Optical MEMS for Steering Smart Pixel Array Output Beams

Project duration: March 2000 - February 2002

DARPA/MTO VLSI PI Review

30 July 2001

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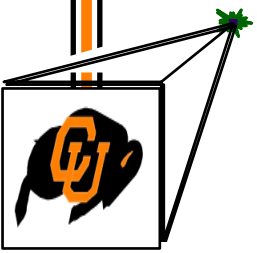
Vision

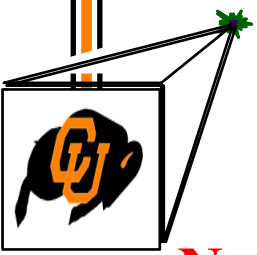


The integration of smart pixel arrays and MEMS will enhance alignment for free-space optical interconnect systems without the need for tighter assembly tolerances, and integration may enable interconnect reconfiguration.

Objective

To demonstrate the use of MEMS to automate the alignment of VCSEL-based smart pixel arrays for optical interconnection.

Research Phases



Near-term objective: Initial system

Mid-term objective: Dynamic

- **Feedback required**

Far-term objective: Interconnect reconfiguration*

- **High speed alignment desirable**
- **Complex steering algorithm may be needed**
- **Large steering angle required**
- **Independent channel control required**

*Not included in DARPA/SPAWAR program

Contents

MEMS at the University of Colorado

Project Accomplishments

Future Demonstrations

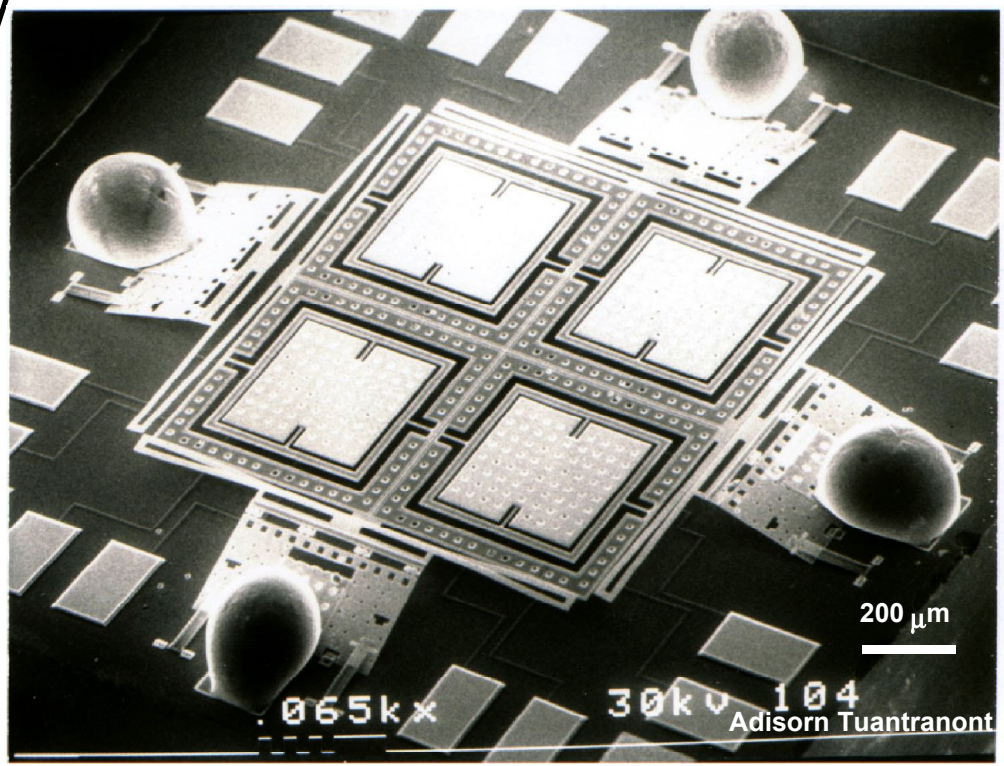
MEMS Personnel at the University of Colorado

