AA OPTO-ELECTRONIC proposes the most complete range of Acousto-Optic devices covering wavelengths from 180 nm up to 11 µm including all associated Radio Frequency drivers and power amplifiers.

- Modulators - Pulses pickers
- Polychromatic modulators
- Fixed & variable frequency shifters
- Deflectors - AOTF
- Q-Switches - Cavity Dumpers
- Fiber pigtailed devices
- Power Amplifiers
- Fixed and variable frequency sources
- Custom developments
We create
We manufacture

AA OPTO-ELECTRONIC
Experience our engineering...

AA was founded in 1979, under the name «Automates et Automatismes». It became a limited company in 1988 under the new name of AA Sa, specialising in acousto-optic components and their associated RF drivers. AA is a world leader in the manufacturing of quality Acousto-optic and radio frequency devices. Close collaboration with universities and research institutes, provided invaluable knowledge and experience in the design and manufacturing processes of Acousto-optic devices and radio-frequency sources. Continuous R&D keeps pace with advances in laser and electronic technology to ensure AA continues to offer state-of-the-arts products. AA offers its customers solutions from prototype design to large volume manufacturing thanks to its internal resources and in-house capabilities. Our Headquarter is located in ORSAY, near Paris. This is also our optical manufacturing center. All RF drivers are manufactured in our St Avertin plant, located 200 kms south of Paris.

Concept Validation

AR Coating
Transducer Bonding
Crystal Sawing Polishing
X Ray Orientation

Pre-Serie Production

Acousto-Optic Polychromatic Modulators

Low Side Lobes Versions

The AOTfNc is a special acousto-optic tunable filter which uses the anisotropic interaction inside a tellurium dioxide crystal to control independently or simultaneously different lines from an incoming UV or VIS/IR laser light (White laser, Ar+, Kr+, HeNe, DPSS, Dye...).

Up to 8 distinct lines can be mixed and separately modulated in order to generate different colorimetric patterns.

The specific crystal cut of the AOTfNc produces good diffraction efficiency (>90%), narrow resolution (1-2 nm), a low cross-talk between lines, and high extinction ratio.

The large separation angle between 0 and 1st orders, as well as the excellent output chromatic colinearity (<0.2 to <0.3 mrd) make this AOTfNc a powerful tool for free space or fiber pigtailed applications. Its associated thermal stabilisation maintains stable diffraction efficiency and reduces dramatically beam drift with single mode fiber pigtailing. This is a major advantage for high sensitivity applications.

<table>
<thead>
<tr>
<th>AOTfNc*</th>
<th>VIS</th>
<th>VIS Low Res</th>
<th>Low -VIS</th>
<th>IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of channels / Lines</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Optical wavelength range</td>
<td>450-700 nm</td>
<td>450-700 nm</td>
<td>400-650 nm</td>
<td>700-1100 nm</td>
</tr>
<tr>
<td>Transmission</td>
<td>&gt; 95%</td>
<td>&gt; 95%</td>
<td>&gt; 90%</td>
<td>&gt; 95%</td>
</tr>
<tr>
<td>Input Light polarization</td>
<td>Linear orthogonal</td>
<td>Linear orthogonal</td>
<td>Linear orthogonal</td>
<td>Linear orthogonal</td>
</tr>
<tr>
<td>Output Light polarization</td>
<td>Linear parallel</td>
<td>Linear parallel</td>
<td>Linear parallel</td>
<td>Linear orthogonal</td>
</tr>
<tr>
<td>Active aperture</td>
<td>3 x 3 mm²</td>
<td>3 x 3 mm²</td>
<td>3 x 3 mm²</td>
<td>2.5 x 2.5 mm²</td>
</tr>
<tr>
<td>Spectral resolution (FWHM)</td>
<td>nom 1-2 nm</td>
<td>nom 4-9 nm</td>
<td>nom 1-4 nm</td>
<td>nom 3.5-9 nm</td>
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<tr>
<td>Separation angle (orders 0-1)</td>
<td>&gt; 4 degrees</td>
<td>&gt; 4 degrees</td>
<td>&gt; 4 degrees</td>
<td>&gt; 4 degrees</td>
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<tr>
<td>Chromatic colinearity (order 1)</td>
<td>&lt; 0.2 mrd</td>
<td>&lt; 0.2 mrd</td>
<td>&lt; 0.3 mrd</td>
<td>&lt; 0.1 mrd</td>
</tr>
<tr>
<td>Temperature stabilization</td>
<td>TN</td>
<td>TN</td>
<td>TN</td>
<td>TN</td>
</tr>
<tr>
<td>AD Efficiency</td>
<td>&gt;= 90 %/line</td>
<td>&gt;= 90 %/line</td>
<td>&gt;= 90 %/line</td>
<td>&gt;= 85% /line</td>
</tr>
<tr>
<td>Rise time</td>
<td>1010 ns / mm</td>
<td>1010 ns / mm</td>
<td>1000 ns / mm</td>
<td>1010 ns/mm</td>
</tr>
<tr>
<td>Max accepted RF power</td>
<td>&lt; 1 W all lines</td>
<td>&lt; 1 W all lines</td>
<td>nom 1 W all lines</td>
<td>nom 1 W all lines</td>
</tr>
</tbody>
</table>

LSL versions available on request: Low Side Lobes (<5%, <1%)

**MDSnC - MULTI DIGITAL SYNTHESIZER**

The MDSnC has been specially designed in order to exploit the best of the AOTfNc features. Its compact design with single power supply, low RF emissions and ease of use will satisfy the most demanding of applications, where accuracy and flexibility are key requirements.

Thanks to its complete digital design and integrated microcontroller setting up is fast, simple and repeatable. Access to and adjustments of functions is simple with either a bright LCD display (with remote control adjustment) or through a RS232 serial link (with computer control) or USB communication.

All parameters are stored in an EEPROM and are automatically loaded after each switch on. Each line is externally controlled by a distinct modulation input signal which can be TTL or analog. Additionally, all lines can be simultaneously controlled by a blanking signal which produces smooth effects without modifying the colorimetric balance. The combination of the modulation input and blanking signals provides the best extinction ratio performance (> 100 dB).
Acousto-Optic Modulators and Fixed Frequency Shifters

Acousto-optic modulators are used to vary and control laser beam intensity in first order. The rise time of the modulator is simply deduced by the necessary time for the acoustic wave to travel through the laser beam. For highest speeds the laser beam will be focused down, forming a beam waist as it passes through the modulator.

The first order beam of a modulator is frequency shifted by the amount of the RF carrier frequency: it acts like as fixed frequency shifter.

