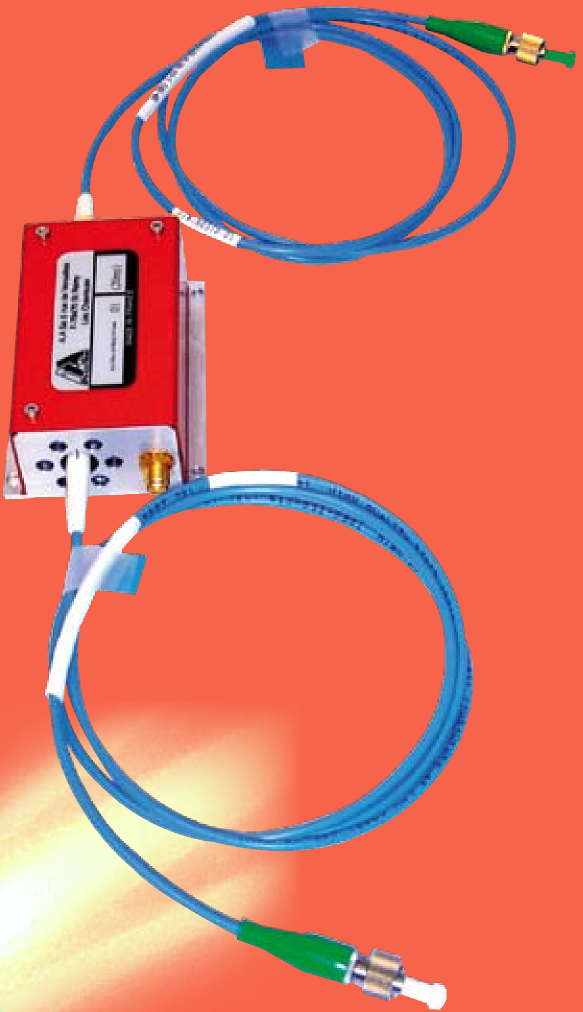
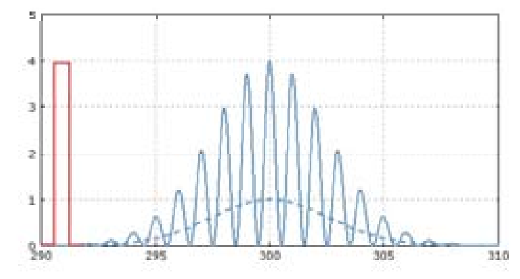
OPTO-ELECTRONIC

Fiber Pigtailed Variable Frequency Shifters

Acousto-optic products





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Introduction Frequency Shift

3- PHYSICAL PRINCIPLES MAIN EQUATIONS

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.

3-1 Interaction conditions

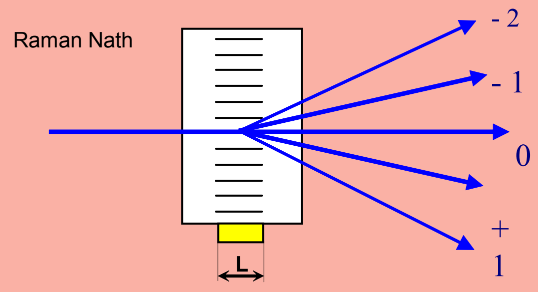
A parameter called the “quality factor, Q”, determines the interaction regime. Q is given by:

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

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 *B, 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.

3-2 Wave vectors constructions

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

$$\vec{K}_d = \vec{K}_i + /- \vec{K}$$

Ki = $2\pi ni/\lambda_o$ – wave vector of the incident beam.
Kd = $2\pi ni/\lambda_d$ – wave vector of the diffracted beam.
K = $2\pi F/v$ – wave vector of the acoustic wave.

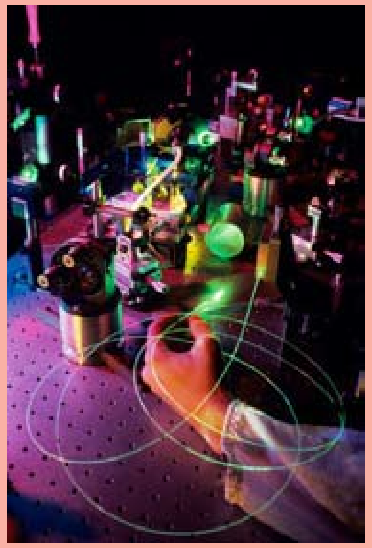
Here F is the frequency of the acoustic wave traveling at velocity v. ni and nd are the refractive indexes experienced by the incident and diffracted beams (these are not necessarily the same).

