

Crystals Selection Guide

NONLINEAR CRYSTALS

LASER CRYSTALS

TERAHERTZ CRYSTALS

RAMAN CRYSTALS

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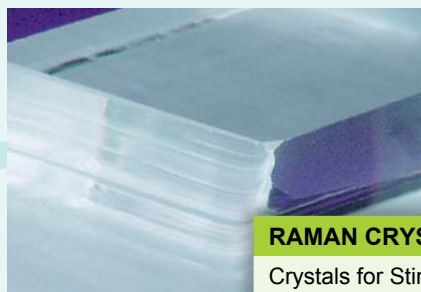
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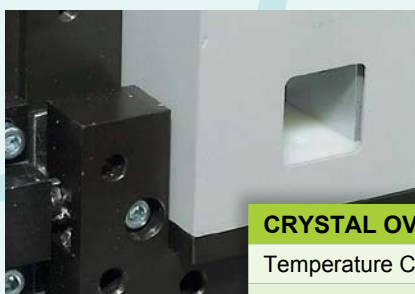
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Nonlinear Crystals

LBO

LITHIUM TRIBORATE



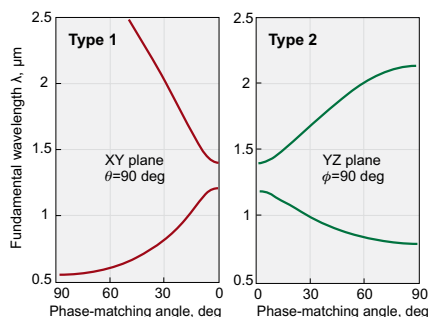
- wide transparency region
- broad Type 1 and Type 2 non-critical phase-matching (NCPM) range
- small walk-off angle
- high damage threshold
- wide acceptance angle
- high optical homogeneity

LBO is well suited for various nonlinear optical applications:

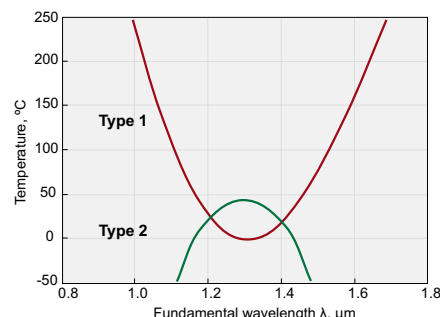
- frequency doubling and tripling of high peak power pulsed Nd doped, Ti:Sapphire and Dye lasers
- optical parametric oscillators (OPO) of both Type 1 and Type 2 phase-matching
- non-critical phase-matching for frequency conversion of CW and quasi-CW radiation.

EKSMA OPTICS OFFERS

- crystals length up to 50 mm and aperture up to 40 × 40 mm
- thin crystals down to 10 μm thickness
- AR, BBAR, P-coating
- different mounting and repolishing services
- accurate quality control
- attractive prices and fast delivery
- one month customer's satisfaction term.



SHG tuning curves of LBO



NCPM SHG temperature dependence of LBO

PHYSICAL AND OPTICAL PROPERTIES

| | | | |
|--|---|----------------|----------------|
| Chemical formula | LiB ₃ O ₅ | | |
| Crystal structure | orthorhombic, mm2 | | |
| Optical symmetry | Negative biaxial | | |
| Space group | Pna2 ₁ | | |
| Density | 2.47 g/cm ³ | | |
| Mohs hardness | 6 | | |
| Optical homogeneity | ∂n = 10 ⁻⁶ cm ⁻¹ | | |
| Transparency region at "0" transmittance level | 155 – 3200 nm | | |
| Linear absorption coefficient at 1064 nm | < 0.01 % cm ⁻¹ | | |
| Refractive indices: | n _x | n _y | n _z |
| at 1064 nm | 1.5656 | 1.5905 | 1.6055 |
| at 532 nm | 1.5785 | 1.6065 | 1.6212 |
| at 355 nm | 1.5971 | 1.6275 | 1.6430 |
| Sellmeier equations (λ, μm) | $n_x^2 = 2.4542 + 0.0113 / (\lambda^2 - 0.0114) - 0.0139 \lambda^2$ $n_y^2 = 2.5390 + 0.0128 / (\lambda^2 - 0.0119) - 0.0185 \lambda^2$ $n_z^2 = 2.5865 + 0.0131 / (\lambda^2 - 0.0122) - 0.0186 \lambda^2$ | | |
| Phase matching range Type 1 SHG | 554 – 2600 nm | | |
| Phase matching range Type 2 SHG | 790 – 2150 nm | | |

NCPM SHG temperature dependence:

| | |
|--|--|
| Type 1 range 950 – 1300 nm | $T1 = -1893.3\lambda^4 + 8886.6\lambda^3 - 13019.8\lambda^2 + 5401.5\lambda + 863.9$ |
| Type 1 range 1300 – 1800 nm | $T2 = 878.1\lambda^4 - 6954.5\lambda^3 + 20734.2\lambda^2 - 26378\lambda + 12020$ |
| Type 2 range 1100 – 1500 nm | $T3 = -21630.6\lambda^4 + 112251\lambda^3 - 220460\lambda^2 + 194153\lambda - 64614.5$ |
| NCPM SHG at 1064 nm Type 1 temperature | 149 °C |
| NCPM SHG at 1319 nm Type 2 temperature | 43 °C |
| Walk-off angle | 4 mrad (Type 1 SHG 1064 nm) |
| Thermal acceptance | 6.4 K×cm (Type 1 SHG 1064 nm) |
| Angular acceptance | 6.5 mrad×cm (Type 1 SHG 1064 nm) |
| | 248 mrad×cm (Type 1 NCPM SHG 1064 nm) |
| Nonlinearity coefficients: | $d_{31} = (1.09 \pm 0.09) \text{ pm/V}$ |
| | $d_{32} = (1.17 \pm 0.14) \text{ pm/V}$ |
| Effective nonlinearity: | |
| XY plane | $d_{\text{oe}} = d_{32} \cos\phi$ |
| YZ plane | $d_{\text{eo}} = d_{\text{eo}} = d_{31} \cos\theta$ |
| Damage threshold for TEM ₀₀ 1064 nm | > 10 GW/cm ² at 10 ns |

LBO crystals
for SHG of Yb:KGW/KYW
laser frequency conversion
Femt* Line see page: 5.30

**Delivery
from stock!**

Please contact EKSMA OPTICS
for special OEM and large volume pricing.

Please contact EKSMA OPTICS for further information
or nonstandard specifications.

STANDARD SPECIFICATIONS

| | |
|--------------------|---|
| Flatness | λ/8 at 633 nm |
| Parallelism | < 20 arcsec |
| Surface quality | 10/5 scratch/dig as per MIL-O-13830A |
| Perpendicularity | < 5 arcmin |
| Angle tolerance | < 30 arcmin |
| Aperture tolerance | ± 0.1 mm |
| Clear aperture | 90% of full aperture |

STANDARD CRYSTALS LIST

| Code | Size, mm | θ, deg | φ, deg | Coating | Application | Price, EUR |
|----------------|----------|--------|--------|-------------------------|--------------------------------|------------|
| LBO-401 | 3x3x10 | 90 | 11.6 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 245 |
| LBO-402 | 3x3x15 | 90 | 11.6 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 325 |
| LBO-403 | 5x5x15 | 90 | 11.6 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 765 |
| LBO-404 | 3x3x15 | 90 | 0 | AR/AR @ 1064+532 nm | NCPM SHG @ 1064 nm, T = 149 °C | 325 |
| LBO-405 | 3x3x20 | 90 | 0 | AR/AR @ 1064+532 nm | NCPM SHG @ 1064 nm, T = 149 °C | 405 |
| LBO-406 | 3x3x10 | 42.2 | 90 | AR/AR @ 1064+532/355 nm | THG @ 1064 nm | 245 |
| LBO-407 | 3x3x15 | 42.2 | 90 | AR/AR @ 1064+532/355 nm | THG @ 1064 nm | 325 |
| LBO-408 | 5x5x15 | 42.2 | 90 | AR/AR @ 1064+532/355 nm | THG @ 1064 nm | 765 |

HOUSING ACCESSORIES

- Ring Holders
for Nonlinear
Crystals
See page 2.27
for more information.



- Positioning
Mount
840-0056
See page 2.28
for more information.



- Kinematic
Positioning
Mount
840-0193
See page 2.28
for more information.



149 °C temperature is required to achieve Non-Critical Phase Matching (NCPM) in LBO at type 1 SHG of 1064 nm application. **TC1 oven** is specially designed for this purpose (see technical specifications, p. 2.30).

CH7 oven is designed to keep the crystal at the elevated temperature (40–60 °C) for thermostabilisation of nonlinear crystal. The elevation of working temperature also extends hygroscopic crystals lifetime. LBO crystal is slightly hygroscopic and polished faces could become foggy after some time of exposition of crystal at ambient environment.

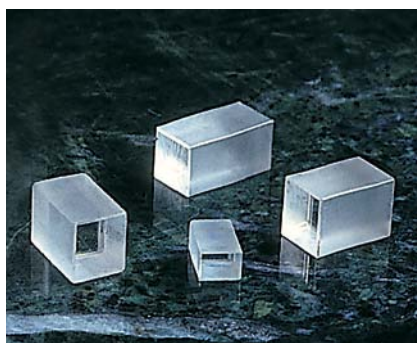
RELATED PRODUCTS

- Crystal Oven TC1
See page 2.30
for more information.
- Nonlinear Crystal
Oven CH7
See page 2.33
for more information.



BBO

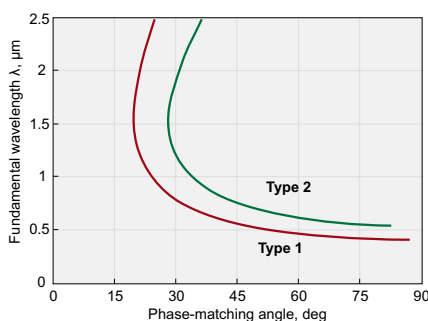
BETA BARIUM BORATE



- wide transparency region
- broad phase-matching range
- large nonlinear coefficient
- high damage threshold
- wide thermal acceptance bandwidth
- high optical homogeneity

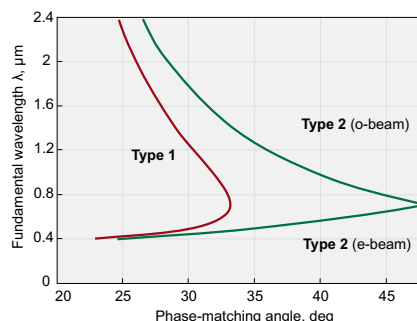
As a result of its excellent properties BBO has a number of advantages for different applications:

- harmonic generations (up to fifth) of Nd doped lasers
- frequency doubling and tripling of ultrashort pulse Ti:Sapphire and Dye lasers
- optical parametric oscillators (OPO) at both Type 1(ooe) and Type 2 (eoe) phase-matching
- frequency doubling of Argon ion and Copper vapour laser radiation
- electro-optic crystal for Pockels cells
- ultrashort pulse duration measurements by autocorrelation.



EKSMA OPTICS OFFERS

- crystal aperture up to 22 × 22 mm
- crystal length up to 20 mm
- thin crystals down to 5 μm thickness
- AR, BBAR, P-coating
- BBO with gold electrodes for e/o applications
- different mounting and repolishing services
- accurate quality control
- attractive prices and fast delivery
- one month customer's satisfaction term.



BBO with gold electrodes for e/o applications

PHYSICAL AND OPTICAL PROPERTIES

| | | |
|--|--|----------------|
| Chemical formula | BaB ₂ O ₄ | |
| Crystal structure | trigonal, 3m | |
| Optical symmetry | Negative Uniaxial (n _o >n _e) | |
| Space group | R3c | |
| Density | 3.85 g/cm ³ | |
| Mohs hardness | 5 | |
| Optical homogeneity | ∂n = 10 ⁻⁶ cm ⁻¹ | |
| Transparency region at "0" transmittance level | 189 – 3500 nm | |
| Linear absorption coefficient at 1064 nm | < 0.1% cm ⁻¹ | |
| Refractive indices | n _o | n _e |
| at 1064 nm | 1.6551 | 1.5426 |
| at 532 nm | 1.6750 | 1.5555 |
| at 355 nm | 1.7055 | 1.5775 |
| at 266 nm | 1.7571 | 1.6139 |
| at 213 nm | 1.8465 | 1.6742 |
| Sellmeier equations (λ, μm) | $n_o^2 = 2.7405 + 0.0184 / (\lambda^2 - 0.0179) - 0.0155 \lambda^2$ $n_e^2 = 2.3730 + 0.0128 / (\lambda^2 - 0.0156) - 0.0044 \lambda^2$ | |
| Phase matching range Type 1 SHG | 410 – 3300 nm | |
| Phase matching range Type 2 SHG | 530 – 3300 nm | |
| Walk-off angle | 55.9 mrad (Type 1 SHG 1064 nm) | |
| Angular acceptance | 1.2 mrad × cm (Type 1 SHG 1064 nm) | |
| Thermal acceptance | 70 K × cm (Type 1 SHG 1064 nm) | |
| Nonlinearity coefficients | $d_{22} = \pm(2.22 \pm 0.09)$ pm/V $d_{31} = \pm(0.16 \pm 0.08)$ pm/V | |
| Effective nonlinearity expressions | $d_{oee} = d_{31} \sin\theta - d_{22} \cos\theta \sin 3\phi$ $d_{eoe} = d_{oee} = d_{22} \cos^2\theta \cos 3\phi$ | |
| Damage threshold for TEM ₀₀ 1064 nm | > 0.5 GW/cm ² at 10 ns ~ 50 GW/cm ² at 1 ps | |

STANDARD SPECIFICATIONS

| | |
|--------------------|--------------------------------------|
| Flatness | up to λ/8 at 633 nm |
| Parallelism | < 20 arcsec |
| Surface quality | 10/5 scratch/dig as per MIL-O-13830A |
| Perpendicularity | < 5 arcmin |
| Angle tolerance | < 30 arcmin |
| Aperture tolerance | ± 0.1 mm |
| Clear aperture | 90% of full aperture |

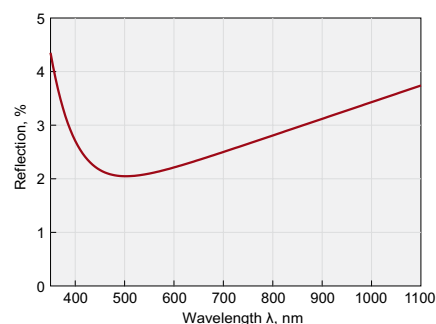
STANDARD CRYSTALS LIST

| Catalogue number | Size, mm | θ , deg | φ , deg | Coating | Application | Price, EUR |
|------------------|-----------|----------------|-----------------|----------------------|----------------------|------------|
| BBO-601H | 6×6×0.1 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 505 |
| BBO-602H | 6×6×0.2 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 505 |
| BBO-603H | 6×6×0.5 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 410 |
| BBO-604H | 6×6×1 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 310 |
| BBO-605H | 6×6×2 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 310 |
| BBO-609H | 6×6×0.1 | 44.3 | 90 | P/P @ 400-800/266 nm | THG @ 800 nm, Type 1 | 505 |
| BBO-610H | 6×6×0.2 | 44.3 | 90 | P/P @ 400-800/266 nm | THG @ 800 nm, Type 1 | 505 |
| BBO-611H | 6×6×0.5 | 44.3 | 90 | P/P @ 400-800/266 nm | THG @ 800 nm, Type 1 | 410 |
| BBO-612H | 6×6×1 | 44.3 | 90 | P/P @ 400-800/266 nm | THG @ 800 nm, Type 1 | 310 |
| BBO-1001H | 10×10×0.1 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 725 |
| BBO-1002H | 10×10×0.2 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 725 |
| BBO-1003H | 10×10×0.5 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 660 |
| BBO-1004H | 10×10×1 | 29.2 | 90 | P/P @ 400-800 nm | SHG @ 800 nm, Type 1 | 625 |

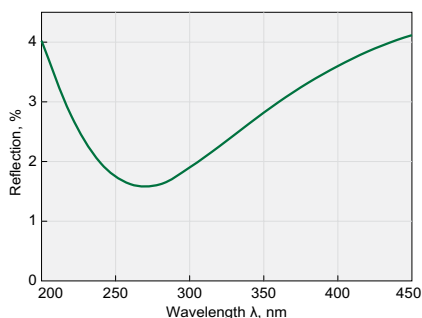
To order unmounted BBO crystals, please remove letter H from code and deduct 50 EUR from price for ring holder.

For safe and convenient handling of BBO crystals, we highly recommend opening ring holders. Standard BBO crystals are provided mounted into 25.4 mm diameter ring holder.

