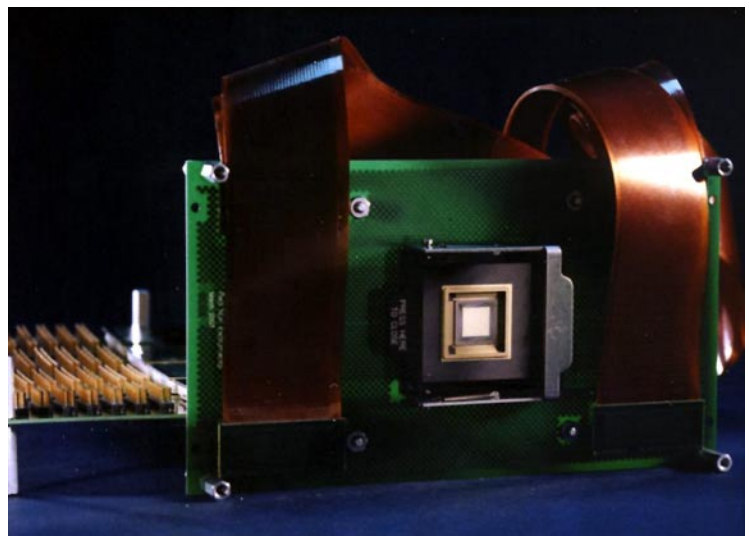
MEMS deformable mirror technologies for the Thirty Meter Telescope (TMT)

Paul Bierden

Boston Micromachines Corp



CfAO TMT MEMS DM Workshop

August 19, 2004, UCSC

Boston Micromachines Corporation

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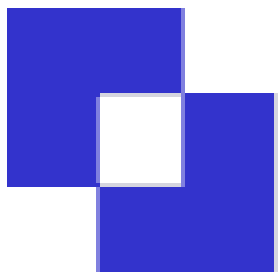

Founded: May 1999

Located: Watertown, MA

Spin Out Technology from Boston University

7 Employees

Focused on commercialization of MEMS mirror products

First sales of flagship product μDM140 in May 2000, product incorporated as enabling technology for R&D 100 Award winning optical instrument in 2003

Broad IP Protection

Frequent technical collaboration with Center for Adaptive Optics

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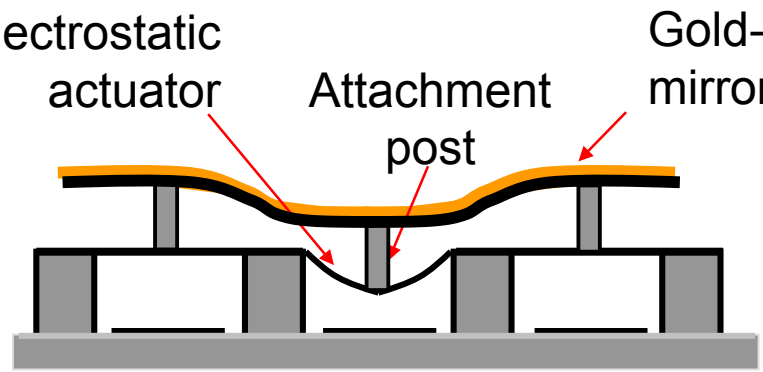
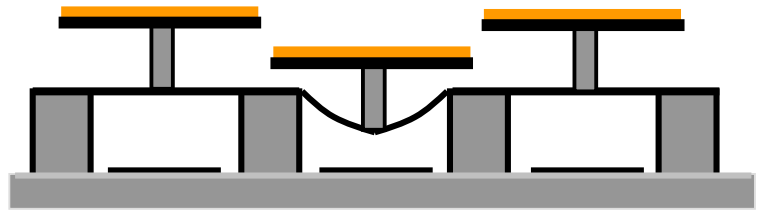
Silicon micromirror design

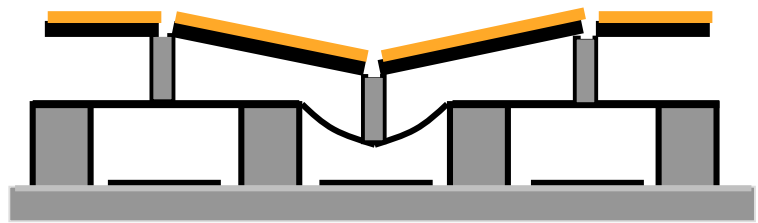


Continuous mirror (smooth phase control)



