$LiNbO_3$, MgO:$LiNbO_3$ and Fe:$LiNbO_3$

$LiNbO_3$ Crystal is widely used as frequency doublers for wavelength > 1μm and optical parametric oscillators (OPOs) pumped at 1064 nm as well as quasi-phase-matched (QPM) devices. Due to its large Electro-Optic (E-O) and Acousto-Optic (A-O) coefficients, $LiNbO_3$ crystal is the most commonly used material for Pockel Cells, Q-switches and phase modulators, waveguide substrate, and surface acoustic wave (SAW) wafers, etc.

I. Pure Lithium Niobate ($LiNbO_3$)

AOTK provides high quality and large size $LiNbO_3$ crystals for laser frequency doublers, OPOs and quasi-phase-matched doublers, as well as waveguide substrate and SAW wafers. High quality $LiNbO_3$ components with aperture of (2 - 15) x (2 - 15) mm^2 and length up to 50 mm for frequency doublers and optical parametric oscillators (OPOs), 50x50x1 mm^3 or Dia. 3" x 1 mm $LiNbO_3$ substrate for waveguide optics, and Dia. 3" & Dia. 4" SAW wafers are available with high volume and at low price.

Basic Properties

1. Structural and Physical Properties

Crystal Structure	Trigonal, point group 3m
Lattice Parameters	a = 5.148Å, c = 13.863Å
Density	4.64 g/cm^3
Mohs Hardness	5
Melting Point	1250°C
Curie Point	1160°C
Thermal Expansion Coefficient	$\alpha_1=\alpha_2=2x10^{-6}/°C$, $\alpha_3 = 2.2x10^{-6}/°C$ at 25°C
Thermal Conductivity	38 W/m/K at 25°C
Elastic Stiffness Constant	$C^E_{11} = 2.04 \times 10^{11}$ N/m^2, $C^E_{33} = 2.46 \times 10^{11}$ N/m^2
Piezoelectric Strain Constant	$d_{22} = 2.04 \times 10^{-11}$ C/N, $d_{33} = 19.22 \times 10^{-11}$ C/N
Dielectric Constant	$\varepsilon_{11}/\varepsilon_0 = 85$, $\varepsilon_{33}/\varepsilon_0 = 29.5$
Absorption Coefficient	~ 0.1%/cm @1064 nm

2. Linear Optical Properties

Transparency Region	420-5200nm
Refractive Indexes	
at 1300 nm	$n_e = 2.146$, $n_o = 2.220$
at 1064 nm	$n_e = 2.156$, $n_o = 2.320$
at 632.8 nm	$n_e = 2.203$, $n_o = 2.286$
Sellmeier Equations (λ in μm)	$n_o^2 = 4.9048+0.11768/(\lambda^2-0.0475)-0.027169\lambda^2$ $n_e^2 = 4.5820+0.099169/(\lambda^2-0.04443)-0.02195\lambda^2$
Optical Homogeneity	~ 5×10^{-5}/cm

3. NonLinear Optical Properties

NLO Coefficients	$d_{33} = 34.4$pm/v $d_{31} = d_{15} = 5.95$ pm/v $d_{22} = 3.07$ pm/v

Effective NLO Coefficients	d_{eff} = 5.7 pm/V or ~14.6 x d_{36} (KDP) for frequency doubling 1300 nm d_{eff} = 5.3 pm/V or ~13.6 x d_{36} (KDP) for OPO pumped at 1064 nm d_{eff} = 17.6 pm/V or ~45.0 x d_{36} (KDP) for quasi-phase-matched structure
Electro-Optic Coefficients	γ^T_{33} = 32 pm/V, γ^S_{33} = 31 pm/V γ^T_{31} = 10 pm/V, γ^S_{31} = 8.6 pm/V γ^T_{22} = 6.8 pm/V, γ^S_{22} = 3.4 pm/V
Half-Wave Voltage, DC Electrical field || z, light $\perp$ z: Electrical field || x or y, light || z:	 3.03 KV 4.02 KV
Optical Damage Threshold	> 200MW/cm² (@ 1064nm, 10ns, 10Hz)

Main Applications

I. Applications for Q-switch Elements

$LiNbO_3$ is extensively used as electro-optic modulator and Q-switch for Nd:YAG, Nd:YLF and Ti:Sapphire lasers as well as modulator for fiber optics, etc. The transverse modulation is mostly employed for $LiNbO_3$. If a $LiNbO_3$ crystal is used as Q-switch crystal, the light propagates in Z-axis and electric field applies to X-axis, the refractive retardation will be $\Gamma = \pi Ln_0^3 \Upsilon_{22} V/\lambda d$. MgO:$LiNbO_3$ and ZnO: $LiNbO_3$ crystals have similar electro-optic properties to $LiNbO_3$ but with higher damage threshold. The specifications of $LiNbO_3$ Q-Switch Elements listed as the following table:

Standard Specifications

Standard Dimension	9x9x25 or 10x10x20mm³
Dimensional Tolerance	(W $\pm$ 0.1mm) x (H $\pm$ 0.1mm) x (L +0.2/-0.1 mm)
Wavefront Distortion	< $\lambda/4$ @633 nm
Angle Tolerance	$\Delta\theta < \pm 0.2°$, $\Delta\phi < \pm 0.2°$
Flatness	$\lambda/8$ @633 nm
Surface Quality	10/5 Scratch/Dig per MIL-O-13830A
Parallelism	< 20 arc seconds
Perpendicularity	< 5 arc minutes
Clear Aperture	> 90% central area
AR Coating	R < 0.2% @1064nm per surface
Electrodes	Au or Cr electrode on both X-surfaces
Quality Warranty Period	one year under proper use

II. Surface Acoustic Wave (SAW) Devices

$LiNbO_3$ crystal is widely applied as an excellent acousto-optic material for surface acoustic wave (SAW) devices (such as filters, oscillators and resonators) and ultrasonic transducer due to its high electro-mechanical coupling factor, low acoustic transmission loss, stable physical and chemical properties.

