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MODEL ADP TRANSVERSE MODULATORS

DATA SHEET 719

INTRODUCTION

Quantum Technology offers electro-optic laser modulation systems with bandwidths from D.C. to 10, 50, 100MHz as well as special traveling wave type 1000MHz systems. They feature truly broad optical range of 300nm-800nm with 45° X cut ADP crystals or 300nm - 1100nm with 45° Z cut D-KDP crystals or 600nm - 4500nm with 0° Y cut LiTaO₃ crystals (see Data Sheet 720).

Any modulator may be obtained individually to interface with existing hardware. A variety of Automatic Bias Controls (ABC) are offered: Sampled, Continuous or DRAW. These systems eliminate optical bias point drift due to thermal fluctuations. High speed photo diode preamplifiers and linearization of the modulator's transfer function are also available. For more information, please refer to Data Sheet 724.

Quantum's custom-built modern crystal growing laboratory has sixty crystal growing tanks. Quantum Technology grows single crystals of Ammonium Dihydrogen Phosphate (ADP) and other crystal isomorphs, each 60x60x160mm³ and weighing over 1 Kgm.

The optical quality of custom grown crystals depends upon the purity of raw chemicals. Therefore the quality of Quantum's E-O modulators is carefully controlled by selecting the purity of starting materials. Quantum has a complete laboratory designed solely for crystal cutting and fabrication, optical polishing, precision measurement of flatness and parallelism and vacuum deposition systems for evaporative deposition of chrome/gold electrodes.

GENERAL DESCRIPTION

Quantum Technology, Inc. (QTI) offers a wide variety of E-O modulators, using r_{41} constant in ADP or r_{63} constant in D-KDP (KD*P) single crystals. QTI is also the *first* company manufacturing E-O modulator's with full in house facility to grow single crystals of water soluble materials of ADP type and fabricate them into identically matched, well oriented rods within 10 seconds of arc and polished flat within 1/10th of a wave at 632.8nm (HeNe) light. QTI offers a complete family of E-O modulators from DC to 10 MHz, 25 MHz, 50 MHz and 100 MHz for intensity, frequency or phase modulation. QTI also offers traveling wave type modulators with bandwidths from D.C. to 1000 MHz that use LiTaO₃ crystals (see Data Sheet 720).

Models 20, 22, 26 and 28 utilize crystals of ADP (45° X cut). The chemical formula for ADP is NH₄H₂PO₄ and that for D-KDP is KD₂PO₄. It has better transmission at 1064nm and is well suited for short pulse (7ns) application as used in the Model 301 since the pulse width is too narrow to excite any piezo-electric resonances.

45° X CUT TRANSVERSE MODULATOR

Crystal ADP is the most popular material for transverse modulators as it has a large electro-optic constant r_{41} which is about three times the electro-optic constant r_{63} . The electro-optic effect due to piezo-electric strains is negligible (less than a few %) when this orientation is employed. Consequently the electrical bandwidth is flat over the specified range.

The modulator is designed to employ the transverse mode of operation whereby the electric field is applied normal to the direction of propagation of the light beam. The optical propagation direction for amplitude modulation is at an angle 45° to the Y or Z axis while the electric field is applied along the X axis, as shown in Figure 1. Transverse field devices have the following distinct features.



- 1) The half-wave voltage is directly proportional to the aspect ratio (d / L) of the crystals.
- 2) Very good temperature compensation is attained since our crystals are polished together resulting in less than $\lambda/10$ optical path length difference.
- 3) The half-wave voltage can be made low by increasing the length or decreasing the electrode distance. Modulation over broad bandwidths up to 100 MHz or more is attainable at moderate power levels.
- 4) Multi-wavelength operation is possible when a special phase compensator is incorporated to compensate residual natural birefringence.
- 5) Intracavity operation is not possible (high loss).

