SENKO®
Advanced Components

Your Source for Optical Interconnect Solutions **Design • Test • Manufacture**

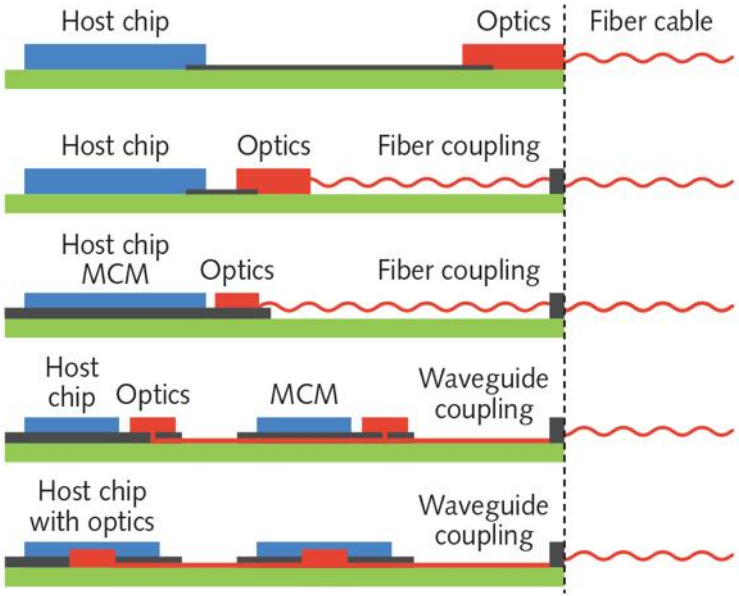
EPIC Meeting on CMOS Compatible Integrated Photonics at imec

Optical Interconnect in Co-Packaged Optics System

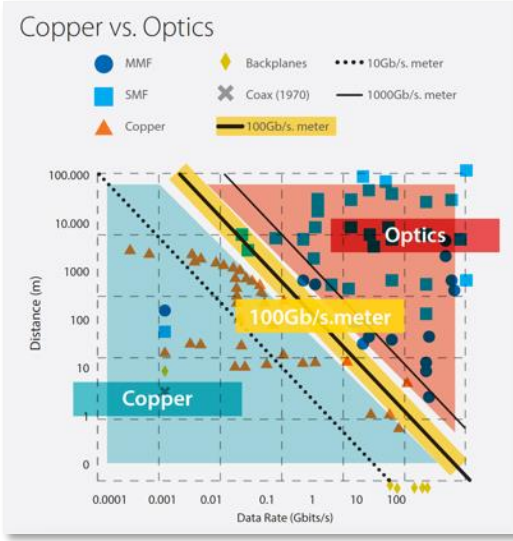
September 7th, 2022

Tiger Ninomiya (Tiger.Ninomiya@senko.com)

The Benefits of Co-Packaged Optics



Source: Laser Focus World



Source: IEEE

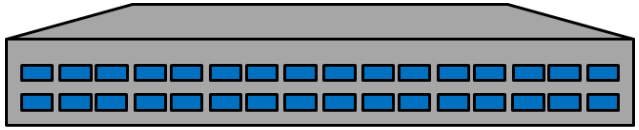
Migration to optics allows higher bitrates and longer reach

Source: Broadcom

Migration to optics enables lower per bit compared to copper

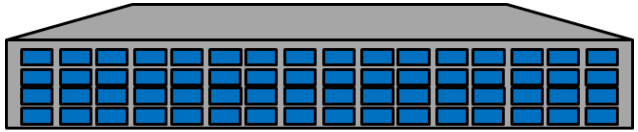
Optical Interconnect in CPO Switch

12.8 T Switch with Pluggable (DR4)



32-port x 8F with MPO-12 = **256F**

51.2T Switch with CPO (DR type)



64-port x 16F MPO-16 = **1024F**

Switch Bandwidth	12.8T		51.2T	
Optics type	FR	DR	FR	DR
Number of transceiver/OE	32 x Pluggable	32 x Pluggable	16 x CPO OE	16 x CPO OE
Bandwidth per transceiver/OE	400G	400G	3.2T	3.2T
Fiber counts per transceiver/OE	2	8	16	64
Wavelength per fiber	4	1	4	1
Total fiber counts	64	256	256	1024