### Associated RF drivers

<table>
<thead>
<tr>
<th>Model</th>
<th>Material</th>
<th>Wavelength (nm)</th>
<th>Aperture (mm²)</th>
<th>Freq (MHz)</th>
<th>Polar</th>
<th>Rise Time (ns)</th>
<th>Modul BW (MHz, AM)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ200-A1.5-266-6B</td>
<td>Fused silica</td>
<td>244-266</td>
<td>1.5 x 2</td>
<td>200</td>
<td>Linear</td>
<td>60</td>
<td>8</td>
<td>85</td>
</tr>
<tr>
<td>MQ2000-A1.5-266.300</td>
<td>Fused silica</td>
<td>266-300</td>
<td>1.5 x 2</td>
<td>200</td>
<td>Linear</td>
<td>60</td>
<td>8</td>
<td>85</td>
</tr>
<tr>
<td>MQ180-A0.2-266.300</td>
<td>Fused silica</td>
<td>266-300</td>
<td>0.2 x 1</td>
<td>180</td>
<td>Linear</td>
<td>10</td>
<td>48</td>
<td>85</td>
</tr>
<tr>
<td>MQ180-A0.2-UV</td>
<td>Fused silica</td>
<td>325-442</td>
<td>0.2 x 1</td>
<td>180</td>
<td>Linear</td>
<td>10</td>
<td>48</td>
<td>80</td>
</tr>
<tr>
<td>MQ110-A3-UV</td>
<td>Fused silica</td>
<td>325-442</td>
<td>3 x 3</td>
<td>110</td>
<td>Linear</td>
<td>50</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>MQ120-A0.2-UV</td>
<td>Fused silica</td>
<td>325-442</td>
<td>0.2 x 1</td>
<td>240</td>
<td>Linear</td>
<td>6</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>MTG130-A3-400-442</td>
<td>TeO2</td>
<td>400-442</td>
<td>3 x 3</td>
<td>130</td>
<td>Linear</td>
<td>1000</td>
<td>0.4</td>
<td>85</td>
</tr>
<tr>
<td>MQ180-A0.25-V5</td>
<td>Fused silica</td>
<td>440-650</td>
<td>0.25 x 1</td>
<td>180</td>
<td>Linear</td>
<td>10</td>
<td>48</td>
<td>70</td>
</tr>
<tr>
<td>MQ210-A2-V5</td>
<td>Quartz</td>
<td>488-633</td>
<td>2 x 2</td>
<td>110</td>
<td>Linear</td>
<td>50</td>
<td>8</td>
<td>85</td>
</tr>
<tr>
<td>MT550-A0.12-V5</td>
<td>TeO2</td>
<td>450-700</td>
<td>0.12 x 1</td>
<td>350</td>
<td>Linear</td>
<td>5</td>
<td>96</td>
<td>80</td>
</tr>
<tr>
<td>MT250-A0.5-V5</td>
<td>TeO2</td>
<td>450-700</td>
<td>0.5 x 2</td>
<td>250</td>
<td>Linear</td>
<td>6</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>MT200-A0.5-V5</td>
<td>TeO2</td>
<td>450-700</td>
<td>0.5 x 2</td>
<td>200</td>
<td>Linear</td>
<td>8</td>
<td>60</td>
<td>80</td>
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<tr>
<td>MT110-A1-V5</td>
<td>TeO2</td>
<td>450-700</td>
<td>1.5 x 2</td>
<td>110</td>
<td>Linear</td>
<td>50</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>MT80-A1-V5</td>
<td>TeO2</td>
<td>450-700</td>
<td>1.5 x 2</td>
<td>80</td>
<td>Linear</td>
<td>50</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>MT80-A1.5-V5</td>
<td>TeO2</td>
<td>450-700</td>
<td>1.5 x 2</td>
<td>350</td>
<td>Linear</td>
<td>5</td>
<td>96</td>
<td>80</td>
</tr>
<tr>
<td>MT250-A0.5-800</td>
<td>TeO2</td>
<td>700-950</td>
<td>0.2 x 1</td>
<td>350</td>
<td>Linear</td>
<td>5</td>
<td>96</td>
<td>80</td>
</tr>
<tr>
<td>MT250-A0.5-800</td>
<td>TeO2</td>
<td>700-950</td>
<td>0.2 x 1</td>
<td>250</td>
<td>Linear</td>
<td>6</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>MT200-A0.5-800</td>
<td>TeO2</td>
<td>700-950</td>
<td>0.5 x 2</td>
<td>200</td>
<td>Linear</td>
<td>8</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>MT110-A1-IR</td>
<td>TeO2</td>
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<td>1 x 2</td>
<td>110</td>
<td>Linear</td>
<td>50</td>
<td>9</td>
<td>85</td>
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<tr>
<td>MT110-A1.5-IR</td>
<td>TeO2</td>
<td>700-950</td>
<td>1.5 x 2</td>
<td>110</td>
<td>Linear</td>
<td>50</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>MT80-A1-IR</td>
<td>TeO2</td>
<td>700-950</td>
<td>1 x 2</td>
<td>80</td>
<td>Linear</td>
<td>23</td>
<td>21</td>
<td>85</td>
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<tr>
<td>MT80-A1.5-IR</td>
<td>TeO2</td>
<td>700-950</td>
<td>1.5 x 2</td>
<td>80</td>
<td>Linear</td>
<td>50</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>MT200-A0.5-1064</td>
<td>TeO2</td>
<td>980-1100</td>
<td>0.5 x 2</td>
<td>200</td>
<td>Linear</td>
<td>8</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>MT200-A0.2-1064</td>
<td>TeO2</td>
<td>980-1100</td>
<td>0.2 x 1</td>
<td>200</td>
<td>Linear</td>
<td>8</td>
<td>60</td>
<td>80</td>
</tr>
</tbody>
</table>

### Acousto-Optic Modulators

These drivers based on quartz oscillators, produce a fixed RF frequency signal. Drivers can be provided at any frequency from 10 to 3 GHz. All models use crystal controlled oscillators. The RF output can be externally modulated. The settling time varies from 2 ns to 100 ns depending on the fixed frequency and RF power. Usually the driver is coupled internally to a power amplifier; if the output power required is very high then the amplifier will be provided separately, offering RF powers up to 500 W CW.

### Associated RF drivers

<table>
<thead>
<tr>
<th>Model</th>
<th>Material</th>
<th>Wavelength (nm)</th>
<th>Aperture (mm²)</th>
<th>Freq (MHz)</th>
<th>Polar</th>
<th>Rise Time (ns)</th>
<th>Modul BW (MHz, AM)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT110-A1-1064</td>
<td>TeO2</td>
<td>980-1100</td>
<td>1 x 2</td>
<td>110</td>
<td>Linear</td>
<td>15</td>
<td>32</td>
<td>85</td>
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<tr>
<td>MT80-A1-1064</td>
<td>TeO2</td>
<td>980-1100</td>
<td>1 x 2</td>
<td>80</td>
<td>Linear</td>
<td>23</td>
<td>21</td>
<td>85</td>
</tr>
<tr>
<td>MT80-A1.5-1064</td>
<td>TeO2</td>
<td>1000-1100</td>
<td>1.5 x 2</td>
<td>80</td>
<td>Linear</td>
<td>50</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>MT800-A3-1064Ac</td>
<td>TeO2</td>
<td>1030-1080</td>
<td>3 x 3</td>
<td>80</td>
<td>Linear</td>
<td>500</td>
<td>1</td>
<td>85</td>
</tr>
<tr>
<td>MQ80-A0.7-TL001080</td>
<td>SO2</td>
<td>1030-1080</td>
<td>0.7 x 1</td>
<td>80</td>
<td>Linear</td>
<td>120</td>
<td>14</td>
<td>85</td>
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<td>MQ40-A1-L1064-W</td>
<td>SO2</td>
<td>1030-1080</td>
<td>3 x 3</td>
<td>40</td>
<td>Linear</td>
<td>120</td>
<td>4</td>
<td>85</td>
</tr>
<tr>
<td>MQ600-A2.5-1064</td>
<td>SO2</td>
<td>1030-1080</td>
<td>2.5 x 2.5</td>
<td>40</td>
<td>Linear</td>
<td>180</td>
<td>2.5</td>
<td>85</td>
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<tr>
<td>MT800-83101-5-1000-1300</td>
<td>TeO2</td>
<td>1000-1500</td>
<td>1.5 x 2</td>
<td>80</td>
<td>Linear</td>
<td>160</td>
<td>3</td>
<td>80</td>
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<tr>
<td>MG180-A1</td>
<td>Doped Glass</td>
<td>1300-1600</td>
<td>1 x 2</td>
<td>40</td>
<td>Random</td>
<td>50</td>
<td>10</td>
<td>85</td>
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<tr>
<td>MG180-A1</td>
<td>Doped Glass</td>
<td>1300-1600</td>
<td>1.2 x 1</td>
<td>80</td>
<td>Random</td>
<td>50</td>
<td>10</td>
<td>85</td>
</tr>
<tr>
<td>MG110-A1</td>
<td>Doped Glass</td>
<td>1300-1600</td>
<td>1.2 x 1</td>
<td>110</td>
<td>Random</td>
<td>25</td>
<td>20</td>
<td>85</td>
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<tr>
<td>MT800-4-2000</td>
<td>TeO2</td>
<td>1900-2100</td>
<td>0.4 x 1</td>
<td>80</td>
<td>Linear</td>
<td>25</td>
<td>20</td>
<td>85</td>
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<tr>
<td>MG40-A6-9300</td>
<td>germanium</td>
<td>9300</td>
<td>6 x 10</td>
<td>40</td>
<td>Linear</td>
<td>120</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>MG40-A8-9300</td>
<td>germanium</td>
<td>9300</td>
<td>8 x 10</td>
<td>40</td>
<td>Linear</td>
<td>120</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>MG90-A10600</td>
<td>germanium</td>
<td>10600</td>
<td>6 x 10</td>
<td>40</td>
<td>Linear</td>
<td>120</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>MG90-A1-10600</td>
<td>germanium</td>
<td>10600</td>
<td>8 x 10</td>
<td>40</td>
<td>Linear</td>
<td>120</td>
<td>4</td>
<td>75</td>
</tr>
</tbody>
</table>

*Other on request*
A pulse picker is an electrically controlled optical switch used to extract single pulses from a fast pulse train. Short and Ultrashort pulses are in most cases generated by a mode-locked laser in the form of a pulse train with a pulse repetition rate of the order of 10 MHz – few GHz.

For various reasons, it is often necessary to pick certain pulses from such a pulse train, i.e., to transmit only certain pulses and block all the others. This can be done with a pulse picker, which is essentially an electrically controlled optical gate.