Energy conservation leads to : Fd = Fi +/- F

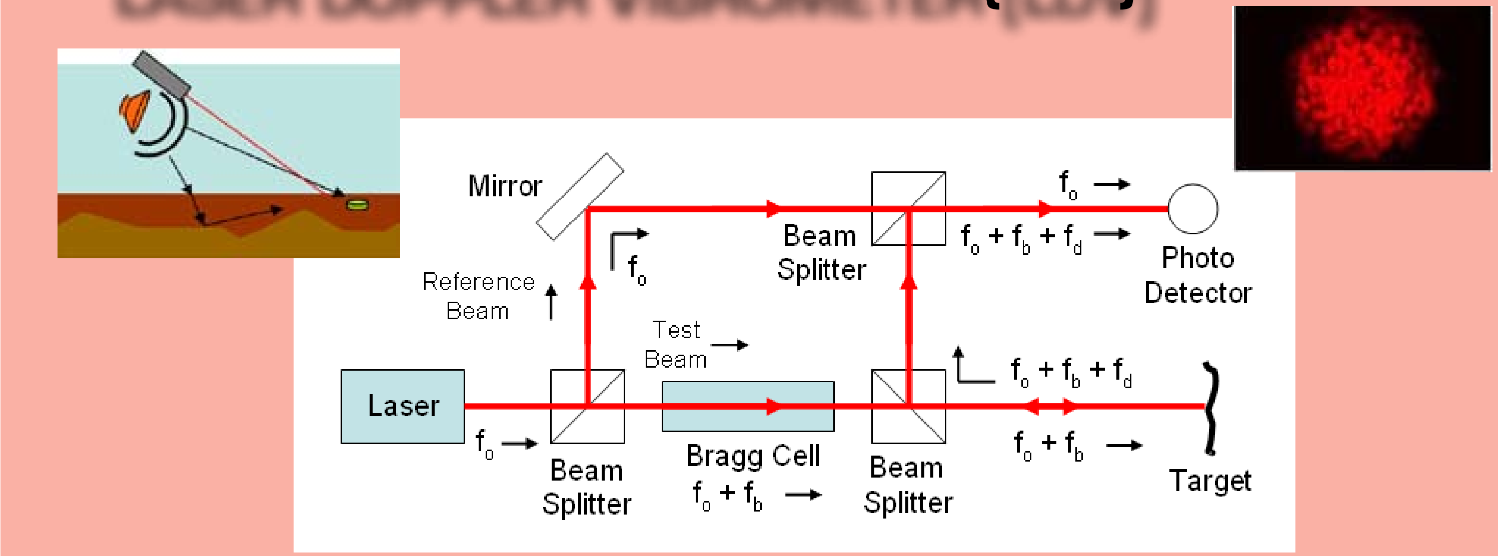
So, the optical frequency of the diffracted beam is by an amount equal to the frequency of the acoustic wave. This “Doppler shift” can generally be neglected since F<<Fd or Fi, but can be of great interest in other applications such as heterodyning, Doppler or OTDR applications.
It is important to notice that the frequency shift can be positive or negative.

Double pass
The double pass inside the same AOS allows to double the frequency shift linked to the interaction. With this method, we can create high shifts values over 500MHz.

Low frequency shifts
The cascade of two frequency shifters, one with positive shift and the second one with negative shift, allows to create small values of frequency shift as low as 0. this method is commonly used for low frequency shifters below 35 MHz.



LASER DOPPLER VIBROMETER (LDV)



A Laser Doppler Vibrometer (LDV) is a scientific instrument that is used to make non-contact vibration measurements of a surface. The laser beam from the LDV is directed at the surface of interest, and the vibration amplitude and frequency are extracted from the Doppler shift of the laser beam frequency due to the motion of the surface. The output of an LDV is generally a continuous analog voltage that is directly proportional to the target velocity component along the direction of the laser beam.

