 (AR-coated) to MIL-PRF-13830B 40/20 (HR-coated) to MIL-PRF-13830B
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦0.25 °
Chamfer	≦0.2 mm × 45 °
Chip	≦0.1 mm

AR-coatings

CASTECH provides the following AR-coatings:

- Dual Band AR-coating (DBAR) of GTR-KTP for SHG of 1064 nm
  low reflectance (R<0.2% @1064 nm and R<0.5% @532 nm)
  High damage threshold (>1 GW/cm^2 @1064 nm, >300 MW/cm^2 @532 nm, at 10 ns, 10 Hz), long durability.
- High reflectivity coating: HR1064 nm & HT 532 nm, R>99.8% @1064 nm, T>95% @532 nm.
- Broad Band AR-coating (BBAR) of GTR-KTP for OPO applications.
- Other coatings are available upon request.

RTP - Rubidium Titanyl Phosphate ($RbTiOPO_4$)

Introduction

Rubidium Titanyl Phosphate ($RbTiOPO_4$ or RTP) is an isomorph of KTP crystal which is used in nonlinear and Electro-Optical applications. It has advantages of high damage threshold (about 1.8 times of KTP), high resistivity, high repetition rate, no hygroscopy and no induced piezo-electric effect with electrical signals up to 60 kHz. Its transmission range is 350 nm to 4500 nm.

Table 1. Basic Properties

Crystal Structure	Orthorhombic
Lattice Parameter	a = 12.96 Å, b = 10.56 Å, c = 6.49 Å
Melting Point	About 1000 °C
Mohs Hardness	about 5 Mohs
Density	3.6 g/cm^3
Thermal Expansion Coefficients	$\alpha_x = 1.01 \times 10^{-5}$ /K, $\alpha_y = 1.37 \times 10^{-5}$ /K, $\alpha_z = -4.17 \times 10^{-6}$ /K
Sellmeier Equations (λ in μm)	$n_x^2 = 2.15559 + 0.93307 [1 - (0.20994 / \lambda)^2] - 0.01452 \lambda^2$ $n_y^2 = 2.38494 + 0.73603 [1 - (0.23891 / \lambda)^2] - 0.01583 \lambda^2$ $n_z^2 = 2.27723 + 1.11030 [1 - (0.23454 / \lambda)^2] - 0.01995 \lambda^2$
Therm-optical Coefficient	$d\lambda/dT = - 0.029$ nm /°C
Electro-optic Constants (Y-cut) (X-cut)	 $r_{33} = 38.5$ pm/V $r_{33} = 35$ pm/V, $r_{23} = 12.5$ pm/V, $r_{13} = 10.6$ pm/V
Electrical Resistivity	about 10^{11}-10^{12} ohm·cm
Static Half Wave Voltage at 1064 nm	4 × 4 × 20 mm: 1,600 V 6 × 6 × 20 mm: 2,400 V 9 × 9 × 20 mm: 3,600 V
Extinction Ratio	> 20 dB @633 nm

Table 2. Specifications

Growing Orientation	Along Y-axis
Maximum Length (5×5 mm^2 aperture)	25 mm
Length Tolerance	+ 0.5/- 0.1 mm
Surface Quality (Scratch/Dig)	20/10 to MIL-PRF-13830B
Flatness	λ/6 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦0.5 °
Coating	AR-coatings
Quality Warranty Period	One year under proper use

KTA - Potassium Titanyl Arsenate ($KTiOAsO_4$)

Introduction

Potassium Titanyl Arsenate ($KTiOAsO_4$ or KTA) is an excellent nonlinear optical crystal for Optical Parametric Oscillation (OPO) application. It has better non-linear optical and electro-optical coefficients, significantly reduced absorption in the 2.0-5.0 µm region, broad angular and temperature bandwidth, low dielectric constants. And its low ionic conductivity results in higher damage threshold compared with KTP.

CASTECH offers KTA

- Crystal length from 0.1mm to 30 mm and size up to 10 × 10 × 30 mm³
- AR-coating from visible to 3300 nm
- Re-polishing, re-coating service
- Fast delivery (15 working days for polished only, 20 working days for AR-coated)

Table 1. Chemical and Structural Properties

Crystal Structure	Orthorhombic, Point group mm2
Lattice Parameter	a = 13.125 Å, b = 6.5716 Å, c = 10.786 Å
Melting Point	1130 °C
Mohs Hardness	Near 5 Mohs
Density	3.454 g/cm³
Thermal Conductivity	K1: 1.8 W/m/K; K2: 1.9 W/m/K; K3: 2.1 W/m/K

Table 2. Optical and Nonlinear Optical Properties

Transparency Range	350-5300 nm				
Absorption Coefficients	<0.05%/cm at 1064 nm <0.05%/cm at 1533 nm <5%/cm at 3475 nm				
NLO Susceptibilities	d_{31} = 2.76 pm/V d_{32} = 4.74 pm/V d_{33} = 18.5 pm/V d_{15} = 2.3 pm/V d_{24} = 3.2 pm/V				
Sellmeier Equation $N_i^2=A_i+B_i\lambda^2/(\lambda^2 - C_i^2) - D_i\lambda^2$ (λ in µm)	index	A	B	C	D
	n_x	1.90713	1.23522	0.19692	0.01025
	n_y	2.15912	1.00099	0.21844	0.01096
	n_z	2.14768	1.29559	0.22719	0.01436
Electro-optic Constants (low frequency)	r_{33} = 37.5 pm/V; r_{23} = 15.4 pm/V; r_{13} = 11.5 pm/V				
SHG Phase Matchable Range	1083-3789 nm				

LN - Lithium Niobate ($LiNbO_3$)

Introduction

Lithium Niobate ($LiNbO_3$ or LN) is widely used as frequency doublers for wavelength > 1μm, optical parametric oscillators (OPOs) pumped at 1064 nm as well as quasi-phase-matched (QPM) devices. Additionally due to its large Electro-Optic (E-O) and Acousto-Optic (A-O) coefficients, $LiNbO_3$ crystal is the most commonly used material for Pockel cells, Q-switches and phase modulators, waveguide substrates, and surface acoustic wave (SAW) wafers, etc. CASTECH can provide $LiNO_3$ crystals with high quality and large size for all these applications.

CASTECH provides

- 50,000 to 100,000 pcs/month of $LiNbO_3$ wedges used for fiber optical isolators and circulators
- Strict quality control
- Technical support
- Fast delivery
- Competitive price

Basic Properties

Table 1. Chemical and Physical Properties

Crystal Structure	Trigonal, Space group R3c, Point group 3m
Lattice Parameter	a = 5.148 Å, c = 13.863 Å
Melting Point	1253℃
Curie Temperature	1140℃
Mohs Hardness	5 Mohs
Density	4.64 g/cm³
Elastic Stiffness Coefficients	$C^E_{11} = 2.33$ ($\times 10^{11}$ N/m²) $C^E_{33} = 2.77$ ($\times 10^{11}$ N/m²)

Table 2. Optical and Nonlinear Optical Properties

Transparency Range	420-5200 nm
Optical Homogeneity	~5 $\times 10^{-5}$ /cm
Refractive Indices	$n_e = 2.146$, $n_o = 2.220$ @1300 nm $n_e = 2.156$, $n_o = 2.232$ @1064 nm $n_e = 2.203$, $n_o = 2.286$ @632.8 nm
NLO Coefficients	$d_{33} = 86 \times d_{36}$ (KDP) $d_{31} = 11.6 \times d_{36}$ (KDP) $d_{22} = 5.6 \times d_{36}$ (KDP)
Effective NLO Coefficients	$d_{eff}(I) = d_{31} \sin\theta - d_{22} \cos\theta \sin 3\Phi$ $d_{eff}(II) = d_{22} \cos^2\theta \cos 3\Phi$
Sellmeier Equations (λ in μm)	$n_o^2 = 4.9048 + 0.11768 / (\lambda^2 - 0.04750) - 0.027169 \lambda^2$ $n_e^2 = 4.5820 + 0.099169 / (\lambda^2 - 0.04443) - 0.02195 \lambda^2$
Damage Threshold	100 MW/cm² (10 ns, 1064 nm)

Table 3. Thermal and Electrical Properties of $LiNbO_3$

Thermal Conductivity	38 W/m/K @25 °C
Thermal Expansion Coefficients (at 25°C)	//a, 2.0×10^{-6} /K //c, 2.2×10^{-6} /K
Resistivity	$2\times10^{-6}\,\Omega\cdot$cm @200 °C
Dielectric Constants	$\varepsilon^S_{11}/\varepsilon_0 = 43$, $\varepsilon^T_{11}/\varepsilon_0 = 78$ $\varepsilon^S_{33}/\varepsilon_0 = 28$, $\varepsilon^T_{33}/\varepsilon_0 = 32$
Piezoelectric Strain Constant	$D_{22} = 2.04 \times 10^{-11}$ C/N $D_{33} = 19.22 \times 10^{-11}$ C/N
Electro-Optic Coefficients	$\gamma^T_{33} = 32$ pm/V, $\gamma^S_{33} = 31$ pm/V, $\gamma^T_{31} = 10$ pm/V, $\gamma^S_{31} = 8.6$ pm/V, $\gamma^T_{22} = 6.8$ pm/V, $\gamma^S_{22} = 3.4$ pm/V
Half-Wave Voltage, DC Electrical field // z, light ⊥ z; Electrical field // x or y, light // z;	 3.03 KV 4.02 KV

Table 4. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1mm) × (L ± 0.2mm)
Clear Aperture	Central 90% of the diameter
Surface Quality (Scratch/Dig)	20/10 to MIL-PRF-13830B
Flatness	λ/8 @633 nm
Transmitted Wavefront Distortion	≦λ/4 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦±0.5°
Quality Warranty Period	One year under proper use

AR-coatings

CASTECH provides the following AR-coatings:

- Dual Band AR-coating (DBAR) at 1064/532 nm on both surface, with low reflectance (R<0.2% @1064 nm and R<0.5% @532 nm)
- AR-coating and gold/chrome plated on side faces for E-O applications
- Other coatings are available upon request

$MgO:LiNbO_3$ - Magnesium Doped Lithium Niobate

Introduction

Compared with $LiNbO_3$ crystal, $MgO:LiNbO_3$ crystal exhibits its particular advantages for NCPM frequency doubling (SHG) of Nd:Lasers, mixing (SFG) and optical parametric oscillators (OPOs). The SHG efficiencies of over 65% for pulsed Nd:YAG lasers and 45% for cw Nd:YAG lasers have been achieved by MgO: $LiNbO_3$ crystals, respectively. MgO: $LiNbO_3$ is also a good crystal for optical parametric oscillators (OPOs) and amplifiers (OPAs), quasi-phase-matched doubler and integrated waveguide.

CASTECH's $MgO:LiNbO_3$ is featured by

- High damage threshold
- Non-critical phase matching (NCPM) at room temperature
- Broad transparency range
- Excellent E-O and NLO properties
- Good mechanical and chemical properties

MgO: $LiNbO_3$ has similar effective nonlinear coefficient to pure $LiNbO_3$. Its Sellmeier equations (for 5 mol% MgO dopant) are (λ in μm)

$$n_o^2(\lambda) = 4.8762 + 0.11554 / (\lambda^2 - 0.04674) - 0.033119 \times \lambda^2$$
$$n_e^2(\lambda) = 4.5469 + 0.094779 / (\lambda^2 - 0.04439) - 0.026721 \times \lambda^2$$

CASTECH offers high quality $MgO:LiNbO_3$ with custom dimensions. AR coating is available upon request.

KDP - Potassium Dihydrogen Phosphate and DKDP or KD*P - Potassium Dideuterium Phosphate

Introduction

Potassium Dihydrogen Phosphate (KDP) and Potassium Dideuterium Phosphate (DKDP) are among the most widely-used commercial NLO materials, characterized by good UV transmission, high damage threshold, and high birefringence, though their NLO coefficients are relatively low. They are usually used for doubling, tripling and quadrupling of a Nd:YAG laser under the room temperature. In addition, they are also excellent electro-optic crystals with high electro-optic coefficients, widely used as electro-optical modulators, such as Q-switches, Pockels Cells, etc.