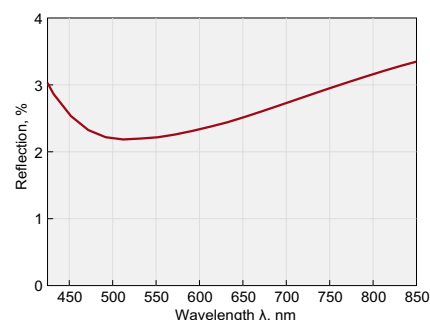
P-protective coating. It's a single or two layers antireflection coating made at specified wavelength range. Typical reflection values are $R \approx 2\%$ in the mid range, $R < 4\%$ at the edges. P coating is recommended for ultra-short pulses applications and features low dispersion.



Typical P-coating for BBO SHG@800 nm application



Typical coating for BBO THG@800 nm or SHG@532 nm applications (output face P@266 nm)



Typical coating for BBO SHG@532 nm application (input face P@532 nm)

Delivery from stock!

Thin BBO crystals for SHG and THG of Ti:Sapphire laser wavelength

Femt* Line see pages: 5.23

BBO crystals for SHG of Yb:KGW/KYW laser frequency conversion

Femt* Line see pages: 5.30

Please contact EKSMA OPTICS for special OEM and large volume pricing.

HOUSING ACCESSORIES

- Ring Holders for Nonlinear Crystals
See page 2.27 for more information.



- Positioning Mount 840-0199 for Nonlinear Crystal Housing

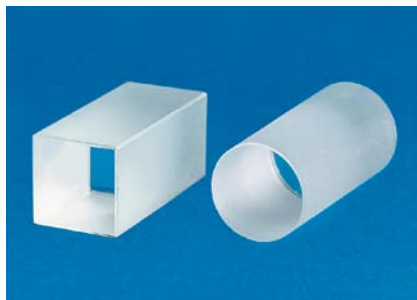
Accepts crystals with aperture up to 12×12 mm and thickness up to 3 mm.

See page 2.29 for more information.



KDP • DKDP

POTASSIUM DIDEUTERIUM PHOSPHATE



APPLICATIONS

- Laser frequency conversion – harmonic generation for high pulse energy, low repetition (<100 Hz) rate lasers;
- Electro-optical modulation;
- Q-switching crystal for Pockels cells.

ELECTRO-OPTICAL/Q-SWITCHING APPLICATION

- EKSMA OPTICS offers highly deuterated D>96% **electro-optic crystal – DKDP** for Q-switching application;
- Standard dimensions of **electro-optic DKDP crystals** for Q-switching are cylinders dia 9×20 mm and dia 12×24 mm however manufacturing of custom size and rectangular shape crystals is available;
- Gold evaporated or silver paste electrodes are available;
- **Dielectric thin film AR coatings** for specified laser wavelengths are available;
- Typical quarter wave voltage 3.4 kV at 1064 nm;
- Typical contrast ratio between crossed polarizers better than 1:2000;
- Damage threshold of AR coated DKDP surface >5 J/cm² at 1064 nm, 10 ns pulses.

FREQUENCY CONVERSION APPLICATIONS

- **DKDP crystals** are used for second harmonic generation of high pulse energy low repetition rate (<100 Hz) Q-switched and mode-locked Nd:YAG lasers. Cut angle of crystal for operation at room temperature is 36.6° for Type 1 phase matching and 53.7° deg for Type 2 phase matching.
- **DKDP crystals** are used for third harmonic generation of high pulse energy Q-switched and mode-locked Nd:YAG lasers via sum frequency generation. Cut angle of crystal for operation at room temperature is 59.3° for Type 2 phase matching.
- Type 1 **DKDP crystals** with non-critical cut angle $\theta=90^\circ$ are used for fourth harmonic generation (532 nm → 266 nm) of high pulse energy Q-switched and mode-locked Nd:YAG lasers. Crystal must be heated at ~50 °C temperature to match NCPM conditions.
- Type 1 **KDP crystals** with close to non-critical cut angle $\theta=76.5^\circ$ are used for fourth harmonic generation (532 nm → 266 nm) of high pulse energy Q-switched and mode-locked Nd:YAG lasers. KDP has lower absorption at UV wavelengths comparing to DKDP.
- **KDP thin crystals** are used for second harmonic generation of Ti:Sapphire laser radiation or pulse duration measurement in single shot autocorrelators. KDP possesses ~2.4 times larger spectral acceptance and correspondingly smaller group velocity mismatch comparing to BBO crystal for SHG of 800 nm, what sometime is very critical parameter for femtosecond wide spectrum pulses.
- KDP crystals can be supplied by EKSMA OPTICS of aperture up to Ø80 mm. Actually KDP remains the only solution for harmonic generation of very high intensity femto-second Ti:Sapphire lasers featuring sub-tera Watt or tera Watt peak power pulses in large >30 mm diameter beams.

PHYSICAL AND OPTICAL PROPERTIES

| Crystals | KDP | DKDP |
|---|--|--|
| Chemical formula | KH ₂ PO ₄ | KD ₂ PO ₄ |
| Symmetry | 42 m | 42 m |
| Hygroscopicity | high | high |
| Density, g/cm ³ | 2.332 | 2.355 |
| Thermal conductivity, W/cm×K | $k_{11}=1.9 \times 10^{-2}$ | $k_{11}=1.9 \times 10^{-2}$ $k_{33}=2.1 \times 10^{-2}$ |
| Thermal expansion coefficients, K ⁻¹ | $a_{11}=2.5 \times 10^{-5}$ $a_{33}=4.4 \times 10^{-5}$ | $a_{11}=1.9 \times 10^{-5}$ $a_{33}=4.4 \times 10^{-5}$ |
| Transmission range, μm | 0.18–1.5 | 0.2–2.0 |
| Residual absorption, cm ⁻¹ (at 1.06 μm) | 0.04 | 0.005 |
| Measured refractive index (at 1.06 μm) | $n_o=1.4938$ $n_e=1.4599$ | $n_o=1.4931$ $n_e=1.4582$ |
| Sellmeier coeff., λ – wavelength in μm | $n^2 = A + \frac{B \lambda^2}{\lambda^2 - C} + \frac{D}{\lambda^2 - E}$ | |
| A | n_o | 2.259276 |
| | n_e | 2.132668 |
| B | n_o | 13.00522 |
| | n_e | 3.2279924 |
| C | n_o | 400 |
| | n_e | 400 |
| D | n_o | 0.01008956 |
| | n_e | 0.008637494 |
| E | n_o | 0.012942625 |
| | n_e | 0.012281043 |
| Nonlinear coeff. d ₃₆ , pm/V (at 1.06 μm) | 0.43 | 0.40 |
| Effective nonlinear coefficient | $d_{oe} = d_{36} \times \sin\theta \times \sin 2\varphi$ $d_{oe} = d_{36} \times \sin\theta \times \cos 2\varphi$ | |
| Laser damage threshold, GW/cm ² at 1.06 μm | 10 ps – 100 | 250 ps – 6 |
| | 1 ns – 10 | 10 ns – 0.5 |
| | 15 ns – 14.4 | |

PHASE MATCHING ANGLES AND BANDWIDTHS FOR SHG OF 1064 nm

| Crystal | KDP | | DKDP | |
|--|------------|------------|------------|------------|
| | Type 1 ooe | Type 2 eoe | Type 1 ooe | Type 2 eoe |
| Type of phase matching | | | | |
| Cut angle θ , deg | 41.2 | 59.1 | 36.6 | 53.7 |
| Acceptances for crystal of 1 cm length (FWHM): | | | | |
| $\Delta\theta$ (angular), mrad | 1.1 | 2.2 | 1.2 | 2.3 |
| ΔT thermal, K | 10 | 11.8 | 32.5 | 29.4 |
| $\Delta\lambda$ spectral, nm | 21 | 4.5 | 6.6 | 4.2 |
| Walk off, mrad | 28 | 25 | 25 | 25 |

STANDARD SPECIFICATIONS

| | |
|--------------------|--|
| Flatness | $\lambda/6$ at 633 nm |
| Parallelism | < 20 arcsec |
| Surface quality | 20/10 scratch/dig as per MIL-O-13830A |
| Perpendicularity | < 5 arcmin |
| Angle tolerance | < 30 arcmin |
| Aperture tolerance | ± 0.1 mm |
| Clear aperture | 90% of full aperture |

ADP, DADP, RDP, CDA and DCDA crystals are available upon request!

STANDARD CRYSTALS LIST

| Code | Size, mm | θ , deg | ϕ , deg | Coating | Application | Price, EUR |
|-----------------|----------|----------------|--------------|----------------------------|-----------------------|------------|
| DKDP-401 | 15x15x13 | 36.5 | 45 | AR/AR @ 1064+532 nm | SHG @ 1064 nm, Type 1 | 485 |
| DKDP-402 | 15x15x13 | 53.5 | 0 | AR/AR @ 1064+532 nm | SHG @ 1064 nm, Type 2 | 485 |
| DKDP-403 | 12x12x20 | 59.3 | 0 | AR/AR @ 1064+532 / 355 nm | THG @ 1064 nm, Type 2 | 475 |
| DKDP-404 | 12x12x20 | 53.5 | 0 | AR/AR @ 1064 / 1064+532 nm | SHG @ 1064 nm | 475 |
| DKDP-405 | 15x15x20 | 53.5 | 0 | AR/AR @ 1064 / 1064+532 nm | SHG @ 1064 nm | 579 |
| DKDP-406 | 15x15x20 | 59.3 | 0 | AR/AR @ 1064+532 / 355 nm | THG @ 1064 nm | 579 |
| KDP-401 | 12x12x5 | 76.5 | 45 | AR/AR @ 532/266 nm | SHG @ 532 nm | 405 |
| KDP-402 | 15x15x7 | 76.5 | 45 | AR/AR @ 532/266 nm | SHG @ 532 nm | 480 |

Delivery from stock!

Please contact EKSMA OPTICS
for special OEM and large volume pricing.

RELATED PRODUCTS

- Nonlinear Crystal Oven CH3
See page 2.31 for more information.
- Nonlinear Crystal Oven CH4
See page 2.32 for more information.



DKDP and KDP crystals are highly hygroscopic. CH3 and CH4 ovens help to protect hygroscopic crystals from moisture. The raised working temperature (40-60 °C) allows to extend crystal lifetime and to keep it thermostable. This helps to stabilise SHG efficiency.

KTP

POTASSIUM TITANYL PHOSPHATE



KTP (KTiOPO_4) is a nonlinear optical crystal, which possesses excellent nonlinear, electrooptical and acousto-optical properties. A combination of high nonlinear coefficient, wide transparency range, and broad angular as well as thermal acceptances makes KTP very attractive for different nonlinear optical and waveguide applications.

EKSMA OPTICS OFFERS

- Crystal size up to $10 \times 10 \times 20$ mm
- Singleband and dualband AR and BBAR coatings
- Standard and customised mounts and housings
- Free technical consulting.

EKSMA OPTICS GUARANTEES

- Accurate quality control
- One month customer's satisfaction term
- Conformity of crystal specifications to highest standards
- Attractive prices
- Fast delivery.

KTP is a standard crystal mostly used in extracavity configuration when a single pass through the crystal is required. KTP crystals are optimised for SHG intracavity configuration in low peak power CW lasers. Due to the large number of passes through the crystal, low insertion losses and high homogeneity are essential for conversion efficiency. The special highest quality material selected by SHG efficiency mapping of each crystal, fine surface polishing and dual band AR coatings with very low losses allow EKSMA OPTICS to produce KTP crystals suitable for intracavity SHG application.

Fig. 1 represents Type 2 SHG tuning curve of KTP in x-y plane. In x-y plane the slope $\partial(\Delta k)/\partial\theta$ is small. This corresponds to quasi-angular noncritical phase-matching, which ensures the double advantage of a large acceptance angle and a small walk off. Otherwise in x-z plane the slope $\partial(\Delta k)/\partial\lambda$ is almost zero for wavelengths in the range $1.5\text{--}2.5\text{ }\mu\text{m}$ and this corresponds to quasi-wavelength noncritical phase-matching, which ensures a large spectral acceptance (see Fig. 2). Wavelength noncritical phase-matching is highly desirable for frequency conversion of short pulses. As a lasing material for OPG, OPA or OPO, KTP can most usefully be pumped by Nd lasers and their second harmonic or any other source with intermediate wavelength, such as a dye laser (near 600 nm). Fig. 3 and Fig. 4 show the phase-matching angles for OPO/OPA pumped at 532 nm in x-y and x-z plane respectively.

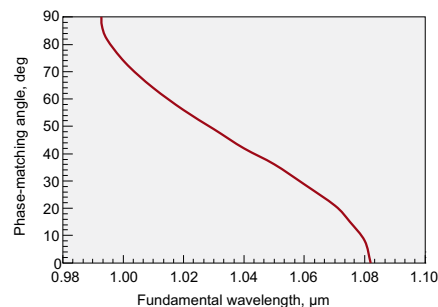


Fig. 1. Type 2 SHG in x-y plane

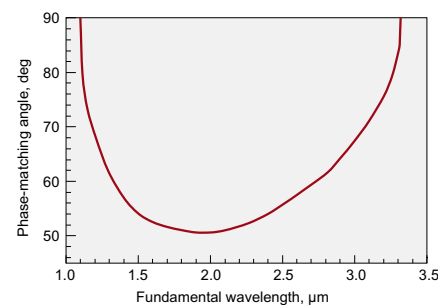


Fig. 2. Type 2 SHG in x-z plane

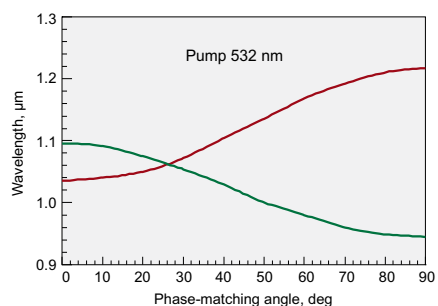


Fig. 3. OPO tuning curve in x-y plane

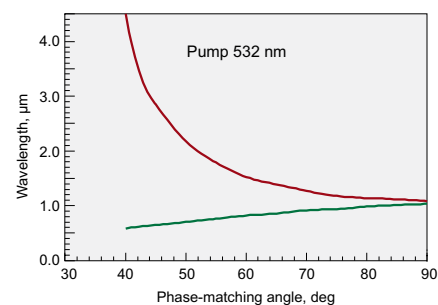


Fig. 4. OPO tuning curve in x-z plane

Please contact EKSMA OPTICS
for special OEM and large volume pricing.

PHYSICAL PROPERTIES

| | |
|--|--|
| Crystal structure | orthorhombic |
| Point group | mm2 |
| Space group | Pna2 ₁ |
| Lattice constants, Å | a = 6.404, b = 10.616, c = 12.814, z = 8 |
| Density, g/cm ³ | 3.01 |
| Melting point, °C | 1172 |
| Transition temperature, °C | 936 |
| Mohs hardness | 5 |
| Thermal expansion coefficients, °C ⁻¹ | a _x = 11×10 ⁻⁶ , a _y = 9×10 ⁻⁶ , a _z = 0.6×10 ⁻⁶ |
| Thermal conductivity, W/cm°C | 13 |
| Not hygroscopic | |

OPTICAL PROPERTIES

| | | |
|--|--|----------------|
| Transparency | 350–4400 nm | |
| Refractive indices | at 1064 nm | at 532 nm |
| | $n_x = 1.7404$ | $n_x = 1.7797$ |
| | $n_y = 1.7479$ | $n_y = 1.7897$ |
| | $n_z = 1.8296$ | $n_z = 1.8877$ |
| Thermooptic coefficients in 0.4 – 1.0 μm range | $\partial n_x / \partial T = 1.1 \times 10^{-5} \text{ (K)}^{-1}$ | |
| | $\partial n_y / \partial T = 1.3 \times 10^{-5} \text{ (K)}^{-1}$ | |
| | $\partial n_z / \partial T = 1.6 \times 10^{-5} \text{ (K)}^{-1}$ | |
| Wavelength dispersion of refractive indices | $n_x^2 = 3.0067 + 0.0395 / (\lambda^2 - 0.04251) - 0.01247 \times \lambda^2$ | |
| | $n_y^2 = 3.0319 + 0.04152 / (\lambda^2 - 0.04586) - 0.01337 \times \lambda^2$ | |
| | $n_z^2 = 3.3134 + 0.05694 / (\lambda^2 - 0.05941) - 0.016713 \times \lambda^2$ | |

NONLINEAR PROPERTIES

| | |
|---|---|
| Phase matching range for: | |
| Type 2 SHG in x-y plane | 0.99±1.08 μm |
| Type 2 SHG in x-z plane | 1.1±3.4 μm |
| For Type 2, SHG @ 1064 nm, cut angle θ=90°, φ=23.5° | |
| Walk-off | 4 mrad |
| Angular acceptances | Δθ = 55 mrad × cm |
| | Δφ = 10 mrad × cm |
| Thermal acceptance | ΔT = 22 K × cm |
| Spectral acceptance | Δν = 0.56 nm × cm |
| Up to 80% extracavity SHG efficiency | |
| Effective nonlinearity | |
| x-y plane | d _{oe} = d _{oe} = d ₁₅ sin ² φ + d ₂₄ cos ² φ |
| x-z plane | d _{eo} = d _{eo} = d ₂₄ sinθ |
| | d ₃₁ = ± 1.95 pm/V d ₃₂ = ± 3.9 pm/V |
| | d ₃₃ = ± 15.3 pm/V d ₂₄ = d ₃₂ d ₁₅ = d ₃₁ |
| | >500 MW/cm ² |
| Damage threshold | for pulses λ=1064 nm, τ=10 ns, 10 Hz, TEM ₀₀ |

STANDARD SPECIFICATIONS

| | |
|--------------------|---|
| Flatness | λ/8 at 633 nm |
| Parallelism | < 20 arcsec |
| Surface quality | 10/5 scratch/dig as per MIL-O-13830A |
| Perpendicularity | < 5 arcmin |
| Angle tolerance | < 30 arcmin |
| Aperture tolerance | ± 0.1 mm |
| Clear aperture | 90% of full aperture |

STANDARD CRYSTALS LIST

| Code | Size, mm | θ | φ | Coating | Application | Price, EUR |
|---------|----------|----|------|---------------------|---------------|------------|
| KTP-401 | 3x3x5 | 90 | 23.5 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 76 |
| KTP-402 | 3x3x10 | 90 | 23.5 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 109 |
| KTP-403 | 4x4x6 | 90 | 23.5 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 118 |
| KTP-404 | 7x7x9 | 90 | 23.5 | AR/AR @ 1064+532 nm | SHG @ 1064 nm | 529 |

HOUSING ACCESSORIES

- Ring Holders for Nonlinear Crystals
See page 2.27 for more information.
- Positioning Mount 840-0199 for Nonlinear Crystal Housing
See page 2.29 for more information.

