CASTECH®

LASER

COMPONENTS

GWU-Lasertechnik

Acousto-Optic Devices

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 experimentations 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 **Phariseau** (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.

Glossary

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

"Zero" order,"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 (QB): 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 (Q): The angle between the zero order and the first order.

RF Bandwidth (DF): 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 (DQ): 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 (DFmod): 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 (h): 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 (PRF): The electrical power delivered by the driver.

Acoustic power (Pa): 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.

Physical Principles

An RF signal applied to a piezo-electric transducer, bonded to a suitable crystal, will generate an acoustic wave. This acts like a “phase grating”, traveling through the crystal at the acoustic velocity of the material and with an acoustic wavelength dependent on the frequency of the RF signal. Any incident laser beam will be diffracted by this grating, generally giving a number of diffracted beams.

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

$$Q = \frac{2\pi\lambda_0 L}{n\Lambda^2}$$

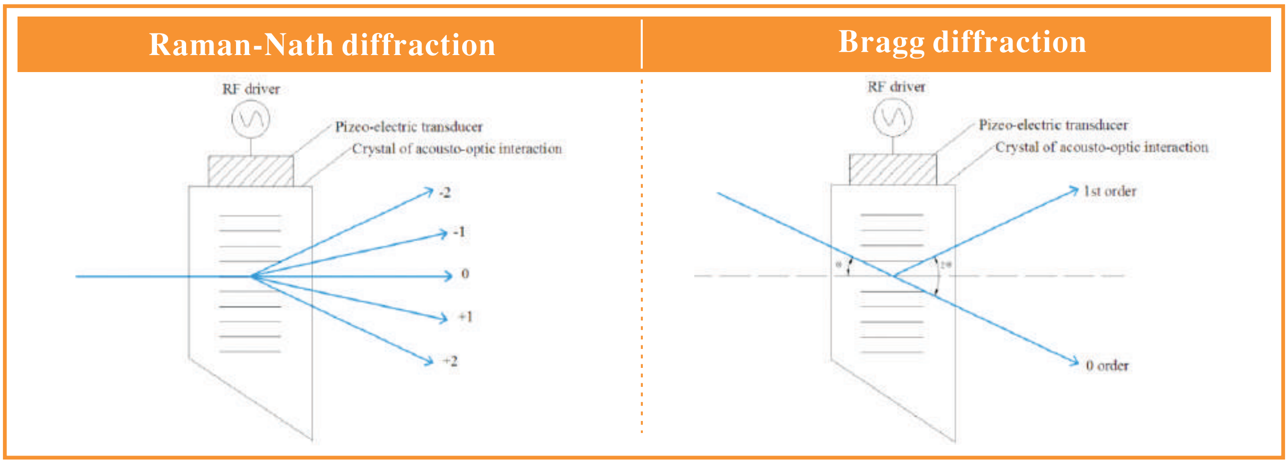
where λ_0 is the wavelength of the laser beam, n is the refractive index of the crystal, L is the distance the laser beam travels through the acoustic wave and Λ is the acoustic wavelength.

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 Θ, only one diffraction order is produced - the others are annihilated by destructive interference.

In the intermediate situation, an analytical treatment isn't possible and a numerical analysis would need to be performed by computer.

Most acousto-optic devices operate in the Bragg regime, the common exception being acousto-optic mode lockers and Q-switches.

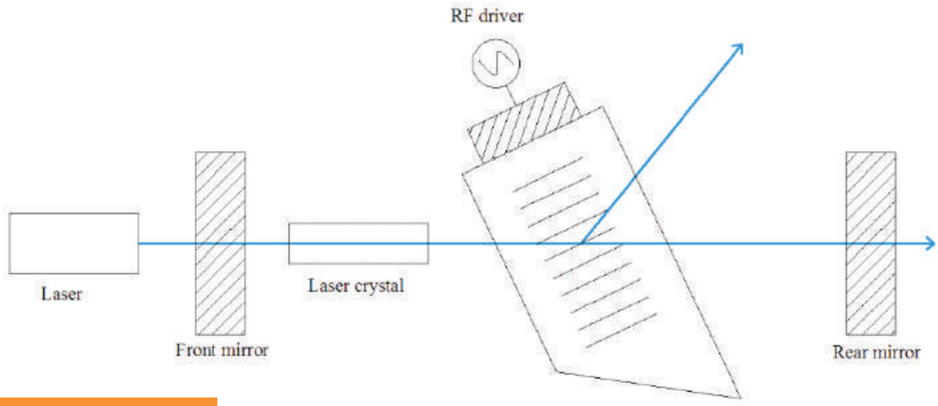


Acousto-Optic Q-Switches

When placed inside a laser cavity, an acousto-optic Q-switch (AOQS) can be used to control the amount of light circulating within the resonator via the acousto-optic effect. When turned on, an AOQS diffracts light out of the optical beam path within the cavity, thus increasing losses and reducing the Q-factor. While loss in the cavity is high and pumping continues, lasing cannot occur, but a population inversion can build up within the gain medium. Once the gain is saturated, the RF power to the acousto-optic Q-switch is turned off, reducing loss within the cavity very quickly. This increases the Q-factor and allows rapid amplification to create a very high intensity, short pulse.

