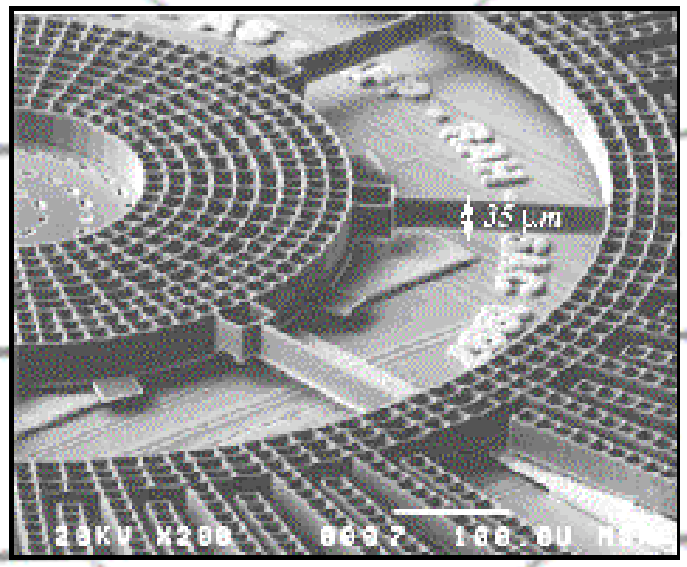
MicroAssembly Technologies



- MEMS SLMs
- MEMS-CMOS Integration
- High Force Actuators
- Low Temperature Bonding
- Nanolaminate Bonding

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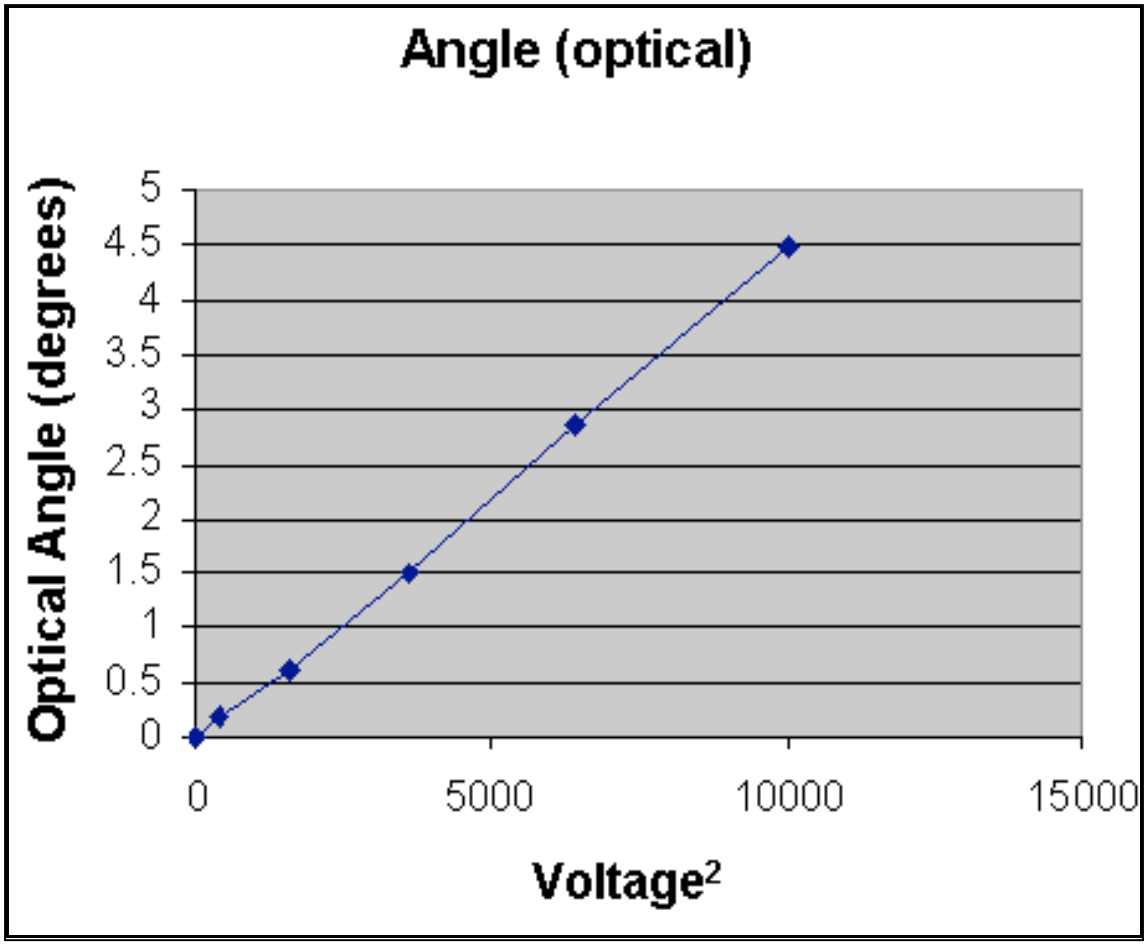
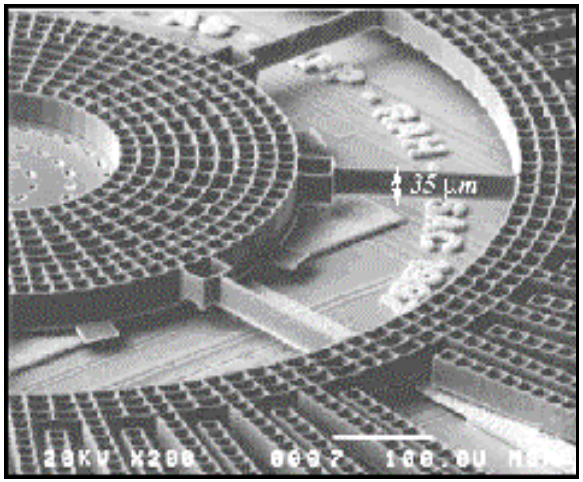
Product: MEMS SLM

