EKSMA
EKSMA Co., Lasers, Optics, Electronics

Ultrathin nonlinear crystals
BBO, LBO, KDP, LiIO$_3$, AgGaS$_2$

Thin crystals for ultrashort pulse applications are available from EKSMA Co. Optimal thickness nonlinear crystals are offered for:

- harmonic generation (SHG, SFG),
- optical parametric generation and amplification (OPG, OPA),
- laser pulses auto and cross correlation,
- difference frequency generation (DFG).

The crystals of thickness down to 100 μm can be prepared as free standing crystals (not attached on any kind of support). However the ring mounts are highly recommended for the 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.

FREE STANDING CRYSTALS

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

* the thickness should be about 2 mm for max aperture KDP and LiIO$_3$

BBO, LBO and KDP 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 +10/-5 μm, for KDP and LiIO$_3$ ±10 μm.

OPTICALLY CONTACTED CRYSTALS

Crystal	Minimal aperture	Maximal aperture	Minimal thickness
BBO	5×5 mm	10×10 mm	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

When a laser operates in ultrashort pulse regime, it is necessary to take into account two effects, which limit optimal thickness of nonlinear crystal. Namely: group velocity mismatch and dispersive spreading.

Dispersive spreading length equals:

$$\mathbf{L}_{dis} = \tau^2 / g$$

where τ is the pulse duration and g is dispersive spreading coefficient. It has typical value about $10^{-28}s^2mm^{-1}$. Therefore $\mathbf{L}_{dis}$ should be considered for pulses of less than 10 femtoseconds only.

For two collinearly propagating pulses, their *quasistatic interaction length* ($\mathbf{L}_{qs}$) is defined as distance over which they separate by a path equal to their pulse width.

$$\mathbf{L}_{qs} = (\nu \, \Delta\omega)^{-1}$$

where ν is the group velocity mismatch (Table 1) and $\Delta\omega$ is the spectral width of the pulse. For the spectral limited pulses ($\tau \, \Delta\omega \approx 1$) this dependence could be modified as

$$\mathbf{L}_{qs} = \tau / \nu$$

Crystal thickness limitations by group velocity mismatch for Type 1 SHG of 800 nm in BBO, LBO, KDP and LiIO$_3$ crystals at different fundamental pulse duration are presented in the Table 2. Also effective coefficients and phase matching angles at room temperature (20°C) are calculated.

STANDARD SPECIFICATIONS OF CRYSTALS

	BBO, LBO	KDP, LiIO$_3$, AgGaS$_2$
flatness	λ/6 at 633 nm	λ/4 at 633 nm
parallelism	< 10 arcsec	< 30 arcsec
angle tolerance	< 15 arcmin	< 30 arcmin
surface quality	10/5 scratch/dig	20/10 scratch/dig

EKSMA Co. provides various AR, BBAR and protective coatings for all free standing crystals. The coatings are not available for optically contacted crystals.

Ring mounts made from anodized aluminium are available for the safe and convenient handling of ultrathin crystals. The standard sizes are dia 1" and 25 or 30 mm. The thickness of mount is 10 mm. Custom shape and size mounts are available too.

TABLE 1. GROUP VELOCITY MISMATCH FOR TYPE 1 NONLINEAR INTERACTION

Crystal	SFM 800+266nm	SFM 800+400nm	SHG 800 nm	SHG 1064 nm	DFG 1.2-2.2 → 3 μm	DFG 1.5-1.7 → 10 μm	OPG 0.8→ 1.2-2.4 μm
BBO	2816 fs/mm	831 fs/mm	201 fs/mm	82 fs/mm	–	–	62 fs/mm
LBO	–	447 fs/mm	120 fs/mm	43 fs/mm	–	–	-133 fs/mm
KDP	–	403 fs/mm	81 fs/mm	8 fs/mm	–	–	–
LiIO$_3$	–	–	648 fs/mm	283 fs/mm	–	–	90 fs/mm
AgGaS$_2$	–	–	–	–	170 fs/mm	-43 fs/mm	–

TABLE 2. QUASISTATIC INTERACTION LENGTH FOR TYPE 1 SHG OF 800 nm. SPECTRAL LIMITED PULSE*

Crystal	200 fs	100 fs	50 fs	20 fs	10 fs	Cut angles θ, φ	coefficient d$_{eff}$
BBO	1.0 mm	0.5 mm	0.25 mm	0.1 mm	0.05 mm	29.2°, 90°	1.97 pm/V
LBO	1.7 mm	0.8 mm	0.4 mm	0.17 mm	0.08 mm	90°, 31.7°	0.72 pm/V
KDP	2.5 mm	1.2 mm	0.6 mm	0.25 mm	0.12 mm	44.9°, 45°	0.28 pm/V
LiIO$_3$	0.3 mm	0.15 mm	0.08 mm	0.03 mm	0.015 mm	42.5°, 0°	2.97 pm/V

* The ultrashort pulses in many cases are frequency-modulated, hence equality $\tau\Delta\omega \approx 1$ is not valid anymore. Therefore, in general case, the optimal thickness of crystal could be less than length indicated in Table 2.

Nonlinear and Laser Crystals