CASTECH's KDP & DKDP products

CASTECH supplies high quality KDP and DKDP crystals in large quantities for these applications. Because their polished surfaces are easier to be moistened, the user is advised to provide the dry condition (＜50%) and the sealed housing for preservation. For this purpose, CASTECH also provides polishing, coating and sealed housing services for the KDP family crystals. Our engineers will serve you to select and design the best crystal, according to the laser parameters you provide.

Table 1. Basic Properties

	DKDP	KDP
Chemical Formula	KD_2PO_4	KH_2PO_4
Transparency Range	200-2100 nm (98% deuterium content)	200-1650 nm
Nonlinear Coefficients	$d_{36} = 0.40$ pm/V	$d_{36} = 0.44$ pm/V
Refractive Index (at 1064 nm)	$n_o = 1.4948$, $n_e = 1.4554$	$n_o = 1.4938$, $n_e = 1.4599$
Electro-optic Coefficients	$r_{41} = 8.8$ pm/V $r_{63} = 25$ pm/V	$r_{41} = 8.8$ pm/V $r_{63} = 10.3$ pm/V
Longitudinal Half-wave Voltage	$V_\pi = 2.98$ KV ($\lambda = 546$ nm)	$V_\pi = 7.65$ KV ($\lambda = 546$ nm)
Absorption Coefficients	0.006 /cm	0.07 /cm
Damage Threshold	>3 GW/cm²	>5 GW/cm²
Extinction Ratio	30 dB	
Sellmeier Equations of DKDP: (λ in μm) $n_o^2 = 1.9575544 + 0.2901391\ \lambda^2 / (\lambda^2 - 0.0281399) - 0.02824391\ \lambda^2 + 0.004977826\ \lambda^4$ $n_e^2 = 1.5057799 + 0.6276034\ \lambda^2 / (\lambda^2 - 0.0131558) - 0.01054063\ \lambda^2 + 0.002243821\ \lambda^4$		
Sellmeier Equations of KDP: (λ in μm) $n_o^2 = 2.259276 + 0.01008956 / (\lambda^2 - 0.012942625) + 13.00522\ \lambda^2 / (\lambda^2 - 400)$ $n_e^2 = 2.132668 + 0.008637494 / (\lambda^2 - 0.012281043) + 3.2279924\ \lambda^2 / (\lambda^2 - 400)$		

Coatings

AR-Coatings are available with high quality upon request**.**

$LiIO_3$ - Lithium Iodate

Introduction

Lithium Iodate ($LiIO_3$) is one of oldest commercial NLO crystals. With high NLO coefficient, $LiIO_3$ is used for frequency-doubling, tripling and mixing of low and medium power lasers.
CASTECH provides large size of $LiIO_3$ crystals with high optical homogeneity. They can be as-cut or polished, and sealed housing with AR-coated windows is also available.

Table 1. Basic Properties

Crystal Structure	Hexagonal, Point Group 6
Transparency Range	300-5000 nm
Nonlinear Coefficient	$d_{15} = -5.5 \times 10^{-12}$ m/V
Refractive Index	negative uniaxial $n_o = 1.8571$, $n_e = 1.7165$ ($\lambda = 1064$ nm)
Sellmeier Equations: (λ in μm) $n_o^2 = 3.415716 + 0.047031 / (\lambda^2 - 0.035306) - 0.008801\ \lambda^2$ $n_e^2 = 2.918692 + 0.035145 / (\lambda^2 - 0.028224) - 0.003641\ \lambda^2$	

Table 2. Specifications

Dimension Tolerance	(W ± 0.2 mm) × (H ± 0.2 mm) × (L + 0.5/-0.2 mm)
Clear Aperture	central 90% of the diameter
Surface Quality (Scratch/Dig)	20/10 to MIL-PRF-13830B
Flatness	$\lambda/4$ @633 nm
Transmitted Wavefront Distortion	$\leqq \lambda/4$ @633 nm
Parallelism	$\leqq$30 arc sec
Perpendicularity	$\leqq$15 arc min
Angle Tolerance	$\leqq 0.5^\circ$
Quality Warranty Period	one year under proper use.

Notes

- $LiIO_3$ is highly hygroscopic. Please keep it in a dry environment, and sealed housing is recommended.
- CASTECH provides both polishing and sealed housing for $LiIO_3$ crystal.
- $LiIO_3$ is not recommended for high power applications, because of the low damage threshold.

$Nd:YVO_4$ - Neodymium Doped Yttrium Orthovanadate

Introduction

Neodymium Doped Yttrium Orthovanadate ($Nd:YVO_4$) is the most efficient laser host crystal for diode pumping among the current commercial laser crystals, especially, for low to middle power density. This is mainly for its absorption and emission features surpassing Nd:YAG. Pumped by laser diodes, $Nd:YVO_4$ crystal has been incorporated with high NLO coefficient crystals (LBO, BBO, or KTP) to frequency-shift the output from the near infrared to green, blue, or even UV. This incorporation to construct all solid state lasers is an ideal laser tool that can cover the most widespread applications of lasers, including machining, material processing, spectroscopy, wafer inspection, light displays, medical diagnostics, laser printing, and data storage, etc. It has been shown that $Nd:YVO_4$ based diode pumped solid state lasers are rapidly occupying the markets traditionally dominated by water-cooled ion lasers and lamp-pumped lasers, especially when compact design and single-longitudinal-mode output are required.

$Nd:YVO_4$'s advantages over Nd:YAG

- As high as about five times larger absorption efficient over a wide pumping bandwidth around 808 nm (therefore, the dependency on pumping wavelength is much lower and a strong tendency to the single mode output)
- As large as three times larger stimulated emission cross-section at the lasing wavelength of 1064 nm.
- Lower lasing threshold and higher slope efficiency.
- As a uniaxial crystal with large birefringence, the emission is only linearly polarized.

CASTECH Provides

- Various doping concentrations from 0.1 to 3%.
- Doping concentration tolerance: ± 0.05% (atm%<1%), ± 0.1% (atm% ≧1%)
- High quality $Nd:YVO_4$ crystals size up to Φ20 x 40 mm^3
- 10,000 pcs of $Nd:YVO_4$ devices per month in sizes 3x3x0.5mm^3 to 4x4x30 mm^3
- Fast delivery
- Competitive price

Figure 1. Absorption Curve of 0.5% $Nd:YVO_4$ (thickness 4 mm)

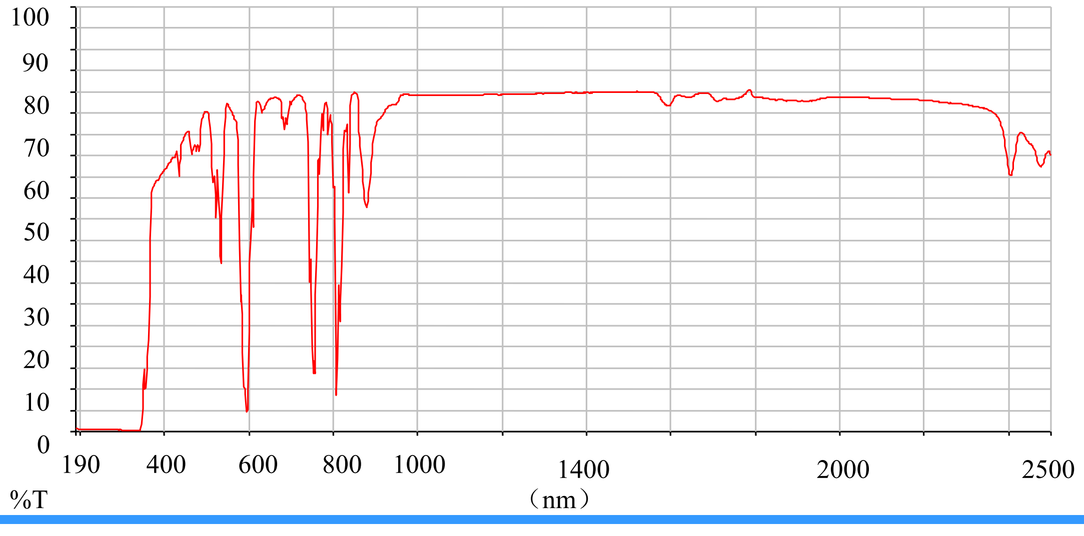


Table 1. Basic Properties

Crystal Structure	Zircon Tetragonal, space group D_{4h}-I4/amd
Lattice Parameter	a = b = 7.1193 Å, c = 6.2892 Å
Density	4.22 g/cm^3
Atomic Density	1.26 $\times 10^{20}$ atoms/cm^3 (Nd 1.0%)
Mohs Hardness	4-5 (Glass-like)
Thermal Expansion Coefficient (300K)	$\alpha_a = 4.43 \times 10^{-6}$/K $\alpha_c = 11.37 \times 10^{-6}$/K
Thermal Conductivity Coefficient (300K)	// C: 0.0523 W/cm/K ⊥C: 0.0510 W/cm/K
Lasing Wavelength	1064 nm, 1342 nm
Thermal Optical Coefficient (300K)	$dn_o/dT = 8.5 \times 10^{-6}$/K $dn_e/dT = 2.9 \times 10^{-6}$/K
Stimulated Emission Cross-section	25 x 10^{-19} cm^2 @1064 nm
Fluorescent Lifetime	90 μs (1% Nd doped)
Absorption Coefficient	31.4 cm^{-1} @810 nm
Intrinsic Loss	0.02 cm^{-1} @1064 nm
Gain Bandwidth	0.96 nm @1064 nm
Polarized Laser Emission	π polarization; parallel to optical axis (c-axis)
Diode Pumped Optical to Optical Efficiency	> 60%
Sellmeier Equations (λ in μm)	$n_o^2 = 3.77834 + 0.069736 / (\lambda^2 - 0.04724) - 0.010813\ \lambda^2$ $n_e^2 = 4.59905 + 0.110534 / (\lambda^2 - 0.04813) - 0.012676\ \lambda^2$

Laser Properties of Nd:YVO_4

1. One most attractive character of Nd:YVO_4 is, compared with Nd:YAG, its 5 times larger absorption coefficient in a broader absorption bandwidth around the 808 nm peak pump wavelength, which just matches the standard of high power laser diodes currently available. This means a smaller crystal that could be used for the laser, leading to a more compact laser system. For a given output power, this also means a lower power level at which the laser diode operates, thus extending the lifetime of the expensive laser diode. The broader absorption bandwidth of Nd:YVO_4 which may reaches 2.4 to 6.3 times that of Nd:YAG. Besides more efficient pumping, it also means a broader range of selection of diode specifications. This will be helpful to laser system makers for wider tolerance for lower cost choice.

2. Nd:YVO_4 crystal has larger stimulated emission cross-section, both at 1064 nm and 1342 nm. When a-axis cut Nd:YVO_4 crystal lasing at 1064 nm, it is about 4 times higher than that of Nd:YAG, while at 1340 nm the stimulated cross-section is 18 times larger, which leads to a CW operation completely outperforming Nd:YAG at 1320 nm. These make Nd:YVO_4 laser be easy to maintain a strong single line emission at the two wavelengths.

3. Another important character of Nd:YVO_4 lasers is, because it is an uniaxial rather than a high symmetry of cubic as Nd:YAG, it only emits a linearly polarized laser, thus avoiding undesired birefringent effects on the frequency conversion. Although the lifetime of Nd:YVO_4 is about 2.7 times shorter than that of Nd:YAG, its slope efficiency can be still quite high for a proper design of laser cavity, because of its high pump quantum efficiency.

The major laser properties of Nd:YVO_4 vs Nd:YAG are listed in Table below, including stimulated emission cross-sections(σ), absorption coefficient (α), fluorescent lifetime (τ), absorption length (L_α), threshold power (P_{th}) and pump quantum efficiency (η_S).