**TeO2 General purpose Pulse Pickers**

<table>
<thead>
<tr>
<th>Model</th>
<th>Wavelength (nm)</th>
<th>Aperture (mm x mm)</th>
<th>Polarisation</th>
<th>Beam Diameter (mm)</th>
<th>Rise Time (ns)</th>
<th>Max Repetition Rate with Duty cycle &lt; 1/100 MHz</th>
<th>Separation Angle (0-1) mrad</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT200-A0.5-800</td>
<td>700-950</td>
<td>0.5 x 1</td>
<td>Linear</td>
<td>0.06 - 0.1</td>
<td>10 - 48</td>
<td>3.3 - 0.69</td>
<td>38 @800nm</td>
<td>75 - 85</td>
</tr>
<tr>
<td>MT200-A0.5-1064</td>
<td>980-1100</td>
<td>0.5 x 1</td>
<td>Linear</td>
<td>0.09 - 0.3</td>
<td>15 - 48</td>
<td>2.2 - 0.69</td>
<td>50.6 @1064nm</td>
<td>75 - 85</td>
</tr>
<tr>
<td>MT250-A0.12-800</td>
<td>700-950</td>
<td>0.12 x 1</td>
<td>Linear</td>
<td>0.04 - 0.1</td>
<td>6 - 16</td>
<td>5.5 - 2</td>
<td>47.6 @800nm</td>
<td>70 - 85</td>
</tr>
<tr>
<td>MT250-A0.12-1064</td>
<td>980-1100</td>
<td>0.12 x 1</td>
<td>Linear</td>
<td>0.05 - 0.1</td>
<td>8 - 16</td>
<td>4.1 - 2</td>
<td>63.3 @1064nm</td>
<td>70 - 85</td>
</tr>
</tbody>
</table>

**SiO2 High Damage Threshold Pulse Pickers**

<table>
<thead>
<tr>
<th>Model</th>
<th>Wavelength (nm)</th>
<th>Aperture (mm x mm)</th>
<th>Polarisation</th>
<th>Beam Diameter (mm)</th>
<th>Rise Time (ns)</th>
<th>Max Repetition Rate with Duty cycle &lt; 1/100 MHz</th>
<th>Separation Angle (0-1) mrad</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ80-A0.7-1064</td>
<td>1000-1100</td>
<td>0.7 x 1</td>
<td>Linear</td>
<td>0.3 - 0.5</td>
<td>33 - 55</td>
<td>100 - 60</td>
<td>14.3 @1064nm</td>
<td>75 - 85</td>
</tr>
<tr>
<td>MQ80-A0.3-1064</td>
<td>1000-1100</td>
<td>0.3 x 1</td>
<td>Linear</td>
<td>0.08 - 0.2</td>
<td>15 - 22</td>
<td>370 - 150</td>
<td>26.8 @1064nm</td>
<td>50 - 70</td>
</tr>
</tbody>
</table>

**Fiber Pigtailed Pulse Pickers**

<table>
<thead>
<tr>
<th>Model</th>
<th>Wavelength (nm)</th>
<th>Fibre Type</th>
<th>Carrier Frequency (MHz)</th>
<th>Rise Time (ns)</th>
<th>Max Repetition Rate with Duty cycle (MHz)</th>
<th>Max Laser Power (W)</th>
<th>Losses (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT250-IR6-FIO</td>
<td>1000-1100</td>
<td>PM, SM</td>
<td>250</td>
<td>6</td>
<td>80</td>
<td>0.5</td>
<td>4</td>
</tr>
<tr>
<td>MT200-IR10-FIO</td>
<td>1000-1100</td>
<td>PM, SM</td>
<td>200</td>
<td>10</td>
<td>48</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>MT160-IR10-FIO</td>
<td>1300-1600</td>
<td>PM, SM</td>
<td>160</td>
<td>10</td>
<td>48</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>MT200-NIR10-FIO</td>
<td>780-820</td>
<td>PM, SM</td>
<td>200</td>
<td>10</td>
<td>48</td>
<td>1</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**Pulse Pickers**

These drivers based on quartz oscillators, produce a fixed RF frequency signal. Pulse is controlled thanks to a TTL signal while amplitude is controlled with an analog signal. Standard MODA driver can also be used in combination with pulse pickers.

<table>
<thead>
<tr>
<th>Model</th>
<th>Carrier Frequency (MHz)</th>
<th>Max RF Power (W)</th>
<th>Rise Time (ns)</th>
<th>Controls</th>
<th>Extinction Ratio</th>
<th>Power Supply</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODAXX-2W PPK</td>
<td>160, 200, 250 MHz</td>
<td>2 W / 50 Ω</td>
<td>3 ns</td>
<td>0/5V / 1KΩ for AM TTL/1 KΩ for pulse</td>
<td>60 dB 60 dB on request</td>
<td>24 VDC or 110/230 VAC</td>
<td>A</td>
</tr>
</tbody>
</table>
### Acousto-Optic Deflectors and Variable Frequency Shifters

A Bragg configuration gives a single first order output beam, which intensity is directly linked to the power of RF control signal, and which angle is directly linked to the RF frequency. By varying the frequency, the output laser beam angle is modified. A deflector is used to scan a laser beam over a range of angles, or to control with accuracy the output angle of the laser beam.

By varying the frequency, the first order beam is also frequency shifted by the amount of RF carrier frequency: it acts like a variable frequency shifter.

The main parameters to qualify a deflector are:

1. **Deflection angle range** and
2. **Resolution.** The deflection angle range is the maximum angle variation of the laser beam, and it is linked to the frequency range of the device. The resolution of a deflection is the number of distinct directions which can be addressed by the deflector: it is linked to the deflection angle range and laser divergence.

Two deflectors can be used in series and at right angles to give full two-dimensional scanning.

### High Resolution

<table>
<thead>
<tr>
<th>Material</th>
<th>Wavelength mm</th>
<th>Aperture mm x mm</th>
<th>Freq (Shift) MHz</th>
<th>Polarisation</th>
<th>Resolution TDF</th>
<th>Deflexion angle</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT5X-310</td>
<td>TeO₂</td>
<td>375-1600</td>
<td>4.5 x 4.5</td>
<td>f(x)</td>
<td>Linear</td>
<td>300 x 133mm</td>
<td>48 x 63mm</td>
</tr>
<tr>
<td>DT5X-400</td>
<td>TeO₂</td>
<td>375-1600</td>
<td>7.5 x 7.5</td>
<td>f(x)</td>
<td>Linear</td>
<td>500 x 133mm</td>
<td>48 x 63mm</td>
</tr>
<tr>
<td>DT5XY-250</td>
<td>2 Axis TeO₂</td>
<td>375-1600</td>
<td>4.5 x 4.5</td>
<td>f(x)</td>
<td>Linear</td>
<td>300 x 300 x 63mm</td>
<td>41 x 41 x 32mm</td>
</tr>
<tr>
<td>DT5XY-400</td>
<td>2 Axis TeO₂</td>
<td>375-1600</td>
<td>7.5 x 7.5</td>
<td>f(x)</td>
<td>Linear</td>
<td>500 x 500 x 63mm</td>
<td>41 x 41 x 32mm</td>
</tr>
<tr>
<td>DT230-B120A0.7-UV</td>
<td>TeO₂</td>
<td>400-450</td>
<td>0.5 x 17.5</td>
<td>23 x 60</td>
<td>Linear</td>
<td>500</td>
<td>11.2 x 40mm</td>
</tr>
<tr>
<td>DT230-B120A0.5-VIS</td>
<td>TeO₂</td>
<td>450-670</td>
<td>0.5 x 17.5</td>
<td>23 x 60</td>
<td>Linear</td>
<td>500</td>
<td>15 x 532 mm</td>
</tr>
</tbody>
</table>

