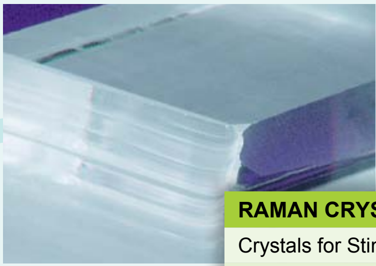
Crystals Selection Guide



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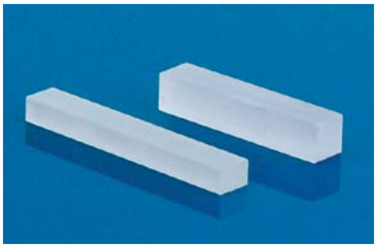
Nonlinear Crystals

LBO — LITHIUM TRIBORATE



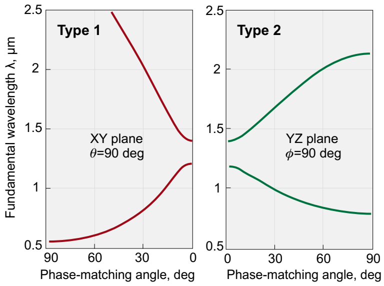
- **wide transparency region**
- **broad Type 1 and Type 2 non-critical phase-matching (NCPM) range**
- **small walk-off angle**
- **high damage threshold**
- **wide acceptance angle**
- **high optical homogeneity**

LBO is well suited for various nonlinear optical applications:

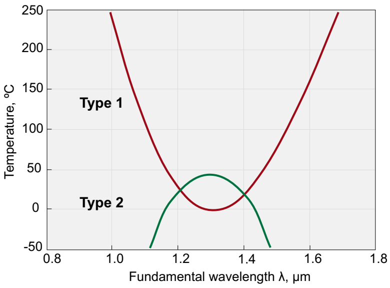
- frequency doubling and tripling of high peak power pulsed Nd doped, Ti:Sapphire and Dye lasers
- optical parametric oscillators (OPO) of both Type 1 and Type 2 phase-matching
- non-critical phase-matching for frequency conversion of CW and quasi-CW radiation.

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 dependance of LBO

PHYSICAL AND OPTICAL PROPERTIES

Chemical formula	LiB_3O_5		
Crystal structure	orthorhombic, mm2		
Optical symmetry	Negative biaxial		
Space group	$Pna2_1$		
Density	2.47 g/cm^3		
Mohs hardness	6		
Optical homogeneity	$\partial n = 10^{-6}$ 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±0.09) pm/V
	d_{32} = (1.17±0.14) pm/V
Effective nonlinearity:	
XY plane	$d_{ooe} = d_{32} \cos\varphi$
YZ plane	$d_{oeo} = d_{eoo} = d_{31} \cos\theta$

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

Wide selection of non-standard size and cut angle LBO crystals is available at **www.eksmaoptics.com**

STANDARD SPECIFICATIONS

Flatness	λ/8 at 633 nm
Parallelism	< 20 arcsec
Surface quality	10-5 scratch & dig (MIL-PRF-13830B)
Perpendicularity	<5 arcmin
Angle tolerance	<30 arcmin
Aperture tolerance	± 0.1 mm
Clear aperture	90% of full aperture

Please contact EKSMA OPTICS for further information or nonstandard specifications.

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

RELATED PRODUCTS

LBO crystals for SHG of Yb:KGW/KYW laser frequency conversion. *See page 5.30*

Crystal Oven TC1

See page 2.30

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).

Nonlinear Crystal Oven CH7

See page 2.33

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 enviroment.

HOUSING ACCESSORIES

Ring Holders for Nonlinear Crystals

See page 2.27

Positioning Mount 840-0056

See page 2.28

Kinematic Positioning Mount 840-0193

See page 2.28

BBO — BETA BARIUM BORATE

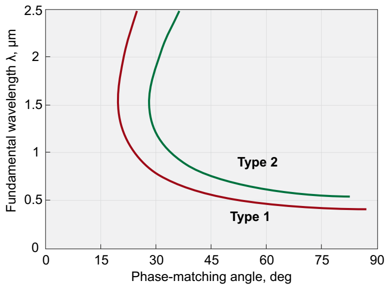
- **wide transparency region**
- **broad phase-matching range**
- **large nonlinear coefficient**
- **high damage threshold**
- **wide thermal acceptance bandwidth**
- **high optical homogenity**

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

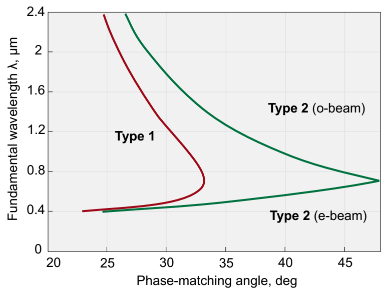
- harmonic generations (up to fifth) of Nd doped lasers
- frequency doubling and tripling of ultrashort pulse Ti:Sapphire and Dye lasers
- optical parametric oscillators (OPO) at both Type 1(ooe) and Type 2 (eoe) phase-matching
- frequency doubling of Argon ion and Copper vapour laser radiation
- electro-optic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



SHG tuning curve of BBO



OPO tuning curves of BBO at 355 nm pump

BBO with gold electrodes for e/o applications

STANDARD SPECIFICATIONS

Flatness	up to λ/8 at 633 nm
Parallelism	< 20 arcsec
Surface quality	10-5 scratch & dig (MIL-PRF-13830B)
Perpendicularity	<5 arcmin
Angle tolerance	<30 arcmin
Aperture tolerance	± 0.1 mm
Clear aperture	90% of full aperture

PHYSICAL AND OPTICAL PROPERTIES

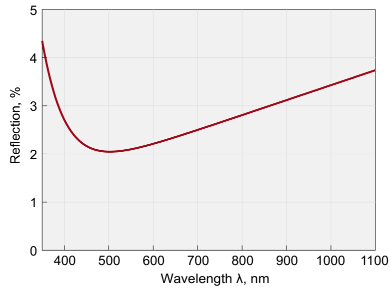
Chemical formula	BaB_2O_4	
Crystal structure	trigonal, 3m	
Optical symmetry	Negative Uniaxial (n_o>n_e)	
Space group	R3c	
Density	3.85 g/cm^3	
Mohs hardness	5	
Optical homogeneity	$\partial n = 10^{-6}$ cm^{-1}	
Transparency region at "0" transmittance level	189 – 3500 nm	
Linear absorption coefficient 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	$d_{22} = \pm(2.22\pm0.09)$ pm/V	
	$d_{31} = \pm(0.16\pm0.08)$ pm/V	
Effective nonlinearity expressions	$d_{ooe} = d_{31}\sin\theta - d_{22}\cos\theta\sin3\varphi$	
	$d_{eoe} = d_{oee} = d_{22}\cos^2\theta\cos3\varphi$	
Damage threshold for TEM_{00} 1064 nm	> 0.5 GW/cm^2 at 10 ns	
	~ 50 GW/cm^2 at 1 ps	

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.