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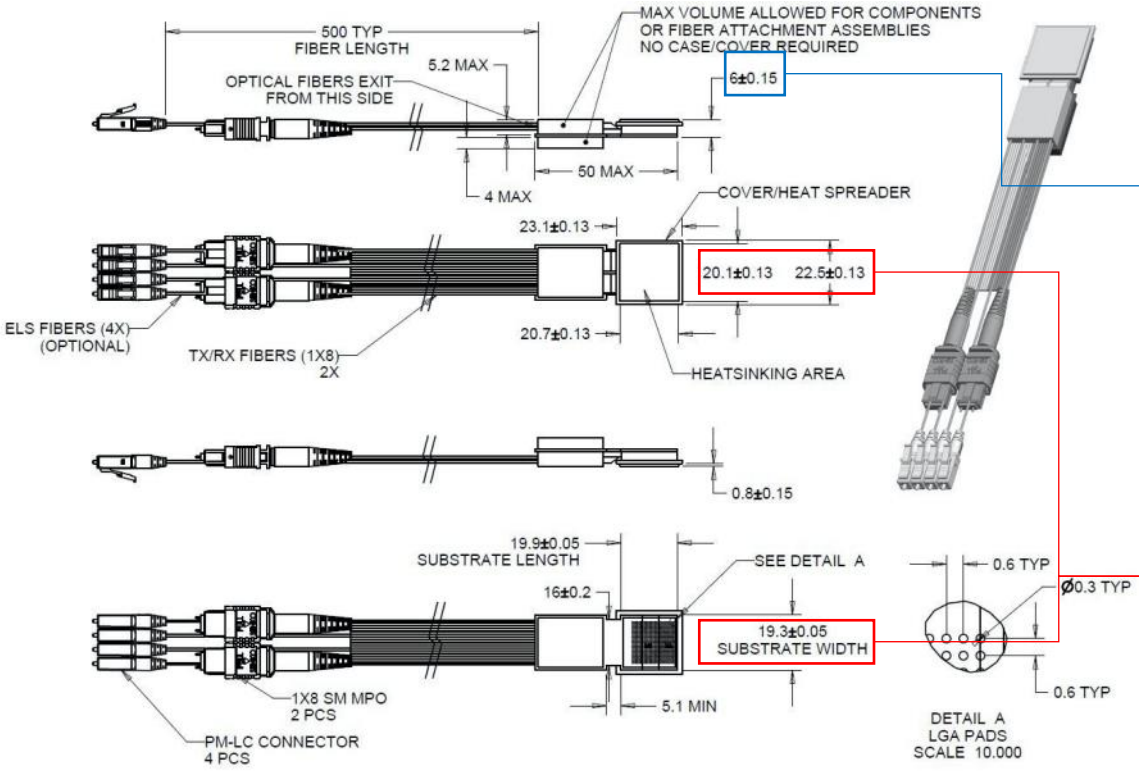
CPO Engine Size requirement



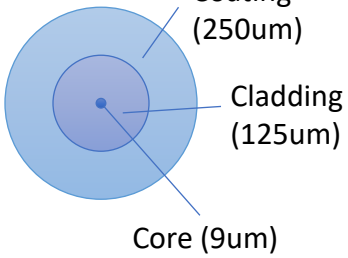
Reference: 3.2 Tb/s Copackaged Optics Optical Module Product Requirements Document, version 1.0, Feb 2021
http://www.copackagedoptics.com/wp-content/uploads/2021/02/JDF-3.2-Tb_s-Copackaged-Optics-Module-PRD-1.0.pdf

Height: 6mm

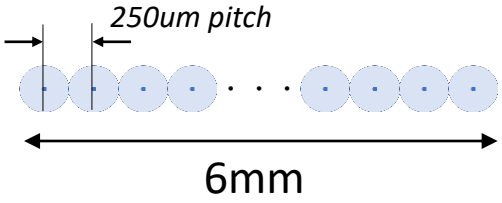
20mm width

CPO OE and fiber width

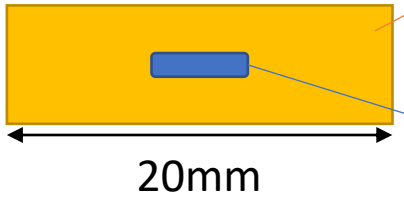
Regular fiber construction



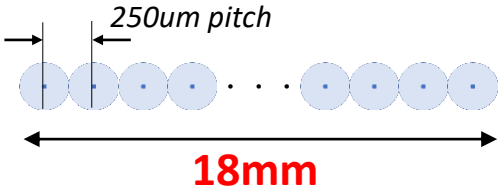
3.2Tb FR CPO OE FR: 24F (16F SMF + 8PMF)



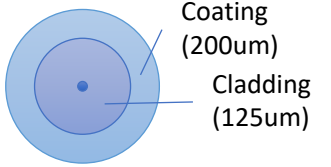
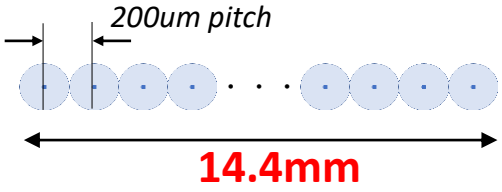
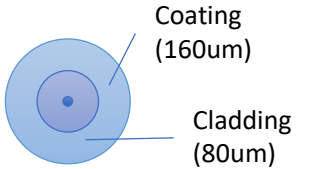
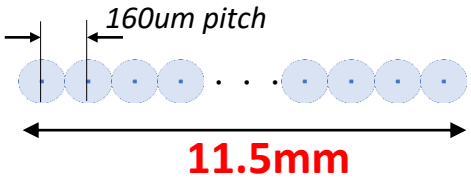
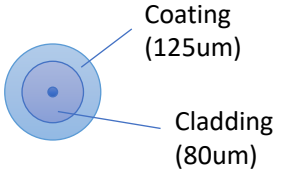
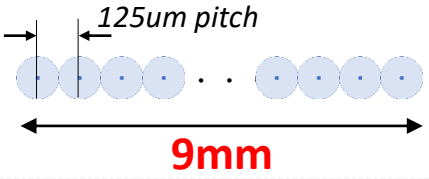
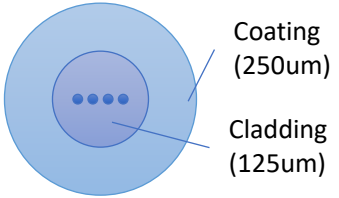
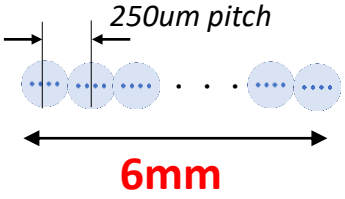
Front view of CPO