Table 2. Laser Properties of Nd:YVO_4 vs Nd:YAG

Laser Crystal	Doping (atm%)	σ (×10^{-19}cm²)	α (cm⁻¹)	τ (μs)	L_α (mm)	P_{th} (mW)	η_S (%)
Nd:YVO_4(a-cut)	1.0	25	31.2	90	0.32	30	52
	2.0	25	72.4	50	0.14	78	48.6
Nd:YVO_4(c-cut)	1.1	7	9.2	90		231	45.5
Nd:YAG	0.85	6	7.1	230	1.41	115	38.6

Nd:YVO_4's parameters

Table 3. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) × (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0. 1 mm) × (L + 0.1/-0.1 mm) × (L＜ 2.5mm)
Clear Aperture	Central 90% of the diameter
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/8 @633 nm (L≧2.5 mm) ≦λ/4 @633 nm (L<2.5 mm)
Transmitted Wavefront Distortion	≦λ/4 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦± 0.5°
Chamfer	≦0.2 mm × 45°
Chip	≦0.1 mm
Damage Threshold	＞1 GW/cm² @1064 nm, 10 ns, 10 Hz (AR-coated)
Quality Warranty Period	One year under proper use

CASTECH provides the following coatings

- Both ends AR/AR-1064/808 nm, R<0.2% @1064 nm, R<0.5% @808 nm, or R<0.1% @1064 nm, R<3% @808 nm
- S1: HR-1064/532 nm, HT-808 nm, R>99.8% @1064/532 nm, T>90% @808 nm
  S2: AR-1064/532 nm, R<0.2% @1064 nm, R<0.5% @532 nm
- S1: HR-1064 nm, HT-808 nm, R>99.8% @1064 nm, T>95% @808 nm
  S2: AR-1064 nm, R<0.1% @1064 nm
- S1, S2 AR-coated, S3: gold/chrome plated
- Both ends AR/AR-1064 nm; S3: AR-808 nm
- Other coatings are available upon request

$Nd:GdVO_4$ - Neodymium Doped Gadolinium Orthovanadate

CASTECH's $Nd:GdVO_4$ is featured by

- Large stimulated emission cross section at laser wavelength;
- High absorption coefficient and wide bandwidth at pump wavelength;
- Low dependency on pump wavelength;
- Good thermal conductivity;
- Low lasing threshold and high slope efficiency;
- High laser induced damage threshold;
- Strongly-polarized laser output.

Table 1. Basic Properties

Crystal Structure	Tetragonal, space group $I4_1/amd$
Lattice Parameter	a = 7.21 Å, c = 6.35 Å
Lasing Transition	$^4F_{3/2} \rightarrow ^4I_{11/2}$
Lasing Wavelength	1062.9 nm
Emission Cross Section (at 1064 nm)	7.6×10^{-19} cm^2
Absorption Cross Section (at 808 nm)	4.9×10^{-19} cm^2
Absorption Coefficient (at 808 nm)	74 cm^{-1}
Index of Refractivity (at 1064 nm)	$n_o = 1.972$, $n_e = 2.192$
Thermal Conductivity (<110>)	11.7 W/m/K
Density	5.47 g/cm^3
Nd Dopant Level (atomic)	0.1%, 0.2%, 0.3%, 0.5%, 0.7%, 1.0%...

Table 2. Material Properties: Comparing $Nd:GdVO_4$ and $Nd:YVO_4$

Crystal	$Nd:GdVO_4$		$Nd:YVO_4$	
Crystal Structure, Space Group	Tetragonal, $I4_1/amd$		Tetragonal, $I4_1/amd$	
Lattice Parameter	a = 7.21 Å, c = 6.35 Å		a = 7.21 Å, c = 6.29 Å	
Melting Temperature (°C)	1780		1825	
Thermal Expansion @25 °C, $\times 10^{-6}$/°C	a	1.5	a	4.43
	c	7.3	c	11.4
Specific Heat @25 °C, cal/mol·K	32.6		24.6	
dn/dT, $\times 10^{-6}$ /°C	4.7		2.7	

Table 3. Information Regarding Neodymium Laser Host Crystals

Crystal	$Nd:YVO_4$	$Nd:GdVO_4$	Nd:YAG
Laser Wavelengths	1064.3 nm, 1342.0 nm	1062.9 nm, 1340 nm	1064.2 nm, 1338.2 nm
Emission Bandwidth (linewidth at 1064 nm)	0.8 nm	No data	0.6 nm
Effective Laser Cross Section (emission cross section at 1064 nm)	15.6×10^{-19} cm^2	7.6×10^{-19} cm^2	6.5×10^{-19} cm^2
Polarization	Parallel to c-axis	Parallel to c-axis	unpolarized
Fluorescence Lifetime with 1% Nd Doping	~ 100 µs	~ 95 µs	~ 230 µs
Pump Wavelength	808.5 nm	808.4 nm	807.5 nm
Peak Pump Absorption at 1% Doping	~ 41 cm^{-1}	~ 57 cm^{-1}	
Thermal Conductivity	5.1 W/m/K	11.7 W/m/K	14 W/m/K
Doping Concentration Range	0.1 - 3.0%	0.1 - 3.0%	0.3- 2.0%

Specifications of $Nd:GdVO_4$ crystal from CASTECH

Table 4. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L +0.2/-0.1 mm)
Clear Aperture	Central 90% of the diameter
Flatness	≦λ/8 @633 nm (L≧2.5 mm) ≦λ/4 @633 nm (L<2.5 mm)
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Transmitted Wavefront Distortion	≦λ/4 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦±0.5°
Chamfer	≦0.2 mm × 45°
Chip	≦0.1 mm
AR Coating	R<0.2% @1064 nm
HR Coating	R>99.8% @1064 nm, T>95% @808 nm
Quality Warranty Period	One year under proper use.

Nd:YAG - Neodymium Doped Yttrium Aluminum Garnet

Introduction

Neodymium Doped Yttrium Aluminum Garnet (Nd:YAG) is the earliest and most famous laser host crystal. Since it combines great advantages in many basic properties, Nd:YAG is the ubiquitous presence for near-infrared solid-state lasers and their frequency-doubler, tripler, and higher order multiplier.

CASTECH's Nd:YAG is featured by

- High gain
- Low threshold
- High efficiency
- Low loss at 1.06 µm
- Good thermal conductivity and thermal shock characteristics
- Mechanical strength
- high optical quality
- Material characteristics that allow for various modes of operation (CW, pulsed, Q-switched, mode locked)

Table 1. Basic Properties

Crystal Structure	Cubic
Lattice Parameter	12.01 Å
Density	4.5 g/cm^3
Melting Point	1970°C
Reflective Index	1.82
Mohs Hardness	8.5 Mohs
Thermal Expansion Coefficient	7.8×10^{-6} /K <111>, 0-250°C
Thermal Conductivity	14 W/cm/K, 20°C 10.5 W/cm/K, 100°C
Stimulated Emission Cross-section	2.8×10^{-19} cm^{-2}
Relaxation Time of Terminal Lasing Level	30 ns
Fluorescent Lifetime	550 µs
Spontaneous Fluorescence	230 µs
Linewidth	0.6 nm
Loss Coefficient	0.003 cm^{-1} @1064 nm

Specifications of Nd:YAG crystal from CASTECH

Table 2. Specifications

Dopant Concentration	Nd: 0.3~2.0 (± 0.1) atm%
Dimension	size up to dia. 15 × 180 mm and maximum diameter of dia. 40 mm × 2 mm
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Wavefront Distortion	λ/8 @633 nm
Flatness	λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm×45°
HR Coating	R>99.8% @1064 nm, R<5% @808 nm
Other HR Coatings, such as HR-1064/532 nm, HR-946 nm, HR-1319 nm and other wavelengths are available.	
Damage Threshold	>500 MW/cm² @1064 nm, 10 ns, 10 Hz (AR-coated)

Table 3. Optical Parameter of Nd:YAG crystal

Diameter (mm)	Standard grade	Excellent grade	Super-excellent grade
Φ3-6.35	≦ 0.5 fringes/inch	≦ 0.25 fringes/inch	≦ 0.1 fringes/inch
	≧ 25 dB	≧ 28 dB	≧ 30 dB
Φ7-10	≦ 0.7 fringes/inch	≦ 0.4 fringes/inch	≦ 0.16 fringes/inch
	≧ 22 dB	≧ 25 dB	≧ 28 dB
Φ11-13	≦ 1 fringes/inch	≦ 0.6 fringes/inch	≦ 0.2 fringes/inch
	≧ 20 dB	≧ 23 dB	≧ 26 dB
Φ14-16	≦ 1.2 fringes/inch	≦ 0.8 fringes/inch	≦ 0.25 fringes/inch
	≧ 18 dB	≧ 20 dB	≧ 23 dB

Higher grade or specific Nd:YAG rods or slabs, and Nd:YAG rods for 946 nm and 1319 nm lasers can be provided. Er:YAG, Yb:YAG and other ion doped YAG crystals are also available upon request.

Nd:KGW - Neodymium Doped Potassium Gadolinium Tungstate ($Nd:KGd(WO_4)_2$)

Introduction

Neodymium doped Potassium Gadolinium Tungstate ($Nd:KGd(WO_4)_2$ or Nd:KGW) is an excellent laser gain material which has low laser oscillations threshold and high emission section. The fluorescent concentration quench effect of the Nd^{3+} ion in the KGW crystal may be weakened due to the W-O covalent bond, so this crystal has a higher doping concentration of active ion. Furthermore, the absorption band at 808 nm of Nd^{3+} in the KGW which has 12 nm FWHM is well matched with the emission wavelength of current commercial laser diode.

Table 1. Basic Properties

Crystal Structure	monoclinic
Space Group	C_{2h} (2/c) - C2/c
Lattice Parameter	a = 8.087 Å, b = 10.374 Å, c = 7.588 Å β = 94.41°
Refractive Index, at 1067 nm	n_g = 2.049, n_p = 1.978, n_m = 2.014
Mohs Hardness	5
Density	7.27 g/cm^3
Melting Point	1075℃
Thermal Conductivity at 373 K	$K_{[100]}$ = 0.026 W/cm/K $K_{[010]}$ = 0.038 W/cm/K $K_{[001]}$ = 0.034 W/cm/K
Young's Modulus	$E_{[100]}$ = 115.8 Gpa, $E_{[010]}$ = 152.5 GPa, $E_{[001]}$ = 92.4 Gpa
Thermal Expansion Coefficient, at 373℃	$\alpha_{[100]} = 4\times10^{-6}$ /K, $\alpha_{[010]} = 1.6\times10^{-6}$ /K, $\alpha_{[001]}$ = 8.5×10^{-6} /K
Lasing Wavelength	911 nm, 1067 nm, 1351 nm
Absorption Band	808 nm (FWHM 12 nm)
Fluorescent Lifetime	110 μs (30% doping), 90 μs (8% doping)

Table 2. Laser Properties

3% Nd:KGW	Emission Wavelength	1070 nm
	Emission Bandwidth	15 nm
	Stimulated Emission Cross-section σ_e	1.48×10^{-20} cm^2
	Fluorescent Lifetime	109 μs
	Gain Bandwidth	15 nm
	Absorption Wavelength	810 nm
	Absorption Bandwidth	14 nm
	Absorption Cross-section σ_α	1.28×10^{-20} cm^2

Specifications of Nd:KGW crystal from CASTECH

Table 3. Specifications of Nd:KGW

Orientation	[010]
Standard Dopant Concentration	Nd: 3%, 5%, 8% atm%
Maximum Length	50 mm
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality (Scratch/Dig)	20/10 to MIL-PRF-13830B
Flatness	λ/6 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Coating	AR-coated

