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 general 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 $\lambda/4$ or $\lambda/2$ 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 were 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 can be 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 \( \lambda/4 \) mode.

1). Off Q-Switching
Light emitted by the laser rod [1] is linearly polarized by the polarizer [2]. If a \( \lambda/4 \) voltage is applied to the Pockels cell [3], then on exit, 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 to oscillate. 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:YalO₃, Alexandrite, Ruby, etc.).

2). On Q-Switching
Unlike off Q-switching, a \( \lambda/4 \) 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.

Pulse Picking
Typically Femto-Second-Lasers emit pulses with a repetition rate of several 10MHz. However many applications like regenerative amplifying require slower repetition rates. Here a Pockels cell can be used as an optical switch: by applying ultra fast and precisely timed \( \lambda/2 \)-voltage pulses on the Pockels cell, the polarization of the laser light can be controlled pulse wise. Thus, combined with a polarizer the Pockels cell works as an optical gate.

Selection Criteria
The selection of the correct Q-switch for a given application is determined by the excitation of the 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.

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 are necessary to generate a laser pulse. This method also extends the life time 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 (DKDP) crystal. So, 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 flash lamp pulses and turned on to close the laser cavity before the onset of the pump pulse.
**Pulse Parameters**

The D-EO-Q series and LN-EO-Q series Q-switches (Pockels cells) are recommended for lasers with a power density of up to 500MW/cm², they are used for lasers with very high amplification.

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 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.

**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.

**Electro Optic Material**

The selection of the electro-optic material depends on its transmission range. Further on the laser parameters and the application as well have to be taken into account.

For wavelengths from 0.25μm to 1.1μm, longitudinal Pockels 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 further into the infrared. KD*P crystal cells with a deuterium content >98% can be used up to 1.3μm.

KD*P can be grown with high optical uniformity and is therefore recommended for large apertures. The spectral window of BBO also a range from 0.25μm to 1.3μm, but besides BBO also provides a low dielectric constant and a high damage threshold. Therefore, BBO is recommended for lasers with high repetition rate and high average powers. RTP, with an optical bandwidth from 0.5μm to 1.5μm combines low switching voltage and high laser induced damage threshold. Together with its relative insensitivity for Piezo effects RTP is best suited for precise switching in high repetition rate lasers with super fast voltage drivers.

For wavelengths from 1.5μm up to 3μm we recommend LiNbO₃.

**Suppression of Piezo Effects**

Like any other insulating material electro optical crystals show Piezo effects when high voltage is applied. The extend of the Piezo ringing depends on the electro optic material and usually its effect on the extinction ratio is negligible when used for Q-switching. However for pulse picking applications, which require highly precise switching behavior, only specially Piezo damped Pockels cells which suppress these ringing effects efficiently.

**State of Polarization**

Some Pockels 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 by adjusting the resonator.

Order Number Introductions
Our standard Q-switches products order number introductions as following:

D-EO-Q-28-33-10-C -> Q-switches Order Number Introductions

Electro-optic Q-switch (EO Q-switch, Pockels Cell)

A Pockels cell alters the polarization state of light passing through it when an applied voltage induces birefringence changes in an electro-optic crystal such as KD*P and BBO. When used in conjunction with polarizers, these cells can function as optical switches, or laser Q-switches. Frequently, Q-switches are employed in laser cavities for the purpose of shortening the output pulse, resulting in a light beam with enhanced peak intensity. In order to provide the device best suited to your purpose, we offer the DKDP (KD*P) series, BBO series and LN (LiNbO3 or MgO:LiNbO3) series Pockels cells.

You can operate the cell with either a pull-up voltage or a pull-down voltage. Changing the polarity will only change the direction of the phase rotation. In other words, the pull-up voltage Q-switch use $\lambda/4$-voltage pulses on the Pockels cell and the pull-down voltage Q-switch use $\lambda/2$-voltage pulses on the Pockels cell, the optical path difference as following Figs. You should not, however, operate the cell with a constant applied voltage potential between the terminals, or a duty cycle greater than ~ 2%.

