# CRYSTAL CATALOG

(2012-2013)

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## NLO Crystals



## Laser Crystals



## Acousto-Optic Crystals and Electro-Optic Crystals

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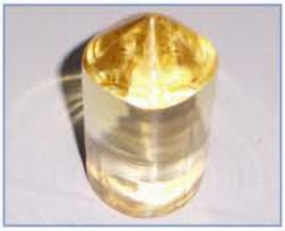



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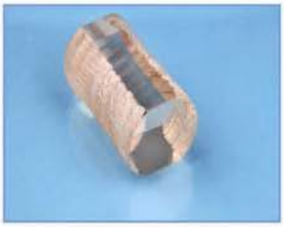



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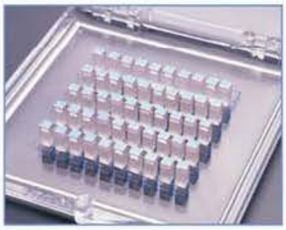




## Laser Components

# Lithium Triborate ($LiB_3O_5$, LBO)

## Introduction

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

## ?#?#?#?? LBO is featured by

- broad transparency range from 160nm to 2600nm (see Figure 1);
- high optical homogeneity ($\delta n \approx 10^{-6}$/cm) and being free of inclusion;
- relatively large effective SHG coefficient (about three times that of KDP);
- high damage threshold;
- wide acceptance angle and small walk-off;
- type I and type II non-critical phase matching (NCPM) in a wide wavelength range;
- spectral NCPM near 1300nm.

## ?#?#?#?? offers

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

**Table 1. Chemical and Structural Properties**

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

**Table 2. Optical and Nonlinear Optical Properties**

| | |
|---|---|
| Transparency Range | 160-2600nm |
| SHG Phase Matchable Range | 551-2600nm (Type I) 790-2150nm (Type II) |
| Therm-optic Coefficient (/ °C, $\lambda$ in µm) | $dn_x/dT=-9.3X10^{-6}$<br>$dn_y/dT=-13.6X10^{-6}$<br>$dn_z/dT=(-6.3-2.1\lambda)X10^{-6}$ |
| Absorption Coefficients | <0.1%/cm at 1064nm <0.3%/cm at 532nm |
| Angle Acceptance | 6.54mrad·cm ( $\phi$ , Type I,1064 SHG)<br>15.27mrad·cm ($\theta$, Type II,1064 SHG) |
| Temperature Acceptance | 4.7°C·cm (Type I, 1064 SHG)<br>7.5°C·cm (Type II,1064 SHG) |
| Spectral Acceptance | 1.0nm·cm (Type I, 1064 SHG)<br>1.3nm·cm (Type II,1064 SHG) |
| Walk-off Angle | 0.60° (Type I 1064 SHG)<br>0.12° (Type II 1064 SHG) |
| NLO Coefficients | $d_{eff}(I)=d_{32}\cos\phi$ (Type I in XY plane)<br>$d_{eff}(I)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ (Type I in XZ plane)<br>$d_{eff}(II)=d_{31}\cos\theta$ (Type II in YZ plane)<br>$d_{eff}(II)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ (Type II in XZ plane) |
| Non-vanished NLO susceptibilities | $d_{31}=1.05 \pm 0.09$ pm/V<br>$d_{32}= -0.98 \pm 0.09$ pm/V<br>$d_{33}=0.05 \pm 0.006$ pm/V |
| Sellmeier Equations ($\lambda$ in µm) | $n_x^2=2.454140+0.011249/(\lambda^2-0.011350)-0.014591\lambda^2-6.60x10^{-5}\lambda^4$<br>$n_y^2=2.539070+0.012711/(\lambda^2-0.012523)-0.018540\lambda^2+2.00x10^{-5}\lambda^4$<br>$n_z^2=2.586179+0.013099/(\lambda^2-0.011893)-0.017968\lambda^2-2.26x10^{-5}\lambda^4$ |

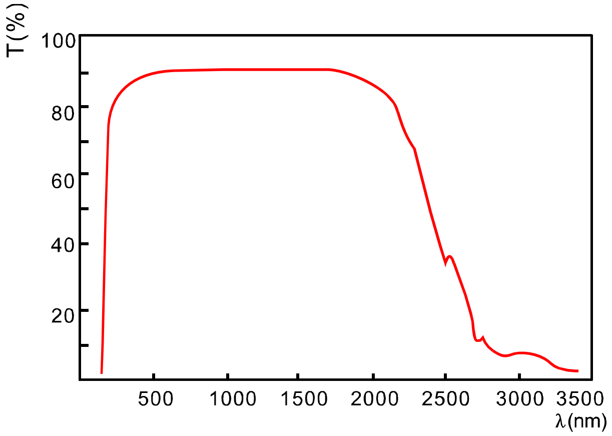



Figure 1. Transparency curve of LBO

## SHG and THG at Room Temperature

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

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

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

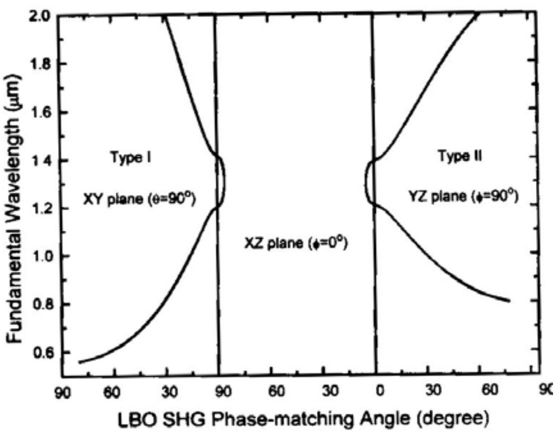



Figure 2. SHG tuning curves of LBO

## Applications

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

## Non-Critical Phase Matching

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

As shown in Fig.3, type I and type II non-critical phase matching can be reached along x-axis and z-axis at room temperature, respectively.

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

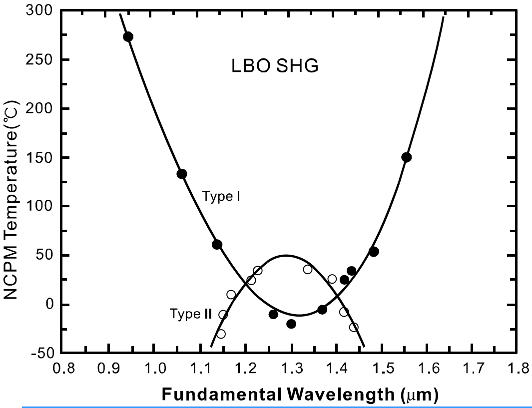



Figure 3. NCPM temperature tuning curves of LBO

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

## Applications

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

## LBO's OPO and OPA

LBO is an excellent NLO crystal for OPOs and OPAs with a widely tunable wavelength range and high powers. These OPO and OPA which are pumped by the SHG and THG of Nd:YAG laser and XeCl excimer laser at 308nm have been reported. The unique properties of type I and type II phase matching as well as the NCPM leave a large room in the research and applications of LBO's OPO and OPA. Fig.4 shows the calculated type I OPO tuning curves of LBO pumped by the SHG, THG and 4HG of Nd:YAG laser in XY plane at the room temperature. And Fig. 5 illustrates type II OPO tuning curves of LBO pumped by the SHG and THG of Nd:YAG laser in XZ plane.

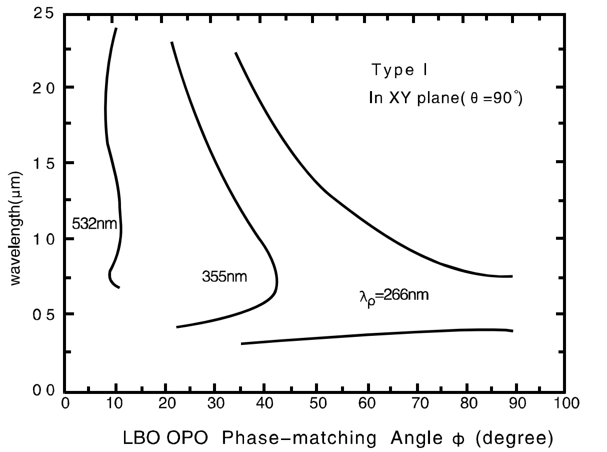



Figure 4. Type I OPO tuning curves of LBO

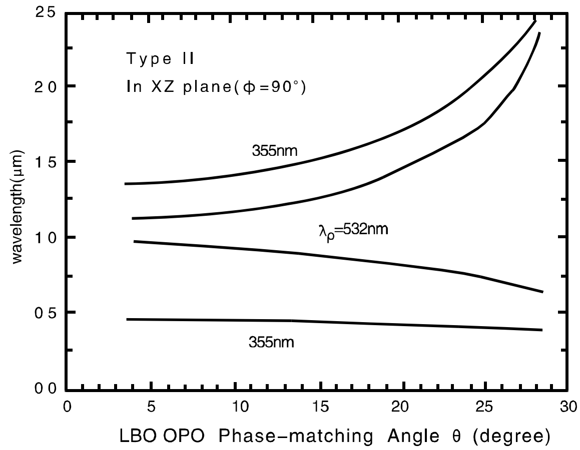



Figure 5. Type II OPO tuning curves of LBO

## Applications

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

## LBO's Spectral NCPM

Not only the ordinary non-critical phase matching (NCPM) for angular variation but also the non-critical phase matching for spectral variation (SNCPM) can be achieved in the LBO crystal. As shown in Fig.2, the phase matching retracing positions are $\lambda_1$=1.31 μm with θ =86.4°, ϕ=0° for Type I and $\lambda_2$=1.30 μm with θ =4.8°, ϕ=0° for Type II. The phase matching at these positions possess very large spectral acceptances Δλ. The calculated Δλ at $\lambda_1$ and $\lambda_2$ are 57nm·cm and 74nm·cm respectively, which are much larger than that of other NLO crystals. These spectral characteristics are very suitable for doubling broadband coherent radiations near 1.3 μm, such as those from some diode lasers, and some OPA/OPO output without linewidth-narrowing components.

## AR-coatings

**?#?#?#?? provides the following AR-coatings:**

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

## ?#?#?#??'s Warranty on LBO Specifications

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

## Notes

- LBO has a low susceptibility to moisture. Users are advised to provide dry conditions for both the use and preservation of LBO.
- Polished surfaces of LBO requires precautions to prevent any damage.
- ?#?#?#?? 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, ?#?#?#?? can provide free holders for you.

# Beta-Barium Borate (β-$BaB_2O_4$ or BBO)

## Introduction

Beta-Barium Borate (β-$BaB_2O_4$ or BBO), discovered and developed by FIRSM, CAS (Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences), now is manufactured and marketed by Fujian ?#?#?#?? Crystals, Inc. (?#?#?#??). The high-quality crystal boule is steadily available from ?#?#?#??, who holds specialized proprietary techniques (flux-method) of the BBO crystal growth.

## CASTECH's BBO is featured by

- Broad phase matchable range from 409.6 nm to 3500 nm;
- Wide transmission region from 190 nm to 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.

## ?#?#?#?? offers

- Strict quality control;
- Crystal length from 0.005 mm to 25 mm and size up to 15x15x15 $mm^3$;
- P-coatings, AR-coatings, mounts and re-polishing services;
- A large quantity of crystals in stock;
- Fast delivery (10 days for polished only, 15 days for AR-coated).

## Basic Properties

**Table 1. Chemical and Structural Properties**

| | |
|---|---|
| Crystal Structure | Trigonal, Space group R3c |
| Lattice Parameter | a=b=12.532Å, c=12.717Å, Z=6 |
| Melting Point | About 1095°C |
| Mohs Hardness | 4 |
| Density | 3.85 $g/cm^3$ |
| Thermal Conductivity | 1.2W/m/K(⊥c); 1.6W/m/K(//c) |
| Thermal Expansion Coefficients | $\alpha_{11}=4\times10^{-6}$/K; $\alpha_{33}=36\times10^{-6}$/K |

**Table 2. Optical and Nonlinear Optical Properties**

| | |
|---|---|
| Transparency Range | 190-3500nm |
| SHG Phase Matchable Range | 409.6-3500nm (Type I) 525-3500nm (Type II) |
| Therm-optic Coefficient (/°C) | $dn_o/dT=-16.6X10^{-6}$<br>$dn_e/dT=-9.3X10^{-6}$ |
| Absorption Coefficients | <0.1%/cm at 1064nm <1%/cm at 532nm |
| Angle Acceptance | 0.8mrad·cm (θ, Type I, 1064 SHG)<br>1.27mrad·cm (θ, Type II, 1064 SHG) |
| Temperature Acceptance | 55°C·cm |
| Spectral Acceptance | 1.1nm·cm |
| Walk-off Angle | 2.7° (Type I 1064 SHG)<br>3.2° (Type II 1064 SHG) |
| NLO Coefficients | $d_{eff}(I)=d_{31}\sin\theta+(d_{11}\cos3\phi- d_{22}\sin3\phi)\cos\theta$<br>$d_{eff}(II)= (d_{11}\sin3\phi + d_{22}\cos3\phi)\cos^2\theta$ |
| Non-vanished NLO susceptibilities | $d_{11} = 5.8 \times d_{36}$(KDP)<br>$d_{31} = 0.05 \times d_{11}$<br>$d_{22} < 0.05 \times d_{11}$ |
| Sellmeier Equations (λ in μm) | $n_o^2=2.7359+0.01878/(\lambda^2-0.01822)-0.01354\lambda^2$<br>$n_e^2=2.3753+0.01224/(\lambda^2-0.01667)-0.01516\lambda^2$ |
| Electro-optic coefficients: | $\gamma_{22} = 2.7$ pm/V |
| Half-wave voltage: | 7 KV (at 1064 nm,$3x3x20mm^3$) |
| Resistivity: | $>10^{11}$ ohm·cm |
| Relative Dielectric Constant: | $\varepsilon^s_{11}/\varepsilon_o$: 6.7<br>$\varepsilon^s_{33}/\varepsilon_o$: 8.1<br>Tan δ <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.

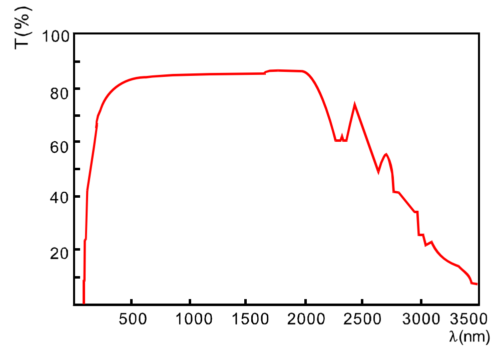



Figure 1. Transparency curve of BBO

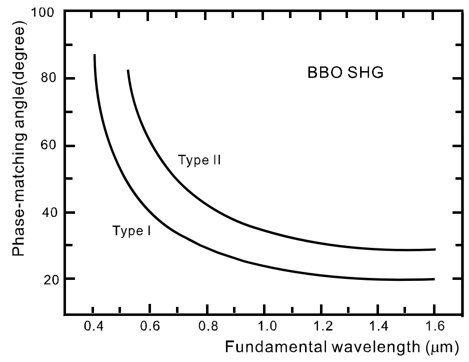



Figure 2. SHG tuning curves of BBO

## 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 213nm. Conversion efficiencies 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 15 W average power at 532 nm was generated in a ?#?#?#?? 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 a 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 (205nm - 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 188.9nm 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, ?#?#?#?? can provide as thin as 0.005mm 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 360nm - 390 nm with pulse energy of 105 mJ (31% SHG efficiency) at 378 nm, and output in the region 244nm - 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 FHG 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 2W, 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-Vapor 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 532 nm

An OPO output ranging from 680 nm to 2400 nm with the peak power of 1.6MW 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 75ps. With a longer crystal, higher conversion efficiency is expected.

### 2. OPO and OPA pumped at 355 nm

In the case of Nd:YAG pumping, BBO's OPOs can generate more than 100mJ, with wavelength tunable from 400nm to 2000nm. Using CASTECH's BBO crystal, the OPO system covers a tuning range from 400nm to 3100nm which guarantees a maximum of 30% and more than 18% conversion efficiency, over the wavelength range from 430nm to 2000nm.

Type II BBO can be used to decrease linewidth near the degenerate points. A linewidth as narrow as 0.05 nm and usable conversion efficiency of 12% were obtained. However, a longer (> 15mm) 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 μ J) and wide tunable (400 nm to 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.

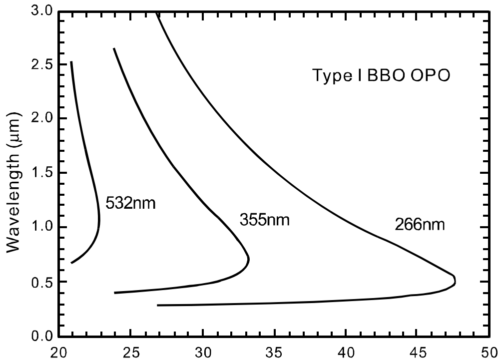



Figure 3. Type I OPO tuning curves of BBO

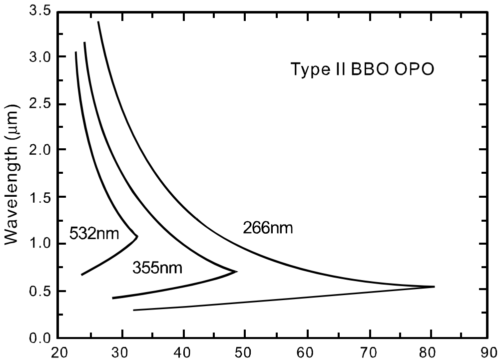



Figure 4. Type II OPO tuning curves of BBO

### 3.Others

A tunable OPO with signal wavelengths between 422nm and 477nm 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 nm - 1370 nm.