21 MS and PhD Research Assistants (GRAs)

9 GRAs and 4 Faculty Involved with MOEMS

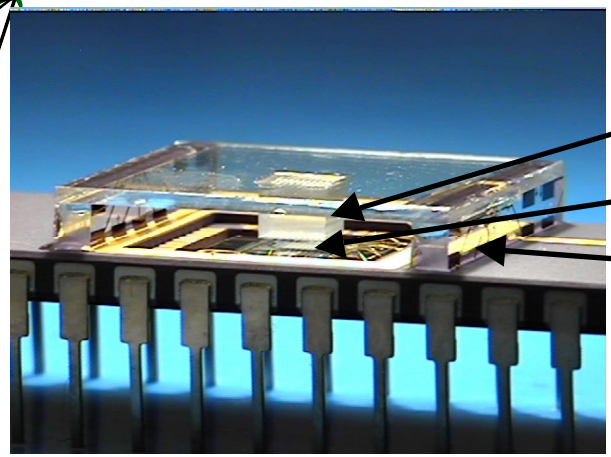
5 GRAs and 3 Faculty on DARPA/SPAWAR Program

MEMS 2-D Optical Scanner

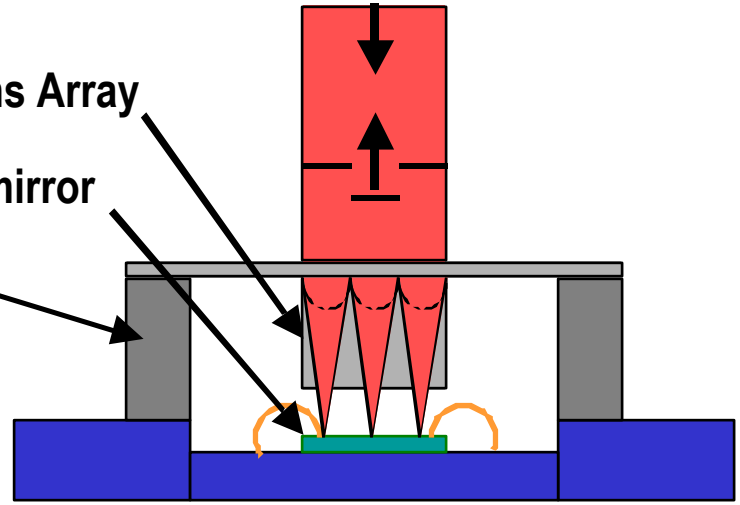


- Electrostatic Actuation
- X-Y Torsional Hinge
- Gimbal Structure
- Mirror Size = 280×280 μm^2
- Beam Steering Angle = 40°
- Voltage = 50-200 V
- Frequency = 10's of KHz
- Gold Reflective Surface

Micromirror/Microlens Integration



Final micromirror package

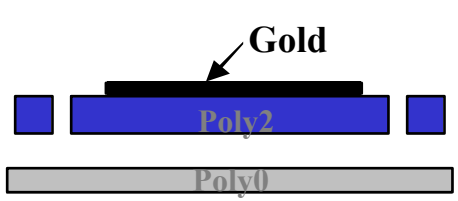


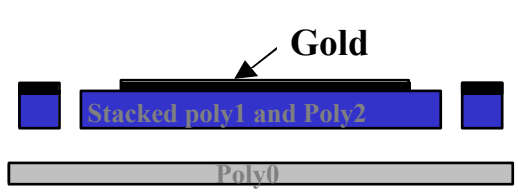
- 2-dimensional Planar Micro Lens (PML)
- 560 μm focal length controlled by spacers
- 250 μm center-to-center spacing
- Flip chipped directly on top of micromirror array

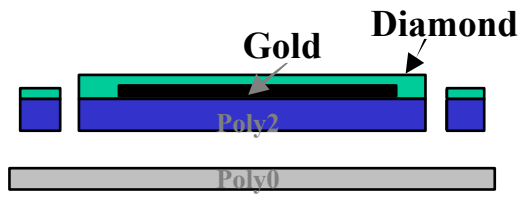
Thermo-Mechanical Modeling

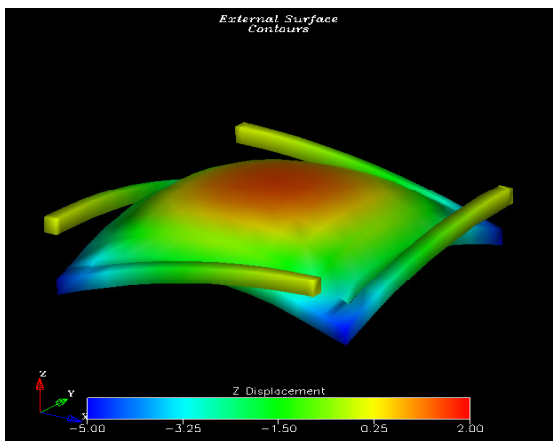
We are using modeling for design, analysis and optimization with respect to:

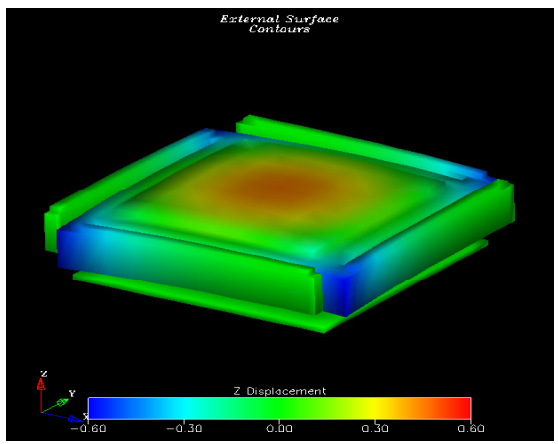
- **Natural frequency of vibration**
- **Heat dissipation capacity**
- **Pull-in voltage**
- **Thermo-mechanical deformation**

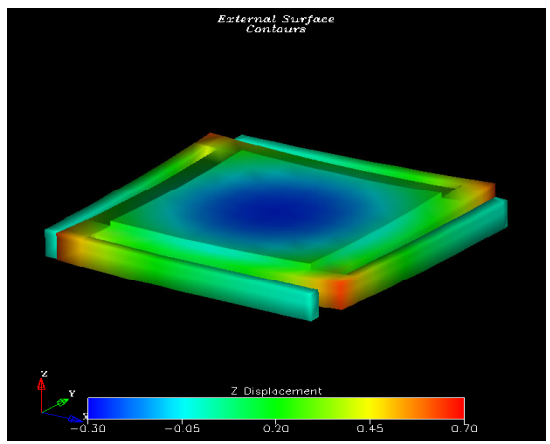












Mirror Area = 200 × 200 µm , Flexure Length = 190 µm , Flexure Width = 10 µm, Diamond Thickness = 1.25 µm

Contents

MEMS at the University of Colorado

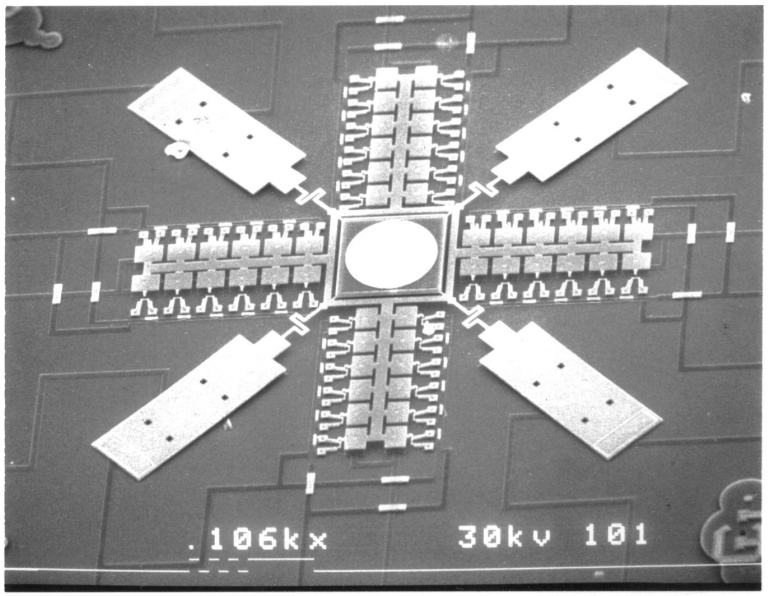
Project Accomplishments

- **Demonstrated accurate alignment/position fixing**
- **Demonstrated steering with decentered microlens**
- **Designed dynamic alignment scheme**