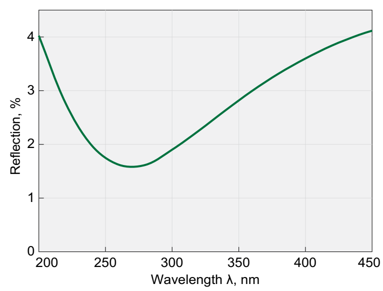
Wide selection of non-standard size and cut angle BBO crystals is available at **www.eksmaoptics.com**



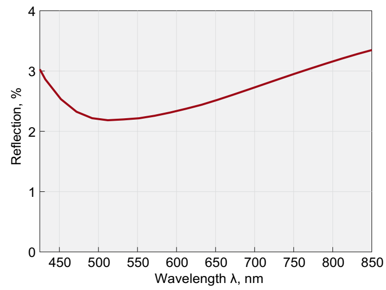
Typical P-coating for BBO SHG@800 nm application

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

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



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)

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

RELATED PRODUCTS

Thin BBO crystals for SHG and THG of Ti:Sapphire laser wavelength
See page 5.23

BBO crystals for SHG of Yb:KGW/KYW laser frequency conversion
See page 5.30

HOUSING ACCESSORIES

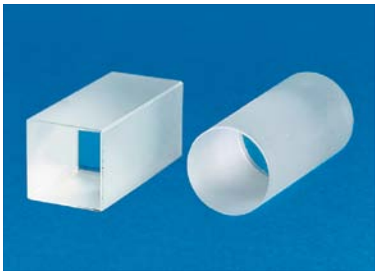
Ring Holders for Nonlinear Crystals
See page 2.27

Positioning Mount 840-0199 for Nonlinear Crystal Housing

Accepts crystals with aperture up to 12x12 mm and thichness up to 3 mm.
See page 2.29

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/cm^2 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 θ=90° 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 θ=76.5° 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 femtosecond 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_2PO_4	KD_2PO_4
Symmetry		42 m	42 m
Hygroscopicity		high	high
Density, g/cm^3		2.332	2.355
Thermal conductivity, W/cm×K		k_{11}= 1.9×10^{-2}	k_{11}= 1.9×10^{-2} k_{33}= 2.1×10^{-2}
Thermal expansion coefficients, K^{-1}		a_{11}= 2.5×10^{-5} a_{33}= 4.4×10^{-5}	a_{11}= 1.9×10^{-5} a_{33}= 4.4×10^{-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 n_e	2.259276 2.132668	2.2409 2.1260
B	n_o n_e	13.00522 3.2279924	2.2470 0.7844
C	n_o n_e	400 400	126.9205 123.4032
D	n_o n_e	0.01008956 0.008637494	0.0097 0.0086
E	n_o n_e	0.012942625 0.012281043	0.0156 0.0120
Nonlinear coeff. d_{36}, pm/V (at 1.06 µm)		0.43	0.40
Effective nonlinear coefficient Type 1 Type 2		 $d_{ooe} = d_{36} \times \sin\theta \times \sin2\varphi$ $d_{eoe} = d_{36} \times \sin\theta \times \cos2\varphi$	
Laser damage threshold, GW/cm^2 at 1.06 µm		10 ps – 100 1 ns – 10 15 ns – 14.4	250 ps – 6 10 ns – 0.5

PHASE MATCHING ANGLES AND BANDWIDTHS FOR SHG OF 1064 nm

Crystal	KDP		DKDP	
Type of phase matching	Type 1 ooe	Type 2 eoe	Type 1 ooe	Type 2 eoe
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 (MIL-PRF-13830B)
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

Wide selection of non-standard size and cut angle DKDP crystals is available at **www.eksmaoptics.com**

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

RELATED PRODUCTS

Nonlinear Crystal Oven CH3

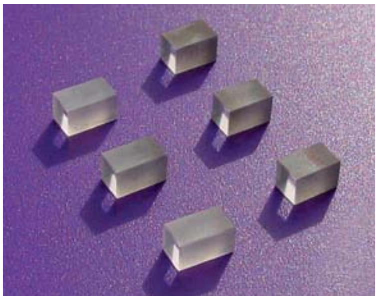
See page 2.31

Nonlinear Crystal Oven CH4

See page 2.32

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



EKSMA OPTICS OFFERS

- Crystal size up to 10×10×20 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 ($KTiOPO_4$) 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.

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 1.5–2.5 μm 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.

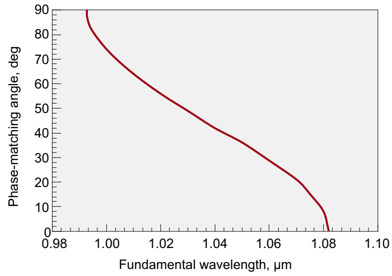


***Fig. 1.** Type 2 SHG in x-y plane*

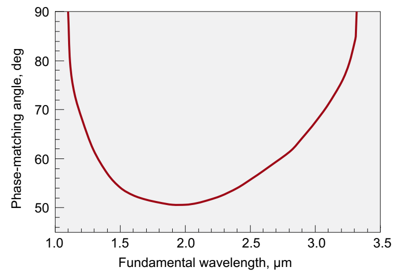


***Fig. 2.** Type 2 SHG in x-z plane*

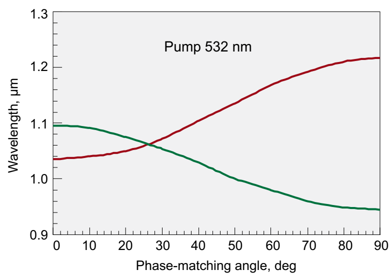


***Fig. 3.** OPO tuning curve in x-y plane*

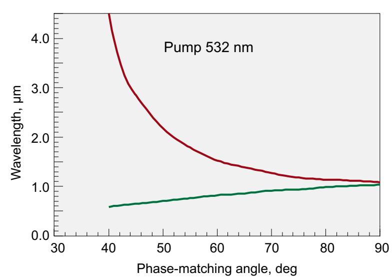


***Fig. 4.** OPO tuning curve in x-z plane*

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}	$a_x = 11\times10^{-6}$, $a_y = 9\times10^{-6}$, $a_z = 0.6\times10^{-6}$
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	$\partial n_x/\partial T = 1.1\times10^{-5}\,(K)^{-1}$	
	$\partial n_y/\partial T = 1.3\times10^{-5}\,(K)^{-1}$	
	$\partial n_z/\partial T = 1.6\times10^{-5}\,(K)^{-1}$	
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	Δv = 0.56 nm × cm
Up to 80% extracavity SHG efficiency	
Effective nonlinearity	
x-y plane	$d_{eoe} = d_{oee} = d_{15}\sin^2\varphi + d_{24}\cos^2\varphi$
x-z plane	$d_{oeo} = d_{eoo} = d_{24}\sin\theta$
	$d_{31} = \pm 1.95$ pm/V $d_{32} = \pm 3.9$ pm/V
	$d_{33} = \pm 15.3$ pm/V $d_{24} = d_{32}$ $d_{15} = d_{31}$
Damage threshold	>500 MW/cm^2 *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 (MIL-PRF-13830B)
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

RELATED PRODUCTS

Crystal Oven TC1

See page 2.30

Ring Holders for Nonlinear Crystals

See page 2.27

Nonlinear Crystal Oven CH7

See page 2.33

Positioning Mount 840-0199 for Nonlinear Crystal Housing

See page 2.29

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	λ/8 at 633 nm
Parallelism	< 20 arcsec
Surface quality	10-5 scratch & dig (MIL-PRF-13830B)
Perpendicularity	< 15 arcmin
Angle tolerance	<± 0.2°
Aperture tolerance	± 0.1 mm
Clear aperture	> 90% central area
Transmitting wavefront distortion	less than λ/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	$d_{eoe} = d_{oee} = d_{15}\sin^2\varphi + d_{24}\cos^2\varphi$
x-z plane	$d_{oeo} = d_{eoo} = d_{24}\sin\theta$
	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 λ=1064 nm, τ=10 ns, 10 Hz, TEM_{00}

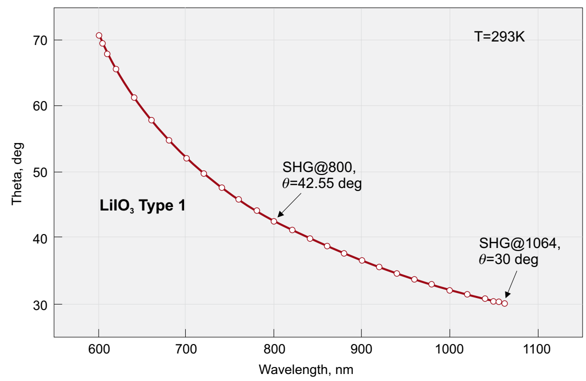
$LiIO_3$ LITHIUM IODATE

APPLICATIONS

- Harmonic generators
- Thin $LiIO_3$ for autocorrelation measurements

EKSMA OPTICS OFFERS:

- The mass production of $LiIO_3$ 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.