Orientation of Crystallographic Axes and Electric Fields in a 45 deg X cut Four Crystal ADP Modulator

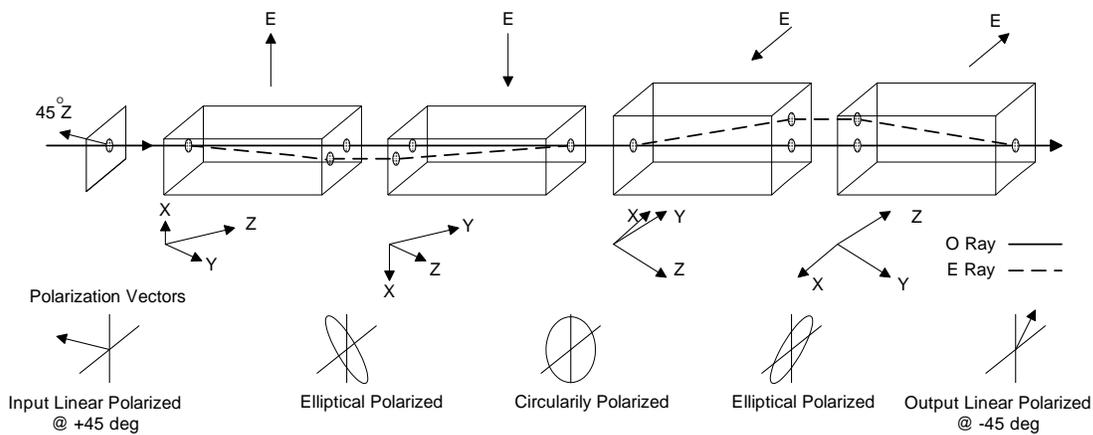


Table 1
Properties of ADP Crystal

Refractive Index at 600nm	dn/dT per $^{\circ}C$	Linear Coeff. of Expansion	E/O Coefficient $m/Volt$	Thermal Conductivity $w/cm^{\circ}K$	Loss Tangent
$n_o = 1.5217$	3×10^{-5}	$\alpha_{33} = 1.7 \times 10^{-6} / ^{\circ}C$	$r_{41} = 24.7 \times 10^{-12}$	$K_{33} = 7.1 \times 10^{-3}$	$\tan s_{33} = 6 \times 10^{-3}$
$n_e = 1.5217$	0	$\alpha_{11} = 35 \times 10^{-6} / ^{\circ}C$	$r_{63} = 8.3 \times 10^{-12}$	$K_{11} = 1.26 \times 10^{-3}$	$\tan s_{11} = 7.3 \times 10^{-3}$

ELECTRO-OPTIC EFFECT

The crystals used in an electro-optic laser modulator exhibit the Pockels effect, i.e. an applied electric field induces a change in birefringence of a useful magnitude.

When a plane polarized beam enters a crystalline medium, it is split into two beams, one polarized in the plane formed by the beam and the optic axis (e ray) and the other polarized in the plane perpendicular to the optic axis and the beam (o ray). The two waves propagate at different indices of refraction n_o and n_e . There is a phase retardation in path length between the two, determined by the index difference. This optical path difference produces a relative phase difference, if the two waves initially have a definite phase relationship. This phase retardation produces a change in net polarization ellipticity as the waves propagate through the modulator. The second pair of crystals is rotated by 90° to compensate for thermally induced birefringence. In phase modulation, the input polarization is in the ZY plane and the second pair of crystals is not rotated 90° as shown.

For amplitude modulation:
$$V_{\pi} = \frac{\lambda (1/n_o^2 + 1/n_e^2)}{2\sqrt{2} r_{41}} \frac{L}{d}$$

For phase modulation:
$$K_p = \frac{\pi n_o^2 r_{41}}{\lambda} \frac{d}{L}$$

Where: V_{π} = half-wave voltage
 n_o = ordinary refractive index
 n_e = extraordinary refractive index
 λ = wavelength (m)
 d = crystal thickness (m)
 L = crystal length (m)
 r_{41} = electro-optic constant (m/V)
 K_p = phase sensitivity (rad/V)

