Introduction Pockels Cells

The Electro-Optic Effect

The linear electro-optic effect, also known as the Pockels effect, describes the variation of the refractive index of an optical medium under the influence of an external electrical field. In this case certain crystals become birefringent in the direction of the optical axis which is isotropic without an applied voltage.

When linearly polarized light propagates along the direction of the optical axis of the crystal, its state of polarization remains unchanged as long as no voltage is applied. When a voltage is applied, the light exits the crystal in a state of polarization which is in generally elliptical.

In this way phase plates can be realized in analogy to conventional polarization optics. Phase plates introduce a phase shift between the ordinary and the extraordinary beam. Unlike conventional optics, the magnitude of the phase shift can be adjusted with an externally applied voltage and a λ/4 or λ/2 retardation can be achieved at a given wavelength. This presupposes that the plane of polarization of the incident light bisects the right angle between the axes which have been electrically induced. In the longitudinal Pockels effect the direction of the light beam is parallel to the direction of the electric field. In the transverse Pockels cell they are perpendicular to each other. The most common application of the Pockels cell is the switching of the quality factor of a laser cavity.

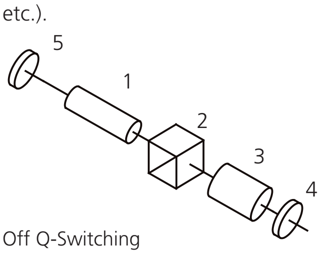
Q-Switching

Laser activity begins when the threshold condition is met. The optical amplification for one round trip in the laser resonator is greater than the losses (output coupling, diffraction, absorption, scattering). The laser continues emitting until either the stored energy is exhausted, or the input from the pump source stops. Only a fraction of the storage capacity is effectively used in the operating mode. If it was possible to block the laser action long enough to store a maximum energy, then this energy could be released in a very short time period.

A method to accomplish this is called Q-switching. The resonator quality, which represents a measure of the losses in the resonator, is kept low until the maximum energy is stored. A rapid increase of the resonator quality then takes the laser high above threshold and the stored energy is released in a very short time. The resonator quality can be controlled as a function of time in a number of ways. In particular, deep modulation of the resonator quality is possible with components that influence the state of polarization of the light. Rotating the polarization plane of linearly polarized light by 90°, the light can be guided out of the laser at a polarizer. The modulation depth, apart from the homogeneity of the 90° rotation, is only determined by the degree of extinction of the polarizer. The linear electro-optical (Pockels) effect plays a predominant role besides the linear magneto-optical (Faraday) and the quadratic electro-optical (Kerr) effect. Typical electro-optic Q-switches operate in a so-called
λ/4 mode.

a) Off Q-Switching

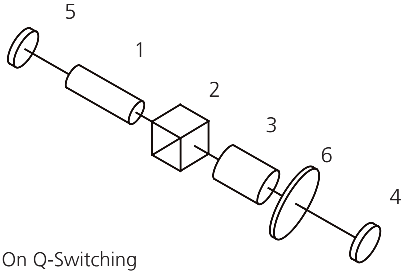
Light emitted by the laser rod (1) is linearly polarized by the polarizer (2). If a λ/4 voltage is applied to the Pockels cell (3) exiting the light is circularly polarized. After reflection from the resonator mirror (4) and a further passage through the Pockels cell, the light is once again polarized, but the plane of polarization has been rotated by 90°. The light is deflected out of the resonator at the polarizer, but the resonator quality is low and the laser does not start oscillating. At the moment the maximum storage capacity of the active medium has been reached, the voltage of the Pockels cell is turned off very rapidly; the resonator quality increases immediately and a very short laser pulse is emitted. The use of a polarizer can be omitted for active materials which show polarization dependent amplification (eg. Nd:$YAlO_3$, Alexandrite, Ruby, etc.).



Off Q-Switching

b) On Q-Switching

Unlike off Q-switching, a λ/4 plate (6) is used between the Pockels cell (3) and the resonator mirror (4). If no voltage is applied to the Pockels cell the laser resonator is blocked: no laser action takes place. A voltage pulse opens the resonator and permits the emission of laser light.



On Q-Switching

Selection Criteria

The selection of the correct Q-switch for a given application is determined by the excitation of the type of laser; the required pulse parameters, the switching voltage, the switching speed of the Pockels cell, the wavelength, polarization state and degree of coherence of the light.

