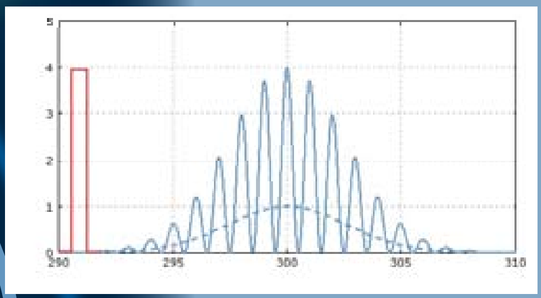
OPTO-ELECTRONIC

# PULSE PICKING

## Acousto-optic products



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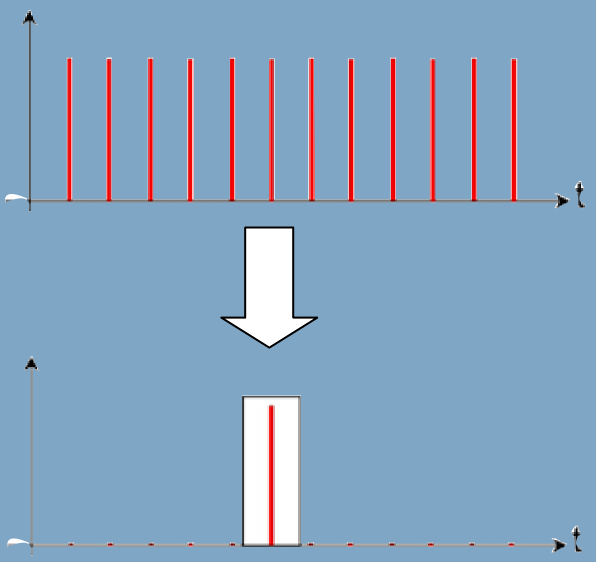
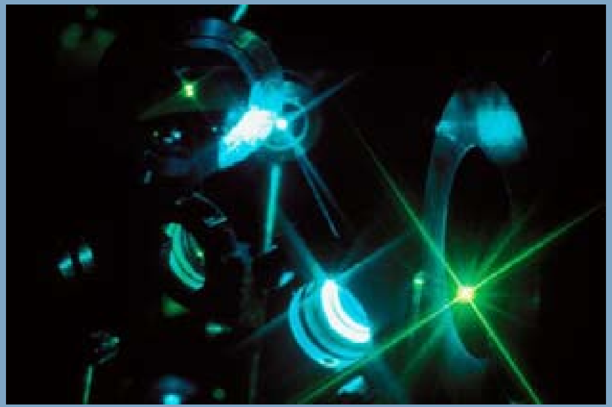
# Introduction
# Pulse Picking

A pulse picker is an electrically controlled optical switche used for extracting single pulses from a fast pulse train.



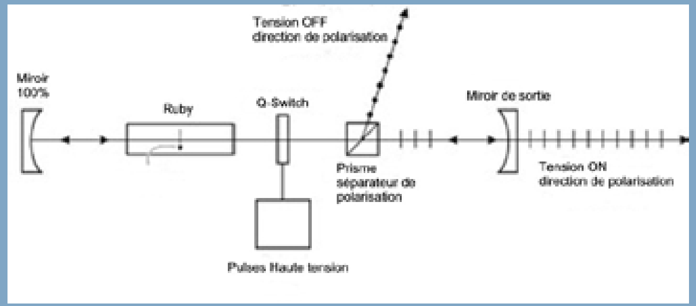
Short and Ultrashort pulses are in most cases generated by a mode-locked laser in the form of a pulse train with a pulse repetition rate of the order of 10 MHz – few GHz.
For various reasons, it is often necessary to pick certain pulses from such a pulse train, i.e., to transmit only certain pulses and block all the others. This can be done with a pulse picker, which is essentially an electrically controlled optical gate.



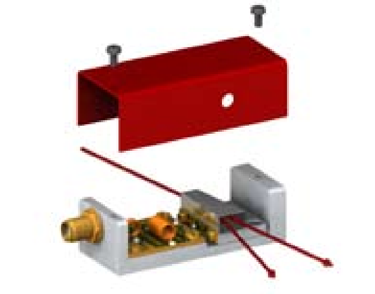
## Types of Pulse Pickers

A pulse picker is in most cases either an electro-optic modulator either an acousto-optic modulator, combined with a suitable fast electronic driver.