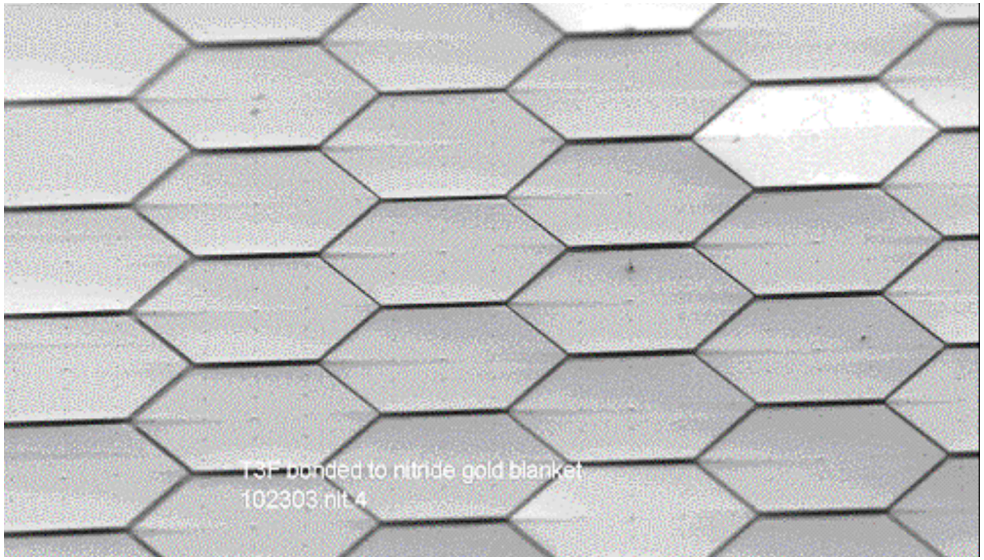
- High Performance Tip-Tilt-Piston Actuators
- Reflector Transfer
- Linear Response

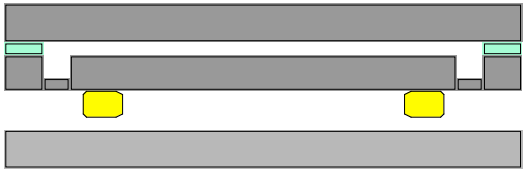
- DoD Contracts (AFOSR, DARPA, MDA)