1. Type of Excitation

Basically, both off and on Q-switching are equivalent in physical terms for both cw and for pulse pumped lasers. On Q-switching is, however, recommended in cw operation because a high voltage pulse and not a rapid high voltage switch-off is necessary to generate a laser pulse. This method also extends the lifetime of the cell. Over a long period of time, the continuous application of a high voltage would lead to electrochemical degradation effects in the KD*P crystal. We advise the use of an on Q-switching driver.

Off Q-switching is more advantageous for lasers stimulated with flash lamps because the $\lambda/4$ plate is not required. In order to prevent the electrochemical degradation of the KD*P crystal in the off Q-switching mode we recommend a trigger scheme in which the high voltage is turned off between the flashlamp pulses and turned on to close the laser cavity before the onset of the pump pulse.

The cell CPC3 is recommended for diode pumped solid state lasers. The cell is ultra compact and will operate in a short length resonator: this is necessary to achieve very short laser pulses.

2. Pulse Parameters

The series LMxx, LMxxIM, and LMxxSG cells are recommended for lasers with a power density of up to 500 MW/cm^2.

The LMxx and LMxxSG cells are used for lasers with very high amplification. The SG cells with sol-gel technology have the same transmission as the immersion cells and both are typically used when a higher transmission is required. At high pulse energies LMxx cells are prefered.

Brewster Pockels cells are recommended for lasers with low amplification, such as Alexandrite lasers. The passive resonator losses are minimal due to a high transmission of 99%.

The CPC series cells are suitable for small, compact lasers and especially for OEM applications. They are available as dry cells (CPCxx, CPCxxSG) and immersion cells (CPCxxIM).

The level of deuterium content in an electro-optic crystal influences the spectral position of the infrared edge. The higher the deuterium level the further the absorption edge is shifted into the infrared spectral region: for Nd: YAG at 1064nm, the laser absorption decreases. Crystals, which are deuterated to >98%, are available for lasers with a high repetition rate or a high average output power.

3. Pockels Cell Switching Voltage

Using double Pockels cells can half the switching voltage. This is achieved by switching two crystals electrically in parallel and optically in series. The damage threshold is very high and the cells are mainly used outside the resonator.

4. Pockels Cell Switching Speed

Cells with an impedance of 50Ω are available both as a single and as a double Pockels cell. These cells are used for rapid switching in the sub-nanosecond range, such as coupling laser pulses into regenerative amplifier units. The cells are available with four connectors which permit control of the timing by means of a delay line.

5. Wavelength

The selection of the electro-optic material depends on its transmission range. For wavelengths from 0.25µm to 1.1µm, longitudinal Pokkels cells made of KD*P and a deuterium content of 95% should be considered. If the deuterium content is higher the absorption edge of the material is shifted farther into the infrared. KD*P crystal cells with a deuterium content >98% can be used up to 1.3µm. For wavelengths up to 3µm we recommend $LiNbO_3$ and $LiTaO_3$.

6. State of Polarization

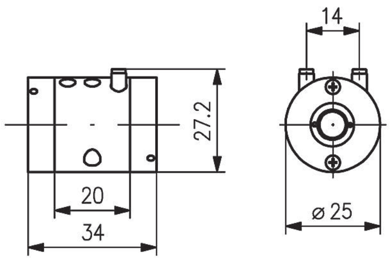
The IQS and CIQS series cells are supplied with an integrated polarizer: the alignment of the Pockels cell relative to the polarizer thus becomes unnecessary. The rotational position of the cell relative to the resonator axis can be chosen at will. However, should the polarization state of the light in the resonator be determined by other components, such as anisotropic amplification of the laser crystal or Brewster surfaces of the laser rod, then the rotational position of the cell will be determined by these factors. Thin film polarizers are used and the substrate is mounted at the Brewster angle. A parallel beam displacement of 1mm results from this configuration and can be compensated for by adjusting the resonator.

7. Degree of Coherence

Longitudinal cells, with very short crystal lengths (a few mm), allow for the modulation of light with a divergence greater than 10 mrad. For this reason we developed the flat Pockels cell FPC22. The aperture is very large: 22.5mm x 22.5mm and the cell can be used for modulation of white light sources.