$LiIO_3$ Second harmonic generation phasematching

PHYSICAL AND OPTICAL PROPERTIES

Crystal structure	hexagonal
Point group	6
Density, g/cm³	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	$d_{ooe} = d_{15}\sin\theta$
Damage threshold, MW/cm²	> 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	λ/6 at 633 nm
Parallelism	< 30 arcsec
Surface quality	20-10 scratch & dig (MIL-PRF-13830B)
Perpendicularity	< 5 arcmin
Angle tolerance (Δθ & Δφ)	< 30 arcmin
Clear aperture	90% of full aperture

HOUSING ACCESSORIES

Ring Holders for Nonlinear Crystals

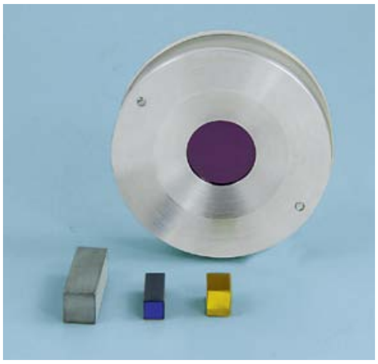
See page 2.27

Positioning Mount 840-0199 for Nonlinear Crystal Housing

See page 2.29

$ZnGeP_2$ • $AgGaSe_2$ $AgGaS_2$ • GaSe

INFRARED NONLINEAR CRYSTALS



Optical nonlinear crystals **$ZnGeP_2$, $AgGaSe_2$, $AgGaS_2$, 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).

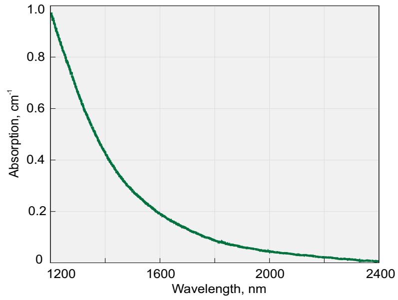
$ZnGeP_2$

$ZnGeP_2$ (ZGP) crystal has transmission band edges at 0.74 and 12 µm. However it's useful transmission range is from 1.9 to 8.6 µm and from 9.6 to 10.2 µm. ZGP crystal has the largest nonlinear optical coefficient and relatively high laser damage threshold. The crystal is successfully used in diverse applications:

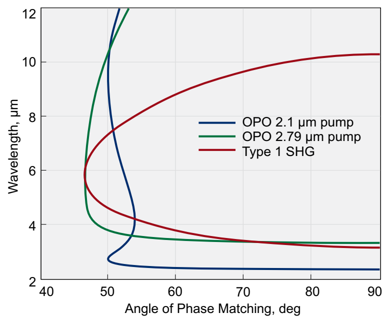
- up-conversion of CO_2 and CO laser radiation to near IR range via harmonics generation and mixing processes;
- efficient SHG of pulsed CO, CO_2 and chemical DF-laser;
- efficient down conversion of Holmium, Thulium and Erbium and laser wavelengths to mid infrared wavelength ranges by OPO process.

Crystals with high damage threshold BBAR coatings and the lowest absorption coefficient $\alpha < 0.05$ cm^{-1} at pump wavelengths 2.05 - 2.1 µm „o"- polarisation are available for OPO applications.

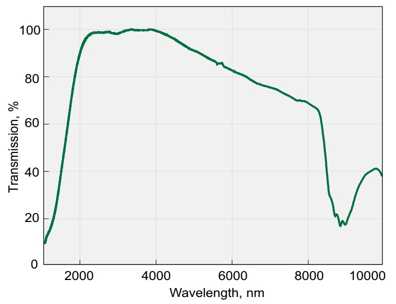
Typical absorption coefficient is <0.03 cm^{-1} at 2.5 - 8.2 µm range.



Absorption spectra of $ZnGeP_2$ crystal near 2 µm



Type 1 OPO and SHG tuning curves in $ZnGeP_2$



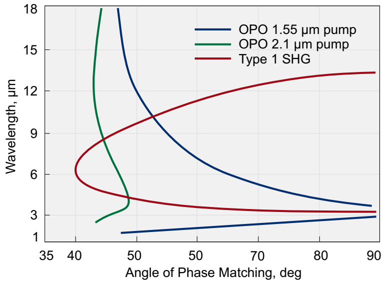
Transmission spectra of 15 mm long AR coated $ZnGeP_2$ crystal for OPO @ 2.1 µm

TYPE 1 $ZnGeP_2$ CRYSTALS for OPO at 3.5-5 µm range pumped at ~2.1 µm

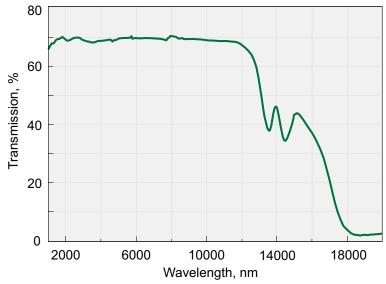
Catalogue number	Size, mm	θ, deg	φ, deg	Coating	Application
ZGP-401	7×5×15	54	0	AR @ 2.1 µm + BBAR @ 3.5-5 µm	OPO@2.1 → 3.5-5 µm
ZGP-402	7×5×20	54	0	AR @ 2.1 µm + BBAR @ 3.5-5 µm	OPO@2.1 → 3.5-5 µm
ZGP-403	7×5×25	54	0	AR @ 2.1 µm + BBAR @ 3.5-5 µm	OPO@2.1 → 3.5-5 µm

$AgGaSe_2$

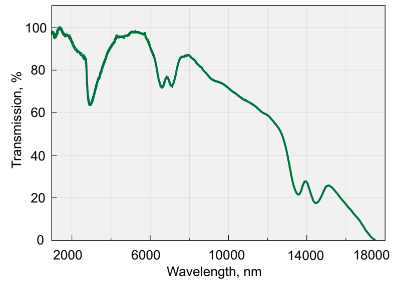
$AgGaSe_2$ has band edges at 0.73 and 18 µm. Its useful transmission range of 0.9–16 µm and wide phase matching capability provide excellent potential for OPO applications when pumped by a variety of currently available lasers. Tuning from 2.5–12 µm has been obtained when pumping by Ho:YLF laser at 2.05 µm; as well as NCPM operation from 1.9–5.5 µm when pumping at 1.4–1.55 µm. Efficient SHG of pulsed CO_2 laser has been demonstrated.



Type 1 OPO and SHG tuning curves in $AgGaSe_2$



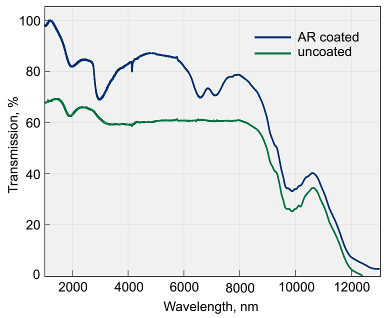
Transmission spectra of 18 mm long uncoated $AgGaSe_2$ crystal



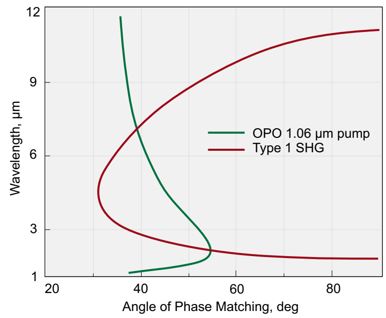
Transmission spectra of 25 mm long AR coated $AgGaSe_2$ crystal

$AgGaS_2$

$AgGaS_2$ 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 countermeasure systems, and SHG of CO_2 laser.



