AO Components
MEMS*

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MEMS Role in TMT AO architectures

Potentially the deformable mirror in all the AO systems

- PFI baseline: 10K actuators for high contrast and large discovery space in the image plane
  - MEMS is a cost-effective solution
  - Small size reduces size of instrument, favorable for stability
- IRMOS baseline: as many as 30 DMs in the system
  - one per IFU, one per guidestar
  - Low cost and small size are the great enabler of MOAO
- NFIRAOS “petite” – a second light option for MCAO
  - 3-4 DMs at multi-conjugate altitudes, widens the field for WIRC
- MIRAO – MEMS at cryo has been tested

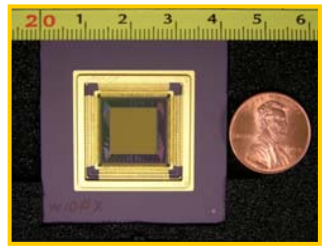
Requirements vs state of the art

	Present capability (can buy today)	Requirement
Continuous mirror surface	One manufacturer	Required for PFI
Segmented mirror surface	Two manufacturers	Possibility for MOAO
Actuator stroke	4 microns (on 100 actuator device)	10 microns or 3 microns + woofer
Number of actuators	1000 (on 1μ stroke device)	10,000 (PFI) 4,000-10,000 (MOAO, MCAO)
Closed Loop Bandwidth	250 Hz	250 Hz
Actuator defect rate	About 1%	0.1% (PFI)
Operating temperature	Room temperature (should work cold, but not tested)	-30C (MOAO, MCAO)

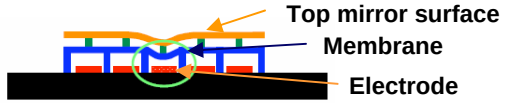
Ongoing work in MEMS Development

- Testing of 1K MEMS in the lab (LAO)
- Consortium* to build 4K and 10K actuator devices for ExAO and MOAO
  - Gemini, CfAO, UCO/Lick (LAO), TMT
  - Identified 2 potential vendors (BMC, MAT)
- Research on higher stroke actuator designs (CfAO)
- Research on nanolaminates and bonding

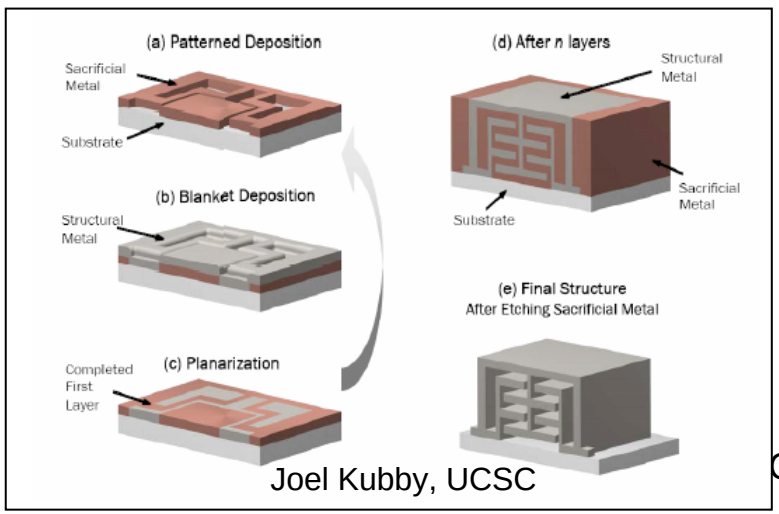
Boston Micromachines Corporation



32x32 actuator MEMS DM



MEMS electrostatic actuator concept
(Tom Bifano, BMC)



Joel Kubby, UCSC

MicroAssembly Technologies, Inc.

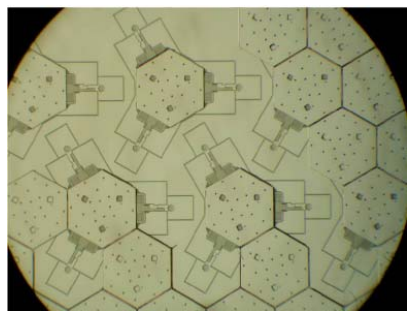


Figure 1. Assembled micromirrors, spaced apart to facilitate testing.