### Low Resolution

<table>
<thead>
<tr>
<th>Material</th>
<th>Wavelength mm</th>
<th>Aperture mm x mm</th>
<th>Freq (Shift) MHz</th>
<th>Polarisation</th>
<th>Resolution TDF</th>
<th>Deflexion angle</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MO110-B30A1-UV</td>
<td>Fused Silica</td>
<td>325-425</td>
<td>1 x 2</td>
<td>110 x 15</td>
<td>Linear</td>
<td>10</td>
<td>1.8 x 35mm</td>
</tr>
<tr>
<td>MT200-B30A0.3-400-442</td>
<td>TeO₂</td>
<td>400-442</td>
<td>0.5 x 2</td>
<td>200 x 25</td>
<td>Linear/Random</td>
<td>23</td>
<td>5.4 x 45 mm</td>
</tr>
<tr>
<td>MT200-B100A0.5-VIS</td>
<td>TeO₂</td>
<td>450-700</td>
<td>0.5 x 2</td>
<td>200 x 50</td>
<td>Linear/Random</td>
<td>47</td>
<td>12.6 x 532 mm</td>
</tr>
<tr>
<td>MT110-B50A1.5-VIS</td>
<td>TeO₂</td>
<td>450-700</td>
<td>1.5 x 2</td>
<td>110 x 25</td>
<td>Linear/Random</td>
<td>23</td>
<td>6.3 x 532 mm</td>
</tr>
<tr>
<td>MT80-B50A1-5-VIS</td>
<td>TeO₂</td>
<td>450-700</td>
<td>1.5 x 2</td>
<td>80 x 15</td>
<td>Linear</td>
<td>14</td>
<td>3.8 x 532 mm</td>
</tr>
<tr>
<td>MT200-B100A0.5-800</td>
<td>TeO₂</td>
<td>750-950</td>
<td>0.5 x 2</td>
<td>200 x 50</td>
<td>Linear</td>
<td>47</td>
<td>18.6 x 756 mm</td>
</tr>
<tr>
<td>MT200-B60A1-800</td>
<td>TeO₂</td>
<td>750-950</td>
<td>1 x 2</td>
<td>200 x 20</td>
<td>Linear/Random</td>
<td>19</td>
<td>7.4 x 800 mm</td>
</tr>
<tr>
<td>MT210-B100A0.5-800</td>
<td>TeO₂</td>
<td>750-950</td>
<td>0.5 x 2</td>
<td>250 x 50</td>
<td>Linear</td>
<td>47</td>
<td>19 x 800 mm</td>
</tr>
<tr>
<td>MT200-B100A0.5-800</td>
<td>TeO₂</td>
<td>750-950</td>
<td>0.5 x 2</td>
<td>200 x 50</td>
<td>Linear/Random</td>
<td>47</td>
<td>19 x 800 mm</td>
</tr>
<tr>
<td>MT110-B50A1.5-IR</td>
<td>TeO₂</td>
<td>700-1100</td>
<td>1.5 x 2</td>
<td>110 x 25</td>
<td>Linear/Random</td>
<td>23</td>
<td>9.5 x 800 mm</td>
</tr>
<tr>
<td>MT80-B50A1.5-IR</td>
<td>TeO₂</td>
<td>700-1100</td>
<td>1.5 x 2</td>
<td>80 x 15</td>
<td>Linear/Random</td>
<td>14</td>
<td>5.7 x 800 mm</td>
</tr>
<tr>
<td>MT200-B100A0.5-1064</td>
<td>TeO₂</td>
<td>980-1100</td>
<td>0.4 x 2</td>
<td>200 x 50</td>
<td>Linear/Random</td>
<td>47</td>
<td>25.3 x 1064 mm</td>
</tr>
<tr>
<td>MT110-B50A1.5-1064</td>
<td>TeO₂</td>
<td>960-1100</td>
<td>1.5 x 2</td>
<td>110 x 15</td>
<td>Linear/Random</td>
<td>14</td>
<td>7.6 x 1046 mm</td>
</tr>
<tr>
<td>MB100-B50A1.5-1064</td>
<td>TeO₂</td>
<td>980-1100</td>
<td>1.5 x 2</td>
<td>80 x 15</td>
<td>Linear/Random</td>
<td>14</td>
<td>7.6 x 1046 mm</td>
</tr>
<tr>
<td>MT80-B30A0.7-1300</td>
<td>TeO₂</td>
<td>1300-1600</td>
<td>0.7 x 1</td>
<td>80 x 15</td>
<td>Linear/Random</td>
<td>14</td>
<td>9.3 x 1300 mm</td>
</tr>
</tbody>
</table>

### Variable Frequency RF Drivers

**VCO drivers** (Voltage Controlled Oscillator)

These drivers are suitable for general purpose applications (raster scan, or random access...). The VCO can be modulated (amplitude) from an external signal.

The frequency is externally controlled by an analog signal. An external medium power amplifier will be required to generate the RF power levels required by the AO device.

### RF Power amplifiers

AA's acousto-optic amplifiers are linear with large bandwidth and medium power. The models below cover a variety of bandwidths from 1 MHz to 3 GHz. Output powers up to 80 W are available. Each amplifier is supplied with its heat sink and all are stable and reliable under all conditions. For high power amplifiers, AA proposes models up to 500 W CW.

### Associated RF drivers

**VCO drivers** (Voltage Controlled Oscillator)

These drivers are suitable for general purpose applications (raster scan, or random access...). The VCO can be modulated (amplitude) from an external signal.

The frequency is externally controlled by an analog signal. An external medium power amplifier will be required to generate the RF power levels required by the AO device.

### Variable Frequency RF drivers

**DDSPA-XX**

**Frequency range**

Max. 10-350 MHz (400 MHz on request)

**Frequency control**

15, 23 or 31 bits (1 bit E/D)

**Frequency Step**

15 KHz, 60 Hz, 0.25 Hz

**Modulation Input**

0.5 V / 50 Ohms (8 bits on request)

**Access Time**

60, 64, 80 ns

**Power Supply**

24VDC or 110-230 VAC

**Output RF Power**

Nominal 0 dBm (to be matched with AA power amplifier)

**DRFA10Y-XX**

**Frequency range**

Adapted at factory to AO device Max. 50-110, 60-150, 90-210, 150-300, 200-350 MHz (Other on request)

**Frequency control**

0.10 V / 10 KOhms

**Modulation Input**

0.5 V / 50 Ohms

**Sweeping Time**

< 3 µs

**Power Supply**

24VDC or 110-230 VAC

**Output RF Power**

Nominal 0 dBm (to be matched with AA power amplifier)

**DDSPA-XX**

- On request DRFA10Y 85-135 MHz, sweeping time 150 ns

**DDS drivers** (Direct Digital Synthesizer)

To get a high resolution driver with fast switching time, AA has designed direct digital synthesizers based on monolithic IC circuits. 3 models have already been released, and different units can be designed to specific requirements.

These models offer high frequency accuracy and stability and extremely fast switching times, generally of a few tens of nanoseconds. The DAC circuits have been designed with utmost care to obtain clean RF signals, with minimum spurious noise.

**RF Power amplifiers**

- On request USB Controller for PC, designed to drive 1 or 2 DDSFR through USB port (Windows XP/NT)
Acousto-Optic Fiber Pigtailed
Modulators, Shifters, Pulse Pickers, Q-switches

These fiber pigtailed devices can be used depending on the models as modulators, fixed frequency shifters or Q-switches. Our standard versions are proposed with a single mode fiber with polarization maintaining. However, on request, we can offer different types of fibers or connectors. These devices are dedicated for telecommunication applications, as well as for printing, microscopy, Q-switching or any other application.

Acousto-Optic Q-Switches
Associated RF drivers

AA propose a complete line of Acousto-optic Q-switches and associated RF drivers, for a wide range of applications. They are manufactured from the highest quality materials, with optimized hard coatings for high damage threshold and long-term operation. All AA Q-switches are designed so as to optimize heat dissipation and beam stability with a unique gluing and mechanical technology which reduces stress during operation.

Air-cooled Q-switches: Compact solutions for short cavities or low gain cavities

<table>
<thead>
<tr>
<th>Model</th>
<th>Material</th>
<th>Polarization</th>
<th>Carrier Freq. MHz</th>
<th>Aperture mm x mm</th>
<th>Losses %</th>
<th>Optional Length mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>QCQ40-A1.5-L1064</td>
<td>QUARTZ</td>
<td>Linear</td>
<td>40.68</td>
<td>1.5 x 2</td>
<td>&gt; 80</td>
<td>32</td>
</tr>
<tr>
<td>QCQ80-A1.2-L1064</td>
<td>QUARTZ</td>
<td>Linear</td>
<td>80</td>
<td>1.2 x 2</td>
<td>&gt; 80</td>
<td>32</td>
</tr>
</tbody>
</table>

Q-Switches RF drivers
Reliable and Stable drivers for Industry...