A high quality acousto-optic Q-switch has several important characteristics:

- Very low loss in the “off” state to maximize output intensity
- Ability to withstand very high peak laser power
- Excellent transducer reliability to allow long-term use without maintenance



Family Products

Operating Frequency	Model	Wave-length	Active Aperture	Optical Material	Cooling
27.12MHz	CAQS-027-al-FSt-w-c	1064,...nm	1.6,2,3,4,5, 6.5,8,...mm	Fused silica	Water-cooled
40.68MHz	CAQS-041-al-CQC-w-c	355,1030, 1064,...nm	0.8,1,1.5,1.8, 2,3,...mm	Crystalline quartz	Conduction -cooled
80MHz	CAQS-080-al-CQC-w-c	355,1030, 1064,...nm	0.5,1,1.5,2, 2.5,3,...mm	Crystalline quartz	Conduction -cooled
	CAQS-080-al-DFC-w-c	1064,...nm	0.5,1,1.5,2, 2.5,3,... mm	Dense flint	Conduction -cooled

Frequency, aperture, wavelength, connector can be customized according to customers' requirements.

Model Number

CAQS — f — al — mt — w — c

f	Frequency	a	Aperture	l	Length	m	Material	t	Acoustic mode	w	Wave-length	c	Connector
027	27.12MHz	005	0.5mm	A	A,B,C... represents different crystal lengths.	FS	Fused silica	L	Longitudinal	355	355nm	AF	SMA-F
041	40.68MHz	010	1.0mm	B		CQ	Crystal quartz	S	Shear	1030	1030nm	AM	SMA-M
080	80MHz	016	1.6mm	C		DF	Dense flint	C	Compressional	1064	1064nm	NF	BNC-F
...		020	2mm	...		...				...		NM	BNC-M
		...										MF	MMCX-F
												MM	MMCX-M
												...	

For detailed data, see the specifications of each product.

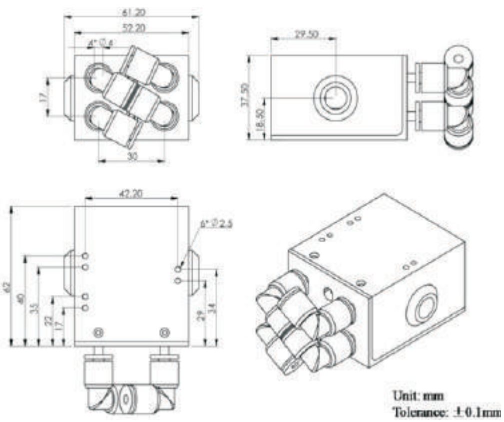
CAQS-027-al-FSt-w-c

Features	Applications
1064 nm	Material processing
Water cooling	Medical
High damage threshold	Scientific
High efficiency	

Specifications

Material	Fused Silica
Wavelength	1064 nm
Transmission（Single pass）	≥99.6%
Damage Threshold	>1GW/cm²
Polarization	Random
Aperture	1.6,2,3,4,5,6.5,8,...mm
Crystal Length	A
RF Frequency	27.12 MHz
RF Power Rating（Maximum）	50 W for compressional acoustic mode
	100W for shear acoustic mode
RF Connector	BNC
Thermal Security Connector	SMA,SMB,SMC
Operating Mode	Raman Nath
Diffraction Efficiency	Nom >60%
Diffraction Angle	3.32 mrad
Input Impedance	50 Ω
VSWR	<1.2:1
Water Flow Rate	>190 cc/minute
Operating Temperature	10℃~40℃
Storage Temperature	0℃~50℃

Dimensions



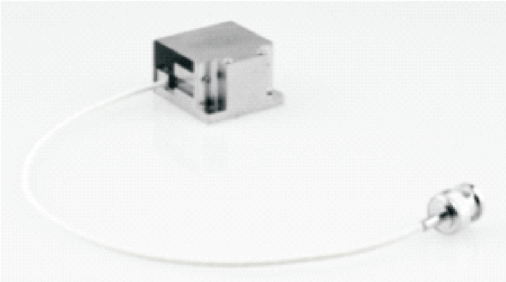
CAQS-041/080-al-mt-w-c

Features

- Compact package
- Conduction-cooled
- High damage threshold
- High efficiency

Applications

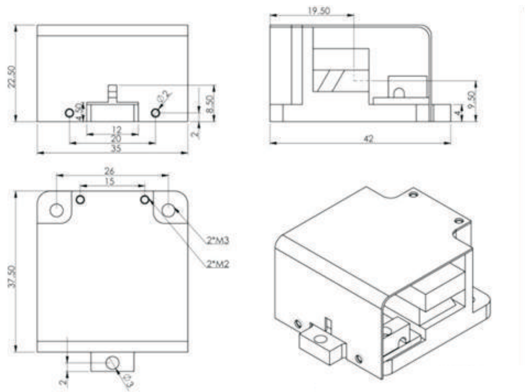
- Material processing
- Medical
- Scientific