3.2Tb DR CPO OE: 72F (64F SMF + 8PMF)

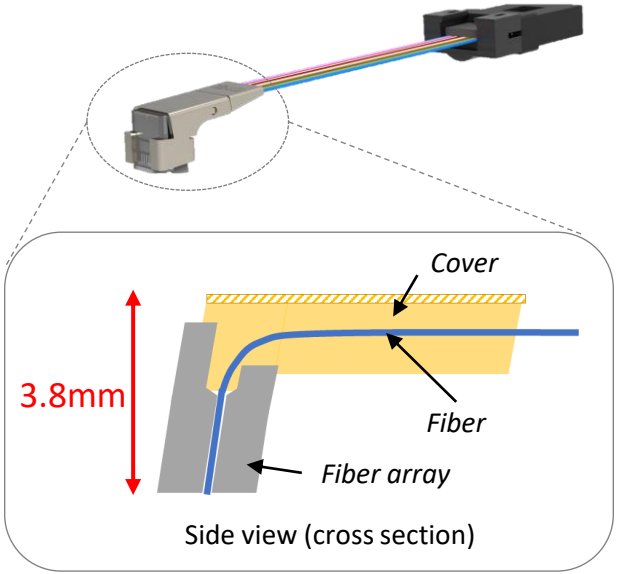


Use of special fiber for the width reduction

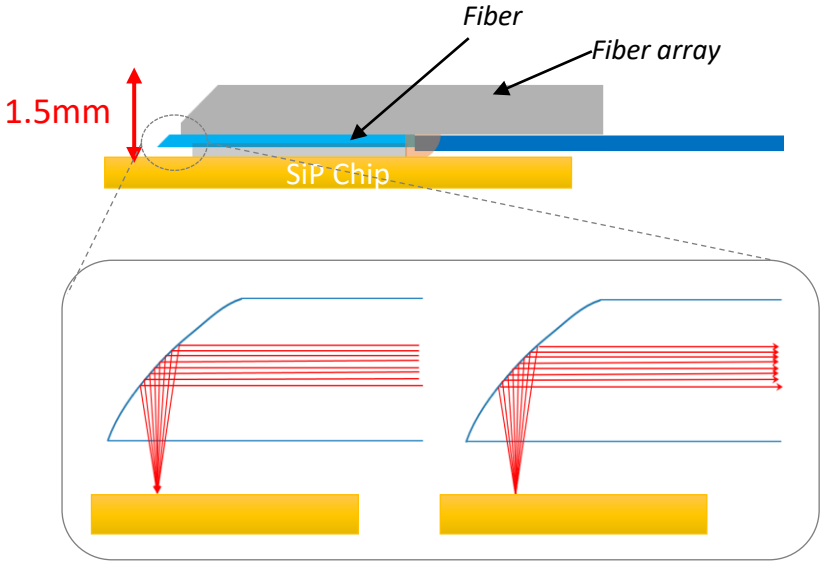
Fiber type	*Fiber construction*			
125um cladding 200um pitch			
80um cladding 160um pitch			
80um cladding 125um pitch			
MCF 4-core 250um pitch (16x MCF + 8xPMF)			

Existing low profile fiber coupler examlples

Fiber Bending Fiber Array



45deg polished fiber coupler



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Emerging coupler technology - Metallic Optical Bench -

Accurate Stamping Technology

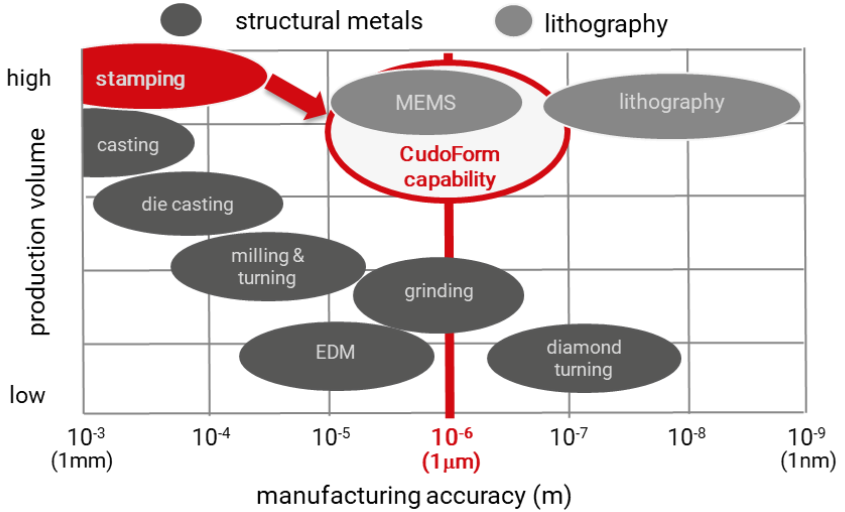
Accuracy at Scale

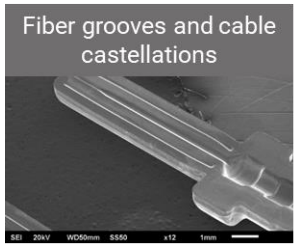
CUDOFORM
a SENKO Technology

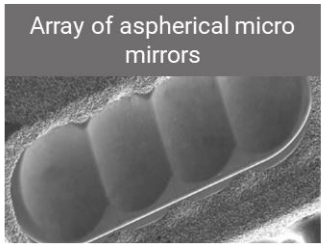
Stamping is a repeatable manufacturing process that offers unique economy of scale for high-volume production of fine-tuned micro-optics.