QMODPx [10-20 Watts]
- Frequency: 24, 27, 12, 40.68, 68, 80, 110 MHz
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 20 Watts
- Extinction Ratio: 45 dB nom
- Heat Exchange: Conduction through baseplate + Fan + Heatsink

QMODP2xx [10-20 Watts] Compact
- Frequency: 24, 27, 12, 40.68, 68, 80, 110 MHz
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 20 Watts
- Extinction Ratio: 45 dB nom
- Heat Exchange: Conduction through baseplate

QMODP3xx [120 Watts]
- Frequency: 24, 27, 12, 40.68 MHz Water cooled QST
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 120 Watts
- Extinction Ratio: 45 dB nom
- Heat Exchange: Conduction through baseplate

QMODP2xx [2 x 30 and 2 x 60 Watts]
Dual Outputs driver for dual-Q-switches 2x30 and 2x60 Watts

AA OPTO-ELECTRONIC - www.aaoptoelectronic.com

QMODP1xx [20-70 Watts]
- Frequency: 24, 27, 12, 40.68, 68, 80, 110 MHz
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 26, 35, 50, 70 Watts
- Extinction Ratio: 45 dB nom
- Security Signals: Thermal QST + driver security
- Heat Exchange: Conduction through baseplate

AA OPTO-ELECTRONIC - www.aaoptoelectronic.com

Industrial Compact design

- Pulses pickers 1064 nm, 6 and 10 ns
- Fast AO Modulators
- Frequency Shifters 1064, 1550 nm
- Q-Switches 1064 nm

QMODP0xx [10-20 Watts]
- Frequency: 24, 27, 12, 40.68, 68, 80, 110 MHz
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 20 Watts
- Extinction Ratio: 45 dB nom
- Heat Exchange: Conduction through baseplate + Fan + Heatsink

QMODP0xx [10-20 Watts] Compact
- Frequency: 24, 27, 12, 40.68, 68, 80, 110 MHz
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 20 Watts
- Extinction Ratio: 45 dB nom
- Heat Exchange: Conduction through baseplate

QMODP1xx [20-70 Watts]
- Frequency: 24, 27, 12, 40.68, 68, 80, 110 MHz
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 26, 35, 50, 70 Watts
- Extinction Ratio: 45 dB nom
- Security Signals: Thermal QST + driver security
- Heat Exchange: Conduction through baseplate

QMODP2xx [2 x 30 and 2 x 60 Watts]
Dual Outputs driver for dual-Q-switches 2x30 and 2x60 Watts

AA OPTO-ELECTRONIC - www.aaoptoelectronic.com

QMODP3xx [120 Watts]
- Frequency: 24, 27, 12, 40.68 MHz Water cooled QST
- Power Supply: 15 VDC or 24 VDC, Class A
- Modulation Input Control: TTL + Analog 0-5 V
- Rise/Fall Time: < 20 ns
- Max RF power: 120 Watts
- Extinction Ratio: 45 dB nom
- Heat Exchange: Conduction through baseplate

QMODP2xx [2 x 30 and 2 x 60 Watts]
Dual Outputs driver for dual-Q-switches 2x30 and 2x60 Watts

AA OPTO-ELECTRONIC - www.aaoptoelectronic.com
Acousto-optic Theory
Application Notes

- Modulators - Pulses pickers
- Polychromatic modulators
- Fixed & variable frequency shifters
- Deflectors - AOTF
- Q-Switches - Cavity Dumpers
- Fiber pigtailed devices
- Power Amplifiers
- Fixed and variable frequency sources
- Custom developments
1- AO HISTORY

Brillouin predicted the light diffraction by an acoustic wave being propagated in a medium of interaction, in 1922. In 1932, Debye and Sears, Lucas and Biquard carried out the first experiments to check the phenomena. The particular case of diffraction on the first order, under a certain angle of incidence, (also predicted by Brillouin), has been observed by Rytow in 1935.

Raman and Nath (1937) have designed a general ideal model of interaction taking into account several orders. This model was developed by Pharisseau (1956) for diffraction including only one diffraction order.

At this date, the acousto-optic interaction was only a pleasant laboratory experimentation. The only application was the measurement of constants and acoustic coefficients.

The laser invention has led the development of acousto-optics and its applications, mainly for deflection, modulation and signal processing. Technical progresses in both crystal growth and high frequency piezoelectric transducers have brought valuable benefits to acousto-optic components’ improvements.

2- GLOSSARY

Bragg cell: A device using a bulk acousto-optic interaction (eg. deflectors, modulators, etc..).

Zero angle, 1st order: The zero order is the beam directly transmitted through the cell. The first order is the diffracted beam generated when the laser beam interacts with the acoustic wave.

Bragg angle (θB): The particular angle of incidence (between the incident beam and the acoustic wave) which gives efficient diffraction into a single diffracted order. This angle will depend on the wavelength and the RF frequency.

Separation angle (θ0): The angle between the zero order and the first order.

RF Bandwidth (ΔF): For a given orientation and optical wavelength there is a particular RF frequency which matches the Bragg criteria. However, there will be a range of frequencies for which the situation is still close enough to optimum for diffraction still to be efficient. This RF bandwidth determines, for instance, the scan angle of a deflector or the tuning range of an AOTF.

Maximum deflection angle (θ0max): The angle through which the first order beam will scan when the RF frequency is varied across the full RF bandwidth.

Rise time (tR): Proportional to the time the acoustic wave takes to cross the laser beam and, therefore, the time it takes the beam to respond to a change in the RF signal. The rise time can be reduced by reducing the beam’s width.

Modulation bandwidth (ΔFm): The maximum frequency at which the light beam can be amplitude modulated. It is related to the rise time and can be increased by reducing the diameter of the laser beam.

Efficiency (n): The fraction of the zero order beam which can be diffracted into the "1st" order beam.

Extinction ratio (ER): The ratio between maximum and minimum light intensity in the "1st" order beam, when the acoustic wave is "on" and "off" respectively.

Frequency shift (F): The difference in frequency between the diffracted and incident light beams. This shift is equal to the acoustic frequency and can be a shift up or down depending on orientation.

Resolution (N): The number of resolvable points, which a deflector can generate - corresponding to the maximum number of separate positions of the diffracted light beam - as defined by the Rayleigh criterion.

RF Power (P RF): The electrical power delivered by the driver.

Acoustic power (P): The acoustic power generated in the crystal by the piezoelectric transducer. This will be lower than the RF power as the electro-mechanical conversion ratio is lower than 1.

3- PHYSICAL PRINCIPLES

3-1 Interaction conditions

A parameter called the “quality factor, Q”, determines the interaction regime. Q is given by:

\[ Q = \frac{2\pi\lambda_1 L}{n\Lambda} \]

where \( \lambda_1 \) is the wavelength of the laser beam, \( n \) is the refractive index of the crystal, \( L \) is the distance the laser beam travels through the acoustic wave, and \( \Lambda \) is the acoustic wavelength.

Q<1 : This is the Raman-Nath regime. The laser beam is incident roughly normal to the acoustic beam and there are several diffraction orders (-2 -1 0 1 2 3...) with intensities given by Bessel functions.

Q>1 : This is the Bragg regime. At one particular incidence angle \( \theta_0 \), only one diffraction order is produced - the others are annihilated by destructive interference.

3-2 Wave vectors constructions

An acousto-optic interaction can be described using wave vectors. Momentum conservation gives us:

\[ \vec{K}_d = \vec{K}_i + \pm \vec{K} \]

Where \( \vec{K}_1 \) is the wave vector of the incident beam. \( \vec{K}_d \) is the wave vector of the diffracted beam.

Here F is the frequency of the acoustic wave traveling at velocity \( v \), and \( \Delta \) are the refractive indexes experienced by the incident and diffracted beams. These are not necessarily the same.

Energy conservation leads to: \( F_d = F_i \pm \Delta F \)

So, the optical frequency of the diffracted beam is by an amount equal to the frequency of the acoustic wave. This “Doppler shift” can generally be neglected since \( F<<F_d \) or \( F_i \), but can be of great interest in heterodyning applications.

Acousto-optic components use a range of different materials in a variety of configurations. These can be described as longitudinal- and shear-mode, isotropic and anisotropic. While all these share the basic principles of momentum and energy conservation, these different modes of operation have very different performances - as shall be seen.

3-3 Characteristics of the diffracted light

Isotropic Interactions

An isotropic interaction is also referred to as a longitudinal-mode interaction. In such a situation, the acoustic wave travels longitudinally in the crystal and the incident and diffracted laser beams see the same refractive index. This is a situation of great symmetry and the angle of incidence is found to match the angle of diffraction. There is no change in polarization associated with the interaction. These interactions usually occur in homogeneous crystals, or in birefringent crystals cut appropriately.

In the isotropic situation, the angle of incidence of the light must be equal to the Bragg angle, θB:

\[ \theta_B = \frac{\Delta F}{2v} \]

where \( \lambda = \lambda_1/n \) is the wavelength inside the crystal, \( v \) is the acoustic velocity and \( F \) is the RF frequency.
Acousto-Optic Theory

The separation angle $\theta$ between the first order and zero order beams is twice the angle of incidence and, therefore, twice the Bragg angle.

\[ \theta = \frac{\Delta F}{v} \]

The diffracted light intensity $I_1$ is directly controlled by the acoustic power $P$: \[ I_1 = I_0 \sin^2 \frac{\eta}{2} \] with \[ \eta = \frac{\pi^2}{2\lambda_0^2} M \frac{L}{H} \]

Here $I_0$ is the incident light intensity, $M$ is the acousto-optic figure of merit for the crystal, $H$ and $L$ are the height and length of the acoustic beam, $\lambda_0$ is the wavelength of the incident beam.

