

Electro-optic modulators

Operation of electro-optic modulators is based on the principle of induced birefringence. Pockels cell is such device which can produce controllable birefringence by applying voltage to the cell. The cell contains uniaxial crystal, which becomes biaxial when electric field is applied. If new axes induced by the applied electric field are at 45° to the plane of polarization of the incident beam, the incident beam is split into two equal orthogonally polarized components. They propagate in a crystal with different velocities because of induced different refraction indexes. Induced birefringence Δn is proportional to the applied electric field and on the crystal length l it gives controlled phase retardation Γ between these components, which is used for the incident beam modulation:

$$\Gamma = \frac{2\pi}{\lambda} \Delta n l$$

where: λ – wavelength of the optical beam.

Voltage sensitivity of the Pockels cell is given by half-wave voltage ($U_{\lambda/2}$). This is the voltage required for phase retardation Γ of 180°. Often used quarter – wave voltage equals $U_{\lambda/4} = \frac{1}{2} U_{\lambda/2}$ and it is voltage required for $\Gamma = 90^\circ$.

There are only two basic designs of Pockels cells:

1. Pockels cell with longitudinal electro-optic effect, employing a crystal in which electric field is applied along the direction of the optical beam.
2. Pockels cell with transverse electro-optic effect, utilizing a crystal in which electric field is perpendicular to the direction of the optical beam. For this type of modulator the half-wave voltage is inversely proportional to the crystal length and directly proportional to the distance between electrodes.

11.1. KDDP – Pockels cells

KDDP crystal is a very efficient material for Pockels cells used in the visible and near – infrared spectral range. This material is available in extremely large sizes with high optical quality. Its large electro-optic coefficients give the lowest operating voltages of all the [x]DP crystal family. Relatively large dielectric constants also give a high uniformity of electric field distribution across the crystal aperture. KDDP crystals are transparent in the range of 350 nm – 1500 nm and can operate at very high optical power densities. These characteristics make KDDP a basic material for Pockels cells used with very high power laser systems.

In the most commonly used longitudinal field configuration KDDP Pockels cells require the same driving voltages independently of the crystal aperture. Attainable contrast ratios > 1000:1 make KDDP Pockels Cells the most suitable for laser-pulse shortening, shaping and many other applications outside the laser resonator.

Series C100[x] and C2002 Pockels cells are manufactured of high quality z-0° cut KDDP crystals with longitudinal field configuration. The series include single and double crystal designs. To produce longitudinal electric field with high uniformity the gold chromium cylindrical ring electrode system is used. All units are filled with an index-matching liquid to protect KDDP crystals from atmospheric water and to reduce optical losses at the crystal and windows surfaces. When maximum transmission is important AR-coated windows can be supplied on special request.

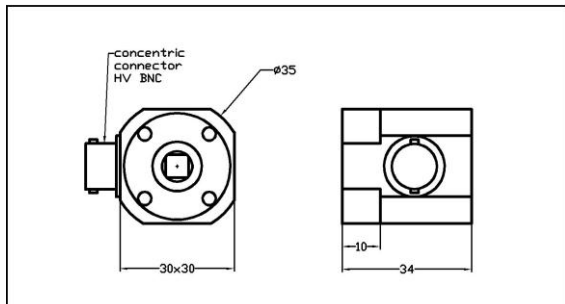
Data of the whole series – KDDP Pockels Cells		
Material	KDDP	
Spectral range	350 – 1500 nm	
Contrast ratio	C 100(x)	1000:1
	C 2002	800:1
Max. power density:	600 MW/cm ²	
Rise time:	< 1 ns	
Min pulse duration:	2 ns	
Wave front distortion:	standard	$\lambda/5$
	on request	$\lambda/10$