Pull-down Voltage Q-switch Optical Path
DKDP (KD*P) Series EO Q-switches

The DKDP (KD*P) (D-EO-Q) series sets the standard for electro-optic Q-switches, these devices provide reliable, stable performance for a diverse range of laser applications. We offer a unique design program that extends the D-EO-Q lifetime. All design units are upgraded with the latest product improvements and are returned with a new one-year warranty. The standard configuration employs a broad band, high damage threshold AR coating for improved durability and performance. The D-EO-Q series is also available with index matching fluid and a choice of end caps. All units are tested for optic and electric function and are supplied with a QA inspection report.

Applications
The D-EO-Q series Q-switches are mainly used for following applications:
1). OEM laser systems;
2). Medical/cosmetic lasers;
3). Versatile R&D laser platforms;
4). Military & aerospace laser systems.

Inside Q-switch, DKDP axis arrangement is shown in the following fig., DKDP Z-axis (optical-axis) and X-axis are parallel to the device central line and electrode central line, respectively. So the laser light and its polarization are adjusted accordingly.

Features
1). Industry-proven performance;
2). Dry;
3). Highest (99.8% KD*P) deuteration levels in industry;
4). Adhesive/Epoxy-free assembly;
5). Apertures from 8mm diameter up to 20mm diameter;
6). Lowest absorption in industry;
7). High-reliability;
8). Economical upgrade/rebuild program;
9). Highest optical damage thresholds;
10). Accessible technical support;
11). Standard performance documentation;
12). Operation up to 1kHz;
13). One-year limited warranty.
## Technical Specifications

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Crystal Type</td>
<td>DKDP (KD*P)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outline Dimension</td>
<td>Φ28x33mm</td>
<td>Φ30(32)x40mm</td>
<td>Φ25.4x39mm</td>
</tr>
<tr>
<td>Aperture</td>
<td>Φ8-12 mm optional</td>
<td></td>
<td>Φ10 mm</td>
</tr>
<tr>
<td>Single Pass Optical Transmission</td>
<td>&gt;98%</td>
<td>&gt;98%</td>
<td></td>
</tr>
<tr>
<td>Voltage (V,(\lambda/4)) @1064nm</td>
<td>3.4 KV</td>
<td>3.2 KV</td>
<td></td>
</tr>
<tr>
<td>Extinction Ratio</td>
<td>&gt;1000:1</td>
<td>&gt;1000:1</td>
<td></td>
</tr>
<tr>
<td>Single Pass Insertion Loss</td>
<td>&lt;2%</td>
<td>&lt;2%</td>
<td></td>
</tr>
<tr>
<td>ICR</td>
<td>&gt;2000:1</td>
<td>&gt;2000:1</td>
<td></td>
</tr>
<tr>
<td>VCR</td>
<td>&gt;1500:1</td>
<td>&gt;1500:1</td>
<td></td>
</tr>
<tr>
<td>Transmitted Wave Front Distortion</td>
<td>&lt;(/10)</td>
<td>&lt;(/10)</td>
<td></td>
</tr>
<tr>
<td>Capacitance</td>
<td>≈17pF</td>
<td></td>
<td>≈3pF</td>
</tr>
<tr>
<td>Spectral Range of Operation</td>
<td>240-1400 nm</td>
<td>240-1400 nm</td>
<td></td>
</tr>
<tr>
<td>Damage Threshold</td>
<td>&gt;1GW/cm² (@1064nm,TEM₀₀, 10ns, 10Hz)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Full Range Enterprise Co., Ltd.

EO Q-switches, Pockels Cells

DKDP - KD*P - LiNbO₃ - BBO - RTP

Nd:YAG Laser, 1064nm, 240-1400nm

Tel: +86-29-88173006  Fax:+86-29-88325832  http://www.chinasupply.net/optical/  E-mail:mirafone@163.net
Introduction

It has been well-known that excellent optical quality BBO is one of ideal electro-optic materials for high average power application. On basis of its significant advantages over all of E-O materials in terms of temperature stability, no thermal blooming, no photo-refractive damage and high damage threshold as well as high optical quality (high extinction ratio), BBO Q-switches (Pockels cell) has been used widely in DPL systems with high average power, high repetition and short pulse (ns) compared to A-O Q-switch.

