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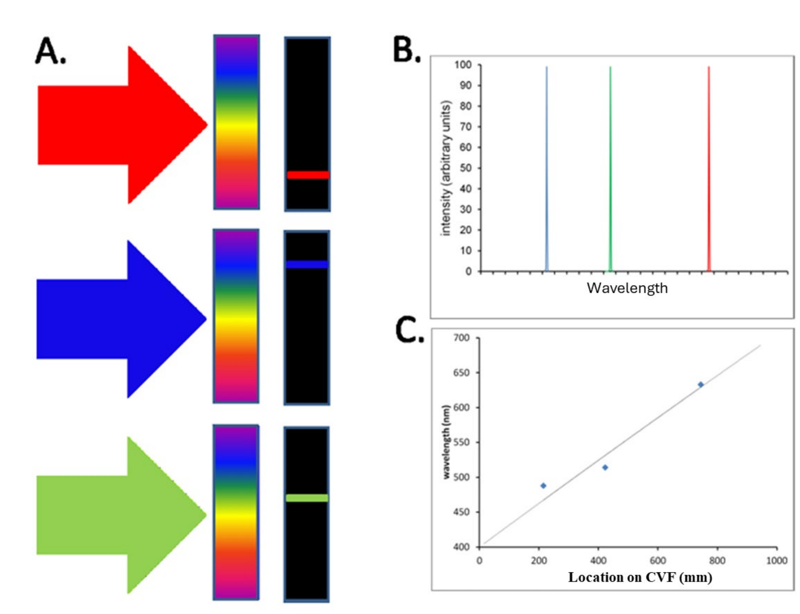
MUSES9-HS electro-optic tunable filter: operation principle

The critical optical element of the electro-optic tunable filter (EOTF) is a Continuously Variable Filter (CVF). The CVF is an optical interference filter whose spectral transmission varies continually along its longish dimension. The wavelength variation is achieved by an interference coating that is intentionally wedged in one direction, creating a continuous shift of the center wavelength along the longish direction of the filter.

Different locations of the CVF transmit different wavelengths (A & B) and block all the other wavelengths. The transmitted wavelengths are linearly varying with the location of the CVF (C). Typical dispersion value is 2nm/mm.

Spectricon has designed and developed the world's first CVF that covers an ultra wide band 370-1100nm. The Spectricon's CVF transmits 94% of the incoming light at any operating spectral band, while, at the same time, rejecting all the out-of-band wavelengths with an incredible blocking efficiency exciding 5 OD.



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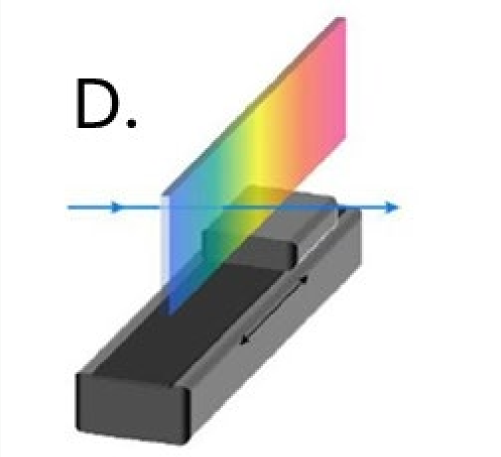
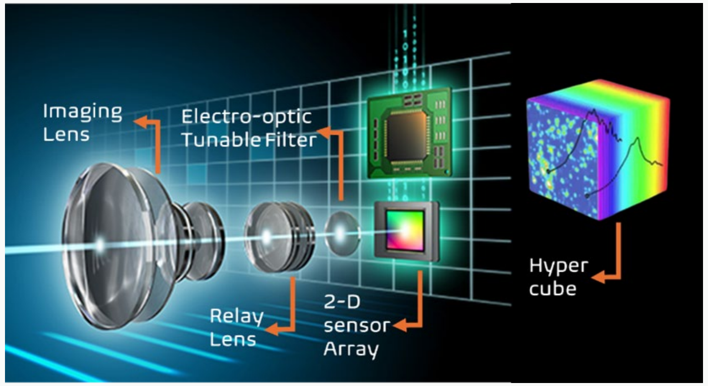
The MUSE9-HS electro-optic tunable filter

CVFs have been used in miniaturized spectrometers, offering, however, single point spectroscopy, low light throughput and spectral range. **Spectricon has achieved to radically improve CVF technology and performance and, more importantly, to invent and introduce to markets the CVF-based hyperspectral imagers.**



MUSES9 HS cameras encapsulate an EOTF, comprising a CVF linear translation mechanism (D) and image manipulation optics. The latter modulates spatially the image to pass through a tiny CVF line, thus achieving narrow band filtering of the whole image. After exiting the CVF, the modulated image is finally reconstructed and captured by the imaging sensor. Image capturing is synchronized with the CVF's linear translation, so that a plethora of narrow band images are captured in a time sequential manner, until acquiring a complete spectral cube.



