

MEMS Components Inside Optical Transceivers

Optical MEMS technology offers high-performance and cost-effective solutions for many components in optical transceivers. Fig. 1 shows a block diagram of an optical transceiver in which various functions performed by MEMS devices are highlighted. The operation of these components and applicable products offered by PMC are described in detail below.

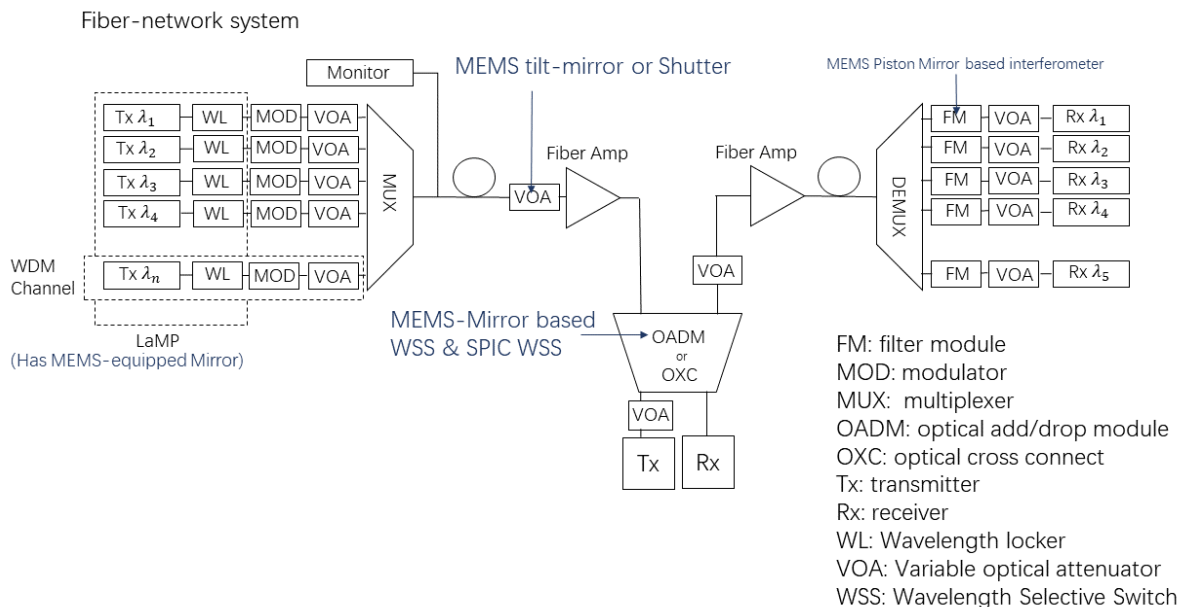


Fig. 1: MEMS-based technology employed in an optical transceiver.

MEMS Variable Optical Attenuator (VOA)

A variable optical attenuator (VOA) is an indispensable component of fiber-optics networks. VOAs are used to control the signal intensity after laser diodes and before photodetectors. The adaptation of coherent digital technology for mid to long-distance communication requires a VOA for power balancing at each wavelength division multiplexing (WDM) channel before the EDFA or SOA-type fiber-optics amplifier. PMC offers two types of free-space VOA based on MEMS shutter

and MEMS tilt-mirror. These two VOA architectures can both be easily integrated into a transceiver package.

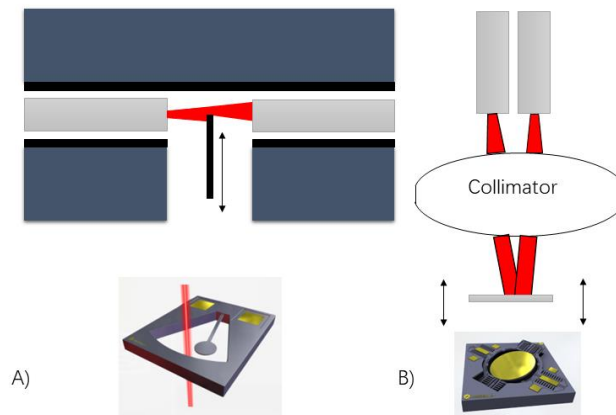


Fig. (2): The working principle (top) and related product (bottom) of (a) MEMS shutter type VOA and (b) MEMS tilt-mirror VOA.

