Data Sheet 705

QUANTUM TECHNOLOGY, INC.

Non-Linear Optical Properties of KTP

Physical Properties of KTP:

Crystal KTP (Potassium Titanyl Phosphate, $KTiOPO_4$) is a non-linear optical (NLO) material, characterized by large NLO coefficient, wide transparency from 350 nm to 4400 nm and moderate damage threshold.

Crystal KTP belongs to an orthorhombic system with point group symmetry of mm2. It is a positive biaxial crystal. It has unit cell dimensions a = 12.814 Å, b = 6.404 Å and c = 10.616 Å. It has a melting point of 1150 °C with partial decomposition, its hardness is 5 on Mohs scale. Its density is 3.03 gms/cm^3 for hydrothermally grown crystal and 2.945 gms/cm^3 for high temperature solution grown material. It has a specific heat of 0.1737 cal/gm°C and thermal conductivity of 0.13 w/cm/°k. At 1064 nm, the absorption loss is less than 1% per cm. It is chemically stable and non-hygroscopic.

Its most popular application is for SHG of CW Acousto-Optically Q switched intracavity operation or for SHG of CW Q switched and modelocked Nd : YAG laser. Recent work indicates that KTP has a great potential as an IR OPO pumped by 1064 nm Nd : YAG laser. Oscillation is obtained around the degenerate wavelength at 2120 nm with a pump threshold of 40 mw / cm^2 in a 30 ns pulse. Broad tuning range and high damage resistance of KTP make OPO an important new source of tunable IR radiation. The properties of KTP make it superior as an electro-optic modulator as well as an optical wave-guide device.

Refractive Indices:

The three principal refractive indices are given by Sellmeier's equations.

$$n^2 = A + \frac{B}{\lambda^2 - C} - D\lambda^2$$

Where λ is expressed in Micrometers.

Parameter	A	B	C	D
n_x	3.0129	0.03807	0.04283	0.01664
n_y	3.0333	0.04106	0.04946	0.01695
n_z	3.3209	0.05305	0.05960	0.01763

Typical Refractive indices for KTP are:

λ Parameter	n_x	n_y	n_z
1064 nm	1.7381	1.7458	1.8302
532 nm	1.7780	1.7887	1.8888

The phase-matching angles for type II
at 1064 nm $\theta = 90°$, $\phi = 21.9°$ to x in xy plane
at 1053 nm $\theta = 90°$, $\phi = 29°$.

NLO Coefficients:

Crystal KTP has five NLO coefficients, namely $d_{31} = 6.5 \times 10^{-12}$ m/v, $d_{32} = 5.0 \times 10^{-12}$ m/v, $d_{33} = 13.7 \times 10^{-12}$ m/v, $d_{24} = 7.6 \times 10^{-12}$ m/v and $d_{15} = 6.1$ m/v.

d_{eff} (Type II) = 7.36×10^{-12} m/v
Angular acceptance = 13 mrad - cm
Temperature acceptance = 20 °C - cm
Spectral bandwidth = 4.5 Å - cm.
Walk-off angle = 1 m rad.
In the xy plane ($\theta = 90°$), d_{eff} (Type II) is given by
$(-d_{15} \sin^2 \phi - d_{24} \cos^2 \phi)$

For SFM of 809 nm and 1064 nm, Crystal KTP will non-critical phase match (NCPM) at room temperature. NCPM SFM of 1319 nm of Nd:YAG and its SHG of 659.5 nm produces 440 nm radiation at temperature around 50 °C. Quantitative results show that there are small differences in birefringence in KTP crystals grown by flux method and hydrothermal method. KTP crystal is also found to be phase matchable for Type II SHG down to 495 nm generation and also for SFM of 1064 nm and dye laser radiation at 810 nm.

Crystal KTP is also attractive for various OPO applications. Besides having large NLO coefficients, KTP possesses low dielectric constants and a high optical damage threshold of 500 mw/cm^2, and fluence damage threshold of 10 J/cm^2. This unique combination of properties make KTP an attractive crystal for the fabrication of optical wave-guide devices, including phase modulators, amplitude modulators and directional couplers.

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SHG of Nd: YAG 1064 nm radiation:

For SHG of CW mode-locked output, 10 W input produces about 1-2 watt of 532 nm radiation with Type II KTP of 5-8 mm length. For SHG of Q switched and mode-locked output 5 mm long KTP crystal produces 30 to 40% efficiency. 10 mm long crystal produces 60% efficiency. For SHG of A-O Q switched at a high repetetion rate of 1 KHz, efficiency of 60% is obtained with a 5 mm length. For CW intracavity operation, crystal damages above 3 watts at 532 nm output. As a comparison, crystal Lithium Iodate gets damaged at 1.5 watts of 532 nm output. Crystal LBO when angle phase-matched produces maximum 532 nm output of 1 watt and when NCPM (90° phase-matched) produces 5 to 6 watt maximum 532 nm output. KTP has an extremely wide acceptance angle and it makes tight focussing possible with excellent long term stability since its temperature half-width is 9 °C.

Under certain conditions, if tighter focussing is used, the peak power density may exceed the damage threshold and photo-refractive damage may take place. This damage may be reduced by operating the crystal at a temperature around 150 °C in a special oven.

KTP with Diode-pumped Nd:YAG laser:

Typical performance is shown below:

1. Intracavity SHG of Diode-pumped Nd:YAG laser.
   Input 200 mW Output 10mW (532 nm)
2. Intracavity SHG of Diode –LNP close-coupled cube. Input 500 mW Output 2.5 mW (523 nm) (LNP Lithium Neodymium Tetraphosphate)
3. Single Pass SHG of Diode Laser
   Input 5 mW Output 3 mW (497 nm)
4. Intracavity SFM of 1064 nm and 809 nm diode-pumped Nd:YAG laser.
   Input 120 mW 50 mW (459 nm)

KTP and KTA (Potassium Titanyl Arsenate) represent two excellent candidates for frequency conversion with SHG or sum-frequency mixing in diode-pumped miniature lasers operated at room temperature. However, direct doubling of diode lasers is ruled out by the phase-matching cut-off at 994 nm for KTP and the slightly shorter cut-off for crystal KTA.

Typical angles for Type II SHG are 22° (1064 nm), 29° (1053 nm), 35° (1047 nm). Crystals of KTP are available in cross-sections up to 10 x 10 mm² and length of 10-12 mms. Crystals with double narrow band anti-reflection coatings are available for high performance systems. Special ovens for operation up to 180 °C are available to reduce photo-refractive damage. Quantum Technology Inc. keeps a complete stock of KD*P, CD*A, KTP, LBO, BBO and $KNbO_3$ crystals.

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