When pumped by a 1mJ, 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 - 2000 nm.

## BBO's E-O Applications

BBO can also be used for E-O applications. It has wide transmission range from UV to about 3500nm. And it has much higher damage threshold than KD*P or $LiNbO_3$. More than 80W output power and 50KHZ repitition rate have been reached by using CASTECH's E-O BBO crystals and $Nd:YVO_4$ crystals as gain media. At 5K HZ, its pulse has width as short as 6.4ns, and energy of 5.7 mJ or peak power of 900 KW. It has advantages over the commercial A-O Q-switched one, including a 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(7KV at 1064nm, $3x3x20mm^3$), long and thin BBO can reduce the voltage requirements. ?#?#?#?? now can supply 25mm long and 1mm thin high optical quality of BBO crystal with Z-cut, AR-coated and Gold/Chrome plated on the side faces.

## Coatings

### ?#?#?#?? provides the following AR-coatings for BBO:

- Dual Band AR-coating (DBAR) of BBO for SHG of 1064nm.
  low reflectance (R<0.2% at 1064nm and R<0.5% at 532nm );
  high damage threshold (>300MW/$cm^2$ at both wavelengths);
  long durability.
- Broad Band AR-coating (BBAR) of BBO for SHG of tunable lasers.
- Broad Band P-coating of BBO for OPO applications.
- Other coatings are available upon request.

## ?#?#?#??'s Warranty on BBO Specifications

- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L≥2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50mW green laser
- Flatness: less than λ/8 @ 633nm
- Transmitting wavefront distortion: less than λ/8 @ 633nm
- Chamfer:≤0.2mm x 45°
- Chip: ≤0.1mm
- Scratch/Dig code: better than 10/ 5 to MIL-PRF-13830B
- Parallelism: ≤20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: ≤0.25°
- Damage threshold[GW/$cm^2$]: >1 for 1064nm, TEM00, 10ns, 10HZ (polished only)
  >0.5 for 1064nm, TEM00, 10ns, 10HZ (AR-coated)
  >0.3 for 532nm, TEM00, 10ns, 10HZ (AR-coated)
- Quality Warranty Period: one year under proper use.

## Note

- 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.
- ?#?#?#?? 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, ?#?#?#?? can provide free holders for you.

# Potassium Titanyl Phosphate($KTiOPO_4$, KTP)

## Introduction

Potassium Titanyl Phosphate ($KTiOPO_4$ or KTP) is widely used in both commercial and military lasers including laboratory and medical systems, 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

## ?#?#?#?? offers

- Strict quality control
- Large crystal size up to 20x20x40mm$^3$ and maximum length of 60mm;
- Quick delivery (2 weeks for polished only, 3 weeks for coated)
- Unbeatable price and quantity discount
- Technical support
- AR-coating, mounting and re-polishing service

**Table 1. Chemical and Structural Properties**

| | |
|---|---|
| Crystal Structure | Orthorhombic, space group $Pna2_1$,point group mm2 |
| Lattice Parameter | a=6.404Å, b=10.616Å, c=12.814Å, Z=8 |
| Melting Point | About 1172°C |
| Mohs Hardness | 5 |
| Density | 3.01 g/cm$^3$ |
| Thermal Conductivity | 13W/m/K |
| Thermal Expansion Coefficient | $\alpha_x$=11x10$^{-6}$/$^0$C, $\alpha_y$=9x10$^{-6}$/$^0$C, $\alpha_z$=0.6x10$^{-6}$/$^0$C |

**Table 2. Optical and Nonlinear Optical Properties**

| | |
|---|---|
| Transparency Range | 350-4500nm |
| SHG Phase Matchable Range | 497-1800nm (Type II) |
| Therm-optic Coefficients (/$^0$C) | $dn_x/dT=1.1X10^{-5}$<br>$dn_y/dT=1.3X10^{-5}$<br>$dn_z/dT=1.6X10^{-5}$ |
| Absorption Coefficients | <0.1%/cm at 1064nm <1%/cm at 532nm |
| For Type II SHG of a Nd:YAG laser at 1064nm | Temperature Acceptance: 24°C·cm<br>Spectral Acceptance: 0.56nm·cm<br>Angular Acceptance: 14.2mrad·cm ( $\phi$ ); 55.3mrad·cm($\theta$)<br>Walk-off Angle: 0.55° |
| NLO Coefficients | $d_{eff}(II) \approx (d_{24} - d_{15})\sin2\phi\sin2\theta - (d_{15}\sin^2\phi + d_{24}\cos^2\phi)\sin\theta$ |
| Non-vanished NLO susceptibilities | $d_{31}$=6.5 pm/V $d_{24}$=7.6 pm/V<br>$d_{32}$=5 pm/V $d_{15}$=6.1 pm/V<br>$d_{33}$=13.7 pm/V |
| Sellmeier Equations ( $\lambda$ in µm) | $n_x^2=3.0065+0.03901/(\lambda^2-0.04251)-0.01327\lambda^2$<br>$n_y^2=3.0333+0.04154/(\lambda^2-0.04547)-0.01408\lambda^2$<br>$n_z^2=3.0065+0.05694/(\lambda^2-0.05658)-0.01682\lambda^2$ |
| 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: | $\varepsilon_{eff}=13$ |

## 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. To date, extra- and intra-cavity frequency doubled Nd:lasers using KTP have become a preferred pumping source for visible dye lasers and tunable Ti:Sapphire lasers as well as their amplifiers. They are also useful green sources for many research and industry applications.

- More than 80% conversion efficiency and 700mJ green laser were obtained with a 900mJ injection-seeded Q-switch Nd:YAG lasers by using extra-cavity KTP.
- 8W green laser was generated from a 15W LD pumped Nd:$YVO_4$ with intra-cavity KTP.
- 200mW green outputs are generated from 1W LD pumped Nd:$YVO_4$ lasers by using CASTECH's 2x2x5mm$^3$ KTP and 3x3x1mm$^3$ Nd:$YVO_4$.
- 2-5mw green outputs are generated from 180mw LD pumped Nd:$YVO_4$ and KTP glued crystals. For more details, please refer to P67.

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

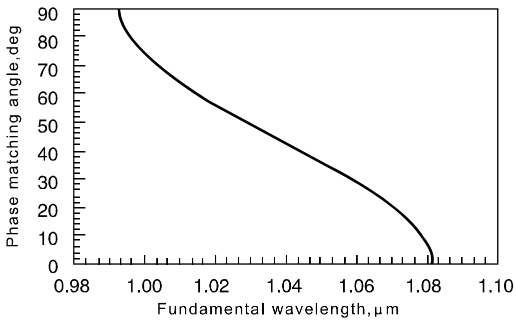



**Fig. 1 Type II KTP SHG in XY Plane**

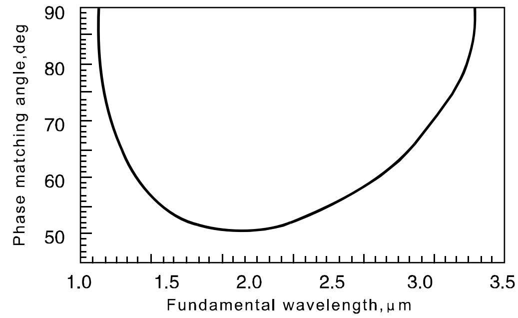



**Fig. 2 Type II KTP SHG in XZ Plane**

## 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 (600nm) to mid-IR (4500nm), 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 1064nm Nd:YAG laser has generated as high as above 66% efficiency for degenerately converting to 2120nm.

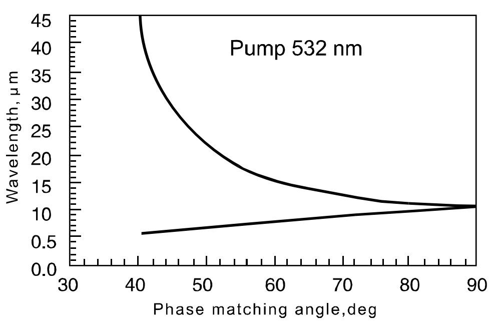



**Fig. 3 OPO pumped at 532 in X-Z plane**

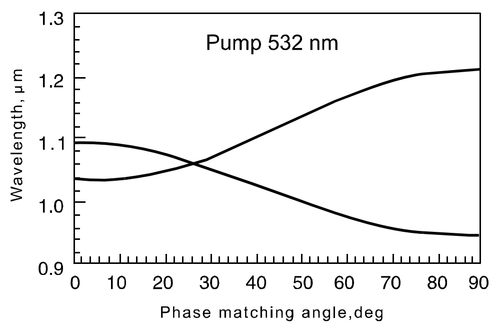



**Fig. 4 OPO pumped at 532 in X-Y plane**

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 0.7μm to 1μm, the output can cover from 1.04μm to 1.45μm (signal) and from 2.15μm to 3.2μm (idler). More than 45% conversion efficiency was obtained with narrow output bandwidth and good beam quality.

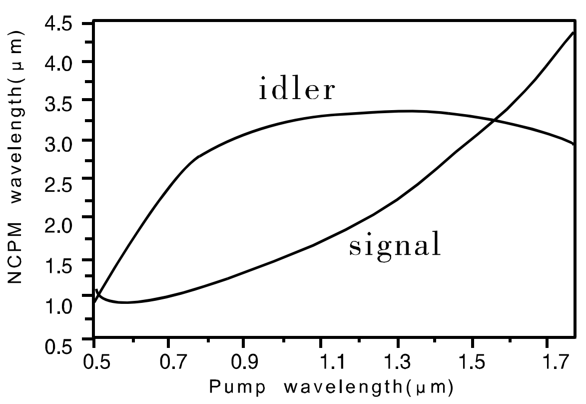



**Fig. 5 Type II NCPM OPO**

## Applications for E-O Devices

In addition to unique NLO features, KTP also has promising E-O and dielectric properties that are comparable to $LiNbO_3$. These advantaged 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 1. Electro-Optic Modulator Materials**

| Material | | | Phase | | | Amplitude | | |
|---|---|---|---|---|---|---|---|---|
| | ε | N | R(pm/V) | k($10^{-6}$/°C) | $N^7r^2/\varepsilon(pm/V)^2$ | r(pm/V) | k($10^{-6}$/°C) | $n^7r^2/\varepsilon(pm/V)^2$ |
| KTP | 15.42 | 1.80 | 35.0 | 31 | 6130 | 27.0 | 11.7 | 3650 |
| $LiNbO_3$ | 27.9 | 2.20 | 8.8 | 82 | 7410 | 20.1 | 42 | 3500 |
| KD*P | 48.0 | 1.47 | 24.0 | 9 | 178 | 24.0 | 8 | 178 |
| $LiIO_3$ | 5.9 | 1.74 | 6.4 | 24 | 335 | 1.2 | 15 | 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 (>15GHZ), 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 waveguides have been applied to the type I quasi-phase-matchable SHG of a tunable Ti:Sapphire laser in the range of 760-960mm, and directly doubled diode lasers for the 400-430nm outputs.

Table 2. Electro-Optic Waveguide Materials

| Materials | r (pm/V) | n | $\varepsilon_{eff}\,(\varepsilon_{11}\varepsilon_{33})^{1/2}$ | $n^3r/\varepsilon_{eff}$ (pm/V) |
|---|---|---|---|---|
| KTP | 35 | 1.86 | 13 | 17.3 |
| $LiNbO_3$ | 29 | 2.20 | 37 | 8.3 |
| $KNbO_3$ | 25 | 2.17 | 30 | 9.2 |
| BNN | 56 | 2.22 | 86 | 7.1 |
| BN | 56-1340 | 2.22 | 119-3400 | 5.1-0.14 |
| GaAs | 1.2 | 3.6 | 14 | 4.0 |
| $BaTiO_3$ | 28 | 2.36 | 373 | 1.0 |

## AR-coatings

**?#?#?#?? provides the following AR-coatings:**

- Dual Band AR-coating (DBAR) of KTP for SHG of 1064nm.
  low reflectance (R<0.2% at 1064nm and R<0.5% at 532nm );
  high damage threshold (>300MW/cm2 at both wavelengths);
  long durability.

- Broad Band AR-coating (BBAR) of KTP for OPO applications.
- High reflectivity coating: HR1064nm&HT532nm, R>99.8%@1064nm, T>90%@532nm.
- Other coatings are available upon request.

## ?#?#?#??'s Warranty on KTP Specifications

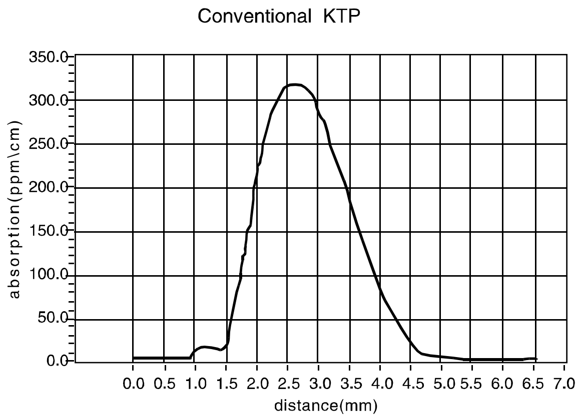
- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L≥2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50mW green laser
- Flatness: less than λ/8 @ 633nm
- Transmitting wavefront distortion: less than λ/8 @ 633nm
- Chamfer: ≤0.2mm x 45°
- Chip: ≤0.1mm
- Scratch/Dig code: better than 10/ 5 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: ≤0.25°
- Damage threshold[GW/$cm^2$ ]: >0.5 for 1064nm, TEM00, 10ns, 10HZ (AR-coated)
  >0.3 for 532nm, TEM00, 10ns, 10HZ (AR-coated)
- Quality Warranty Period: one year under proper use.

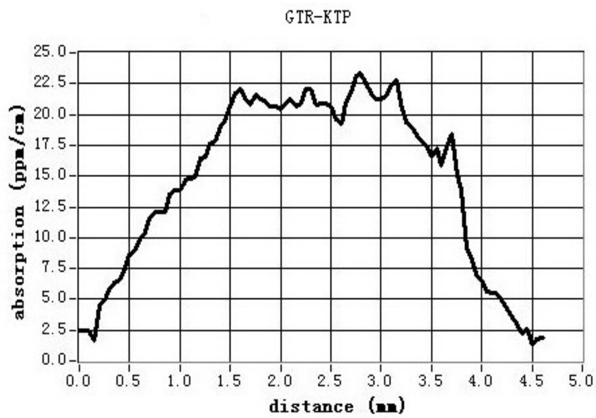
# Gray-track Resistance KTP($KTiOPO_4$, GTR-KTP)

## Introduction

Potassium Titanyl Phosphate ($KTiOPO_4$ or KTP) is an excellent NLO crystal, widely used in both commercial and military lasers. However conventional KTP suffer a significant drawbacks. The gray track phenomena in conventional KTP limit its application in high repetition and high power laser system. The occurrence of gray-track can be measured by an increase of bulk absorption by a strong CW 532nm green laser within several minutes. This measurement can be performed with Photo-thermal Common-path interferometer.

### 1. Longitudinal Test (Before Gray Tracking Test ):

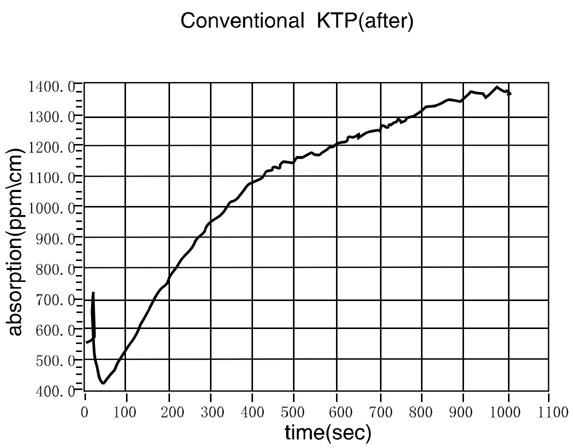


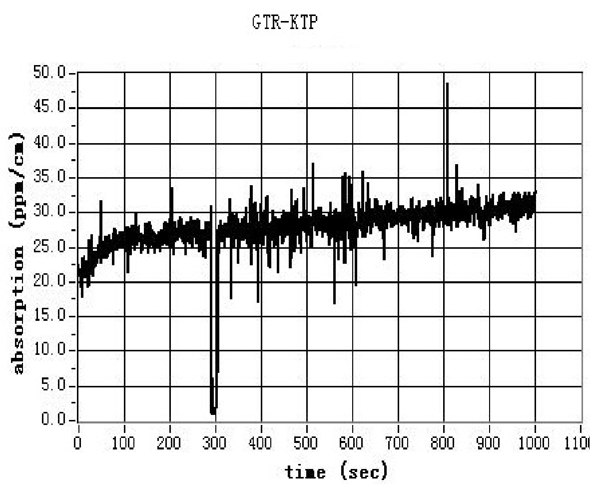




It appears that the absorption of GTR-KTP at 1064nm is only 1/10 of conventional KTP.

