Introducing the Future:
Advanced MEMS Platform for Optical Networks

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1 Introduction

Optical MEMS are critical components in the deployment of agile all-optical communication networks. This paper provides an overview of a cutting edge Optical MEMS platform that will advance the performance of telecommunications modules light years beyond current market offerings. The platform creates a more linerar device that is easier to use with a lower operating voltage. Both of these results in lower cost of ownership through easier module assembly and lower cost drive electronics.

Micralyne has launched this platform to address emerging network needs that drive higher levels of agility and remote configuration. The advanced Optical MEMS platform has been used to demonstrate successful fabrication of two MEMS devices; a cost effective mirror array for use in a 1x2 Wavelength Selective Switch (WSS) module, and a revolutionary mirror array to achieve a high port count 1x23 WSS module for Reconfigurable Optical Add-Drop Multiplexer (ROADM) applications. The inherent strength of the platform is to scale beyond these early devices and address next generation capability in terms of Optical Cross-Connects (OXC), integrated, multi-function multi-WSS chips and arrays of devices.

2 MEMS Components in Optical Telecom

In 2009, the estimated global IP traffic was greater than 160 exabytes ($x10^{18}$). This volume is expected grow at a Compound Annual Growth Rate (CAGR) of 38 percent.[1] In addition to this rapid growth, the nature of the data transmitted is evolving thanks to uses such as video-on-demand, internet gaming, and ambient video. The growth and variety of IP content presents many challenges to service providers. They must provide an outstanding user experience, while continually reducing the cost per bit transmitted. The demand for network flexibility and ever-increasing bandwidth has given rise to constant advancement of telecom network technology and the emergence of the Agile and configurable optical network.

MEMS devices play an important role in the evolution of communication equipment. Several successful deployments of MEMS-enabled components have demonstrated that the technical advantages of MEMS devices can be delivered with the reliability required by the telecom industry. MEMS are commonly found in Variable Optical Attenuators (VOA), VOA arrays, Optical Channel Monitors (OCM), low and high port count WSS, and OXC.

3 Advanced Optical MEMS Platform Description

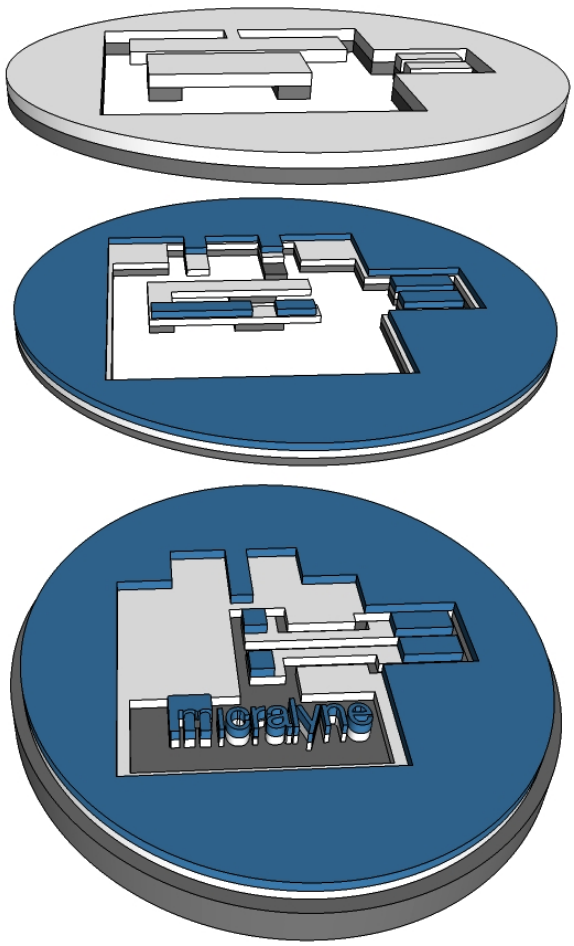

Figure A: Exploded view of a three wafer stack with etched microstructures.