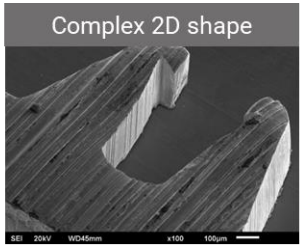
CudoForm's proprietary processes enable:

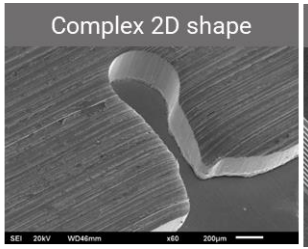
- ✓ Unprecedented accuracy
- ✓ Microstructures
- ✓ Reflective optical surfaces

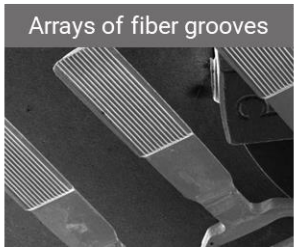


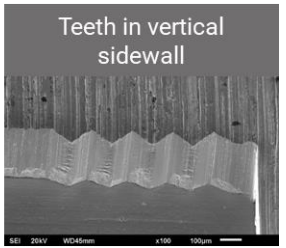












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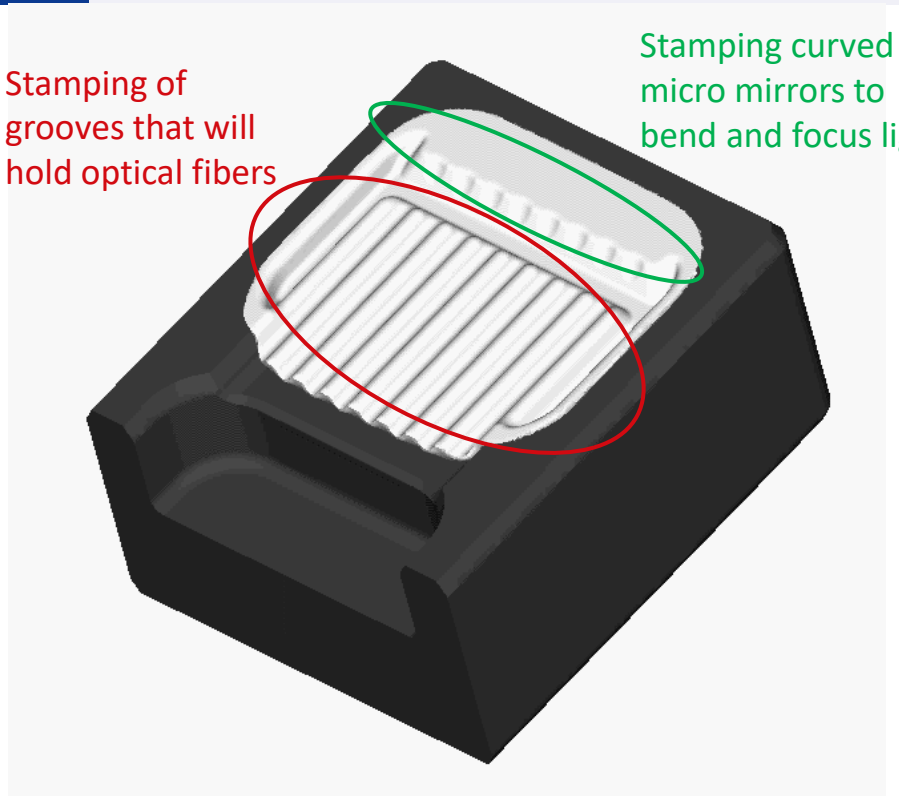
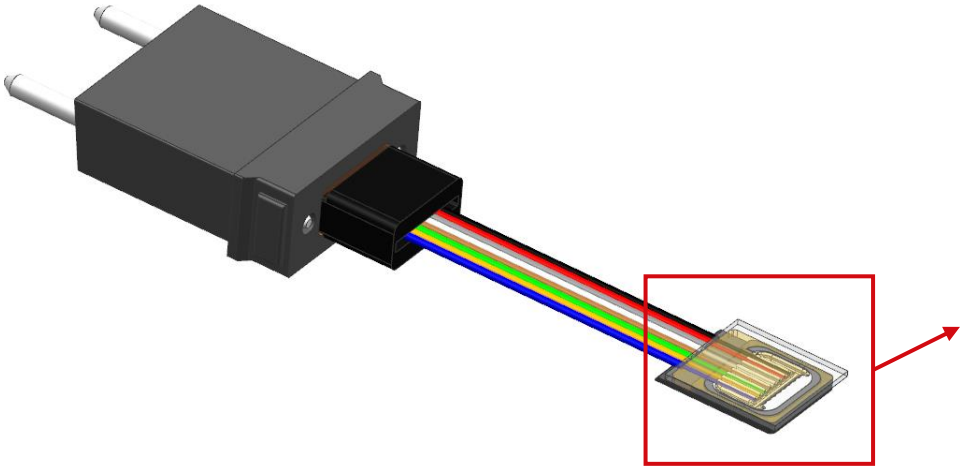
Stamping arrays of grooves and mirrors