AOTK supplies large quantities of $LiNbO_3$ boules, as-cut or finished ϕ3" and ϕ4" wafers available up to 20,000 pieces per month with good quality and very low price.

Typical Applications of Piezoelectronic $LiNbO_3$

- Surface Acoustic Wave (SAW) Device
- Bulk Acoustic Wave (BAW) Device
- Leaky Surface Acoustic Wave (LBAW) Device
- Piezoelectric Transducer (PET)
- Piezoelectric Sensor (PES)

Typical Properties of Piezoelectric $LiNbO_3$

Orientation	127.86° Y-cut	Y-cut
SAW Velocity	3970 m/s	3485 m/s
Electromechanical Coupling Factor	K_s^2 = 5.5%	K_s^2 = 4.3%
Temperature Coefficients of Delay (TCD)	78 x 10^{-6}/°C	95 x 10^{-6}/°C
Temperature Coefficients of Velocity (TCV)	-60 x 10^{-6}/°C	-80 x 10^{-6}/°C

Specifications of $LiNbO_3$ SAW Wafer

Type Specifications	Boule		Wafer	
Diameter	Φ3"	Φ4"	Φ3"	Φ4"
Length or Thickness (mm)	≤100	≤50	0.35-1.0	
Orientation	127.86°Y, 64°Y, 135°Y, X, Y, Z, and other cut			
Ref. Flat Orientation	X, Y			
Ref. Flat Length	22±2mm	32±2mm	22±2mm	32±2mm
Front Side Polishing			Mirror polished 5-15 Å	
Back Side Lapping			0.3-1.0 μm	
Flatness (μm)			< 15	
Bow (μm)			< 25	

Note:

I. Other dimension is also available upon request.

II. Wafers are packaged in plastic containers (25 pieces wafers each).

III. Waveguide Substrates

$LiNbO_3$ crystal is the mostly used inorganic substrate for electro-optic waveguide applications.

Specifications of $LiNbO_3$ Waveguide Substrates

Standard Dimension	1) 50x50x1 mm^3 for X-cut, Y-cut, or Z-cut 2) ϕ3"x1 mm^3 for Y-cut or Z-cut 3) Other dimension is available upon request
Orientation Tolerance	< 10'
Surfaces Finish	One surface polished to better than λ/2 (with mount) and free from surface defects when observed by a 50X microscope, the other face fine ground

II. Magnesium Oxide Doped Lithium Niobate (MgO:$LiNbO_3$)

MgO:$LiNbO_3$ crystal is widely used for high power frequency doubling (SHG), mixing (SFG) and optical parameter oscillator(OPO). MgO:$LiNbO_3$ has similar effective nonlinear coefficients as pure $LiNbO_3$. But it has the advantages such as high damage threshold (over 300MW/cm^2 @ 1064 nm, 12ns), noncritical phase matching (NCPM) at room temperature, excellent E-O and NLO properties, good mechanical and chemical properties compared with pure $LiNbO_3$.

Its Sellmeier equations (7 mol% MgO doping) are:

$$n_o^2 = 4.8762+0.115540/(\lambda^2-0.04674)-0.033119\lambda^2 \ (\lambda \text{ in } \mu m)$$

$$n_e^2 = 4.5469+0.094779/(\lambda^2-0.04439)-0.026721\lambda^2$$

Over 45% and 60% of SHG efficient are obtained in pulsed and cw Nd:YAG lasers respectively, by angle tuned phase matchable SHG of Nd:YAG laser (1064 nm) and NCPM SHG of laser lasers (1053 nm) of MgO:$LiNbO_3$ at room temperature. MgO:$LiNbO_3$ is also a good crystal for high power quasi-phase-matched waveguide structure for doubler, optical parametric oscillator (OPO) and amplifier (OPA).

AOTK supplies the typical sizes of MgO:$LiNbO_3$ crystals - 5x5x(20-30) mm^3 for OPO and frequency doubler, (20-25)x(20-25)x1 mm^3 for waveguide substrates. Other sizes and AR or HR-coatings are available upon request.

III. Iron Doped Lithium Niobate (Fe:$LiNbO_3$)

Fe:$LiNbO_3$ is a excellent photorefractive crystal with high electro-optic coefficients, high photorefractive sensitivity and diffraction efficiency without applied electric field. Therefore, Fe:$LiNbO_3$ crystal will find the suitable applications in phase conjugation and holographic recording. High quality Fe:$LiNbO_3$ crystal, with size as large as ϕ3" and iron doped concentrations from 0.01 to 0.1 atm%, could be supplied by AOTK. Some special fabrications are also available to meet customers' requirements.

AOTK, Inc. 1502, No. 694 Xianyue Rd. Xiamen 361009, P.R. China
Phone: +86-592-550 2081 Fax: +86-592-550 2082 E-mail: sales@aotk.com www.AOTK.com