**EOM:** In the case of an electro-optic device, a pulse picker consists of a Pockels cell and some polarizing optics, the Pockels cell manipulates the polarization state, and the polarizer then transmits or blocks the pulse depending on its polarization.



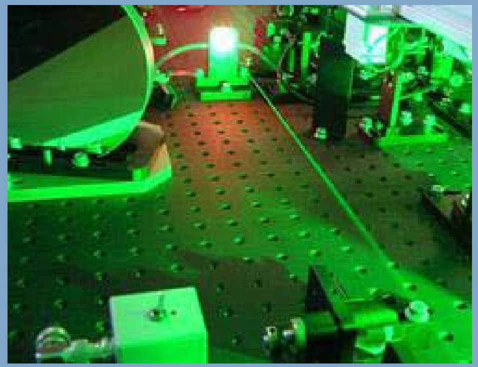
**AOM:** The principle of an acousto-optic pulse picker is to apply a short RF pulse to the acousto-optic modulator so as to deflect the wanted pulse into a slightly modified direction. The deflected pulses can then pass an aperture, whereas the others are blocked.
In any case, the required speed of the modulator is determined by the temporal distance of pulses in the pulse train (i.e. by the pulse repetition rate of the pulse source), rather than by the pulse duration.



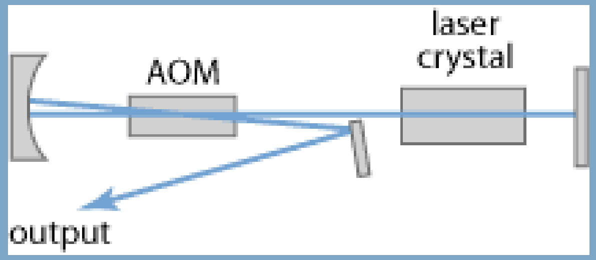
*The EOM is a fast solution but generally does not offer high repetition rates due to the high voltage driver which cannot be switchable at high repetition rate. In this case, despite the AOM is slower, it will be preferred offering repetition rates over MHz.*

## Applications of Pulse Pickers

Some typical applications of a pulse picker are described in the following:

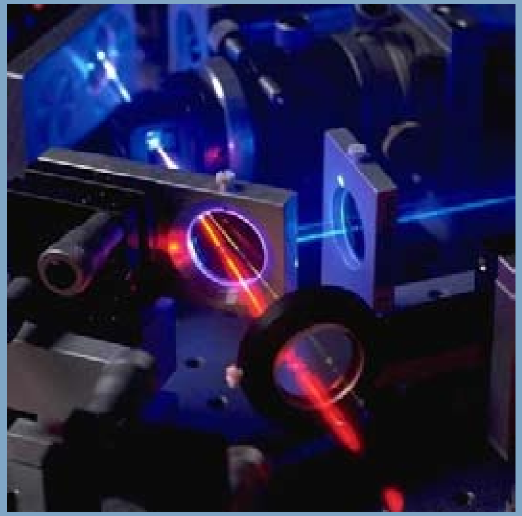


- To obtain high pulse energies in ultrashort pulses, it is frequently necessary to reduce the pulse repetition rate. This can be achieved by placing a pulse picker between the seed laser and the amplifier. The amplifier will then act only on the wanted pulses. The blocked pulses do not necessarily constitute a strong energy loss since the average power of the seed laser may be small compared with the average output power of the amplifier, and the remaining average power can be sufficient for saturating the amplifier.



- In a cavity-dumped laser, a pulse picker (then often called cavity dumper) extracts the circulating pulse from the cavity in only every Nth round trip. During all the other round trips, the pulse experiences low optical losses and can be amplified to a high energy.