Micralyne has introduced a configurable process platform that can be tailored to meet the needs of advanced module integrators. The process platform includes a unique combination of established MEMS technologies. The Engineering team at Micralyne has leveraged its extensive experience in developing bulk machined MEMS devices to create a flexible platform designed to created high performance tilting mirrors. Key processes within the platform include high-aspect ratio Deep Reactive Ion Etch (DRIE), aligned wafer to wafer bonding, non-contact stepper photolithography, and low stress mirror metallization.

The most advanced embodiment of this platform includes three functional layers of silicon that each contain etched microstructures **(Figure A)**. Wafer level bonding is designed to allow interlayer conductivity where required, with options including Si-Si and Si-metal bonding. Micralyne uses alignment and precision stepper capabilities to meet stringent device requirements. Flexibility in design and process fabrication enable a large range of novel devices.

Stepper lithography provides non-contact exposures with excellent repeatability, consistency, alignment accuracy, throughput, and quality. A minimum line / space CD of 450 nm is achievable, while a 90 nm three sigma layer to layer overlay is possible on planar surfaces. Micralyne has demonstrated that precise lithography alignment can be maintained when using 3D wafer stacking. With thoughtful process design, out-of-plane features can be aligned with only a small decrease in overlay tolerance.

This process flow can be used to create a vertical comb drive actuator, which is an important structure in the fabrication of advanced optical MEMS **(Figure B)**. The comb drive actuator provides nearly linear tilt response to the applied voltage at high angles. A well designed comb drive actuator can also significantly reduce the voltage requirement to achieve high angles. This can provide a cost savings at the module level by simplifying the calibration of an assembled module and by reducing the need for high voltage driver chips.

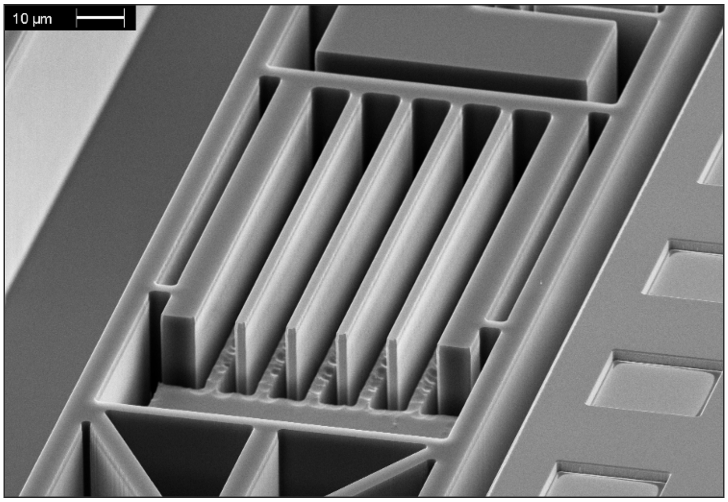

Figure B: Comb drive actuator

4 Example 1 - 1x2 Wavelength Selective Switch MEMS

The Micralyne Optical MEMS platform has been used to fabricate simple unidirectional (1D) tilting optical devices **(Figure C)**. These can be configured for use in VOAs and low port count WSS modules. Using a very simple process flow, we are able to create arrays of mirrors driven by vertical comb drives. The result is an array of mirrors requiring low actuation voltage and linear voltage-theta curve within its designed operating range **(Figure D)**.