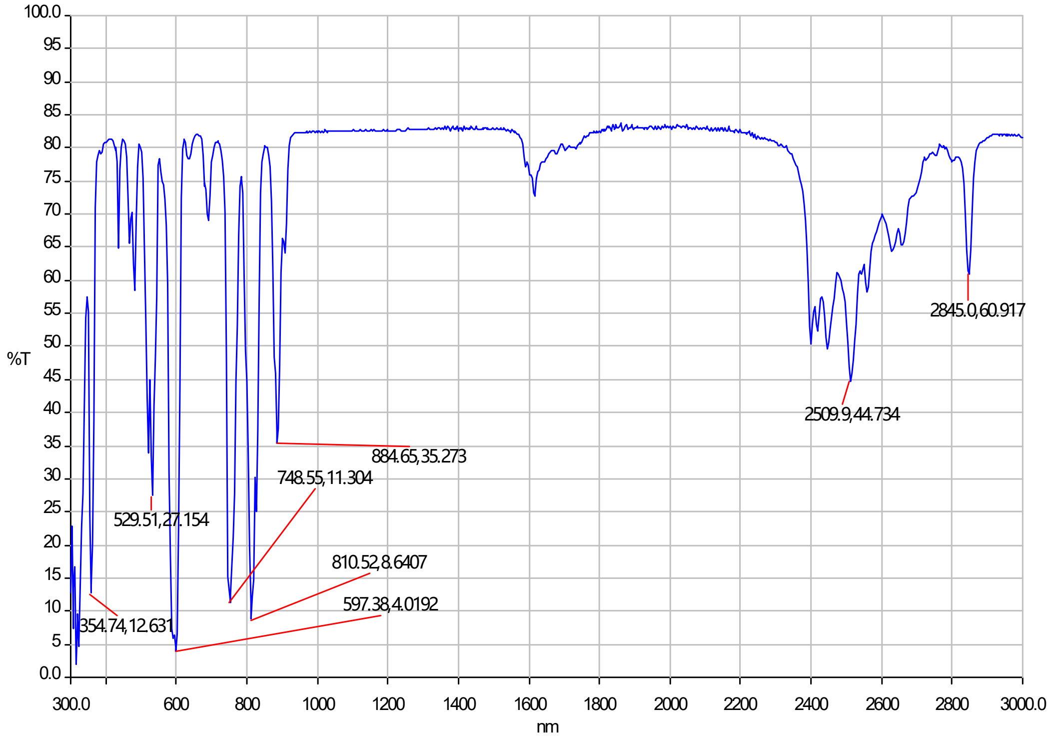


Figure 1. Transparency curve of Nd:KGW

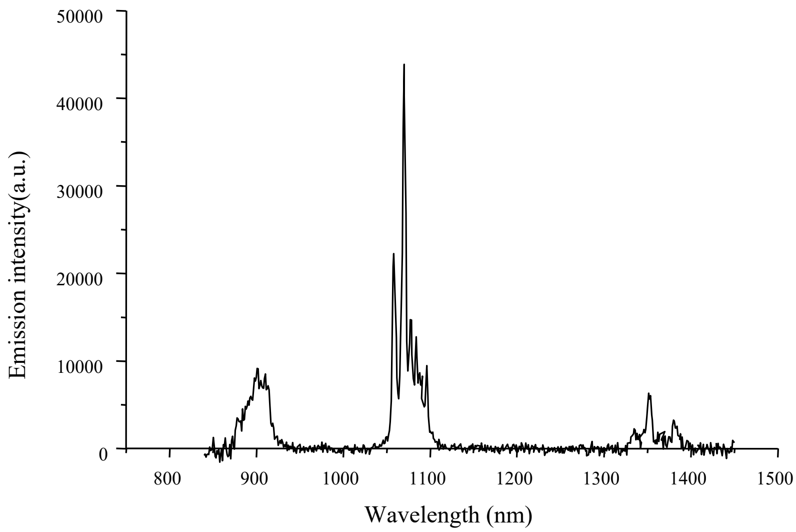


Figure 2. Emission spectra of 3% Nd:KGW

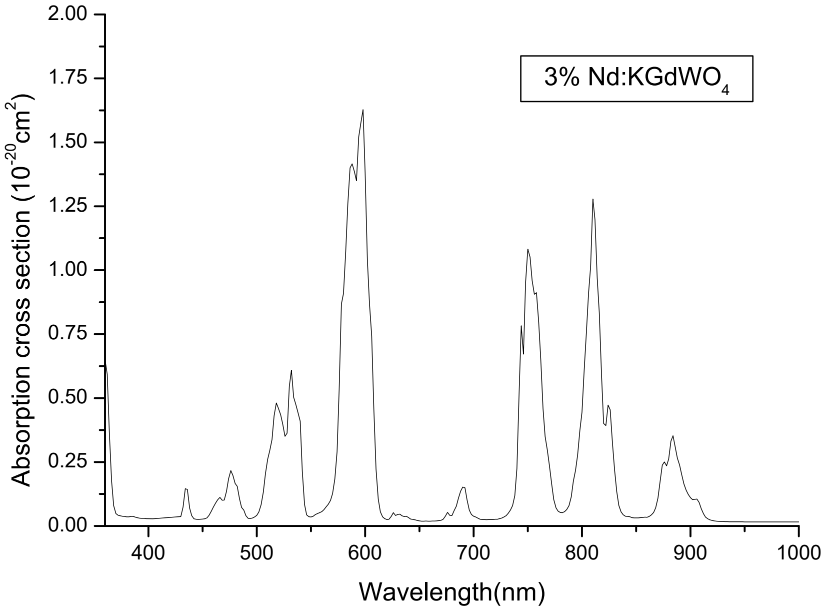


Figure 3. Absorption spectra of 3% Nd:KGW

Nd:YLF - Neodymium Doped Yttrium Lithium Fluoride ($Nd:YLiF_4$)

Introduction

CASTECH grows Nd:YLF crystals using Czochralski method. The use of high quality starting materials for crystal growth, whole boule interferometry, and precise inspection of scattering particle in crystal using He-Ne laser assure that each crystal will perform well.

CASTECH's general Nd:YLF production capabilities including

- Rod sizes from 2 mm to 10 mm in diameter and from 1 mm to 150 mm in length
- Orientation of rod axis to crystal axis <1 degree
- Polished only or AR coated rods
- Nd dopant concentrations between 0.4 and 1.2 at%
- Large rod and slab dimensions and non-standard dopant concentrations are available upon request

Table 1. Basic Properties

Chemical Formula	$LiY_{1.0-x}Nd_xF_4$
Crystal Structure	Tetragonal
Space Group	$I4_1/a$
Nd atoms / cm^3	1.40×10^{20} atoms/cm^3 for 1% Nd doping
Modulus of Elasticity	85 GPa
Lattice Parameter	a = 5.16 Å, c = 10.85 Å
Melting Point	819°C
Mohs Hardness	4~5 Mohs
Density	3.99 g/cm^3
Thermal Conductivity	0.063 W/cm/K
Specific Heat	0.79 J/g/K
Thermal Expansion Coefficient	8.3×10^{-6} /K // c, 13.3×10^{-6} /K ⊥ c

Table 2. Optical Properties

Transparency Range	180-6700 nm
Peak Stimulated Emission Cross Section	1.8×10^{-19} /cm² (E // c) at 1047 nm 1.2×10^{-19} /cm² (E ⊥ c) at 1053 nm
Fluorescence Lifetime	485 μs for 1% Nd doping
Scatter Losses	<0.2% /cm

Peak Absorption Coefficient (for 1.2% Nd)	α = 10.8 cm⁻¹ (792.0 nm E // c)
	α = 3.59 cm⁻¹ (797.0 nm E ⊥ c)

Laser Wavelength	1047 nm (// c, a-cut crystal) 1053 nm (⊥ c, a or c-cut crystal)

Sellmeier Equations (λ in μm):

$$n_o^2 = 1.38757 + 0.70757\lambda^2 / (\lambda^2 - 0.00931) + 0.18849\lambda^2 / (\lambda^2 - 50.99741)$$
$$n_e^2 = 1.31021 + 0.84903\lambda^2 / (\lambda^2 - 0.00876) + 0.53607\lambda^2 / (\lambda^2 - 134.9566)$$

Table 3. Index of Refraction

Wavelength (nm)	n_o	n_e
262	1.485	1.511
350	1.473	1.491
525	1.456	1.479
1050	1.448	1.47
2065	1.442	1.464

Table 4. dn / dT

Wavelength (nm)	E // c	E ⊥ c
436	-2.44×10^{-6}/°C	-0.54×10^{-6}/°C
578	-2.86×10^{-6}/°C	-0.91×10^{-6}/°C
1060	-4.30×10^{-6}/°C	-2.00×10^{-6}/°C

Specifications of Nd:YLF crystal from CASTECH

Table 5. Specifications

Standard Dopant Concentration	Nd: 1.1 ± 0.1%
Surface quality (scratch/dig)	10/5 to MIL-PRF-13830B
Wavefront Distortion	≦λ/4 @633 nm
Surface Flatness	λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm × 45°
End Coating	R<0.15% @1047/1053 nm

Yb:CALGO - Ytterbium Doped Calcium Gadolinium Aluminate ($Yb:CaGdAlO_4$)

Introduction

Ytterbium Doped Calcium Gadolinium Aluminate ($Yb:CaGdAlO_4$ or Yb:CALGO) is a promising new laser gain material which possess several important advantages. The crystal structure of CALGO is tetragonal. When it is pumped at 979 nm under pi configuration, we can get broad emission spectra from 994 nm to 1050 nm in theta configuration. This implies a very low quantum defect (down to 1.5%) and gives a good expectation of obtaining ultra-fast pulse. In addition, Yb:CALGO also has a thermal conductivity of up to k=6.7 W/m/K, making it suitable for high-power laser applications.

CASTECH's $Yb:CaGdAlO_4$ is featured by

- High absorption coefficient @979 nm
- High stimulated emission cross section
- Low laser threshold
- Extremely low quantum defect
- Broad output @994-1050 nm
- High slope efficiency with diode pumping (up to 55%)
- Various Yb-doping concentration

Applications

- Over 5.5 W output power is obtained by 23 W incident pumping diode laser with 10% output coupler;
- Output power as high as 12.5 W and 94 fs pulses for 28 W pumping power was reported.

Table 1. Basic Properties

Crystal Structure	Tetragonal
Point group	I4/mm
Lattice Parameter	a = 3.6585 Å, c = 1.1978 Å
Melting Point	1850 ℃
Mohs Hardness	6 Mohs
Density	4.8 g/cm^3
Thermal Conductivity	$K_{[001]}$ = 6.3 W/m/K, $K_{[100]}$ = 6.9 W/m/K
Thermal Expansion Coefficients	10.1×10^{-6}/K (// a), 16.2×10^{-6}/K (// c)
Laser Wavelength	994-1050 nm
Absorption Wavelength	979 nm
Absorption Cross Section (phi configuration at 979 nm)	2.7×10^{-20} cm^2

Specifications of Yb: $CaGdAlO_4$ crystal from CASTECH

Table 2. Specifications of Yb: $CaGdAlO_4$

Orientation	a or c
Standard Dopant Concentration	Yb: 1%, 2%, 3%, 5% atm%
Maximum Length	50 mm
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Coating	AR-1030/980 nm, R<0.2% @1030 nm, R<0.5% @980 nm. Other coatings are available upon request.

Yb:YAG - Ytterbium Doped Yttrium Aluminum Garnet ($Yb:Y_3Al_5O_{12}$)

Introduction

Ytterbium Doped Yttrium Aluminum Garnet ($Yb:Y_3Al_5O_{12}$, Yb:YAG) is one of the most promising laser-active materials and more suitable for diode-pumping than the traditional Nd-doped systems. Compared with the commonly used Nd:YAG crystal, Yb:YAG crystal has a much larger absorption bandwidth to reduce thermal management requirements for diode lasers, a longer upper-laser level lifetime, three to four times lower thermal loading per unit pump power. Yb:YAG crystal at 1030 nm is a good substitute for a Nd: YAG crystal at 1064 nm and its second harmonic at 515 nm may replace Ar-ion laser (with a large volume), which emit at 514 nm.