Diffraction efficiency (relative) is the ratio $I_1/I_0$:
\[ \frac{I_1}{I_0} = \sin^2 \left( \frac{\pi}{2} \frac{P}{P_t} \right) \] with \[ P_t = \frac{\lambda_0^2}{2M \frac{L}{H}} \]

For a given orientation, if the RF frequency is slightly different from that required to match the Bragg criterion, diffraction will still occur. However, the diffraction efficiency will drop. The situation is shown in the figure below, where the acoustic wave-vector, $K$, is longer than the ideal “Bragg” wave-vector, $K_0$.

A complicated analysis leads to the result:
\[ \Delta \phi = \Delta \lambda L \sin \eta \frac{\Delta \phi}{4} \]

where $\Delta \phi = \Delta K \lambda L$, and is called the “phase asymmetry”.

Anisotropic interaction

In an anisotropic interaction, on the other hand, the refractive indexes of the incident and diffracted beams will be different due to a change in polarization associated with the interaction. This can be seen in the figure below where the acoustic wave vector $K_1$ connects the index curves of the incident and diffracted waves. ($K_2$ simply represents a similar interaction at a very different RF frequency).

The same asymmetry which causes the difference in refractive indexes also causes the acoustic wave to travel in a “shear-mode” and, in the particular example of tellurium dioxide, this results in a drastic reduction in the acoustic velocity.

Anisotropic interactions generally offer an increase in efficiency and in both acoustic and optical bandwidth. They are used almost universally in large aperture devices. The reduction in the acoustic velocity, seen in shear-mode tellurium dioxide, lends this material to be used in high resolution deflectors.

The increased bandwidth available from shear-mode devices can be seen most immediately in the figure below where the interaction configuration is chosen so that the acoustic wave-vector lies tangential to the diffracted beam’s index ellipse.

This means that the length of the acoustic wave-vector can vary quite grossly while only producing small changes in the length of the diffracted beam’s wave-vector. So, in this situation, DK (and, hence, DF) is quite insensitive to changes in RF frequency.

Shear-mode interactions are very much more complex to analyze, requiring detailed information on crystal cut, refractive indexes, orientation. However, these interactions have a lot of advantages and most deflectors and all AOTFs will use shear-mode interactions. The reduced acoustic velocity makes these devices very much slower than longitudinal-mode units and this can be seen as a disadvantage in some circumstances.

5- CONSTITUTION OF A BRAGG CELL

Although acoustic interactions can be observed in liquids, practical devices use crystals or glasses as the interaction medium, with RF frequencies in the MHz to GHz range. A piezo-electric transducer generates the acoustic wave when driven by an RF signal.

The transducer is placed between 2 electrodes. The top electrode determines the active limits of the transducer. The ground electrode is bonded to the crystal.

The transducer thickness is chosen to match the acoustic frequency to be generated. The height of the electrode $H$ depends on the type of application, and must exceed the laser beam diameter. For a deflector, it is selected in order to collimate the acoustic beam inside the crystal during propagation.

The electrode length $L$ is chosen to give the required bandwidth and efficiency. The shape of the electrode can be varied for impedance matching or to “shape” the acoustic wave. An “apodization” of the acoustic signal can be obtained by optimizing the shape of the electrode.

An impedance matching circuit is added to couple the transducer to the driver. Indeed, this circuit is necessary to adapt the Bragg cell to the impedance of the RF source (in general 50 Ohms), to avoid power returned losses. The RF power return loss is characterized with the VSWR of the AO device.

The crystal will generally be AR coated to reduce reflections from the optical surfaces. Alternatively, the faces can be cut to Brewster’s angle for a specific wavelength. A variety of different materials can be used. All have their own advantages and disadvantages.
Modulators

Such a device allows the modulation of the light intensity. The Bragg interaction regime with only one diffracted order is used for these devices.

Rise time:
The rise time ($T_r$) of the modulator is proportional to the acoustic traveling time through the laser beam. The rise time of a fast modulator must be very short:

$$T_r = \frac{\phi}{v}$$

$\phi$: constant depending on laser beam profile
$v$: beam diameter
$\phi$: acoustic velocity

$\phi$ is the only parameter to minimize $T_r$. Consequently, one focuses the incident light beam on the acoustic beam in order to reduce the beam diameter and reduce rise time… $\phi$ is equal to 0.66 in the case of a TEM00 beam.

$$T_r = 0.66 \frac{\phi}{v}$$

(Valid for a TEM00 laser beam, 1/e² dia)

Limitations
To allow the interaction, ($L$) must remain sufficiently large compared with the acoustic wavelength.

The light beam has a divergence which cannot be neglected. To preserve the efficiency of the interaction on all the bandwidth $\Delta \lambda$, it is necessary to reach the Bragg conditions for all the “angles” of the light beam.

For this purpose, the acoustic divergence (DIVA) ($=\pi/L$) where $\lambda$ is the acoustic wavelength and $L$ the dimension of the ultrasonic source) must compensate for light divergence DIVO.

If DIVO>>DIVA: the “asynchronism” is very large for the directions of incidence far away from the Bragg angle, and then the interaction will not occur correctly. The section of the diffracted light beam is then elliptic.

If DIVO<<DIVA: the bandwidth is reduced. An acoustic divergence slightly higher than the light divergence makes it possible to neglect the ellipticity all while maintaining the bandwidth.

Lastly, let us remind that the efficiency of the modulator is related to $\sqrt{P/P_0}$ and that $P_0$ is inversely proportional to $L$. For a maximum acceptable value of $P_0$ by the crystal (which takes account the maximum power that can withstand the crystal), one reaches a limit of the efficiency.

$$T_{\text{rise}} = \frac{\phi}{v}$$

For DIVO<<DIVA: the bandwidth is reduced. An acoustic divergence slightly higher than the light divergence makes it possible to neglect the ellipticity all while maintaining the bandwidth.

Contrast ratio (static and dynamic)
The incident laser beam properties have a significant impact upon modulator performances (temporal response and extinction ratio).

The static contrast ratio measures the ability of the modulator to separate the different diffraction orders (especially 0 and 1st orders).

As a consequence, the lower carrier frequencies and highly focused beams will be a physical limitation of the static extinction ratio. The Gaussian profile (TEM00) gives the best performances and will be considered in the following part. The far field 1st order beam (propagating at angle $(\theta_0)$ is typically separated from the 0 order $(\theta_0)$ with a beam block which is placed such that angles up to 0 are stopped (angles higher than $+2\theta_0$ can also be stopped to suppress higher orders scattering light).

TEM00 static contrast ratio can be written as:

$$C_R = \frac{\int_{0}^{\theta_c} I(\theta)d\theta}{\int_{-\theta_c}^{\theta_c} I(\theta)d\theta}$$

The static CR is physically limited by imperfection of the crystal and scattered light.

The dynamic contrast ratio is the reduction of the CR due to the finite response time of the AOM.

This leads to a reduction of the contrast ratio of ON light intensity to OFF light intensity in dynamic operation. The dynamic contrast ratio is directly related to the modulation bandwidth of the modulator.

Analog Modulation bandwidth
The rise time is a convenient and easy tool to characterize a modulator’s temporal response. However, a more complete characterization can be useful for accurate results. The AOM temporal response is a linear convolution integral which can be analyzed with Fourier transforms to get the Modulation Transfer Function (MTF) of the AOM.

Without giving detailed calculations, the MTF of an acousto-optic modulator in response to a Gaussian input light profile is:

$$MTF(f) = \exp\left(-\frac{f^2}{f_c^2}\right)$$

From which we can deduce the relationship between $f$-3dB and rise time:

$$F_{-3dB} = \frac{0.48}{T_r}$$

An other common measure of frequency response rolloff is the analog modulation bandwidth at –3dB (50% reduction point) which is related to $f_c$ by

$$F_{-3dB} = \frac{\log_{10} 2 f_c}{T_r}$$

The dynamic contrast ratio is directly related to the modulation bandwidth of the modulator.

Applications:
- Laser Printing
- Transmission of a video signal
- Noise eater
- Mode-locker

Specific application:
Multi-beam modulators. Several discrete frequencies (F1,F2,…,Fn) belonging to the bandwidth of the modulator are sent in the modulator. The diffracted beams are ordered separately, in different directions.