RELATED PRODUCTS

- Crystal Oven TC1
See page 2.30 for more information.
- Nonlinear Crystal Oven CH7
See page 2.33 for more information.

KTA

POTASSIUM TITANYLE ARSENATE

Potassium titanyle arsenate (KTiOAsO_4), or KTA, is a nonlinear optical crystal for Optical Parametric Oscillation (OPO) application. It has good nonlinear optical and electro-optical properties, e.g. significantly reduced absorption in band range of 2.0-5.0 μm , broad angular and temperature bandwidth, low dielectric constants.

PRIMARY APPLICATIONS

- OPO for mid IR generation – up to 4 μm
- Sum and Difference Frequency Generation in mid IR range
- Electro-optical modulation and Q-switching

EKSMA OPTICS OFFERS:

- KTA crystals size up to 15×15×30 mm
- AR and BBAR coatings for VIS-IR and mid IR ranges
- Standard and customized mounts and housings
- Technical consulting

SPECIFICATIONS

| | |
|-----------------------------------|-----------------------------------|
| Flatness | $\lambda/8$ at 633 nm |
| Parallelism | < 20 arcsec |
| Surface quality | 10/5 scratch/dig (MIL-PRF-13830B) |
| Perpendicularity | < 15 arcmin |
| Angle tolerance | < $\pm 0.2^\circ$ |
| Aperture tolerance | ± 0.1 mm |
| Clear aperture | > 90% central area |
| Transmitting wavefront distortion | less than $\lambda/8$ @ 633 nm |

PHYSICAL PROPERTIES

| | |
|-----------------------------|------------------------------------|
| Crystal structure | orthorhombic |
| Point group | mm2 |
| Space group | Pna21 |
| Lattice constants, Å | a = 13.125, b = 6.5716, c = 10.786 |
| Density, g/cm ³ | 3.45 |
| Melting point, °C | 1130 |
| Mohs hardness | 5 |
| Thermal conductivity, W/m×K | $k_1=1.8$, $k_2=1.9$, $k_3=2.1$ |
| Not hygroscopic | |

NONLINEAR & OPTICAL PROPERTIES

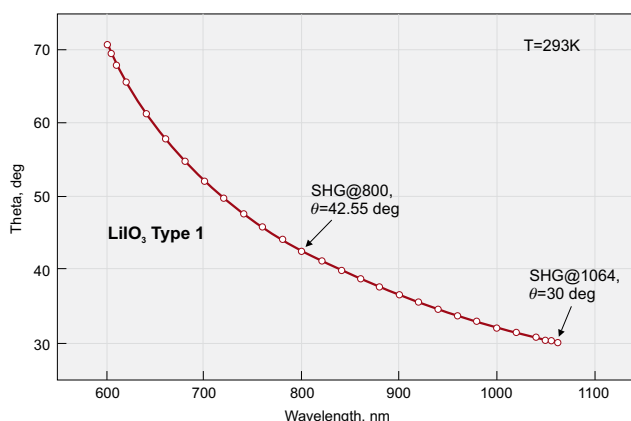
| | |
|---|--|
| Transparency | 350 – 5300 nm |
| Wavelength dispersion of refractive indices | $n_x^2 = 1.90713 + 1.23522 \times \lambda^2 / (\lambda^2 - 0.196922) - 0.01025 \times \lambda^2$ $n_y^2 = 2.15912 + 1.00099 \times \lambda^2 / (\lambda^2 - 0.218442) - 0.01096 \times \lambda^2$ $n_z^2 = 2.14768 + 1.29559 \times \lambda^2 / (\lambda^2 - 0.227192) - 0.01436 \times \lambda^2$ |
| Electro optical constants | $r_{33} = 37.5$ pm/V, $r_{23} = 15.4$ pm/V, $r_{13} = 11.5$ pm/V |
| Effective nonlinearity | |
| x-y plane | $d_{\text{oe}} = d_{\text{oe}} = d_{15} \sin^2 \varphi + d_{24} \cos^2 \varphi$ |
| x-z plane | $d_{\text{eo}} = d_{\text{eo}} = d_{24} \sin \theta$ |
| | $d_{31}=2.3$ pm/V, $d_{32}=3.66$ pm/V, $d_{33}=15.5$ pm/V |
| | $d_{24} = 3.64$ pm/V, $d_{15} = 2.3$ pm/V |
| Damage threshold | >500 MW/cm ² for pulses $\lambda=1064$ nm, $\tau=10$ ns, 10 Hz, TEM ₀₀ |

LiIO₃**LITHIUM IODATE****APPLICATIONS**

- Harmonic generators
- Thin LiIO₃ for autocorrelation measurements

EKSMA OPTICS OFFERS:

- The mass production of LiIO₃ crystals
- Attractive discounts for OEM customers
- Different shapes (slabs, cylinders, Brewster ends) are available
- Standard open ring holders
- Recoating and repolishing service
- AR, BBAR and P - coatings according to customer's choice
- P-coatings optimised at pump wavelengths
- BBAR coatings for wavelength tuned Ti:Sapphire and other lasers.

*LiIO₃ Second harmonic generation phase matching***PHYSICAL AND OPTICAL PROPERTIES**

| | |
|---|---|
| Crystal structure | hexagonal |
| Point group | 6 |
| Density, g/cm ³ | 4.487 |
| Mohs hardness | 3.5–4.0 |
| Transparency range, nm | 280–4000 |
| Absorption at 1064 nm, cm ⁻¹ | < 0.05 |
| Refractive indices at 1064 nm | $n_o = 1.8571, n_e = 1.7165$ |
| at 800 nm | $n_o = 1.8676, n_e = 1.7245$ |
| at 532 nm | $n_o = 1.8982, n_e = 1.7480$ |
| Phase matching range for Type 1 SHG, nm | 570–4000 |
| Acceptances for Type 1 SHG at 1064 nm | |
| Angular, mrad×cm | 0.77 |
| Spectral, cm ⁻¹ ×cm | 12.74 |
| Walk-off for Type 1 SHG at 1064 nm, mrad | 74.30 |
| Nonlinear optical coefficient d ₁₅ , pm/V | 2.2 (at 1064 nm) |
| Effective nonlinearity | $d_{\text{oe}} = d_{15} \sin \theta$ |
| Damage threshold, MW/cm ² | > 100 for TEM ₀₀ , 1064 nm, 10 ns, 10 Hz |
| Wavelength dispersion of refractive indices (λ – in μm) | |
| $n_o^2 = 2.083648 + \frac{1.332068 \lambda^2}{\lambda^2 - 0.035306} - 0.008525 \lambda^2$ | $n_e^2 = 1.673463 + \frac{1.245229 \lambda^2}{\lambda^2 - 0.028224} - 0.003641 \lambda^2$ |

SPECIFICATIONS

| | |
|---|---------------------------------------|
| Flatness | $\lambda/6$ at 633 nm |
| Parallelism | < 30 arcsec |
| Surface quality | 20/10 scratch/dig as per MIL-O-13830A |
| Perpendicularity | < 5 arcmin |
| Angle tolerance ($\Delta\theta$ & $\Delta\phi$) | < 30 arcmin |
| Clear aperture | 90% of full aperture |

HOUSING ACCESSORIES

- Ring Holders for Nonlinear Crystals
See page 2.27 for more information.

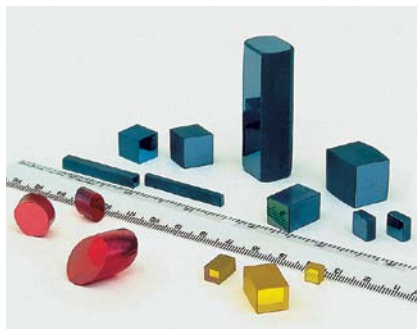


- Positioning Mount 840-0199 for Nonlinear Crystal Housing
See page 2.29 for more information.



ZnGeP₂ • AgGaSe₂ AgGaS₂ • GaSe

INFRARED NONLINEAR CRYSTALS



Optical nonlinear crystals **ZnGeP₂**, **AgGaSe₂**, **AgGaS₂**, **GaSe** have gained tremendous interest for middle and deep infrared applications due to their unique features. The crystals have large effective optical nonlinearity, wide spectral and angular acceptances, broad transparency range, non-critical requirements for temperature stabilization and vibration control, are well mechanically processed (except GaSe).

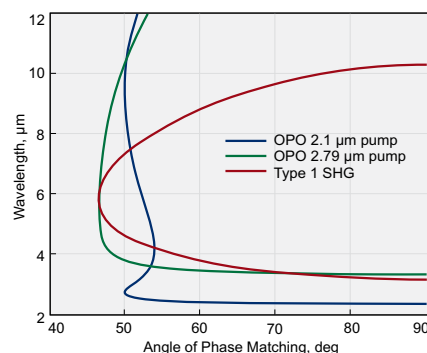
ZnGeP₂

ZnGeP₂ has band edges at 0.74 and 12 μm with useful transmission range from 1.9 to 10.6 μm. ZnGeP₂ has the largest nonlinear optical coefficient and relatively high laser damage threshold. It was successfully used in the following applications:

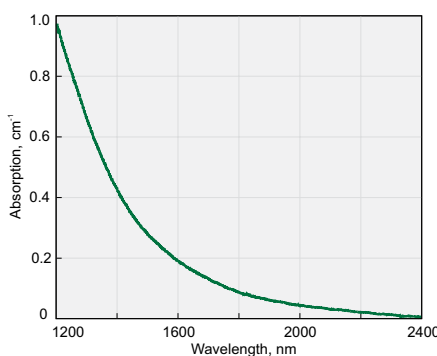
- up-conversion of CO₂ laser light to near IR range via mixing with 10.6 μm;
- sum frequency generation of CO and CO₂ laser radiation;
- efficient SHG of pulsed CO, CO₂ and chemical DF-laser, OPO light generation in mid infrared when pumped by erbium and holmium lasers.

ZnGeP₂ crystals with lowest absorption <0.04 cm⁻¹ @ 2.1 μm are available from

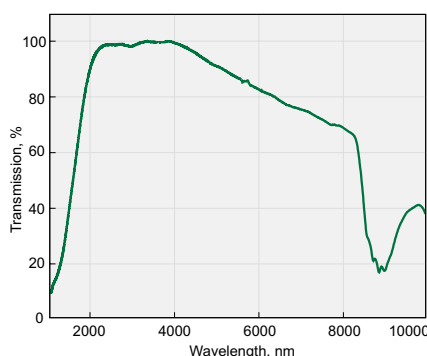
EKSMA OPTICS for better suitability for OPO or OPA application, then pumping 2.05–2.1 μm, with antireflection coatings.



Type 1 OPO and SHG tuning curves in ZnGeP₂



Absorption spectra of ZnGeP₂ crystal near 2 μm



Transmission spectra of 15 mm long AR coated ZnGeP₂ crystal for OPO @ 2.1 μm

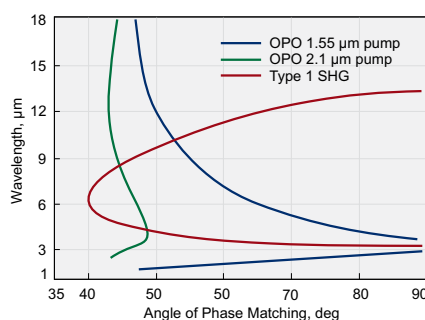
ZGP TYPE 1 CRYSTALS

| Catalogue number | Size, mm | θ, deg | φ, deg | Coating | Application |
|------------------|----------|--------|--------|-------------------------------|--------------|
| ZGP-401 | 7×5×15 | 54 | 0 | AR @ 2.1 μm + BBAR @ 3.5-5 μm | OPO @ 2.1 μm |
| ZGP-402 | 7×5×20 | 54 | 0 | AR @ 2.1 μm + BBAR @ 3.5-5 μm | OPO @ 2.1 μm |
| ZGP-403 | 7×5×25 | 54 | 0 | AR @ 2.1 μm + BBAR @ 3.5-5 μm | OPO @ 2.1 μm |

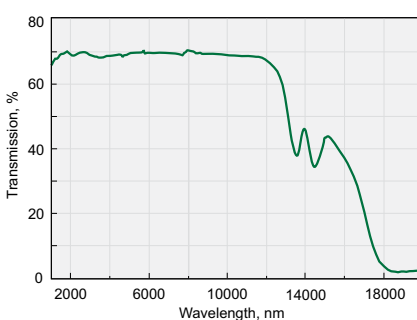
AgGaSe₂

AgGaSe₂ has band edges at 0.73 and 18 μm. Its useful transmission range of 0.9–16 μm and wide phase matching capability provide excellent potential for OPO applications when pumped by a variety of currently available lasers. Tuning from

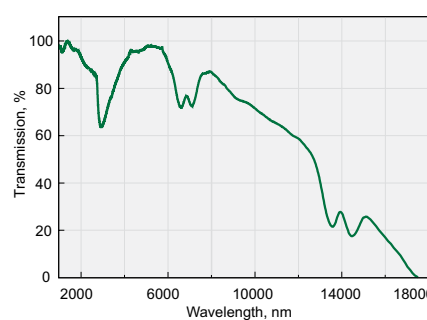
2.5–12 μm has been obtained when pumping by Ho:YLF laser at 2.05 μm; as well as NCPM operation from 1.9–5.5 μm when pumping at 1.4–1.55 μm. Efficient SHG of pulsed CO₂ laser has been demonstrated.



Type 1 OPO and SHG tuning curves in AgGaSe₂



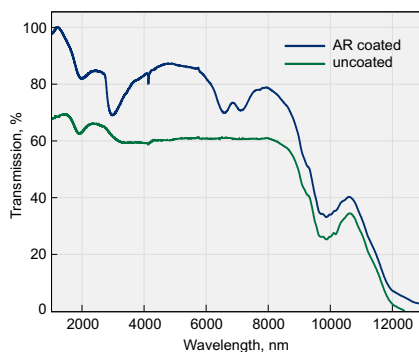
Transmission spectra of 18 mm long uncoated AgGaSe₂ crystal



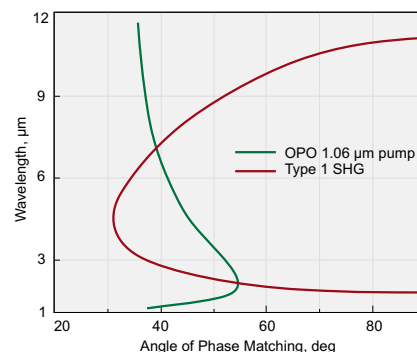
Transmission spectra of 25 mm long AR coated AgGaSe₂ crystal

AgGaS₂

AgGaS₂ is transparent from 0.53 to 12 μm . Although nonlinear optical coefficient is the lowest among the above mentioned infrared crystals, its high short wavelength transparency edging at 550 nm is used in OPOs pumped by Nd:YAG laser; in numerous difference frequency mixing experiments using diode, Ti:Sapphire, Nd:YAG and IR dye lasers covering 3–12 μm range; direct infrared counter-measure systems, and SHG of CO₂ laser.