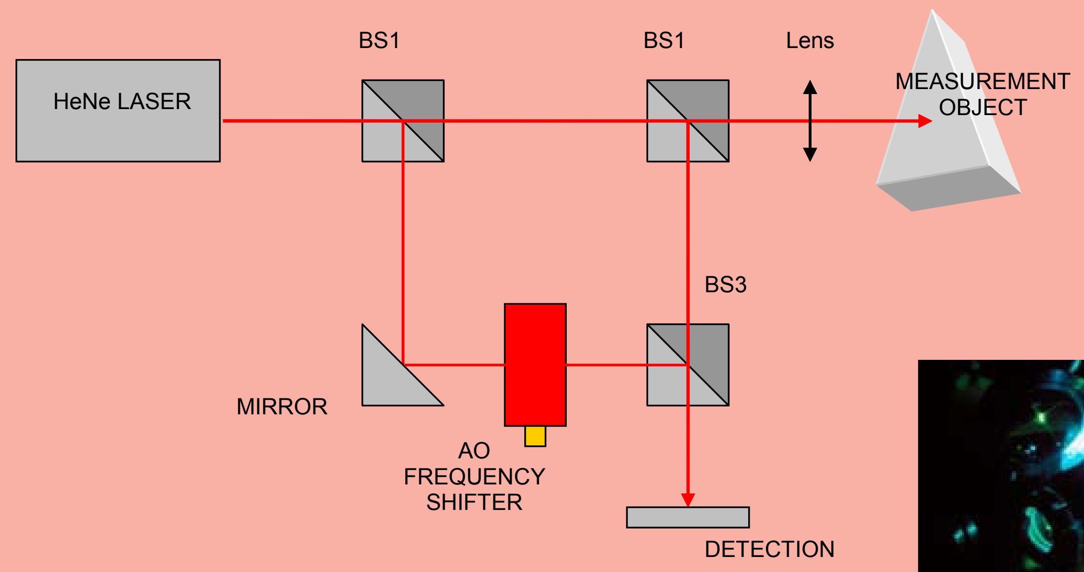
A vibrometer is generally a two beam laser interferometer that measures the frequency (or phase) difference between an internal reference beam and a test beam. The most common type of laser in an LDV is the Helium-Neon laser[1], although laser diodes[2], fiber lasers, and Nd:YAG lasers are also used. The test beam is directed to the target, and scattered light from the target is collected and interfered with the reference beam on a photodetector, typically a photodiode. Most commercial vibrometers work in a heterodyne regime by adding a known frequency shift (typically 30-40 MHz) to one of the beams. This frequency shift is usually generated by a Bragg cell, or acousto-optic modulator.

A schematic of a typical laser vibrometer is shown below. The beam from the laser, which has a frequency fo, is divided into a reference beam and a test beam with a beamsplitter. The test beam then passes through the Bragg cell, which adds a frequency shift fb. This frequency shifted beam then is directed to the target. The motion of the target adds a Doppler shift to the beam given by fd = 2*v(t)*cos(α)/λ, where v(t) is the velocity of the target as a function of time, α is the angle between the laser beam and the velocity vector, and λ is the wavelength of the light.

Light scatters from the target in all directions, but some portion of the light is collected by the LDV and reflected by the beamsplitter to the photodetector. This light has a frequency equal to fo + fb + fd. This scattered light is combined with the reference beam at the photo-detector. The initial frequency of the laser is very high (> 1014 Hz), which is higher than the response of the detector. The detector does respond, however, to the beat frequency between the two beams, which is at fb + fd (typically in the tens of MHz range).

The output of the photodetector is a standard frequency modulated (FM) signal, with the Bragg cell frequency as the carrier frequency, and the Doppler shift as the modulation frequency. This signal can be demodulated to derive the velocity vs. time of the vibrating target.

Optical Heterodyne detection



Optical heterodyne detection is special case of heterodyne detection. In heterodyne detection, a signal of interest at some frequency is non-linearly mixed with a reference «local oscillator» (LO) that is set at a close-by frequency. The desired outcome is the difference frequency, which carries the information (amplitude, phase, and frequency modulation) of the original higher frequency signal, but is oscillating at a lower more easily processed carrier frequency.

Optical heterodyne detection has special characteristics and special problems that distinguish it from conventional RF heterodyne detection. While an old technique, key limiting issues were solved only as recently as 1994 with the invention of Synthetic array heterodyne detection.

In heterodyne detection, one modulates, usually by a frequency shift, one of two beams prior to detection. A special case of heterodyne detection is optical heterodyne detection, which detects the interference at the beat frequency. The AC signal now oscillates between the minimum and maximum levels every cycle of the beat frequency. Since the modulation is known, the relative phase of the measured beat frequency can be measured very precisely even if the intensity levels of the beams are (slowly) drifting. This phase is identical in value to the phase one measures in the homodyne case. There are many additional benefits of optical heterodyne detection including improved signal to noise ratio when one of the beams is weak.