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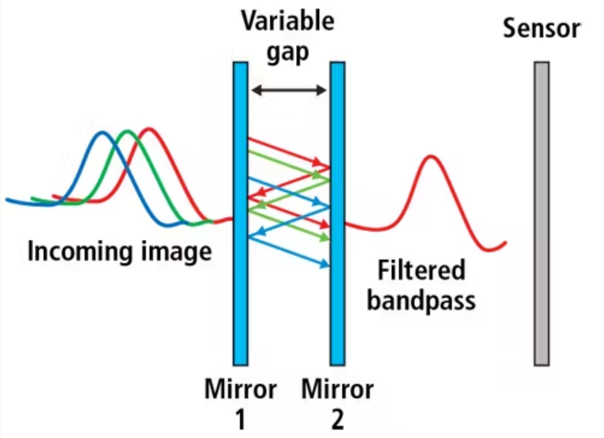
Fabry-Perot tunable filter-based Hyperspectral Cameras

SPECTRICON

Fabry-Pérot interferometers are basically resonant optical cavities made of two plane-parallel, highly-reflecting surfaces that are slightly spaced, typically from hundreds of micrometers to a few millimeters (A). The large reflectivity of the plates causes multiple back and forth reflections across the cavity for each incident ray. Individual rays then split and interfere coherently among themselves. The difference of optical path among two consecutive reflections is such that it causes resonances on the transmission under some conditions.



Fabry-Pérot design is delicate, since mirror defects, tuning accuracy (≈ λ/2), image, ghost images, angle of incidence etc., cause a long list of errors in measuring spectra.

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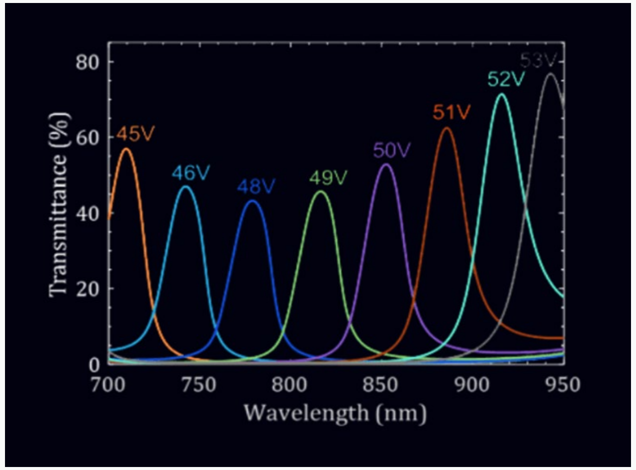
Limitations of F-P Systems

The inherent limitations of F-P systems are:

1. Limited tuning range: In Si sensor spectral range they can cover (typically) 490-640nm with one module or the range 640-910 with a second module. To expand the range, some manufacturers use both modules, and images are captured with two sensors. However, even this combined design miss a significant part of the 370-1100nm spectrum, particularly in the blue portion of the spectrum.
2. To minimize the ray angle dependance, F-P cameras use a fixed lens, placed behind the resonator and a small size sensor. This has the following negative consequences
   - Limits applicability to the fixed Field-of-View
   - No focusing options
   - No freedom to adapt to a variety of optical instruments
   - Poor dynamic range due to small pixel size of the small area sensor
3. Published evaluations of F-P systems have shown several channel leaks in the measured wavelength range. In the image area there is an approximately 1.5 nm shift in the channel wavelengths, and up to 10% variation in the channel bandwidths. The expanded uncertainties (k = 2) for the measured channel bandwidths, sensitivities and wavelengths are 7.9%, 9.5% and 0.64 nm, respectively[1]. Moreover, low and non uniform transmittance, remarkable channel cross-talking and wavelength shifts within the spectral image are additional common drawbacks of F-P technology.



1. “Setup for characterizing the spectral responsivity of Fabry–Pérot-interferometer-based hyperspectral cameras” by O. Pekkala et al

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Fabry-Perot, MUSE9-HS comparison table

	Fabry Perot	MUSES9-HS
Tuning range	~300nm	640nm
Full width at half max	30nm	10nm
Filter Transmittance	non uniform 40-70%	uniform 95%
Out of band leaks	5-10%	0.001%
Tunning speed	5ms (camera shutter limited)	20ms (camera shutter limited)
Camera spatial resolution	2 megapixels	6.4 megapixels
Lens	Fixed	Selectable