Table 2
Modulator Specifications

Model No.	20	22-100	22-50	22S	327	28
Material	ADP				D-KDP	ADP
Spectral Range nm	300 - 800				300-1100	300-800
$V_{\pi/2}$ @ 633 nm Volts @ 488 nm	115 90					230 180
Phase Sensitivity mrad/Volt @633 nm	27					13
Capacitance pF	180pF	Transmission line 100 ohm	Transmission line 50 ohm	Transmission line 100 ohm		80pF or Transmission line 100 ohm Model 28-100
Useful Aperture mm	2.5					
Transmission @633 nm	>90%					
Frequency Response (-3 dB)	DC-10 MHz	DC-25 MHz	DC-50 MHz	Risetime 2 ns or less	DC-50 MHz	
Connectors	Two BNC	Two Triax for RF One Twinax for Bias	Four Triax for RF One Twinax for Bias	Two SMC for RF One Twinax for Bias	Two Banana Jack or Two BNC	
Used on System	Model 3030C	Model 3030	Model 3050	Model 3100	Pulse Picker	Noise Eater, 3030C or 3030
Dimensions Dia. x L inch	1.97 x 8.90				1.97 x 4.98	

- UV or IR operation available as option. Please add - λ nm after Model No.
- Contrast ratio is 5001:1 @ 633nm, 250:1 @ 514nm and 200:1 @ 488nm as measured with a 1mm beam diameter.
- Large aperture of 3.5mm² is available for all modulators. $V_{\pi/2}$ increases by 33%. Please add-LA after Model No.
- For multiline modulator used for shuttering all Argon laser lines simultaneously. Please add-ML after Model No. Contrast ratio for -ML series is 100:1 typical.
- For Model 28 Banana jack connector is standard. To order BNC connectors please add-BNC after Model No.
- Phase modulator option on all modulators, please add -P after Model No.
- Typical power handling is 3.5W/mm² after which thermal blooming occurs.
- ORDER DESCRIPTION:** Model No. -BNC-ML-P-LA - λ nm. Omit option designations as necessary.

Note that the contrast ratio is dependent on the beam divergence and the beam quality. In general, it degrades with high beam divergence and also with lower wavelength. The spectral response is improved in the UV to 300nm when index matching fluid is changed and BK7 glass windows are replaced with Spectrosil windows. Index matching fluid expansion is offset by pressure relieving, epoxy sealed bellows in all models except Model 28 where an expansion cavity is employed. Bandwidth can be generally improved by lowering the impedance and matching the electrical signal velocity with the optical group velocity within a quarter wave. The half-wave voltage can be decreased to 65 volts at 633nm, for example, by employing eight crystal rods in place of four rods (doubling the total length). However, the contrast ratio degrades due to increased volume imperfections. As there is always some uncompensated natural birefringence, Quantum uses a special compensator to make multi-wavelength operation possible as an option. For other applications, modulators with apertures of 6mm and half-wave voltages of 290 volts, at 633nm, are available. Intracavity operation is not generally possible because of long length and reflection losses.

Transmission line type driving as in Model 22 has the following advantages:

- 1) Elimination of cable's parasitic capacitance,
- 2) Considerable reduction in power requirements.
- 3) Higher bandwidth of at least of 2.5x's for the 100 ohm systems and 5x's for the 50 ohm systems.

Model 28 employs the same configuration as in Model 20. The basic difference in these two models is the crystal interaction length. For Model 28, it is 100mms as compared to 200mms for Model 20. Removable alignment apertures on each end of all models facilitate easy cleaning of the epoxy sealed windows or overall length reduction by 12.5mm.

In order to assure optimum optical transmission, intended operating wavelength should be specified. The standard AR coating is 450nm to 650nm (<0.65% reflectance). Special AR coatings in UV, visible or IR region are available upon request. Low cost and low power (to 1 watt) Model 19HP dielectric polarizer is available as well as high power calcite polarizer Model 19 GLE.

Quantum Technology, Inc. designs and manufactures complete electro-optical modulating systems with options such as Sampled, Continuous or DRAW ABC Assemblies and Transfer Function Linearizer. We can assist you with custom modifications of E-O Systems. Please call our specialists today at **(407) 333-9348**.