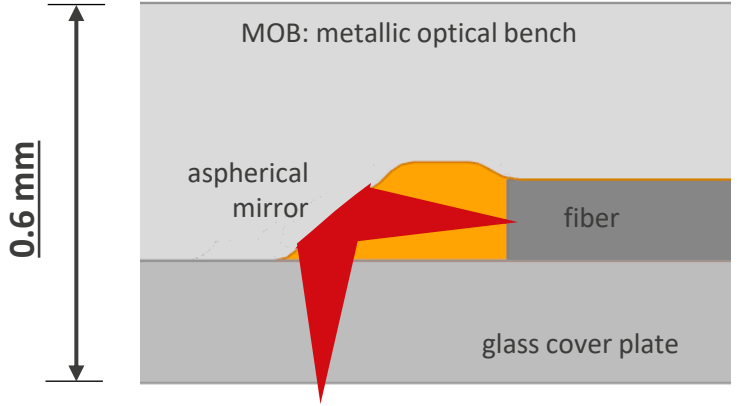


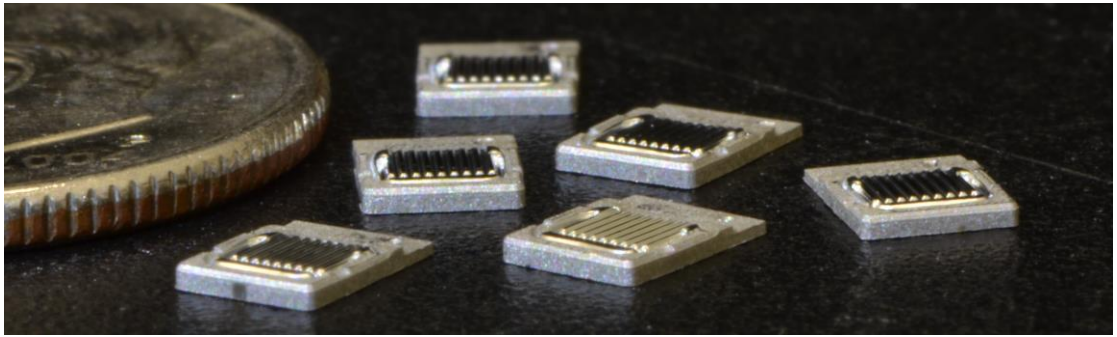
- Accurate stamping tools establish alignment between mirrors and grooves
- Correct for elastic deflection during stamping
- Correct for elastic spring-back after stamping
- Hard tools with accurate micro-scale features
- Hard tools with mirror finishes

Grooves and mirrors are aligned because of alignment in stamping tool

MOBs thinness as little as 0.6 mm

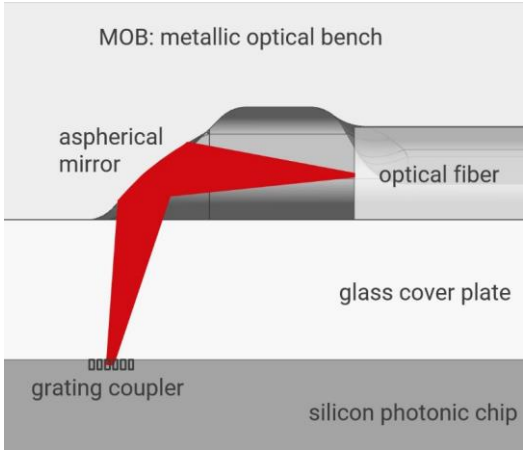




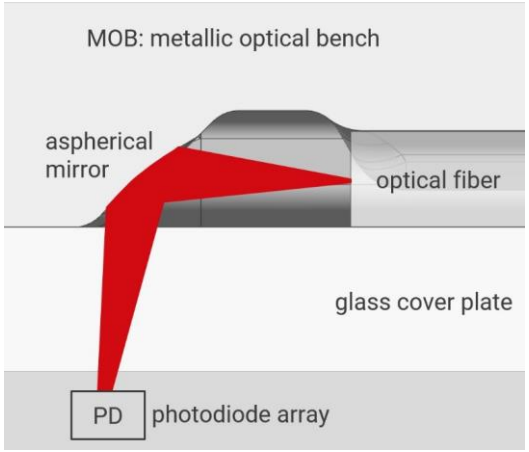


Total height: 0.6 mm to achieve the connectivity between fiber to grating coupler, photodiodes, or VCSEL. Flipped.

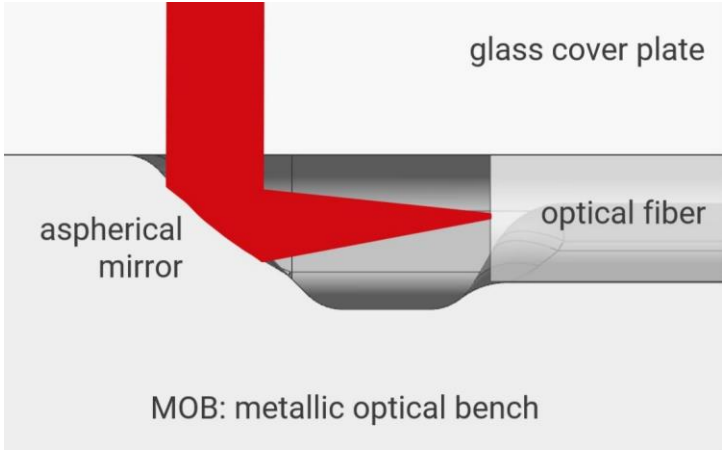
MOB Custom Design Examples



Design #1: silicon photonics



Design #2: photodiode arrays



Design #3: expanded-beam

Freeform optics in micro mirror arrays are suited to almost any optical connection