Transmission spectra of 14 mm long AR coated and uncoated AgGaS₂ crystal used for OPO pumped by Nd:YAG laser



Type 1 OPO and SHG tuning curves in AgGaS₂

LIST OF STANDARD AgGaS₂ CRYSTALS

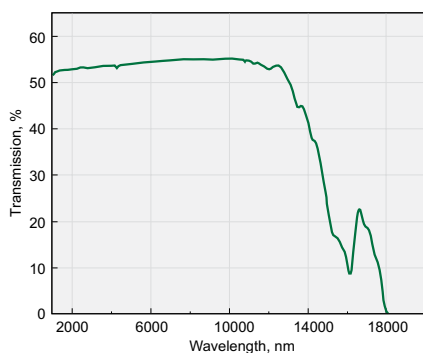
| Code | Size, mm | θ , deg | ϕ , deg | Coating | Application | Price, EUR |
|----------|----------|----------------|--------------|--|--|------------|
| AGS-401H | 5×5×1 | 39 | 45 | BBAR/BBAR @ 1.1-2.6 / 2.6-11 μm | OPO @ 1.2-2.4 μm → 2.4-11 μm | 695 |
| AGS-402H | 6×6×2 | 50 | 0 | BBAR/BBAR @ 1.1-2.6 / 2.6-11 μm | OPO @ 1.2-2.4 μm → 2.4-11 μm | 770 |

Crystals are mounted into open ring holders (see page 2.27).

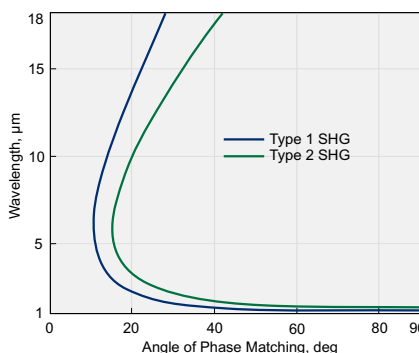
GaSe

GaSe has band edges at 0.65 and 18 μm . GaSe has been successfully used for efficient SHG of CO₂ laser, for SHG of pulsed CO, CO₂ and chemical DF-laser ($\lambda = 2.36 \mu\text{m}$) radiation; up conversion of CO and CO₂ laser radiation into the visible range; infrared pulses generation via difference frequency mixing of Neodym-

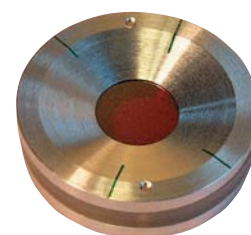
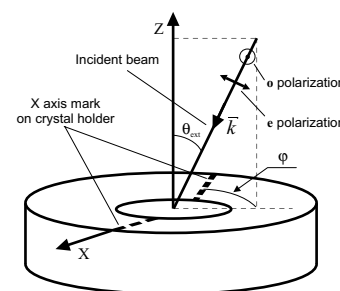
ium and infrared dye laser or (F-)centre laser pulses; OPG light generation within 3.5–18 μm ; efficient TeraHertz generation in 100–1600 μm range. It is impossible to cut crystals for certain phase matching angles because of material structure (cleave along (001) plane) limiting areas of applications.



Transmission spectra of 17 mm long uncoated GaSe crystal



Type 1 and Type 2 SHG tuning curves in GaSe



Cleaved GaSe crystal glued into special ring holder

HOUSING ACCESSORIES

- Ring Holders for Nonlinear Crystals
See page 2.27 for more information.



PHYSICAL PROPERTIES

| Crystal | | ZnGeP ₂ | AgGaSe ₂ | AgGaS ₂ | GaSe |
|----------------------------|---|--------------------|---------------------|--------------------|-----------|
| Crystal Symmetry | | Tetragonal | Tetragonal | Tetragonal | Hexagonal |
| Point Group | | 42m | 42m | 42m | 62m |
| Lattice Constants, Å | a | 5.465 | 5.9901 | 5.757 | 3.742 |
| | c | 10.771 | 10.8823 | 10.305 | 15.918 |
| Density, g/cm ³ | | 4.175 | 5.71 | 4.56 | 5.03 |

OPTICAL PROPERTIES

| Crystal | | ZnGeP ₂ | AgGaSe ₂ | AgGaS ₂ | GaSe |
|---|----------------|--------------------|---------------------|--------------------|---------|
| Optical transmission, μm | | 0.74–12 | 0.73–18 | 0.53–12 | 0.65–18 |
| Indices of Refraction at | | | | | |
| 1.06 μm | n _o | 3.2324 | 2.7005 | 2.4508 | 2.9082 |
| | n _e | 3.2786 | 2.6759 | 2.3966 | 2.5676 |
| 5.3 μm | n _o | 3.1141 | 2.6140 | 2.3954 | 2.8340 |
| | n _e | 3.1524 | 2.5823 | 2.3421 | 2.4599 |
| 10.6 μm | n _o | 3.0725 | 2.5915 | 2.3466 | 2.8158 |
| | n _e | 3.1119 | 2.5585 | 2.2924 | 2.4392 |
| Absorption Coefficient, cm ⁻¹ at | | | | | |
| 1.06 μm | | 3.0 | <0.02 | <0.09 | 0.25 |
| 2.5 μm | | 0.03 | <0.01 | 0.01 | 0.05 |
| 5.0 μm | | 0.02 | <0.01 | 0.01 | 0.05 |
| 7.5 μm | | 0.02 | — | 0.02 | 0.05 |
| 10.0 μm | | 0.4 | — | <0.6 | 0.05 |
| 11.0 μm | | 0.8 | — | 0.6 | 0.05 |

NONLINEAR OPTICAL PROPERTIES

| Crystal | | ZnGeP ₂ | AgGaSe ₂ | AgGaS ₂ | GaSe |
|---|--|--------------------|---------------------|--------------------|------|
| Laser damage threshold, MW/cm ² | | 60 | 25 | 10 | 28 |
| at pulse duration, ns | | 100 | 50 | 20 | 150 |
| at wavelength, μm | | 10.6 | 2.05 | 1.06 | 9.3 |
| Nonlinearity, pm/V | | 111 | 43 | 31 | 63 |
| Phase matching angle for Type 1 SHG at 10.6 μm, deg | | 76 | 55 | 67 | 14 |
| Walk-off angle at 5.3 μm, deg | | 0.57 | 0.67 | 0.85 | 3.4 |

THERMAL PROPERTIES

| Crystal | | ZnGeP ₂ | AgGaSe ₂ | AgGaS ₂ | GaSe |
|---|---|---------------------|----------------------|--------------------|------|
| Melting point, °C | | 1298 | 851 | 998 | 1233 |
| Thermal Expansion Coefficient, 10 ⁻⁶ /°K | | | | | |
| | ⊥ | 17.5 ^(a) | 23.4 ^(c) | 12.5 | 9.0 |
| | ⊥ | 9.1 ^(b) | 18.0 ^(d) | | |
| | | 1.59 ^(a) | -6.4 ^(c) | -13.2 | 8.25 |
| | | 8.08 ^(b) | -16.0 ^(d) | | |

a) at 293–573 K, b) at 573–873 K, c) at 298–423 K, d) at 423–873 K

SELLMEIER EQUATIONS FOR CALCULATION OF INDICES OF REFRACTION

| Crystal | | A | B | C | D | E | F | Expression |
|---------------------|----------------|--------|---------|---------|---------|--------|------|---|
| ZnGeP ₂ | n _o | 8.0409 | 1.68625 | 0.40824 | 1.2880 | 611.05 | — | $n^2 = A + B\lambda^2 / (\lambda^2 - C) + D\lambda^2 / (\lambda^2 - E)$ |
| | n _e | 8.0929 | 1.8649 | 0.41468 | 0.84052 | 452.05 | — | |
| AgGaSe ₂ | n _o | 6.8507 | 0.4297 | 0.15840 | 0.00125 | — | — | $n^2 = A + B / (\lambda^2 - C) - D\lambda^2$ |
| | n _e | 6.6792 | 0.4598 | 0.21220 | 0.00126 | — | — | |
| AgGaS ₂ | n _o | 3.3970 | 2.3982 | 0.09311 | 2.1640 | 950.0 | — | $n^2 = A + B / (1 - C/\lambda^2) + D / (1 - E/\lambda^2)$ |
| | n _e | 3.5873 | 1.9533 | 0.11066 | 2.3391 | 1030.7 | — | |
| GaSe | n _o | 7.443 | 0.405 | 0.0186 | 0.0061 | 3.1485 | 2194 | $n^2 = A + B/\lambda^2 + C/\lambda^4 + D/\lambda^6 + E/(1 - F/\lambda^2)$ |
| | n _e | 5.76 | 0.3879 | -0.2288 | 0.1223 | 1.855 | 1780 | |

BBO • LBO • KDP
LiIO₃ • AgGaS₂ • GaSe

ULTRATHIN NONLINEAR CRYSTALS



Thin crystals are used in different applications with femtosecond pulses:

- Harmonic generation (SHG, SFG)
- Optical parametric generation and amplification (OPG, OPA)
- Difference frequency generation (DFG)
- Pulse width measurements by auto and cross correlation
- THz frequency generation (in GaSe crystal)

The propagation of a ultrashort optical pulses through the crystal results in a delay of the pulses because of Group Velocities Mismatch (GVM), a duration broadening because of Group Delay Dispersion (GDD) and a frequency chirp.

Unfortunately those effects forces to limit nonlinear crystal thickness in frequency generation schemes.

For two collinearly propagating pulses with different group velocities their quasistatic interaction length (L_{qs}) is defined as distance over which they separate by a path equal to the one of the pulses duration (or to the desired pulse duration):

$$L_{qs} = \tau / \text{GVM} ;$$

where GVM is the group velocity mismatch and τ is the duration of the pulse. GVM calculations are presented for the most popular Type 1 phase matching applications for different crystals in Table 2.

Optimal BBO, LBO, KDP and LiIO₃ crystal thicknesses which are limited by GVM for Type 1 SHG of 800 nm at different fundamental pulse duration are presented in the Table 3. Also effective coefficients and phase matching angles at room temperature (20 °C) are calculated. If longer crystal will be used this will cause second harmonic pulse broadening to the duration longer than fundamental pulse duration (or desired pulse duration).

Group delay dispersion (GDD) has an important impact on the propagation of pulses, because a pulse always has certain spectral width, so that dispersion will cause its frequency components to propagate with different velocities. In case of crystals where we have normal dispersion when refractive index decreases with increasing wavelength this leads to a lower group velocity of higher-frequency components, and thus to a positive chirp. The frequency dependence of the group velocity also has an influence on the pulse duration. If the pulse is initially unchirped, dispersion in a crystal will always increase its duration. This is called dispersive pulse broadening. For an originally unchirped Gaussian pulse with the duration τ_0 , the pulse duration is increased according to:

$$t = \tau_0 \sqrt{1 + \left(\frac{4 \ln 2 \cdot D \cdot L}{\tau_0^2} \right)^2}$$

L – thickness of the crystal in mm. D – second order group delay dispersion or dispersion parameter. Table 1 gives D parameter for Type 1 phase matching SHG @ 800 nm for 800 nm pulse with „o“ polarization and 400 nm pulse with „e“ polarization in different crystals.

Table 1. D parameter for Type 1 SHG @ 800 nm orientation crystals for 800 nm (o-pol) and 400 nm (e-pol) pulses

| Crystal | D at 800 nm | D at 400 nm |
|-------------------|---------------------------|---------------------------|
| BBO | 75 fsec ² /mm | 196 fsec ² /mm |
| LBO | 47 fsec ² /mm | 128 fsec ² /mm |
| KDP | 27 fsec ² /mm | 107 fsec ² /mm |
| LiIO ₃ | 196 fsec ² /mm | 589 fsec ² /mm |

We may calculate that spectrum limited initial 30 fsec Gaussian pulse at 400 nm will be broadened to 35 fsec pulse after passing 1 mm thickness BBO crystal.

Table 2. Group velocity mismatch between shortest and longest wave pulse for Type 1 phase matching

| Crystal | SFM 800+266 nm | SFM 800+400 nm | SHG 800 nm | SHG 1030 nm | SHG 1064 nm | DFG 1.26-2.18 → 3 μm | DFG 1.48-1.74 → 10 μm |
|--------------------|-------------------|-------------------|---------------|----------------|----------------|-------------------------|--------------------------|
| BBO | 2074 fs/mm | 737 fs/mm | 194 fs/mm | 94 fs/mm | 85 fs/mm | – | – |
| LBO | – | 448 fs/mm | 123 fs/mm | 51 fs/mm | 44 fs/mm | – | – |
| KDP | – | 370 fs/mm | 77 fs/mm | 1 fs/mm | -7 fs/mm | – | – |
| LiIO ₃ | – | – | 559 fs/mm | 285 fs/mm | 262 fs/mm | – | – |
| AgGaS ₂ | – | – | – | – | – | 170 fs/mm | -10 fs/mm |

Table 3. Quasistatic interaction length for Type 1 SHG of 800 nm

| Crystal | 200 fs | 100 fs | 50 fs | 20 fs | 10 fs | Cut angles θ, φ | Coefficient deff |
|-------------------|--------|---------|---------|---------|----------|------------------------------|------------------|
| BBO | 1.0 mm | 0.5 mm | 0.26 mm | 0.1 mm | 0.05 mm | 29.2°, 90° | 2.00 pm/V |
| LBO | 1.6 mm | 0.8 mm | 0.4 mm | 0.16 mm | 0.08 mm | 90°, 31.7° | 0.75 pm/V |
| KDP | 2.6 mm | 1.3 mm | 0.6 mm | 0.26 mm | 0.13 mm | 44.9°, 45° | 0.30 pm/V |
| LiIO ₃ | 0.4 mm | 0.18 mm | 0.01 mm | 0.04 mm | 0.018 mm | 42.5°, 0° | 3.59 pm/V |

Free standing crystals

The crystals of thickness down to 100 μm can be supplied as free standing crystals not attached to the support. However the ring mounts are highly recommended for safe handling of these thin crystals. The tolerance is

$\pm 50 \mu\text{m}$ for crystals of thickness down to 300 μm and $\pm 20 \mu\text{m}$ for crystals of thickness down to 100 μm .

GaSe crystal is supplied glued in to dia $\varnothing 40$ mm ring holder only.

Other Ultrathin BBO crystals available
Femt* Line see pages: 5.23; 5.30

| Crystal | Minimal aperture | Maximal aperture | Minimal thickness |
|--------------------|--------------------|--------------------|-------------------|
| BBO | 5×5 mm | 20×20 mm | 0.1 mm |
| LBO | 5×5 mm | 30×30 mm | 0.1 mm |
| KDP | 4×4 mm | 100×100 mm | 0.1 mm* |
| LiIO ₃ | 4×4 mm | 50×50 mm | 0.1 mm* |
| AgGaS ₂ | 5×5 mm | 15×15 mm | 0.1 mm |
| GaSe | $\varnothing 5$ mm | $\varnothing 7$ mm | 0.01 mm |

* the thickness should be about 0.5 mm for max aperture KDP and LiIO₃

Optically contacted crystals

BBO, LBO, KDP and LiIO₃ crystals of thickness less than 100 μm can be supplied optically contacted on UV Fused Silica substrates sizes 10×10×2 mm or 12×12×2 mm. Other sizes of substrates

are also available on request. The tolerances of BBO and LBO crystal thickness are $\pm 10/-5 \mu\text{m}$, for KDP and LiIO₃ $\pm 10 \mu\text{m}$.

| Crystal | Minimal aperture | Maximal aperture | Minimal thickness |
|-------------------|------------------|------------------|--------------------|
| BBO | 5×5 mm | 10×10 mm | 10±5 μm |
| LBO | 5×5 mm | 10×10 mm | 20 μm |
| KDP | 4×4 mm | 10×10 mm | 20 μm |
| LiIO ₃ | 5×5 mm | 10×10 mm | 20 μm |

EKSMA OPTICS provides various AR, BBAR and protective coatings for all free standing crystals and optically contacted crystals.

Ring mounts made from anodized aluminium and teflon are available for safe and convenient handling of ultrathin crystals.

STANDARD SPECIFICATIONS OF CRYSTALS

| Crystals | BBO, LBO | KDP, LiIO ₃ , AgGaS ₂ | GaSe |
|-----------------|-----------------------|---|----------------------------------|
| Flatness | $\lambda/6$ at 633 nm | $\lambda/4$ at 633 nm | cleaved |
| Parallelism | < 10 arcsec | < 30 arcsec | perpendicularly to optical axis. |
| Angle tolerance | < 15 arcmin | < 30 arcmin | Polish is not available |
| Surface quality | 10/5 scratch/dig | 20/10 scratch/dig | |

HOUSING ACCESSORIES

- Ring Holders for Nonlinear Crystals
See page 2.27 for more information.



- Positioning Mount 840-0199 for Nonlinear Crystal Housing
See page 2.29 for more information.





Laser Crystals

Nd:YAG

NEODYMIUM DOPED YTTRIUM ALUMINIUM GARNET



Nd:YAG crystal is the most popular lasing media for solid-state lasers. EKSMA OPTICS offers standard specifications high optical quality Nd:YAG rods with high damage threshold AR @ 1064 nm coatings.

Please contact EKSMA OPTICS for further information or non-standard specifications.