CASTECH's Yb:YAG Crystal is featured by

- Very low fractional heating, less than 11%
- Very high slope efficiency
- Broad absorption bands, about 8 nm @940 nm
- No excited-state absorption or up-conversion
- Conveniently pumped by reliable InGaAs diodes at 940 nm (or 970 nm)
- High thermal conductivity and large mechanical strength
- High optical quality

Table 1. Optical and Spectral Properties of Yb: YAG Crystal

Laser Transition	$^2F_{5/2} \rightarrow ^2F_{7/2}$
Laser Wavelength	1030 nm
Photon Energy	1.93×10^{-19} J (@1030 nm)
Emission Linewidth	9 nm
Emission Cross Section	2.0×10^{-20} cm^2
Fluorescence Lifetime	1.2 ms
Diode Pump Band	940 nm or 970 nm
Pump Absorption Band Width	8 nm
Index of Refraction	1.82
Thermal Optical Coefficient	9×10^{-6} /°C
Loss Coefficient	0.003 cm^{-1}

Specifications of Yb: YAG crystal from CASTECH

Table 2. Material and Specifications

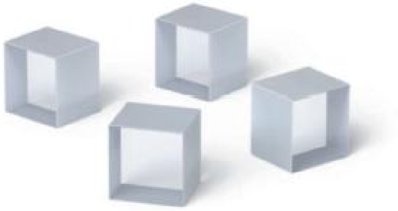
Dopant Concentration	Yb: 5~15 at%
Rod Sizes	Diameter: 2~20 mm, Length: 5~150 mm Upon request of customer
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality	10/5 to MIL-PRF-13830B
Wavefront Distortion	< λ/8 @633 nm
Flatness	λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Extinction Ratio	≧28 dB
Barrel Finish	Ground Finish: 400# Grit
Chamfer	≦0.2 mm × 45°
AR Coating Reflectivity	AR-1030/940 nm, R < 0.2% @1030 nm, R < 0.5% @940 nm. Other coatings are available upon request.
Single Pass Loss	$< 3 \times 10^{-3}$ cm^{-1}

$Yb:CaF_2$ - Ytterbium Doped Calcium Fluoride

Introduction

Ytterbium-doped Calcium fluoride (Yb: CaF_2), grown by Czochralski technique, is with long fluorescence lifetime and broad absorption bands, which make it an ideal material for laser diode pumping.

$Yb:CaF_2$ exhibits broad emission bandwidth as well as limited non-linear effects under intense irradiation, supporting generation of ultra-short pulses and high-power operation.



CASTECH's laser crystal Yb: CaF_2 is featured by

- Low quantum defect, long fluorescence lifetime
- Wide optical transmission range (0.12 µm~10 µm)
- Low dispersion behavior
- Limited nonlinear effects under intense laser irradiation
- Customized coatings are available

Table 1. Basic Properties

Dopant Concentration	1~10 at.%
Absorption Peak Wavelength	979 nm
Absorption Cross Section @980 nm	5.4×10^{-21} cm^2
Emission Cross Section @1035 nm	2.3×10^{-21} cm^2
Fluorescence Lifetime	2.2 ms
Refractive Index @1035 nm	1.42866
Crystal Structure	Cubic
Cleavage Plane	(111)
Melting Point	1418 ℃
Nonlinear Refractive Index	1.9×10^{-16} cm^2/W
Density	3.18 g/cm^3
Thermal Conductivity	9.71 W/m/K
Thermal Expansion Coefficient	18.41×10^{-6} /K
Mohs Hardness	4 Mohs

Yb:KGW - Ytterbium Doped Potassium Gadolinium Tungstate ($Yb:KGd(WO_4)_2$)

Introduction

Ytterbium doped Potassium Gadolinium Tungstate ($Yb:KGd(WO_4)_2$ or Yb:KGW) is an excellent laser gain material which has important advantages over the widely used Nd^{3+} doped materials. Its broad spectral emission band 1023-1060 nm allows the generation of short (ps or fs) laser pulses. Its wide absorption spectrum at 980 nm and high absorption of pump radiation allow an efficient use of diode laser pumping. Compared with YAG used as hosts for Yb^{3+}, KGW has the advantage of larger absorption cross section, which decreases the minimum pump intensity necessary to achieve transparency in the quasi-two-level system of ytterbium.

CASTECH's Yb: KGW is featured by

- High absorption coefficient @ 981nm
- High stimulated emission cross section
- Low laser threshold
- Extremely low quantum defect
- Broad polarized output at 1023–1060 nm
- High slope efficiency with diode pumping
- High Yb doping concentration

Table 1. Basic Properties

Crystal Structure	Monoclinic
Point Group	C2/c
Lattice Parameter	a = 8.09 Å, b = 10.43 Å, c = 7.588Å, β = 94.4°
Refractive Index, at 1067 nm	$n_g = 2.033$, $n_p = 2.037$, $n_m = 1.986$
Melting Point	1075 °C
Mohs Hardness	5
Density	7.27 g/cm³
Thermal Conductivity at 373 K	$K_{[100]} = 0.026$ W/m/K, $K_{[010]} = 0.038$ W/m/K; $K_{[001]} = 0.034$ W/m/K
Thermal Expansion Coefficients at 373 K	$\alpha_{[100]} = 4 \times 10^{-6}$ /K, $\alpha_{[010]} = 1.6 \times 10^{-6}$ /K, $\alpha_{[001]} = 8.5 \times 10^{-6}$ /K
Lasing Wavelength	1023-1060 nm
Absorption Band	981 nm (FWHM 3.7 nm)
Fluorescent Lifetime	600 µs (5% doping)

Table 2. Specifications

Orientation	[010]
Standard Dopant Concentration	Yb: 5 atm %
Maximum Length	50 mm
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality (Scratch/Dig)	20/10 to MIL-PRF-13830B
Flatness	λ/6 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Coating	AR-1030/980 nm, R < 0.2% @1030 nm, R < 0.5% @980 nm. Other coatings are available upon request.

Cr^{4+}:YAG - Chromium Doped Yttrium Aluminum Garnet

Introduction

Chromium Doped Yttrium Aluminum Garnet (Cr^{4+}:YAG) is an excellent crystal for passively Q-switching diode pumped or lamp-pumped Nd:YAG, Nd:YLF, Nd:YVO_4 or other Nd and Yb doped lasers at wavelength from 0.8 to 1.2 µm. Because of its chemically stable, durable, UV resistant, good thermal conductivity and high damage threshold (＞500 MW/cm^2) and being easy to be operated, it will replace traditional material, such as LiF, organic Dye and color centers.

CASTECH provides Cr^{4+}:YAG with Cr^{4+} doping level from 0.5 mol% to 3 mol%. The size could be from 2 × 2 mm^2 to 14 × 14 mm^2 with length from 0.1 mm to 12 mm available. We can control the initial transmission from 10% to 92% according to customers' requirements.

Table 1. Basic Properties

Crystal Structure	Cubic
Dopant Level	0.5 mol~3 mol%
Mohs Hardness	8.5 Mohs
Refractive Index, at 1064 nm	1.82
Damage Threshold	500 MW/cm^2 @1064 nm, 10 ns, 10 Hz (AR-coated)

The preliminary experiments of CASTECH's Cr^{4+}:YAG showed that the pulse width of passively Q-switched lasers could be as short as 5 ns for diode pumped Nd:YAG lasers and repetition as high as 10 kHz for diode pumped Nd:YVO_4 lasers. Furthermore, an efficient green output @532 nm, and UV output @355 nm and 266 nm were generated, after a subsequent intracavity SHG in KTP or LBO, THG and FOHG in LBO and BBO for diode pumped and passively Q-switched Nd:YAG and Nd:YVO_4 laser.

Cr^{4+}:YAG is also a laser crystal with tunable output from 1.35 µm to 1.55 µm. It can generate ultrashort pulse laser (to fs pulsed) when pumped by Nd:YAG laser at 1.064 µm.

Note

When ordering Cr^{4+}:YAG crystal, please specify the size, initial transmission and coatings. For further information, please contact CASTECH.

Cr:LiSAF - Chromium Doped Colquiriite (Cr^{3+}:$LiSrAlF_6$)

Introduction

CASTECH provides high quality, Cr-doped Colquiriite crystal (Cr:LiSAF, Cr^{3+}:$LiSrAlF_6$) using the Czochralski technique. It is an excellent laser material with high energy storage and high slope efficiency. It is also an ideal working material under conditions of ultra short pulse and ultra high power. Currently, Cr:LiSAF related products such as flashlight pumping and diode pumping laser have been widely used.

Table 1. Basic properties

Chemical Formula	Cr^{3+}: $LiSrAlF_6$
Crystal Structure	Trigonal
Point Group	P31c
Lattice Parameter	a = 5.084 Å, c = 10.21 Å
Cr atoms/cm³ for 1% doping	8.75×10^{19}
Fracture Toughness (Mpam)	0.40 (// c)
Melting Point	766 ℃
Density	3.45 g/cm³
Modulus of Elasticity	109 GPa
Thermal Expansion Coefficients	-10×10^{-6} /K (// c) 25×10^{-6} /K (⊥c)
Thermal Conductivity	3.3 W/m/K (// c) 3.0 W/m/K (⊥c)
Specific Heat	0.842 J/g·K @25 ℃

Table 2. Optical Properties

Emission Peak	846 nm
Peak Stimulated Emission Cross Section	4.8×10^{-20} /cm²(// c)
Fluorescence Lifetime	67 μs
Scatter Losses	< 0.2%/cm
dn/dT	-4.8×10^{-6} /℃ (// c) -2.5×10^{-6} /℃ (⊥c)

Sellmeier Equations (λ in μm)

$$n_c^2 = 1.98448 + 0.00235 / (\lambda^2 - 0.010936) - 0.01057 \lambda^2$$
$$n_a^2 = 1.97673 + 0.00309 / (\lambda^2 - 0.00935) - 0.00828 \lambda^2$$

Table 2. Optical Properties

Emission Peak	846 nm
Peak Stimulated Emission Cross Section	4.8×10^{-20} /cm²(// c)
Fluorescence Lifetime	67 µs
Scatter Losses	<0.2%/cm
dn/dT	-4.8×10^{-6} /°C (// c) -2.5×10^{-6} /°C (⊥c)
Sellmeier Equations (λ in µm) $n_c^2 = 1.98448 + 0.00235 / (\lambda^2 - 0.010936) - 0.01057\,\lambda^2$ $n_a^2 = 1.97673 + 0.00309 / (\lambda^2 - 0.00935) - 0.00828\,\lambda^2$	

Crystal	Wavelength (nm)	n_c	n_a
$Cr^{3+}:LiSAF_6$	846	1.407	1.405
	670	1.409	1.407
	423	1.413	1.412
	290	1.420	1.420
	266	1.422	1.424

Specifications of $Cr^{3+}:LiSAF_6$ crystal from CASTECH

Table 3. Specifications

Dopant Concentration	Cr: 0.5~1.0 mol % atm%
Size	Rod sizes from 2 mm to 16 mm in diameter and from 1 mm to 60 mm in length
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Parallelism	20 arc sec
Flatness	λ/8 @633 nm
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm x 45 °
AR-coated	R<0.10% @850 nm

Large rod and slab dimensions and non-standard dopant concentrations are available upon request.

Er:YAG - Erbium Doped Yttrium Aluminum Garnet

Introduction

Erbium Doped Yttrium Aluminum Garnet (Er:YAG) is an excellent laser crystal which lases at 2940 nm. This band is at the hydroxyl absorption peak which can be strongly absorbed by biological tissues. So it widely applies to medical area, such as dental (hard tissues), orthopedics, etc.

CASTECH's laser crystal Er:YAG is featured by

- High slope efficiency
- Operate well at room temperature
- Operate in a relatively eye-safe wavelength range

Table 1. Optical and Spectral Properties

Laser Transition	$^4I_{3/2} \rightarrow ^4I_{11/2}$
Laser Wavelength	2940 nm
Photon Energy	6.75×10^{-20} J @2.940 µm
Emission Cross Section	3×10^{-20} cm^2
Refractive Index	1.79 @2.940 µm
Pump Bands	600~800 nm

Table 2. Specifications

Dopant Concentration	Er: ~50 atm%
Rod Sizes	Diameter: 3~6 mm, Length: 50~120 mm; Upon request of customer
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Wavefront Distortion	λ/8 @633 nm
Flatness	λ/8 @633 nm
Parallelism	≦30 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm×45°
Extinction Ratio	≧25 dB
AR Coating Reflectivity	≦0.2% @2940 nm

Er:Yb:YAB - Erbium, Ytterbium Co-doped Yttrium Aluminum Borate (Er:Yb:$YAl_3(BO_3)_4$)

Introduction

At present, Er^{3+} / Yb^{3+} Co-doped Yttrium Aluminum Borate (Er:Yb:$YAl_3(BO_3)_4$, Er:Yb:YAB) crystal has been considered as an excellent 1.55 µm laser material, because it has high thermal conductivity, high Er^{3+}/Yb^{3+} energy transfer efficiency and weak upconversion loss. Compared with Er^{3+}/Yb^{3+} co-doped phosphato glass, Er:Yb:$YAl_3(BO_3)_4$ crystal can achieve 1530 nm continuous laser output with high (maximum) power and high slope efficiency. Due to the strong penetration ability to smoke, excellent transparency in atmosphere and high sensitivity for the room-temperature Ge as well as InGaAs photodiodes, eye-safe 1.55 µm laser can be widely used in many applications, such as LiDAR laser ranging, three-dimensional imaging and target recognition.