Temperature tolerance (preliminary test)

Damp Heat

85℃ temperature and 85% humidity
168 hours

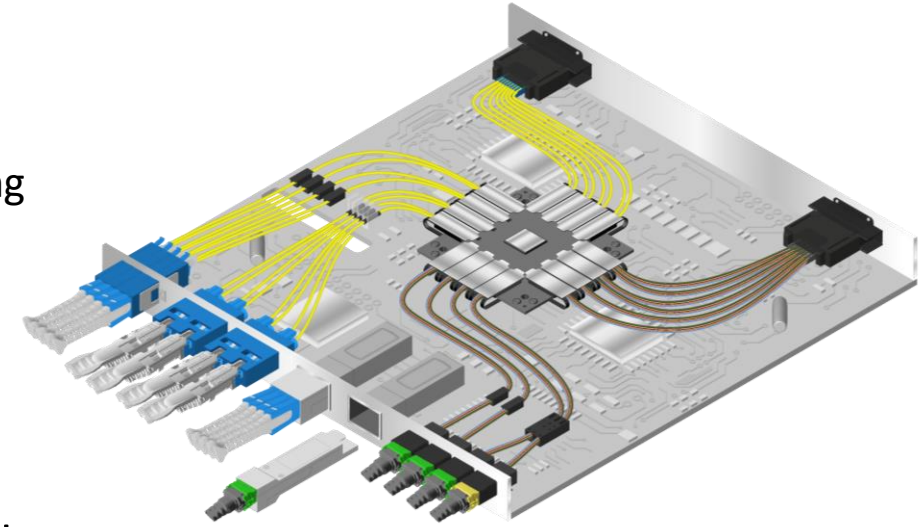
Temperature Dependent Loss

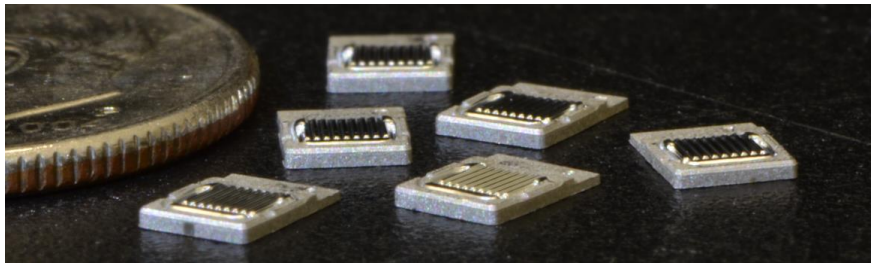
85℃ hot plate

Test	Results (delta IL dB)
Damp Heat	**Pass** • Max: 0.30 • Min: 0.02 • Ave: 0.13 • StDev: 0.0199
Temperature Dependent Loss	**Pass** • Max: 0.30 • Min: 0.07 • Ave: 0.19 • StDev: 0.0193

Summary

- For coming CPO:
  - The increase of total fiber counts
  - Tight space limitations for fiber coupling
- Potential resolutions
  - Use of emerging fiber types
    - Smaller diameter (cladding or coating)
    - Multi-Core Fiber
  - Use of low-profile couplers
- Introduction to Metallic Optical Bench
  - Low-profile
  - Better CTE using metallic materials
  - Customizable
  - Consistent performance against heat