The MEMS shutter VOA (transmission-type VOA) shown in Fig. 2(a) provides the most direct approach to attenuation. The beam path connecting two fibers can be interrupted by a blocker. This micro-attenuator can reduce both the size and intensity of the beam. The MEMS shutter has a large 500um aperture in a small 3.2x1.9 mm² footprint which can be easily integrated into any free space optics or fiber optics system.

MEMS tilt-mirror VOAs (reflection-type VOA) have less polarization-dependent loss in comparison with the shutter-insertion type attenuator [2]. This architecture also reduces the package size and is scalable to fiber-array multichannel I/O. The tilt mirror can be used to adjust the coupling efficiency between two fibers, which are placed in the focal plane of the collimator. An extremely small shift of ~0.3 degrees from the perfect coupling angle can result in a completely 40dB blockage [1]. Therefore, MEMS tilt-mirror VOAs often require a very small voltage (<5V) during electrostatic actuation. PMC also provides a MEMS mirror matrix and linear array for the beam steering of fiber array I/O. Each mirror size ranges from sub-millimeter to millimeter and has either single or two-axis tilting which also enables optical cross-connect and wavelength-selective switching applications [3]. The monolithic MEMS tilt-mirror chip is made of single crystal silicon

which has exceptionally high mechanical reliability. The Au or Al thin-film reflective coating has high reflectance in the telecom wavelength range, ensuring low-insertion loss for the final product.

MEMS Tunable Optical Filters to Suppress Amplified Spontaneous Emissions (ASE)

In response to insatiable demand for network bandwidth, service providers are working to upgrade the global optical transport infrastructure with 100 Gb/s to 400 Gb/s DWDM coherent transmission, including analog and digital coherent optics (ACO and DCO) pluggable transceiver modules. This requires the deployment of extended range pluggable optical coherent transceivers. Next generation transceivers are expected to hit higher data rates in the long-distance operation mode while maintaining a small footprint. Accomplishing this challenge requires more features such as power balancing and ASE noise suppression to be built inside the transceiver module. A MEMS tilt-mirror that can be co-packaged with a grating inside a hermetically sealed package can form a compact tunable optical filter for ASE noise suppression.

Tunable optical filters (TOF) improve the signal fidelity and increase the reach by filtering the optical noise generated at the transmitter. TOF is designed to be embedded in transceivers with highly compact form factors such as 400G+ Transceivers in CFP / CFP2 form factors. TOF has achieved a record low-voltage specification of 12V and does not need a specific high voltage IC to drive the component.

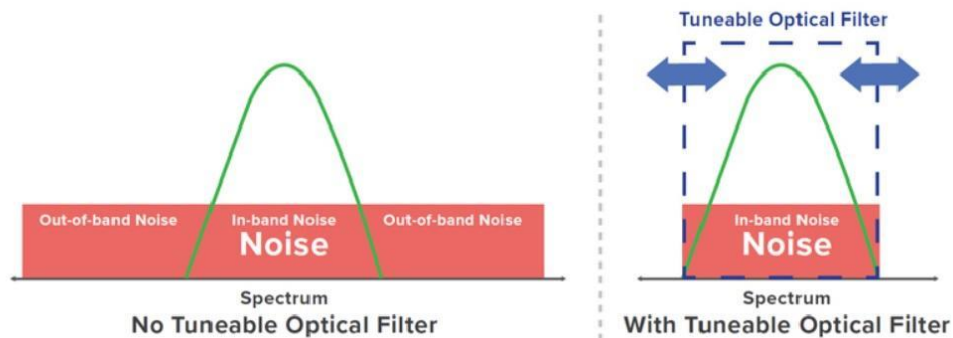


Fig. 3: Tunable Optical Filter (TOF) ^[4]

Larger form factors such as CFP2s and embedded optical engines can also contain TOFs that block the out-of-band noise caused by amplification and/or laser side modes, as shown in Figure 3. Without a TOF or other techniques to minimize out-of-band noise, this noise would accumulate from all the various sources in a colorless add scenario with a combiner or coupler, as shown on the left of Figure 4, thus making coherent filterless/colorless add/drop very challenging.