A scanning system (for example deflecting) in the perpendicular direction allows, amongst other thing, application, to form characters (printer).
Acousto-Optic Deflectors and Frequency Shifters

Deflectors

This component is used to deflect the light beam. In most applications, a high resolution is requested. For this purpose, one uses large-sized crystals (up to 30 mm or more) in order to work with large beam diameters, decrease optical divergence and increase resolution.

Resolution

Static resolution \( N \)

Static Resolution of an AOD is defined as the number of distinct directions that can have the diffracted beam. The center of two consecutive points will be separated by the laser beam diameter (at \( 1/e^2 \)) in the case of a TEM00 beam.

\[
N = \frac{\Delta \theta}{\text{DIVO}}
\]

\( \Delta \theta \): deflection angle range

\( \text{DIVO} \): laser beam divergence

\[
N = \frac{\pi \Delta F}{4 \nu V}
\]

for a TEM00 laser beam

\( \Delta F \): AO frequency range

\( \nu \): beam diameter (\( 1/e^2 \))

\( V \): acoustic velocity

Access time \( T_a = \frac{\phi}{V} \)

\( T_a \) is called access time of the deflector. It corresponds to the necessary time for the acoustic wave to travel through the laser beam and thus to the necessary time for the deflector to commute from one position to another one. A deflector is often characterized with the time x bandwidth product \( T_a \times \Delta F \).

Dynamic resolution \( N_d \)

When the field of the frequencies does not consist any more of discrete values but of a continuous sweeping, it is necessary to define the dynamic resolution, which takes account of the "gradient" of frequencies.

In the case of a linear frequency sweeping: In \( z=0 \) (at the crystal's entry), the frequency \( F \) is equal to:

\[
F = F_0 + \frac{dF}{dt} t + \frac{F_f}{2}
\]

In \( z \), the frequency is equal to

\[
N_d = N(\frac{F_f}{F_0}) + 1
\]

The angle of deviation \( (\theta) \) is now a function of the distance \( (z) \) and of time \( (t) \).

\[
\theta = -\frac{\lambda}{2 \mu} \frac{dF}{dt} \frac{d}{dz} \left( \frac{F_f}{F_0} \right)
\]

In \( z \) and \( z+dz \), the angle of deviation is not the same one. There is focusing, in only one plan, of the diffracted beam. It is significant to notice this effect of cylinder lens, intervening during sequential sweeping (television with raster scan, printing...).

Equivalent cylindrical focal length:

\[
F_{(c)} = d^2 \frac{V}{\lambda} \frac{F_f}{F_0} \frac{dF}{dt}
\]

\( dF/dt \): frequency modulation slope

\( \lambda \): parameter depending on beam profile (=1 for rectangular shape, about 1.34 for TEM00)

The dynamic resolution translates a consecutive reduction in the number of points resolved for this purpose. It can be written versus static resolution as:

\[
N_d = N(1 - \frac{T_a}{T} + 1)
\]

- \( N_d \): dynamic resolution
- \( N \): static resolution
- \( T_a \): access time
- \( T \): sweeping time from \( F_{min} \) to \( F_{max} \)

Examples:

\[
\begin{align*}
N & \quad T_a \quad T & \quad F_{max} \\
1000 & \quad 10 & \quad 50 & \quad 800 \\
2500 & \quad 50 & \quad 50 & \quad 1
\end{align*}
\]

Efficiency and bandwidth

The bandwidth is limited to an octave to avoid the overlap of orders 1 and 2.

The efficiency curve versus frequency has the following shape for isotropic interaction:

\[
\text{Standardized effectiveness}
\]

Some applications require a quasi-constant efficiency on all the bandwidth. This can be obtained by decreasing width (L) of the ultrasonic beam, but with the detriment of the maximum efficiency. Particular case of anisotropic interaction: the bandwidth of the anisotropic interaction can be increased compared with isotropic interaction.

With specific interaction angles, there can be two synchronous frequencies to match the Bragg conditions, so that the deflection angle range can be broadened with good efficiency.

Frequency Shifters

These components use the modification of frequency of the diffracted light. \((F_d=F_i+F)\) All the applications using optical heterodyning or Doppler effect are using this property.

Note: the frequency shifter is also a modulator as well as a deflector.

Fixed Frequency Shifts

Multiple Travels Frequency Shifts (+/-)

Case of Low frequency Shifts

Examples:

\[
\begin{align*}
\nu & \quad \nu & \quad \nu & \quad \nu \\
F & \quad F_1 & \quad F_2 & \quad F_{max}
\end{align*}
\]

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**Acousto-Optic RF drivers**

**Output RF power**

The output RF power FRF through a 50 Ω load (R) is related to the peak to peak signal amplitude Vpp by the relation:

$$ FRF = \frac{V_{pp}^2}{8R} = \frac{400}{8R} $$

**VSWR (voltage stationary wave ratio)**

This parameter gives an information on the reflected and transmitted RF power to a system. In order to have the best matching between an acousto-optic device and a radio frequency source/amplifier, one will have to optimize both impedance matching on the acousto-optic device and a radio frequency source/amplifier, one will have to optimize both impedance matching on the acousto-optic device and a radio frequency source/amplifier.

<table>
<thead>
<tr>
<th>VSWR</th>
<th>Reflected POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.002 / 1</td>
<td>0.0001 %</td>
</tr>
<tr>
<td>1.068 / 1</td>
<td>0.1 %</td>
</tr>
<tr>
<td>1.15 / 1</td>
<td>0.5 %</td>
</tr>
<tr>
<td>1.22 / 1</td>
<td>1 %</td>
</tr>
<tr>
<td>1.5 / 1</td>
<td>4 %</td>
</tr>
<tr>
<td>2 / 1</td>
<td>11 %</td>
</tr>
<tr>
<td>2.5 / 1</td>
<td>18 %</td>
</tr>
<tr>
<td>3 / 1</td>
<td>25 %</td>
</tr>
</tbody>
</table>

**TTL MODULATION (ON/OFF)**

The TTL modulation input of your driver is compatible with standard TTL signals. It allows the driver to be driven ON and OFF.

- When applying a “0” level (< 0.8 V) on “MOD IN”, no output signal.
- When applying an “1” level (> 2.4 V) on “MOD IN”, maximum output signal level.

It will be noted that a TTL modulation input can be piloted with an analog input signal.

**Amplitude Modulation**

**ANALOG MODULATION (0-Vmax)**

The analog modulation input of your driver controls linearly and continuously the output RF amplitude of the signal from 0 to maximum level.

- When applying 0 V on “MOD IN”, no output signal
- When applying Vmax on “MOD IN”, maximum output signal level

The output RF waveform is a double-sideband amplitude modulation carrier. Vmax can be adjusted at factory from 1 V to 10 V.

**Output RF signal to rise from 10 % to 90 % of the maximum amplitude.**

**EXTINCTION RATIO**

The extinction ratio of your driver specified in the test sheet is the ratio between the maximum output RF level (MOD IN = max value) with the maximum output level (MOD IN = MIN value).

A bad modulation input signal can be responsible for the extinction ratio deterioration.

**FREQUENCY CONTROLS**

**ANALOG CONTROL (0-Vmax)**

The analog frequency control input of your driver controls linearly and continuously the output RF frequency of the signal from Fmin (minimum frequency) to Fmax (maximum frequency).

The minimum and maximum frequencies are set at factory, and can be slightly adjusted with potentiometers “OFF-SET” and “GAIN”.

The typical linearity of the frequency versus input command for standard VCOs is typically +/- 5%.

**Digital 8 bit AMPLITUDE MODULATION**

A byte (8 bit //) controls the amplitude of the output RF signal. A D/A converter converts the 8 bits command (N) on an analog signal which controls linearly the output amplitude.

256 levels are available:
- When N=00000000, no output RF signal
- When N=11111111, maximum output level

**Rise and Fall Time**

The rise time Tr and fall time Tf of your driver specified in your test sheet corresponds to the necessary time for the output RF signal to rise from 10 % to 90 % of the maximum amplitude value, after a leading edge front. This time is linked to carrier frequency and RF technology.

The class A drivers from AA, offer the best rise/fall time performances.

**Sweeping time (VCO)**

This is the maximum necessary time to sweep frequency from minimum to maximum, or maximum to minimum.

This value will be taken as the maximum random access time, though it depends on the frequency step.

When applying 0 V on “FREQ IN”, Frequency = F min
- When applying Vmax on “FREQ IN”, Frequency = F max

(Standard frequency control input : 0-10 V / 1KHz)

**8 BITS FREQUENCY CONTROL (15, 23, 31b)**

A byte (8 bit //) controls the frequency of the output RF signal. A D/A converter converts the 8 bits command (N) on an analog signal which controls linearly the output frequency.