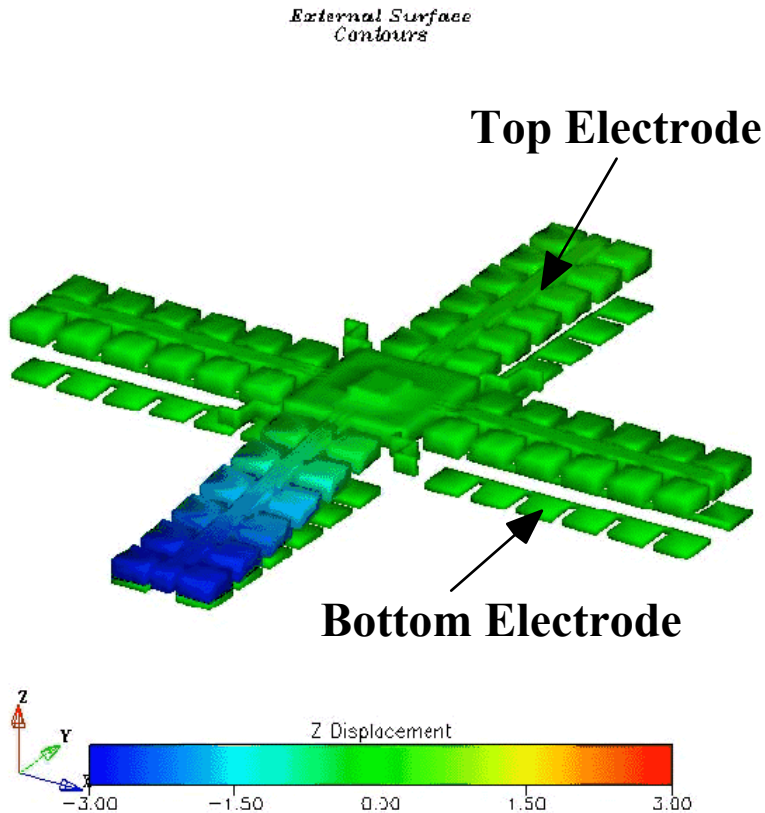
Future Demonstrations

Electrostatically Tilted Micro-mirrors for Manufacturing Alignments

Electrostatic Scanner Design

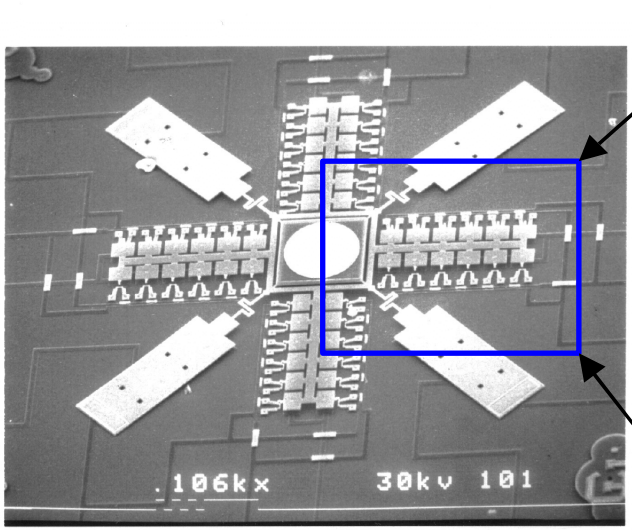


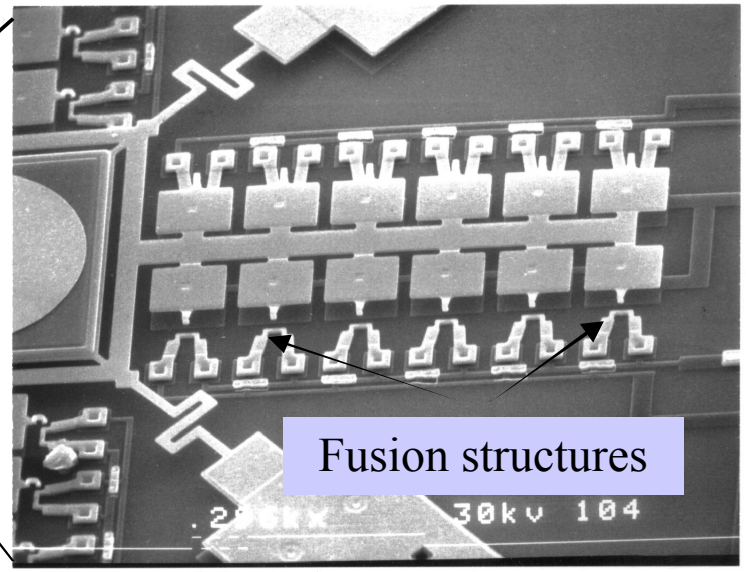
Color-Coded Displacement

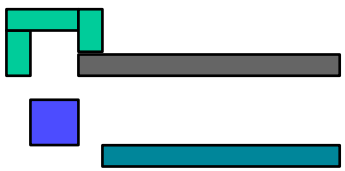


Position Fixing

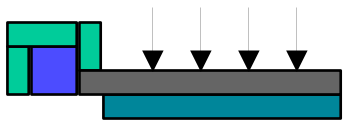