Transmission spectra of 14 mm long AR coated and uncoated $AgGaS_2$ crystal used for OPO pumped by Nd:YAG laser



Type 1 OPO and SHG tuning curves in $AgGaS_2$

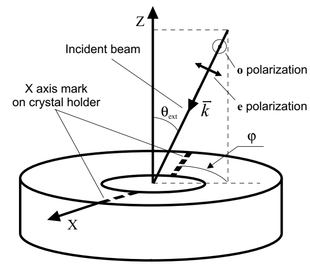
LIST OF STANDARD $AgGaS_2$ CRYSTALS

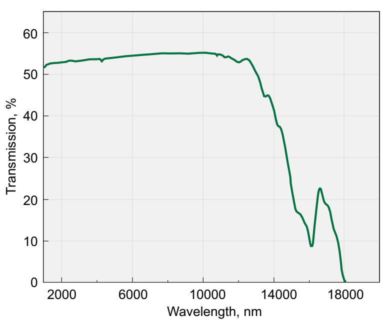
Code	**Size,** mm	**θ,** deg	**φ,** deg	Coating	Application	**Price,** EUR
AGS-401H	5×5×1	39	45	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	OPO @ 1.2-2.4 µm -> 2.4-11 µm	695
AGS-402H	6×6×2	50	0	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	OPO @ 1.2-2.4 µm -> 2.4-11 µm	770

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

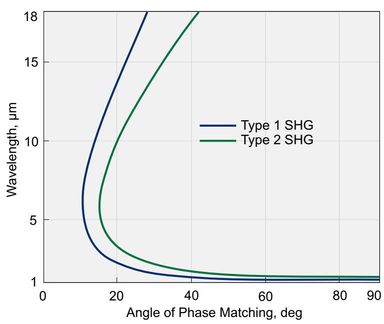
GaSe

GaSe has band edges at 0.65 and 18 µm. GaSe has been successfully used for efficient SHG of CO_2 laser, for SHG of pulsed CO, CO_2 and chemical DF-laser (λ = 2.36 µm) radiation; up conversion of CO and CO_2 laser radiation into the visible range; infrared pulses generation via difference frequency mixing of Neodymium 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.

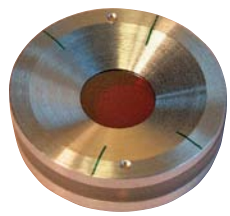




Transmission spectra of 17 mm long uncoated GaSe crystal



Type 1 and Type 2 SHG tuning curves in GaSe



Cleaved GaSe crystal glued into special ring holder

GaSe, Z-CUT

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

RELATED PRODUCTS

Ring Holders for Nonlinear Crystals

See page 2.27

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/cm³		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/cm²	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 $LiIO_3$ • $AgGaS_2$ • 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):

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

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 $LiIO_3$ 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	–	–
LiIO3	–	–	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 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 ±50 µm for crystals of thickness down to 300 µm and ±20 µm for crystals of thickness down to 100 µm.

GaSe crystal is supplied glued in to dia Ø40 mm ring holder only.

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	Ø5 mm	Ø7 mm	0.01 mm

** the thickness should be about 0.5 mm for max aperture KDP and $LiIO_3$*

Optically contacted crystals

BBO 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 crystal thickness is +10/-5 µm.

Crystal	Minimal aperture	Maximal aperture	Minimal thickness
BBO	5×5 mm	10×10 mm	10±5 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	λ/6 at 633 nm	λ/4 at 633 nm	cleaved perpendicularly to optical axis. Polish is not available
Parallelism	< 10 arcsec	< 30 arcsec	
Angle tolerance	< 15 arcmin	< 30 arcmin	
Surface quality	10/5 scratch/dig	20/10 scratch/dig	

RELATED PRODUCTS

Other Ultrahin BBO crystals available. *See pages 5.23; 5.30*

Ring Holders for Nonlinear Crystals
See page 2.27

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

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 (MIL-PRF-13830B)
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 1.16

Visualizator 990-0840
See page 1.16

Yb:KGW • Yb:KYW — Yb-DOPED POTASSIUM GADOLINIUM TUNGSTATE

- **high absorption coefficient @ 981 nm**
- **high stimulated emission cross section**
- **low laser threshold**
- **extremely low quantum defect $\lambda_{pump}/\lambda_{se}$**
- **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(WO$_4$)$_2$**) and Yb-doped Potassium Itrium Tungstate (**Yb:KY(WO$_4$)$_2$**) single crystals are the laser crystals for diode or laser pumped solid-state laser applications.

APPLICATIONS

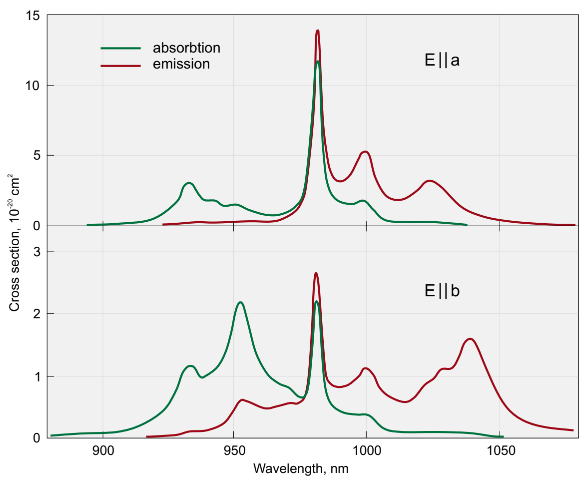
- Yb:KGW and Yb:KYW thin (100–150 µm) crystals are used as lasing materials to generate ultrashort (hundreds of fsec) high power (>22 W) pulses. Standard pumping @ 981 nm, output: 1023–1060 nm
- Yb:KGW and Yb:KYW can be used as ultrashort pulses amplifiers
- Yb:KGW and Yb:KYW are some of the best materials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

CUSTOM MANUFACTURING CAPABILITIES

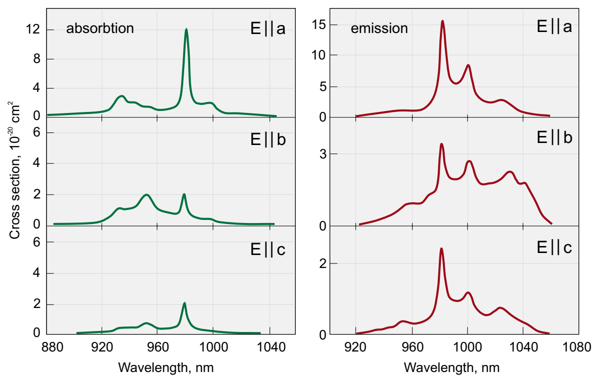
- Various shapes (slabs, rods, cubes)
- Different dopant levels
- Diversified coatings