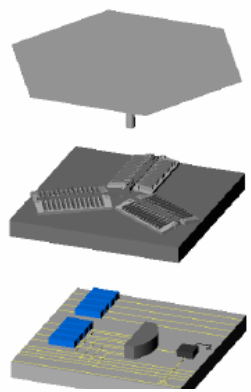


Figure 2. SLM Architecture: A modular design incorporates three layers, mirror, actuator and electrical backplane. The layers are assembled using a proprietary bonding process.

The 1K MEMS has achieved a 10^6 contrast goal in the lab

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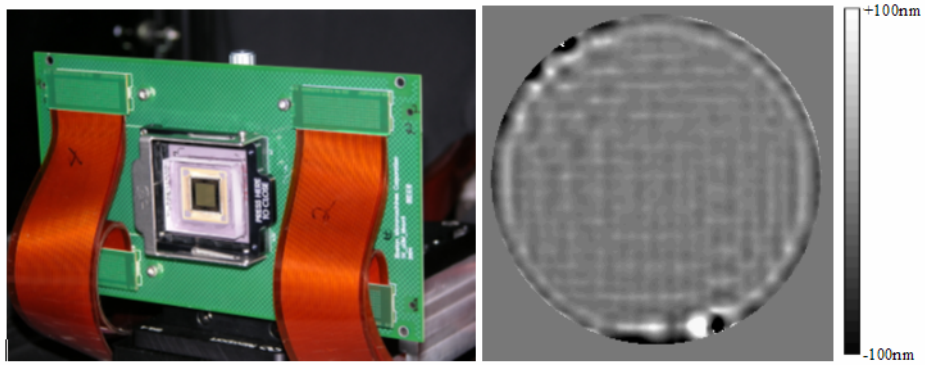

Figure 7. Left: the MEMS deformable mirror is shown in its mount.Right: grey-scale display of wavefront phase, as measured by PSDI, of a 9-mm diameter circular beam of light reflected off the central area of the MEMS. The MEMS device has a 10-mm square active area. An iterative algorithm using PSDI measurements determines the voltage commands required to achieve maximum flatness. The residual wavefront error visible, on the order of 5 nm rms, is mostly "print-through" of actuator mounting structure to the continuous mirror surface. This high spatial frequency ripple scatters light mostly outside of the discovery region in the final image.

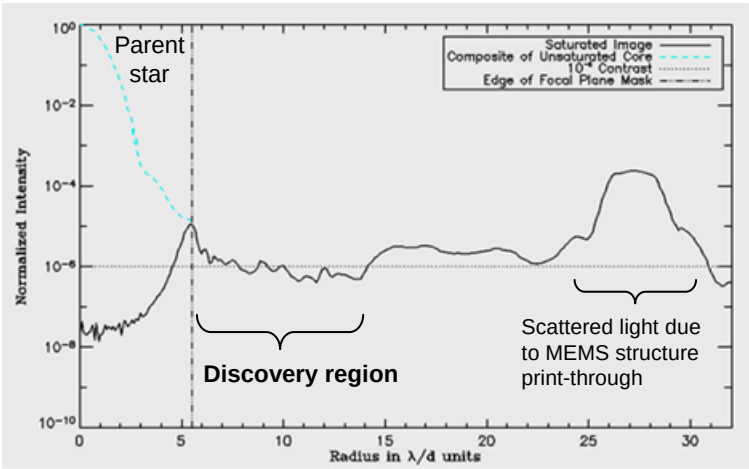

Figure 6. Far-field contrast with the MEMS device flattened to ~<1 nm rms in its controlled spatial frequency band and the shaped pupil mask used to suppress diffraction. The dark hole (discovery region) extends to 14 λ/d. From 6-10 λ/D the average contrast is 1.21 x 10^{-6}, in the 7-14 λ/D range contrast is 7.89 x 10^{-7}.

- Closed-loop with 32x32 Hartmann sensor on Kolmogorov turbulator plate
- About 2 nm rms residual wavefront error

Follow-on Work

- Producing 4K prototype devices in FY06
- Usable 4K mirrors out of fab in 28 months (Dec 07)
- Scale-up to 10K mirror using same process – output from first fabs in 2007

WBS	Task Name	Duration
1	Prototype Actuator Design, Fab, Test	6 mons
2	Design 4k device & chip carrier, Fab, Test	9 mons
3	Fab 4k science grade device	12 mons
4	Design 10k device & chip carrier, Fab, Test	9 mons
5	Fab 10k science grade device	12 mons