PROPERTIES OF 1.0% Nd:YAG AT 25°C

| | |
|---------------------------|--|
| Formula | $Y_{2.97}Nd_{0.03}Al_5O_{12}$ |
| Crystal structure | Cubic |
| Density | 4.55 g/cm ³ |
| Melting point | 1970 °C |
| Mohs hardness | 8.5 |
| Transition | $^4F_{3/2} \rightarrow ^4I_{11/2}$ @ 1064 nm |
| Fluorescence lifetime | 230 µs for 1064 nm |
| Thermal conductivity | 0.14 Wcm ⁻¹ K ⁻¹ |
| Specific heat | 0.59 Jg ⁻¹ K ⁻¹ |
| Thermal expansion | 6.9×10^{-6} °C ⁻¹ |
| $\partial n / \partial t$ | 7.3×10^{-6} °C ⁻¹ |
| Young's modulus | 3.17×10^4 Kg/mm ² |
| Poisson ratio | 0.25 |
| Thermal shock resistance | 790 Wm ⁻¹ |
| Refractive index | 1.818 @ 1064 nm |

STANDARD RODS SIZES

| Code | Diameter, mm | Length, mm | Doping, % | Wedge of the ends, deg | Price, EUR |
|------------------|--------------|------------|-----------|------------------------|------------|
| E-Y-3-0.8-A/A | 3 | 65 | 0.8 | 0/0 | 265 |
| E-Y-3-1.1-A/A | 3 | 65 | 1.1 | 0/0 | 325 |
| E-Y-4-0.8-A/A | 4 | 65 | 0.8 | 3/3 parallel | 410 |
| E-Y-4-1.1-A/A | 4 | 65 | 1.1 | 3/3 parallel | 410 |
| E-Y-6.35-1.1-A/A | 6.35 | 85* | 1.1 | 3/3 parallel | 875 |
| E-Y-8-1.1-A/A | 8 | 85* | 1.1 | 3/3 parallel | 1065 |
| E-Y-10-1.1-A/A | 10 | 85* | 1.1 | 3/3 parallel | 1695 |
| E-Y-12-0.8-A/A | 12 | 100* | 0.8 | 3/3 parallel | 2280 |
| E-Y-12-1.1-A/A | 12 | 100* | 1.1 | 3/3 parallel | 2280 |

* rods with barrel grooving, except 10 mm at both ends of the rod without grooving.

SPECIFICATIONS OF STANDARD Nd:YAG LASER RODS

| | |
|--------------------|---|
| Nd Doping Level | 0.8% or 1.1% |
| Orientation | <111> crystalline direction |
| Surface Quality | 10-5 scratch/dig as per MIL-O-13830A |
| Surface Flatness | λ/10 at 633 nm |
| Parallelism | < 10 arcsec |
| Perpendicularity | < 5 arcmin for plano/plano ends |
| Diameter Tolerance | +0/-0.05 mm |
| Length Tolerance | +1/-0.5 mm |
| Clear Aperture | > 90 % of full aperture |
| Chamfers | 0.1 mm at 45 deg |
| Coating | both sides coated AR @ 1064 nm, R < 0.2%, AOI = 0 deg |
| Barrel grooving | all dia 6.35, 8, 10, 12 mm rods with barrel grooving |

RELATED PRODUCTS

• Laser Safety Eyewear

See page 1.36 for more information.



• Visualizator 990-0840

See page 1.36 for more information.



Yb:KGW • Yb:KYW

Yb-DOPED POTASSIUM GADOLINIUM TUNGSTATE



APPLICATIONS

- Yb:KGW and Yb:KYW thin (100–150 μm) crystals are used as lasing materials to generate ultrashort (hundreds of fsec) high power (>22 W) pulses. Standard pumping @ 981 nm, output: 1023–1060 nm
- Yb:KGW and Yb:KYW can be used as ultrashort pulses amplifiers
- Yb:KGW and Yb:KYW are some of the best materials for high power thin disk lasers

CUSTOM MANUFACTURING CAPABILITIES

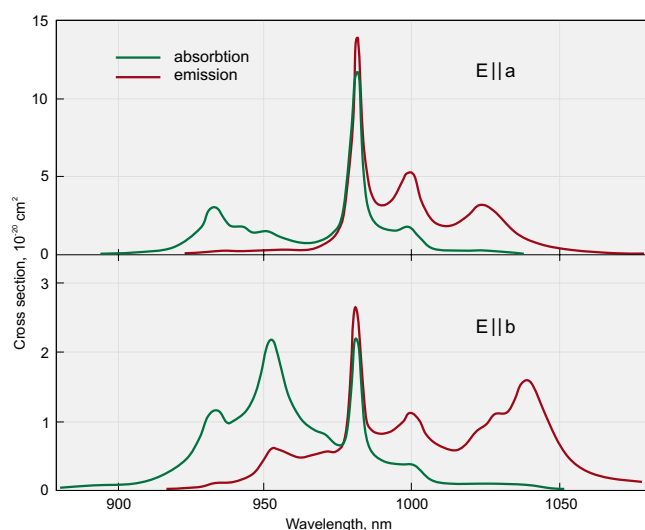
- Various shapes (slabs, rods, cubes)
- Different dopant levels
- Diversified coatings

- high absorption coefficient @ 981 nm
- high stimulated emission cross section
- low laser threshold
- extremely low quantum defect $\lambda_{\text{pump}}/\lambda_{\text{se}}$
- broad polarized output at 1023–1060 nm
- high slope efficiency with diode pumping (~ 60%)
- high Yb doping concentration

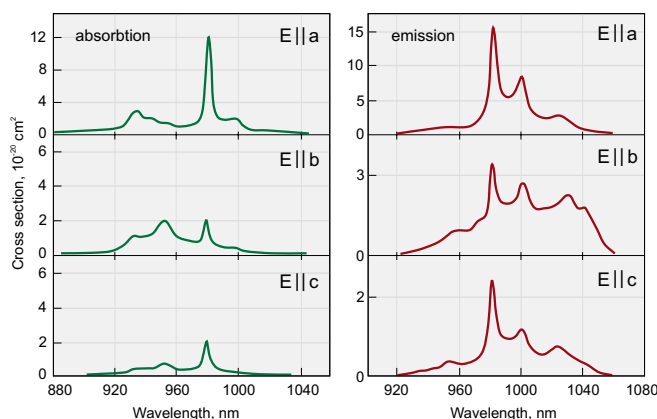
Yb-Doped Potassium Gadolinium Tungstate (Yb:KGd(WO₄)₂) and Yb-doped Potassium Itrium Tungstate (Yb:KY(WO₄)₂) single crystals are the laser crystals for diode or laser pumped solid-state laser applications.

PROPERTIES OF Yb:KGW AND Yb:KYW

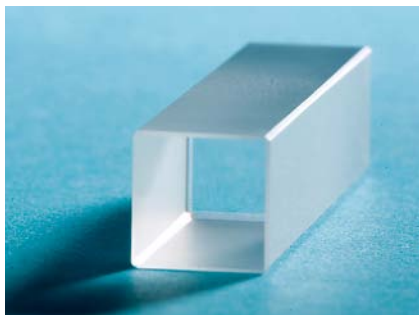
| Name | Yb:KGW | Yb:KYW |
|---|--|---|
| Yb ³⁺ concentration | 0.5–5% | 0.5–100% |
| Crystal structure | monoclinic | monoclinic |
| Point group | C2/c | C2/c |
| Lattice parameters | a=8.095 Å, b=10.43 Å, c=7.588 Å, $\beta=94.43^\circ$ | a=8.05 Å, b=10.35 Å, c=7.54 Å, $\beta=94^\circ$ |
| Thermal expansion | $\alpha_a=4 \times 10^{-6}/^\circ\text{C}$, $\alpha_b=3.6 \times 10^{-6}/^\circ\text{C}$, $\alpha_c=8.5 \times 10^{-6}/^\circ\text{C}$ | — |
| Thermal conductivity | $K_a=2.6 \text{ W/mK}$, $K_b=3.8 \text{ W/mK}$, $K_c=3.4 \text{ W/mK}$ | — |
| Density | 7.27 g/cm ³ | 6.61 g/cm ³ |
| Mohs' hardness | 4–5 | 4–5 |
| Melting temperature | 1075 °C | — |
| Transmission range | 0.35–5.5 μm | 0.35–5.5 μm |
| Refractive indices ($\lambda=1.06 \mu\text{m}$) | $n_o=2.037$, $n_p=1.986$, $n_m=2.033$ | — |
| $\partial n/\partial t$ | $0.4 \times 10^{-6} \text{ K}^{-1}$ | $0.4 \times 10^{-6} \text{ K}^{-1}$ |
| Laser wavelength | 1023–1060 nm | 1025–1058 nm |
| Fluorescence lifetime | 0.3 ms | 0.3 ms |
| Stimulated emission cross section ($E \parallel a$) | $2.6 \times 10^{-20} \text{ cm}^2$ | $3 \times 10^{-20} \text{ cm}^2$ |
| Absorption peak and bandwidth | $\alpha_a=26 \text{ cm}^{-1}$, $\lambda=981 \text{ nm}$, $\Delta\lambda=3.7 \text{ nm}$ | $\alpha_a=40 \text{ cm}^{-1}$, $\lambda=981 \text{ nm}$, $\Delta\lambda=3.5 \text{ nm}$ |
| Absorption cross section | $1.2 \times 10^{-19} \text{ cm}^2$ | $1.33 \times 10^{-19} \text{ cm}^2$ |
| Lasing threshold | 35 mW | 70 mW |
| Stark levels energy (in cm ⁻¹) of the ² F _{5/2} manifolds of Yb ³⁺ @ 77K | 10682, 10471, 10188 | 10695, 10476, 10187 |
| Stark levels energy (in cm ⁻¹) of the ² F _{7/2} manifolds of Yb ³⁺ @ 77K | 535, 385, 163, 0 | 568, 407, 169, 0 |



Absorption and emission spectra of Yb(5%):KYW



Absorption and emission spectrae of Yb(5%):KGW

Nd:KGW**Nd-DOPED POTASSIUM GADOLINIUM TUNGSTATE**

Nd:KGW crystals are low lasing threshold, highly efficient laser material exceptionally suitable for laser rangefinding applications.

The efficiency of Nd:KGW lasers is 3–5 times higher than the one of Nd:YAG lasers. Nd:KGW laser medium is one of the best choices ensuring effective laser generation at low pump energies (0.5 – 1 J). These crystals supplied by EKSMA OPTICS feature high optical quality and great value of bulk resistans for laser radiation.

STANDARD SPECIFICATIONS

| | |
|----------------------|----------------------------|
| Orientation | [010] ±30 min |
| Dopant concentration | 2-10 at % |
| Diameter tolerance | +0.0/-0.1 mm |
| Length tolerance | +1.0/-0.0 mm |
| Chamfer | 45(±10) deg × 0.2(±0.1) mm |
| Flatness | λ/10 @ 633 nm |
| Parallelism | better than 30 arcsec |
| Perpendicularity | better than 15 arcmin |
| Surface finishing | 10/5 scratch/dig |
| Absorption losses | < 0.005 cm ⁻¹ |

PHYSICAL AND LASER PROPERTIES

| | |
|----------------------------|---|
| Chemical formula | KGd(WO ₄):Nd |
| Lattice constants | a = 8.095 Å, b = 10 Å, c = 7.588 Å |
| Optical orientation | n _g = b, n _p c = 20 deg |
| Angle between optical axis | 86.5 angular grad |
| Density | 7.27 g/cm ³ |
| Mohs hardness | 5 |
| Thermal conductivity | 2.8 W/(m×grad) [100] 2.2 W/(m×grad) [010] 3.5 W/(m×grad) [001] |
| Thermal expansion | 4×10 ⁻⁶ grad ⁻¹ [100] 3.6×10 ⁻⁶ grad ⁻¹ [010] 8.5×10 ⁻⁶ grad ⁻¹ [001] |
| Phase transition | 1005 °C |
| Melting point | 1075 °C |
| Transmission range | 0.35–5.5 μm |
| Refractive index | n _g = 2.033 @ 1.067 μm n _p = 1.937 @ 1.067 μm n _m = 1.986 @ 1.067 μm |
| Transition | ⁴ F _{3/2} → ⁴ I _{11/2} |
| Laser wavelength | 1.0672 μm |
| Fluorescence lifetime | 120 μs |
| Fluorescent width | 24 cm ⁻¹ |
| Emission cross-section | 4.3×10 ⁻¹⁹ cm ⁻² |
| Emission temperature drift | 8.5×10 ⁻⁴ nm, K ⁻¹ |

Ti:Sapphire**TITANIUM DOPED SAPPHIRE**

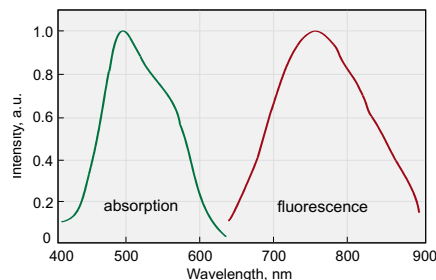
Al₂O₃:Ti³⁺ – titanium-doped sapphire crystals combine outstanding physical and optical properties with broadest lasing range.

Al₂O₃:Ti³⁺ indefinitely long stability and useful lifetime added to the lasing over entire band of 660–1050 nm challenge “dirty” dyes in variety of applications. Medical laser systems, lidars, laser spectroscopy, direct femtosecond pulse generation by Kerr-type mode-locking – there are few of existing and potential applications.

| Ti ₂ O ₃ wt % | a, cm ⁻¹ @ 490 nm | a, cm ⁻¹ @ 514 nm | a, cm ⁻¹ @ 532 nm |
|-------------------------------------|------------------------------|------------------------------|------------------------------|
| 0.03 | 0.7* | 0.6 | 0.5 |
| 0.05 | 1.1 | 0.9 | 0.8 |
| 0.07 | 1.5 | 1.3 | 1.2 |
| 0.10 | 2.2 | 1.9 | 1.7 |
| 0.12 | 2.6 | 2.2 | 2.0 |
| 0.15 | 3.3 | 2.8 | 2.5 |
| 0.20 | 4.3 | 3.7 | 3.4 |
| 0.25 | 5.4 | 4.6 | 4.1 |

* Presented values are given with ±0.05 cm⁻¹ accuracy.

The absorption band of Ti:Sapphire centered at 490 nm makes it suitable for variety of laser pump sources – argon ion, frequency doubled Nd:YAG and YLF, copper vapour lasers. Because of 3.2 μs fluorescence lifetime Ti:Sapphire crystals can be effectively pumped by short pulse flashlamps in powerful laser systems.

**STANDARD SPECIFICATIONS**

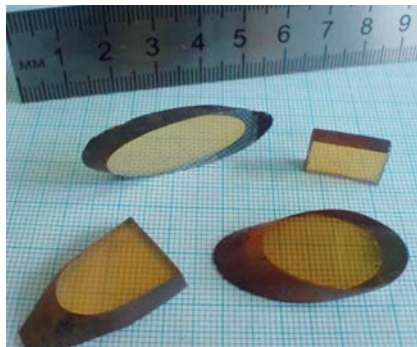
| | |
|--|---|
| Orientation | optical axis C normal to rod axis |
| Ti ₂ O ₃ concentration | 0.03–0.25 wt % |
| Figure Of Merit | > 150 (> 300 available on special requests) |
| Size | up to 20 mm dia and up to 130 mm length |
| End configurations | flat/flat or Brewster/Brewster ends |
| Flatness | λ/10 @ 633 nm |
| Parallelism | 10 arcsec |
| Surface finishing | 10/5 scratch/dig |
| Wavefront distortion | λ/4 inch |

PHYSICAL AND LASER PROPERTIES

| | |
|-----------------------|--|
| Chemical formula | Ti ³⁺ :Al ₂ O ₃ |
| Crystal structure | Hexagonal |
| Lattice constants | a=4.748, c=12.957 |
| Density | 3.98 g/cm ³ |
| Mohs hardness | 9 |
| Thermal conductivity | 0.11 cal/(°C×sec×cm) |
| Specific heat | 0.10 cal/g |
| Melting point | 2050 °C |
| Laser action | 4-Level Vibronic |
| Fluorescence lifetime | 3.2 μsec (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 |

$\text{Dy}^{3+}:\text{PbGa}_2\text{S}_4$

LEAD THIOGALLATE WITH DYSPROSIUM IONS CO-DOPED BY ALKALI METALS

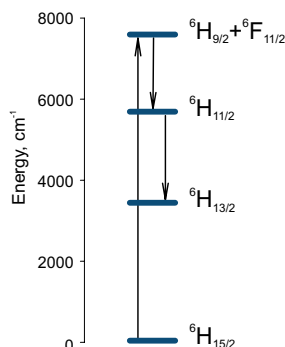


EKSMA OPTICS offers novel unique crystal – lead thiogallate (PbGa_2S_4) with dysprosium ions (Dy^{3+}) co-doped by alkali metals.