BBO spectra range is 190-3300nm. **B-EO-Q series Q-switch** (Pockels Cell) transmittance is greater than 98% over 300-2000nm, the capacitance is much small, about 2pF, so its switching time is much fast, about <300ps. Intrinsic extinction ratio of high quality BBO is greater than 2000:1 (@632nm), wavefront distortion is $<\lambda/8$ (@632nm).

Temperature stability of B-EO-Q series Q-switch is much high in comparison to KD*P and LiNbO$_3$ series Q-switch, accordingly, there is no thermal blooming inside it.

For BBO Q-switch, there is almost no pizeoelectrical ringing in operation from single shot to repetition rates of more than 300 KHz. Its $\lambda/4$-voltage is proportional to the ratio of width between electrodes to overall crystal length, so the crystal width decrease and its length increase minish the $\lambda/4$-voltage.
BBO crystal is slightly hygroscopic, so BBO Q-switch is of all hermetical structure, its two ends have protective two fused-silica windows coated AR-coating.

Besides its good surface treatment (no naked-eye mechanical scratches on housing surface), the housing of B-EO-Q series Q-switch is of oxidized aluminum, acting as heat-sink, also protecting Q-switch from static damage while its operation safety is considered absolutely.

Matching the housing heat-sink, its core mounting BBO crystal is ceram with properties of HV-resistance and good heat-sink. In its assembly, no encapsulant or cement are used, which makes it sure that there is no pollution in operation of laser system.

In a word, all designs are much scientific and industrial, no POM or PTFE (polymer plastic) is used. It is well known that the utilization of POM and PTFE which is used generally as the housing of Q-switch or modulators, causing a large amount of "migration" of the electrodes over a long time of use.

**Applications**
The **B-EO-Q series** Q-switches are mainly used for following applications:
1). High repetition rate DPSS Q-switch;
2). High repetition rate Regenerative Amplifier control;
3). Cavity Dumping;
4). Beam Chopper.

Inside Q-switch, BBO axis arrangement is shown in the following fig., BBO Z-axis (optical-axis) and Y-axis are parallel to the device central line and electrode central line, respectively. So the laser light and its polarization are adjusted accordingly.

**Features**
1). High repetition rate;
2). High peak power damage resistance;
3). Low absorption
4). UV transmission
5). Low acoustic noise;
6). Transmitted wave front distortion: <\lambda/10 @632nm;
7). Capacitance: \approx2\mu F;
8). Transmittance: >98.5%;
9). Resonance free operation;
10). No thermal blooming;
11). No piezoelectric ringing under 300KHz;
12). No photo-refractive damage;
13). Protective fused-silica AR-coated windows;
14). Oxidized aluminum housing as heat-sink, protecting Q-switch from static;
15). No migration of the electrodes over a long time of use;
16). All hermetical structure;
17). No encapsulant or no cement inside the device.
### Technical Specifications