Fusing polysilicon by heating



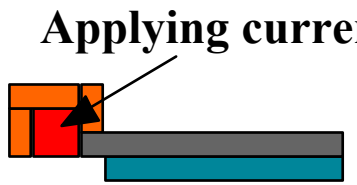




Right after release

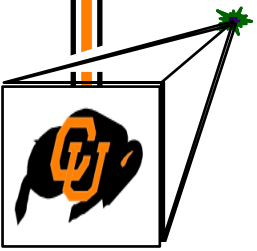


"Snap down"

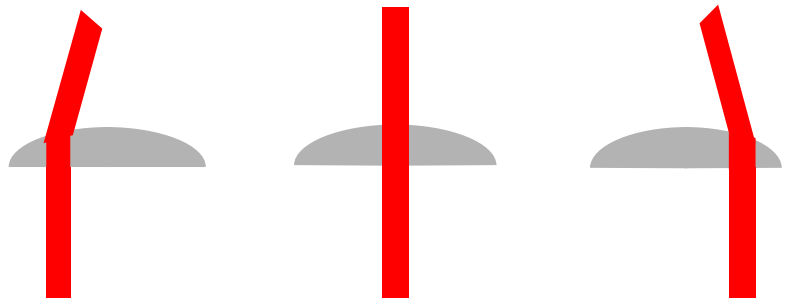


Heating and fixing

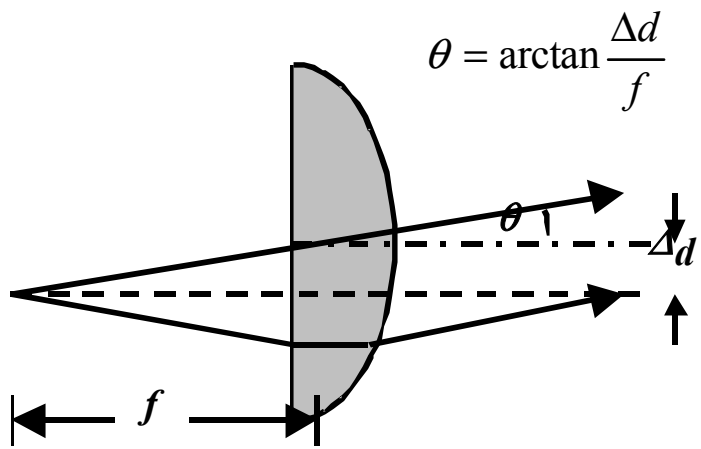
Beam Steering With Decentered Microlens



Beam propagating through off-axis lens will be directed to a non-zero field angle.