Technical specification – KDDP Pockels Cells				
Type	C 1001	C 1002	C 1003	C 2002
Crystal material	KDDP			
Aperture [mm]	8	10 – 12	10	10
Quarter wave voltage [kV]	630 nm	1.9	1.9	1.9
	1064 nm	3.2	3.2	3.2
Max. voltage [kV]	7.5	7.5	7.5	5.0
Capacitance [pF]	10	11	11	12
Connector	concentric		double concentric	concentric
	H.V.BNC			BNC
Cell diameter [mm]	35	35	35	36
Cell length [mm]	35	40	35	53
Max transm. with AR coating [%]	> 98	> 98	> 98	> 97

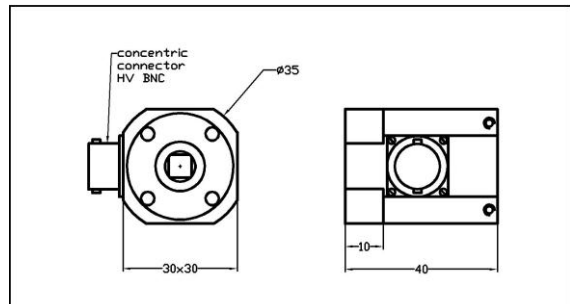
Options:

- Modification of the standard types according to your request
- Integrated Q-switch (fixed connection with polarizer)
- Dry Pockels Cells

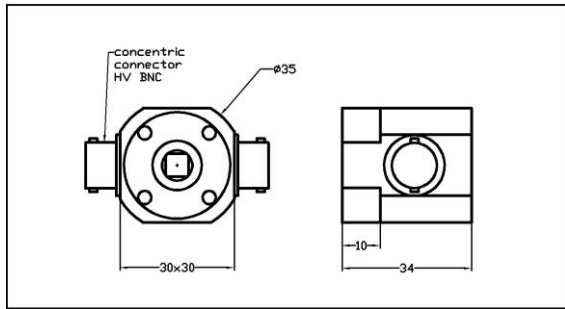
Main dimensions:



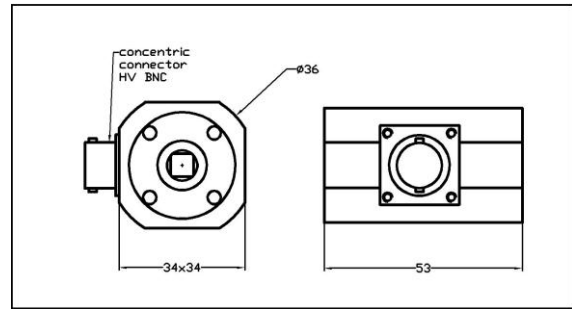
C 1001



C 1002



C 1003



C 2002

11.2. Lithiumniobate Pockels cells

The Lithiumniobate Pockels Cells are used in the laser applications for medicine, industry and research. The Pockels cells are specified for Q-switch applications inside a laser resonator or for modulating of a laser beam outside the resonator.

Lithiumniobate is a very suitable crystal for the use in Pockel Cells because of its special properties. The most important physical characteristics are the large electro-optical coefficient, the transparency in the spectral range from 400 nm up to 4500 nm, and a high melting point of 1250°C. Because of the hardness and insolubility the crystal does not need any additional protection.

The series of C 104[x] Pockels Cells operates in the transverse field mode with a relative low quarter wave voltage. Gold chromium electrodes are applied along two sides of the crystal to provide a uniform electrical field across the aperture. Crystals are oriented and cut in such a way as to provide Z-axis optical propagation.

Because of the high refractive index of LiNbO_3 it is advisable to coat the crystal with an efficient antireflection coating. We offer narrow- and broad-band antireflection coating for the required wavelength. The crystal of the C 1045 and C 1045S is cut at Brewster angle and AR coating is not used. C1045S is constructed for Er: YAG lasers. It is closed by sapphire windows and filled with dry nitrogen. The polarizing effect of Brewster faces eliminates the need of polarizer.