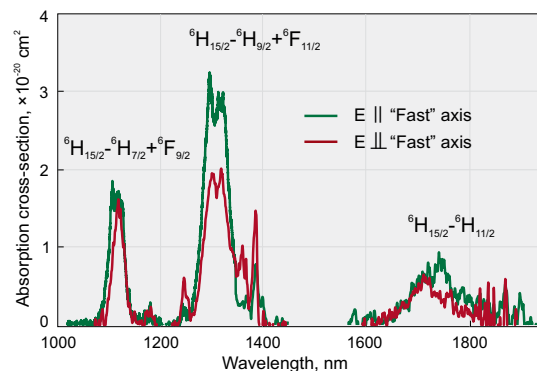
Crystal shows efficient laser emission at room temperature in mid IR range at 4.3-5.5 micron wavelengths.

PHYSICAL PROPERTIES

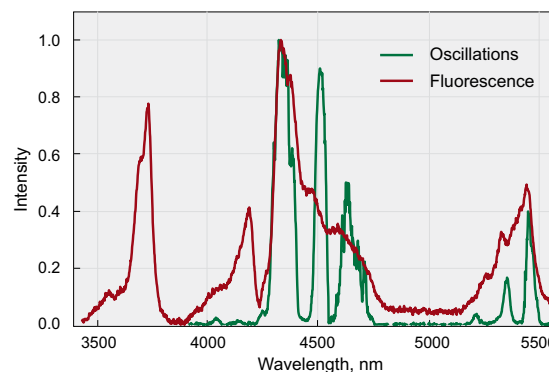
| | |
|---|-----------------|
| Transmission range | 0.44-12 microns |
| Dy^{3+} concentration in crystal | 0.5 mol. % |
| Non hygroscopic | |



Energy diagram of Dy^{3+} ion



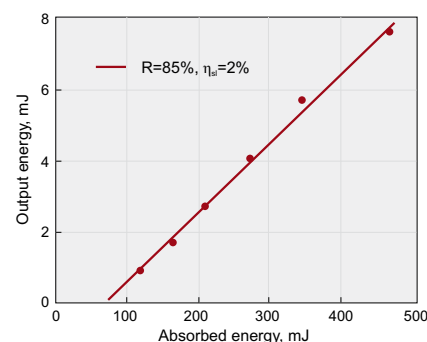
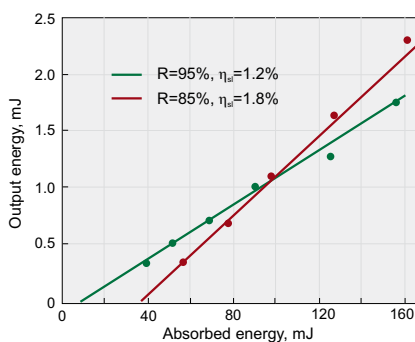
Polarized absorption cross-section spectrum of Dy^{3+} ions in PbGa_2S_4 crystal

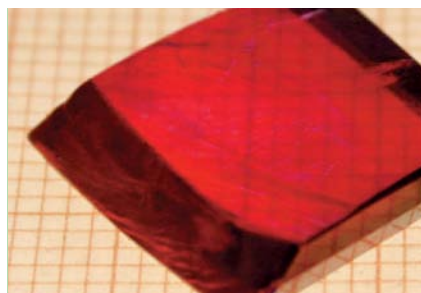


Emission cross-section and oscillation spectrum of Dy^{3+} ions in PbGa_2S_4 crystal

LASING PROPERTIES WITH FREE RUNNING 1.318 μm Nd:YAG LASER PUMP

| | |
|-----------------------------------|---|
| Obtained oscillation wavelengths: | 4.3 μm ; 4.53 μm ; 4.65 μm , 5.5 μm |
| Absorption at pump | $\sim 1 \text{ cm}^{-1}$ |
| Cross-section at 4.3 mm | $1 \times 10^{-20} \text{ cm}^2$ |
| Lasing threshold | < 20 mJ |
| Lasing pulse duration | < 1 ms |
| Laser efficiency | up to 2% |

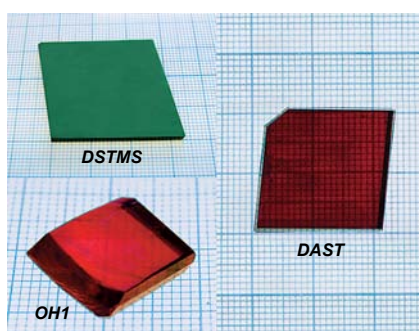




Terahertz Crystals

DSTMS • DAST • OH1

ORGANIC TERAHERTZ CRYSTALS



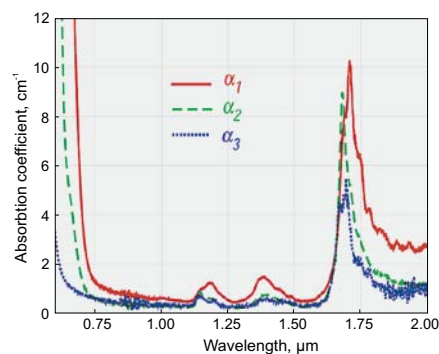
EKSMA OPTICS offers organic DSTMS, DAST, OH1 crystals for THz generation and detection using different femtosecond laser pump sources.

ORGANIC TERAHERTZ GENERATORS AND DETECTORS:

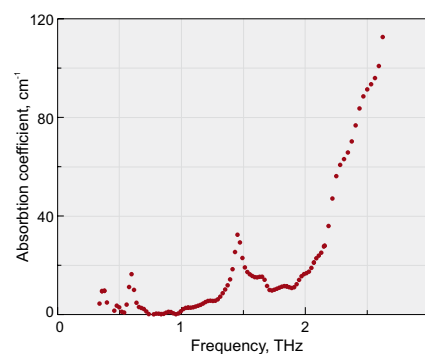
- DSTMS – efficient terahertz generation in 0.3-15 THz range
- DAST – efficient terahertz generation in 0.1-17 THz range
- OH1 – efficient terahertz generation in 0.1-3 THz range

APPLICATIONS OF ORGANIC DSTMS, DAST AND OH1 CRYSTALS:

- Efficient THz generation and detection
- Fast electro-optic modulation (>200 GHz)
- Optical parametric generation
- Efficient doubling of 1.55 microns radiation



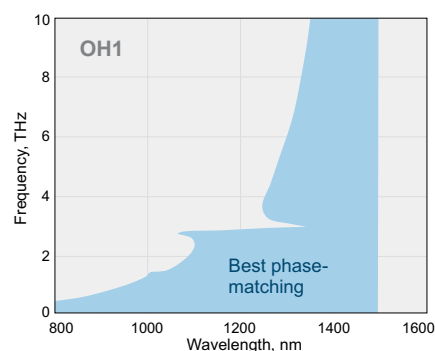
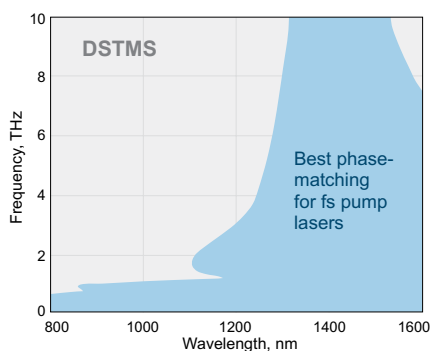
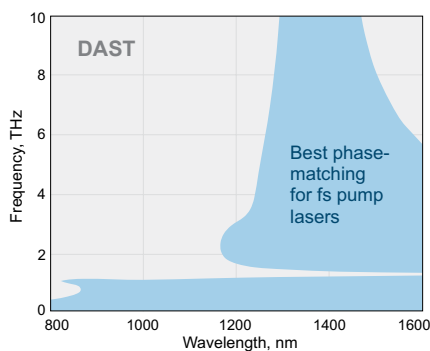
Absorption Spectrum of DSTMS, DAST THz crystals



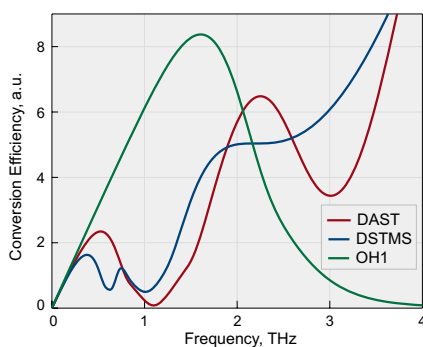
Absorption Spectrum of OH1 crystals

PHYSICAL PROPERTIES OF ORGANIC TERAHERTZ CRYSTALS

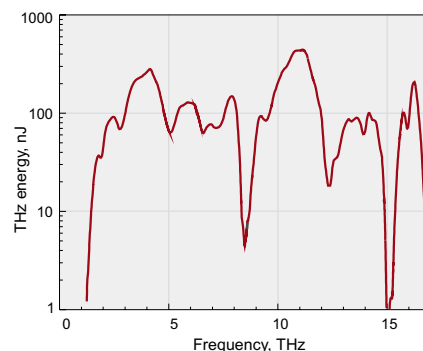
| Crystal | DSTMS | DAST | OH1 |
|--------------------------------|--|--|---|
| Point group symmetry | m | m | mm2 |
| Melting temperature, °C | 250 | 256 | 212 |
| Refractive indices | $n_1 = 2.07 @ 1550 \text{ nm}$ $n_2 = 1.64 @ 1550 \text{ nm}$ | $n_1 = 2.519 @ 720 \text{ nm}$ $n_2 = 1.720 @ 720 \text{ nm}$ $n_3 = 1.635 @ 720 \text{ nm}$ | $n_2 = 1.58 @ 1319 \text{ nm}$ $n_3 = 2.15 @ 1319 \text{ nm}$ |
| Nonlinear optical coefficients | $d_{111} = 214 \pm 20 \text{ pm/V @ } 1990 \text{ nm}$ $d_{122} = 31 \pm 4 \text{ pm/V @ } 1990 \text{ nm}$ $d_{212} = 35 \pm 4 \text{ pm/V @ } 1990 \text{ nm}$ | $d_{11} = 1010 \text{ pm/V @ } 1318 \text{ nm}$ $d_{11} = 290 \text{ pm/V @ } 1542 \text{ nm}$ $d_{26} = 39 \text{ pm/V @ } 1542 \text{ nm}$ | $d_{333} = 120 \pm 10 \text{ pm/V @ } 1990 \text{ nm}$ $d_{223} = 13 \pm 2 \text{ pm/V @ } 1990 \text{ nm}$ $d_{322} = 8.5 \pm 2 \text{ pm/V @ } 1990 \text{ nm}$ |
| Electro-optic coefficients | $r_{111} = 37 \pm 3 \text{ pm/V @ } 1990 \text{ nm}$ | $r_{11} = 92 \text{ pm/V @ } 720 \text{ nm}$ $r_{11} = 53 \text{ pm/V @ } 1313 \text{ nm}$ $r_{11} = 47 \text{ pm/V @ } 1535 \text{ nm}$ | $r_{333} = 109 \pm 4 \text{ pm/V @ } 633 \text{ nm}$ $r_{333} = 75 \pm 7 \text{ pm/V @ } 785 \text{ nm}$ $r_{333} = 56 \pm 2 \text{ pm/V @ } 1064 \text{ nm}$ $r_{333} = 52 \pm 7 \text{ pm/V @ } 1319 \text{ nm}$ |



Best phase-matching



THz Conversion Efficiency in DAST, DSTMS and OH1 crystals



THz generation in DAST

ORGANIC TERAHERTZ CRYSTALS

| Catalogue number | Description |
|--|--|
| DSTMS THz Crystals for fsec lasers pump. Diagonal cut. | |
| DSTMS-150 | C-plates, with diagonal cut. Thickness 150-200 microns |
| DSTMS-200 | C-plates, with diagonal cut. Thickness 200-400 microns |
| DSTMS-400 | C-plates, with diagonal cut. Thickness 400-800 microns |
| DSTMS THz crystals for fsec lasers pump. Perpendicular cut. | |
| DSTMS-500 | With perpendicular cut, 3×4 mm aperture. Thickness – 500 microns to 1 mm |
| DAST THz Crystals for fsec lasers pump. Diagonal cut. | |
| DAST-150 | C-plates, with diagonal cut. Thickness 150-200 microns |
| DAST-200 | C-plates, with diagonal cut. Thickness 200-400 microns |
| DAST-400 | C-plates, with diagonal cut. Thickness 400-800 microns |
| DAST THz crystals for fsec lasers pump. Perpendicular cut. | |
| DAST-500 | With perpendicular cut, 3×4 mm aperture. Thickness – 500 microns to 1 mm |
| OH1 THz Crystals for fsec lasers pump. Diagonal cut. | |
| OH1-150 | C-plates, with diagonal cut. Thickness 150-200 microns |
| OH1-200 | C-plates, with diagonal cut. Thickness 200-400 microns |
| OH1-400 | C-plates, with diagonal cut. Thickness 400-800 microns |

ZnTe

ZnTe (Zinc Telluride) crystals with $\langle 110 \rangle$ orientation are used for THz generation by optical rectification process. Optical rectification is a difference frequency generation in media with large second order susceptibility. For femtosecond laser pulses which have large bandwidth the frequency components interact with each other and their difference produce bandwidth from 0 to several THz. Detection of the THz pulse occurs via free-space electro-optic detection in another $\langle 110 \rangle$ oriented ZnTe crystal. The THz pulse and the visible pulse are propagated collinearly through the ZnTe crystal. The THz pulse induces a birefringence in ZnTe crystal which is read out by a linearly polarized visible pulse. When both the visible pulse and the THz pulse are in the crystal at the same

time, the visible polarization will be rotated by the THz pulse. Using a $\lambda/4$ waveplate and a beamsplitting polarizer together with a set of balanced photodiodes, it is possible to map THz pulse amplitude by monitoring the visible pulse polarization rotation after the ZnTe crystal at a variety of delay times with respect to the THz pulse. The ability to read out the full electric field, both amplitude and delay, is one of the attractive features of time-domain THz spectroscopy.

ZnTe are also used for IR optical components substrates and vacuum deposition.

NOTE: ZnTe crystal contains micro bubbles and they are visible in projection of illuminated crystal. However this does not affect the THz generation. We do not accept complains on presence of bubbles in crystal.

ZnTe, $\langle 110 \rangle$ CUT

| Catalogue number | Size, mm | Thickness, mm |
|------------------|----------|---------------|
| ZnTe-200 | 10×10 | 0.2 |
| ZnTe-500 | 10×10 | 0.5 |
| ZnTe-1000 | 10×10 | 1.0 |

GaSe

GaSe (Gallium Selenide) crystals used for THz generation shows a large bandwidth of up to 41 THz. GaSe is a negative uniaxial layered semiconductor with a hexagonal structure of 62 m point group and a direct bandgap of 2.2 eV at 300 K. GaSe crystal features high damage threshold, large non-linear optical coefficient (54 pm/V), suitable transparent range, and low absorption coefficient, which make it an alternative solution for broadband mid infrared electromagnetic waves generation. Due to broadband THz

generation and detection using a sub-20 fs laser source, GaSe emitter-detector system performance is considered to achieve comparable or even better results than using thin ZnTe crystals. In order to achieve frequency selective THz wave generation and detection system, GaSe crystals of appropriate thickness should be used.

NOTE: because of material structure it is possible to cleave GaSe crystal along (001) plane only. Another disadvantage is softness and fragility of GaSe.

GaSe, Z-CUT

| Catalogue number | Clear aperture, mm | Thickness, μm |
|------------------|--------------------|--------------------------|
| GaSe-30 | Ø7 | 30 |
| GaSe-100 | Ø7 | 100 |
| GaSe-1000 | Ø7 | 1000 |



Raman Crystals

KGW • Ba(NO₃)₂

CRYSTALS FOR STIMULATED RAMAN SCATTERING



EKSMA OPTICS offers crystalline materials – **Barium Nitrate – Ba(NO₃)₂** and **undoped potassium gadolinium tungstate KGd(WO₄)₂** or KGW which have attracted much interest for stimulated Raman scattering (SRS). These materials can be used for frequency conversion in lasers for extending the tuning range. SRS in crystals is compatible with current all-solid-state technology and provides a very simple, compact means of frequency conversion.

Ba(NO₃)₂ has a highest Raman gain co-

efficient. The gain coefficient affects the threshold for Raman laser. However, the thermal lensing is particularly strong in this material. This is indicated by the large value $\partial n/\partial T$ and low thermal conductivity. Thermal effects are significantly smaller in KGW. This along with the high damage threshold make the crystal an excellent candidate for power scaling.

Comparing Ba(NO₃)₂ and KGW for Raman application Ba(NO₃)₂ is more optimal in case of ns and longer pulses, KGW – in case of shorter pulses.