Standard Pockels Cell RTPC 4 SC

- RTP-based cell
- For Q-switching with high refresh rates
- Two crystals in compensation layout
- Wavefront deformation: < λ/4
- Damage threshold: > 600 MW/cm² at 1064 nm, 10 ns, 1 Hz (typical, not guaranteed)
- Free aperture: 3.6 mm
- Transmission: > 98 %
- Extinction ratio: > 200:1
- λ/4-voltage [1]: 1.3 kV
- Capacity: 3 pF
- Optional with integrated Brewster polarizer: RTPC n BP
- Optional with integrated λ/4 plate: RTPC n WP
- Other specifications, e.g. different aperture or higher clearance ratio on request



1) DC at 1064 nm

Standard Pockels Cell RTPC 4 SC

Order-No	Pockels Cell [2]
84503080021	RTPC 4 SC

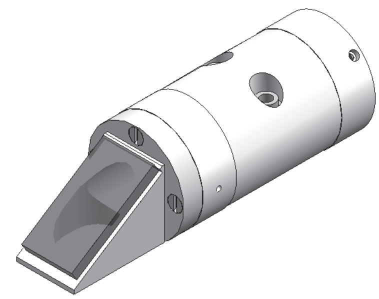
2) Order number valid for 1064 nm, 99 % deuteration

Electro Optics

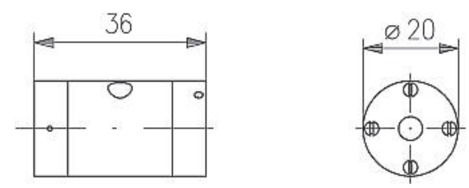
Standard BBO Pockels Cells BBPC Series

- BBO-based Pockels cell
- For Q-switching with high refresh rates
- Wave front deformation: < λ/4
- Damage threshold: > 300 MW/cm² at 1064 nm, 10 ns, 1 Hz (typical, not guaranteed)
- Optional with integrated Brewster polarizer: BBPC n BP
- Optional with integrated λ/4 disk: BBPC n WP
- NEW: Now optional with Piezo attenuator: BBPC n PP
- Other specifications on request

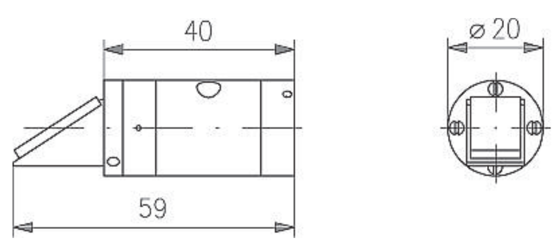
Please state the applied wavelength when ordering.



BBPC



BBPC BP



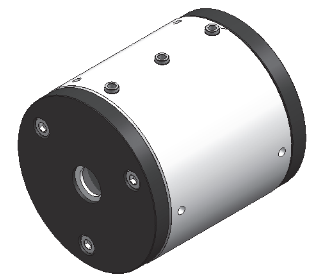
Standard BBO Pockels Cells BBPC Series

Order-No	Pockels Cell 1) 4)	Free aperture	Transmission	Extinction ratio (voltage-free)	λ/4-voltage 2)	Capacity	BP version 3)
84503083012	BBPC 3 (BP)	2.8 mm	>98 % (>95 %)	>1000:1 (>500:1)	3.4 kV	4 pF	-
84503083008	BBPC 4 (BP)	3.6 mm	>98 % (>95 %)	>1000:1 (>500:1)	4.5 kV	4 pF	-
84503083020	BBPC 5 (BP)	4.6 mm	>98 % (>95 %)	>1000:1 (>500:1)	5.7 kV	4 pF	-

1) BP version with integrated Brewster polarizer in brackets ()
2) DC at 1064 nm
3) With missing order number, please state the product name when ordering.
4) Order number valid for 1064 nm

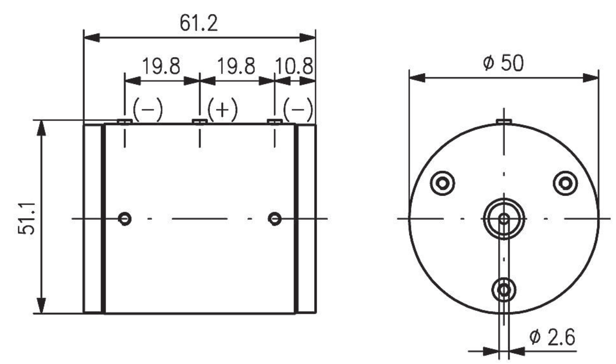
Double BBO Pockels Cell DPC 3

- BBO-based Pockels cell
- Two crystals in series
- Low switching voltage
- Preferred for extra cavity applications
- For pulse pickers at mode locking lasers



- Wave front deformation: < λ/4
- Damage threshold: > 300 MW/cm² at 1064 nm, 10 ns, 1 Hz (typical, not guaranteed)
- Other specifications on request
- Free aperture: 2.6 mm
- Transmission: > 96 %
- Extinction ratio (voltage-free): > 1000:1
- λ/4-voltage[1)]: 1.7 kV (DC at 1064 nm)
- Capacity: 8 pF