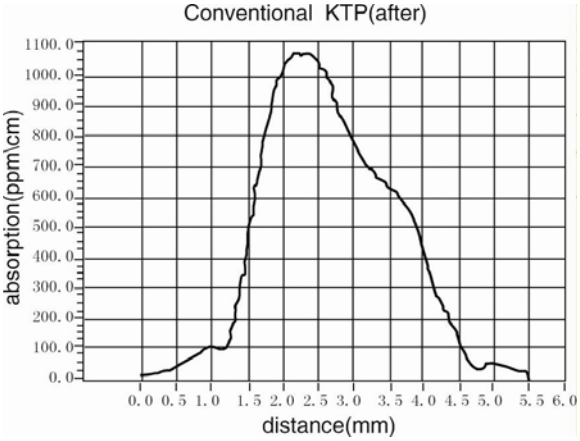
### 2. Gray Tracking Test:

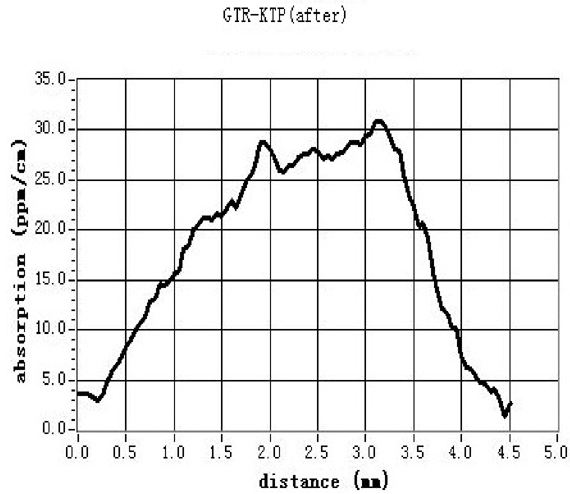
When a green laser beam(400mW, beam diameter 0.07mm, power density $10KW/cm^2$) goes through the crystal, it causes an increase in the IR absorption of the crystal. This phenomenon is correlated with "gray tracking effect". The following graphs show the different absorption levels at 1064nm between CASTECH's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



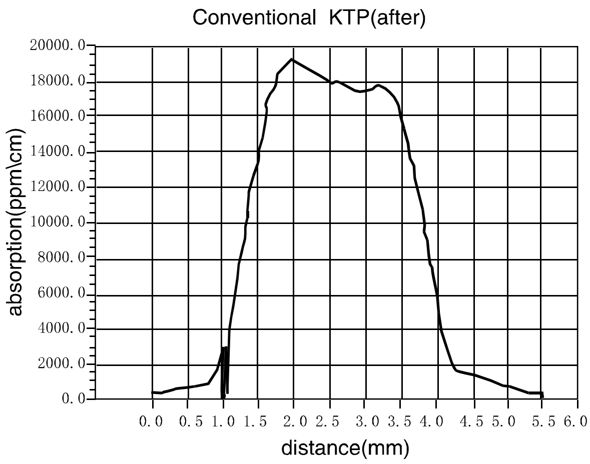



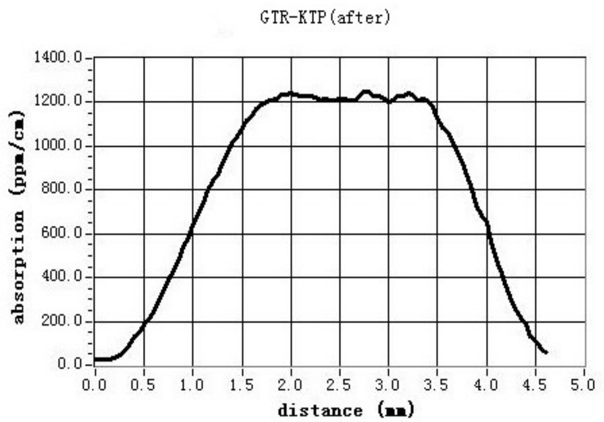
### 3. Transverse scan after gray tracking test (at 1064 nm):




### 4. Transverse scan after gray tracking test (at 532 nm) :

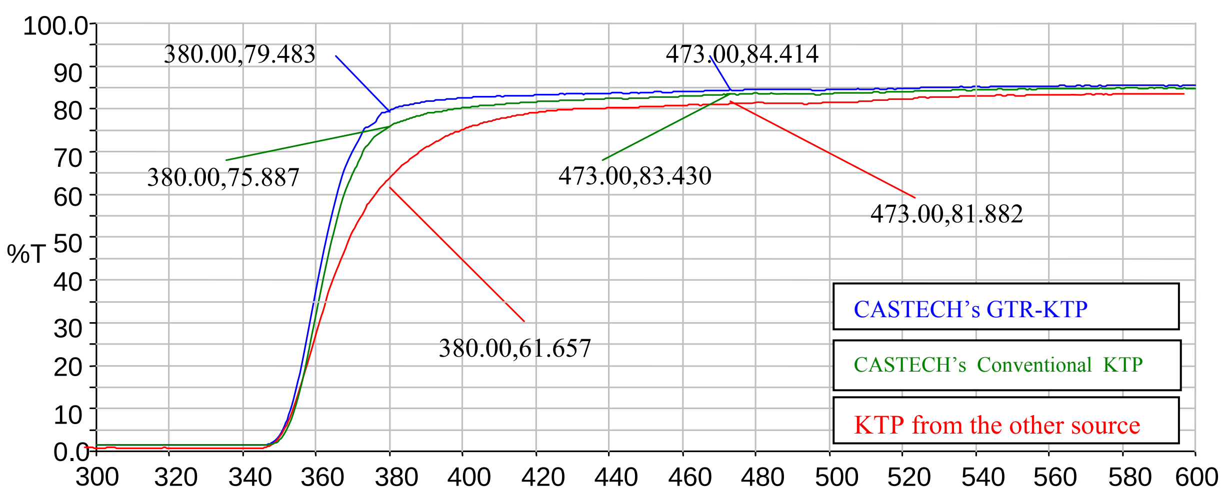



### 5. Damage threshold testing:

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

### 6. Transmission curve in the visible and UV region:



Apparently ?#?#?#??'s GTR-KTP has lower absorption than the conventional KTP in the range of 350-550nm.

We can conclude that ?#?#?#??'s GTR-KTP is expected to have a higher gray track resistance than the regular flux grown KTP crystals.

## ?#?#?#?? provides the following AR-coatings

- IBS, IAD or E-beam coating methods are available upon request.
- Dual Band AR-coating (DBAR) of GTR-KTP for SHG of 1064nm.
  low reflectance (R<0.2% at 1064nm and R<0.5% at 532nm );
  high damage threshold (>1.2GW/cm$^2$ at 1064nm, >300MW/cm$^2$ at 532nm, at 10ns, 2.5HZ) long durability.
- Broad Band AR-coating (BBAR) of GTR-KTP for OPO applications.
- High reflectivity coating: HR1064nm&HT532nm, R>99.8%@1064nm, T>95%@532nm.
- Other coatings are available upon request.

## ?#?#?#?? offers GTR-KTP with

- Strict quality control
- Large crystal size up to 7x7x20mm$^3$
- Quick delivery(2 weeks for polished only, 3 weeks for coated)
- Unbeatable price and quantity discount
- Technical support
- AR, HR-coating, mounting and re-polishing service

## CASTECH's Warranty on GTR-KTP Specifications

- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L⩾2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50mW green laser
- Flatness: less than λ/8 @ 633nm
- Transmitting wavefront distortion: less than λ/8 @ 633nm
- Chamfer: ⩽0.2mmx45$^0$
- Chip: ⩽0.1mm
- Scratch/Dig code: better than 10/5(polished only) to MIL-PRF-13830B
  better than 20/10(AR-coated) to MIL-PRF-13830B
  better than 40/20(HR-coated) to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ⩽5 arc minutes
- Angle tolerance: ⩽0.25°

# RTP Crystal

## Introduction

RTP (Rubidium Titanyle Phosphate – $RbTiOPO_4$) 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 hygroscopic and no induced piezo-electric effect with electrical signals up to 60 kHz. Its transmission range is 350nm to 4500nm.

### Basic Properties

| | |
|---|---|
| Crystal structure | Orthorhombic |
| Cell Parameters | a = 12.96 Å; b =10.56 Å; c =6.49 Å |
| Mohs hardness | About 5 |
| Density (g/cm$^3$) | 3.6 |
| Melting Point: | About 1000˚C |
| Thermal Expansion Coefficients (/K) | $\alpha_x$=1.01x10$^{-5}$, $\alpha_y$=1.37x10$^{-5}$<br>$\alpha_z$=-4.17x10$^{-6}$ |
| Sellmeier equations (λ in μm) | $n_x^2$=2.15559 + 0.93307[1-(0.20994/λ)$^2$] - 0.01452 λ$^2$<br>$n_y^2$=2.38494 + 0.73603[1-(0.23891/λ)$^2$] - 0.01583 λ$^2$<br>$n_z^2$=2.27723 + 1.11030[1-(0.23454/λ)$^2$] - 0.01995 λ$^2$ |
| Thermo-optical coefficients (dλ/dT) | -0.029 nm /$^0$C |
| Electro-optic constants(Y-cut)<br>(X-cut) | $r_{33}$=38.5 pm/V<br>$r_{33}$=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 | 4x4x20 mm: 1,600 V<br>6x6x20 mm: 2,400 V<br>9x9x20 mm: 3,600 V |
| Extinction Ratio | >20dB@633nm |

### Specifications

| | |
|---|---|
| Growing Orientation | Along Y-axis |
| Maximum length(5x5mm$^2$ aperture) | 25mm |
| Length tolerance (mm) | +0.5 / -0.1 |
| Width and height tolerance (mm) | ±0.1 |
| Parallelism | < 30 " |
| Perpendicularity | < 15' |
| Surface quality | 20/10 |
| Coating | AR-coatings |

# Potassium Titanyle Arsenate($KTiOAsO_4$, KTA)

## Introduction

Potassium Titanyle Arsenate($KTiOAsO_4$), or KTA crystal, 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 conductivities result in higher damage threshold compared with KTP .

## ?#?#?#?? offers KTA

- Crystal length from 0.1mm to 30mm and size up to 10x10x30mm
- AR-coating from visible to 3300nm
- Re-polishing, re-coating service
- Fast delivery(10 working days for polished only, 15 working days for AR-coated)

**Table 1. Basic properties**

| | |
|---|---|
| Crystal Structure | Orthorhombic, point group mm2, |
| Lattice parameter | a=13.125Å, b=6.5716Å, c=10.786Å |
| Melting point | 1130 °C |
| Mohs Hardness | near 5 |
| Density | 3.454g/$cm^3$ |
| Thermal conductivity | K1:1.8W/m/K; K2: 1.9W/m/K; K3: 2.1W/m/K |

**Table 2. Optical and Nonlinear Optical Properties**

| | | | | | |
|---|---|---|---|---|---|
| Transparency Range | 350-5300nm | | | | |
| Absorption Coefficients | @ 1064 nm <0.05 %/cm<br>@ 1533 nm <0.05 %/cm<br>@ 3475 nm <5%/cm | | | | |
| NLO susceptibilities (pm/V) | $d_{31}$ = 2.76, $d_{32}$ = 4.74, $d_{33}$ = 18.5 , $d_{15}$ = 2.3, $d_{24}$ = 3.2 | | | | |
| Sellmeier Equation<br>$N_i^2=A_i+B_i\lambda^2/(\lambda^2-C_i^2)-D_i\lambda^2$<br>(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 | ).22719 | 0.01436 |
| Electro-optical constants (pm/V)<br>(low frequency) | $r_{33}$=37.5; $r_{23}$=15.4; $r_{13}$=11.5 | | | | |
| SHG Phase Matchable Range | 1083-3789nm | | | | |

# $BiB_3O_6$ (BIBO) Crystal

## Introduction

$BiB_3O_6$ (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 ?#?#?#?? for the growth of BIBO single crystals.

## ?#?#?#?? offers

- Strict quality control;
- Large crystal size up to $10x10x15mm^3$ ;
- AR-coating, mounts and repolishing services;
- Fast delivery.

**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 =$105.62^0$, Z=2 |
| Melting Point | 726°C |
| Mohs Hardness | 5-5.5 |
| Density | 5.033 $g/cm^3$ |
| Thermal Expansion Coefficient | $\alpha_a$=4.8 x $10^{-5}$/K , $\alpha_b$= 4.4 x $10^{-6}$/K, $\alpha_c$=-2.69 x $10^{-5}$/K |

**Table 2. Optical and Nonlinear Optical Properties**

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

## ?#?#?#??'s Warranty on BIBO Specifications

- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L⩾2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- Flatness: less than $\lambda/8$ @ 633nm
- Transmitting wavefront distortion: less than $\lambda/8$ @ 633nm
- Chamfer: ⩽0.2mmx45°
- Chip: ⩽0.1mm
- Scratch/Dig code: better than 10/ 5 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ⩽5 arc minutes
- Angle tolerance: $\Delta\theta \leqslant 0.25°$, $\Delta\phi \leqslant 0.25°$
- Damage threshold[GW/cm$^2$]: >0.3 for 1064nm, TEM00, 10ns, 10HZ
- Quality Warranty Period: one year under proper use.

# Lithium Niobate Crystal ($LiNbO_3$)

## Introduction

$LiNbO_3$ Crystal is widely used as frequency doublers for wavelength >1μm and 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 substrate, and surface acoustic wave(SAW) wafers, etc. **?#?#?#??** can provide $LiNbO_3$ crystals with high quality and large size for all these applications.

### Structural and Physical Properties of $LiNbO_3$

| | |
|---|---|
| Crystal Structure: | Trigonal, Space group R3c, Point group 3m |
| Cell Parameters: | a=5.148 Å , c=13.863 Å |
| Melting Point: | 1253°C |
| Curie Temperature: | 1140°C |
| Mohs Hardness: | 5 |
| Density: | 4.64 g/cm$^3$ |
| Elastic Stiffness Coefficients | $C^E_{11}$ =2.33(×$10^{11}$N/m$^2$ )<br>$C^E_{33}$ =2.77(×$10^{11}$N/m$^2$ ) |

### Optical and Electro-optical Properties of $LiNbO_3$

| | |
|---|---|
| Transparency Range: | 420-5200nm |
| Optical Homogeneity: | ~ 5 x $10^{-5}$ /cm |
| Refractive indices at 1064nm: | $n_e$ = 2.146, $n_o$ = 2.220 @ 1300 nm<br>$n_e$ = 2.156, $n_o$ = 2.232 @ 1064 nm<br>$n_e$ = 2.203, $n_o$ = 2.286 @ 632.8 nm |
| NLO Coefficients: | $d_{33}$ = 86 x $d_{36}$ (KDP)<br>$d_{31}$ =11.6 x $d_{36}$ (KDP)<br>$d_{22}$ = 5.6 x $d_{36}$ (KDP) |
| Effective NLO Coefficients: | $d_{eff}(I)=d_{31}\sin\theta-d_{22}\cos\sin3\phi$<br>$d_{eff}(II)=d_{22}\cos^2\theta\cos3\phi$ |
| Electro-Optic Coefficients | $\gamma^T_{33}$ = 32 pm/V, $\gamma^S_{33}$ = 31 pm/V,<br>$\gamma^T_{31}$ =10 pm/V, $\gamma^S_{31}$=8.6 pm/V,<br>$\gamma^T_{22}$ = 6.8 pm/V, $\gamma^S_{22}$= 3.4 pm/V, |
| Half-Wave Voltage, DC<br>Electrical field // z, light ⊥ z:<br>Electrical field // x or y, light // z: | <br>3.03 KV<br>4.02 KV |
| Damage Threshold | 100 MW/cm$^2$ (10 ns, 1064nm) |

### Thermal and Electrical Properties of $LiNbO_3$

| | |
|---|---|
| Melting Point: | 1250°C |
| Curie Temperature: | 1140°C |
| Thermal Conductivity: | 38W/m/K @25°C |
| Thermal Expansion Coefficients (at 25°C): | //a, $2.0\times10^{-6}$/K<br>//c, $2.2\times10^{-6}$/K |
| Resistivity: | $2\times10^{-6}$ Ω·cm @200°C |
| Dielectric Constants: | $\varepsilon^S_{11}/\varepsilon_0=43$  $\varepsilon^T_{11}/\varepsilon_0=78$<br>$\varepsilon^S_{33}/\varepsilon_0=28$  $\varepsilon^T_{33}/\varepsilon_0=32$ |
| Piezoelectric Strain Constant: | $D_{22}=2.04(\times10^{-11}C/N)$<br>$D_{33}=19.22(\times10^{-11}C/N)$ |

**The Sellmeier equations (λ in μm) :**

$$n_o^2 = 4.9048 + 0.11768/(\lambda^2 - 0.04750) - 0.027169\lambda^2$$

$$n_e^2 = 4.5820 + 0.099169/(\lambda^2 - 0.04443) - 0.02195\lambda^2$$

## Specifications

- Transmitting wavefront distortion: less than λ/4 @ 633 nm
- Dimension tolerance: (W ± 0.1 mm) x (H ± 0.1 mm) x (L ± 0.2mm)
- Clear aperture: > 90% central area
- Flatness: λ/8 @ 633 nm
- Scratch/Dig code: 20/10 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: 5 arc minutes
- Angle tolerance: < ± 0.5°
- AR coating: dual wave band AR coating at 1064/532 nm on both surfaces, with R < 0.2% at 1064nm and R < 0.5% at 532nm per surface.