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Growing Together

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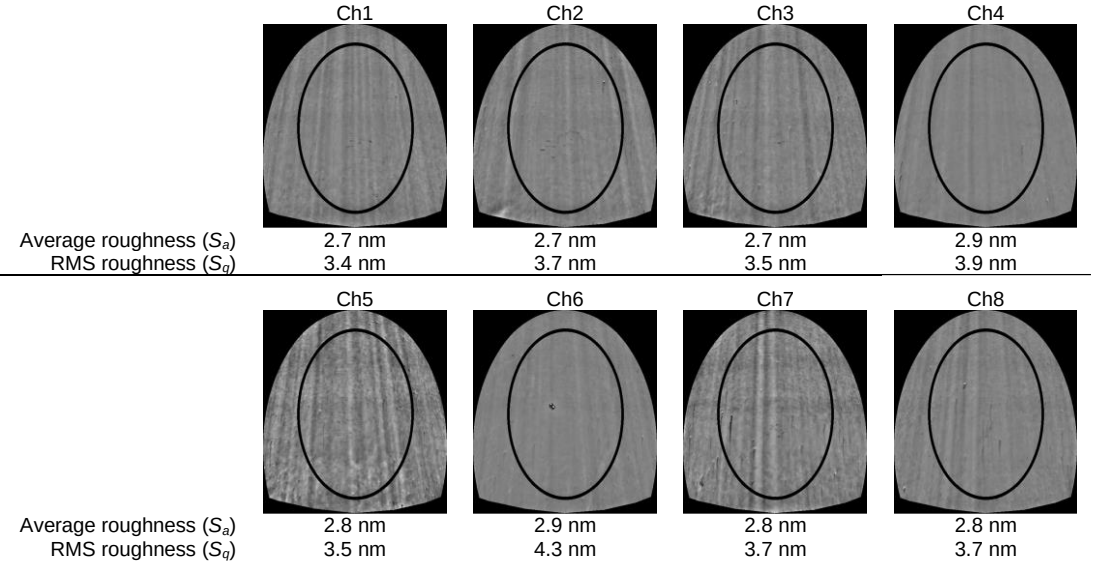
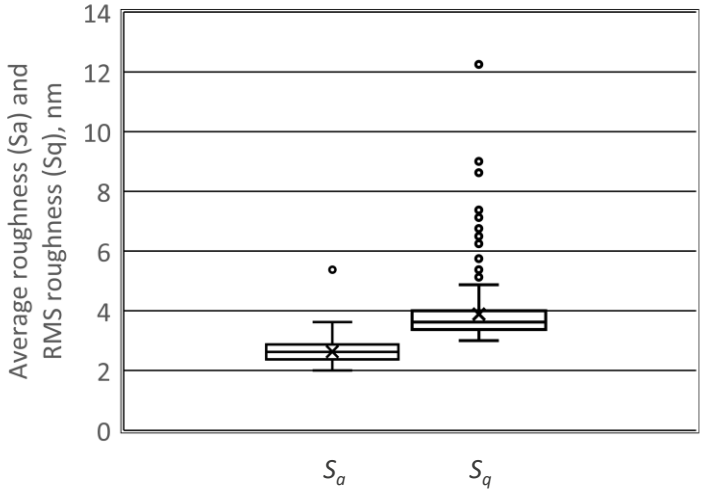
Assessment of surface finish on stamped mirrors



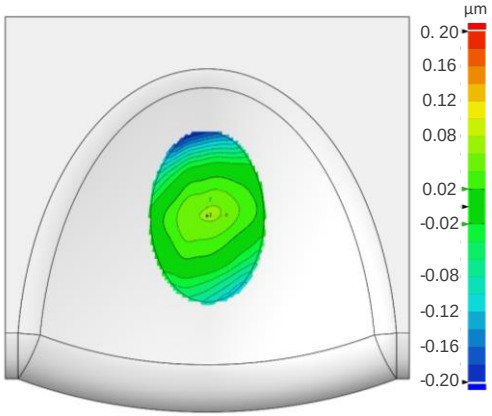
Typical surface finish for stamped mirrors in an 8X1 array, measured with a scanning white light interferometer

Statistical distribution of surface roughness attributes
Sa: Areal arithmetic average
Sq: Areal root mean square (RMS)

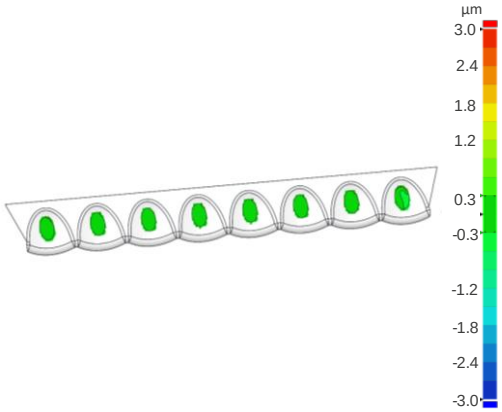


Optical quality, mirror finish on micro aspherical mirrors produced by stamping process

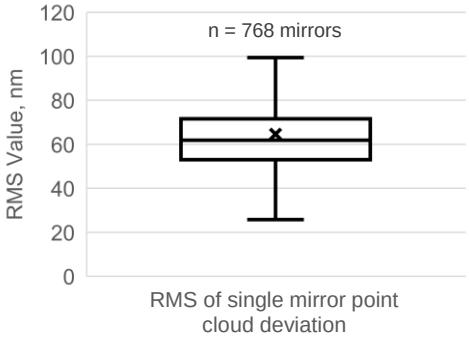
Form error for individual stamped mirrors and mirror array



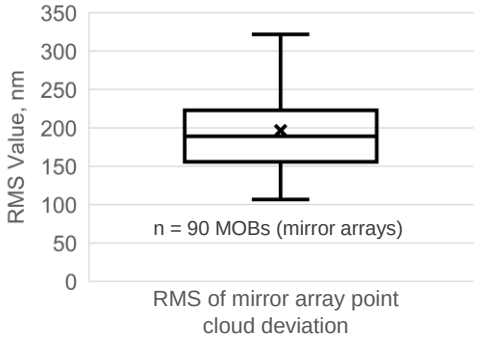
(a)



(b)



(c)

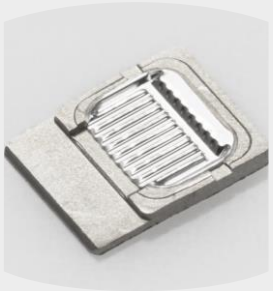


(d)

Form error measured with SWLI (a) Example of individual mirror form error defined as deviations from reference geometry in CAD model, (b) form error in apertures of mirror array, defined as deviations from reference geometry, (c) box plot of RMS of deviations for a batch of 768 individual mirrors stamped into metallic optical benches, (d) box plot of RMS of deviations for a batch of 90 mirror arrays stamped in metallic optical benches.