Table 1. Basic Properties

Chemical Formula	Er:Yb:$YAl_3(BO_3)_4$
Crystal Structure	D^3_7 - R32, a = b = 9.293 Å, c = 7.245 Å
Atomic Density	0.55×10^{20} cm^{-3} (1at.% Yb^{3+} or Er^{3+})
Mohs Hardness	7.5 Mohs
Density	3.7 g/cm^3
Refractive Index	1.75 (n_o); 1.68 (n_e) @1550 nm
Thermal Expansion Coefficient	⊥c: 2.0×10^{-6} K^{-1} // c: 9.7×10^{-6} K^{-1} (25 at.% Yb^{3+})
	⊥c: 1.2×10^{-6} K^{-1} // c: 8.5×10^{-6} K^{-1} (10 at.% Yb^{3+})
Conductivity	4.7 W/m/K

Table 2. Performance Parameter Table

	$Er:Yb:YAl_3(BO_3)_4$	Er^{3+}/Yb^{3+} co-doped phosphate glass
Pumping Wavelength	976 nm	976 nm
Peak Absorption Cross-section	3×10^{-20} cm^2 (σ polarization)	1×10^{-20} cm^2
FWHM of Absorption Band	19 nm	10 nm
Peak Fluorescence Wavelength	1530 nm	1533 nm
Central Wavelength of Luminescence	470 nm	470 nm
Peak Emission Cross-section	2×10^{-20} cm^2 (σ polarization)	0.8×10^{-20} cm^2
Fluorescence Lifetime	0.3 ms	8 ms
Refraction Index	1.75 (n_o)	1.54
Conductivity	4.7 W/m/K	0.8 W/m/K
Maximum Output Power	＞1 W	350 mW
Maximum Slope Efficiency	＞30%	＞30 %
Lasing Wavelength	1520-1600 nm	1528-1565 nm

Specifications of Er:Yb:YAB crystal from CASTECH

Table 3. Specifications

Dopant Concentration	Er^{3+}: 0.1~3 at.%, Yb^{3+}: 5~30 at.%
Cross-section	$(1 \times 1) \sim (15 \times 15)$ mm^2
Thickness	0.5~10 mm
Dimension Tolerance	±0.1 mm
Surface Quality (Scratch / Dig)	10/5 to MIL-PRF-13830B
Transmitted Wavefront Distortion	λ/8 @633 nm
Flatness	λ/6 @633 nm
Parallelism	≦30 arc sec
Coating	AR- or HR- coating

*** We can also provide you $Er:Yb:GdAl_3(BO_3)_4$ and $Er:Yb:LuAl_3(BO_3)_4$ with similar tech specs above.**

Er:Cr:YSGG - Erbium, Chromium Co-doped Yttrium Scandium Gallium Garnet

Introduction

Erbium, Chromium doped Yttrium Scandium Gallium Garnet (Er:Cr:YSGG) provides an efficient laser crystal for generating 2800 nm light in an important water absorption band. It becomes one of the most promising laser crystals recently owing to its high conversion efficiency, stable chemical properties, long fluorescent lifetime. Now Er:Cr:YSGG is widely used in dentistry, environmental researching, optical communication, remote sensing technology and military etc.

CASTECH's laser crystal Er:Cr:YSGG is featured by

- Lowest threshold and highest slope efficiency of common Erbium doped crystals
- High conversion efficiency
- Operates CW, free-running or Q-switched
- high optical quality
- The intrinsic crystal disorder increases pump line widths and tenability
- Can be flash lamp pumped via Cr bands or diode pumped via Er bands
- Long fluorescent lifetime

Table 1. Basic Properties

Crystal Structure	Cubic, Garnet
Chemical Formula	$Y_{2.93}Sc_{1.43}Ga_{3.64}O_{12}$
Lattice Parameter	12.42 Å
Doping Consent	Cr: 0.5 $\times$ 10^{20} (at/cm^3)，Er: 4 $\times$ 10^{21} (at/cm^3)
Growth Method	Czochralski
Density	5.67 g/cm^3 (Cr & Er doped)
Refractive Index	1.92 @1000 nm
Thermal Expansion Coefficient	8.1 $\times$ 10^{-6}/K
Thermal Conductivity	8 (W/m/K)
Mohs Hardness	8 Mohs
Thermo-optical Factor (dn/dT)	12.3 $\times$ 10^{-6} /K
Emission Cross-section	5.2 $\times$ 10^{-21} cm^2
Fluorescent Lifetime	1400 μs

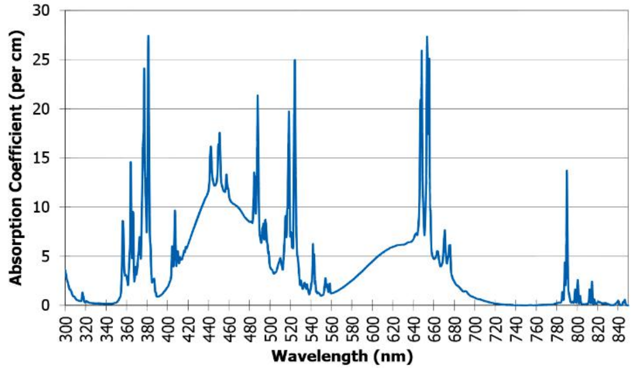


Figure 1. Er:Cr:YSGG absorption coefficient

Nd:Ce:YAG - Neodymium, Cerium Co-doped Yttrium Aluminum Garnet

Introduction

In double doped Nd:Ce:YAG crystals, Cerium are chosen as sensitizer for Nd^{3+} ions because of its strong absorption in UV spectral region at flash lamp pumping and efficient energy transfer to the Nd^{3+} excited state. As a result - thermal distortion in Nd:Ce:YAG is appreciably less and the output laser energy is greater than that in Nd:YAG at the same pumping. Therefore it is possible or realize high power lasers with good beam quality. Lasing wavelength at 1064 nm, laser damage threshold and thermal conductivity of the Nd:Ce:YAG crystals are the same as for Nd:YAG.

CASTECH's laser crystal Nd:Ce:YAG is featured by

- High efficiency
- Low threshold
- Good anti-violet radiation property
- Good thermal stability
- High optical quality

Table 1. Basic Properties

Laser Transition	$^4I_{3/2}\rightarrow{}^4I_{11/2}$
Laser Wavelength	1.064 μm
Photon Energy	1.86×10^{-19} J @1.064 μm
Emission Linewidth	4.5 Å @1.064 μm
Emission Cross Section (Nd 1 at.%)	$2.7\sim8.8 \times 10^{-19}$ cm^2
Fluorescence Lifetime (Nd 1 at.%)	230 μs
Refractive Index	1.8197 @1.064 μm

Table 2. Specifications

Dopant Concentration	Nd: 1.1~1.4 atm%, Ce: 0.05~0.1 atm%
Rod Sizes	Diameter: 3~6 mm, Length: 40~80 mm; Upon request of customer
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Wavefront Distortion	λ/4 @633 nm
Flatness	λ/8 @633 nm
Parallelism	≦30 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm×45°
AR Coating	≦0.2% @1064 nm

Ho:Cr:Tm:YAG - Holmium, Chromium, Thulium Co-doped Yttrium Aluminum Garnet

Introduction

Holmium, Chromium, Thulium Co-doped Yttrium Aluminum Garnet (Ho:Cr:Tm:YAG) is a high efficient laser material which lases at 2.1 µm. It has wide applications in surgery, dentistry, atmospheric testing, etc.

CASTECH's laser crystal Ho:Cr:Tm:YAG is featured by

- High slope efficiency
- Pumped by flash lamp or diode
- Operates well at room temperature
- Operates in a relatively eye-safe wavelength range

Table 1. Basic Properties

Laser Transition	$^5I_7 \rightarrow {}^5I_8$
Laser Wavelength	2.097 µm
Photon Energy	9.55×10^{-20} J
Emission Cross Section	7×10^{-21} cm^2
Fluorescence Lifetime	8.5 ms
Refractive Index	1.80 @2.08 µm
Absorption Linewidth	4 nm
Diode Pump Band	781 nm
Major Pump Bands	400~800 nm

Table 2. Specifications

Dopant Concentration	Ho:~0.35 at.%, Tm:~5.8 at.%, Cr:~1.5 at.%
Rod Sizes	Diameter: 3~6 mm, Length: 50~120 mm; Upon request of customer
Dimensional Tolerances	Diameter: ±0.1mm Length: ±0.5 mm
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Wavefront Distortion	λ/4 @633 nm
Flatness	λ/8 @633 nm
Parallelism	≦30 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm×45°
AR Coating	≦0.2% @2094 nm

Ti:Sapphire - Titanium Doped Sapphire

Introduction

Titanium Doped Sapphire (Ti:Sapphire) is the most widely used laser crystal for widely tunable and ultrashort pulsed lasers with high gain and power outputs. CASTECH possesses the advanced growth method of Temperature Gradient Technique (TGT), and it supplies large-sized (Dia.30×30 mm^3) Ti:Sapphire crystal in high quality free of light scatter, with the dislocation density less than 10^2 cm^{-2}. The TGT grown sapphire crystal is characterized by the (0001) oriented growth, high doping level (α_{490} = 4.0 cm^{-1}), high gain and laser damage threshold.

Main Applications

- The tunable wavelengths that cover a broad range from 700 to 1000 nm make Ti:Sapphire an excellent substitute for dye lasers in many applications.
- Doubling by NLO crystals such as BBO in an ultra-thin, Ti:Sapphire can be used to generate UV and DUV (up to 193 nm) laser with ultrafast pulses below 10 fs.
- Ti:Sapphire is also widely used as the pump source of OPOs to expand the tunable range.

Table 1. Basic Properties

Chemical Formula	Ti^{3+}: Al_2O_3
Crystal Structure	Hexagonal
Lattice Parameter	a = 4.758 Å, c = 12.991 Å
Density	3.98 g/cm^3
Melting Point	2040 ℃
Mohs Hardness	9
Thermal Conductivity	52 W/m/k
Specific Heat	0.42 J/g/K
Laser Action	4-level Vibronic
Fluorescence Lifetime	3.2 μs (T = 300K)
Tuning Range	660-1050 nm
Absorption Range	400-600 nm
Emission Peak	795 nm
Absorption Peak	488 nm
Refractive Index	1.76 @800 nm
Peak Cross-section	3~4 $\times$ 10^{-19} cm^2
Thermal Expansion	8.40 $\times$ 10^{-6} /℃

Specifications of Ti:Sapphire crystal from CASTECH

Table 2. Specifications

Orientation	Optical axis C normal to rod axis
Ti_2O_3 concentration	0.06-0.26 at.%
Figure Of Merit (FOM)	100~250 (＞250 available upon special requests)
α_{490}	1.0-4.0 cm^{-1}
Diameter	2~30 mm or specified
Path Length	2~30 mm or specified
End Configurations	Flat/Flat or Brewster/Brewster ends
Surface Quality (Scratch / Dig)	40/20 to MIL-PRF-13830B
Flatness	≦λ/8 @633nm
Wavefront Distortion	≦λ/4 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min

Note

AR-Coating is available upon request.

