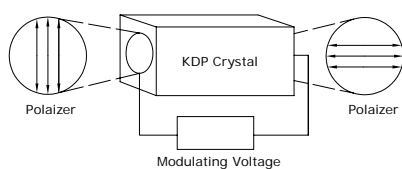
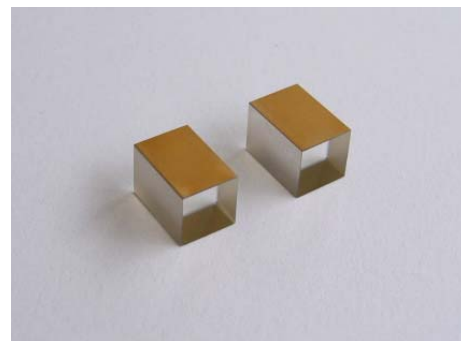


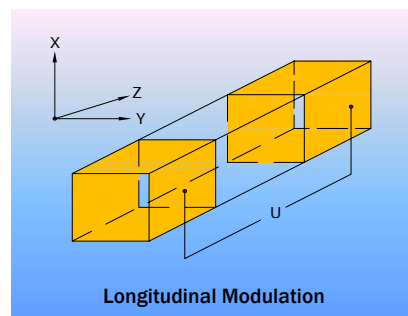
E-O Crystals

When an electric field (E) is applied to an Electro-Optic (E-O) crystal, the refractive index of E-O crystal will change linearly to electric field. The phenomenon is called linear Electro-Optic effect. For KD*P crystal, for example, the change of the refractive index (Δn) is $\Delta n = 0.5n^3_0r_{63}E$ if both the directions of light propagation and electric field are along the z-axis, where n_0 is refractive index without electric field and r_{63} is electro-optic coefficient of KD*P.

If a linearly polarized light passes through an E-O crystal, the phase retardation (Γ) will be induced by Δn to $\Gamma = 2\pi\Delta nL$, where L is crystal length, for KD*P, again as an example, $\Gamma = \pi Ln^3_0r_{63}E/\lambda$. It is clear that the phase of light will change together with electric field (E). This is called electro-optic **phase modulation**. If two crossed polarizers are placed at input and output ends of E-O crystal separately, the output intensity of light will be $I = I_0\sin^2(\Gamma/2)$, where I_0 is input intensity. That means the intensity or amplitude of light can also be modulated by electric field. This is called **amplitude modulation**.



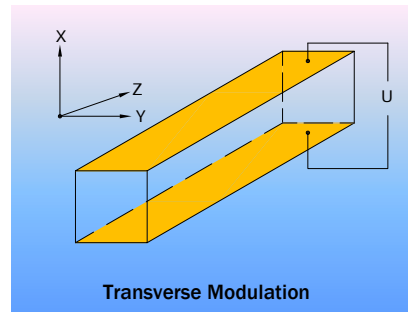
Amplitude modulation



Longitudinal Modulation

There are two kinds of E-O modulations. One is longitudinal E-O modulation if the directions of electric field and light propagation are the same. The KDP isomorphous crystals are normally used in this scheme. If the directions of electric field and light propagation are perpendicular, it is called transverse E-O modulation. The LiNbO₃, MgO:LiNbO₃, ZnO:LiNbO₃, BBO and KTP crystals are usually employed in this scheme.

The half-wave voltage (V_π) is defined as the voltage at ($\Gamma=\pi$, for example, $V_\pi=\lambda/(2n_0^3r_{63})$ for KD*P and $V_\pi=\lambda d/(2n_0^3r_{22}L)$ for LiNbO₃, where λ is light wavelength and d is the distance between the electrodes.



Transverse Modulation

Electro-Optic Modulator Materials

Materials			Phase			Amplitude		
	ϵ	n	r pm/v	K 10 ⁻⁶ /°C	n^7r^2/ϵ (pm/v) ²	r pm/v	K 10 ⁻⁶ /°C	n^7r^2/ϵ (pm/v) ²
KTP	15.42	1.80	35.0	31	6130	27.0	11.7	3650
LiNbO ₃	27.9	2.20	28.8	82	7410	20.1	42	3500
KD*P	48.0	1.47	24.0	9	178	24.0	8	178
LiIO ₃	5.9	1.74	6.4	24	335	1.2	15	124

BBO Crystal

BBO crystal is the electro-optic material of choice for high average power Pockels cell applications at the wavelength range from 200nm to 2500nm. BBO has significant advantages over other materials in terms of laser power handling abilities, temperature stability, and substantial freedom from piezoelectric ringing. Because it relies on the electro optic effect, switching time-aided by the low capacitance of the Pockels cell – is very fast. The wide transparency range of BBO allows it to be used in diverse applications. BBO has a high damage threshold and a low dielectric constant and is useful in high repetition rate, high average power (up to 150W) diode pumped solid state lasers (DPSS lasers).