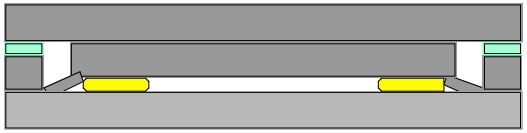


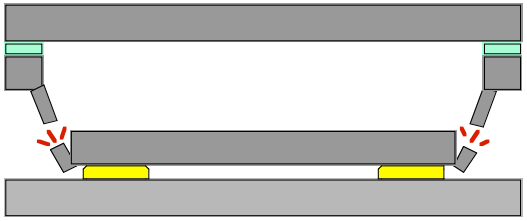
Tool: MEMS Transfer Process











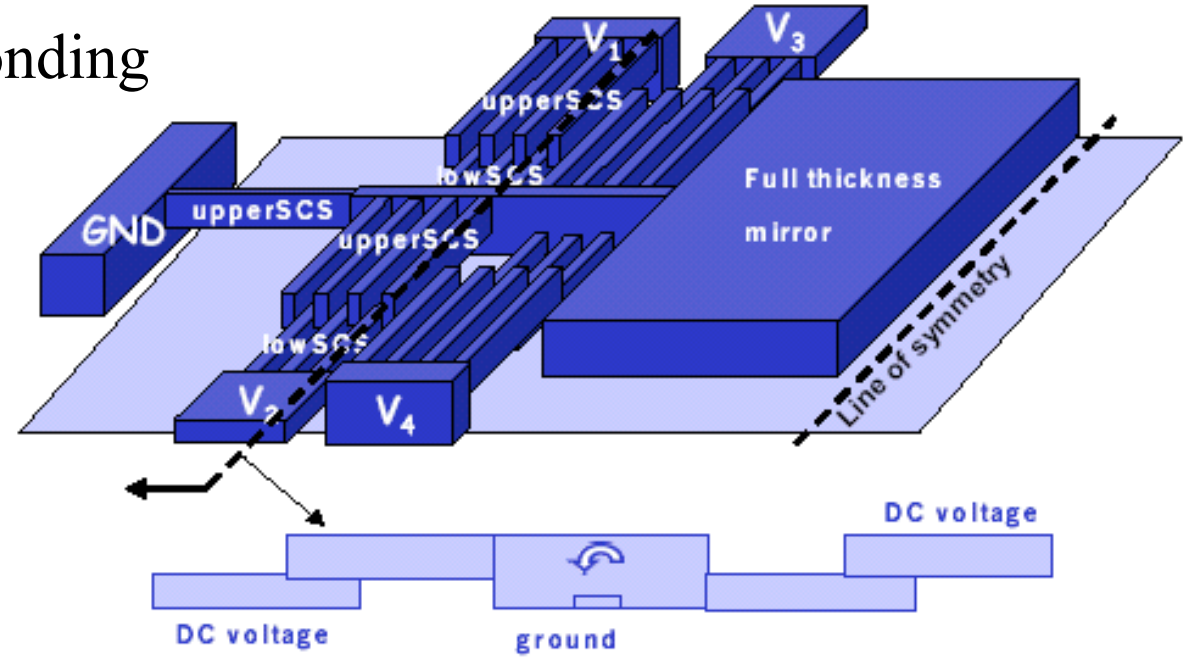
Low Temperature Bonding

- 300°C standard CMOS-compatible process, room temperature for Silicon substrates
- Thousands of reflectors at a time
- MEMS-CMOS Integration: Monolithic performance
- Hermetic/vacuum sealing

- Microbump integration: 100% yield, N=1024
- Pilot production

Relevant Technologies

- Electrostatic Comb Drive Piston Actuators*
  - Thick and Thin Single Crystalline Silicon (SOI) Mirrors
  - 5 Generations of Actuator Design & Fabrication (in collaboration with ARI)
  - Cryo Devices
- Nanolaminate Bonding



* patents pending

High Performance Piston Actuators

Relevant Part Under Development

- Comb drive piston actuators
- Piston stroke: 6 μm
- Frequency response: 27 kHz
- Size: 300 μm