- A pulse picker can be used for injection and extraction of pulses in a regenerative amplifier. (See AO fiber pulse picker)



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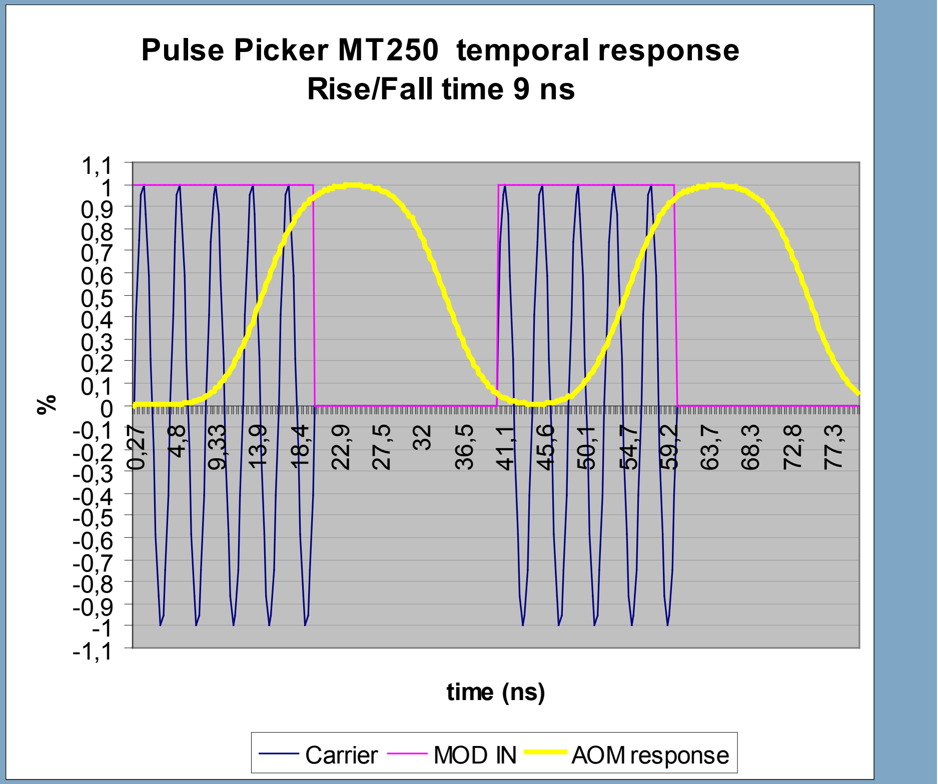
# How to choose an AO Pulse Picker?

**Depending on the application, different properties of a pulse picker can be critical:**

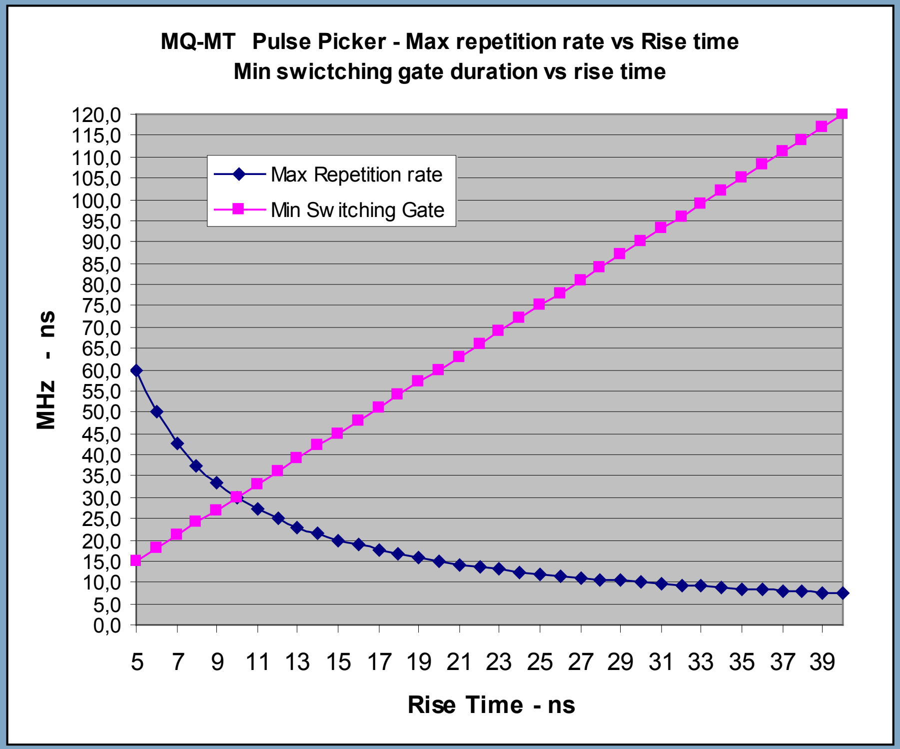
- **The switching time** (particularly for high input pulse repetition rates) or Rise/Fall time