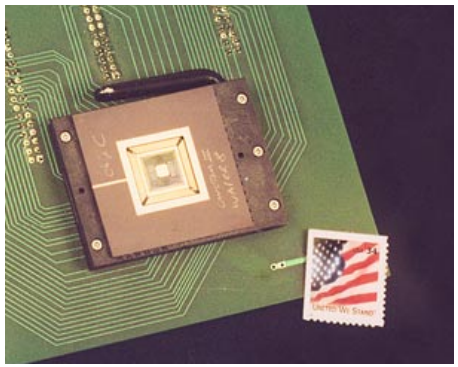
Segmented mirror (uncoupled control)

- Electrostatic actuation
- Foundry silicon micromachining

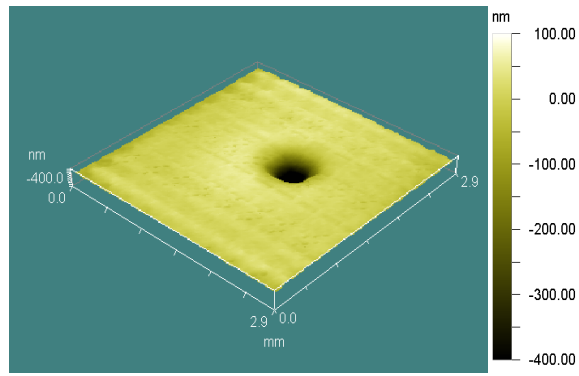


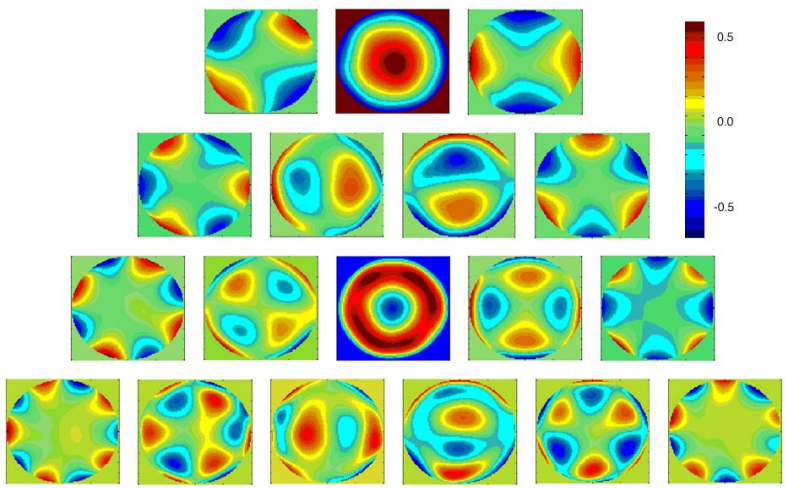
Hybrid mirror (stress-relieved)