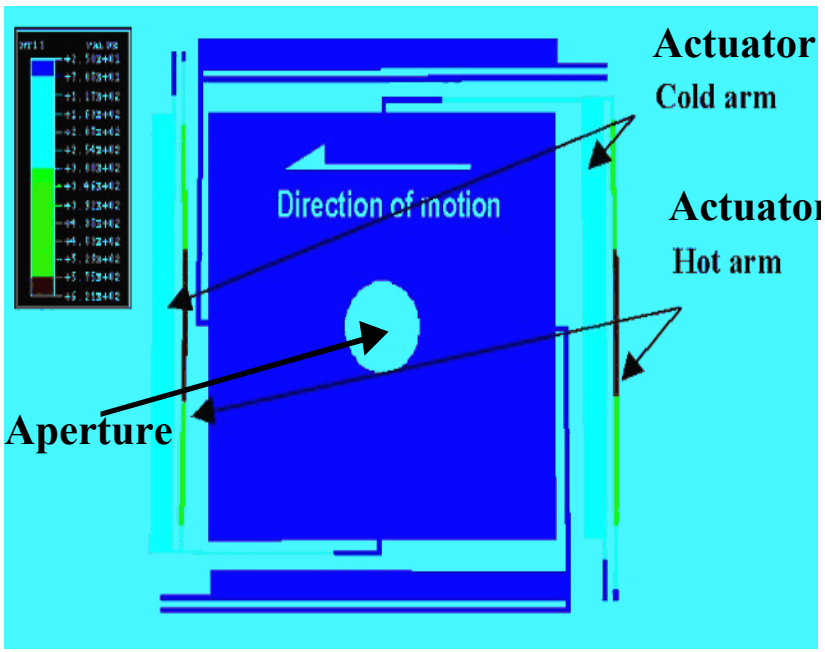


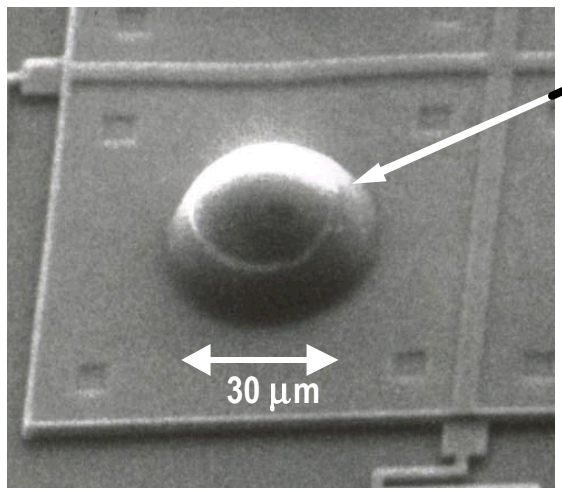
Steering angle depends on displacement and focal length of the microlens.



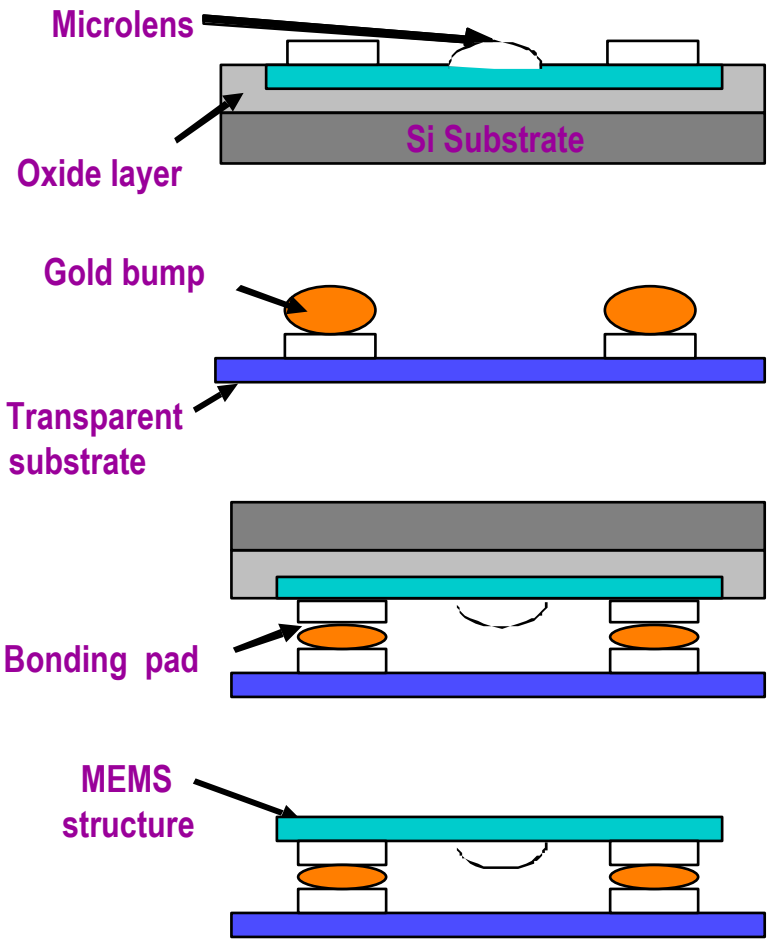
MEMS-Controllable Microlens

- **Configuration:**
  - 2-dimensional array of individually controllable microlenses
  - 250 μm element spacing compatible with VCSEL array
  - Thermal actuators coupled to the polymer microlens fabricated on a polysilicon plate with aperture
  - Push and pull mechanism of actuators → linear motion