Ba(NO₃)₂ PHYSICAL AND OPTICAL PROPERTIES

| | |
|------------------------------|--------------------------------------|
| Crystal symmetry | cubic, P2 ₃ |
| Transmission range | 0.35–1.8 μm |
| Density | 3.25 g/cm ³ |
| Hardness Mohs | 2.5–3 |
| Refractive indices @ 1064 nm | n = 1.555 |
| Raman shift | 1048 cm ⁻¹ |
| Raman gain, pump 1064 nm | 11 cm/GW |
| Thermal conductivity, W/mK | 1.17 |
| $\partial n/\partial T$ | -20×10 ⁻⁶ K ⁻¹ |
| Optical Damage Threshold | ~ 0.4 GW/cm ² |

KGW PHYSICAL AND OPTICAL PROPERTIES

| | |
|------------------------------|--|
| Crystal symmetry | monoclinic, C2/c |
| Transmission range | 0.35–5.5 μm |
| Density | 7.27 g/cm ³ |
| Hardness Mohs | 4-5 |
| Refractive indices @ 1064 nm | n _g = 2.061; n _m = 2.010; n _p = 1.982 |
| Raman shift | 901 cm ⁻¹ (p[mm]p) 768 cm ⁻¹ (p[gg]p) |
| Raman gain, pump 1064 nm | 3.3 cm/GW (901 cm ⁻¹) 4.4 cm/GW (768 cm ⁻¹) |
| Thermal conductivity, W/mK | K _a =2.6; K _b =3.8; K _c =3.4 |
| $\partial n/\partial T$ | 0.4 × 10 ⁻⁶ K ⁻¹ |
| Optical Damage Threshold | > 10 GW/cm ² |

Raman wavelengths in KGW crystal (oscillation coefficient 901.5 cm⁻¹) and Ba(NO₃)₂ crystal (oscillation coefficient 1048.6 cm⁻¹) are given in the table below.

| Stokes | KGW pumped @ 532 nm | KGW pumped @ 1064 nm | Ba(NO ₃) ₂ pumped @ 532 nm | Ba(NO ₃) ₂ pumped @ 1064 nm | Typical efficiency, % |
|-------------|---------------------|----------------------|---|--|-----------------------|
| 1 Stoke | 558 | 1177 | 563 | 1197 | 35–70 |
| 2 Stoke | 588 | 1316 | 598 | 1369 | 20–40 |
| 3 Stoke | 621 | 1494 | 638 | 1599 | 10–15 |
| 4 Stoke | 658 | 1726 | 684 | 1924 | <10 |
| 1 Antistoke | 507 | 970 | 503 | 957 | 10–30 |

STANDARD SPECIFICATIONS

| | Ba(NO ₃) ₂ | KGW |
|--------------------------------|-----------------------------------|----------|
| Surface quality, scr/dig | 40/20 | 10/5 |
| Flatness @ 633 nm | λ/4 | λ/8 |
| Maximal element dimensions, mm | 10×10×100 | 10×10×80 |

Co²⁺:MgAl₂O₄ Cr⁴⁺:YAG

PASSIVE Q-SWITCHING CRYSTALS

EKSMA OPTICS offers a wide choice of solid-state saturable absorbers such as: **Co²⁺:MgAl₂O₄**, **Cr⁴⁺:YAG**.

Co²⁺:MgAl₂O₄ is a relatively new material for passive Q-switching in lasers emitting from 1.2 to 1.6 μm , in particular, for eye-safe 1.54 μm Er:glass laser, but also works at 1.44 μm and 1.34 μm wavelengths. High absorption cross section ($3.5 \times 10^{-19} \text{ cm}^2$) permits Q-switching of Er:glass laser without intracavity focusing both with flash-lamp and diode-laser pumping. Negligible excited-state absorption results in high contrast of Q-switch, i.e.

the ratio of initial (small signal) to saturated absorption is higher than 10 (Fig. 1).

Cr⁴⁺:YAG is one of the best passive Q-switch for high power lasers emitting at $\sim 1 \mu\text{m}$ wavelength. Standard diameter apertures – 5, 8, 9.5 mm and various initial transmission (or optical density) are available upon request. Also Cr⁴⁺:YAG laser rods for ultra-short pulse solid-state lasers are available.

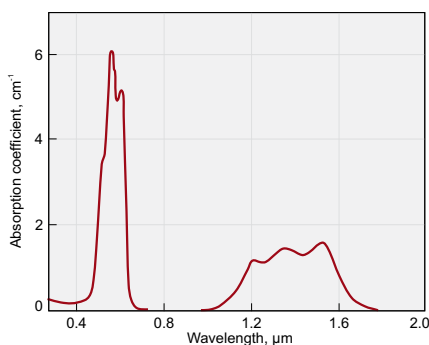


Fig. 1. Absorption spectra of the Co²⁺:MgAl₂O₄ crystal

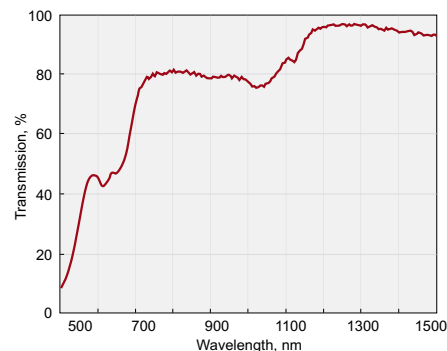


Fig. 2. Transmission of AR coated at 1064 nm Cr:YAG Q-switch with initial transmission of 80% at 1064 nm

SPECIFICATIONS

| | Co:MgAl ₂ O ₄ | Cr ⁴⁺ :YAG |
|---|--|--|
| Working wavelength range, μm | 1.2 – 1.6 | 0.8 – 1.2 |
| Absorption cross-section, cm^2 | 3.5×10^{-19} (at 1.54 μm) | 5×10^{-18} (at 1.06 μm) |
| Initial transmittance, % | 30–99 | 20–99 |
| Aperture, mm | 5–12 | 5, 8, 9.5 |
| Thickness, mm | 1–5 | 1–5 |
| Coatings* | AR @ 1.54 μm , R<0.2% | AR @ 1.06 μm , R<0.15% |

Fe:ZnSe, Cr:ZnSe, Co:ZnS solid-state saturable absorbers also are available upon request



Positioners & Holders

830-0001

RING HOLDERS FOR NONLINEAR CRYSTALS



830-0001-10



830-0001-06

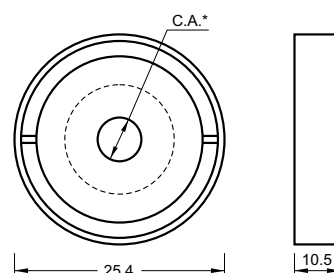
- Black anodized aluminium body
- Teflon or white anodized aluminium adapter for particular crystal size
- Easy assembling and disassembling

Ring mounts made from black anodized aluminum and Teflon or white anodized aluminium adapter are available for safe and convenient handling of nonlinear crystals. The crystals are glued into white anodized aluminium adapter (830-0001-06). No glue is used for fixation of the crystal into open ring holder with teflon adapter. The standard sizes are Ø25.4 or Ø30 mm and thickness – 6, 10.5, 13.5 or 17.5 mm depending on crystal size.

Please indicate the exact crystal size when ordering.

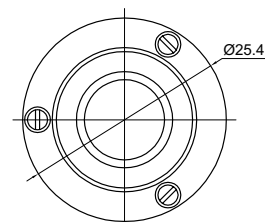
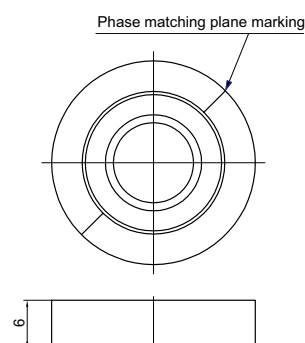
| Part No | Diameter, mm | Thickness, mm | Max. acceptable crystal size, mm | Price, EUR |
|-------------|--------------|---------------|----------------------------------|------------|
| 830-0001-06 | 25.4 | 6 | 12×12×0.5 | 50 |
| 830-0001-10 | 25.4 | 10.5 | 12×12×3 | 50 |
| 830-0001-13 | 25.4 | 13.5 | 12×12×6 | 50 |
| 830-0001-17 | 25.4 | 17.5 | 12×12×15 | 90 |
| 830-0002-10 | 30 | 10.5 | 15×15×3 | 50 |
| 830-0002-13 | 30 | 13.5 | 15×15×6 | 50 |
| 830-0002-17 | 30 | 17.5 | 15×15×15 | 90 |

Delivery: 2-3 weeks ARO.



* C.A. - depends on crystal aperture

830-0001-10



830-0001-06

HOUSING ACCESSORIES

- Positioning Mount 840-0199 for Nonlinear Crystal Housing

See page 2.29 for more information.



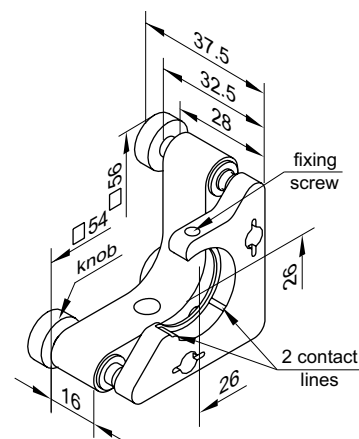
840-0056-11**POSITIONING MOUNT**

- Tilt range 9°
- Travel range 4 mm
- Mounting on either of 2 sides
- Sensitivity of 3 arcsec and 1 μm
- Kinematic with clear edge design
- A screw pushes via seat of hardened stainless steel

Kinematic Mount 840-0056-11 is used for precise angular and linear alignment of 1" ring holders with nonlinear crystals.

Mount has a resting flange to stop the holder. One fixing screw secures the optics against 2 contact lines, which make 2 contact points. To prevent damage to the holder, the tip of the fixing screw is made of plastic.

Platform of 840-0056-11 is preloaded by two strong coil springs, ensuring tight kinematic fit. A thick base of the mount adds stability. This allowed to eliminate part of the mount, keeping clear one edge. As standard, mount 840-0056-11 comes with the screws 870-0080.

**RELATED PRODUCTS**

- Motorized version 940-0060-01

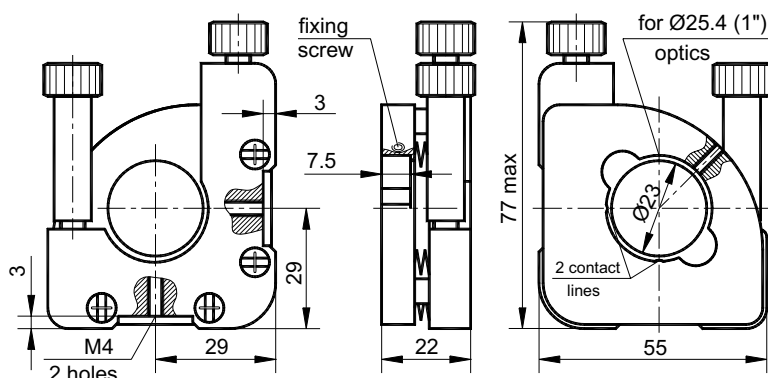
See page 8.139 for more information.



| Code | Price, EUR |
|-------------|------------|
| 840-0056-11 | 75 |

840-0193**KINEMATIC POSITIONING MOUNT**

- For $\varnothing 25.4$ mm (1 inch) ring holders
- Kinematic design
- Tilt/tip range $\pm 2^\circ$
- Sensitivity 3 arcsec
- Both tilt and tip controlled from aside the optical path
- Fine adjustment screws with 0.25 mm pitch
- Hardened seats under adjustment screws



| Code | Weight, kg | Price, EUR |
|----------|------------|------------|
| 840-0193 | 0.12 | 87 |

840-0199

POSITIONING MOUNT FOR NONLINEAR CRYSTAL HOUSING



- Accepts Ø25.4 mm and up to 10.5 mm thickness ring housings
- Kinematic design
- Wedge and ball drive mechanism
- Tilt/tip range: $\pm 2^\circ$
- Sensitivity: 3 arcsec
- Fine adjustment screws with 0.25 mm pitch
- Hardened seats under adjustment screws
- Rotation range: 360°
- Scale gradation: 2°
- Compact and robust design
- Material: black anodized aluminum



This kinematic mount accepts crystal housings of Ø25.4 mm and thickness up to 10.5 mm. The housing is stopped by a rest-flange inside the central aperture of the platform, and is secured by a threaded retaining ring.

The rotation position (X axis) is indicated on 360° angular scale with a gradation of 2° . The rotation platform has a removable rod

that allows continuous 360° rotation without obscuring the aperture. This removable rod can be fitted into any of the four holes on the perimeter of rotation platform.

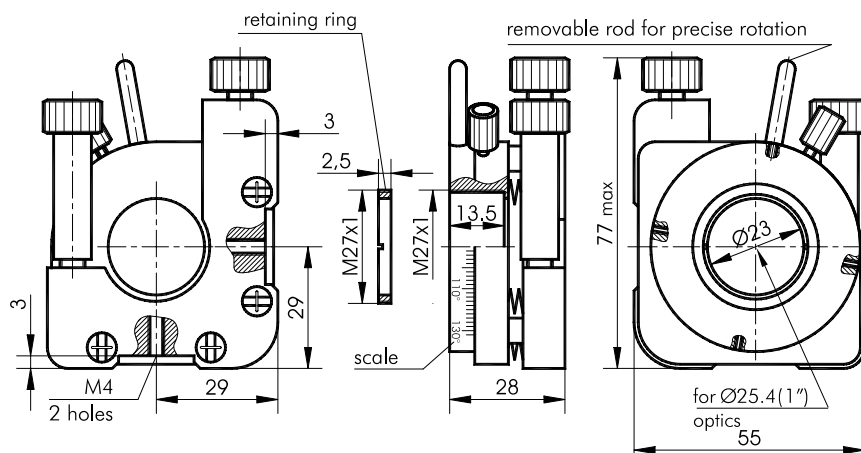
Angular adjustment range of tilt/tip (Z, Y axes) is $\pm 2.5^\circ$. Two high resolution stainless steel vertical-drive screws with a pitch of 0.25 mm and "wedge and ball" mechanism ensure smooth and precise angular tilt/tip adjustment with 3 arc sec sensitivity. For tilting, the platform it is preloaded against the base with high quality springs.

Large knobs on the adjusting screws relieve the strain on operator fingers during adjustment.

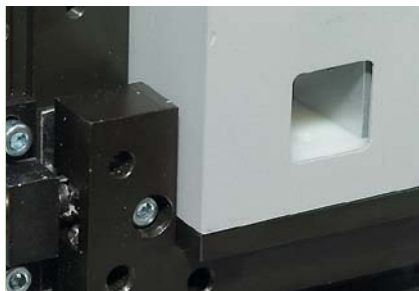
Both screws protrude from the top allowing convenient adjustment outside the laser beam path and providing easy access for adjustments in densely packed optical set-ups.

An extra M4 tapped hole on the side of the base allows you to operate the mount as a side-drive adjustment control mount. The mount is made of black anodized aluminium to help minimize reflections.

A retaining ring M27×1, two Teflon rings and a tightening key to fix the crystal ring housing is included.



| Code | Weight, kg | Price, EUR |
|----------|------------|------------|
| 840-0199 | 0.12 | 165 |



Crystal Ovens

Many of widely used nonlinear crystals are susceptible to ambient humidity, for example KD*P, BBO, LBO. Protective coatings applied to the surface can reduce degradation to some extent only. To improve the protection of surfaces of the crystals from the degradation it is desirable to keep the crystals at higher than ambient

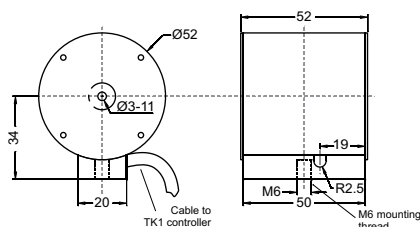
temperature, which helps avoid condensation on the crystal surfaces.

In addition, if the crystal is used for harmonics generation, the phase-matching angle depends on crystal temperature. For example, the output power of second harmonics generator based on KD*P crystal can decrease by 50 % if the crystal tem-

perature changes just by one degree, hence for good laser stability precise crystal temperature stabilization is necessary. EKSMA OPTICS offers various solutions for precise crystal heating. CH series crystal ovens provide reliable, stable performance and can accommodate wide range of crystals.

TC1 • CO1

TEMPERATURE CONTROLLER TC1 WITH OVEN CO1



TC1 and CO1 dimensions

TC1 and CO1 is high temperature set (up to 200 °C) consisting of thermocontroller TC1 and crystal oven CO1. TC1 has two independent outputs and can control two CO1 ovens simultaneously. Through RS232 computer interface it can be controlled from PC. Actual crystal temperature is shown on LED display.

The nonlinear crystal is mounted into adapter before insertion into oven CO1. Such design facilitates handling and replacement of the crystal. The nonlinear crystal can be sealed with fused silica windows in order to provide extra protection. The standard adapters are 15, 30 and 50 mm length with apertures of 3×3, 4×4, 5×5, 6×6 mm size. Customized adapters for crystals up to 12×12 mm size are available. In addition, adapters for Brewster-cut and PPLN crystals are available too.