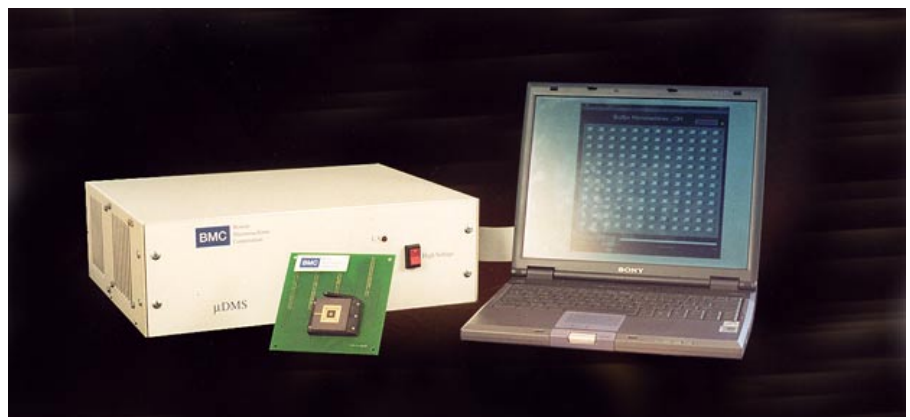
BMC μDM140 System



Clear aperture of mirror	3.3mm
Actuator Count	140
Stroke	0-2μm







High quality mirror, mature product, worldwide sales

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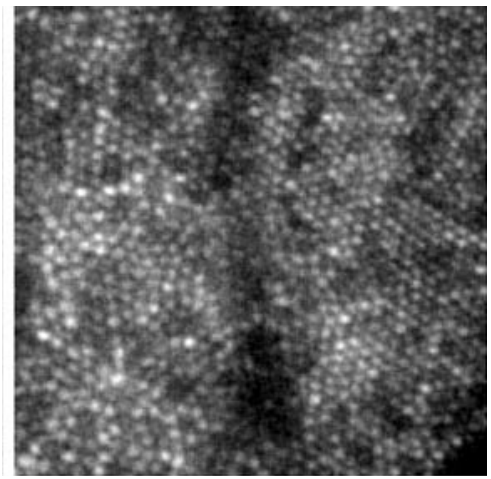
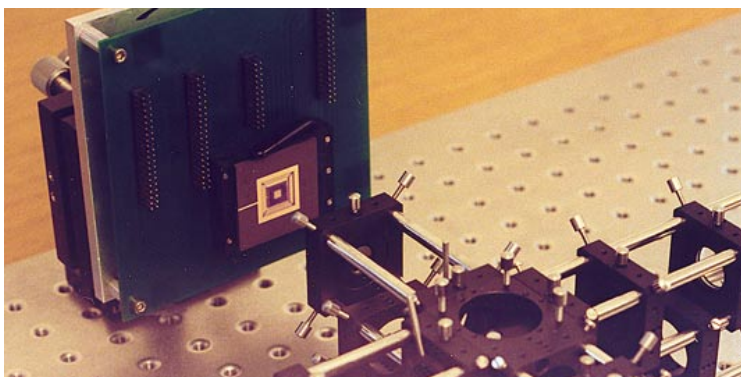
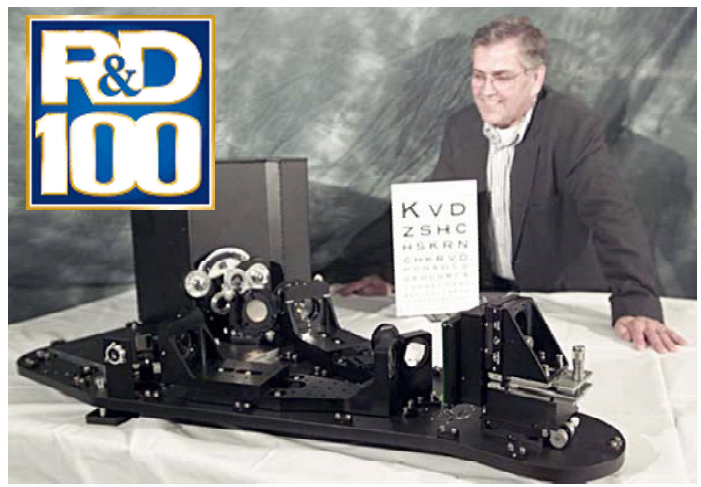
Vision science with µDMs



Retinal Imaging

Because the eye's cornea and lens are generally imperfect, retinal imaging and vision compensation are two important application areas for Adaptive Optics with µDMs