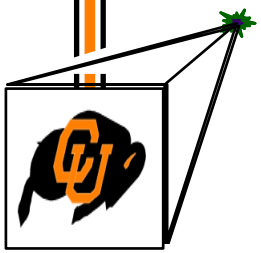


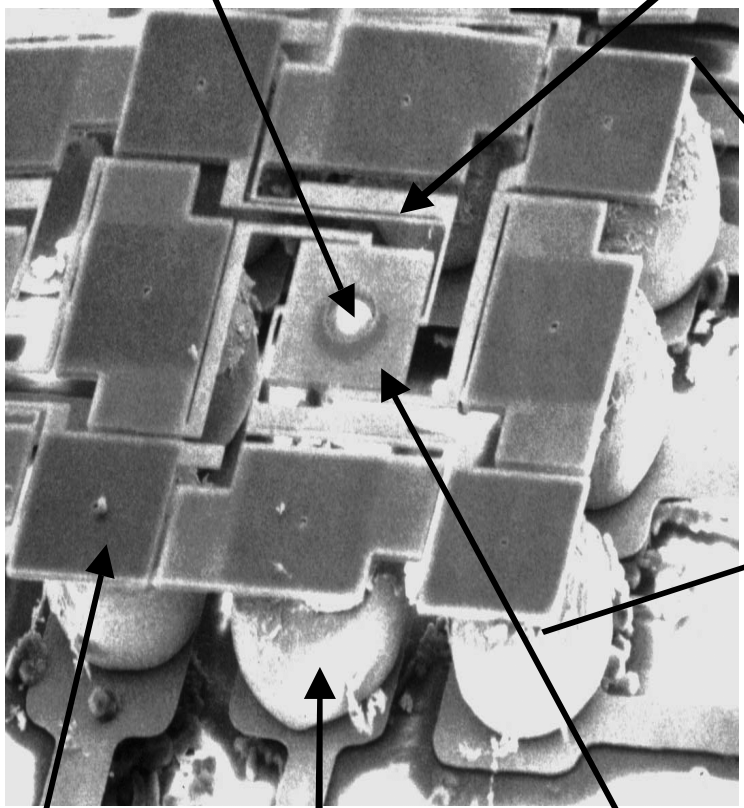
MEMS Flip-Chip Transfer / Integration

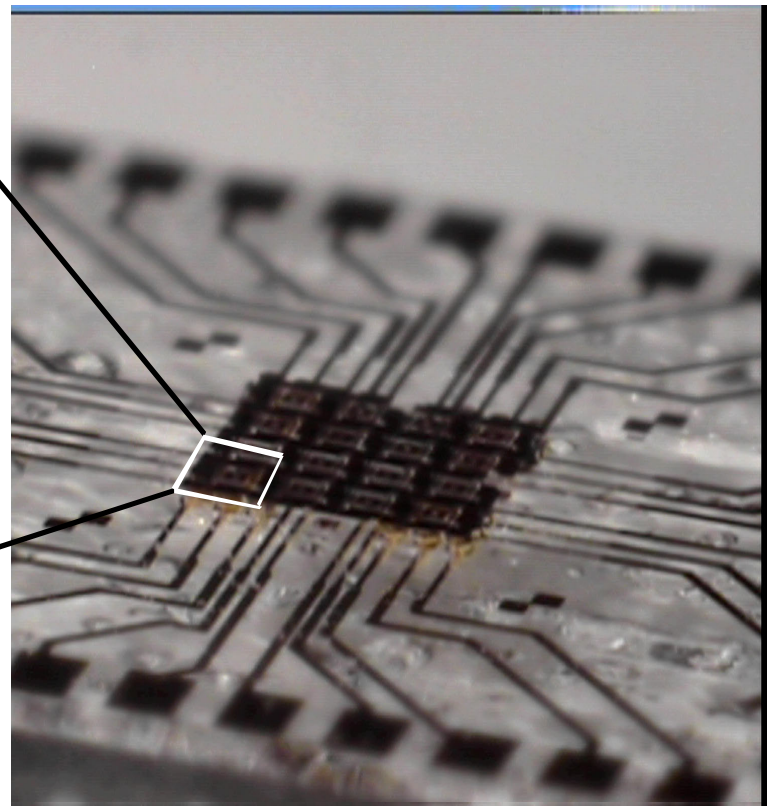


- Photo-BCB microlens fabrication
- Substrate fabrication with matching bonding pad
- Flip-chip bonding
- HF release of MEMS structure