Other coatings are available upon request.

# Magnesium Doped Lithium Niobate $MgO:LiNbO_3$

## 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 doublers and integrated waveguide.

## $MgO:LiNbO_3$ is characterized by

- High damage threshold
- Noncritical 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 5mol% MgO dopant) are ( λ in μm):

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

Different dimensions of $MgO:LiNbO_3$ with high quality are available from ?#?#?#??. The AR coating is available upon request.

# Potassium Dihydrogen Phosphate (KDP) and Potassium Dideuterium Phosphate (DKDP or KD*P)

## Introduction

Potassium Dihydrogen Phosphate (KDP) and Potassium Dideuterium Phosphate (KD*P ) 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.

## ?#?#?#??'s KDP & KD*P products

**?#?#?#??**supplies high quality KDP and KD*P 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, **?#?#?#??** also provides polishing 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.

**Basic Properties**

| | KDP | KD*P |
|---|---|---|
| Chemical Formula | $KH_2PO_4$ | $KD_2PO_4$ |
| Transparency Range | 200-1500nm | 200-1600nm |
| Nonlinear Coefficients | $d_{36}$=0.44pm/V | $d_{36}$=0.40pm/V |
| Refractive index (at 1064nm) | $n_o$=1.4938, $n_e$=1.4599 | $n_o$=1.4948, $n_e$=1.4554 |
| Electro-optical Coefficients | $r_{41}$=8.8pm/V<br>$r_{63}$=10.3pm/V | $r_{41}$=8.8pm/V<br>$r_{63}$=25pm/V |
| Longitudinal half-wave voltage: | $V_\pi$=7.65KV(λ=546nm) | $V_\pi$=2.98KV(λ=546nm) |
| Absorptance: | 0.07/cm | 0.006/cm |
| Optical damage threshold: | >5 GW/cm$^2$ | >3 GW/cm$^2$ |
| Extinction ratio: | | 30dB |
| Sellmeier equations of KDP: (λ in µm) | | |
| $n_o^2 = 2.259276 + 0.01008956/(\lambda^2 - 0.012942625) + 13.00522\lambda^2/(\lambda^2 - 400)$<br>$n_e^2 = 2.132668 + 0.008637494/(\lambda^2 - 0.012281043) + 3.2279924\lambda^2/(\lambda^2 - 400)$ | | |
| Sellmeier equations of DKDP: (λ in µm) | | |
| $n_o^2 = 1.9575544 + 0.2901391\lambda^2/(\lambda^2 - 0.0281399) - 0.02824391\lambda^2 + 0.004977826\lambda^4$<br>$n_e^2 = 1.5005779 + 0.6276034\lambda^2/(\lambda^2 - 0.0131558) - 0.01054063\lambda^2 + 0.002243821\lambda^4$ | | |

# Lithium Iodate ($LiIO_3$)

## Introduction

$LiIO_3$ crystal is one of the oldest commercial NLO crystals. For the high NLO coefficient. $LiIO_3$ is used for frequency-doubling, tripling and mixing of low and medium power lasers.

**?#?#?#??** provides large size of $LiIO_3$ crystals with high optical homogeneity. They may be as-cut and polished. And sealed housing with AR-coated windows is also available.

### Basic Properties

| | |
|---|---|
| Point Group | 6 |
| Transparency Range | 300-5000nm |
| Nonlinear coefficient | $d_{15} = -5.5\times10^{-12}$m/V |
| Refractive Index | negative uniaxial<br>$n_o$=1.8571, $n_e$=1.7165 ($\lambda$=1064nm) |
| Sellmeier Equations: ($\lambda$ in $\mu$m) | |

$$n_o^2 = 3.415716 + 0.047031/(\lambda^2 - 0.035306) - 0.008801\lambda^2$$
$$n_e^2 = 2.918692 + 0.035145/(\lambda^2 - 0.028224) - 0.003641\lambda^2$$

## Notes to the user of $LiIO_3$

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

## Crystal Specifications

- Transmitting wavefront distortion: less than $\lambda/4$ @ 633 nm
- Dimension tolerance: (W ± 0.2 mm) x (H ± 0.2 mm) x (L + 0.5 /-0.2mm)
- Clear aperture: > 90% central area
- Flatness: $\lambda/4$ @ 633 nm
- Scratch/Dig code: 20/10 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: 5 arc minutes
- Angle tolerance: < ± 0.5°
- Quality Warranty Period: one year under proper use.

# Neodymium Doped Yttrium Orthovanadate (Nd:$YVO_4$)

## Introduction

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 outputs are required.

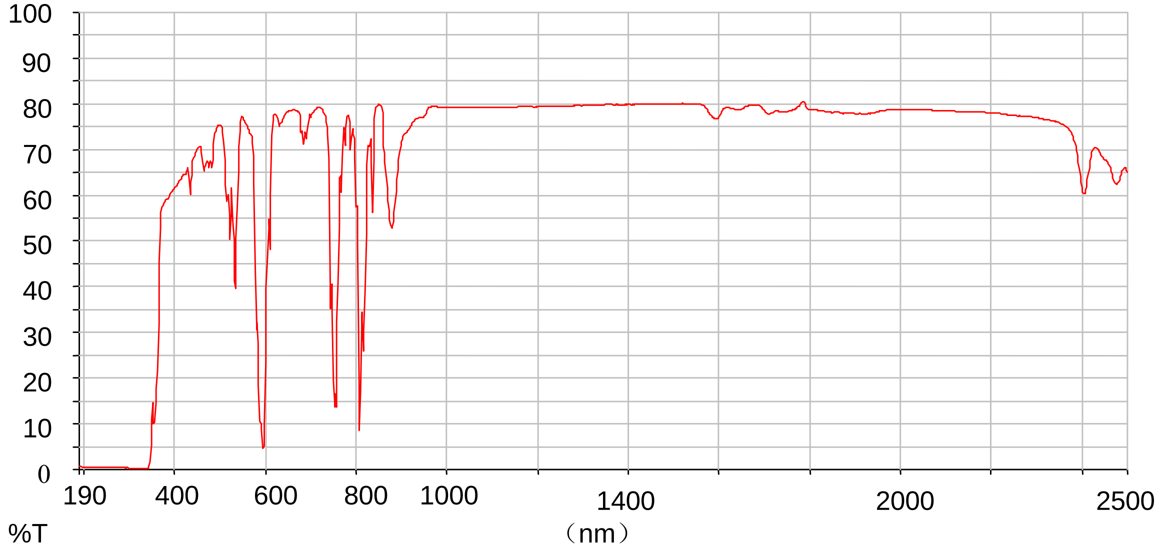
## Nd:$YVO_4$ 's advantages over Nd:YAG

- 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 1064nm
- Lower lasing threshold and higher slope efficiency
- As a uniaxial crystal with a large birefringence, the emission is only a linearly polarized.

## ?#?#?#?? Provides

- Various doping concentration from 0.1% to 3%.
- Doping concentration tolerance: ±0.05%(atm%<1%), ±0.1%(atm%≥1%)
- Various size bulk and finished high quality Nd:$YVO_4$ crystals up to ϕ35x50mm$^3$ and ϕ20x20mm$^3$, respectively;
- 10,000 pcs of Nd:$YVO_4$ devices per month in sizes 3x3x0.5 to 4x4x8mm
- With quick delivery
- With competitive price.

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



## Basic Properties

| | |
|---|---|
| Crystal Structure:<br>Cell Parameter: | Zircon Tetragonal, space group $D_{4h}$-I4/amd<br>a=b=7.1193 Å, c=6.2892 Å |
| Density: | 4.22g/$cm^3$ |
| Atomic Density: | 1.26x$10^{20}$ atoms/$cm^3$ (Nd 1.0%) |
| Mohs Hardness: | 4-5 (Glass-like) |
| Thermal Expansion Coefficient (300K): | $\alpha_a$=4.43x$10^{-6}$/K<br>$\alpha_c$=11.37x$10^{-6}$/K |
| Thermal Conductivity Coefficient (300K): | //C: 0.0523W/cm/K<br>⊥C: 0.0510W/cm/K |
| Lasing wavelength: | 1064nm, 1342nm |
| Thermal optical coefficient (300K): | $dn_o/dT=8.5\times10^{-6}$/K<br>$dn_e/dT=2.9\times10^{-6}$/K |
| Stimulated emission cross-section: | $25\times10^{-19}cm^2$ @1064nm |
| Fluorescent lifetime: | 90μs (1% Nd doped) |
| Absorption coefficient: | 31.4$cm^{-1}$ @810nm |
| Intrinsic loss: | 0.02$cm^{-1}$ @1064nm |
| Gain bandwidth: | 0.96nm @1064nm |
| Polarized laser emission: | π polarization; parallel to optical axis (c-axis) |
| Diode pumped optical to optical efficiency: | >60% |
| Sellmeier equations (λ in μm) | $n_o^2=3.77834+0.069736/(\lambda^2-0.04724)-0.010813\lambda^2$<br>$n_e^2=4.59905+0.110534/(\lambda^2-0.04813)-0.012676\lambda^2$ |

## 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 808nm 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-sections, both at 1064nm and 1342nm. When a-axis cut Nd:$YVO_4$ crystal lasing at 1064m, it is about 4 times higher than that of Nd:YAG, while at 1340nm the stimulated cross-section is 18 times larger, which leads to a CW operation completely outperforming Nd:YAG at 1320nm. 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 ( $η_s$).

**Laser Properties of Nd:$YVO_4$ vs Nd:YAG**

| LASER CRYSTAL | DOPING (atm%) | σ ($x10^{-19}cm^2$) | α ($cm^{-1}$) | τ (μs) | $L_α$ (mm) | $P_{th}$ (mW) | $η_S$ (%) |
|---|---|---|---|---|---|---|---|
| Nd:$YVO_4$(a-cut) | 1.0<br>2.0 | 25<br>25 | 31.2<br>72.4 | 90<br>50 | 0.32<br>0.14 | 30<br>78 | 52<br>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 |

**Typical Results**

- Diode pumped Nd:$YVO_4$ laser output comparing with diode pumped Nd:YAG laser.

| Crystals | Size ($mm^3$) | Pump Power | Output (at 1064nm) |
|---|---|---|---|
| Nd:$YVO_4$ | 3x3x1 | 850mW | 350mW |
| Nd:$YVO_4$ | 3x3x5 | 15W | 6W |
| Nd:YAG | 3x3x2 | 850mW | 34mW |

- Diode pumped Nd:YVO4+KTP green laser.
- 8W green laser was generated from a 15W LD pumped 0.5%Nd:$YVO_4$ with intracavity KTP.
- 200mW green outputs are generated from 1 W LD pumped 2%Nd:$YVO_4$ lasers by using CASTECH's 2x2x5mm KTP and 3x3x1mm Nd:$YVO_4$.

## ?#?#?#?? provides the following coatings

- Both ends AR/AR-1064/808nm, R<0.2%@1064nm,R<2%@808nm
- S1:HR@1064&532 nm,HT808 nm, R>99.8%@1064&532nm,T>90%@808nm
  S2:AR@1064&532 nm, R<0.2%@1064nm,R<0.5%@532nm
- S1:HR@1064,HT808, R>99.8%@1064nm,T>95%@808nm
  S2:AR@1064, R<0.1%@1064nm.
- S1,S2 AR-coated, S3:gold/chrome plated.
- Both ends AR/AR-1064 nm; S3:AR-808 nm
- Other coatings are available upon request.

## CASTECH's Warranty on $Nd:YVO_4$ Specifications

- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L≥2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.2/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- Flatness: less than λ/8 @ 633nm (L≥2.5mm); less than λ/4 @ 633nm (L<2.5mm)
- Transmitting wavefront distortion: less than λ/4 @ 633nm
- Chamfer: ≤0.2mm@$45^0$
- Chip: ≤0.1mm
- Scratch/Dig code: better than 10/ 5 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: ≤0.5°
- Damage threshold[$GW/cm^2$ ]: >1 for 1064nm, TEM00, 10ns, 10Hz (AR-coated)
- Quality Warranty Period: one year under proper use.

# Neodymium Doped Gadolinium Orthovanadate ($Nd:GdVO_4$)

## 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.

### Specifications

| | |
|---|---|
| Crystal structure | Tetragonal |
| Space Group | $I4_1/amd$ |
| Lattice parameter | a=0.721nm, b=0.635nm |
| Lasing Transition | $^4F_{3/2} \rightarrow {}^4I_{11/2}$ |
| Lasing wavelength | 1062.9nm |
| Emission Cross Section (at 1064nm) | $7.6x10^{-19}$ $cm^2$ |
| Absorption Cross Section (at 808nm) | $4.9x10^{-19}$ $cm^2$ |
| Absorption Coefficient (at 808nm) | $74cm^{-1}$ |
| Index of Refractivity (at 1064nm) | $n_o$=1.972, $n_e$=2.192 |
| Thermal Conductivity (<110>) | 11.7W/m/K |
| Density | $5.47g/cm^3$ |
| Nd Dopant level (atomic) | 0.1%, 0.2%, 0.3%, 0.5%, 0.7%, 1.0%... |

### 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 constants (nm) | a:0.721 b:0.635 | | a:0.721 b:0.629 | |
| Melting temperature($^0C$) | 1780 | | 1825 | |
| Thermal expansion @$25^0C$, $x10^{-6}/^0C$ | a | 1.5 | a | 4.43 |
| | b | 7.3 | b | 11.4 |
| Specific heat @$25^0C$, cal/mol·K | 32.6 | | 24.6 | |
| dn / dT, $x10^{-6}$ $/^0C$ | 4.7 | | 2.7 | |

## Information Regarding Neodymium Laser Host Crystals

| Crystal | $Nd:YVO_4$ | $Nd:GdVO_4$ | Nd:YAG |
|---|---|---|---|
| Laser wavelengths | 1064.3nm,1342.0 nm | 1062.9 nm,1340 nm | 1064.2 nm,1338.2 nm |
| Emission bandwidth (linewidth at 1064 nm) | 0.8nm | No data | 0.45nm |
| Effective laser cross section (emission cross section at 1064 nm) | $15.6 \times 10^{-19}$ $cm^2$ | $7.6 \times 10^{-19} cm^2$ | $6.5 \times 10^{-19} cm^2$ |
| Polarization | Parallel to c-axis | Parallel to c-axis | unpolarized |
| Radioactive lifetime (microseconds) at 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, W/m/K | 5.1 | 11.7 | 14 |
| Doping concentration range | 0.1 - 3.0% | 0.1 - 3.0% | 0.1-2.0% |

## ?#?#?#?? Warranty on $Nd:GdVO_4$ Specifications

- Transmitting wavefront distortion: less than λ /4 @ 633nm
- Dimension tolerance:(W±0.1mm)x(H±0.1mm)x(L+0.2/-0.1 mm)
- Clear aperture:>90% central area
- Flatness: λ /8 @ 633 nm, and λ /4 @ 633nm for thickness less than 2mm
- Scratch/Dig code: 10/5 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: 5 arc minutes
- Angle tolerance:<±0.5°
- AR coating: R<0.2% at 1064nm,
- HR coating: R>99.8%@1064nm, T>95%@808nm
- Quality Warranty Period: one year under proper use.

# Neodymium Doped Yttrium Aluminum Garnet (Nd:YAG ) Crystal

## Introduction

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.