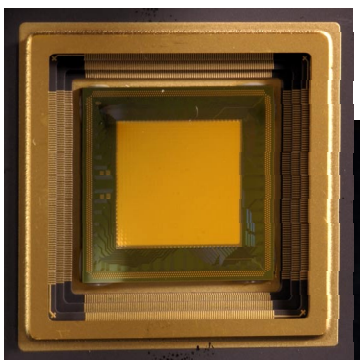


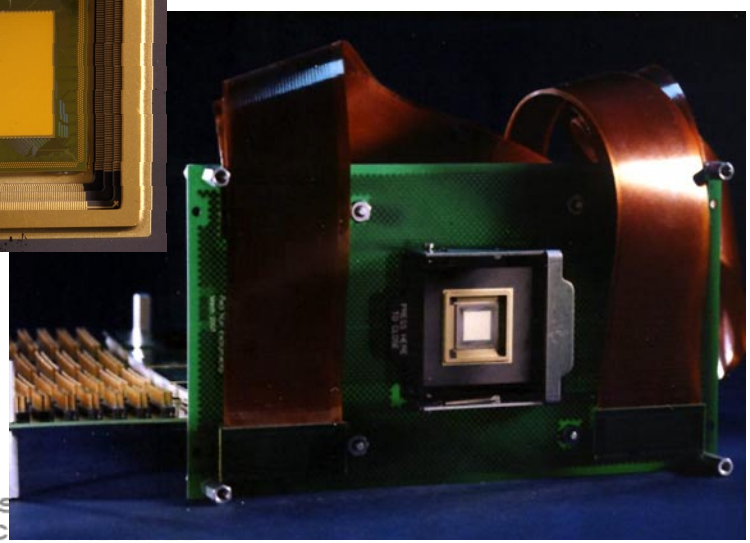


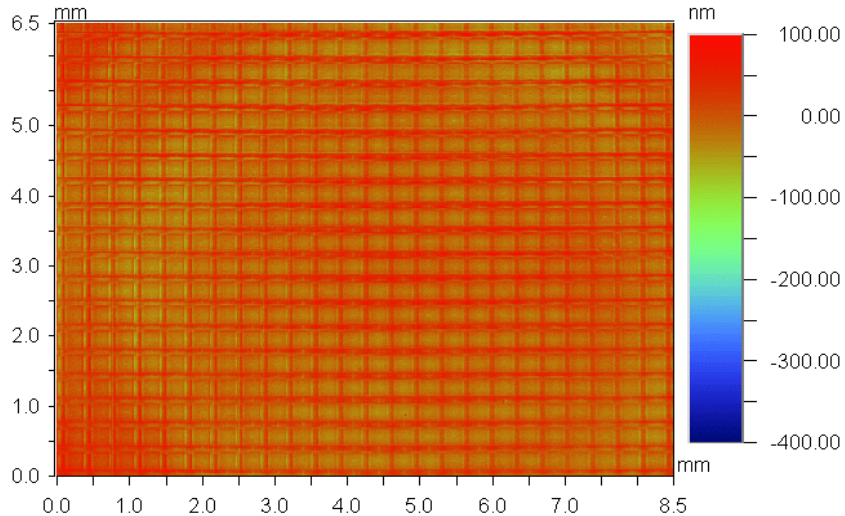
Phoropter, built by LLNL with BU/BMC µDM140

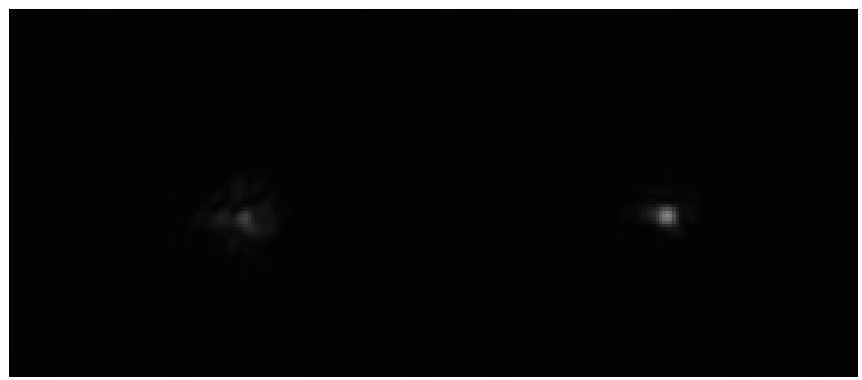
Laser Communication with kilo-pixel mirror

Element Count	1024
Stroke	1μm
Resolution	1/250
Surface roughness	~4nm RMS
Flatness	~20nm RMS
Reflectivity	~98% @633nm
Power capacity	>50W/cm^2 @830nm









Left: Uncorrected beam after 1km.

Right: Corrected beam after 1km.