Data of the whole series – LiNbO_3 Pockels Cells		
Material	LiNbO_3	
Spectral range	400 nm – 4500 nm	
Contrast ratio:	200:1	
Transmission with AR coating:	98%	
Max. power density:	200 MW/cm ² , (1 Hz)	
Rise time:	app. 2 ns	
Min pulse duration:	5 ns	
Wave front distortion:	standard	$\lambda/4$
	on request	$\lambda/8$

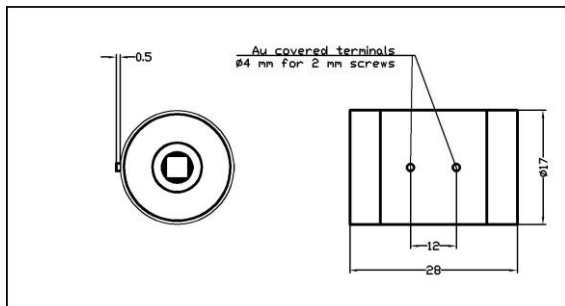
Technical specification – LiNbO₃ Pockels Cells

Type	C 1041	C 1043	C 1044A	C 1044B	C 1045	C 1045S
Crystal material	LiNbO ₃					
Aperture [mm]	4	6	8	8	5	5
Quarter wave voltage [kV]	633 nm	0,350	0,400	0,575	0,575	0,400
	1064 nm	0,700	0,800	1,150	1,150	0,800
	3000 nm					1,650
Max. voltage [kV]	3.0	2.5		5		
Capacitance [pF]	20	25				
Connector	terminals	concentric		2 concentric	concentric	
	M2	HV BNC				
Cell diameter [mm]	17	36	36	24 x 40	24 x 50	35
Cell length [mm]	28	34	35	35	36	44
Crystal surface	Plan / plan				Brewster	

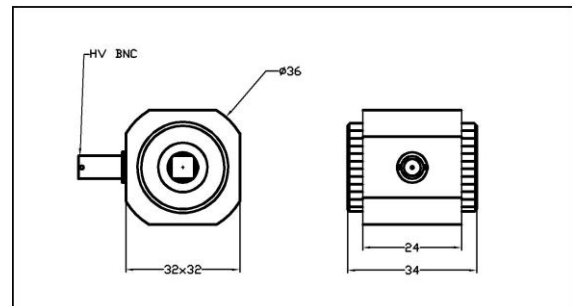
Options:

- Modification of the standard types according to your request
- Integrated Q-switch (fixed connection with polarizer)
- Double crystal version
- Phase modulators

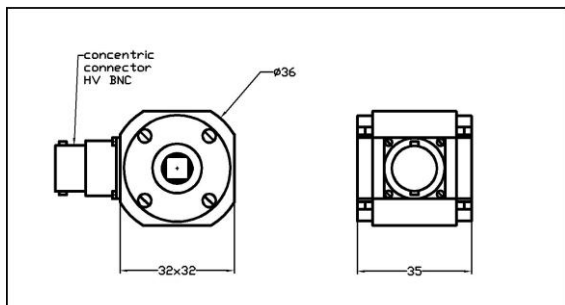
Main dimensions:



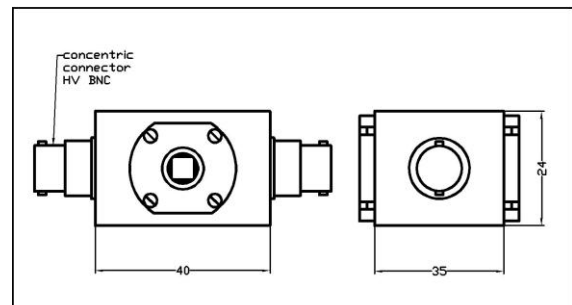
C 1041



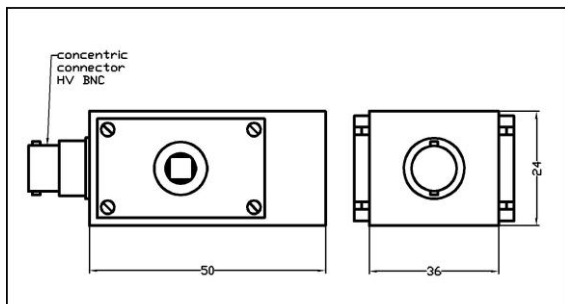
C 1043



C 1044A



C 1044B



C 1045