For an AO pulse picker, the rise/fall time is linked to the laser beam diameter inside the AOM.
We define this time for the AO to reach efficiency from 10 to 90% in first order. For fast rise/fall times, the beam will be focussed inside AOM downto few 10s of micrometers.



- **The maximum repetition rate for the switching**

For an AOM, this time is directly linked to rise/fall time of the AOM.
Nevertheless, the average RF power inside AOM will be another limit so as to not get thermal effects, or simply to avoid water cooling.



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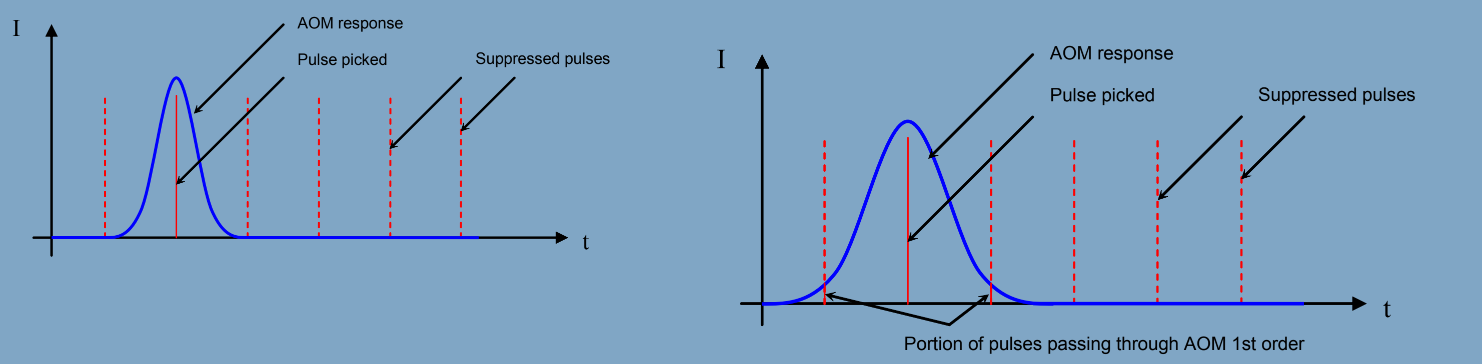
- **The energy loss of transmitted pulses**
It is directly linked to diffraction efficiency of AO device, or what is called losses in case of a fiber coupled device. For most AO pulse pickers, it can reach 75 to 90%.

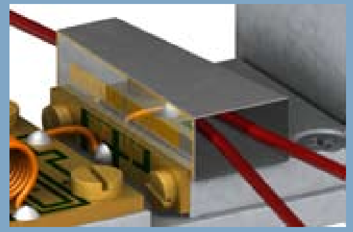
- **The degree of suppression of unwanted pulses**
It is related to the extinction ratio of the AOM and associated RF driver. Most of the time the main problem is linked to dynamic extinction ratio. For instance, the fall time of the AOM is not fast enough so that a portion of the next (or previous) pulse is also passing through AOM first order.



- **The optical bandwidth (particularly for broadband pulses fs)**
The output first order angle is proportional to the wavelength. In case the linewidth of the incoming beam is brroaden because of an ultra-short pulse then it can lead to a broadening of output first order angle. In an other hand, the transmission of the AOM can be affected because of a mismatch with transmission curve of the AOM AR coating.

- **The chromatic dispersion (particularly for broadband pulses, with durations <<100 fs)**
The optical velocity inside the interaction medium is different for each wavelength. Broader will be the input spectrum, higher will be the chromatic dispertion of the pulse. This effect will be more sensitive in TeO2 (High refractive index) than in fused silica.