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, β=94.43°	a=8.05 Å, b=10.35 Å, c=7.54 Å, β=94°
Thermal expansion	$\alpha_a=4\times10^{-6}$ /°C, $\alpha_b=3.6\times10^{-6}$ /°C, $\alpha_c=8.5\times10$	—
Thermal conductivity	K_a=2.6 W/mK, K_b=3.8 W/mK, K_c=3.4 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 (λ=1.06 µm)	n_g=2.037, n_p=1.986, n_m=2.033	—
∂n/∂t	0.4×10^{-6} K^{-1}	0.4×10^{-6} K^{-1}
Laser wavelength	1023–1060 nm	1025–1058 nm
Fluorescence lifetime	0.3 ms	0.3 ms
Stimulated emission cross section (**E**‖a)	2.6×10^{-20} cm^2	3×10^{-20} cm^2
Absorption peak and bandwidth	α_a=26 cm^{-1}, λ=981 nm, Δλ=3.7 nm	α_a=40 cm^{-1}, λ=981 nm, Δλ=3.5 nm
Absorption cross section	1.2×10^{-19} cm^2	1.33×10^{-19} cm^2
Lasing threshold	35 mW	70 mW
Stark levels energy (in cm^{-1}) of the $^2F_{5/2}$ manifolds of Yb^{3+} @ 77K	10682, 10471, 10188	10695, 10476, 10187
Stark levels energy (in cm^{-1}) of the $^2F_{7/2}$ manifolds of Yb^{3+} @ 77K	535, 385, 163, 0	568, 407, 169, 0

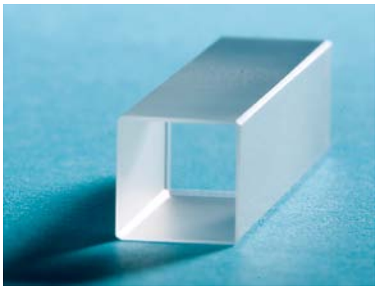


Absorption and emission spectra of Yb(5%):KYW



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

Nd:KGW — Nd-DOPED POTASSIUM GADOLINIUM TUNGSTATE



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.

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

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 Quality	10-5 scratch & dig (MIL-PRF-13830B)
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_pc = 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	$^4F_{3/2}\rightarrow{}^4I_{11/2}$
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

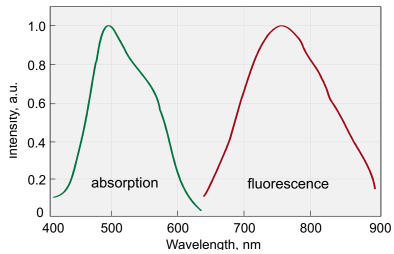
$Al_2O_3:Ti^{3+}$ indefinitely long stability and useful lifetime added to the lasing over entire band of 660 – 1050 nm challenge "dirty" dyes in variety of applications. Medical laser systems, lidars, laser spectroscopy, direct femtosecond pulse generation by Kerr-type mode-locking – there are few of existing and potential applications.

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.

$Al_2O_3:Ti^{3+}$ – titanium-doped sapphire crystals combine outstanding physical and optical properties with broadest lasing range.

Ti_2O_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.*



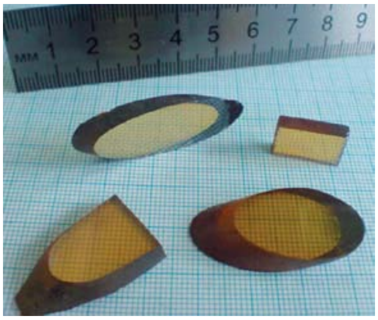
STANDARD SPECIFICATIONS

Orientation	optical axis C normal to rod axis
Ti_2O_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 Quality	10-5 scratch & dig (MIL-PRF-13830B)
Wavefront distortion	λ/4 inch

PHYSICAL AND LASER PROPERTIES

Chemical formula	$Ti^{3+}:Al_2O_3$
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
Absorbtion range	400–600 nm
Emission peak	795 nm
Absorption peak	488 nm
Refractive index	1.76 @ 800 nm

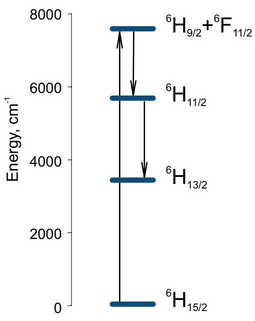
$Dy^{3+}:PbGa_2S_4$ LEAD THIOGALLATE WITH DYSPROSIUM IONS CO-DOPED BY ALKALI METALS



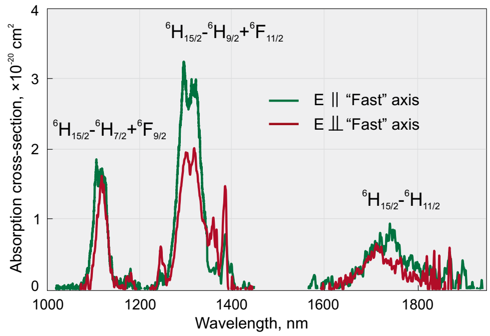
EKSMA OPTICS offers novel unique crystal – lead thiogallate ($PbGa_2S_4$) with dysprosium ions (Dy^{3+}) co-doped by alkali metals. Crystal shows efficient laser emission at room temperature in mid IR range at 4.3-5.5 micron wavelengths.

PHYSICAL PROPERTIES

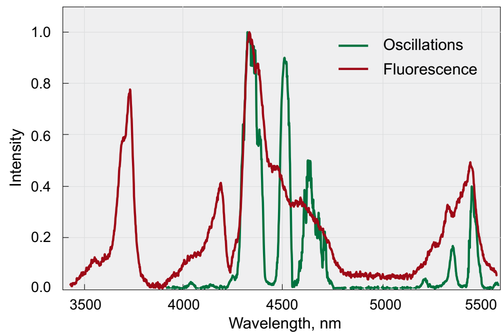
Transmission range	0.44-12 microns
Dy^{3+} concentration in crystal	0.5 mol. %
Non hygroscopic	



Energy diagram of Dy^{3+} ion



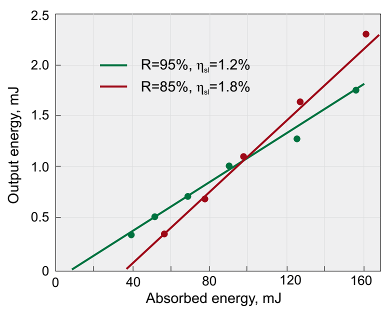
Polarized absorption cross-section spectrum of Dy^{3+} ions in $PbGa_2S_4$ crystal

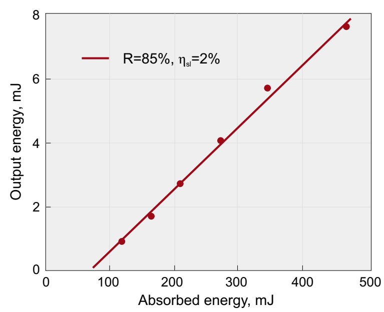


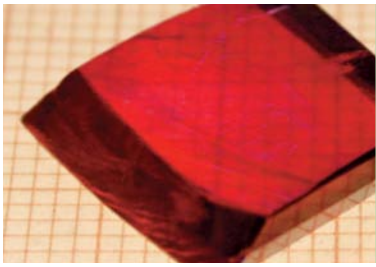
Emission cross-section and oscillation spectrum of Dy^{3+}ions in $PbGa_2S_4$ crystal

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	~ 1 cm^{-1}
Cross-section at 4.3 mm	$1×10^{-20}$ cm^2
Lasing threshold	< 20 mJ
Lasing pulse duration	< 1 ms
Laser efficiency	up to 2%

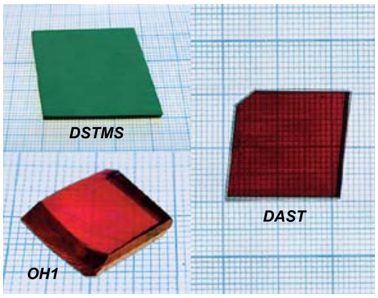






Terahertz Crystals

DSTMS • DAST • OH1 ORGANIC TERAHERTZ CRYSTALS



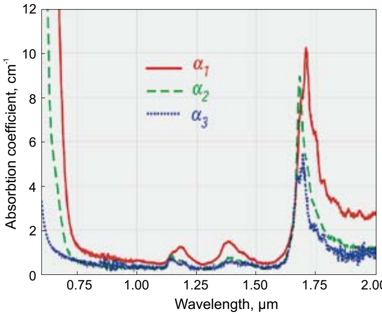
EKSMA OPTICS offers organic DSTMS, DAST, OH1 crystals for THz generation and detection using different femtosecond laser pump sources.