Electro-optic Pockels cells are used in applications that require fast switching of the polarization direction of a beam of light. These uses include Q-switching of laser cavities, coupling light into and out from regenerative amplifiers, and, when used in conjunction with a pair of polarizers, light intensity modulation. Pockels cells are characterized by fast response, since the Pockels Effect is largely an electronic effect that produces a linear change in refractive index when an electric field is applied, and are much faster in response than devices based on acoustic changes in a material.

Because of crystal symmetry and the desire for the light beam to experience no birefringence in the absence of an electric field, BBO Pockels cells are transverse-field devices. It has electro-optic coefficients $\gamma_{11}=2.7\text{pm/V}$ and $\gamma_{22}, \gamma_{31}<0.1 \gamma_{11}$. It can be used for Q-Switching a CW diode pumped Nd:YAG laser with average power >50W.

AOTK provides high quality BBO crystals with Z-cut, AR-coating and Au-electrodes for high power application. The standard size is 3x3x18mm, 3x3x20 mm, 4x4x20mm. Please contact AOTK for more information on BBO Q-switching elements.

KD*P Crystal

KD*P crystal is widely applied for electro-optic application as Q-switch and Pockels cells. KD*P is routinely used for Q-switching applications from the UV out to about 1.1 μm where absorption limits its use in active cavities, although it can be useful at longer wavelengths when a few percent of absorption can be tolerated. KD*P has high optical uniformity and is useful for large aperture applications.

The device of longitudinal Pockels' cell using crystal of >98% deuterated DKDP is normally used for Q-switch of laser radiation. These Pockels' cells are manufactured from the crystals that have been specially selected for their low optical loss and strain free property. The crystal is in the form of a cylinder and two silver ring electrodes are used to produce the longitudinal electric field.

KTP Crystal

In addition to unique NLO features, KTP also has promising E-O and dielectric properties that are comparable to LiNbO_3 . These advantaged properties make KTP extremely useful to various E-O devices. KTP is expected to replace LiNbO_3 crystal in the considerable volume application of E-O modulators, especially for mode-locking diode laser pumped Nd:YAG and Nd:YLF lasers as well as Ti:Sapphire and Cr:LiSrAlF₆ laser. When other merits of KTP are combined into account, such as high damage threshold, wide optical bandwidth (>15GHZ), thermal and mechanical stability, and low loss, etc.

LiNbO₃ Crystal

Lithium Niobate (LiNbO_3) has higher transmission, and high contrast ratio at average powers in the KW range. Applications that utilize the large electro-optic coefficients of lithium niobate are optical modulation and Q-switching of infrared wavelengths. Because the crystal is nonhygroscopic and has a low half-wave voltage, it is often the material of choice for Q-switches in military applications. The crystal can be operated in a Q-switch configuration with zero residual birefringence and with an electric field that is transverse to the direction of light propagation. Because piezoelectric ringing can be severe, piezoelectrically damped designs can be very useful. The damage threshold of the intrinsic material at 1064nm with a 10 nsec pulse is approximately 3J/cm². With appropriate AR coatings, a surface damage threshold of 300-500 MW/cm² can be achieved for the same conditions.

The light propagates in z-axis and electric field applies to x-axis, the refractive retardation will be $\Gamma = \pi L n r_{22} V / \lambda d$. The electro-optic coefficients of LiNbO₃ are: $r_{33} = 32$ pm/V, $r_{31} = 10$ pm/V, $r_{22} = 6.8$ pm/V at low frequency and $r_{33} = 31$ pm/V, $r_{31} = 8.6$ pm/V, $r_{22} = 3.4$ pm/V at high electric frequency.

Standard Specifications

Dimensional Tolerance	(W ± 0.1mm) x (H ± 0.1mm) x (L +0.2/-0.1 mm)
Wavefront Distortion	< λ/8 @633 nm
Angle Tolerance	Δθ < ± 0.2°, Δφ < ± 0.2°
Flatness	λ/10 @633 nm
Surface Quality	10/5 Scratch/Dig per MIL-O-13830A
Parallelism	< 10 arc seconds
Perpendicularity	< 5 arc minutes
Clear Aperture	> 90% central area
AR Coating	R < 0.2% @1064nm
Quality Warranty Period	one year under proper use

Standard Products

Part No.	Crystal	Dimension	Orientation	End Faces	Side
E0001	BBO	3x3x18mm	Z-cut	AR@ 1064nm	Au on X Face
E0002	BBO	3x3x20mm	Z-cut	AR@ 1064nm	Au on X Face
E0003	KD*P	20x20x17mm	Z-cut	Uncoated	Uncoated
E0004	LiNbO ₃	9x9x25mm	Z-cut	AR@ 1064nm	Au on X Face
E0005	LiNbO ₃	10x10x20mm	Z-cut	AR@ 1064nm	Au on X Face

All statements, technical information and recommendations related to the products herein are based upon information believed to be reliable or accuracy or completeness thereof is not guaranteed, and no responsibility is assumed for any inaccuracies. The user assumes all risks and liability whatsoever in connection with the use of a product or its application, AOTK reserves the right to change at any time of a product offered for sale herein. AOTK makes no representations that the products herein are free from any intellectual property claims of others. Please contact AOTK for more information.