- **The size of the active aperture**
This is the area where the acousto-optic effect can occur. The laser beam must be completely inside this area in order to get maximum performances. This aperture will also be linked to requested rise time.



- **The outer dimensions/cooling**
Because generally the duty cycle of the pulse picker is low (<<1% ON), then the average RF power inside AOM is low and consequently we can have a high efficiency, air cooled pulse picker either based on TeO2, either based on Fused Silica. Nevertheless, due to the low figure of Merite of SiO2, the necessary RF peak power will be much higher than with TeO2.

- **The damage threshold**
The TeO2 pulse picker will be selected for its low driving RF power, while the SiO2 pulse picker will be chosen for its higher damage threshold.
TeO2 (Typ 100W/mm², <30 MW/cm² with ns pulses @1µm)
SiO2 (Typ > 1GW/cm² with ns pulses @1µm)

- The capabilities of the corresponding electronic driver, regarding rise/Fall time, extinction ratio, synchronization and control signals.

# Selection of AA Standard Pulses Pickers

## TeO2 General purpose Pulse Pickers

| Model | Material | Wavelength nm | Aperture mmxmm | Polarisation | Beam diameter mm | Rise Time ns | Max Repetition rate with Duty cycle < 1/10 MHz | Separation angle (0-1) mrd | Efficiency % |
|---|---|---|---|---|---|---|---|---|---|
| MT200-A0.4-IR | TeO2 | 700-900 | 0.4 x 1 | Linear | 0.06 - 0.3 | 10 - 48 | 3.3 - 0.69 | 38 @800nm | 75 - 85 |
| MT200-A0.4-1064 | TeO2 | 980-1100 | 0.4 x 1 | Linear | 0.09 - 0.3 | 15 - 48 | 2.2 - 0.69 | 50.6 @1064nm | 75 - 85 |
| MT250-A0.12-IR | TeO2 | 700-900 | 0.12 x 1 | Linear | 0.04 - 0.1 | 6 - 16 | 5.5 - 2 | 47.6 @800nm | 70 - 85 |
| MT250-A0.12-1064 | TeO2 | 980-1100 | 0.12 x 1 | Linear | 0.05 - 0.1 | 8 - 16 | 4.1 - 2 | 63.3 @1064nm | 70 - 85 |

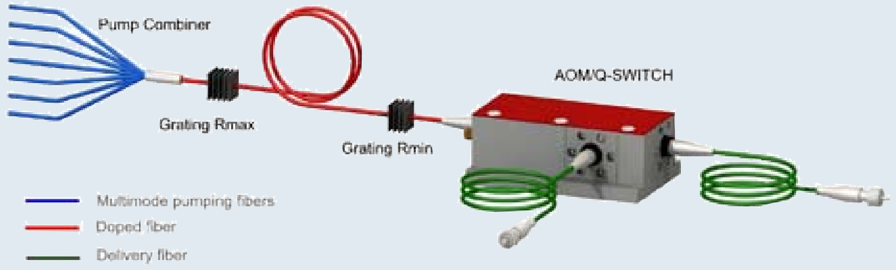
## SiO2 High Damage Threshold Pulse Pickers

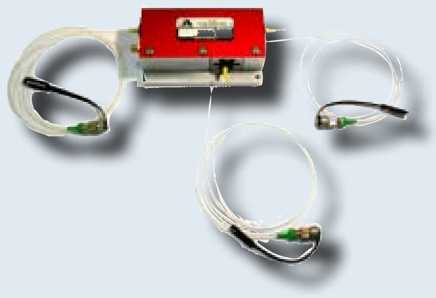
| Model | Material | Wavelength nm | Aperture mmxmm | Polarisation | Beam diameter mm | Min Rise Time ns | Max Repetition rate with Duty cycle < 1/100 KHz | Separation angle (0-1) | Efficiency % |
|---|---|---|---|---|---|---|---|---|---|
| MQ80-A0.7-1064 | SiO2 | 1000-1100 | 0.7 x 1 | Linear | 0.3 - 0.5 | 33 - 55 | 100 - 60 | 14.3 @1064nm | 75 - 85 |
| MQ150-A0.3-1064 | SiO2 | 1000-1100 | 0.3 x 1 | Linear | 0.08 - 0.2 | 9 - 22 | 370 - 150 | 26.8 @1064nm | 50 - 70 |