## Advantages Of Nd:YAG

- 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)

**Basic Properties**

| | |
|---|---|
| Crystal structure: | Cubic |
| Lattice constant: | 12.01 Å |
| Melting point: | 1970°C |
| Density: | 4.5g/cm$^3$ |
| Reflective Index: | 1.82 |
| Thermal Expansion Coefficient: | 7.8x10$^{-6}$ /K <111>, 0-250 °C |
| Thermal Conductivity (W/m/K): | 14, 20°C<br>10.5, 100°C |
| Mohs hardness: | 8.5 |
| Stimulated Emission Cross Section: | 2.8x10$^{-19}$ cm$^{-2}$ |
| Relaxation Time of Terminal Lasing Level: | 30 ns |
| Radiative Lifetime: | 550 µs |
| Spontaneous Fluorescence: | 230 µs |
| Linewidth: | 0.6 nm |
| Loss Coefficient: | 0.003 cm$^{-1}$ @1064nm |

## Specifications of Nd:YAG crystal from ?#?#?#??

- Dimention: size up to dia.15x180mm and maximum diameter of dia.40mmx2mm
- Nd Dopant Level: 0.3~2.0(±0.1)atm%
- Diameter tolerance: ±0.05mm
- Length tolerance: ±0.5mm
- Perpendicularity: < 5 arc minutes
- Parallelism: <10 arc seconds
- Wavefront distortion: λ/8
- Flatness: λ/10
- Scratch/Dig: 10/5 @MIL-PRF-13830B
- Chamfer: 0.1mmx45°
- HR-Coating: R>99.8%@1064nm and R<5%@808nm
- AR-Coating (Single layer $MgF_2$): R<0.25%@1064nm
- Other HR coatings, such as HR@1064/532 nm, HR@946 nm, HR@1319 nm and other wavelengths are also available.
- Damage Threshold: >500MW/$cm^2$

| Optical Parameter of Nd:YAG crystal | | | |
|---|---|---|---|
| Diameter (mm) | Standard grade | Excellence grade | Superexcellence grade |
| ϕ 3-6.35 | ⩽0.5 fringes/inch | ⩽0.25 fringes/inch | ⩽0.1 fringes/inch |
| | ⩾25dB | ⩾28dB | ⩾30dB |
| ϕ 7-10 | ⩽0.7 fringes/inch | ⩽0.4 fringes/inch | ⩽0.16 fringes/inch |
| | ⩾22dB | ⩾25dB | ⩾28dB |
| ϕ 11-13 | ⩽1 fringes/inch | ⩽0.6 fringes/inch | ⩽0.2 fringes/inch |
| | ⩾20dB | ⩾23dB | ⩾26dB |
| ϕ 14-16 | ⩽1.2 fringes/inch | ⩽0.8 fringes/inch | ⩽0.25 fringes/inch |
| | ⩾18dB | ⩾20dB | ⩾23dB |

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.

# Chromium Doped Yttrium AIuminum Garnet Crystal ($Cr^{4+}$:YAG)

## Introduction

$Cr^{4+}$:YAG Crystal 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 materials, such as LiF, organic Dye and color centers.

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

**Basic Properties of $Cr^{4+}$:YAG**

| | |
|---|---|
| Crystal Structure | Cubic |
| Dopant Level | 0.5 mol% ~ 3 mol% |
| Hardness | 8.5 |
| Damage Threshold | > 500 MW/$cm^2$ |
| Refractive Index | 1.82 @ 1064 nm |

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

$Cr^{4+}$: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 Cr4+:YAG crystal, please specify the size, initial transmission and coatings. For further information, please contact ?#?#?#??.

# Ho:Cr:Tm:YAG

## Introduction

**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.

## Advantages of Ho:Cr:Tm:YAG Crystal

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

### Optical and Spectral Properties of Ho:Cr:Tm:YAG Crystals

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

### Specifications of Ho:Cr:Tm:YAG crystal from ?#?#?#??

| | |
|---|---|
| Dopant concentration | Ho:~0.35 at%, Tm:~5.8at%, Cr:~1.5at% |
| Wavefront Distortion | ≤ 0.125 λ /inch(@1064nm) |
| Extinction Ratio | ≥25 dB |
| Rod Sizes | Diameter:3~6mm,Length:50~120mm Upon request of customer |
| Dimensional Tolerances | Diameter:+0.00/-0.05mm, Length: ± 0.5mm |
| Barrel Finish | Ground Finish: 400# Grit |
| Parallelism | ≤30" |
| Perpendicularity | ≤5′ |
| Flatness | λ /10 |
| Surface Quality | 10/5 |
| Chamfer | 0.006"±0.002" at 45$^0$± 5° |
| AR Coating Reflectivity | ≤ 0.25% (@2094nm) |

# Nd:Ce:YAG

## Introduction

In double doped Nd:Ce:YAG crystals Cerium are chosen as sensitizer for Nd3+ ions because of its strong absorption in UV spectral region at flash lamp pumping and efficient energy transfer to the Nd3+ 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 to 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.

## Advantages of Nd:Ce:YAG Crystal

1、High efficiency
2、Low threshold
3、Good anti-violet radiation property
4、Good thermal stability
5、High optical quality

### Optical and Spectral Properties of Nd:Ce:YAG Crystal

| | |
|---|---|
| Laser Transition | $^4F_{3/2}$--> $^4I_{11/2}$ |
| Laser Wavelength | 1.064μm |
| Photon Energy | $1.86\times10^{-19}$J@1.064μm |
| Emission Linewidth | 4.5Å @1.064μm |
| Emission Cross Section (Nd1at%) | 2.7~$8.8\times10^{-19}cm^{-2}$ |
| Fluorescence Lifetime (Nd1at%) | 230μs |
| Index of Refraction | 1.8197@1064nm |

### Specifications of Nd:Ce:YAG crystal from ?#?#?#??

| | |
|---|---|
| Dopant concentration | Nd:1.1～1.4at%,Ce:0.05～0.1at% |
| Wavefront distortion | ≤ 0.2λ/inch |
| Extinction Ratio | ≥28 dB |
| Rod Sizes | Diameter:3～6mm,Length:40～80mm, Upon request of customer |
| Dimensional Tolerances | Diameter+0.000″/-0.002″,Length ±0.02″ |
| Barrel Finish | Ground Finish: 400# Grit |
| Parallelism | ≤10″ |
| Perpendicularity | ≤5′ |
| Flatness | λ/10 |
| Surface quality | 10-5(MIL-PRF-13830B) |
| Chamfer | 0.006″±0.002″ at 45° ± 5° |
| AR coating reflectivity | ≤ 0.25% (@1064nm) |

# Yb:YAG

## Introduction

**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 1030nm is a good substitute for a Nd:YAG crystal at 1064nm and its second harmonic at 515nm may replace Ar-ion laser (with a large volume), which emit at 514nm.

## Advantages of Yb:YAG Crystal

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

### Material and Specifications

| | |
|---|---|
| Dopant concentration | Yb: 5~15 at% |
| Wavefront Distortion | ≤ 0.125 λ /inch |
| Extinction Ratio | ≥28 dB |
| Rod Sizes | Diameter:2~20mm, Length:5~150mm<br>Upon request of customer |
| Dimensional Tolerances | Diameter:+0.00"/-0.002"mm,<br>Length: ± 0.02" |
| Barrel Finish | Ground Finish: 400# Grit |
| Parallelism | ≤10" |
| Perpendicularity | ≤5′ |
| Flatness | λ /10 |
| Surface Quality | 10-5(MIL-PRF-13830B) |
| Chamfer | 0.006"±0.002" at $45^0$± 5° |
| AR Coating Reflectivity | ≤ 0.25% (@1030nm) |
| Single pass loss | $<3\times10^{-3}cm^{-1}$ |

## Optical and Spectral Properties of Yb:YAG Crystal

| | |
|---|---|
| Laser Transition | $^2F_{5/2} \rightarrow {}^2F_{7/2}$ |
| Laser Wavelength | 1030nm |
| Photon Energy | $1.93\times10^{-19}$J(@1030nm) |
| Emission Linewidth | 9nm |
| Emission Cross Section | $2.0\times10^{-20}cm^2$ |
| Fluorescence Lifetime | 1.2 ms |
| Diode Pump Band | 940nm or 970nm |
| Pump Absorption Band Width | 8 nm |
| Index of Refraction | 1.82 |
| Thermal Optical Coefficient | $9\times10^{-6}/^0C$ |
| Loss Coefficient | 0.003 $cm^{-1}$ |

# Er:YAG

## Introduction

**Er:YAG** is an excellent laser crystal which lases at 2940 nm. This wavelength is the most readily absorbed into water and hydroxylapatite of all existing wavelengths and is considered a highly surface cutting laser. It has wide applications in medical applications, such as dental (hard tissues), orthopedics, etc.

## Advantages of Er:YAG Crystal

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

### Material and Specifications

| | |
|---|---|
| Dopant concentration | Er: ~50 at% |
| Wavefront Distortion | ≤0.125 λ /inch(@1064nm) |
| Extinction Ratio | ≥25 dB |
| Rod Sizes | Diameter:3~6mm, Length:50~120 mm<br>Upon request of customer |
| Dimensional Tolerances | Diameter:+0.000"/-0.002",<br>Length: ± 0.02" |
| Barrel Finish | Ground Finish: 400# Grit |
| Parallelism | ≤10" |
| Perpendicularity | ≤5′ |
| Flatness | λ /10 |
| Surface Quality | 10-5(MIL-PRF-13830B) |
| Chamfer | 0.006"±0.002" at $45^0$± 5° |
| AR Coating Reflectivity | ≤ 0.25% (@2940nm) |

### Optical and Spectral Properties of Er:YAG Crystal

| | |
|---|---|
| Laser Transition | $^4I_{11/2}$ to $^4I_{13/2}$ |
| Laser Wavelength | 2940nm |
| Photon Energy | $6.75\times10^{-20}$J(@2940nm) |
| Emission Cross Section | $3\times10^{-20}$ cm$^2$ |
| Index of Refraction | 1.79 @2940nm |
| Pump Bands | 600~800 nm |

# Nd:YLF Crystal

## Introduction

?#?#?#?? 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 assures that each crystal will perform well.

### Optical Properties

| | |
|---|---|
| Transparency Range: | 180 - 6700 nm |
| Peak Stimulated Emission Cross Section | $1.8\times10^{-19}/cm^2$(E ‖ c) at 1047nm<br>$1.2\times10^{-19}/cm^2$(E ⊥ c) at 1053nm |
| Spontaneous Fluorescence Lifetime | 485 μs for 1% Nd doping |
| Scatter Losses | <0.2%/cm |
| Peak Absorption Coefficient(for 1.2% Nd) | $\alpha = 10.8cm^{-1}$ (792.0 nm E ‖ c)<br>$\alpha = 3.59cm^{-1}$ (797.0 nm E ⊥ c) |
| Laser Wavelength | 1047nm (‖ c, a-cut crystal)<br>1053nm(⊥ c, a or c-cut crystal) |

### Physical Properties

| | |
|---|---|
| Chemical Formula | $LiY_{1.0-x}Nd_xF_4$ |
| Space Group | $I4_1/a$ |
| Nd atoms/cm³ | $1.40 \times 10^{20}$ atoms/cm³ for 1% Nd doping |
| Modulus of Elasticity | 85 GPa |
| Crystal Structure: | Tetragonal |
| Cell Parameters: | a=5.16 Å , c=10.85 Å |
| Melting Point: | 819°C |
| Mohs Hardness: | 4~5 |
| Density: | 3.99 g/cm³ |
| Thermal Conductivity | 0.063 W/cm/K |
| Specific Heat | 0.79 J/g/K |
| Thermal Expansion Coefficients | $8.3\times10^{-6}$/k ‖c<br>$13.3\times10^{-6}$/ k ⊥ c |

### 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 | 1.470 |
| 2065 | 1.442 | 1.464 |

### dn/dT

| Wavelength(nm) | E ‖ c | E ⊥ c |
|---|---|---|
| 436 | $-2.44 \times 10^{-6}/^0C$ | $-0.54 \times 10^{-6}/^0C$ |
| 578 | $-2.86 \times 10^{-6}/^0C$ | $-0.91 \times 10^{-6}/^0C$ |
| 1060 | $-4.30 \times 10^{-6}/^0C$ | $-2.00 \times 10^{-6}/^0C$ |

### The Sellmeier equations (λ in μm):

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

## CASTECH's general Nd:YLF production capabilities including

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

### Specifications

| | |
|---|---|
| Standard Dopant | 1.1 ± 0.1% |
| Wavefront Distortion | < λ /4 per inch @633nm |
| Parallelism | <10 arc seconds |
| Perpendicularity | <5 arc minutes |
| Chamfer | 0.13 ± 0.07mm @45° |
| Surface Quality | 10/5 |
| End Coating | R<0.15%@1047/1053nm |
| Surface Flatness | λ /8 @632.8nm |

# Titanium Doped Sapphire Crystal (Ti: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. ?#?#?#?? possesses the advanced growth method of Temperature Gradient Technique (TGT), and it supplies large-sized (Dia.30x30mm) 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 ( $\alpha_{490} = 4.0 cm^{-1}$), 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 10fs.
- Ti:Sapphire is also widely used as the pump source of OPOs to expand the tunable range.

**Basic Properties**

| | |
|---|---|
| Chemical formula: | $Ti^{3+}:Al_2O_3$ |
| Crystal structure: | Hexagonal |
| Lattice constants: | a=4.758Å, c=12.991Å |
| Density: | 3.98 g/cm$^3$ |
| Melting point: | 2040$^o$C |
| 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: | $3\sim4\times10^{-19}cm^2$ |
| Thermal Expansion: | $8.40\times10^{-6}$/℃ |

## Standard product specifications

- Orientation: Optical axis C normal to rod axis
- $Ti_2O_3$ concentration: 0.06 - 0.26atm %
- Figure Of Merit (FOM): 100~250 (>250 available upon special requests)
- $\alpha_{490}$: 1.0~4.0cm$^{-1}$
- Diameter: 2~30mm or specified
- Path Length: 2~30mm or specified
- End configurations: Flat/Flat or Brewster/Brewster ends
- Flatness: <λ/10 @ 633 nm
- Parallelism: <10 arc sec
- Surface finishing: <40/20scratch/dig to MIL-PRF-13830B
- Wavefront distortion: <λ/4 per inch

**Note: AR Coating is available upon request.**

# Cr-doped Colquiriite (Cr:LiSAF)

## Introduction

?#?#?#?? provides high quality, Cr-doped Colquiriite crystal (Cr:LiSAF) using the Czochralski technique. It is excellent laser material with high energy storage and high slope efficiency. It is also 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.

## Physical and Optical Properties

### Physical Properties

| | |
|---|---|
| Chemical Formula | $Cr^{3+}$:$LiSrAlF_6$ |
| Lattice Parameters(Å) | a=5.084 |
| | c=10.21 |
| Crystal structure | trigonal |
| Space Group | P$\bar{3}$1c |
| Cr atoms/$cm^3$ for 1% doping | 8.75x$10^{19}$ |
| Fracture Toughness(Mpam) | 0.40( ‖ c) |
| Melting Point (℃) | 766 |
| Density(g/$cm^3$) | 3.45 |
| Modulus of Elasticity(GPa) | 109 |
| Thermal Expansion | -10( ‖ c) |
| Coefficient ($10^{-6}$ / K) | 25(⊥c) |
| Thermal Conductivity (W/m/K) | 3.3( ‖ c) |
| | 3.0(⊥ c) |
| Specific Heat(J/g·K) (@25℃) | 0.842 |

### Optical Properties

| | |
|---|---|
| Emission Peak(nm) | 846 |
| Peak Stimulated Emission Cross Section(×$10^{-20}$$cm^2$) | 4.8( ‖ c) |
| Spontaneous Fluorescence Lifetime(μs) | 67 |
| Scatter Losses(%/cm) | <0.2 |
| dn/dT(×$10^{-6}$/ $^0$C) | -4.8( ‖ c) |
| | -2.5(⊥c) |

**The 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:LiSAF | 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:LiSAF

- Size: Rod sizes from 2mm to 16mm in diameter and from 1mm to 180mm in length
- Cr dopant concentrations: 0.5~1.0 mol%
- Parallelism: <10 arc seconds
- Perpendicularity: <5 arc minutes
- Chamfer: 0.13±0.07mm X 45°
- Scratch/Dig code: 10/5 to MIL-PRF-13830B
- Flatness: λ/8 @ 632.8nm
- AR coating: R<0.10% @ 850nm

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

# Nd:KGW

## Introduction

Neodymium doped Potassium-Gadolinium Tungstate crystals (Nd:KGd$(WO_4)_2$ or Nd:KGW) is an excellent laser gain material which has low laser oscillations threshold and higher 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 808nm of $Nd^{3+}$ in the KGW which has 12nm FWHM is well matched with the emission wavelength of current commercial laser diode.