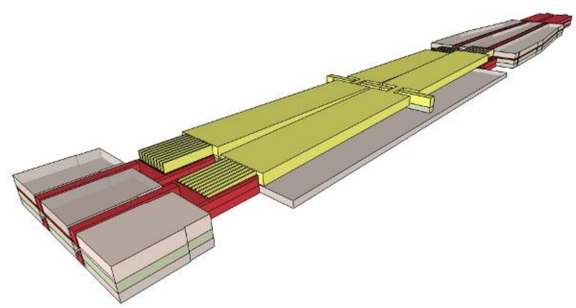

Figure C: Section sketch of a low tilt mirror array

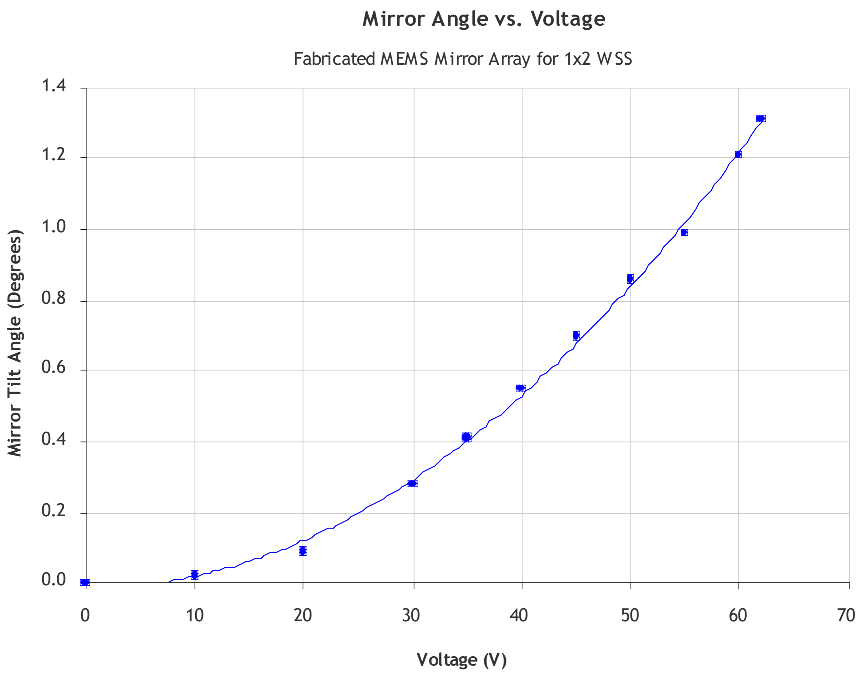

Figure D: MEMS for 1x2 WSS - Mirror tilt response to an applied voltage

The WSS 1x2 MEMS demonstrated is comprised of all-silicon wiring, actuators **(Figure E)**, and mechanical structures. The mirror surface and bond pads are coated with thin film gold metallization for high reflectivity and excellent wirebond performance. This elegant process has been shown to be highly manufacturable and is designed with volume manufacturing in mind. This is critical for deployment as optical switching migrates towards the edge of optical networks.

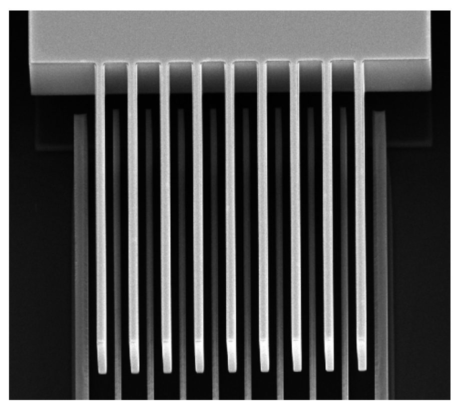

Figure E: Comb drive for 1x2 WSS

5 Example 2 - 1x23 Wavelength Selective Switch MEMS

The Optical MEMS Platform has provided a device for use in a high port count WSS **(Fig. F)**. Key elements of this design include:

1 Vertical comb drive actuators **(Figure G)** for greatly improved tilt-voltage drive linearity, higher tilt angles, and reduced voltage requirement compared to parallel plate actuators.

2 Hidden MEMS actuator and hinge enabling uninterrupted usable mirror surfaces in excess of 1.2 mm long.

3 Specially designed electrostatic roll drives for hitless functionality, capable of a high degree of decoupling from port-tilt actuation while requiring low voltages (< 50V) for full actuation

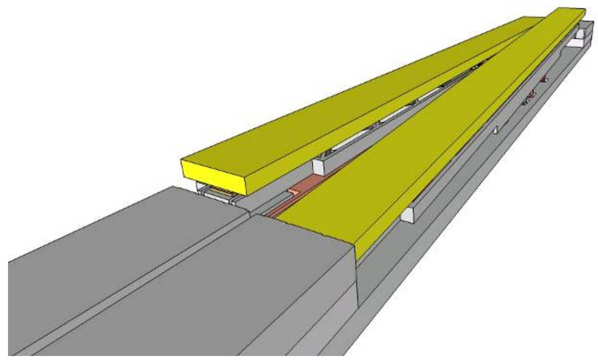

Figure F: MEMS for 1x23 WSS

Considering the tilt angles and the large usable mirror surface achievable with this design, optical designers are provided with a beam steering option capable of achieving the high port counts required of next-generation WSS MEMS. Additionally, the decoupled hitless and port tilt actuation can be used to provide a simple switching path, and enables a dramatic improvement in port-to-port switching speed.