## Fiber Pigtailed Pulse Picker

| Model | Material | Wavelength nm | Fiber Type | Number of ports | Min Rise Time ns | Max Repetition rate with Duty cycle < 1/10 MHz | Losses dB Nom |
|---|---|---|---|---|---|---|---|
| MT110-IR20-FIO | TeO2 | 1000-1100 | SM or PM | 2 | 20 | 1.6 | 2.5 |
| MT200-IR10-FIO | TeO2 | 1000-1100 | SM or PM | 2 | 10 | 3.2 | 5 |
| MT250-IR6-FIO | TeO2 | 1000-1100 | SM or PM | 2 | 6 | 5.5 | 5.5 |
| MT110-IR25-3FIO | TeO2 | 1000-1100 | SM or PM | 3 | 25 | 1.3 | 2.5 |

Fiber Laser





## ASSOCIATED RF DRIVERS

Driver MODAXX
TTL or Analog control

Driver QMODP0XX
TTL and Analog control

Driver QMODP1XX
TTL and Analog control

# NOTES on Pulse Picker operation

## 1] Effect of the driver on pulse picking

The rise and fall time of the driver has a critical influence on average switching time of the pulse picker, especially in the case of fast switching time. The average rise/fall time of the AOM is linked to intrinsic rise time of AOM and driver as follows :

$$T_{r\_avr} = \sqrt{T_{rAO}^2 + T_{rRF}^2}$$

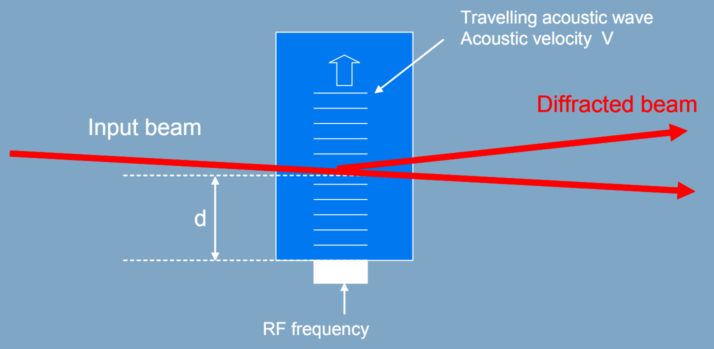
*Example:*
*Tr  AO = 8 ns*
*Tr Driver = 10 ns     --> Taverage = 12.8 ns*

## 2] Synchronization of the pulse and Delay time

The acousto-optic interaction occurs after a certain time (delay time) after the trig signal. This time called «delay time» corresponds to the acoustic propagation from transducer to laser beam after distance d. This corresponds to 238 ns/mm in TeO2-L and 168 ns/mm in fused silica. The synchronisation of the AO open gate with the laser pulse to be picked can be realized in two ways:

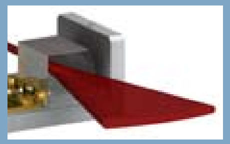
1- Mechanical way: by translating AO cell along acoustic axis, and thus modifying distance d

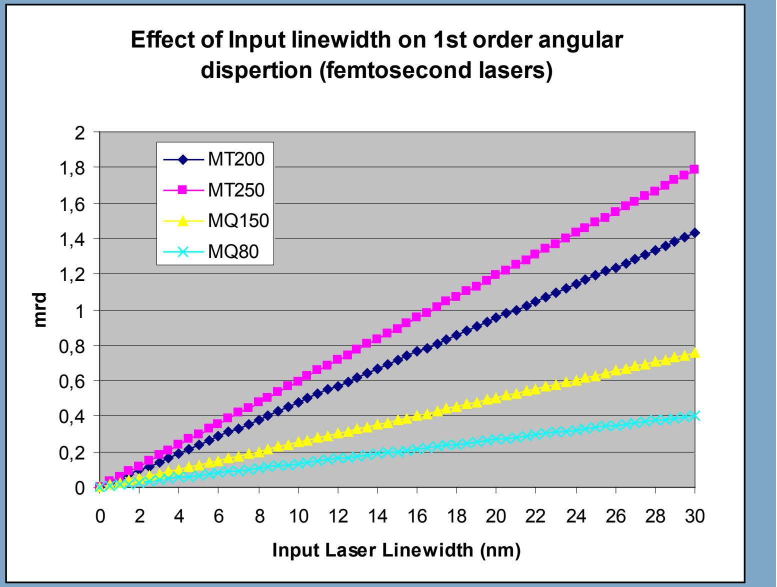
2- Electronic way: either by introducing delay on RF driver trigg signal, either by introducing delay on output RF signal