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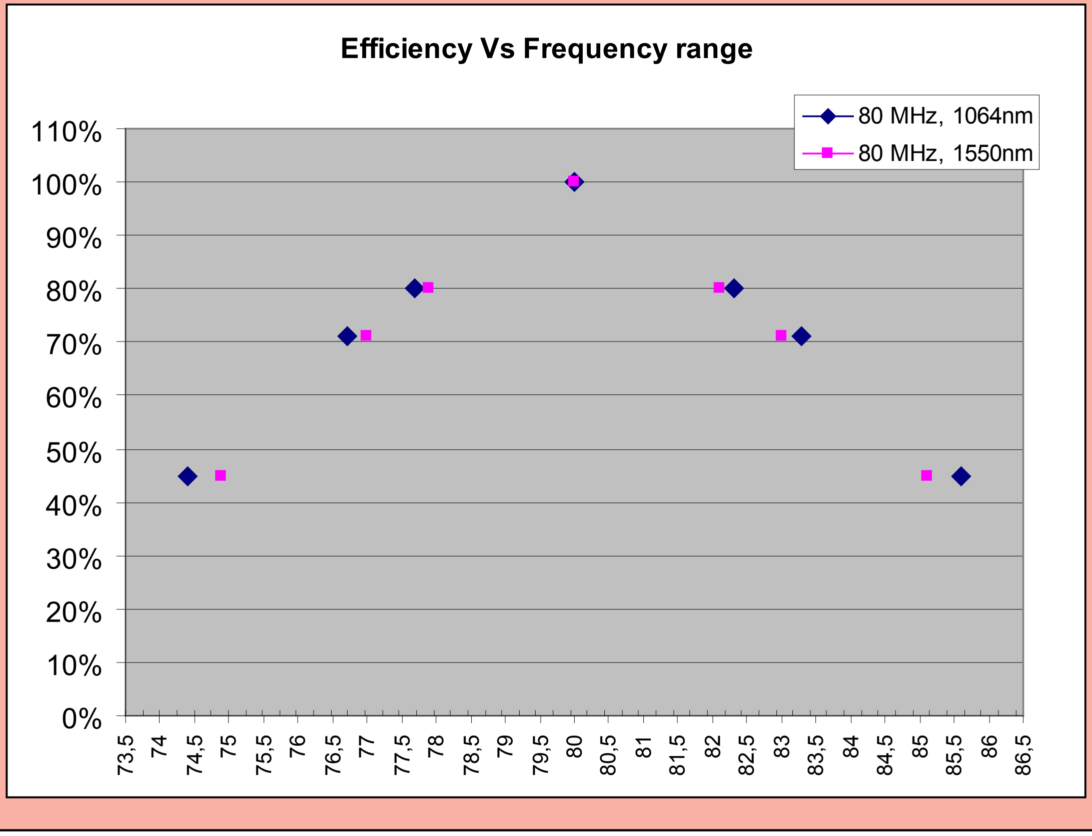
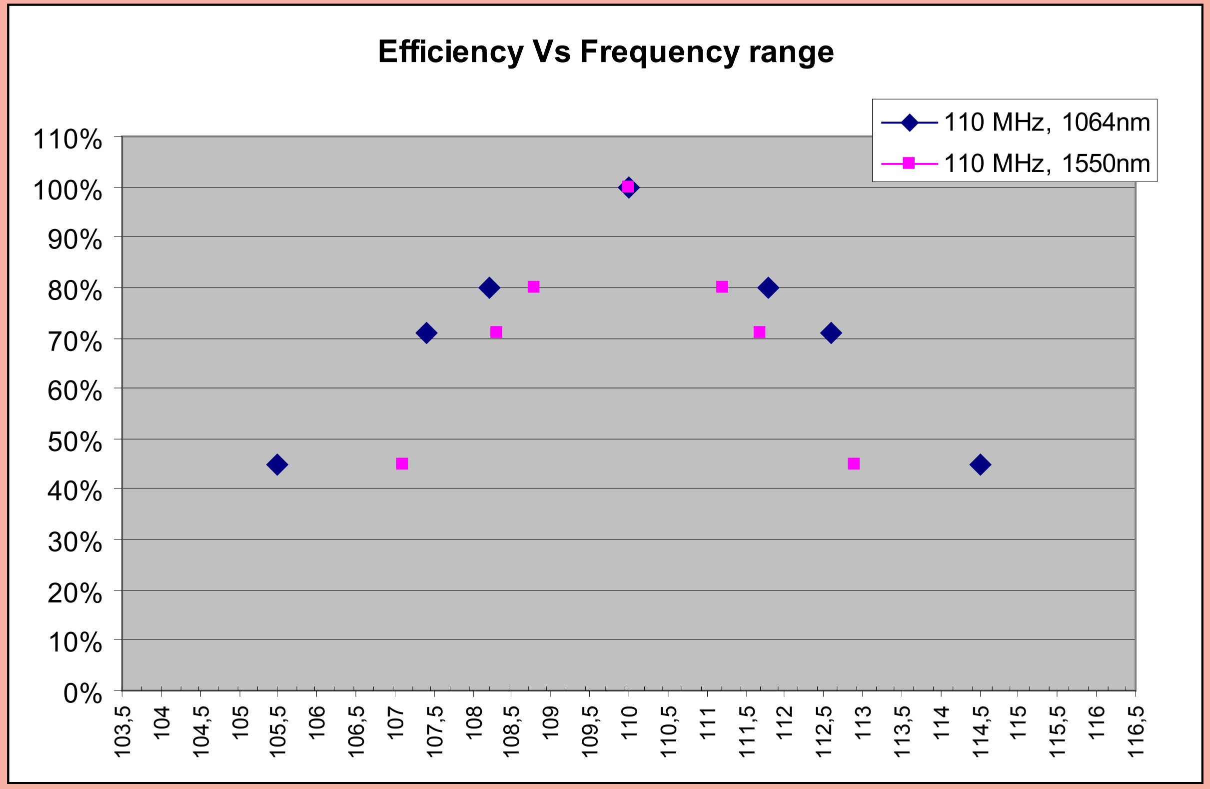
Selection of AA Standard Fibre Pigtailed Variable Frequency Shifters