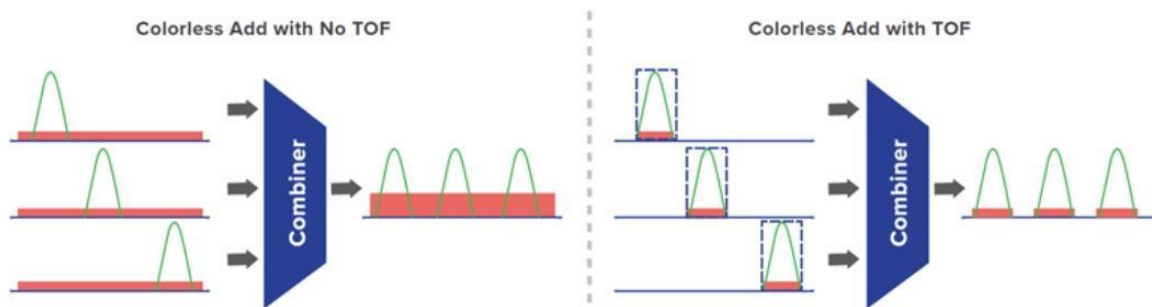


Fig. 4: Colorless Add with and without TOF ^[4]

CFP2s typically have higher transmit power and better colorless support when they include a TOF, and they provide demarcation when placed in a transponder/muxponder. Embedded 800G optical engines, with their more powerful digital ASIC/DSP, TOF and higher transmit power, provide an excellent solution for DCI and metro core networks where spectral efficiency/fiber capacity is a high priority, in the case of metro core networks where the number of ROADM cascades is high, and for long-haul and submarine networks where maximum wavelength capacity-reach and spectral efficiency are typically the highest priorities.

PMC offers a portfolio of MEMS mirrors with different mirror size/operating voltage/die size/tilting range that work with a variety of optical designs. Table 1 shows an example of a 1.4x1.4mm² MEMS mirror that is ideal for constructing a miniTOF component which can be assembled inside a high-performance transceiver module.

Parameter	Condition	Unit	Specification		
			Min	Typical	Max
Chip dimension	Length	mm	1		1.7
	Width		1		1.7
	Thickness			TBD	
Mirror diameter	Circular	mm	0.6	0.8	1
Actuation voltage	X axis, at room temp.	V	12		60
Max tilt angle	+/-X axis	deg.		2	
Response Time	From neutral to max tilt angle using a step function input	ms		1	
Temperature Stability	Over -5 to 75 °C	deg.			0.001
Durability	Hermetic sealed	Cycle		10 ⁹	
Operating temperature		°C	-5		75
Storage temperature range	5% humidity	°C	-40		85

Table 1. Product specification of miniTOF MEMS mirror offered by PMC

PMC's MEMS Products are Designed for Reliability and Volume Manufacturing

Preciseley is an expert in the design and manufacturing of high-performance MEMS mirrors for telecom/datacom and industrial applications, with nearly two decades of experience in high volume MEMS mirror production and millions of units shipped. Our mirrors are widely deployed in telecom applications with rigorous shock, vibration, and reliability requirements specified by Telcordia standards. We understand the importance of “design for manufacturing” and have been delivering innovative, high-quality products worldwide for over 16 years.

Reference

- [1] Isamoto, Keiji, et al. "A 5-V operated MEMS variable optical attenuator by SOI bulk micromachining." *IEEE Journal of selected topics in quantum electronics* 10.3 (2004): 570-578.
- [2] A. Bashir, et al. "A MEMS-Based VOA With Very Low PDL", *IEEE Photon. Technol. Lett.*, vol. 16, no. 4, pp. 1047-1049, Apr. 2004.
- [3] Tiansheng Zhou, "[Optical MEMS mirror and MEMS array for WSS](#)", Jul. 8, 2022
- [4] Paul Momtahan (June 30, 2021), Go Big or Go Home?, <https://www.infinera.com/blog/go-big-or-go-home/>