## 3] 1st orderAngle broadening vs input linewidth

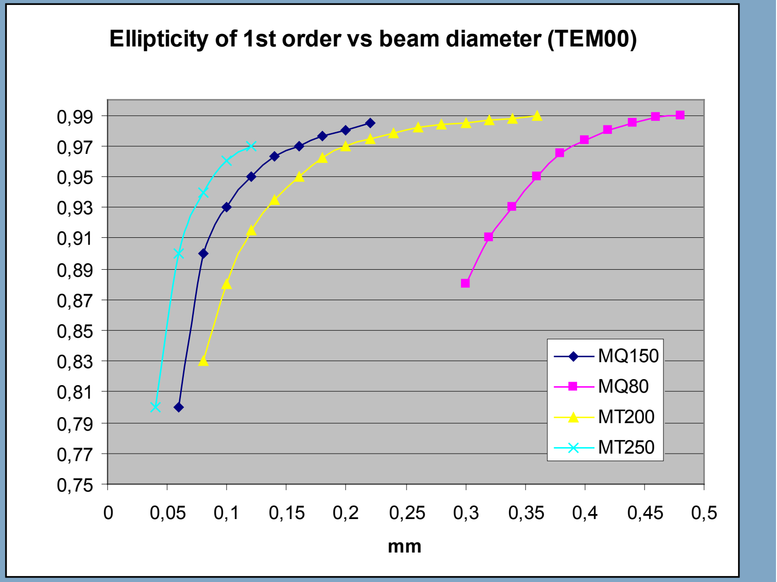
The output first order angle is proportional to the wavelength. In case the linewidth of the incoming beam is brroaden because of an ultra-short pulse then it can lead to a broadening of output first order angle.




Effect of Input linewidth on 1st order angular dispertion (femtosecond lasers)

## 4] Effect of highly focussed beams inside AOM

To get correct diffraction efficiency and low ellipticity of first order, there must be a convenient overlap between acoustic divergence and optical input divergence. At the contrary, first order beam becomes highly eliptical and diffraction efficiency drops.

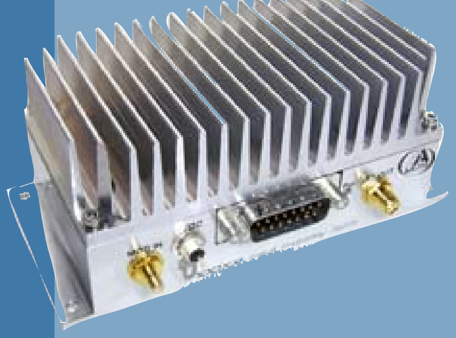

Ellipticity of 1st order vs beam diameter (TEM00)

# ASSOCIATED RF DRIVERS

## MODAxx

1 to 20 Watts

Power supply  24 VDC
 80, 110, 200, 250 MHz
AM control TTL or Analog 0-1V / 0-5V
Rise / Fall time  typ 2-10 ns (freq dependant)
Heat exchange Heatsink+fan+conduction
Class A



## QMODP0

10 to 20 Watts

Power supply  24 VDC
80 MHz, 110 MHz
Pulse control  TTL or TTL reversed
Power control  Analog 0-5V (PAC or FAC)
Rise / Fall time  typ 10-20 ns
Heat exchange Heatsink+fan+conduction
Class AB

## QMODP1

10 to 20 Watts version

Power supply  24 VDC
80, 110 MHz
Pulse control  TTL reversed
Power control  Analog 0-5V (PAC or FAC)
Riise / Fall time  typ 20 ns
Heat exchange:  conduction through baseplate
Class AB
Thermal security

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