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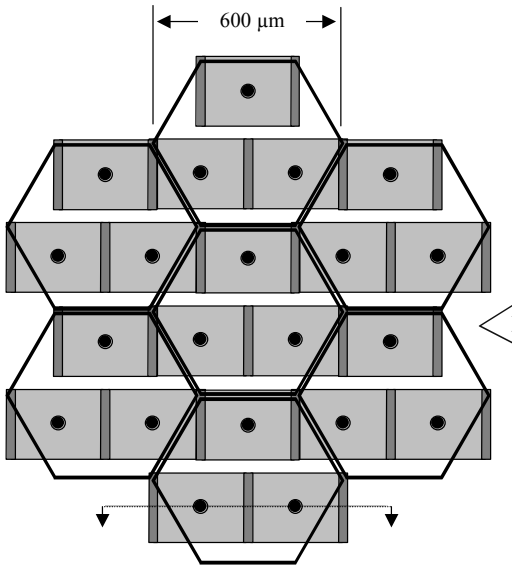
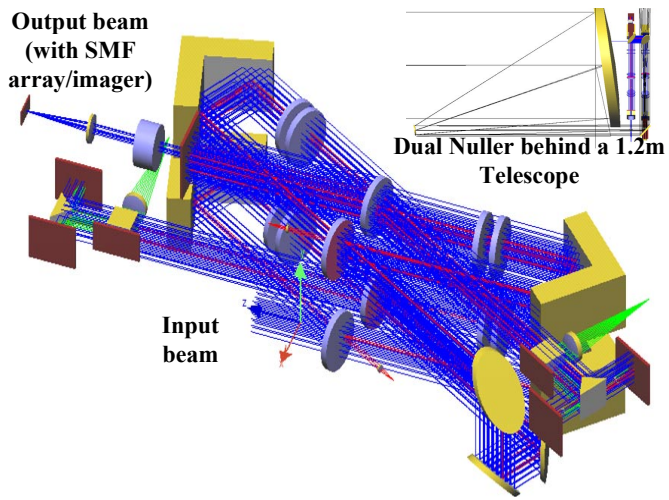
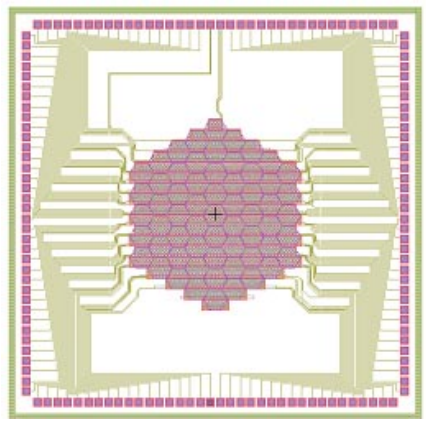
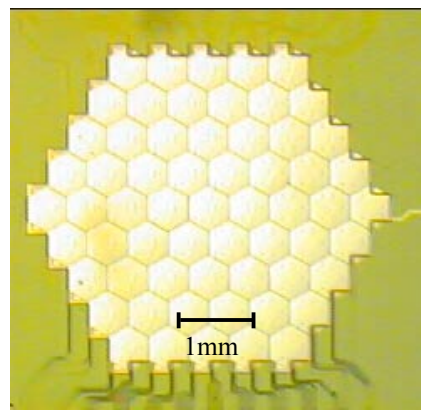
Advanced Deformable MEMS Mirror Systems for the Terrestrial Planet Finder Mission