ORGANIC TERAHERTZ GENERATORS AND DETECTORS:

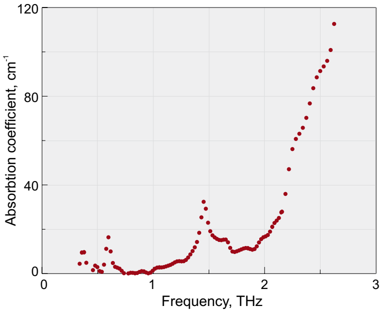
- DSTMS – efficient terahertz generation in 0.3-15 THz range
- DAST – efficient terahertz generation in 0.1-17 THz range
- OH1 – efficient terahertz generation in 0.1-3 THz range

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



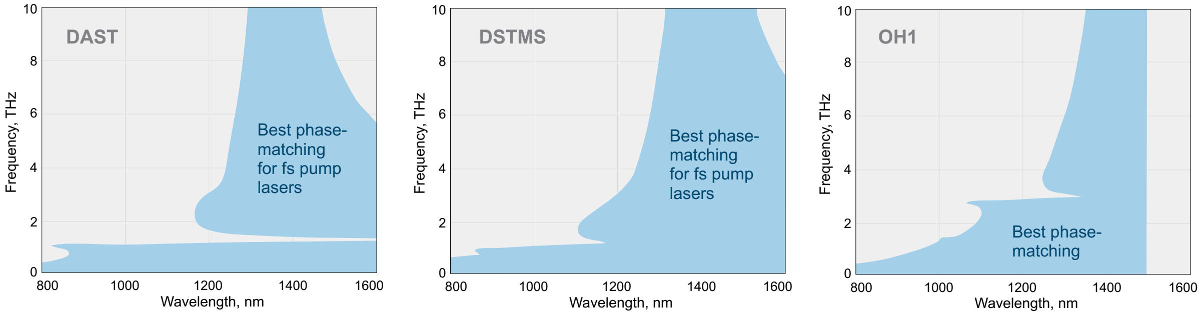
Absorption Spectrum of DSTMS, DAST THz crystals



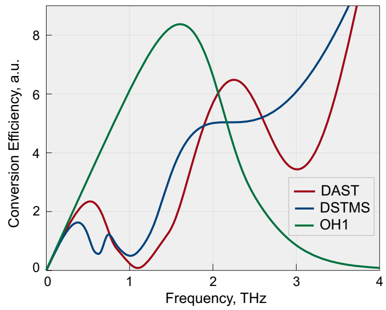
Absorption Spectrum of OH1 crystals

PHYSICAL PROPERTIES OF ORGANIC TERAHERTZ CRYSTALS

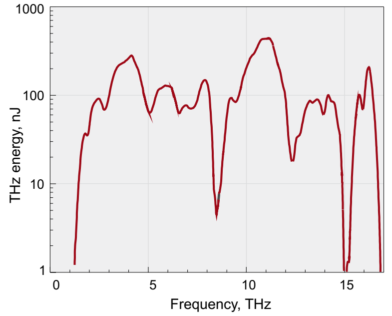
Crystal	DSTMS	DAST	OH1
Point group symmetry	m	m	mm2
Melting temperature, °C	250	256	212
Refractive indices	n_1 = 2.07 @ 1550 nm n_2 = 1.64 @ 1550 nm	n_1 = 2.519 @ 720 nm n_2 = 1.720 @ 720 nm n_3 = 1.635 @ 720 nm	n_2 = 1.58 @ 1319 nm n_3 = 2.15 @ 1319 nm
Nonlinear optical coefficients	d_{111} = 214±20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

GaSe • ZnTe — SEMICONDUCTOR TERAHERTZ CRYSTALS

ZnTe

ZnTe (Zinc Telluride) crystals with <110> 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 <110> 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 λ/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, <110> CUT

Catalogue number	**Size,** mm	**Thickness,** mm
ZnTe-100	10×10	0.1
ZnTe-200	10×10	0.2
ZnTe-500	10×10	0.5
ZnTe-1000	10×10	1.0

GaSe

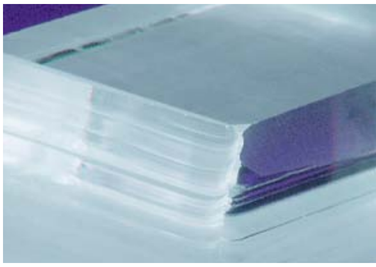
GaSe (Gallium Selenide) crystals used for THz generation shows a large bandwidth of up to 41 THz. GaSe is a negative uniaxial layered semiconductor with a hexagonal structure of 62 m point group and a direct bandgap of 2.2 eV at 300 K. GaSe crystal features high damage threshold, large nonlinear optical 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

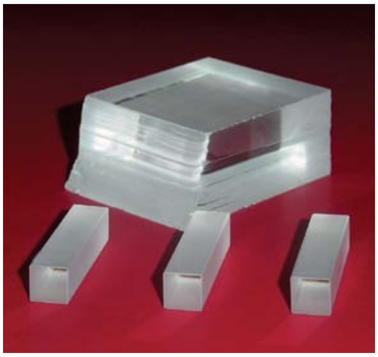
Catalogue number	**Clear aperture,** mm	**Thickness,** µm
GaSe-30	Ø7	30
GaSe-100	Ø7	100
GaSe-1000	Ø7	1000

NONLINEAR CRYSTALS
LASER CRYSTALS
TERAHERTZ CRYSTALS
RAMAN CRYSTALS
POSITIONERS & HOLDERS
CRYSTAL OVENS



Raman Crystals

KGW • $Ba(NO_3)_2$ — CRYSTALS FOR STIMULATED RAMAN SCATTERING



EKSMA OPTICS offers crystalline materials – **Barium Nitrate – $Ba(NO_3)_2$** and **undoped potassium gadolinium tungstate $KGd(WO_4)_2$** 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.

$Ba(NO_3)_2$ has a highest Raman gain coefficient. 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 ∂n/∂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 $Ba(NO_3)_2$ and KGW for Raman application $Ba(NO_3)_2$ is more optimal in case of ns and longer pulses, KGW – in case of shorter pulses.

$Ba(NO_3)_2$ PHYSICAL AND OPTICAL PROPERTIES

Crystal symmetry	cubic, $P2_13$
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
∂n/∂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
∂n/∂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 $Ba(NO_3)_2$ 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, scratch & dig (MIL-PRF-13830B)	40-20	10-5
Flatness @ 633 nm	λ/4	λ/8
Maximal element dimensions, mm	10×10×100	10×10×80

Co^{2+}:$MgAl_2O_4$ Cr^{4+}:YAG

PASSIVE Q-SWITCHING CRYSTALS

EKSMA OPTICS offers a wide choice of solid-state saturable absorbers such as: **Co^{2+}:$MgAl_2O_4$, Cr^{4+}:YAG**.

Co^{2+}:$MgAl_2O_4$ 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 (3.5×10^{-19} 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).

Cr^{4+}:YAG is one of the best passive Q-switch for high power lasers emitting at ~1 µm wavelength. Standard diameter apertures – 5, 8, 9.5 mm and various initial transmission (or optical density) are available upon request. Also Cr^{4+}:YAG laser rods for ultra-short pulse solid-state lasers are available.

