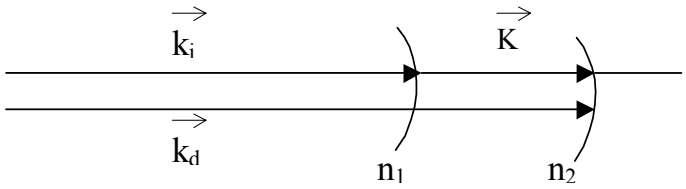
Tunable filters (AOTF) for spectroscopic applications

The extraction of a spectral component of an incoming light source can be carried out by the acousto-optic interaction.

The angle of deflection of an acousto-optic deflector is proportional to the optical wavelength. It is thus possible to extract a particular wavelength. The spectral resolution is then limited by diffraction due to finished dimension (D) of the light beam. The limit of the spectral width can be deduced as:

$$\Delta\lambda_0 = \frac{\lambda_0 V}{D}\frac{1}{F}$$

A good resolution ($\lambda_0/\Delta\lambda_0$ high) imposes a large dimension (D) of the light beam. The numerical aperture of such systems is thus obligatorily very low and thus their utilization is very limited. The collinear anisotropic interaction makes it possible to tune the filter by simple variation of the acoustic frequency, under significant numerical aperture:



$$\eta \approx \eta_0 \sin c^2\left(\frac{\Delta k L}{2\pi}\right)$$ (collinear AOTF efficiency)

The non collinear anisotropic interaction, is also usable under a high angle of incidence ($\theta_i \geq 10°$). This last configuration allows the use of materials with high figure of merit coefficients. (TeO2)

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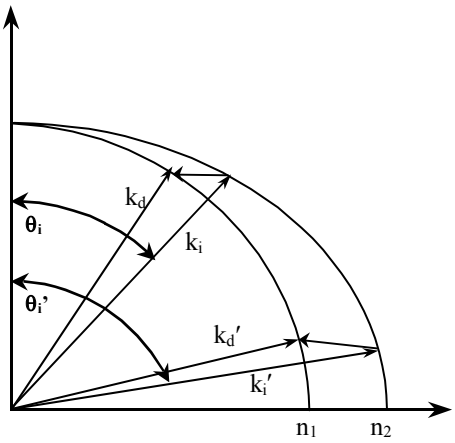
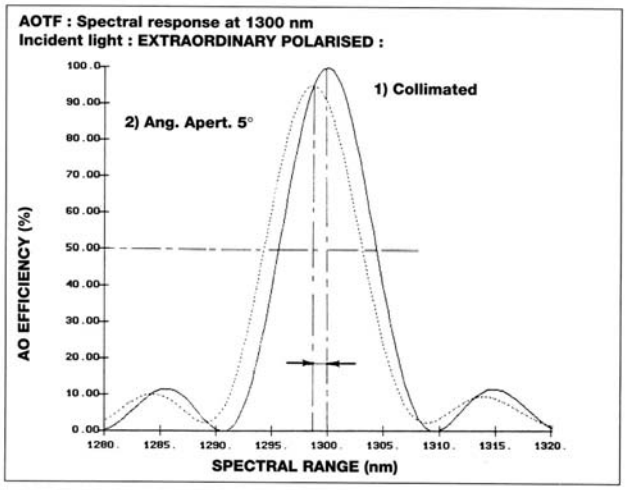


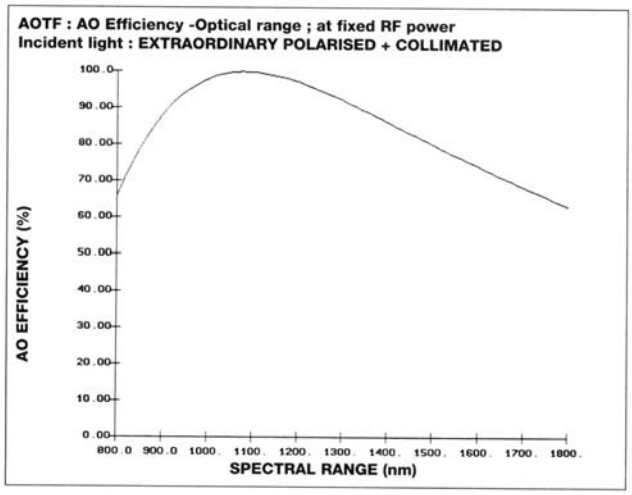
One can show that a large angular aperture is possible as long as the tangents at the point of incidence and synchronism are parallel (the light rays are then parallel in the crystal)

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 ($\Delta\lambda$).

$$\lambda = a\frac{\Delta n(\lambda)}{F} \qquad \Delta\lambda = b\frac{\lambda^2}{L}$$