<table>
<thead>
<tr>
<th>Order No.</th>
<th>B-EO-Q-20-31-X-C</th>
<th>B-EO-Q-30-36-X-C</th>
<th>B-EO-Q-30-60-X-C</th>
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<tbody>
<tr>
<td>Crystal Type</td>
<td>BBO</td>
<td>BBO</td>
<td>BBO</td>
</tr>
<tr>
<td>Outline Dimension</td>
<td>Φ20x31mm</td>
<td>Φ30x36mm</td>
<td>Φ30x60mm</td>
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<tr>
<td>Aperture</td>
<td>Φ2.5-3.9 mm optional</td>
<td>Φ4.0-5.5 mm optional</td>
<td></td>
</tr>
<tr>
<td>Single Pass Optical Transmission</td>
<td>&gt;98%</td>
<td>&gt;98%</td>
<td></td>
</tr>
<tr>
<td>Voltage (V_λ/4) @1064nm</td>
<td>3.4 KV</td>
<td>4.5 KV</td>
<td></td>
</tr>
<tr>
<td>Extinction Ratio</td>
<td>&gt;1000:1</td>
<td>&gt;1000:1</td>
<td></td>
</tr>
<tr>
<td>Single Pass Insertion Loss</td>
<td>&lt;2%</td>
<td>&lt;2%</td>
<td></td>
</tr>
<tr>
<td>ICR</td>
<td>&gt;2000:1</td>
<td>&gt;2000:1</td>
<td></td>
</tr>
<tr>
<td>VCR</td>
<td>&gt;500:1</td>
<td>&gt;500:1</td>
<td></td>
</tr>
<tr>
<td>Transmitted Wave Front Distortion</td>
<td>&lt;λ/10</td>
<td>&lt;λ/10</td>
<td></td>
</tr>
<tr>
<td>Capacitance</td>
<td>≈2pF</td>
<td>≈2pF</td>
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<tr>
<td>Typical Risetime</td>
<td>&lt;300ps</td>
<td>&lt;300ps</td>
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<tr>
<td>Damage Threshold</td>
<td>&gt;850MW/cm² (@1064nm, 10ns); &gt;5GW/cm² (@1064nm, 100ps)</td>
<td></td>
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</tr>
</tbody>
</table>

**Note:** To inquiry or order a B-EO-Q series Q-switch, please specify the **Order No.**, according to **Order Number**. Introductions listed above, for standard products, we only need to know the main specification: applied wavelength, diameter, length, aperture and electrode type. For special request, in order for us to recommend a...
**LiNbO₃ Series EO Q-switches**

With LiNbO₃ and MgO:LiNbO₃ crystals high Electro-Optical Coefficients, non-hygrosopic and working in transverse mode, LiNbO₃ (LN-EO-Q) series Q-switch (Pockels Cell) can be used in low power systems, and could be very compact, suitable for compact systems, and the λ/2-voltage could be very low. By doping MgO in LiNbO₃, the damage threshold of LiNbO₃ Pockels cells has been increased dramatically.

**Features**
1. LiNbO₃-based Q-switch (Pockels cell);
3. For wavelengths up to 3μm;
4. Brewster cells for laser with low amplification;
5. Transmitted Wave Front Distortion: < λ/4;
6. Damage threshold: >100MW/cm² (at 1064nm, 10ns, 1Hz, typical, not guaranteed);
7. MgO doped LiNbO₃ available for high power systems.

**Technical Specifications**

<table>
<thead>
<tr>
<th>Order No.</th>
<th>LN-EO-Q-28-31-X-C</th>
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<tbody>
<tr>
<td>Crystal Type</td>
<td>LiNbO₃</td>
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<td>Outline Dimension</td>
<td>Φ28x31mm</td>
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<tr>
<td>Aperture</td>
<td>7x7x15mm, 9x9x25mm, 10x10x20mm optional</td>
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<tr>
<td>Single Pass Optical Transmission</td>
<td>&gt;98%</td>
</tr>
<tr>
<td>Voltage (V_λ/4) @1064nm</td>
<td>3.0 KV</td>
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<tr>
<td>Extinction Ratio</td>
<td>&gt;450:1</td>
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<tr>
<td>Transmitted Wave Front Distortion</td>
<td>&lt;λ/4</td>
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<td>Spectral Range of Operation</td>
<td>0.85 - 3μm</td>
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<td>Damage Threshold</td>
<td>&gt;100MW/cm² (at 1064nm, TEM₀₀, 10ns, 1Hz)</td>
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</table>

**Note:** To inquiry or order a LN-EO-Q series Q-switch, please specify the **Order No.** according to **Order Number**

Introductions listed above, for standard products, we only need to know the main specification: aperture and electrode type. For special request, in order for us to recommend a best Q-switch to meet your requirements, please download & fill the EO Q-switch Questionnaire Form and send back to us.