During the acousto-optic interaction, the first order beam is shifted by the amount of the RF carrier frequency. This shift can be positive or negative. When the Carrier frequency is varied, the frequency shift can be modified in a certain frequency range. This becomes a variable frequency shifter. However, the variation of frequency is accompanied by a variation of the first order beam angle. In case of fiber pigtailed AOS, this angle variation introduces a fiber mis-coupling which reduces the frequency bandwidth of the fiber AOS.

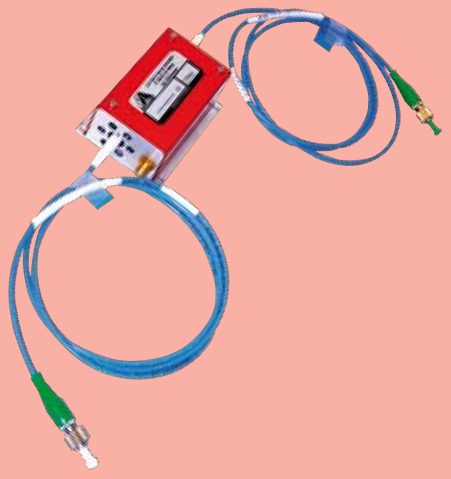




Selection of AA Standard Variable frequency Shifters

Variable Frequency Shifters VISIBLE

Model	Wavelength nm	Min Losses dB	Frequency Shift Band -1.5 dB (nom)	Frequency Shift Band -3dB (nom)	Rise Time ns	Fiber type
MT200-BG18-FIO	478-630	3	200 +/- 7.5 MHz	200 +/- 11 MHz	18	SM, PM
MT200-R18-FIO	630-700	2.5	200 +/- 7.5 MHz	200 +/- 11 MHz	18	SM, PM

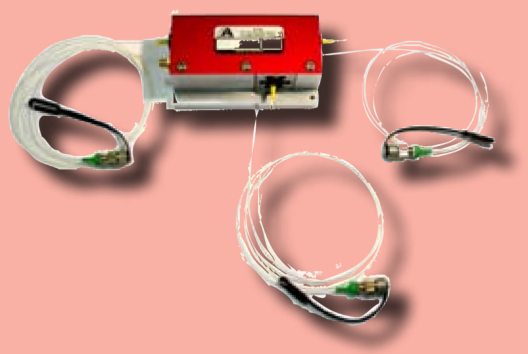


Variable Frequency Shifters 1064 nm

Model	Wavelength nm	Min Losses dB (nom)	Frequency Shift Band -1.5 dB (nom)	Frequency Shift Band -3dB (nom) MHz	Rise Time ns	Fiber type
MT80-IR60-FIO	1000-1100	1.5	80 +/- 2.5 MHz	80 +/- 3.7 MHz	60	SM, PM
MT110-IR20-FIO	1000-1100	2.5	110 +/- 7 MHz	110 +/- 10 MHz	20	SM, PM
MT200-IR10-FIO	1000-1100	4	200 +/- 10 MHz	200 +/- 15MHz	10	SM, PM