SPECIFICATIONS

| Model | TC1+CO1-30 | TC1+CO1-50 |
|---|--------------------|-------------|
| Quantity of ovens possible to connect to one controller TC1 | 2 | 1 |
| Temperature tuning range | RT – 200 °C | |
| Maximum crystals dimensions | 12×12×30 mm | 12×12×50 mm |
| Sealing (optional) | FS windows | |
| Accuracy | ± 0.5 °C | |
| Long-term stability | ± 0.1 °C | |
| Resolution | 0.1 °C | |
| Powering requirements | 90–264 V, 47–66 Hz | |
| Power consumption | 45 W | |
| Sensor type | PT1000 | |
| Output connector | DB9 | |
| Serial interface | RS232 (DB 9) | |
| Dimensions, Dia×D | Ø52×52 mm | Ø52×72 mm |

Specifications are subject to changes without advance notice.

| Code ** | Description, features | Price, EUR |
|---------------------------------------|---|------------|
| Thermocontroller TC1 | | |
| TC1 | Thermocontroller, Fuzzy logic, RT-200 °C, can control two CO1 ovens, long-term stability ±0.1 °K, worldwide mains | 556 |
| Crystal Ovens for TC1 | | |
| <i>For crystal length up to 30 mm</i> | | |
| CO1-30-y/y | Standard crystal sizes * | 401 |
| CO1-30-y/z | Custom crystal sizes | 443 |
| CO1-30S-y/y | Sealed, standard crystal sizes * | 608 |

* Sizes 3×3, 4×4, 5×5, 6×6, 12×12 are standard.

** y/y, y/z – crystal size.

| Code ** | Description, features | Price, EUR |
|---|---|------------|
| Crystal Ovens for TC1 | | |
| <i>For crystal length up to 50 mm</i> | | |
| CO1-50-y/y | Standard crystal sizes * | 495 |
| CO1-50-y/z | Custom crystal size | 505 |
| CO1-50S-y/y | Sealed, standard crystal sizes * | – |
| <i>For Brewster-angle cut crystal</i> | | |
| CO1-30BA-y/y | For Brewster-angle cut crystal | 495 |
| CO1-30BAS-y/y | Sealed, for Brewster-angle cut crystal | 670 |
| <i>For PPLN crystals</i> | | |
| CO1-30PP-y/y | For PPLN crystals | 464 |
| Mounting accessories | | |
| <i>Crystal holders</i> | | |
| AD1 | Spare crystal holder for CO1-30 oven | 68 |
| AD2 | Spare crystal holder for CO1-50 oven | 78 |
| <i>Mounting stages for crystals ovens</i> | | |
| MS-4 | Adapter for CO1 oven mounting on tilt stage. Tilt stage should be ordered separately | 46 |

* Sizes 3×3, 4×4, 5×5, 6×6, 12×12 are standard.

** y/y, y/z – crystal size.

CH3

OVEN FOR NONLINEAR CRYSTALS



On request we can manufacture ovens for crystals with aperture up to 60×60 mm or even larger.

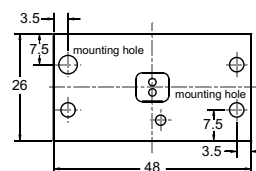
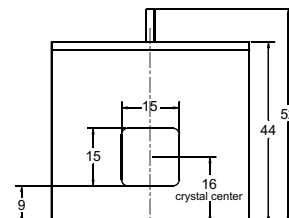
CH3-15 is compact oven with build-in thermocontroller for temperature up to 60 °C. It is ideal for larger aperture crystals like KD*P. The crystals with up to 15 × 15 mm dimensions can be mounted. CH3-30 model can fit crystals with up to 30 mm length.

Each oven is made exactly for specified crystal, so it cannot be used for different size crystals.

SPECIFICATIONS

| Model | CH3-15 | CH3-30 |
|--------------------------------------|---------------------|-------------|
| Temperature tuning range near preset | ± 5 °C | |
| Maximum crystals dimensions | 15×15×15 mm | 15×15×30 mm |
| Preset temperature | 30-60 (80) °C | |
| Long-term stability | ± 0.2 °C | |
| Powering requirements | 12-15 V DC | |
| Power consumption | 6 W | |
| Sensor type | NTC Thermo resistor | |
| Output connector | Molex 2 pin | |
| Dimensions, W×H×D | 48×44×26 mm | 48×44×36 mm |

Specifications are subject to changes without advance notice.



CH3 dimensions

| Code ** | Description, features | Price, EUR |
|---|--|------------|
| CH3-15 – fixed temperature crystal ovens, temperature tuning range ±5 °K, crystal length up to 15 mm | | |
| CH3-15-y/y-x | Standard crystal sizes * | 299 |
| CH3-15-y/z-x | Non-standard crystal size | 340 |
| CH3-15-y/y-80 | For temperature up to 80 °C | 360 |
| CH3-30 – fixed temperature crystal ovens, temperature tuning range ±5 °K, crystal length up to 30 mm | | |
| CH3-30-y/y-x | Standard crystal sizes * | 340 |
| CH3-30-y/z-x | Non-standard crystal size | 381 |
| CH3-30-y/y-80 | Version for temperature up to 80 °C | 391 |
| Mounting accessories | | |
| MS-1 | Two axis tilt adjustment 5 degrees range, suitable for all types of CH3, CH4 or CH7 crystal ovens | 144 |
| MS-2 | Two axis tilt stage, adjustment in 5 degree range, fits two pc. of CH3, CH4 or CH7 ovens | 248 |
| MS-3 | Adapter for CH3, CH4 or CH7 mounting on rotary stage, 15 degrees fine tuning, angle read-out. Rotary stage should be ordered separately | 56 |
| Power supply PS-12 | | |
| PS-12 | Power supply for CH3, CH4 or CH7 crystal oven, 100-240 VAC mains, +12 VDC output | 51 |

* Sizes 3×3, 4×4, ..., 15×15 are standard.

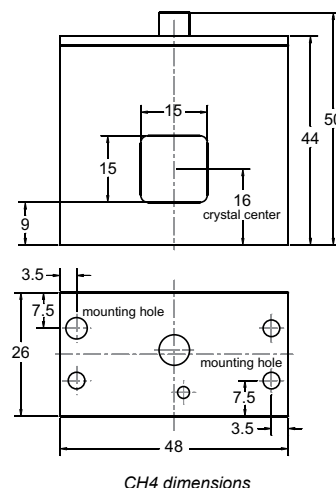
** y/y, y/z – crystal size, x – preset temperature in degrees of Celsius (30-60 °C range).

CH4

OVEN FOR NONLINEAR CRYSTALS



CH4 oven has identical mechanical design as CH3. The pre-set temperature can be adjusted in ± 5 °C range by the help of potentiometer. The current temperature is not indicated. In addition, CH4 has "temperature ready" output signal, changing state when pre-set temperature is reached. CH4-50 model can fit crystals with up to 50 mm length.



SPECIFICATIONS

| Model | CH4-15 | CH4-30 | CH4-50 |
|--------------------------------------|-------------|---------------------|-------------|
| Temperature tuning range near preset | | ± 5 °C | |
| Maximum crystals dimensions | 15×15×15 mm | 15×15×30 mm | 15×15×50 mm |
| Preset temperature | | 30-60 (80) °C | |
| Long-term stability | | ± 0.2 °C | |
| Temperature OK output signal | | Present | |
| Powering requirements | | 12-15 V DC | |
| Power consumption | 6 W | 6 W | 9 W |
| Sensor type | | NTC Thermo resistor | |
| Output connector | | Binder 719, 3 pin | |
| Dimensions, W×H×D | 48×44×26 mm | 48×50×36 mm | 48×50×56 mm |

Specifications are subject to changes without advance notice.

| Code ** | Description, features | Price, EUR |
|---|---|------------|
| CH4-15 – Provides READY signal, stability ± 0.2 °K, crystal length up to 15 mm | | |
| CH4-15-y/y-x | Standard crystal sizes * | 319 |
| CH4-15-y/z-x | Non-standard crystal sizes | 360 |
| CH4-15-y/y-80 | Version for temperature up to 80 °C | 381 |
| CH4-30 – Provides READY signal, stability ± 0.2 °K, crystal length up to 30 mm | | |
| CH4-30-y/y-x | Standard crystal sizes * | 360 |
| CH4-30-y/z-x | Non-standard crystal sizes | 401 |
| CH4-30-y/y-80 | Version for temperature up to 80 °C | 413 |
| CH4-50 – Provides READY signal, stability ± 0.2 °K, crystal length up to 50 mm | | |
| CH4-50-y/y-x | Standard crystal sizes * | 401 |
| CH4-50-y/z-x | Non-standard crystal sizes | 443 |
| CH4-50-y/y-80 | Version for temperature up to 80 °C | 454 |
| Mounting accessories | | |
| MS-1 | Two axis tilt adjustment 5 degrees range, suitable for all types of CH3, CH4 or CH7 crystal ovens | 144 |
| MS-2 | Two axis tilt stage, adjustment in 5 degrees range, fits two pc. of CH3, CH4 or CH7 ovens | 248 |
| MS-3 | Adapter for CH3, CH4 or CH7 mounting on rotary stage, 15 degrees fine tuning, angle read-out. Rotary stage should be ordered separately | 56 |
| Power supply PS-12 | | |
| PS-12 | Power supply for CH3, CH4 or CH7 crystal oven, 100-240 VAC mains, +12 VDC output | 51 |

* Sizes 3×3, 4×4, ..., 15×15 are standard.

** y/y, y/z – crystal size, x – preset temperature in degrees of Celsius (30-60 °C range).

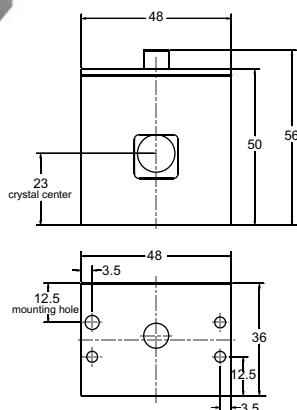
CH7

OVEN FOR NONLINEAR CRYSTALS



CH7 is compact oven with build-in thermo-controller for temperature up to 60 °C. CH7 oven provides more crystal mounting options in comparison to CH3 or CH4. Like in CO1, each crystal is mounted into adapter before insertion in oven. CH7 and CO1 crystal adapters are compatible. Maximum crystal size for this model is 12×12 mm and the length of the crystal – 30 mm.

The pre-set temperature can be adjusted in ± 5 °C range by the help of potentiometer. The current temperature is not indicated. CH7 has “temperature ready” signal, changing state when pre-set temperature is reached. For additional protection of crystal surfaces from the dust or other contamination, we offer windowed version CH7-20.



CH7 dimensions

SPECIFICATIONS

| Model | CH7-15 | CH7-30 |
|--------------------------------------|---------------------|-------------|
| Temperature tuning range near preset | ± 5 °C | |
| Maximum crystals dimensions | 12×12×15 mm | 12×12×30 mm |
| Sealing (optional) | FS windows | |
| Preset temperature | 30-60 (80) °C | |
| Long-term stability | ± 0.2 °C | |
| Temperature OK output signal | Present | |
| Powering requirements | 12-15 V DC | |
| Power consumption | 6 W | |
| Sensor type | NTC Thermo resistor | |
| Output connector | Binder 719, 3 pin | |
| Dimensions, W×H×D | 48×50×44 mm | 48×50×56 mm |

Specifications are subject to changes without advance notice.

| Code ** | Description, features | Price, EUR |
|---|--|------------|
| CH7-15 – Provides READY signal, stability ± 0.2 °K, crystal length up to 15 mm | | |
| CH7-15-y/y-x | Standard crystal sizes * | 401 |
| CH7-15-y/z-x | Non-standard crystal sizes | 443 |
| CH7-15-y/y-80 | Version for temperature up to 80 °C | 454 |
| CH7-30 – Provides READY signal, stability ± 0.2 °K, crystal length up to 30 mm | | |
| CH7-30-y/y-x | Standard crystal sizes * | 464 |
| CH7-30-y/z-x | Non-standard crystal sizes | 505 |
| CH7-30-y/y-80 | Version for temperature up to 80 °C | 515 |
| CH7-20 – Provides READY signal, with AR coated windows for crystal protection | | |
| CH7-20-y/y-x | Fixed temperature in RT-60 °C range, crystal size limited to 10×10×20 mm | 670 |
| CH7-20-y/y-80 | Version for temperature up to 80 °C | 721 |
| Power supply PS-12 | | |
| PS-12 | Power supply for CH3, CH4 or CH7 crystal oven, 100-240 VAC mains, +12 VDC output | 51 |

* Sizes 3×3, 4×4, ..., 12×12 are standard.

** y/y, y/z – crystal size, x – preset temperature in degrees of Celsius (30-60 °C range).

RELATED PRODUCTS

- **Mount MS-1** for fine tuning of CH3, CH4 or CH7 angle is available. The tuning range is $\pm 2.5^\circ$.



- **MS-2 type mount** can fit two CH3, CH4 or CH7 type ovens and is ideal for holding second and third or fourth harmonics generators.



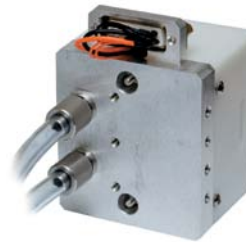
**TC2 • CO10
CO11 • CO12**
**PRECISION RESISTIVE HEATER KIT TC2
AND CO10 SERIES OVENS**


- Crystal's temperature stabilization
- Fast temperature control using active cooling
- External temperature is kept low by insulation – no need for gloves
- No alignment is required when crystal is removed and replaced
- 4 screws to remove to exchange crystals
- Crystals can be replaced without removing the oven from the experiment
- LabVIEW based software included

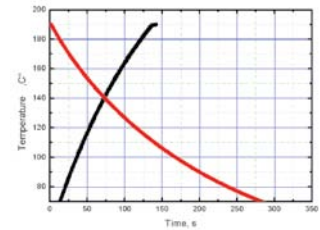
APPLICATIONS

- Fast temperature tuning of generated wavelengths in periodically oriented and noncritical phase-matching nonlinear crystals
- Temperature tuning of Bragg grating wavelengths
- Thermostat of tuning temperature

With combination of temperature controller, CO10 series ovens are designed specifically for tuning and conditioning the periodically poled bulk devices (PPSLT, PPLN & PP-MgO:LN) and other nonlinear crystals. The oven is designed to hold the crystal with dimensions of 30×16×1 mm. Custom made oven is also available. The crystal heater provides temperature stabilization for crystals with an accuracy of 0.1°C. The crystal temperature can be changed from 50°C to 200 °C.



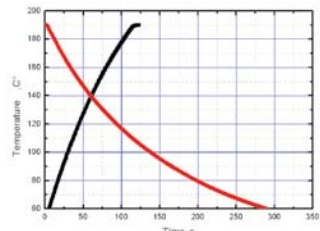
Oven CO10



Heating-Cooling diagrams of CO10



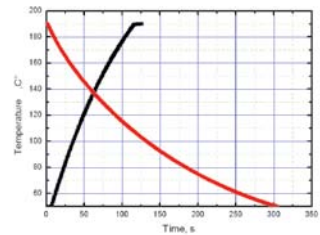
Oven CO11



Heating-Cooling diagrams of CO11



Oven CO12



Heating-Cooling diagrams of CO12

SPECIFICATIONS

| Code | Description, features | Price, EUR |
|-----------------------------|--|------------|
| Thermocontroller TC2 | Thermocontroller for CO10, CO11, CO12 fast temperature tuning PPLN crystall ovens | 741 |
| CO10 | Water cooled fast temperature control oven for PPLN crystals | 1195 |
| CO11 | Air cooled fast temperature control oven for PPLN crystals | 1174 |
| CO12 | Cooled by mounting on heat transferring body fast temperature control oven for PPLN crystals | 1329 |

| Model | CO10 | CO11 | CO12 |
|---|---|--------------------|--------------------|
| Resolution, °C | | 0.1 | |
| Long term stability, °C | | ±0.1 | |
| Basic accuracy, °C | | ±0.5 | |
| Temperature sensor type | | PT1000 | |
| General specifications: | | | |
| controllability | manual or via RS232 port | | |
| mains | 90-264 VAC; 50/60 Hz | | |
| max power consumption, W | 45 | | |
| TC2 controller dimensions (H×W×D), mm | 67×155×160 | | |
| weight, kg | 1.5 | | |
| operating temperature | -15 °C to +35 °C | | |
| storage temperature | -40 °C to +70 °C | | |
| connectors | 15-pin D-sub receptacle or 9-pin D-sub plug | | |
| Temperature control range, °C | 50-200 | 60-200 | 70-200 |
| Cooling type | Water | Air | Heatsink |
| Heating time, s | 130 (50-190 °C) | 120 (60-190 °C) | 110 (70-190 °C) |
| Cooling time (190 °C -50/60 °C), s | 305 | 290 | 290 |
| Cooling temperature change velocity, °C/s * | 1.1-0.25 | 1.0-0.1 | 1 -0.1 |
| Heating temperature change velocity, °C/s * | 1.5-0.7 | 1.5-0.7 | 1.5-0.7 |
| Set heater temperature, °C | 50 | 60 | 70 |
| Dimensions (H×W×D), mm | 85×71×65 | 95×71×65 | 91×90.5×56 |

* Depends on temperature.