The Visible Nulling Coronagraph





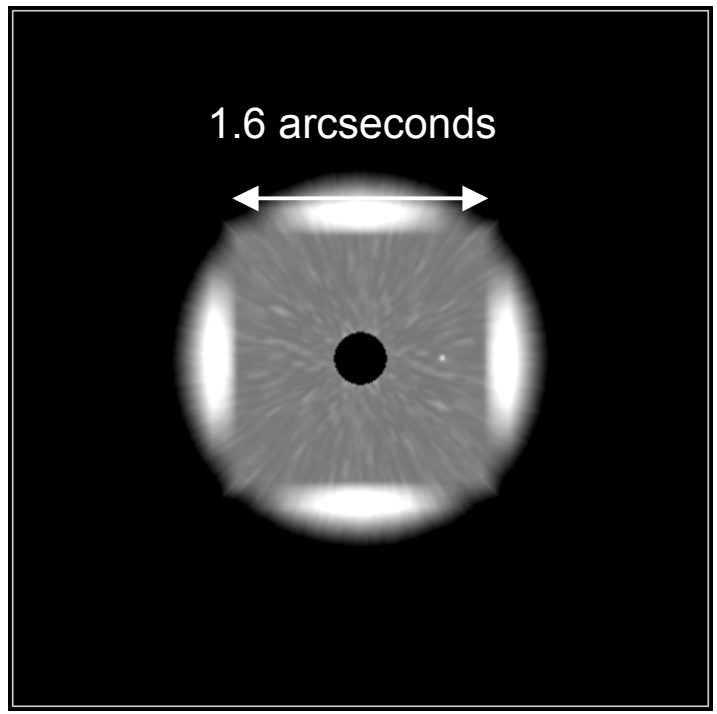
Low Stroke (1um)
High Precision (0.1 Å)
High Surface Quality (1nm RMS)

JPL

Boston Micromachines Corporation

eXtreme Adaptive Optics Planet Imager: XAOPI

- Ultra-high contrast AO system for Keck telescope sponsored by the NSF Center for Adaptive Optics
- 4096-actuator continuous-facesheet MEMS
- Science goal: direct detection of warm extrasolar Jovian planets
- MEMS testing to take place at UCSC Laboratory for Adaptive Optics (1024 actuator MEMS now)
- LLNL, UC Berkeley, UCSC, UCLA, Caltech, JPL team
- Development study for fabrication and packaging underway for 4096 device



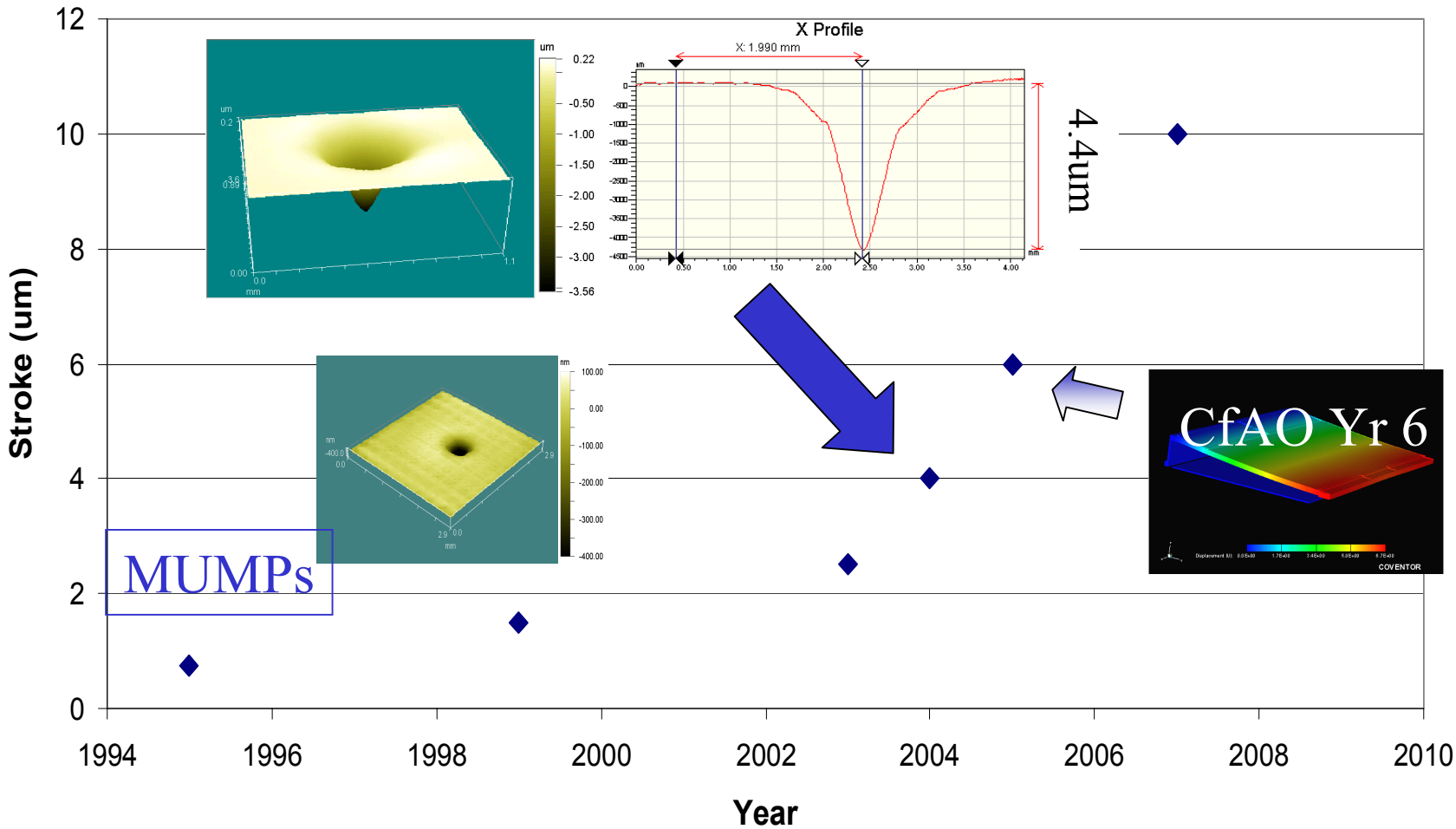
Simulated 15 minute XAOPI H-band image showing a 8 Jupiter-mass planet near a solar-type star