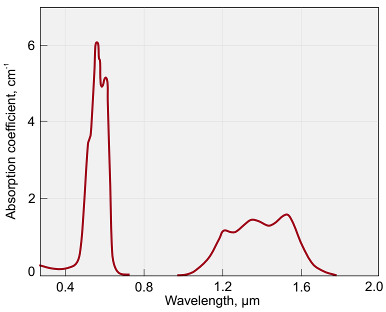


Fig. 1. *Absorption spectra of the Co^{2+}: $MgAl_2O_4$ crystal*

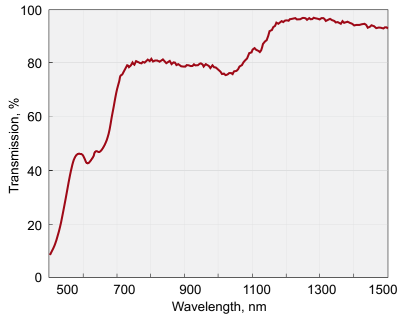
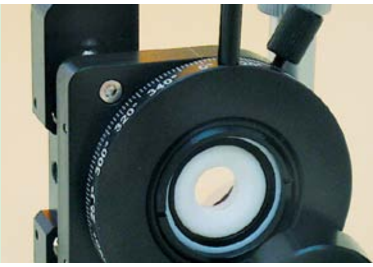


Fig. 2. *Transmission of AR coated at 1064 nm Cr:YAG Q-switch with initial transmission of 80% at 1064 nm*

SPECIFICATIONS

	Co:$MgAl_2O_4$	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

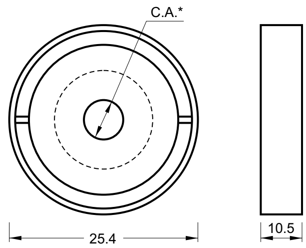
830-0001 RING HOLDERS FOR NONLINEAR CRYSTALS

830-0001-10

830-0001-06

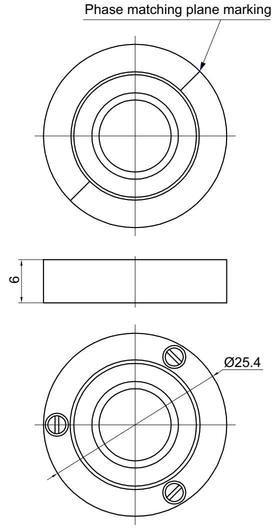
- **Black anodized aluminium body**
- **Teflon or white anodized aluminium adapter for particular crystal size**
- **Easy assembling and disassembling**

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.



** C.A. - depends on crystal aperture*

830-0001-10



830-0001-06

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

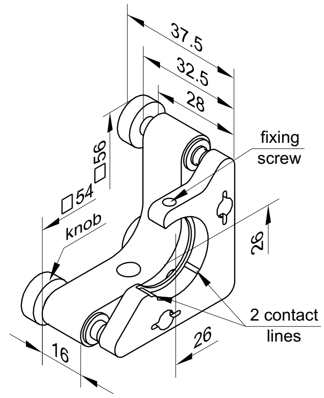
HOUSING ACCESSORIES

Positioning Mount 840-0199 for Nonlinear Crystal Housing

See page 2.29

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.

Code	Price, EUR
840-0056-11	75

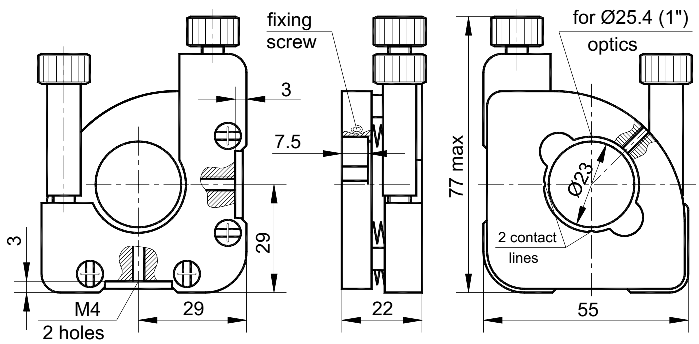
RELATED PRODUCTS

Motorized version 940-0060-01

See page 8.141

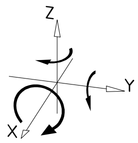
840-0193 KINEMATIC POSITIONING MOUNT

- **For Ø25.4 mm (1 inch) ring holders**
- **Kinematic design**
- **Tilt/tip range ±2°**
- **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: ±2°**
- **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.

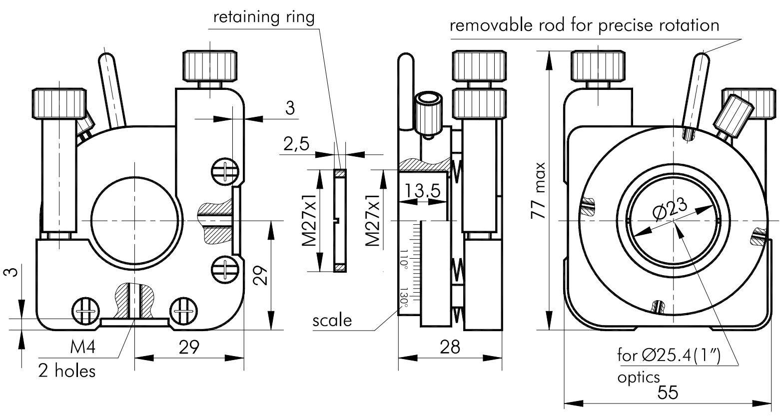
Angular adjustment range of tilt/tip (Z, Y axes) is ±2.5°. Two high resolution stainless steel vertical-drive screws with a pitch of 0.25 mm and “wedge and ball” mechanism ensure smooth and precise angular tilt/tip adjustment with 3 arc sec sensitivity. For tilting, the platform it is preloaded against 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

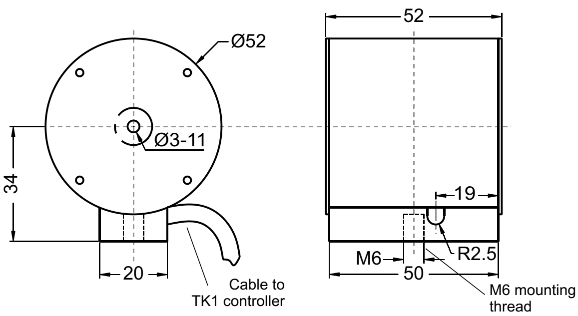
Many of widely used nonlinear crystals are susceptible to ambient humidity, for example KD*P, BBO, LBO. Protective coatings applied to the surface can reduce degradation to some extent only. To improve the protection of surfaces of the crystals from the degradation it is desirable to keep the crystals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



TC1 and CO1 dimensions

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 ºC, can control two CO1 ovens, long-term stability ±0.1 ºK, worldwide mains	711
Crystal Ovens for TC1		
For crystal length up to 30 mm		
CO1-30-y/y	Standard crystal sizes *	570
CO1-30-y/z	Custom crystal sizes	625
CO1-30S-y/y	Sealed, standard crystal sizes *	860

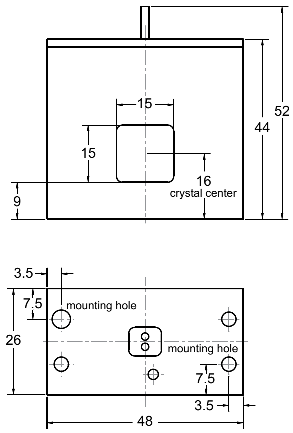
** Sizes 3×3, 4×4, 5×5, 6×6,12×12 are standard.* *** y/y, y/z – crystal size.*

Code **	Description, features	Price, EUR
Crystal Ovens for TC1		
For crystal length up to 50 mm		
CO1-50-y/y	Standard crystal sizes *	699
CO1-50-y/z	Custom crystal size	713
CO1-50S-y/y	Sealed, standard crystal sizes *	–
For Brewster-angle cut crystal		
CO1-30BA-y/y	For Brewster-angle cut crystal	719
CO1-30BAS-y/y	Sealed, for Brewster-angle cut crystal	969
For PPLN crystals		
CO1-30PP-y/y	For PPLN crystals	656
Mounting accessories		
Crystal holders		
AD1	Spare crystal holder for CO1-30 oven	98
AD2	Spare crystal holder for CO1-50 oven	116
Mounting stages for crystals ovens		
MS-4	Adapter for CO1 oven mounting on tilt stage. Tilt stage should be ordered separately	–

** Sizes 3×3, 4×4, 5×5, 6×6,12×12 are standard.* *** y/y, y/z – crystal size.*

CH3 OVEN FOR NONLINEAR CRYSTALS

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.