### Basic Properties

| | |
|---|---|
| Crystal structure | monoclinic |
| Space group | $C_{2h}$(2/c)-C2/c |
| Cell Parameters | a = 8.087 Å; b = 10.374 Å; c = 7.588 Å<br>ß=94.41˚ |
| Refractive index, at 1067 nm | $n_g$ = 2.049; $n_p$ = 1.978; $n_m$ = 2.014 |
| Mohs hardness | 5 |
| Density, $g/cm^3$ | 7.27 |
| Melting Point | 1075˚C |
| Thermal conductivity at 373K, W x $cm^{-1}$ x $K^{-1}$ | $K_{[100]}$ = 0.026; $K_{[010]}$= 0.038; $K_{[001]}$ = 0.034 |
| Young's modulus, GPa | $E_{[100]}$ = 115.8; $E_{[010]}$= 152.5; $E_{[001]}$ = 92.4 |
| Thermal expansion coefficient, at 373K | $\alpha_{[100]}$ = 4 x $10^{-6}K^{-1}$; $\alpha_{[010]}$= 1.6 x $10^{-6}K^{-1}$; $\alpha_{[001]}$= 8.5 x $10^{-6}K^{-1}$ |
| Lasing Wavelength | 911nm,1067nm,1351nm |
| Absorption band | 808nm (FWHM 12nm) |
| Fluorescent lifetime | 110 µs (3% doping), 90 µs (8% doping) |

### Laser Properties

| | | |
|---|---|---|
| 3%Nd:KGW | Emission wavelength | 1070nm |
| | Emission bandwidth | 15nm |
| | Stimulated emission cross-section $\sigma_e$($x10^{-20}cm^2$) | 1.48 |
| | Fluorescent lifetime (µs) | 109 |
| | Gain bandwidth | 15nm |
| | Absorption wavelength | 810nm |
| | Absorption bandwidth | 14nm |
| | Absorption cross-section $\sigma_\alpha$ ($x10^{-20}cm^2$) | 1.28 |

## Specifications of Nd:KGW

| | |
|---|---|
| Orientation | [010] |
| Standard Dopant concentration (at. %) | 3%, 5%, 8% |
| Maximum length | 50mm |
| Length tolerance, mm | +1.0 / -0.0 |
| Diameter tolerance, mm | +/-0.1 |
| Parallelism | < 30″ |
| Perpendicularity | < 15' |
| Surface quality | 20/10 |
| coating | AR-coated |

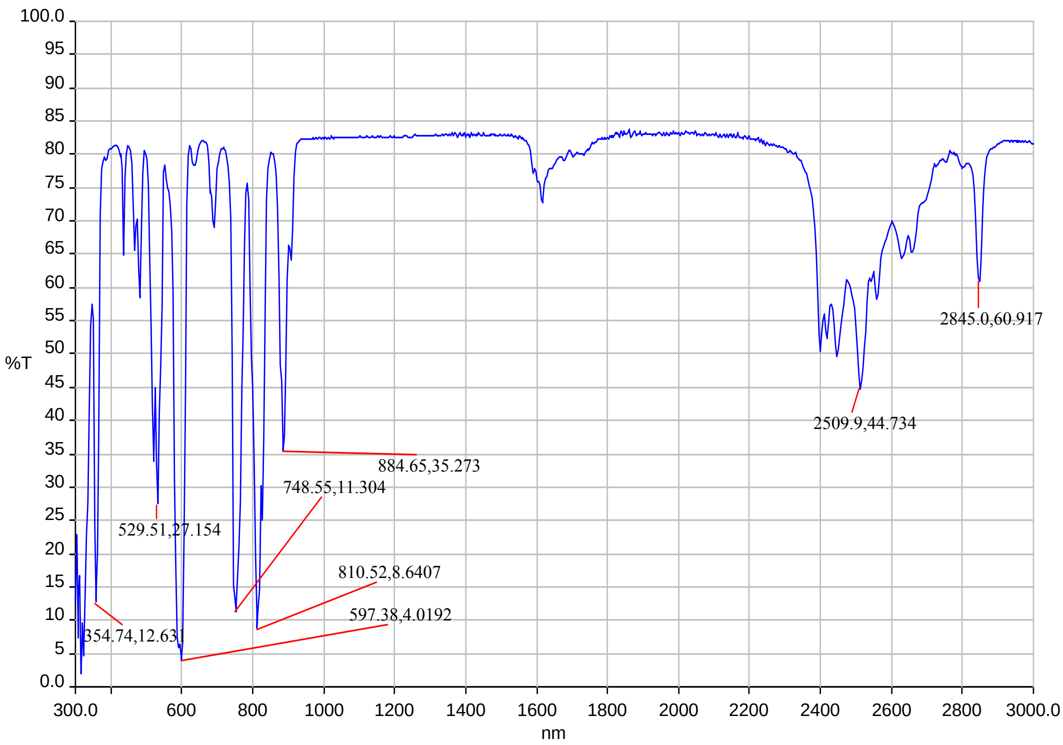



**Figure 1.Transparency curve of Nd:KGW**

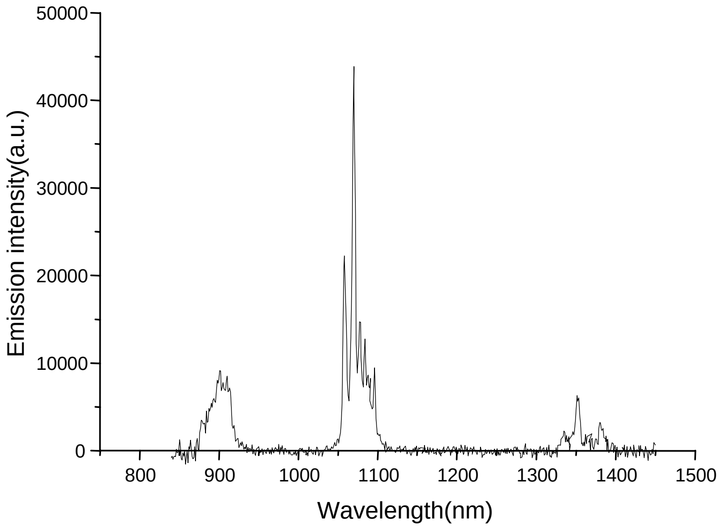



**Figure 2. Emission spectra of 3%Nd:KGW**

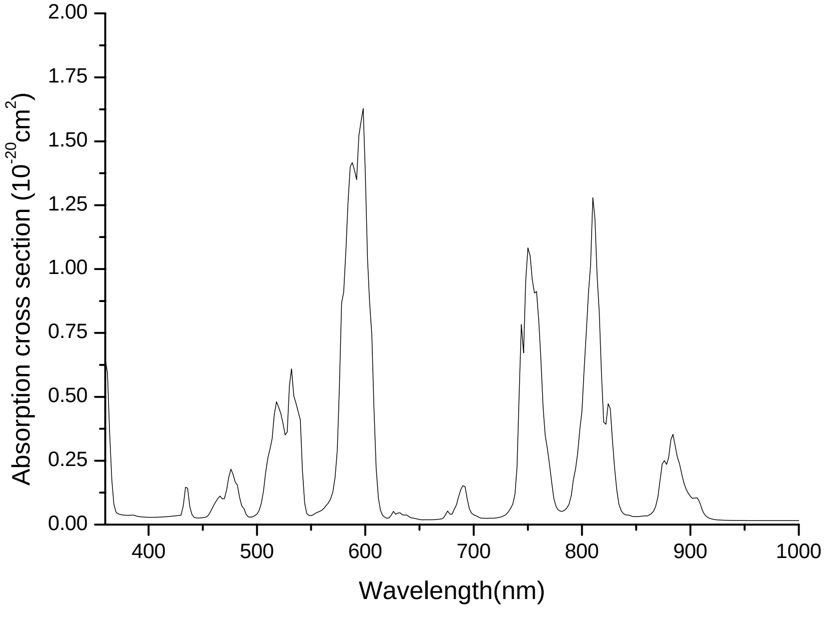



**Figure 3. Absorption spectra of 3%Nd:KGW**

# Yb:KGW

## Introduction

Ytterbium doped Potassium-Gadolinium Tungstate crystals - ($Yb:KGd(WO_4)_2$ 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 1023-1060nm 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.

**Basic Properties:**

| | |
|---|---|
| Crystal structure | monoclinic |
| Point group | C2/c |
| Cell Parameters | a = 8.09Å; b = 10.43Å; c = 7.588Å<br>β =94.4° |
| Refractive index, at 1067 nm | $n_g$ = 2.033; $n_p$ = 2.037; $n_m$ = 1.986 |
| Mohs hardness | 5 |
| Density, $g/cm^3$ | 7.27 |
| Melting Point | 1075℃ |
| Thermal conductivity at 373K, W x $cm^{-1}$ x $K^{-1}$ | $K_{[100]}$ = 0.026; $K_{[010]}$= 0.038; $K_{[001]}$ = 0.034 |
| Thermal expansion coefficient, at 373K | $α_{[100]} = 4 \times 10^{-6}K^{-1}$; $α_{[010]} = 1.6 \times 10^{-6}K^{-1}$;<br>$α_{[001]} = 8.5 \times 10^{-6}K^{-1}$ |
| Lasing Wavelength | 1023-1060nm |
| Absorption band | 981nm (FWHM 3.7nm) |
| Fluorescent lifetime | 600 µs (5% doping) |

**Specifications of Yb:KGW**

| | |
|---|---|
| Orientation | [010] |
| Standard Dopant concentration (at. %) | 5% |
| Maximum length | 50mm |
| Length tolerance, mm | +1.0 / -0.0 |
| Diameter tolerance, mm | +/-0.1 |
| Parallelism | < 30″ |
| Perpendicularity | < 15′ |
| Surface quality | 20/10 |
| coating | AR-coated |

# Diffusion Bonded Crystals

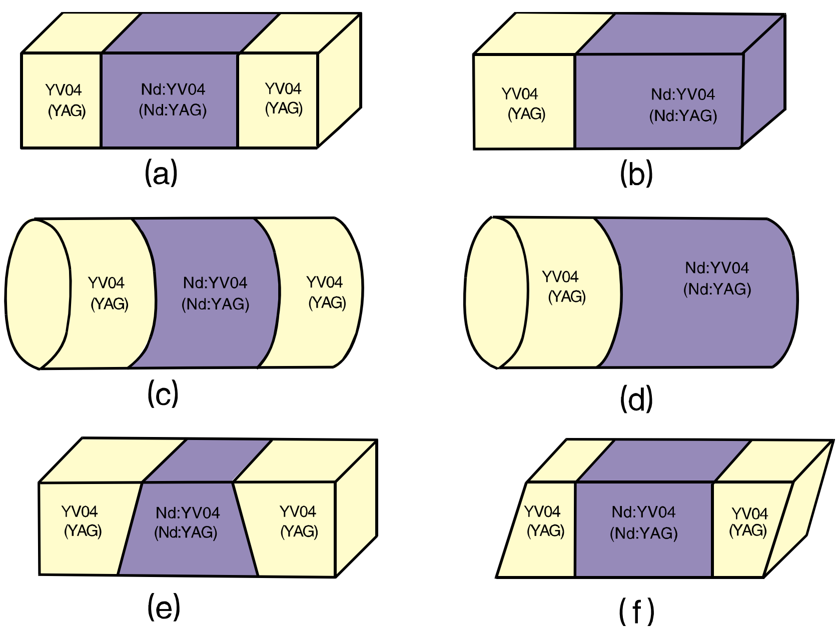
## Introduction

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.

?#?#?#?? can supply 2 kinds of Diffusion Bonded Crystals: $YVO_4$+Nd:$YVO_4$+$YVO_4$ and YAG+ Nd:YAG+YAG.

| Material | Doping concentration | Aperture ($mm^2$) | Length of laser crystal (mm) |
|---|---|---|---|
| $YVO_4$+Nd:$YVO_4$+$YVO_4$ | 0.1-3% | 2x2-10x10 | 1-20 |
| $YVO_4$+Nd:$YVO_4$+$YVO_4$ | 0.1-3% | ϕ 2-10 | 3-20 |
| YAG+Nd:YAG+YAG | 0.5-1.1% | 2x2-10x10 | 1-30 |
| YAG+Nd:YAG+YAG | 0.5-1.1% | ϕ 2-10 | 3-30 |

We have several assembly types as follows




For other assembly type please contact us for more information.

# $LiTaO_3$ Crystal

## Introduction

$LiTaO_3$ is an E-O crystal widely used for E-O devices, due to its good optical NLO and E-O properties, as well as high damage threshold. **?#?#?#??** supplies high quality $LiTaO_3$ boules and wafers with the following specifications for standard applications. We can also offer other specifications upon request:

### Basic Properties of $LiTaO_3$

| | |
|---|---|
| Crystal Structure | Trigonal, Space group R3c, Point group 3m |
| Cell Parameters | a=5.154 Å , c=13.781 Å |
| Melting Point | 1650°C |
| Curie Temperature | 607°C |
| Mohs Hardness | 5.5 |
| Density | 7.46g/cm$^3$ |
| Dielectric Constants | $\varepsilon_{11}/\varepsilon_0$ : 51.7<br>$\varepsilon_{33}/\varepsilon_0$ : 44.5 |
| Elastic Stiffness Coefficients | $C^E_{11}$ : 2.33 ( x $10^{11}$ N/m$^2$ )<br>$C^E_{33}$ : 2.77 ( x $10^{11}$ N/m$^2$ ) |
| Piezoelectric Strain Constants | $d_{22}$ : 2.4 ( x $10^{-11}$ C/N )<br>$d_{33}$ : 0.8 ( x $10^{-11}$ C/N ) |
| Transmission range | 400 - 4500nm |
| Electro-optical coefficients | $r_{33}$=30.4pm/V |
| Refractive index at 632.8nm | $n_o$=2.176, $n_e$=2.180 |

### Typical Specifications

| Type / Specifications | Boule | | Wafer | |
|---|---|---|---|---|
| Diameter | ϕ3" | | ϕ3″ | ϕ4″ |
| Length or Thickness | ≤100mm | nm | 0.35-0.5 mm | |
| Orientation | 127.86°Y, 64°Y, 135°Y, X, Y, Z, and other cut | | | |
| Ref. Flat Orientation | X, Y | | | |
| Ref. Flat Length | 22±2mm | 2mm | 22±2mm | 32±2mm |
| Front Side Polishing | | | Mirror polished 5-15 Å | |
| Back Side Lapping | | | 0.3-1.0 μm | |
| Flatness (μm) | | | ≤ 15 | |
| Bow (μm) | | | ≤ 25 | |

# $LiNbO_3$ Crystal

## Introduction

$LiNbO_3$ is widely used as electro-optic modulators and Q-switches for Nd:YAG, Nd:YLF and Ti:Sapphire lasers as well as modulators for fiber optics. The following table list the specifications of a typical $LiNbO_3$ crystal used as Q-switch with transverse E-O modulation. The light propagates in z-axis and electric field applies to x-axis. The electro-optic coefficients of $LiNbO_3$ are: $r_{33}$ = 32 pm/V, $r_{31}$ = 10 pm/V, $r_{22}$ = 6.8 pm/V at low frequency and $r_{33}$ = 31 pm/V, $r_{31}$ = 8.6 pm/V, $r_{22}$ = 3.4 pm/V at high electric frequency. The half–wave voltage: $V_{\pi} = \lambda\, d/n_o^3 \gamma_c l$, $\gamma_c = (n_e/n_o)^3 \gamma_{33} - \gamma_{13}$.

### $LiNbO_3$ Q-Switch Specifications

| | |
|---|---|
| Size | 9 X 9 X 25 $mm^3$ or 4 X 4 X 15 $mm^3$ |
| | Other size is available upon request |
| Tolerance of size | Z-axis: ± 0.2 mm |
| | X-axis and Y-axis: ± 0.1 mm |
| Chamfer | less than 0.5 mm at 45° |
| Accuracy of orientation | Z-axis: <±5' , X-axis and Y-axis: < ±10' |
| Parallelism | < 20" |
| Finish | 10/5 scratch/dig |
| Flatness | λ /8 at 633 nm |
| AR-coating | R < 0.2% @ 1064 nm |
| Electrodes | Gold/Chrome plated on X-faces |
| Wavefront distortion | < λ /4 @ 633 nm |
| Extinction ratio | > 400:1 @ 633 nm, ϕ 6 mm beam |

$LiNbO_3$ is also a good acousto-optic crystal and used for surface acoustic wave (SAW) wafer and A-O modulators. ?#?#?#?? provides acoustic (SAW) grade $LiNbO_3$ crystals in wafers, as-cut boules, finished components and custom fabricated elements.

### Typical SAW Properties

| Cut Type | SAW Velocity $\nu_s$ (m/s) | Electromechanical Coupling Factor $\kappa^2_s$ (%) | Temperature Coefficient of Velocity TCV ($10^{-6}/^oC$) | Temperature Coefficient of Delay TCD ($10^{-6}/^oC$) |
|---|---|---|---|---|
| 127.86º Y-X | 3970 | 5.5 | -60 | 78 |
| Y-X | 3485 | 4.3 | -85 | 95 |

## Typical Specifications

| Specifications \ Type | Boule | | Wafer | |
|---|---|---|---|---|
| Diameter | ϕ3" | ϕ4" | ϕ3" | ϕ4" |
| Length or Thickness (mm) | ≤ 100 | ≤ 50 | 0.35-0.5 | |
| Orientation | 127.86°Y, 64°Y, 135°Y, X, Y, Z, and other cut | | | |
| Ref. Flat Orientation | X, Y | | | |
| Ref. Flat Length | 22±2mm | 32±2mm | 22±2mm | 32±2mm |
| Front Side Polishing | | | Mirror polished 5-15 Å | |
| Back Side Lapping | | | 0.3-1.0 µm | |
| Flatness (µm) | | | ≤ 15 | |
| Bow (µm) | | | ≤ 25 | |

?#?#?#?? can offer other sizes and specifications of wafers upon request.