Specifications

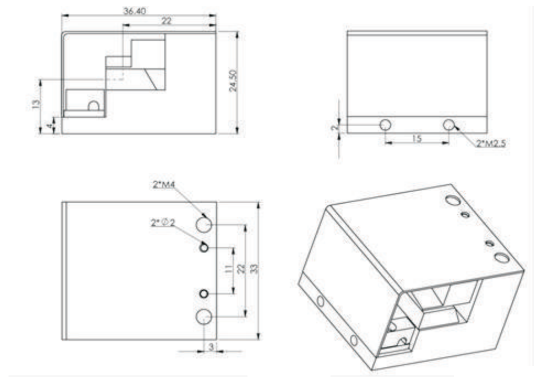
Model	CAQS-041-al-CQC-w-c	CAQS-080-al-DFC-w-c	CAQS-080-al-CQC-w-c
Material	Crystal quartz	Dense flint glass	Crystal quartz
Wavelength	355,1030,1064,...nm	1047-1064 nm	355,1030,1064,...nm
Transmission(Single pass)	≥99.6%	≥99.6%	≥99.6%
Damage Threshold	> 1GW/cm²	> 1GW/cm²	> 1GW/cm²
AR Coating Reflection	< 0.2% per surface	< 0.2% per surface	< 0.2% per surface
Polarization	Linear, vertical to base	Random	Linear, vertical to base
Aperture	0.8,1,1.5,1.8,2,3,...mm	0.5,1,...mm	0.5,1,1.5,2,...mm
Crystal Length	A, B	A	A, B
Acoustic Mode	Compressional	/	Compressional
RF Frequency	40.68 MHz	80 MHz	80 MHz
RF Power Rating(Maximum)	20 W	3 W	15 W
RF Connector	SMA,BNC,MMCX,...	SMA,BNC,...	SMA,BNC,MMCX,...
Rise Time(10~90%)	113 ns/mm	177 ns/mm	113 ns/mm
Loss Modulator	≥85%	≥50%	≥85%
Diffraction Angle	7.5 mrad	23.3 mrad	14.9 mrad
VSWR	< 1.2:1	< 1.25:1	< 1.2:1
Cooling	Conduction-cooled	Conduction-cooled	Conduction-cooled
Storage Temperature	-20℃~70℃	-20℃~70℃	-20℃~70℃

CAQS-041-al-CQC-w-c



Model Ⅰ

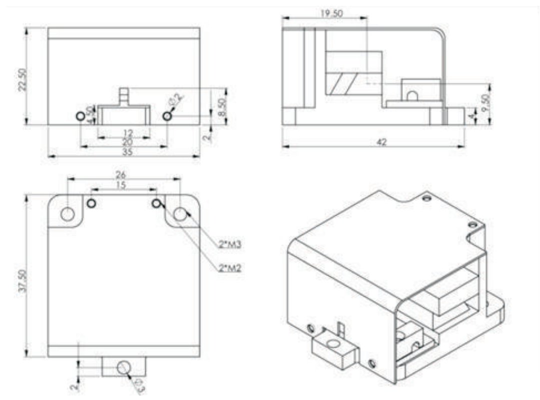
Unit:mm
Tolerance: ±0.1mm



Model Ⅱ

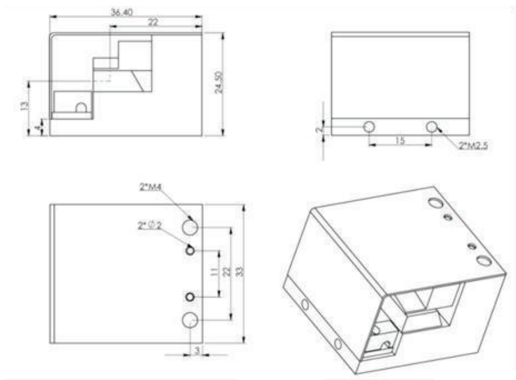
Unit:mm
Tolerance: ±0.1mm

CAQS-080-al-CQC-w-c



Model Ⅰ

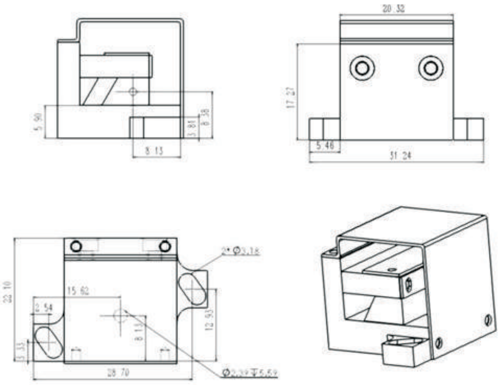
Unit:mm
Tolerance: ±0.1mm



Model Ⅱ

Unit:mm
Tolerance: ±0.1mm

CAQS-080-al-DFC-w-c



Unit:mm
Tolerance: ±0.1mm

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