Δn: birefringence(=$|n_2-n_1|$)
a and b are parameters which depends of θ_i and θ_a
Examples:





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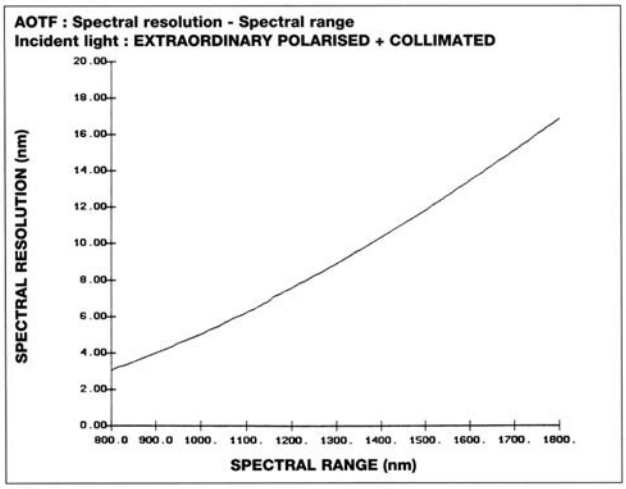


Characteristics of AOTFs

- The transmitted beam and the diffracted beam can be separated spatially or using polarizers.
- Can work in polarized light, or random polarization (lasers or lamps)
- Access time to a wavelength: several μs
- Temporal sweeping of the spectrum: μs to ms
- Possible auto calibration between each measurement
- Temporal modulation and synchronous detection
- Random or sequential access to any wavelength

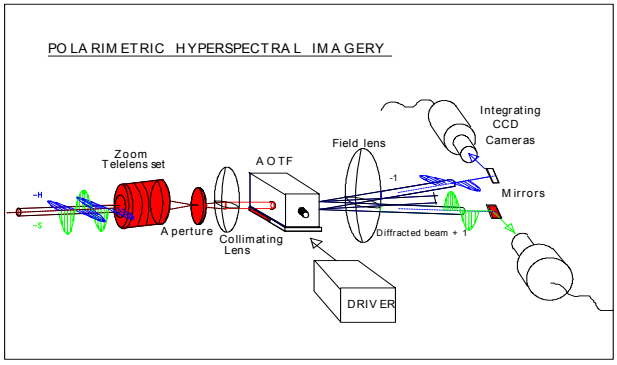
Applications

The development of these devices is not so old, and many applications are still to come. The speed of measurements and the absence of any mechanical movement are the remarkable specifications of the acousto-optic filters.

- Multi-spectral imagery (the AOTF is inserted in the imagery system)
- Spectral analysis
- Absorption, fluorescence analysis
- Polarimetric analysis

POLARIMETRIC HYPERSPECTRAL IMAGERY

Many laboratories have orientated their researchs using AOTF for polarimetric hyperspectral imagery.
The AOTF technology has opened many potential applications, especially in geoscience, air and space borne remote sensing, target detection, vegetation analysis…
The great advantage using an AOTF is to be capable of measuring spatial, spectral and polarization characteristics of a target, in real time, without moving parts, only with a single instrument.
The multiplication of the analysis criterion (multi-spectral images+ H&S polarization images) improve the accuracy of the detection, and let us think to great developments in the near future.



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AA models from UV to IR :

Model	Source	Wavelength nm	Aperture mmxmm	Field of View degrees	Tuning Time µs	Polarization	Resolution nm-3dB	Efficiency
AA.AOTF.1	Lamp	350-600	5x5	7	<7.5	Linear/Random	5-35	80
AA.AOTF.2	Laser/Lamp	360-530	2x2	1	<3	Linear/Random	1.5-5	85
AA.AOTF.3	Lamp	400-700	5x5	5	<7.5	Linear/Random	5-30	80
AA.AOTF.nc	Laser	450-700	3x3	2	<4.5	Linear	1-2	90
AA.AOTF.5	Lamp	480-620	5x5	8	<7.5	Linear/Random	3-10	80
AA.AOTF.6	Laser/Lamp	500-850	5x5	3	<7.5	Linear/Random	1-3	80-60
AA.AOTF.7	Laser/Lamp	600-900	5x5	4	<7.5	Linear/Random	<4	70
AA.AOTF.8	Laser/Lamp	800-1800	5x5	4	<7.5	Linear/Random	2-15	60
AA.AOTF.10	Lamp	1250-2500	3x3	20	<4.5	Linear/Random	2-10	70-30
AA.AOTF.11	Laser	1520-1560	2x3	3	<3	Linear	1.5	70
AA.AOTF.12	Lamp	2800-4000	3x3	20	<4.5	Linear/Random	10-25	15-5

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