Courtesy of B. McIntosh

Boston Micromachines Corporation

CfAO

BMC DM Roadmap
Stroke



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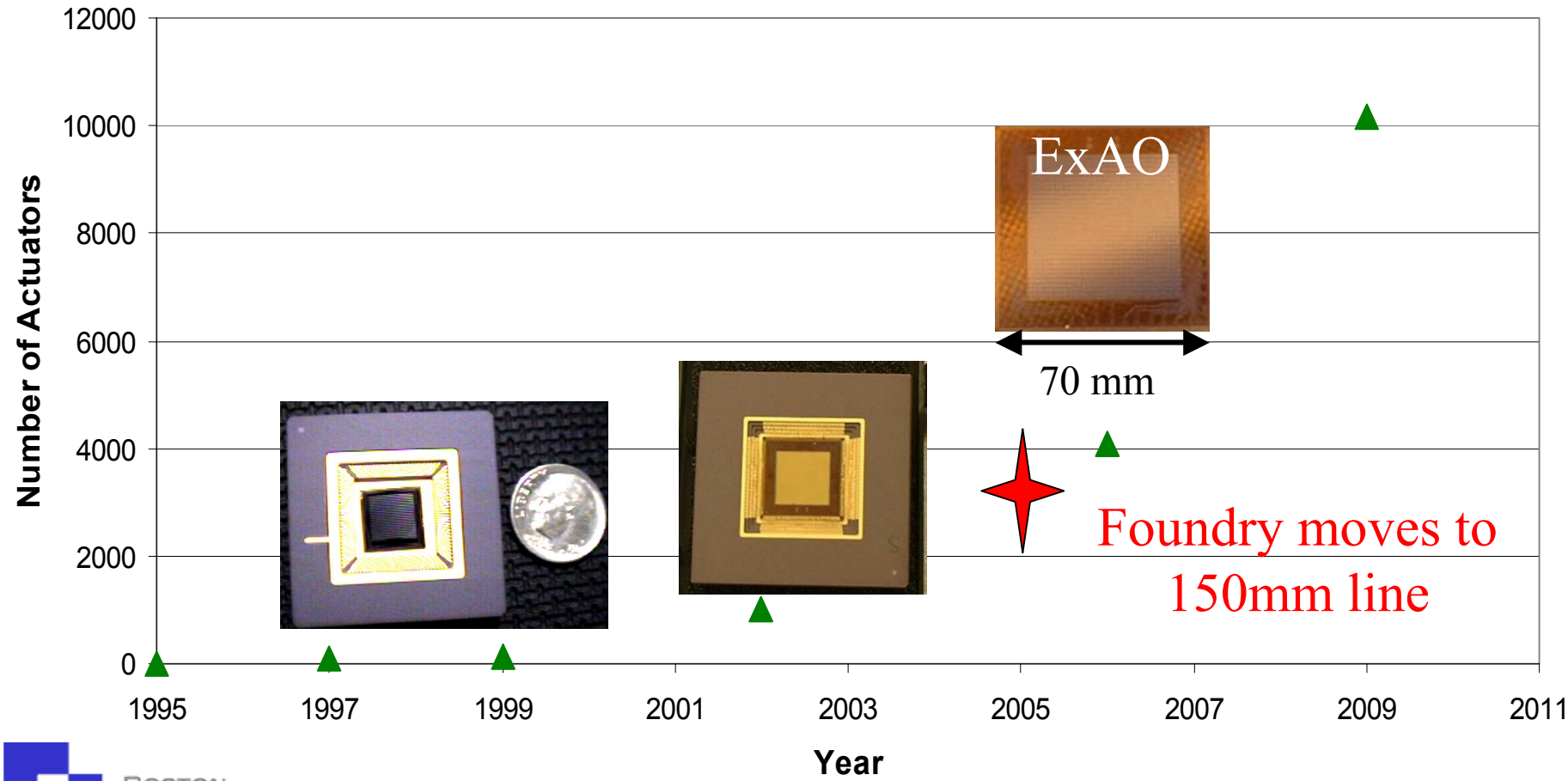
BMC DM Roadmap
Actuator Count



