QUANTUM TECHNOLOGY, INC.

Quantum Park • 108 Commerce Street • Suite 101 / Lake Mary, Florida 32746-6212 / U.S.A.
Telephone: (407) 333-9348 / Cable: QUANTECH / Telex: 372-7798 / FAX: (407) 333-9352

DATA SHEET 708

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CHARACTERISTICS OF SINGLE CRYSTAL LITHIUM IODATE ($LiIO_3$)

A. INTRODUCTION:

When an electromagnetic wave is incident on a material media, it tends to polarize the electrons of the media. For small field strengths this polarization is proportional to the electric field E. For larger field strengths there may be a significant component of polarization generated which is proportional to E^2. E^2 contains a component at the second harmonic frequency $\omega_2 + 2\omega_1$ with a wave vector $\underline{k_2} = 2\underline{k_1}$. The amount of energy transferred to the second harmonic also depends upon the difference between the wave vectors of this driving polarization and the freely propagating wave at ω_2. For collinear waves, this difference has a magnitude

$$\Delta k = k_2 - 2k_1 \qquad (1)$$

The distance over which the driving polarization and the freely propagating wave can remain sufficiently in phase to allow energy transfer is $\pi/\Delta k$ and is termed the coherence length. Normal dispersion of crystalline media at optical frequencies prevents coherence lengths of more than a few microns unless use is made of the natural birefringence which occurs in optically anisotropic crystals. By an appropriate choice of polarizations and propagation directions, it is possible to obtain $\Delta k = 0$ (termed a phase matched condition) and achieve substantial conversion of energy to the second harmonic.

For the type of phase matching used in the $LiIO_3$ doubler, the Δk of Eq. (1) will be equal to zero if the refractive index at the fundamental equals the refractive index at the second harmonic ($n_1 = n_2$).

In uniaxial crystals like $LiIO_3$, the two indices are given by

$$n = n^o$$

$$n(\theta) = \frac{n^o n^e}{[(n^o)^2 \sin^2\theta + (n^e)^2 \cos^2\theta]^{1/2}} \qquad (2)$$

for an arbitrary direction of propagation through the crystal. n^o and n^e are the ordinary and extraordinary indices and θ is defined in Figure 1. Because $LiIO_3$ has $n^o > n^e$ (negative birefringence), phase matched harmonic generation in the presence of normal dispersion requires that $n_2 = n_2(\theta) = n_1^o$. (The subscripts 1 and 2 refer to the indices at the fundamental and second harmonic respectively.) This condition and Eq. (2) yields the phase matching angle θ_m. For Type I process it is

$$\sin^2(\theta_m) = \frac{(n_2^e)^2\,[(n_2^o)^2 - (n_1^o)^2]}{(n_1^o)^2\,[(n_2^o)^2 - (n_2^e)^2]} \qquad (3)$$

For example: $\theta_m = 34.1°$ for doubling 946nm
$\theta_m = 29.4°$ for doubling 1046nm
and $\theta_m = 27.1°$ for doubling 1123nm

B. PROPERTIES:

The refractive indices n^o and n^e are shown in Table I measured at 20°C.

TABLE I

Wavelength	n^o	n^e
400nm	1.948	1.780
436nm	1.931	1.766
500nm	1.908	1.754
530nm	1.901	1.750
578nm	1.888	1.742
690nm	1.875	1.731
800nm	1.868	1.724
1060nm	1.860	1.719

Single crystals of Lithium Iodate belong to point group 6 of the hexagonal system. It has a density of 4.490 gm/cm³. It has a high melting point of 420°C as compared to other crystals grown in water solution. Its hardness is about 4 on Mohs hardness scale. The non-linear susceptibility coefficient

$$d_{31} = 11 \pm 1.5\,(d_{36}) \text{ of KDP.}$$

The effective non-linear coefficient for Type I process is given by

$$d_{eff} = d_{31} \sin\theta_m$$

where θ_m is the phase matching angle shown in Fig. 1.