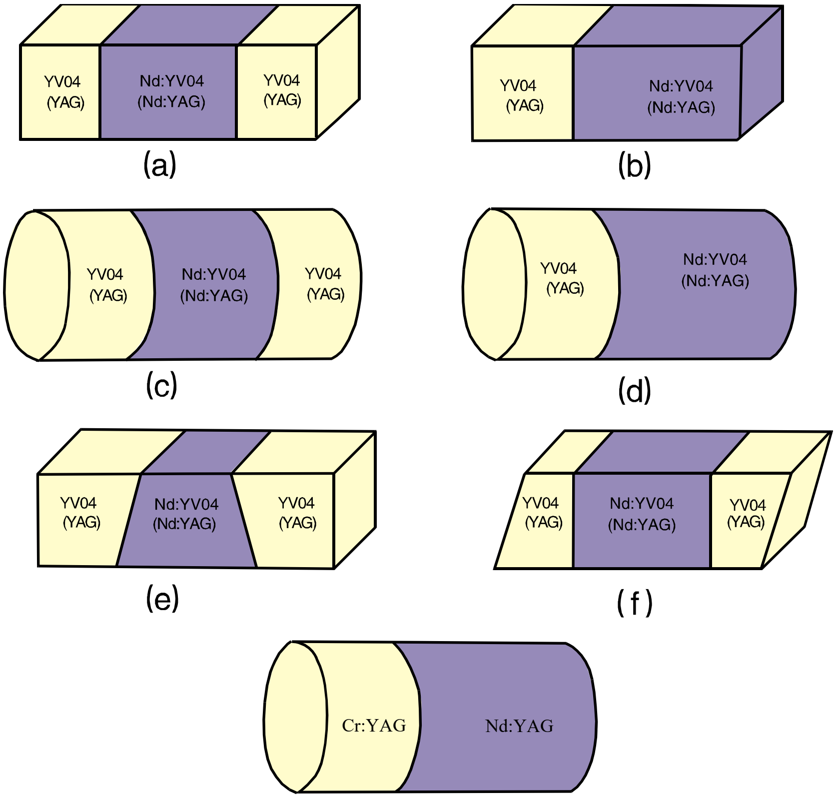
Diffusion Bonded Crystals

Introduction

Diffusion Bonded Crystals consist of one laser crystal and one or two undoped material. They are combined by optical contact method and further bonded under high temperature. Diffusion Bonded Crystal helps to decrease thermal lensing effect considerably.

CASTECH can supply different kinds of Diffusion Bonded Crystals like: YVO_4 + Nd:YVO_4 + YVO_4、YAG + Nd:YAG + YAG、Cr:YAG + Nd:YAG ...

We have several assembly types as follows



(g)

For other assembly type please contact us for more information.

TGG - Terbium Gallium Garnet ($Tb_3Ga_5O_{12}$)

Introduction

Terbium Gallium Garnet ($Tb_3Ga_5O_{12}$, TGG) is an excellent magneto-optical crystal used in various Faraday devices (Rotators and Isolators) in the range of 400 nm-1100 nm, excluding 475 nm-500 nm.

CASTECH's magneto-optical crystal TGG is featured by

- Large Verdet constant (35 Rad $T^{-1}m^{-1}$)
- High thermal conductivity (7.4 W $m^{-1}K^{-1}$)
- High laser damage threshold (>1 GW/cm^2)

Table 1. Basic Properties

Chemical Formula	$Tb_3Ga_5O_{12}$
Lattice Parameter	a = 12.355 Å
Growth Method	Czochralski
Density	7.13 g/cm^3
Melting Point	1725℃
Mohs Hardness	8 Mohs
Refractive Index	1.954 @1064 nm

Specifications of TGG crystal from CASTECH

Table 2. Specifications

Orientation	[111] within ±15′
Extinction Ratio	>30 dB
Diameter Tolerance	± 0.1 mm
Length tolerance	± 0.2 mm
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	<λ/8 @633 nm
Wavefront Distortion	<λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm × 45°
AR coating	<0.2% at 1064 nm

TSAG - Terbium Scandium Aluminum Garnet ($Tb_3Sc_2Al_3O_{12}$)

Introduction

Terbium Scandium Aluminum Garnet ($Tb_3Sc_2Al_3O_{12}$, TSAG) is the key isolator material for next generation fiber laser. As an ideal magneto-optic crystal in visible and infrared regions, TSAG has the advantages of high Verdet constant, excellent thermal and mechanical properties.

CASTECH's magneto-optical crystal TSAG is featured by

- Large Verdet constant (48 Rad $T^{-1}m^{-1}$ at 1064 nm), about 20-30% higher than that of TGG
- Low absorption (<3000 ppm/cm at 1064 nm), about 30% less than that of TGG
- High power compliant
- Low thermally-induced birefringence
- Ideal for compact magneto-optic devices

Main Applications

- Faraday Rotators
- Optical Isolators

Table 1. Basic Properties

Transparency Range	400-1600 nm
Crystal Structure	Cubic, Space group Ia3d
Chemical Formula	$Tb_3Sc_2Al_3O_{12}$
Lattice Parameter	a = 12.3 Å
Growth Method	Czochralski
Density	5.91 g/cm^3
Melting Point	1970 ℃ ± 10 ℃

Specifications of TSAG crystal from CASTECH

Table 2. Specifications

Orientation	within±15′
Extinction Ratio	＞30 dB
Diameter Tolerance	± 0.1 mm
Length Tolerance	± 0.2 mm
Surface Qquality (scratch/dig)	10/5 to MIL-PRF-13830B
Flatness	＜λ/8 @633 nm
Wavefront Distortion	＜λ/8 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Chamfer	≦0.2 mm × 45°
AR coating	<0.2% @1064 nm Other coatings are available upon request

YVO_4 - Yttrium Orthovanadate

Introduction

Yttrium Orthovanadate (YVO_4) is a positive uniaxial crystal grown with Czochralski method. It has good temperature stability, physical and mechanical properties. It is ideal for optical polarizing components because of its wide transparency range and large birefringence. It is an excellent synthetic substitute for Calcite ($CaCO_3$) and Rutile (TiO_2) crystals in many applications including fiber optic isolators and circulators, interleavers, beam displacers and other polarizing optics (refer to Table 1).

Table 1. Comparison of Basic Properties Between YVO_4 and Other Birefringent Crystals

		YVO_4	TiO_2	$CaCO_3$	$LiNbO_3$
Thermal Expansion (/°C)	c-axis	11.4×10^{-6}	9.2×10^{-6}	26.3×10^{-6}	16.7×10^{-6}
	a-axis	4.4×10^{-6}	7.1×10^{-6}	5.4×10^{-6}	7×10^{-6}
Refractive Index	n_o	1.9447 @1550 nm	2.454 @1530 nm	1.6346 @1497 nm	2.2151 @1440 nm
	n_e	2.1486 @1550 nm	2.710 @1530 nm	1.4774 @1497 nm	2.1413 @1440 nm
Birefringence (n_e-n_o)		0.2039 @1550 nm	0.256 @1530 nm	-0.1572 @1497 nm	-0.0738 @1440 nm
Mohs Hardness		5	6.5	3	5
Deliquescence		None	None	Weak	None
Transparency Range		0.4-5 μm	0.4-5 μm	0.35-2.3 μm	0.4-5 μm

A reliable supplier of $Nd:YVO_4$ crystals

CASTECH is one of the earliest companies who have mastered the advanced growth technique of $Nd:VYO_4$ crystal and completed its strong mass-production line that can provides:

- Various size of bulk and finished high quality YVO_4 crystals up to Φ35 x 50 mm^3 and Φ20 x 20 mm^3, respectively;
- Large quantity YVO_4 wedges and displacers used for fiber optical isolators and circulators, interleavers, in size of 1.25 x 1.25 x 0.5 mm^3 to 3 x 3 x 15 mm^3 to meet OEM customer's requirement;
- Quick delivery;
- Competitive price;
- Strict quality control;
- Technical support.

Table 2. Basic Properties

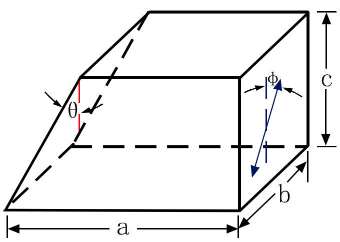
Transparency Range	High transmittance from 0.4 to 5 μm
Crystal Structure	Zircon Tetragonal, space group D_{4h}
Lattice Parameter	a = b = 7.12 Å; c = 6.29 Å
Density	4.22 g/cm³
Mohs Hardness	5, glass-like
Hygroscopic Susceptibility	Non-hygroscopic
Thermal Expansion Coefficient	$\alpha_a = 4.43\times10^{-6}$ /K; $\alpha_c = 11.37\times10^{-6}$ /K
Thermal Conductivity Coefficient	// C: 5.23 W/m/K; ⊥C: 5.10 W/m/K
Thermal Optical Coefficient	$dn_a/dT = 8.5\times10^{-6}$ /K; $dn_c/dT = 3.0\times10^{-6}$ /K
Crystal Class	Positive uniaxial with $n_o = n_a = n_b$, $n_e = n_c$
Refractive Indices, Birefringence ($\Delta n = n_e - n_o$) and Walk-off Angle at 45° (ρ)	$n_o = 1.9929$, $n_e = 2.2154$, $\Delta n = 0.2225$, $\rho = 6.04°$ at 630 nm $n_o = 1.9500$, $n_e = 2.1554$, $\Delta n = 0.2054$, $\rho = 5.72°$ at1300 nm $n_o = 1.9447$, $n_e = 2.1486$, $\Delta n = 0.2039$, $\rho = 5.69°$ at 550 nm
Sellmeier Equation (λ in μm)	$n_o^2 = 3.77834 + 0.069736 / (\lambda^2 - 0.04724) - 0.0108133\,\lambda^2$ $n_e^2 = 4.59905 + 0.110534 / (\lambda^2 - 0.04813) - 0.0122676\,\lambda^2$

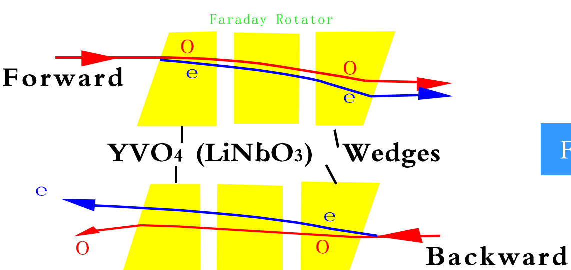
Applications

YVO_4 crystals are widely used in fiber-optic isolators, beam displacers and optical circulators, etc.

Table 3. Specifications of Birefringent Wedges
for Fiber-Optic Isolators

Aperture	1.0 × 1.0 mm² to 4 × 4 mm²
Dimension Tolerance	±0.1mm
Wedge Angle Tolerance	±0.1 °
Optical Axis Orientation	±0.5 °
Flatness	λ/4 @633 nm
Surface Quality (Sctrach/Dig)	20/10 to MIL-PRF-13830B
AR-Coating	R<0.2% @1550 or 1310 nm
Standard Size	1.25 mm × 1.25 mm × 0. 5 mm with 13 ° or 15 ° wedge, phi = 22.5 °



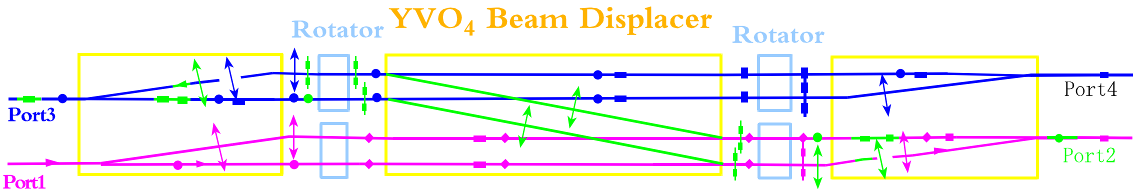


Fiber Optical Isolator

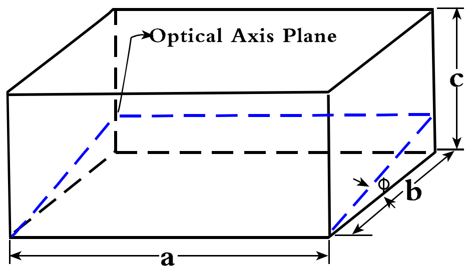
Table 4. Specifications of YVO_4 Beam Displacers for Fiber-Optic Circulators or Interleaver

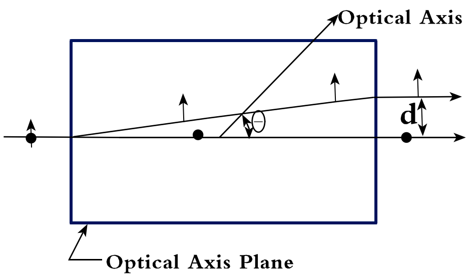
Dimension Tolerance	(W ± 0.05 mm) × (H ± 0.05 mm) × (L ± 0.1 mm)
Optical Axis Orientation	± 0.5 °
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Flatness	λ/4 @633 nm
Surface Quality (Scratch/Dig)	20/10 to MIL-PRF-13830B
AR-Coating	R<0.2% @1550 nm or 1310 nm ± 40 nm
Standard Size	2.6 × 2.6 × 10 mm³, θ = 45 °, Φ = 0 °

Note: Other sizes and specifications are available upon request.