# Yttrium Vanadate ($YVO_4$) Crystal

## Introduction

The Yttrium Orthovanadate ($YVO_4$) is a positive uniaxial crystal grown with Czochralski method. It has good temperature stability and 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 | $11.4x10^{-6}$ | $9.2x10^{-6}$ | $26.3x10^{-6}$ | $16.7x10^{-6}$ |
| | a-axis | $4.4x10^{-6}$ | $7.1x10^{-6}$ | $5.4x10^{-6}$ | $7x10^{-6}$ |
| Refractive Index | $n_o$ | 1.9447@1550nm | 2.454@1530nm | 1.6346@ 1497nm | 2.2151@ 1440nm |
| | $n_e$ | 2.1486@1550nm | 2.710@1530nm | 1.4774@ 1497nm | 2.1413@ 1440nm |
| Birefringence ($n_e$-$n_o$) | | 0.2039@1550nm | 0.256@1530nm | -0.1572@ 1497nm | -0.0738@ 1440nm |
| Mohs Hardness | | 5 | 6.5 | 3 | 5 |
| Deliquescence | | None | None | Weak | None |
| Transparency range | | 0.4-5μm | 0.4-5μm | 0.35-2.3μm | 0.4-5μm |

## A reliable supplier of $YVO_4$ crystals

?#?#?#?? is one of the earliest companies who have mastered the advanced growth technique of $YVO_4$ crystal. Now ?#?#?#?? has completed its strong mass-production line that can provide:

- Various size of bulk and finished high quality $YVO_4$ crystals up to ϕ35x50mm³ and ϕ20x20mm³, respectively;
- Large quantity $YVO_4$ wedges and displacers used for fiber optical isolators and circulators, interleavers, in size of 1.25x1.25x0.5mm³ to 3x3x15mm³ to meet OEM customer's requirement;
- Quick delivery;
- Very competitive price;
- Strict quality control;
- Technical support;

**Basic Properties of $YVO_4$ crystal**

| | |
|---|---|
| Transparency Range: | High transmittance from 0.4 to 5μm |
| Crystal Symmetry: | Zircon Tetragonal, space group $D_{4h}$ |
| Crystal Cell: | a=b=7.12Å; c=6.29Å |
| Density: | 4.22 g/cm³ |

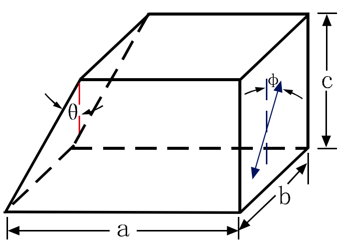
| | |
|---|---|
| Mohs Hardness: | 5, glass-like |
| Hygroscopic Susceptibility: | Non-hygroscopic |
| Thermal Expansion Coefficient: | $\alpha_a = 4.43 \times 10^{-6}$/K; $\alpha_c = 11.37 \times 10^{-6}$/K |
| Thermal Conductivity Coefficient : | //C: 5.23 W/m/K; ⊥C: 5.10 W/m/K |
| Crystal Class: | Positive uniaxial with $n_o=n_a=n_b$, $n_e=n_c$ |
| Thermal Optical Coefficient: | $dn_a/dT = 8.5\times10^{-6}$/K; $dn_c/dT = 3.0\times10^{-6}$/K |
| Refractive Indices, Birefringence ($\Delta n = n_e - n_o$) and Walk-off Angle at 45º ( ρ ): | $n_o = 1.9929$, $n_e = 2.2154$, $\Delta n = 0.2225$, $\rho = 6.04^o$ at 630nm<br>$n_o = 1.9500$, $n_e = 2.1554$, $\Delta n = 0.2054$, $\rho = 5.72^o$ at 1300nm<br>$n_o = 1.9447$, $n_e = 2.1486$, $\Delta n = 0.2039$, $\rho = 5.69^o$ at 1550nm |
| Sellmeier Equation ( λ in μm): | $n_o^2 = 3.77834 + 0.069736/(\lambda^2 - 0.04724) - 0.0108133\,\lambda^2$<br>$n_e^2 = 4.59905 + 0.110534/(\lambda^2 - 0.04813) - 0.0122676\,\lambda^2$ |

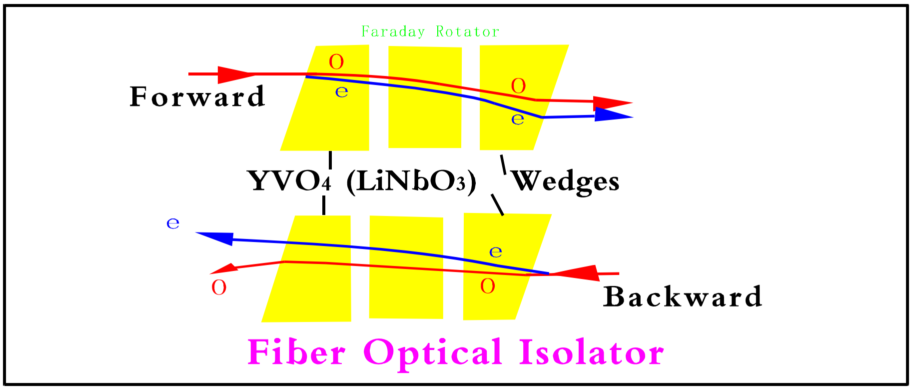
## $YVO_4$ crystal application

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

### 1.Specifications of birefringent wedges for fiber-optic isolators

| | |
|---|---|
| Aperture | 1.0 x 1.0 mm² to 4 x 4 mm² |
| Dimension tolerance | +/-0.05mm |
| Wedge Angle tolerance | +/-0.1° |
| Optical axis orientation | +/-0.5° |
| Flatness | λ/4 @ 632.8 nm |
| Surface Quality | 20-10 |
| AR-coating | R<0.2% @1550 or 1310nm |
| Standard Size | 1.25mmx1.25mmx0.5mm with 13° or 15° wedge, phi=22.5° |

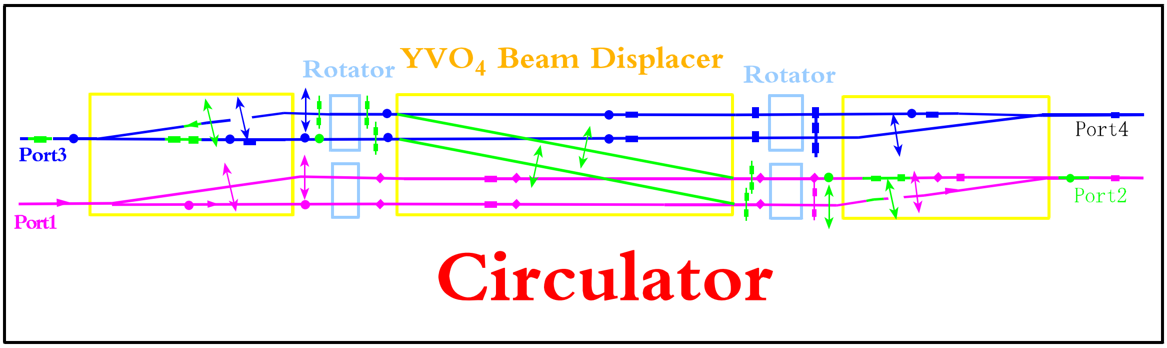


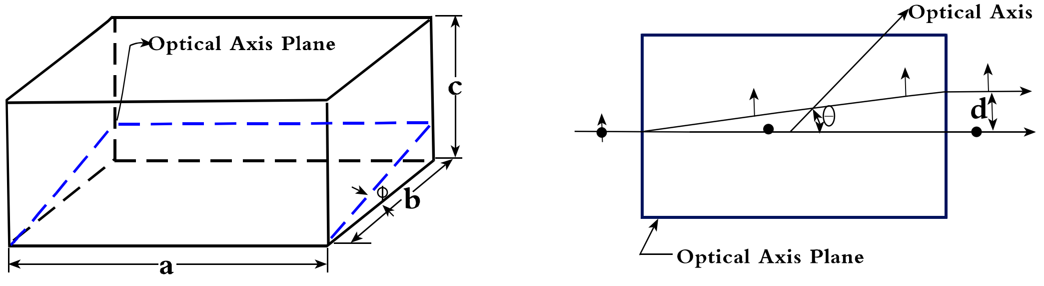
## Specifications of $YVO_4$ beam displacers for fiber-optic circulators or interleaver

| | |
|---|---|
| Dimension tolerance | W (±0.05mm)xH (±0.05mm) xL (±0.1mm) |
| Optical axis orientation | ±0.5° |
| Parallelism | <15 arc sec |
| Perpendicularity | <10 arc min |
| Flatness | λ/4 @ 632.8 nm |
| Surface Quality | 20/10 |
| AR-coating | R<0.2% @ 1550 nm or 1310nm ± 40 nm |
| Standard Size | 2.6x2.6x10mm, θ=45°, ϕ=0° |

Note: Other sizes and specifications are available upon request




$YVO_4$ Beam Displacer for Circulator



# $LiNbO_3$

## Introduction

$LiNbO_3$ crystal combines low cost, good mechanical and physical properties as well as high optical homogeneity. Therefore, $LiNbO_3$ wedges have been widely used in fiber isolators and circulators.

## ?#?#?#?? provides

- 50,000 to 100,000 pcs/month of $LiNbO_3$ wedges used for fiber optical isolators and circulators
- Reliable Delivery
- Strict quality control
- Technical support
- Very competitive price

### Basic Properties of $LiNbO_3$

| | |
|---|---|
| Crystal Structure: | Trigonal, Space group R3c, Point group 3m |
| Melting Point: | 1253°C |
| Mohs Hardness: | 5 |
| Density: | 4.64 $g/cm^3$ |
| Deliquescence | None |
| Optical Homogeneity | ~$5x10^{-5}$/cm |
| Transparency Range | 420nm-5200nm |
| Absorption Coefficient: | ~0.1%/cm @1064nm |
| Refractive indices at 1064nm: | $n_e$ = 2.146, $n_o$ = 2.220 @ 1300 nm<br>$n_e$ = 2.156, $n_o$ = 2.232 @ 1064 nm<br>$n_e$ = 2.203, $n_o$ = 2.286 @ 632.8 nm |
| Thermal Expansion Coefficients ( at $25^0$C) | //a, $2.0x10^{-6}$/K<br>//c, $2.2x10^{-6}$/K |
| Thermal Conductivity Coefficient: | 38 W/m/K at $25^0$C |
| Thermal Optical Coefficient: | $dn_o/dT=-0.874x10^{-6}$/K at 1.4μm<br>$dn_e/dT=39.073x10^{-6}$/K at 1.4μm |
| The Sellmeier equations (λ in μm) | $n_o^2 = 4.9048 + 0.11768/(\lambda^2-0.04750) - 0.027169\lambda^2$<br>$n_e^2 = 4.5820 + 0.099169/(\lambda^2-0.04443) - 0.02195\lambda^2$ |

## Specifications of $LiNbO_3$ wedges

| | |
|---|---|
| Aperture | 1.0 x 1.0 $mm^2$ to 4 x 4 $mm^2$ |
| Dimension tolerance | ±0.05mm |
| Wedge Angle tolerance | ±0.1° |
| Optical axis orientation | ±0.5° |
| Flatness | λ/4 @ 632.8 nm |
| Surface Quality | 20-10 |
| AR-coating | R<0.2% @1550nm±40nm |
| Standard Size | 1.25mmx1.25mmx0.5mm with 13° or 15° wedge, phi=22.5° |

**Note:** Other sizes and coatings are available upon request.

# CsI、CsI(Tl)、CsI(Na)

## Introduction

Cesium Iodide is a material with high γ-ray stopping power due to its relative high density and atomic number. For scintillation counting, it is used either in its undoped form or doped with sodium or thallium. CsI is resistant to thermal and mechanical shock. Compared to NaI(Tl), it is relatively soft and plastic, and does not cleave. Because it has no cleavage plane, it is quite rugged. So it is well suited for well logging, space research or other applications where severe shock conditions are encountered.

CsI(pure) has an emission maximum at 315 nm with an intensity much smaller than either of the activated types of this material. The 315 nm emission is characterized by a relatively short decay time of 16 ns, thus the material can be used for fast timing applications.

CsI(Tl) is one of the brightest scintillator. The maximum of the broad emission situated at 550nm is is well suited for photodiode readout. CsI(Tl) is slightly hygroscopic with plastic mechanical properties. Combined with the relatively good radiation hardness properties, CsI(Tl) is well suited for High Energy Physics.

CsI(Na) has a wavelength of emission peak at 420nm and is well matched to the photocathode sensitivity of bialkali photomultiplier and has a light output yielding to 85% of NaI(Tl). Compared to NaI(Tl), it is a relatively soft and plastic material without cleavage plan which makes the material interesting where severe environmental conditions are encountered

## Main Advantages

- High γ-ray stopping power
- High density and atomic number

## Main Properties

| Properties | CsI | CsI(Tl) | CsI(Na) |
|---|---|---|---|
| Density [g/cm3] | 4.51 | 4.51 | 4.51 |
| Melting point [℃] | 721 | 721 | 721 |
| Thermal expansion coefficient [$C^{-1}$] | $54 \times 10^{-6}$ | $54 \times 10^{-6}$ | $54 \times 10^{-6}$ |
| Cleavage plane | none | none | none |
| Hardness (Mohs) | 2 | 2 | 2 |
| Hygroscopic | slightly | slightly | yes |
| Wavelength of emission max. [nm] | 315 | 550 | 420 |
| Lower wavelength cutoff [nm] | 260 | 320 | 300 |
| Refractive index @ emission max | 1.95 | 1.79 | 1.84 |
| Primary decay time [ns] | 16 | 1000 | 630 |
| Light yield [photons/keV γ] | 2 | 54 | 41 |
| Photoelectron yield [% of NaI(Tl)] (for γ-rays) | 4-6 | 45 | 85 |

**Notes:**

**CsI crystal is slightly hygroscopic, please use or keep it in dry environment.**

# NaI(Tl)

## Introduction

NaI (TI) is the most extensively used material of all the available scintillators. It is grown by host material sodium iodide doped with appropriate percentage of thallium. The main emission wavelength is 415nm, which well matched with the working wavelength of photomultiplier tubes (PMTs). It has very high luminescence efficiency and exhibits no significant self absorption of the scintillation light and has good resolution ability to X-ray and $\gamma$-ray.

## Main Advantages

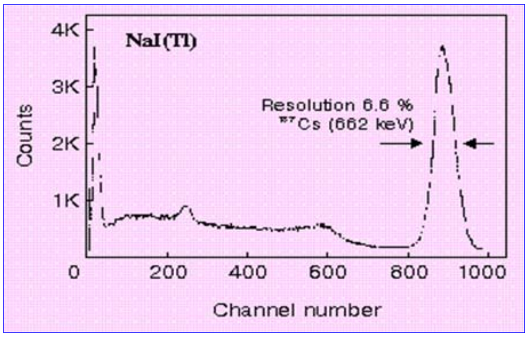
- High light output.
- The emission wavelength（415nm）match well with the working wavelength of photomultiplier tubes (PMTs).
- No significant self absorption of scintillation light.
- Available in single crystal or polycrystalline forms in a wide variety of sizes and geometries.
- Widely used for radiation detection: in nuclear medicine, for environmental monitoring, in nuclear physics, aerial survey, well logging and in many other applications.

## Main Properties：

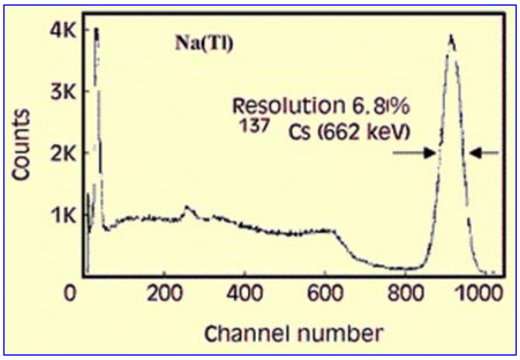
| | |
|---|---|
| Density [$g/cm^3$] | 3.67 |
| Melting point [K] | 924 |
| Thermal expansion coefficient [$C^{-1}$] | $47.7 \times 10^{-6}$ |
| Cleavage plane | <100> |
| Hardness (Mho) | 2 |
| Hygroscopic | yes |
| Wavelength of emission max. [nm] | 415 |
| Refractive index @ emission max | 1.85 |
| Primary decay time [ns] | 250 |
| Light yield [photons/keV $\gamma$ ] | 38 |
| Temperature coefficient of light yield | $-3\%C^{-1}$ |

## ?#?#?#?? offers

- Cylinder-shaped crystals： Φ11mm×200mm ～ Φ68mm×300mm
  Special-shaped series: trigonal prism, tetragonal prism, hexagonal prism and so on.
  Wafer: Φ1mm×3mm ～ Φ170mm×20mm
  Side window: Φ37mm×120mm ～ Φ50mm×150mm
- Fast delivery（within 1 month）.




Cylinder-shaped crystals




Side window and wafers

**Notes:**

**NaI(Tl) crystal is hygroscopic, please use or keep it in dry environment.**

# $LaBr_3(Ce)$

## Introduction

Cerium-doped lanthanum bromide $LaBr_3(Ce)$ is a newly developed scintillation crystal with hexagonal structure, colorless, transparent. It offers the best energy resolution, fast emission and excellent linearity. LaBr3(Ce) has higher light output than NaI(Tl) and also better energy resolution. LaBr3(Ce) is a promising scintillation crystal used for various applications including Gamma-ray detect, Nuclear-medical imaging (PET,SPECT), High-energy physics, Security, Geological exploration and environmental monitoring fields.

## Main Advantages

- Fast decay time
- Best energy resolution
- Higher light output than NaI(Tl)
- Very stable light output over a wide range of temperatures.