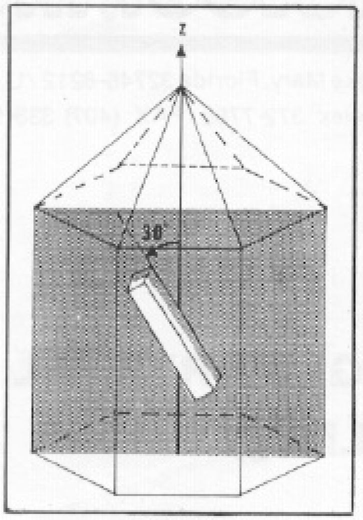


Fig. 1

The computer generated curve based on eqn. 3 and the available refractive indices are shown in Fig. 2.

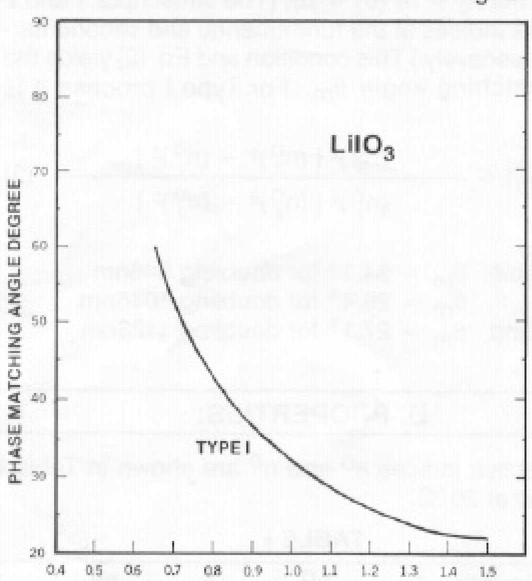
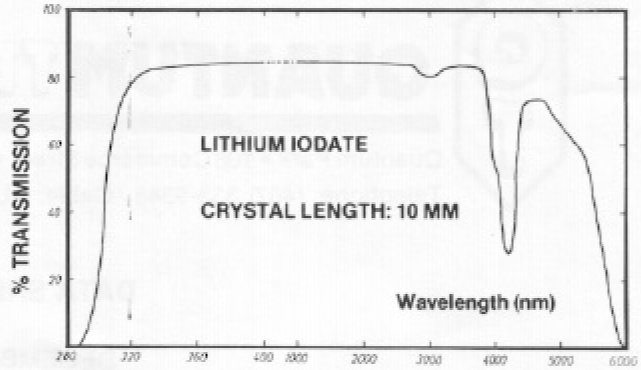


Fig. 2

The transmission band for a 10mm long Lithium Iodate crystal without AR coatings is shown in Fig. 3.



SPECTRAL TRANSMISSION OF $LiIO_3$ (no AR-coating)

Fig. 3

Optically clear single crystals are available for intracavity Nd:Yag laser doubling or for up or down conversion applications. The phase matching angle is independent of temperature, making it more stable in operation than KDP crystal. Lithium Iodate crystals are adversely affected by moisture and should be kept in dry atmosphere or hermetically sealed in a cell filled with index matching fluid. It has a large birefringence (≈0.15). Large single crystals cut for proper crystal orientation within 10 minutes of arc are available, optically polished and antireflection coated for the fundamental and second harmonic wavelengths. Due to extremely low temperature dispersion of the refractive index, it cannot be noncritically phase-matched (90° phase matching). It can only be angle phase-matched for Type I operation. The wider transmission range makes it a desirable material for optical parametric oscillators (OPO) with tunable outputs from the blue, visible to the intermediate infra-red.

REFERENCES

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TABLE 2: The Non-linear properties of crystals measured at 1064nm Nd:YAG radiation

Parameter / Material	d/d KDP	Phase-Match Angle Degree	Absorption % per cm	Angular Acceptance Width L X Δ Θ cm-mrad	Spectral Acceptance Width L X Δ λ cm-Å (FWHM)	Temp Acceptance Width L XΔ T cm - °c	Walk-Off Angle mrad	Damage Threshold 10 ns pulse Mw/cm²
KDP	1.0	41.0	3.0	1.0	-	3.5	23.0	200
D-KDP*	0.92	53.5	0.5	5.0	55.7	6.7	18.0	500
D-CDA	0.92	82.0	0.5	30.0	22.5	6.0	1.5	500
$LiIO_3$	12.7	29.4	0.8	0.3	-	-	71.0	50
BBO	4.4	22.0	-	1.5	-	55.0	51.0	5000
KTP*	15.0	24.0	1.0	15.0	-	25.0	1.0	400

* These crystals are oriented for Type II phasematching