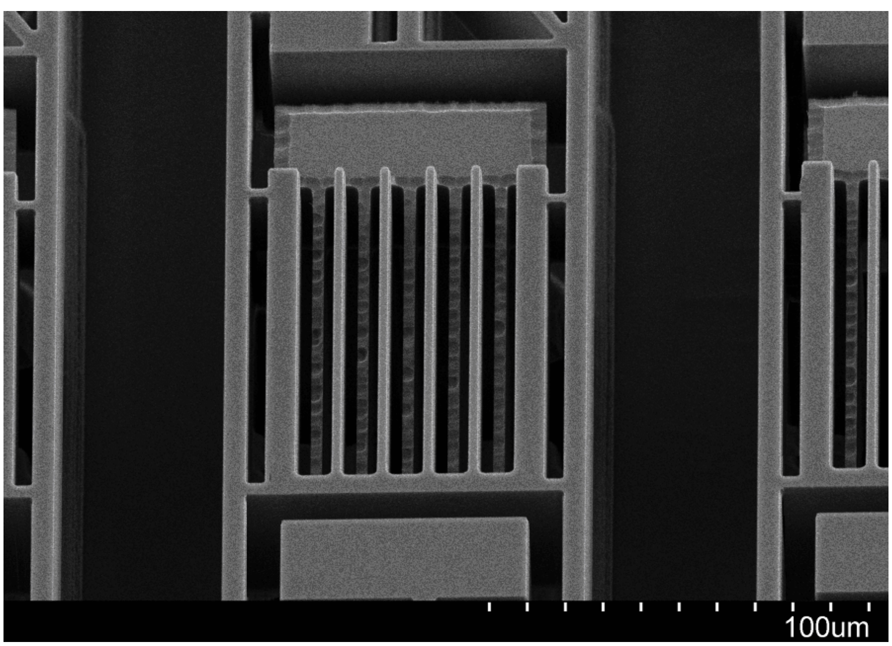

Figure G: Vertical comb drive actuators for port tilt actuation in 1xN WSS MEMS.

Devices have been fabricated at Micralyne, demonstrating both the high port tilt angles **(Figure H)** and the hitless tilt **(Figure I)**.

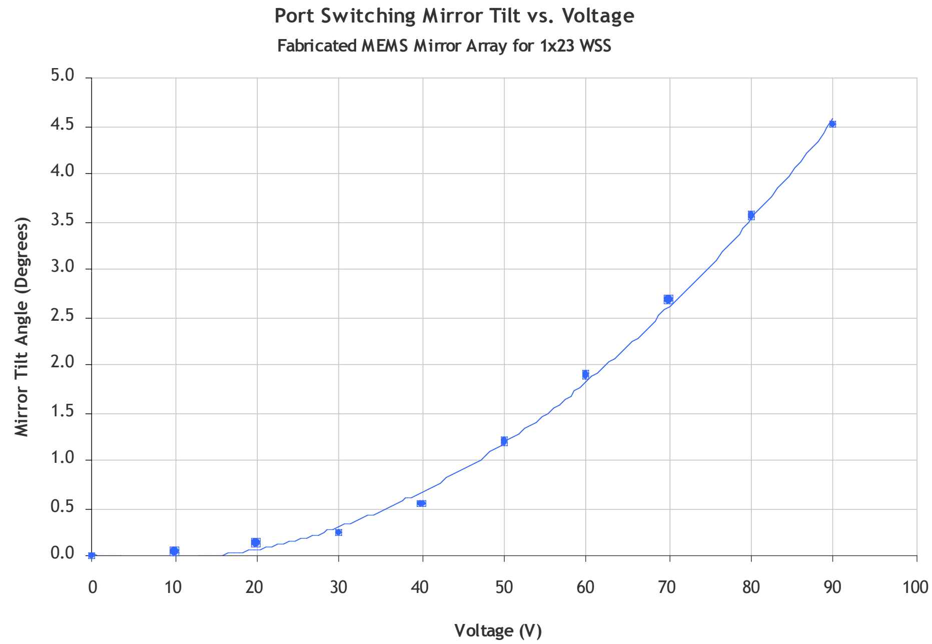

Figure H: Typical tilt drive characteristic of a 1440-µm-long1xN WSS device incorporating vertical comb drives for tilt actuation.