## Main Properties:

| | |
|---|---|
| Density [g/cm3] | 5.08 |
| Melting point [K] | 1116 |
| Thermal expansion coefficient [10-6/° C] | 8 along C-axis |
| Cleavage plane | <100> |
| Hygroscopic | yes |
| Wavelength of emission max. [nm] | 380 |
| Refractive index @ emission max | ~1.9 |
| Primary decay time [ns] | 16 |
| Light yield [photons/MeV γ] | 61000 |
| Photoelectron yield [% of NaI(Tl)] (for γ-rays) | 165 |

# $LaCl_3(Ce)$

## Introduction

Cerium-doped lanthanum chloride $LaCl_3(Ce)$ is a newly developed scintillation crystal with hexagonal structure, colorless, transparent. It offers superior energy resolution, fast emission and excellent linearity. It has light output similar to NaI(Tl) but much better energy resolution. LaCl3(Ce) is a promising scintillation crystal used for various applications including Gamma-ray detect, Nuclear-medical imaging (PET,SPECT), High-energy physics, Security, Geological exploration and environmental monitoring fields.

## Main Advantages:

- Fast decay time
- Superior energy resolution
- Very stable light output over a wide range of temperatures.

## Main Properties:

| | |
|---|---|
| Density [g/cm3] | 3.85 |
| Melting point [℃] | 1062 |
| Thermal expansion coefficient [10-6/° C] | 11 along C-axis |
| Cleavage plane | [100] |
| Hygroscopic | yes |
| Wavelength of emission max. [nm] | 350 |
| Lower wavelength cutoff [nm] | 313 |
| Refractive index @ emission max | ~1.9 |
| Primary decay time [ns] | 28 |
| Light yield [photons/MeV γ ] | 49000 |
| Photoelectron yield [% of NaI(Tl)] (for γ -rays) | 70-90 |

# Terbium Gallium Garnet (TGG) Crystal

## Introduction

TGG is an excellent magneto-optical crystal used in various Faraday devices (Rotator and Isolator) in the range of 400nm-1100nm, excluding 475-500nm.

## Main Advantages:

- Large Verdet constant (35 Rad $T^{-1}m^{-1}$).
- Low optical losses (<0.1%/cm)
- High thermal conductivity (7.4W $m^{-1}K^{-1}$).
- High laser damage threshold (>1GW/$cm^2$).

## Main Properties:

| | |
|---|---|
| Chemical Formula | $Tb_3Ga_5O_{12}$ |
| Lattice Parameter | a=12.355Å |
| Growth Method | Czochralski |
| Density | 7.13g/$cm^3$ |
| Mohs Hardness | 8.0 |
| Melting Point | 1725 ℃ |
| Refractive Index | 1.954 at 1064nm |

## ?#?#?#?? supply TGG crystal with:

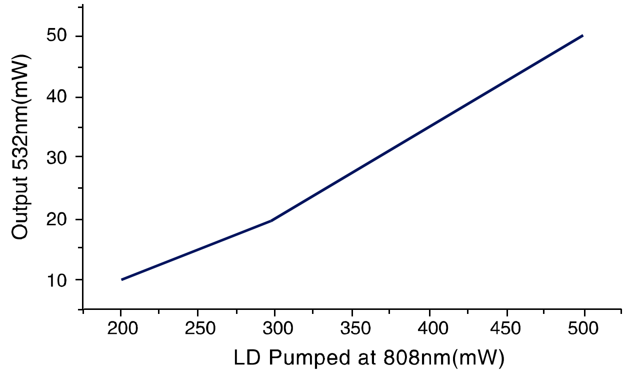
| | |
|---|---|
| Orientation | [111] within ±15 arc min |
| Wave Front Distortion | < 1/8 wave |
| Extinction Ratio | > 30dB |
| Diameter Tolerance | +0.00mm/-0.05mm |
| Length Tolerance | +0.2mm/-0.2mm |
| Chamfer | 0.10mm @ 45° |
| Flatness | < 1/10 wave at 633nm |
| Parallelism | < 30 arc Seconds |
| Perpendicularity | < 5 arc min |
| Surface Quality | 10/5 Scratch/Dig |
| AR coating | <0.2% |

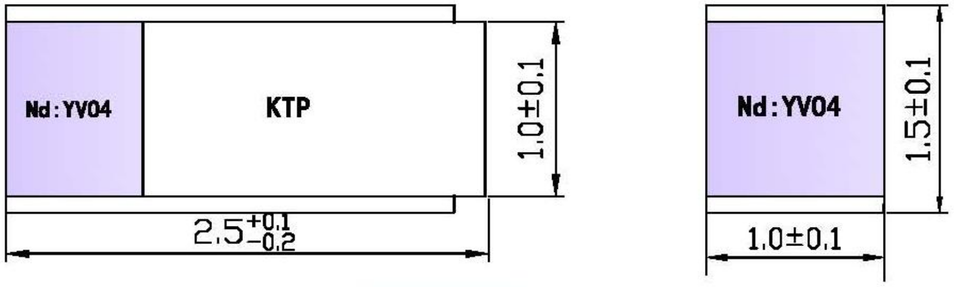
# Optical-contacted Crystals (Green Laser )

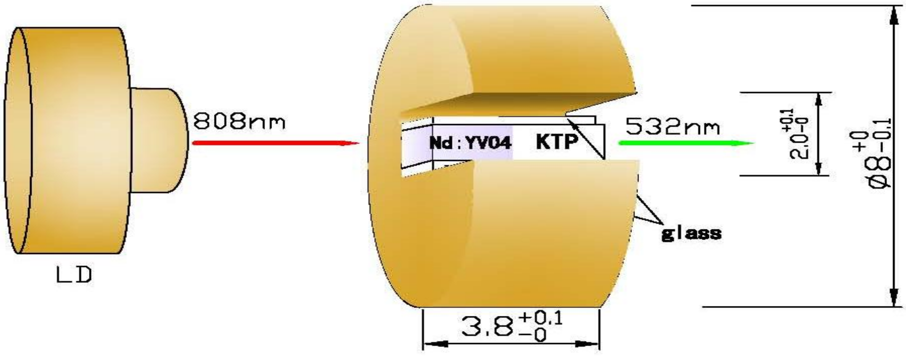
## Introduction

Optical-contacted crystals are consisted of laser crystal Nd:$YVO_4$ and non-linear optical crystal KTP. They are combined together by optical-contacted method without cement and can generate as high as 70mW 532nm green laser with 500mW diode pumping. They have the advantages of high conversion efficiency, compact design and low cost etc.

?#?#?#?? is able to steadily supply Optical-contacted crystals (Nd:$YVO_4$+KTP) with large amount (more than 100,000pcs/month). The main dimension option is 1.8x1.3x2.5mm. We can also supply free copper holder (Dia.8mm) upon request. For the other size of copper holder please inquire our sales people.




We have 4 kinds of Optical-contacted crystals (Nd:$YVO_4$+KTP) according to the output 532nm power:

A. 1W LD pumped, output 532nm power>100mW
B. 500mW LD pumped, output 532nm power>50mW
C. 300mW LD pumped, output 532nm power>25mW
D. 200mW LD pumped, output 532nm power>5mW

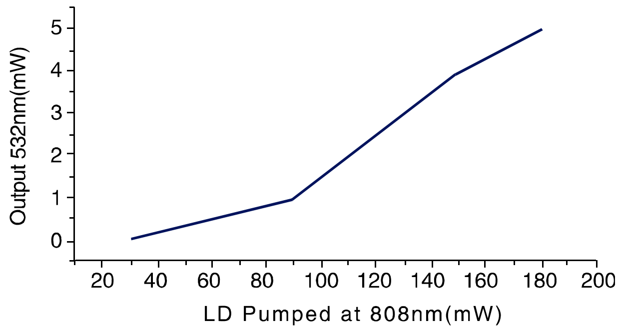
# Glued Crystals (Green Laser)

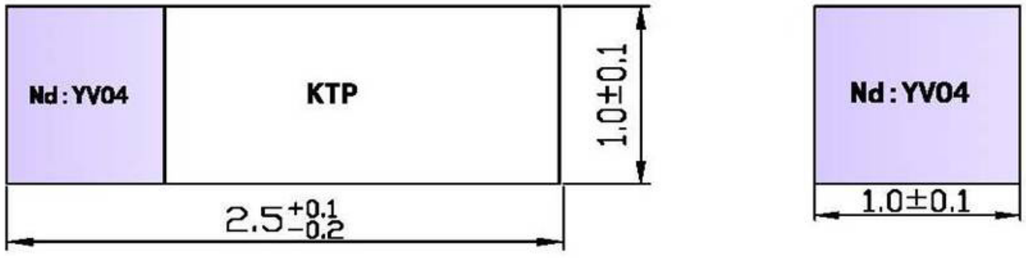
## Introduction

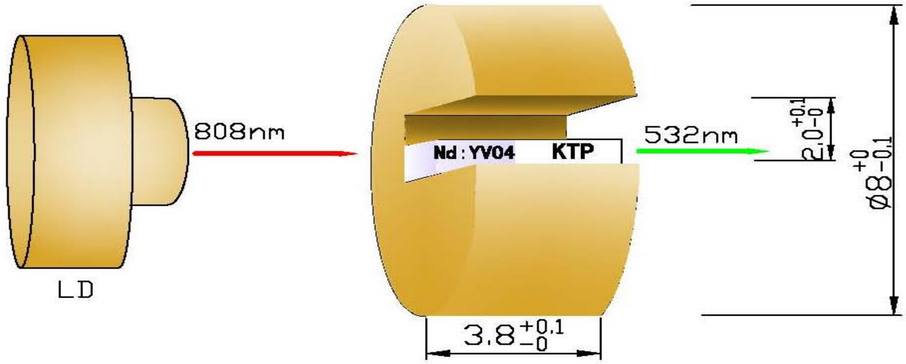
Glued crystals ($Nd:YVO_4$+KTP) are consisted of laser crystal $Nd:YVO_4$ and non-linear optical crystal KTP. They are combined together by UV glue and can generate as high as 10mW 532nm green laser with 200mw diode pumping. They have the advantages of high conversion efficiency, compact design, low cost, etc..

?#?#?#?? is able to steadily supply Glued crystals ($Nd:YVO_4$+KTP) with large amount (more than 100,000pcs/month). The main dimension option is 1.3x1.3x2.5mm. We can also supply free copper holder(Dia.8mm) upon request. For the other size of copper holder please inquire our sales people.

| | |
|---|---|
| Size | 1.3x1.3x2.5mm |
| Coating | Input: HR-(1064/532)nm,HT-808nm, R>99.8%@1064nm&532nm,T>95%@808nm<br>Output: HR-1064nm, HT-532nm, R>99.8%@1064nm, T>95%@532nm |
| Pumping | 808(+/-1)nm |
| Output | 532nm |
| Clear Aperture | >80% |
| Working temperature | 20~ 30°C |






We have 2 kinds of Glued crystals (Nd:$YVO_4$+KTP) according to the output 532nm power:

A. 200mW LD pumped, output 532nm power>5mW.

B. 200mW LD pumped, output 532nm power>1mW.

For pumping power>200mW and output 532nm power larger than 10mW we recommend our another product: Optical-contacted crystals (Nd:$YVO_4$+KTP), P63.

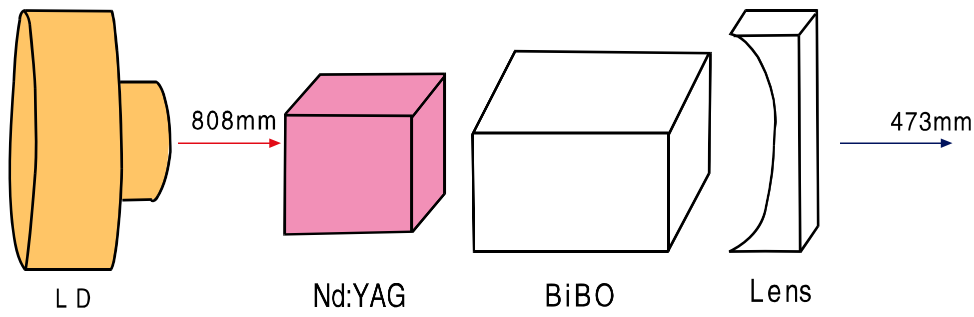
# Crystal Kit for Blue Laser

## Introduction

In order to meet the demand for low power blue laser, ?#?#?#?? bought the authorization of BIBO patent from FEE, a German company, and developed the low power crystal kit for blue laser. With 2 W LD pumping, such a crystal kit can generate as high as 70mW 473nm blue laser.

## A set of blue laser kit include

Nd:YAG: 3x3x2mm, S1: HR-946&473nm, HT-1319/1064/808nm; S2: AR-946&473nm
BIBO: 2x2x5mm, AR/AR-946/473nm
Output Mirror：phi10x3mm, S1: HR-946nm, HT-473nm; S2: AR-473nm



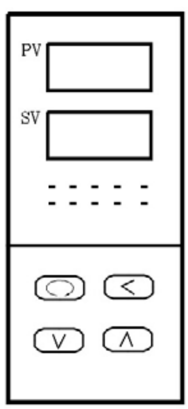
# Oven & Temperature Controller

## Introduction

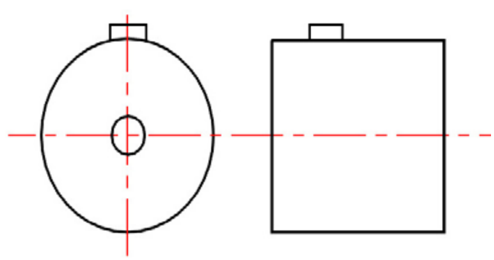
?#?#?#?? provides oven and temperature controller for heating the crystal and controlling its temperature to a certain value.

### Specifications

| Temperature Controller | Oven |
|---|---|
| • Purpose ASIC processor<br>• PID control<br>• Auto tuning<br>• RS-232 interface (optional)<br>• Programmable (optional)<br>• Stability: ±0.1°C<br>• Size: 50×100×135$mm^3$<br>• Normal Package Standard<br>• Voltage: 110/220V AC, two types | • Design: Radioactive heat compensation<br>• Plane temperature distribution<br>• Fast tuning<br>• Size: ϕ50mm×55mm (regular)<br>ϕ30mm×45mm (mini)<br>• Cavity size: ϕ10mm×55mm (regular)<br>ϕ10mm×45mm (mini)<br>• Sensor: Pt100 thermocouple<br>• Working temperature: ≤180°C |




Temperature Controller



Oven

## Applications:

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

## Note:

1、There are two types of applied voltage on oven, 110V and 220V. 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.

2、Special oven size, holder of crystals and right-angle support setting applications are available upon request.

# BBO Pockels Cell

## Introduction

Beta-Barium Borate (BBO) is the electro-optic material of choice for high average power Pockels cell applications ranging from 210nm in the UV to beyond 2µm in the IR. The wide transparency range of BBO allows it to be used in diverse applications.

Besides single crystal cell, ?#?#?#?? employs dual crystal geometry to minimize drive voltage.

## CASTECH's BBO Pockels cell is featured by

- Minimal piezoelectric ringing
- Low absorption
- High extinction ratio
- Small capacitance
- Broad transmission range (from 210nm to 2000nm)
- Compact Design

## Specifications:

| Single crystal cell | | | | |
|---|---|---|---|---|
| Model | BPC3S | BPC4S | BPC5S | BPC6S |
| Material | BBO | BBO | BBO | BBO |
| Aperture (mm) | 2.8 | 3.8 | 4.8 | 5.8 |
| λ /4 Voltage (KV) @1064nm | 2.8 | 3.9 | 4.7 | 5.8 |
| Extinction ratio @1064nm | >1000:1 | | | |
| Optical transmission （%） | >99% | | | |
| Capacitance (pF) | <3pF | | | |
| Damage Threshold | 500MW/cm$^2$@1064nm,10ns | | | |
| Spectra range (nm) | 210-2000 | | | |
| Dimension (mm) | Φ25.4X50 | | Φ30.0X50 | |

| Dual crystal cell | | | | |
|---|---|---|---|---|
| Model | BPC4D | BPC5D | BPC6D | BPC7D |
| Material | BBO | BBO | BBO | BBO |
| Aperture (mm) | 3.8 | 4.8 | 5.8 | 6.8 |
| λ /4 Voltage (KV) @1064nm | 2.5 | 3.0 | 3.6 | 4.2 |
| Extinction ratio @1064nm | >500:1 | | | |
| Optical transmission,% | >98.5% | | | |
| Capacitance (pF) | <5pF | | | |
| Damage Threshold | 500MW/cm$^2$@1064nm,10ns | | | |
| Spectra range (nm) | 210-2000 | | | |
| Dimension (mm) | Φ30.0X67 | | | |

## BBO Pockels Cell Driver

Together with BBO Pockels cell, Q-Switch Driver is used as laser selectors or pulse choppers with pulse and CW, Q-switched and mode locked lasers, operating at repetition rates up to 50KHz.

## Specifications of Pockels Cell Driver

| | |
|---|---|
| Voltage range | adjustable range ±500V |
| Repetition frequency | 0～50KHz |
| Risetime | <10ns |
| Pulse width | <5us |
| Life time | 10,000 hours |
| Power | 220V(AC) or 24V(DC) |
| Trigger method | TTL electrical level |
| Dimension | 300×110×220mm |
| Weight | <5Kg |