256 steps are available : refer to your test sheet for pin connexions.
- When N=00000000, RF signal frequency = F minimum
- When N=11111111, RF signal frequency = F maximum
Acousto-Optic AOTF - Tunable Filters

One can show that a large angular aperture is possible as long as the tangents at the point of incidence and synchronism are parallel (the light rays are then parallel in the crystal).

A wide length of interaction (L) and an adequate configuration of the wave vectors (synchronism on a small range of K) guarantee obtaining a low bandwidth and thus a low spectral width (Dl).

\[ \lambda = \frac{\Delta(\lambda)}{F} \quad \delta\lambda = \frac{\lambda^2}{L} \]

Dn: birefringence (=|n2-n1|)

a and b are parameters which depend on \( \theta_i \) and \( \theta_a \)

Examples:

- TeO2
- \( \eta \approx \eta_0 \sin^2 \left( \frac{\Delta K L}{2\pi} \right) \)

Confocal Microscopy

Confocal microscopy is an imaging technique used to increase micrograph contrast and/or to reconstruct three-dimensional images by using a spatial pinhole to eliminate out-of-focus light or flare in specimens that are thicker than the focal plane. This technique has been gaining popularity in the scientific and industrial communities. Typical applications include life sciences and semiconductor inspection.

**CONFOCAL LASER SCANNING MICROSCOPY**

Confocal laser scanning microscopy (CLSM or LSCM) is a valuable tool for obtaining high resolution images and 3-D reconstructions. The key feature of confocal microscopy is its ability to produce blur-free images of thick specimens at various depths. Images are taken point-by-point and reconstructed with a computer, rather than projected through an eyepiece. The principle for this special kind of microscopy was developed by Marvin Minsky in 1953, but it took another thirty years and the development of lasers for confocal microscopy to become a standard technique toward the end of the 1980s.

**IMAGE FORMATION**

In a laser scanning confocal microscope a laser beam passes a light source aperture and then is focused by an objective lens into a small (ideally diffraction-limited) focal volume within a fluorescent specimen. A mixture of emitted fluorescent light as well as reflected laser light from the illuminated spot is then recollected by the objective lens. A beam splitter separates the light mixture by allowing only the laser light to pass through and reflecting the fluorescent light into the detection apparatus. After passing a pinhole the fluorescent light is detected by a photo-detection device (photomultiplier tube (PMT) or avalanche photodiode) transforming the light signal into an electrical one which is recorded by a computer.

The detector aperture obstructs the light that is not coming from the focal point, as shown by the dotted grey line in the image. The out-of-focus points are thus suppressed, most of their returning light is blocked by the pinhole. This results in sharper images compared to conventional fluorescence microscopy techniques and permits one to obtain images of various z axis planes (z-stacks) of the sample.

| Applications example |

Confocal microscopy is useful for confocal microscopy to become a standard technique in the scientific and industrial communities. Typical applications include life sciences and semiconductor inspection.

**Application example**

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Pulsed lasers have some advantages versus continuous lasers. In some applications, such as optical communications, pulses convey information. Short pulses are used to achieve very large peak powers. All the emitted energy is compressed into very short pulses, so as to reach very large peak powers. Some applications rely on optical pulses to take snap-shots of very rapidly occurring processes, such as fast chemical reactions, or electronic processes in semiconductors. Lasers can produce flashes of light that are many orders of magnitude shorter and brighter than ordinary flashlight. In some circumstances, it is the laser excitation mechanism itself that restricts the laser to pulsed mode operation, to reduce unwanted thermal load on the laser.

A simple way to generate pulsed output is to put an optical switch (AO modulator for instance) at the output of a continuous wave laser (CW). By turning on and off, user can get pulses of light. For some applications, this is not efficient and this is preferable to use a switch (Q-Switch) inside the laser cavity. This has at least two advantages: When the switch is closed, the laser cannot operate. This means the pump energy is not lost but stored in the active material in the form of excited atoms, or in the cavity in the form of light. When the switch is abruptly opened all the stored energy may be regained in a short pulse, generating peak powers that are many times higher than the average (CW) power.

**Q-Switching**

The Q or Quality factor of a laser cavity describes the ability of the cavity to store light energy in the form of standing waves. The Q factor is the ratio of energy contained in the cavity divided by the energy lost during each round trip in the cavity:

\[ Q = \frac{2\pi}{\text{Energy stored in the cavity}} \]

\[ \text{Energy lost in a cycle} \]

This means that a cavity with high losses dissipates a lot of energy per cycle hence it has a low Q value. A high Q cavity means the energy loss per cycle is small in the given cavity.

By inserting a device in the cavity which is capable of controlling the loss of a cavity, we are effectively controlling the Q of the cavity. This device acts as an optical shutter or switch inside the cavity, which, when closed, absorbs or scatters the light, resulting in a lossy, low Q cavity. When the shutter is open, the cavity becomes low loss, high Q. This switch is called a Q-SWITCH.

**Acousto-optic Q-Switches**

A Q-switch is a special modulator which introduces high repetition rate losses inside a laser cavity (typ 1 to 100 kHz). They are designed for minimum insertion loss and to be able to withstand very high laser powers. In normal use an RF signal is applied to disflect a portion of the laser cavity flux out of the cavity. This increases the cavity losses and prevents from oscillation. When the RF signal is switched off, the cavity losses decrease rapidly and an intense laser pulse evolves.

It is essential in Q-switching to correlate the timing sequence of the optical pumping mechanism with the Q-switching. This means the following: Assume that at the time when the laser pumping is turned on, the Q of the cavity is low. The high loss prevents laser action occurring so the energy from the pumping source is deposited in the upper laser level of the medium. At the instant, when the population inversion is at its highest level, the switch is suddenly open to reduce the cavity loss.

Because of the very large built up population difference, laser oscillations will quickly start and the stored energy is emitted in a single giant pulse.

The lasing stops because the pulse quickly depletes the upper laser level to such an extent that the gain is reduced to below threshold.

This operation is periodically repeated in order to obtain the operating regime.

The associated RF driver in combination with the convenient Q-switch is a key component for a Q-switching application. This one must be a class A driver with the fastest fall time in order to get an optimum falling slope of the cavity losses and to get the shortest and highest energy in each pulse. A synchronore driver can be essential for some applications where synchronism pulse to pulse is critical. Phase locked drivers are also available in case of use of multi Q-switches in the same cavity.

The triggered signals or control signals of the driver may be chosen to have the opportunity to shape the Q-switch losses in time and perform the Q-switching effect safely and efficiently. The thermal security interlock is essential to protect the Q-switch from overheating and to improve its lifetime. Other securities such as VSWR control or disconnection protection can facilitate the task of the user and make the use of the system more safe.

Depending on space and available resources, the choice of the driver will oriented towards an air, conduction through baseplate or water cooling driver, an OEM compact version or a 110/230 VAC version.

**Q-Switching Diagram**

![Q-Switching Diagram](image)

**AA Drivers - Methods of control**

**Basic Pulse control (DPC input)**

For all AA drivers, the Laser pulses are triggered by a TTL signal (Digital Pulse Control).

This input allows to control the Q-switch with two states:
- No losses (TTL=0): No RF power applied on Q-switch = Laser pulse can evolve
- Full Losses (TTL=1): Full RF Power applied on Q-switch = Laser Cavity Blocked

**Analog Power control (FAC input)**

AA provides a supplementary analog input in order to control the RF power level in this input is between 0 and 5V (Typ 0-5Vols) – it means, that if it is not connected, then signal is ramped to 0, then output power is disabled. The analog FAC signal controls linearly the RF amplitude of the output signal.

Note that the analog power control is combined with TTL pulse control (DPC) as follows:
- Output RF power = (TTL (DPC) × Analog (FAC)) / 0.8
- If TTL (DPC) = 0, Output RF Power = 0 whatever is FAC input (0 or 5 V)
- If TTL (DPC) = 1, Output RF Power = FAC / 0.5 Maximum if FAC = 5V, Xx versus FAC input

**Pulse Analog Control (PAC / RF OFF Analog Control)**

The PAC input is an alternative analog input, which controls the RF OFF level of the driver.

This input (analog 0-5V typ) is pulled up. It means that when it is not connected, the signal ramped up to 5 Volts, and the driver can operate normally.

The analog PAC signal controls linearly the RF OFF amplitude of the output signal. It controls the threshold of leakage. Note that the PAC Amplitude control is combined with TTL pulse control (DPC) as follows:
- RF POWER OUTPUT = (TTL (DPC) × Analog (PAC)) / 0.8
- If TTL (DPC) = 0, Output RF Power = 0 if PAC=0V
- Maximum if PAC = 5V, Xx versus PAC input
- If TTL (DPC) = 1, Output RF Power = PAC / 0.5 whatever is PAC input (0 or 5V)