CH3 dimensions

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.

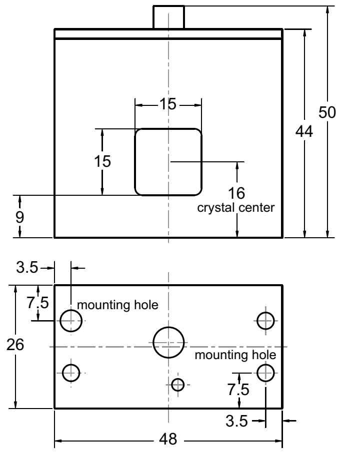
On request we can manufacture ovens for crystals with aperture up to 60×60 mm or even larger.

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 *	374
CH3-15-y/z-x	Non-standard crystal size	425
CH3-15-y/y-80	For temperature up to 80 °C	450
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 *	425
CH3-30-y/z-x	Non-standard crystal size	476
CH3-30-y/y-80	Version for temperature up to 80 °C	489
Mounting accessories		
MS-1	Two axis tilt adjustment 5 degrees range, suitable for all types of CH3, CH4 or CH7 crystal ovens	180
MS-2	Two axis tilt stage, adjustment in 5 degree range, fits two pc. of CH3, CH4 or CH7 ovens	310
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	70
Power supply PS-12		
PS-12	Power supply for CH3, CH4 or CH7 crystal oven, 100-240 VAC mains, +12 VDC output	64

** 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.



CH4 dimensions

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 *	399
CH4-15-y/z-x	Non-standard crystal sizes	450
CH4-15-y/y-80	Version for temperature up to 80 °C	476
CH4-30 – Provides READY signal, stability ±0.2 °K, crystal length up to 30 mm		
CH4-30-y/y-x	Standard crystal sizes *	450
CH4-30-y/z-x	Non-standard crystal sizes	501
CH4-30-y/y-80	Version for temperature up to 80 °C	516
CH4-50 – Provides READY signal, stability ±0.2 °K, crystal length up to 50 mm		
CH4-50-y/y-x	Standard crystal sizes *	501
CH4-50-y/z-x	Non-standard crystal sizes	554
CH4-50-y/y-80	Version for temperature up to 80 °C	568
Mounting accessories		
MS-1	Two axis tilt adjustment 5 degrees range, suitable for all types of CH3, CH4 or CH7 crystal ovens	180
MS-2	Two axis tilt stage, adjustment in 5 degrees range, fits two pc. of CH3, CH4 or CH7 ovens	310
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	70
Power supply PS-12		
PS-12	Power supply for CH3, CH4 or CH7 crystal oven, 100-240 VAC mains, +12 VDC output	64

* *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

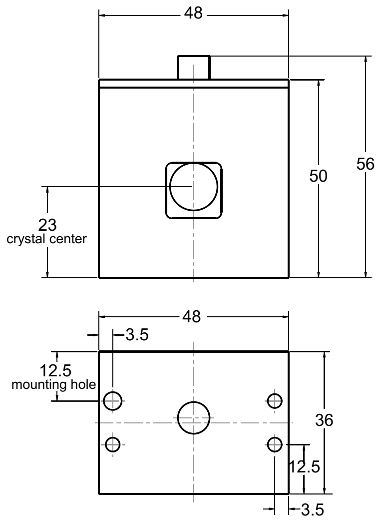
CH7 is compact oven with build-in thermo-controller for temperature up to 60 °C. CH7 oven provides more crystal mounting options in comparison to CH3 or CH4. Like in CO1, each crystal is mounted into adapter before insertion in oven. CH7 and CO1 crystal adapters are compatible. Maximum crystal size for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

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.



CH7 dimensions

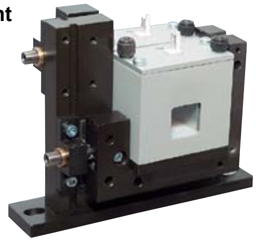
Code **	Description, features	Price, EUR
CH7-15 – Provides READY signal, stability ±0.2 °K, crystal length up to 15 mm		
CH7-15-y/y-x	Standard crystal sizes *	501
CH7-15-y/z-x	Non-standard crystal sizes	554
CH7-15-y/y-80	Version for temperature up to 80 °C	568
CH7-30 – Provides READY signal, stability ±0.2 °K, crystal length up to 30 mm		
CH7-30-y/y-x	Standard crystal sizes *	580
CH7-30-y/z-x	Non-standard crystal sizes	631
CH7-30-y/y-80	Version for temperature up to 80 °C	644
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	838
CH7-20-y/y-80	Version for temperature up to 80 °C	901
Power supply PS-12		
PS-12-CH7	Power supply for CH3, CH4 or CH7 crystal oven, 100-240 VAC mains, +12 VDC output	64
Mounting stages for crystal ovens		
MS-1		180
MS-2		310

** 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 ± 2.5°.

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.



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TC2 • CO10 CO11 • CO12

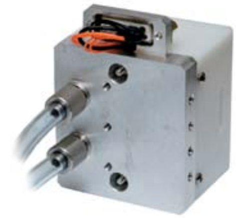
PRECISION RESISTIVE HEATER KIT TC2 AND CO10 SERIES OVENS

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.

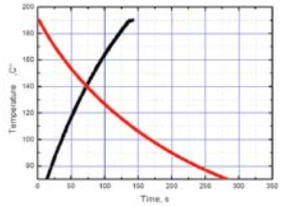
- **Crystal's temperature stabilization**
- **Fast temperature control using active cooling**
- **External temperature is kept low by insulation – no need for gloves**
- **No alignment is required when crystal is removed and replaced**
- **4 screws to remove to exchange crystals**
- **Crystals can be 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**

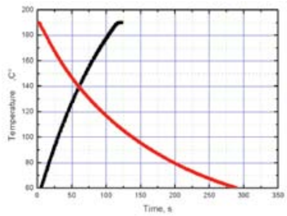


Oven CO10



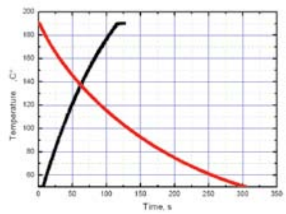
Heating-Cooling diagrams of CO10

Oven CO11



Heating-Cooling diagrams of CO11

Oven CO12



Heating-Cooling diagrams of CO12

Code	Description, features	Price, EUR
Thermocontroller TC2	Thermocontroller for CO10, CO11, CO12 fast temperature tuning PPLN crystall ovens	926
CO10	Water cooled fast temperature control oven for PPLN crystals	1494
CO11	Air cooled fast temperature control oven for PPLN crystals	1468
CO12	Cooled by mounting on heat transfering body fast temperature control oven for PPLN crystals	1661

SPECIFICATIONS

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.*