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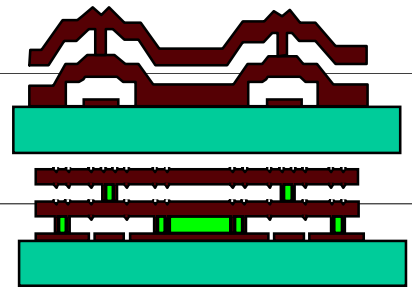
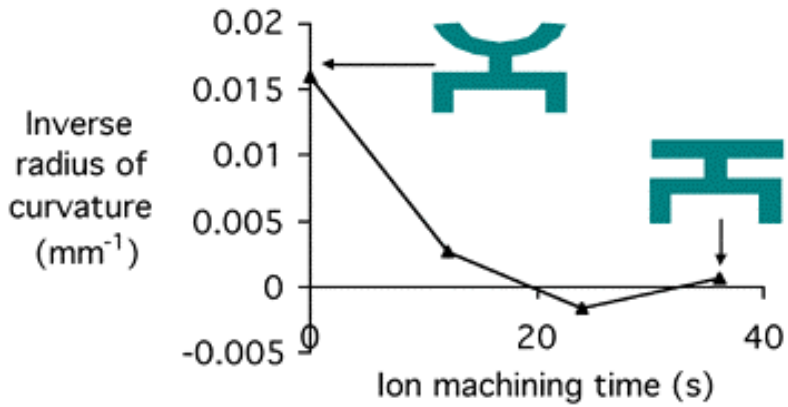
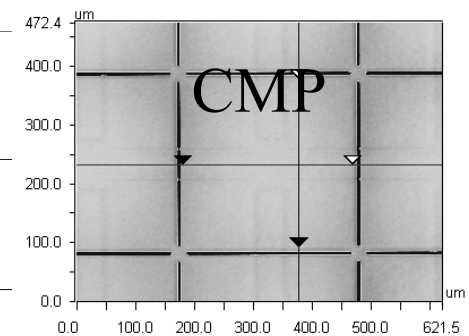
BMC DM Roadmap
Surface Quality







Surface Finish (nm RMS)

120
100
80
60
40
20
0

1995 1997 1999 2001 2003 2005 2007 2009 2011

Year

Boston Micromachines Corporation

Immediate DM Work Required for TMT

- Fabrication tests for high pixel count, large aperture devices
- Reliability and lifetime studies
- Electronics development (high pixel and high bit count)

Summary

Boston Micromachines has a history of producing deformable mirrors for adaptive optics systems. The future plans for the company match well with the needs for the TMT AO system.

More Info: pab@bostonmicromachines.com

Boston Micromachines Corporation