▸ *Please state the applied wavelength when ordering.*



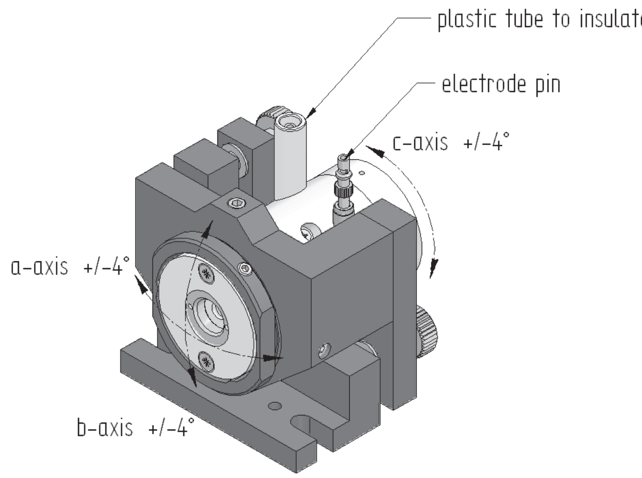
Double Pockels Cell DPC 3

Order-No	Pockels Cell [1)]
84503040000	DPC 3

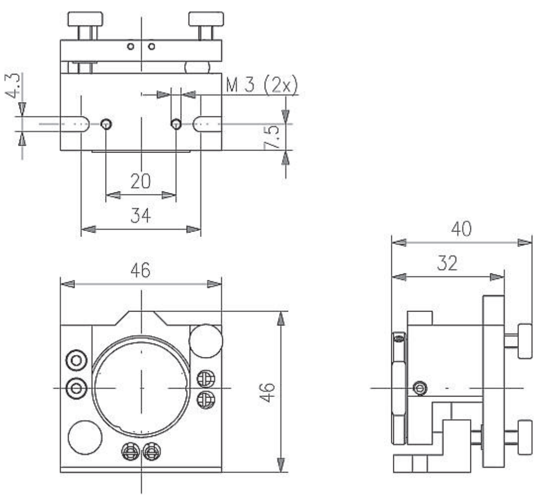
[1)] Order number valid for 1064 nm

Pockels Cells Positioner

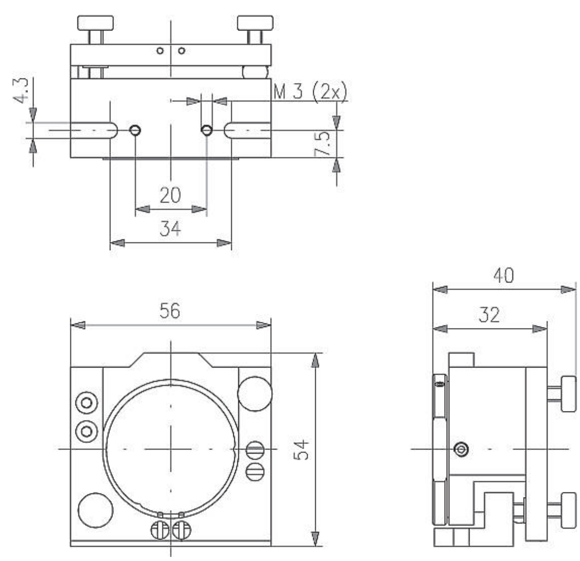
- Compact and stable design
- Easy adjustment of incline, tilt and rotation
- Adjustment via fine thread screws with counternuts
- For Pockels cells with a diameter of up to 35 mm
- Optional, special OEM modifications available



Positioner 25



Positioner 35



Pockels Cells Positioner

Order-No	Pockels Cells Positioner 25	Pockels Cells Positioner 35	Diameter Pockels cell (mm)	Tilt range	Beam height	Weight	Dimensions
84503021127	yes	no	12.7	±4°	24 mm	< 100 g	46 x 46 x 40 mm^3
84503021190	yes	no	19	±4°	24 mm	< 100 g	46 x 46 x 40 mm^3
84503021210	yes	no	21	±4°	24 mm	< 100 g	46 x 46 x 40 mm^3
84503021230	yes	no	23	±4°	24 mm	< 100 g	46 x 46 x 40 mm^3
84503021250	yes	no	25	±4°	24 mm	< 100 g	46 x 46 x 40 mm^3
84503021254	yes	no	25.4	±4°	24 mm	< 100 g	46 x 46 x 40 mm^3
84503021350	no	yes	35	±4°	24 mm	~ 100 g	56 x 54 x 40 mm^3