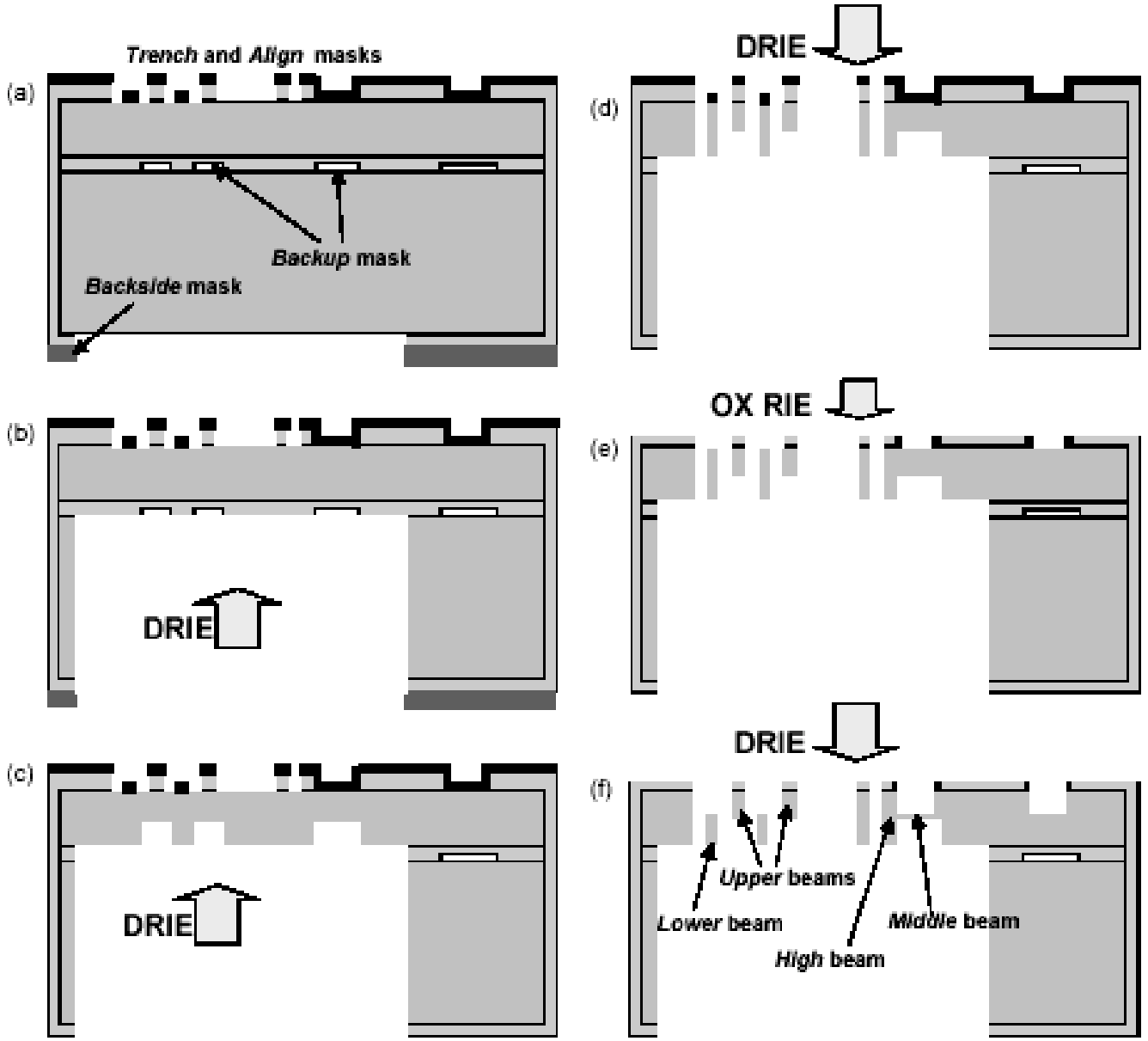
- Conservative fabrication design rules (less than 10:1)
- Possible: Larger stroke, higher frequency response
- Already demonstrated much faster tip-tilt-piston devices*

* patents pending

Comb vs. Parallel Plate

- Parallel Plate
  - Foundry Process
  - “Proven”
- Comb Drive
  - High Energy Density: Stroke, Frequency Response
  - Fabrication Challenges: Alignment, Assembly, Large Arrays
- MicroAssembly Approach
  - Reduce etch steps
  - “Disintegration” and Assembly vs. Monolithic

Earlier Comb Process (ARI, 2001)



Nanolaminate Bonding

- Bond to dummy substrates
- Bond to actuators from BMC

- Low temperature thermocompression process
- Print-through concerns
- Edge effects

- Subcontract from LLNL

Nanolaminate Bonding: 1st Result

Surface Stats:

Ra: 491.80 nm

Rq: 611.67 nm

Rt: 6.17 um

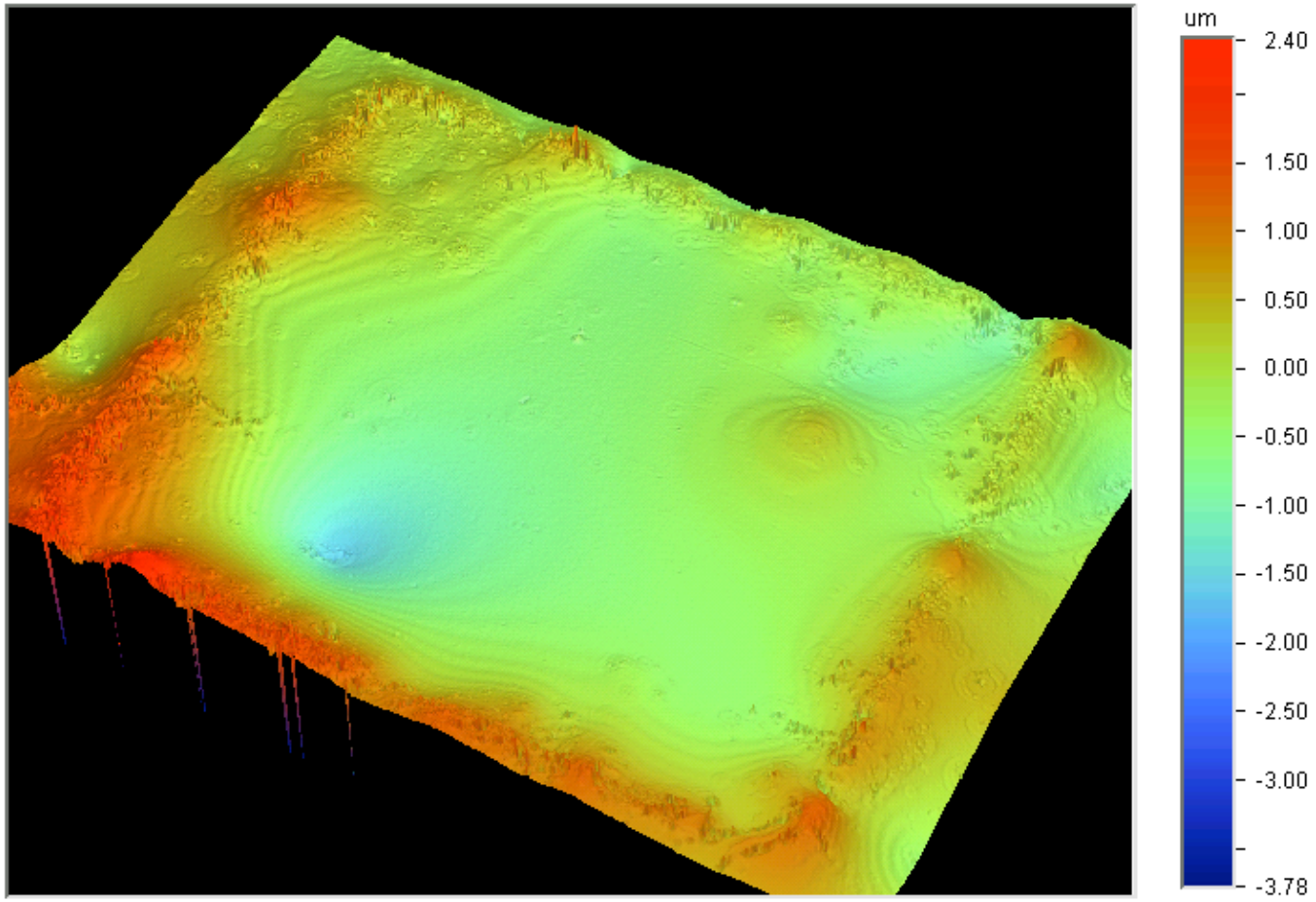
Measurement Info:

Magnification: 5.17

Measurement Mode: VSI

Sampling: 1.63 um

Array Size: 736 X 480



Latest Bonding Result

Surface Stats:

Ra: 129.24 nm

Rq: 247.88 nm

Rt: 4.82 um

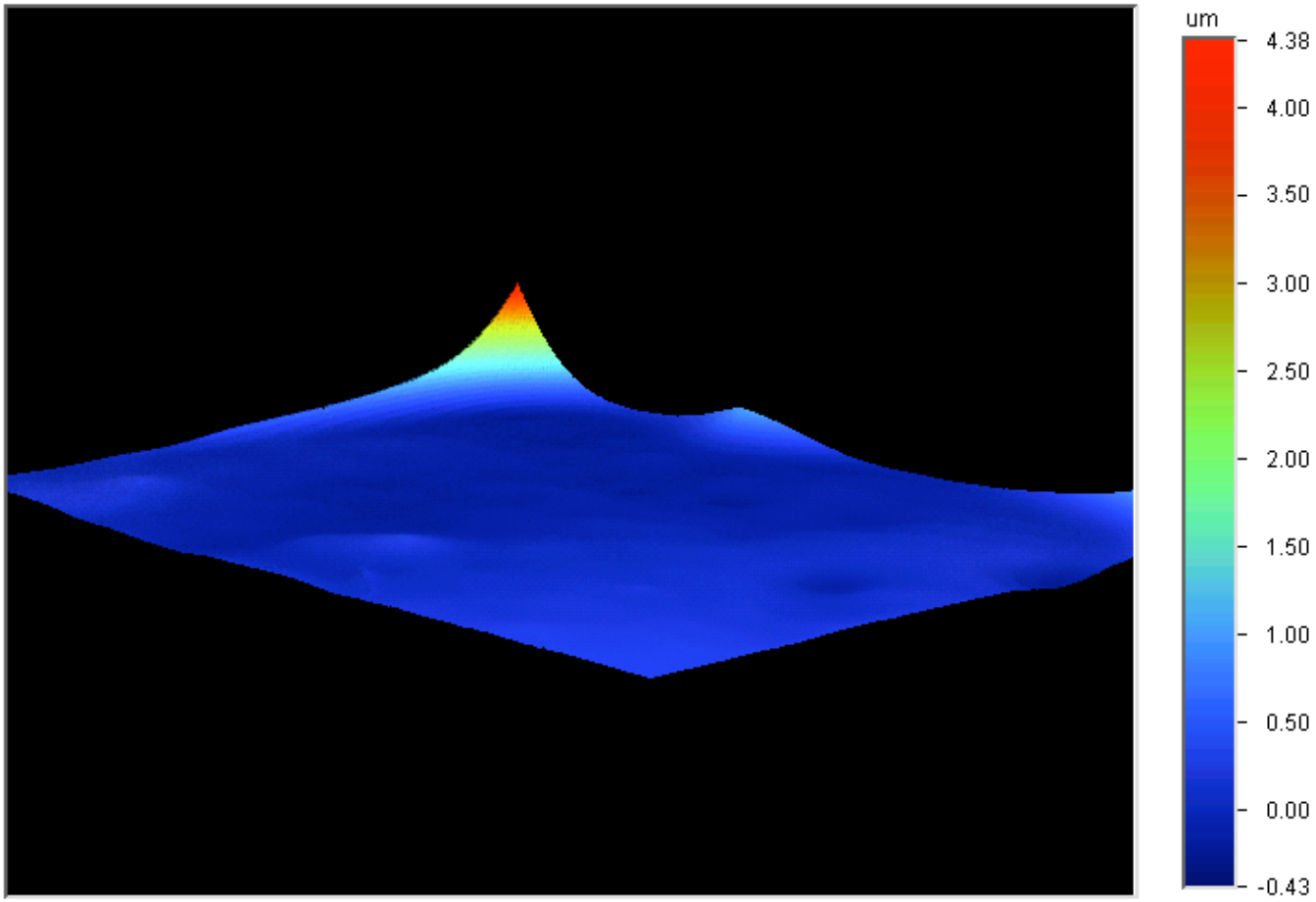
Measurement Info:

Magnification: 1.02

Measurement Mode: VSI

Sampling: 8.20 um

Array Size: 736 X 480



Title:

Latest Bonding Result

Surface Statistics:

Ra: 5.95 nm

Rq: 7.73 nm

Rz: 43.50 nm

Rt: 44.26 nm

Set-up Parameters:

Size: 736 X 480

Sampling: 820.31 nm

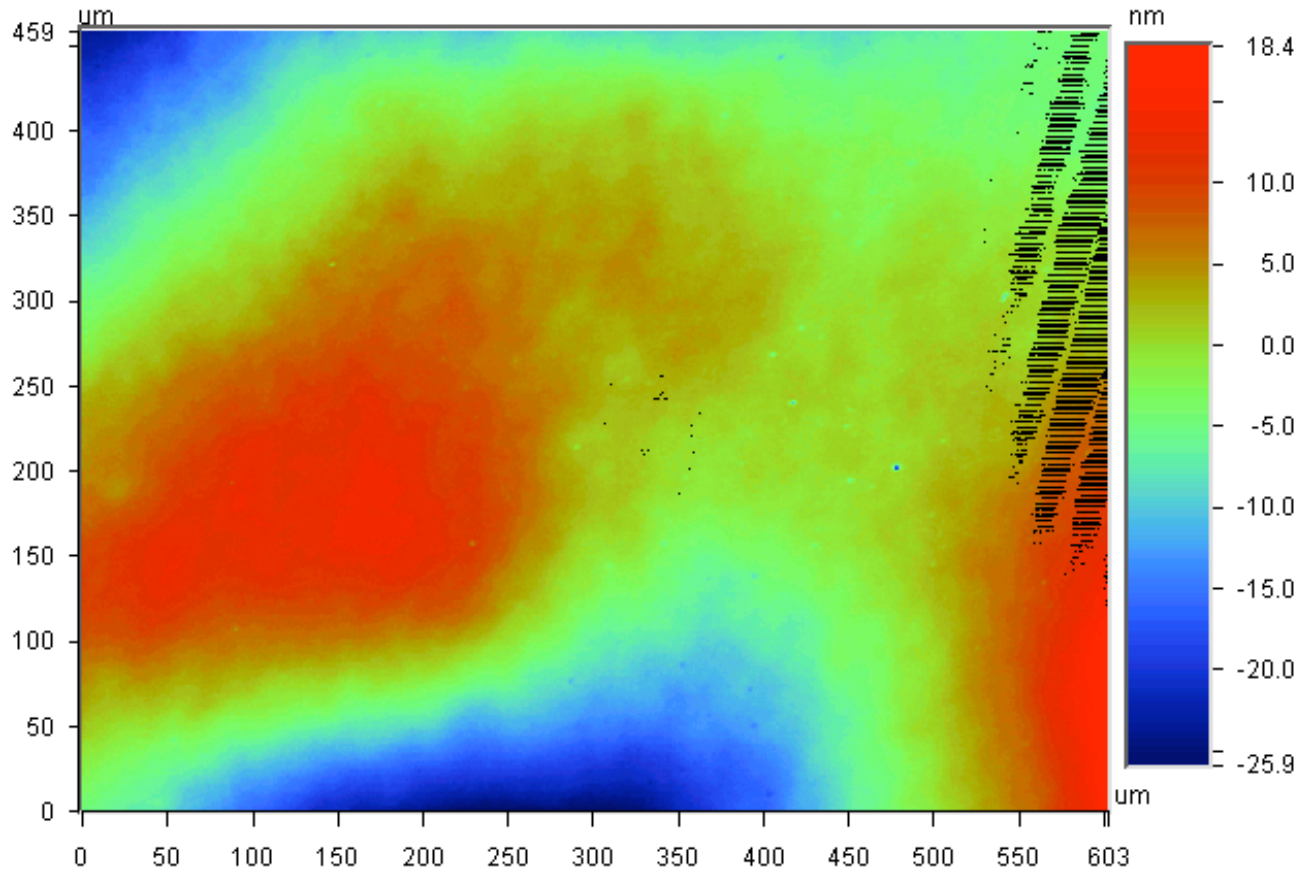
Processed Options:

Terms Removed:

Tilt

Filtering:

None



Latest Bonded Sample

Next Steps

- MEMS SLM
  - Drive Electronics
  - MEMS Fabrication Iterations
- Collaboration with LLNL and Other System Designers
- Nanolaminate Bonding
  - Larger Substrates
  - Edge Effects
  - Actuator-Nanolaminate Bonding

Applications: Free Space Optics Telecom, Imaging, Targeting, Ophthalmic, Tweezers