- Form error for individual mirror less than 100nm, for mirror array less than 300nm

Current Families of Optical Components

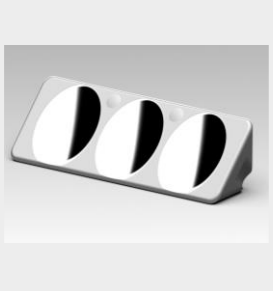


MOB

MOB: Metallic Optical Benches

MOR

MOR: Metallic Optical Reflectors



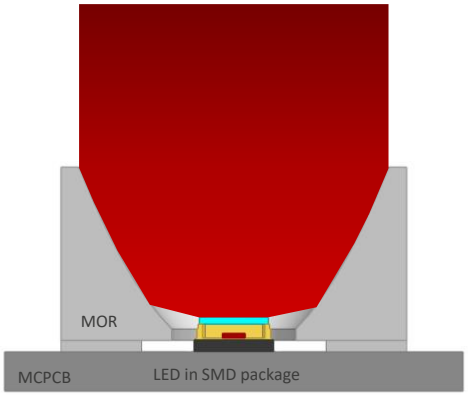
MLR

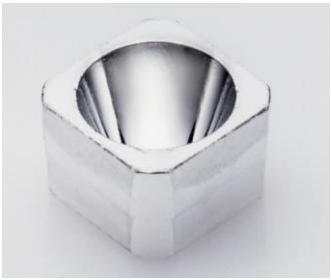
MLR: Metallic Laser Reflectors

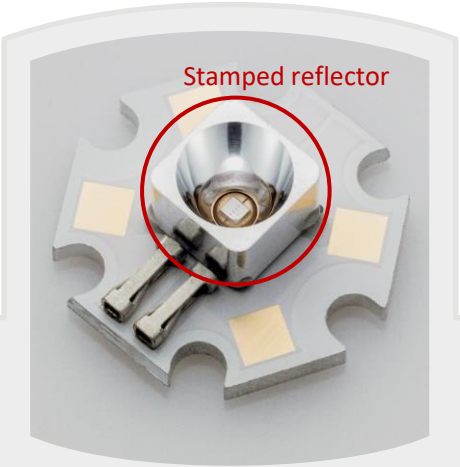
MOR: Metallic Optical Reflector

Example of optical component stamped by CudoForm

- Reflective mirror for shaping LED light
- Versions for bare dies and SMD packaged LEDs (3535, 6060, 6868)
- Tolerances below 2 µm
- Optically smooth mirrors condense or shape light from LED
- Size as small as 6.0 x 6.0 mm
- Rugged and thermally stable
- Constructed of aluminum







Proof of stamping excellence and proprietary process

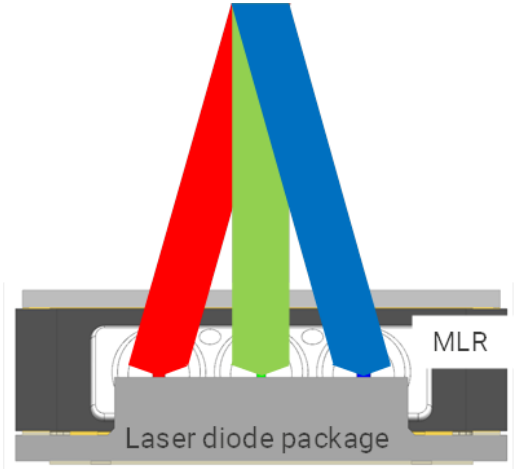
UV-C LED star-board module with MOR surrounding LED. The MOR concentrates emitted light so that applications receive greater dose in shorter time with less power.

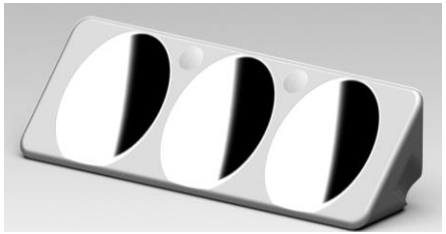
Chen et al. "Stamped metallic optical reflectors for ultraviolet light emitting diodes". Proc. Photonics West. 2022.

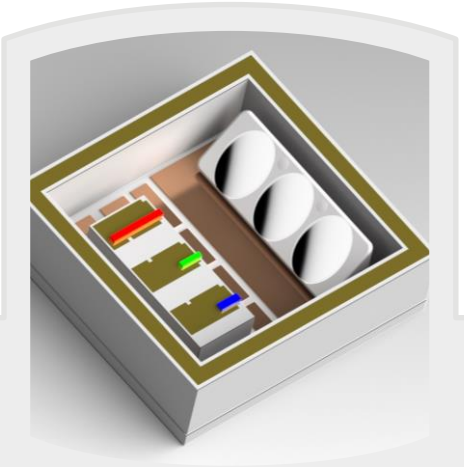
MLR: Metallic Laser Reflector

Example of optical component stamped by CudoForm

- Compatible with hermetic packages
- Shapes light emitted by laser diodes
- Focus, expand, or collimate
- Beam correction (FA and SA)
- Beam combination
- Tolerances below 1 µm
- Optically smooth mirrors
- For single lasers or arrays
- Rugged and thermally stable
- Constructed of aluminum







Application of stamped mirrors in laser beam module

Rendering of MLR used to shape and combine RGB laser beams in hermetic module.

Chen et al. “Improvements in size, weight, and cost of laser modules for AR|VR|MR using stamped reflective optics”. Submitted to SPIE Photonics West. 2023.