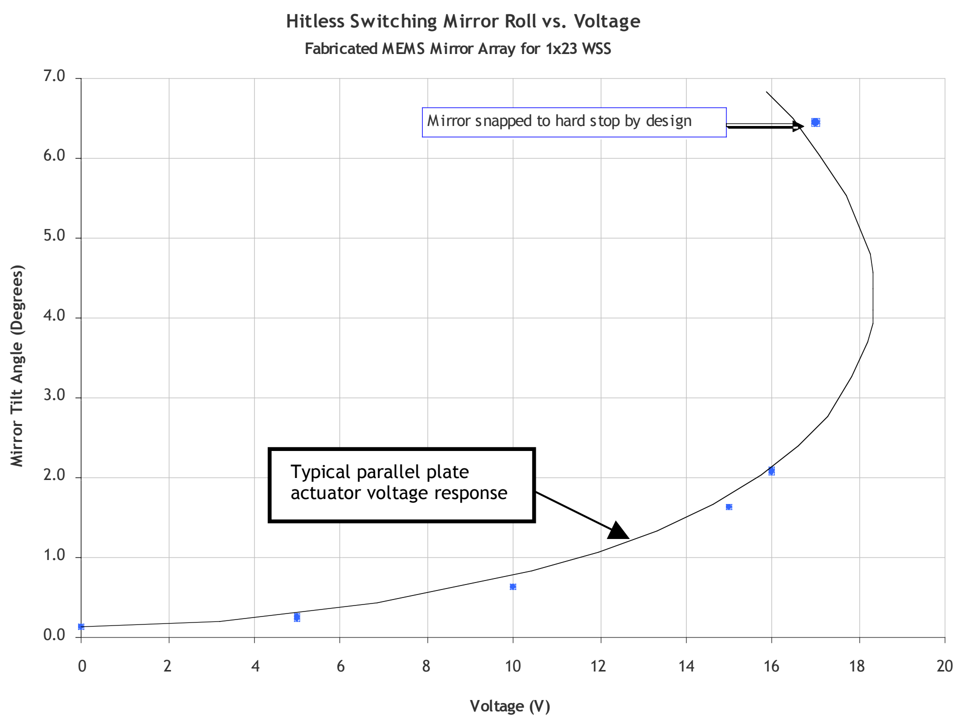

Figure I: Typical roll drive characteristic of a 1440-µm long 1xN WSS device incorporating low voltage, decoupled roll actuation.

These designs have proven capable of achieving tilt up to 4.5º using 1440 µm mirrors, a suitable combination of mirror length and tilt angle capable of meeting the demands of the high port count WSS market.

Additionally, these devices have demonstrated the feasibility of a low drive voltage roll drive scheme **(Figure I)**, including full roll actuation (in excess of 5 º) with a sub-20 V applied voltage.

The end result is an Optical MEMS for a high port count WSS design that provides module engineers and optical designers a high degree of latitude in creating their next generation modules, through its unique performance characteristics and design features.

6 Summary

Micralyne has created an Optical MEMS platform that will provide module designers with a depth of process technology and design guidance ideally suited for advanced telecom applications. Key performance requirements such as near linear mirror tilt response, at a significantly reduced voltage, have been demonstrated. This will enable overall cost savings at the module level.

We have presented a novel process that provides the benefits of a vertical comb drive, in an elegant and highly manufacturable format. This process will be able to quickly ramp up into volume production.

7 References

1 "Hyperconnectivity and the Approaching Zettabyte Era", Cisco White Paper, June 9, 2009

2 "ROADMs and the Future of Metro Optical Networks", Heavy Reading, Vol. 3, No. 8, May 2005,