Variable Frequency Shifters 1550 nm

Model	Wavelength nm	Min Losses dB (nom)	Frequency Shift Band -1.5 dB (nom)	Frequency Shift Band -3dB (nom)	Rise Time ns	Fiber type
MA40-IIR120	1550	2	40 +/- 1.5 MHz	--	120	SM, PM
MT80-IIR60-FIO	1550	2.5	80 +/- 2.5 MHz	80 +/- 3.7 MHz	60	SM, PM
MT110-IIR20-FIO	1550	3	110 +/- 7 MHz	110 +/- 10 MHz	20	SM, PM



Large Spectrum SLC Fiber pigtailed AOM

Model	Wavelength nm	Min Losses (nom)	Configuration	Carrier Frequency MHz	Rise Time ns	Fiber type
MT80-IIR30-SCL-3Fio-SM	* S band : 1460-1530 nm * C band : 1530-1565 nm * L band : 1565-1625 nm	2 dB @1550nm 5 dB over SCL	3 ports Input + 0 + 1st orders	110	30	SM
MT80-IIR30-SCL-Fio-SM	* S band : 1460-1530 nm * C band : 1530-1565 nm * L band : 1565-1625 nm	2 dB @1550nm 5 dB over SCL	2 ports Input + 1st order	110	30	SM

Others on request

Variable frequency drivers

VCO and DDS based

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.

Model: DRFA10Y-XX

Frequency range:	Adapted at factory to AO device max 40-100, 60-150, 80-200, 140-300, 190-350 MHz (Other on request)
Frequency control:	0-10 V / 1 Kohms
Modulation Input:	0-5 V / 50 ohms
Sweeping time:	≤1 µs
Power Supply:	24VDC, 110-230 VAC
Output RF power*:	Nominal 0 dBm

--> On request DRFA1.5Y 85-135 MHz, sweeping time 150 ns

* To be used in association with AA power amplifiers

DDS drivers

(Direct Digital Synthesizer)

To get a high resolution driver with fast switching time, AA has designed direct digital synthetisers 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.

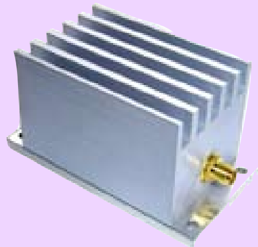
Model: DDSPA-XX

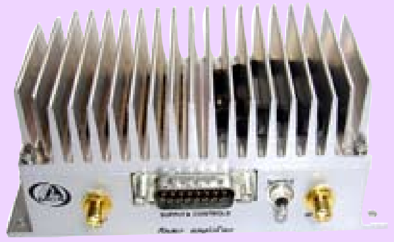
Frequency range:	Adapted at factory to AO device Max 10-350 MHz (400 MHz on request)
Frequency control:	15, 23 or 31 bits
Frequency step:	15 KHz, 1 KHz, 0.25 Hz
Modulation Input:	0-5 V / 50 ohms, Option: 8 bits
Access time:	40, 64, 80 ns
Power Supply:	24VDC, 110-230 VAC
Output RF power*:	Nominal 0 dBm

--> On request USB Controller for PC, designed to drive 1 or 2 DDSPA through USB port (Windows XP/NT)

* To be used in association with AA power amplifiers

RF Power amplifiers





AA's acousto-optic amplifiers are linear with large bandwidth and medium power.he models below cover a variety of bandwidths from 1MHz 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.

Model	Frequency Range	Gain nom	Output Power	Flatness	Power Supply
AMPA-B-30	20-450 MHz	34 dB	1 Watt	+/- 0,5 dB	24 VDC
AMPA-B-33	20-600 MHz	40 dB	2 watts	+/- 0,5 dB	24 VDC
AMPA-B-36	20-210 MHz	40 dB	4 watts	+/- 1 dB	24 VDC
AMPA-B-40	20-210 MHz	41 dB	10 watts	+/- 1 dB	24 VDC

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