Circulator





YVO_4 Beam Displacer for Circulator

α-BBO- Alpha-Barium Borate (α-BaB_2O_4)

Introduction

Alpha-Barium Borate (α-BaB_2O_4, α-BBO) is a negative uniaxial crystal which has large birefringence over a broad transparent range of 190 nm-3500 nm. α-BBO is an excellent crystal especially in UV and high power applications. The physical, chemical, thermal and optical properties of α-BBO crystal are similar to those of β-BBO. However, the nonlinear optical properties of α-BBO crystal are nonexistent due to the central symmetry of its crystal structure. α-BBO crystal is not recommended for NLO processes.

CASTECH's birefringent crystal α-BBO is featured by

- High UV transmittance
- Large birefringence
- Low bulk absorption suitable for high power applications
- High damage threshold
- Stable physical and mechanical properties.

Table 1. Basic Properties

Crystal Structure	Trigonal
Transparency Range	190-3500 nm
Density	3.85 g/cm^3
Hygroscopic Susceptibility	Low
Hardness	4.5 Mohs
Thermal Expansion Coefficients	-9.3 × 10^{-6}/°C（C） -9.5 × 10^{-6}/°C（A）
Damage Threshold	1 GW/cm^2 @1064 nm, 10 ns, 10 Hz (AR-coated)
Refractive Indices	n_o = 1.6776, n_e = 1.5534, @532 nm n_o = 1.6579, n_e = 1.5379, @1064 nm
Sellmeier Equation (λ in μm)	$n_o^2 = 2.7471 + 0.01878 / (\lambda^2 - 0.01822) - 0.01354\ \lambda^2$ $n_e^2 = 2.37153 + 0.01224 / (\lambda^2 - 0.01667) - 0.01516\ \lambda^2$

Table 2. Specifications

Size	Aperture up to Φ50 mm and length up to 40 mm
Surface Quality	10/5 to MIL-PRF-13830B
Flatness	λ/4 @633 nm
Optical Axis Orientation	6 arc min
Parallelism	20 arc sec
Clear Aperture	＞90%
Coating	AR-coating or P-coating
Mount	Upon Customer's Specification

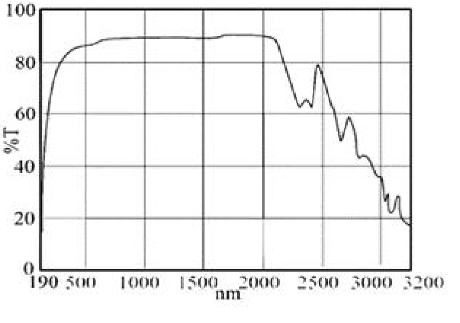


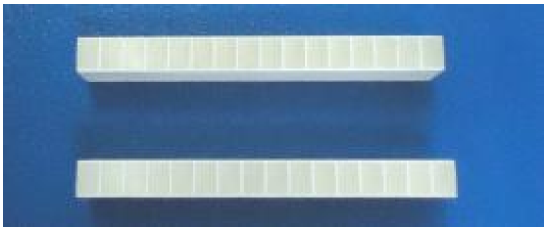
Figure 1. Transparency Curve

CWO - Cadmium Tungstate Scintillation Crystal ($CdWO_4$)

Introduction

Cadmium Tungstate ($CdWO_4$, CWO) single crystal is an important scintillation material applied in the radiation detection technology, especially for security checking, industrial CT and medical imaging. Large-size CWO single crystals with high quality are grown successfully by vertical Bridgman process in our company in recent years. CWO single crystal has a density as high as 7.9 g/cm^3 without any deliquescence. Under high-energy rays radiation such as X-rays or γ-rays, the crystal exhibits the luminescence output with a central wavelength of 470 nm. The crystal possesses a series of scintillation properties such as a relative light yield 2~3 times of BGO crystal, a low afterglow only 10^{-2} grade relative to CsI (Tl) crystal and a γ-ray radiation hardness of 107 rad. Our company provides the mass products of CWO wafers and array elements, which can meet the technical requirements for radiation detection devices.

CWO Crystal Boule



CWO Crystal Array Elements

Basic Properties of CWO Single Crystal

Crystal orientation	[100], [010]
Crystal structure	Monoclinic system, Space group p2/c
Crystal lattice	a = 5.029 Å, b = 5.859 Å, c = 5.074 Å; α = γ = 90 °, β = 91.47 °
Melting point	1276 ℃
Density	7.9 g/cm^3
Thermal expansion coefficient	6.39×10^{-6} /K ([100]), 1.09×10^{-5} /K ([010])
Refractive index	2.3
Hardness	4.5 Mohs
Colour	Nearly colorless to pale yellowish brown
Deliquescence	None
Central wavelength of luminescence	470 nm
Relative light yield index	20-30 (NaI (Tl) crystal with a light yield index 100 is used as reference)
Absolute light yield	2760 ± 50 p.e/MeV
Energy resolution	7.8-12%
Luminescence decay time	1.3 μs (36%, fast), 11.5 μs (64%, slow)
Afterglow	≦0.04% @3 ms
γ-ray radiation hardness	107 rad

Figures

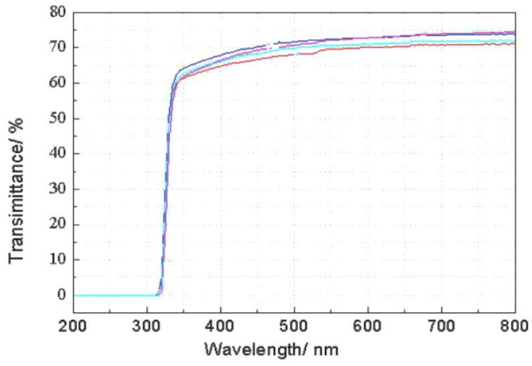


Fig.1 Ultraviolet-visible transmission spectra

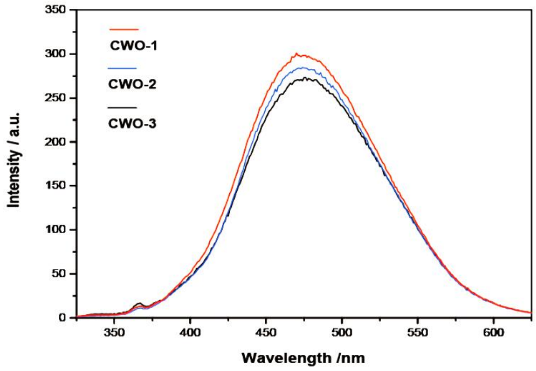


Fig.2 X-ray stimulated luminescence spectra

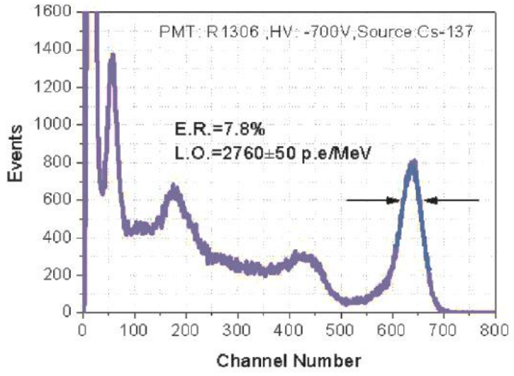


Fig.3 Energy spectrum and light yield of CWO wafer under γ-ray excitation

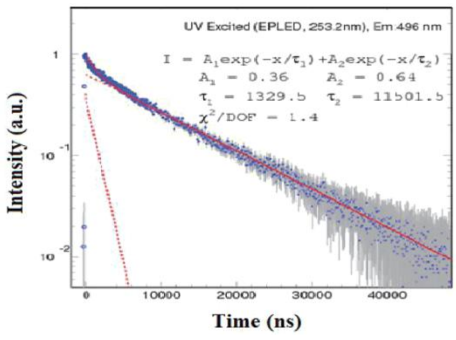


Fig.4 Luminescence decay time of CWO wafer under UV excitation

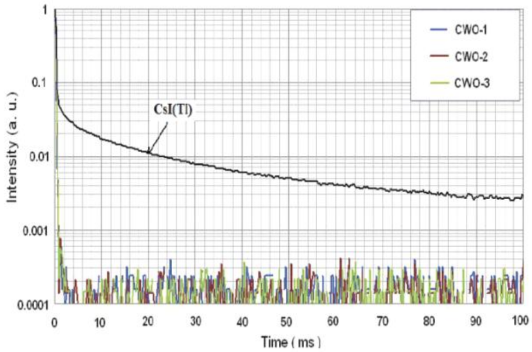


Fig.5 Afterglow of CWO crystal less than 0.04% @3 ms under γ-ray excitation which only 10^{-2} grade relative to CsI(Tl) crystal

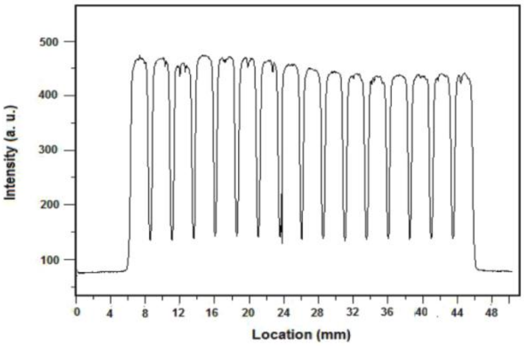


Fig.6 Relative light yield uniformity of crystal array elements

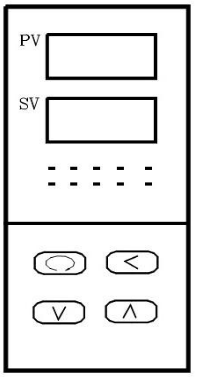
Oven & Temperature Controller

Introduction

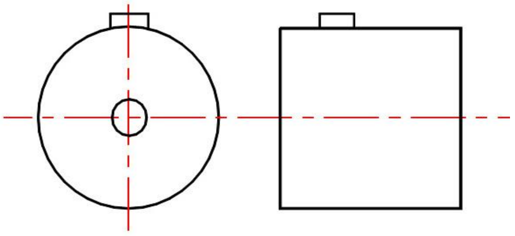
CASTECH provides oven and temperature controller for heating the crystal and controlling its temperature to a certain value.

Table 1. Typical Specifications

Temperature Controller	Oven
· Purpose ASIC processor	· Design: Radioactive heat compensation
· PID control	· Plane temperature distribution
· Auto tuning	· Fast tuning
· RS-232 interface (optical) · Programmable (optional)	· Size: Φ 50 mm × 55 mm (regular) Φ 30 mm × 45 mm (mini)
· Stability: ± 0.1 °C	· Cavity size: Φ 10 mm × 55 mm (regular) Φ 10 mm × 45 mm (mini)
· Size: 50 × 100 × 135 mm³	
· Normal Package Standard	· Sensor: Pt100 thermocouple
· Voltage: 110/220V AC, two types	· Working temperature: 40 - 180 °C



Temperature Controller



Oven

Applications

Heating nonlinear crystals is usually employed in NCPM, OPO, OPA, etc.

Note

- There are two types of applied voltage on oven, 110 V and 220 V. Please confirm it when order and check it before plug in the power. Burned and other damages, which caused by improper power selection, are not guaranteed to repair.
- Special oven size, holder of crystals and right-angle support setting applications are available upon request.

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