# Enhanced optical filter technologies for compact multi-mode spectral imaging payloads for earth observation


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In the last decade the drastic improvement of access to space has opened unprecedented opportunities for earth observation and demonstrated the large potential of compact and lightweight optical payloads onboard small satellites. Many constellations are emerging that allow us to monitor the earth at higher temporal, spatial and spectral resolutions than ever before and provide the necessary data on climate change, availability and health state of natural resources and impact of human activities on our planet. The miniaturization process of optical instruments to match performance with compatibility with small satellites is a key enabler in this respect. A highly integrated solution of thin film optical filters and the detector brings great benefits and innovative solutions for compact multi-and hyperspectral payloads.

Imec leverages its background in semiconductor fab, equipment and process technology and has developed a process to design and manufacture interference-based optical filters in a monolithic way directly at detector wafer level. They are deposited and patterned directly on top of image sensor pixels. Due to the lithographic accuracy with which this process is executed this approach generates an extreme degree of freedom up to the level to deposit an individual filter at single pixel level. This approach opens new opportunities in defining highly optimized geometric filter layouts. This unique CMOS-based infrastructure provides very compact, robust, clean and high-yield optical filter integration with scalability to high-volume and low cost.

The unique filter deposition offers a number of clear advantages

- There is no need for an alignment step between filter and detector as the spectral detector is a completely integrated device
- Due to the lithographic accuracy of the process the alignment of filter against the pixel array has a subpixel accuracy
- There is a minimal loss in the transition zones from one filter region to other providing room for including filters with different characteristics in the same focal plane
- The combination of multiple detector lines under one filter supports digital Time Delayed Integration to boost the signal to noise ratio of the acquired signal

The baseline typical Fabry-Pérot Filter is composed of a transparent cavity layer with two mirrors at each side of that layer. The mirrors are Bragg reflectors consisting of a multiple layer stack of alternating high and low refractive index materials. The reflectivity of these mirrors defines the spectral range, the Full Width Half Max (FWHM) and the quality of the filter. The cavity thickness defines the central wavelength of the optical filter. Combining this with a deposition process tuned for optical materials also enables more complex filter stacks, such as multiple cavity and high OD filters.

After successful demonstration of Fabry-Pérot Filters for both CMOS and InGaAs detectors, imec has developed a next generation filter technology using multi-cavity filter. The response of the filter has a Gaussian profile and results in a significant enhancement of the In-band filter energy in comparison to the Lorentzian profile of a single cavity filter.

In addition to the optimization of the filter stack itself by means of the multi cavity configuration, the accurate patterning capabilities also allow to create geometric filter patterns that deviate from the standard line-based patterns. Imec has demonstrated in the past several versions of a mosaic pattern within which filters have been organised in a 4x4 or 5x5 mosaic composing of 16 or 25 unique filters. In

application fields like industrial vision and medical imaging for assisted surgery the benefits are real-time video. Earth observation instruments operating from small satellites are traditionally line scanning instruments due to the linear motion from the orbiting satellite. Also for earth observation applications from satellites non-linear filter geometries have advantages. Imec has designed and produced a new hybrid layout containing a mosaic pattern combining the advantages of a mosaic pattern with the ability to process the data in a line-based approach to ultimately provide the highest spatial resolution. This imager can be used in a low-data rate, low resolution mode for early detection and high-resolution high data rate mode for more accurate scanning.

This paper will present the new achievements related new filter developments to improve the out of band signal of the filter response like multiple cavity filters and demonstrate non-linear new filter layouts for earth observation applications.