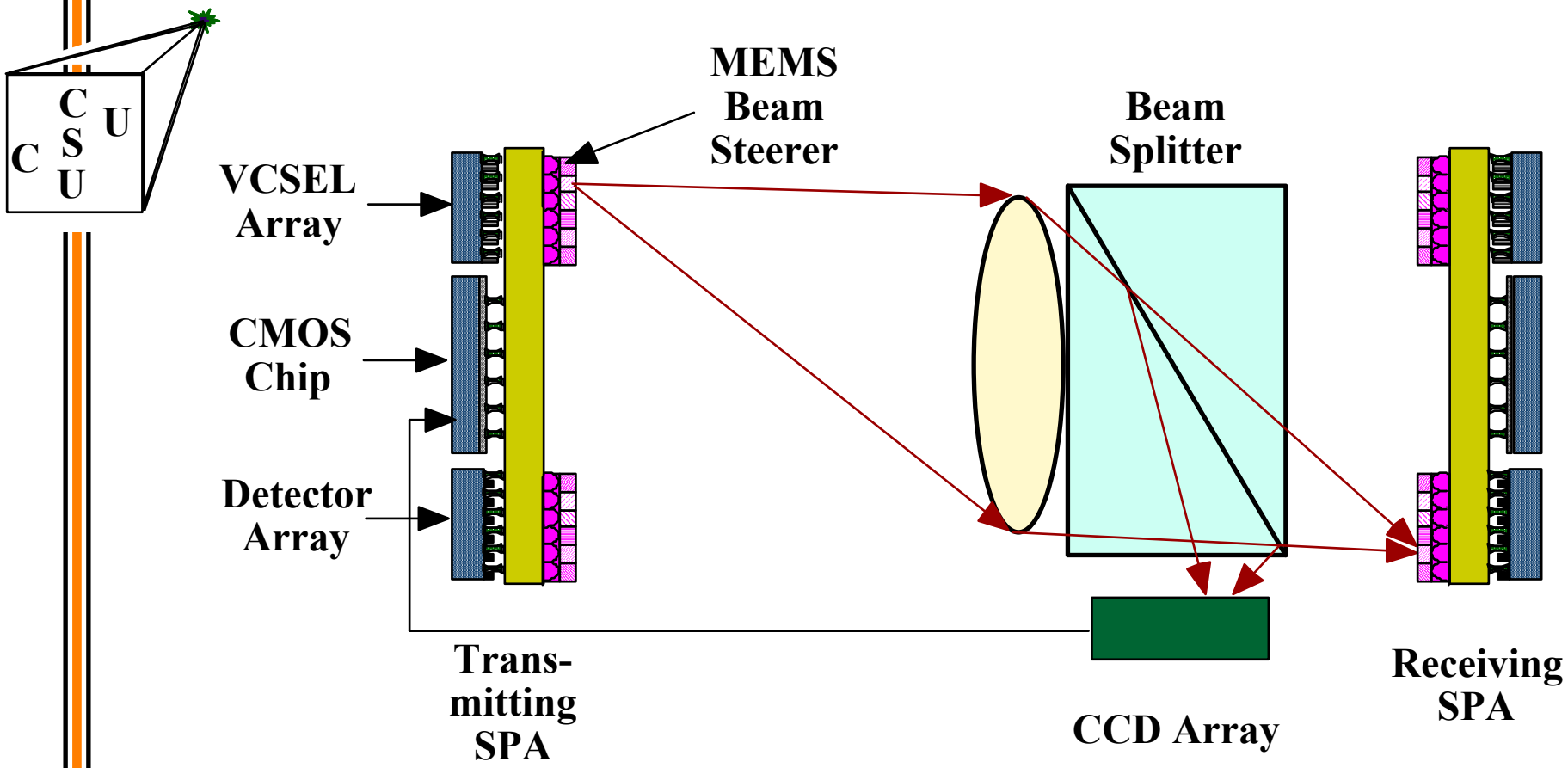
Flip-chip Assembled MEMS-controllable Microlens Array on a Glass Substrate



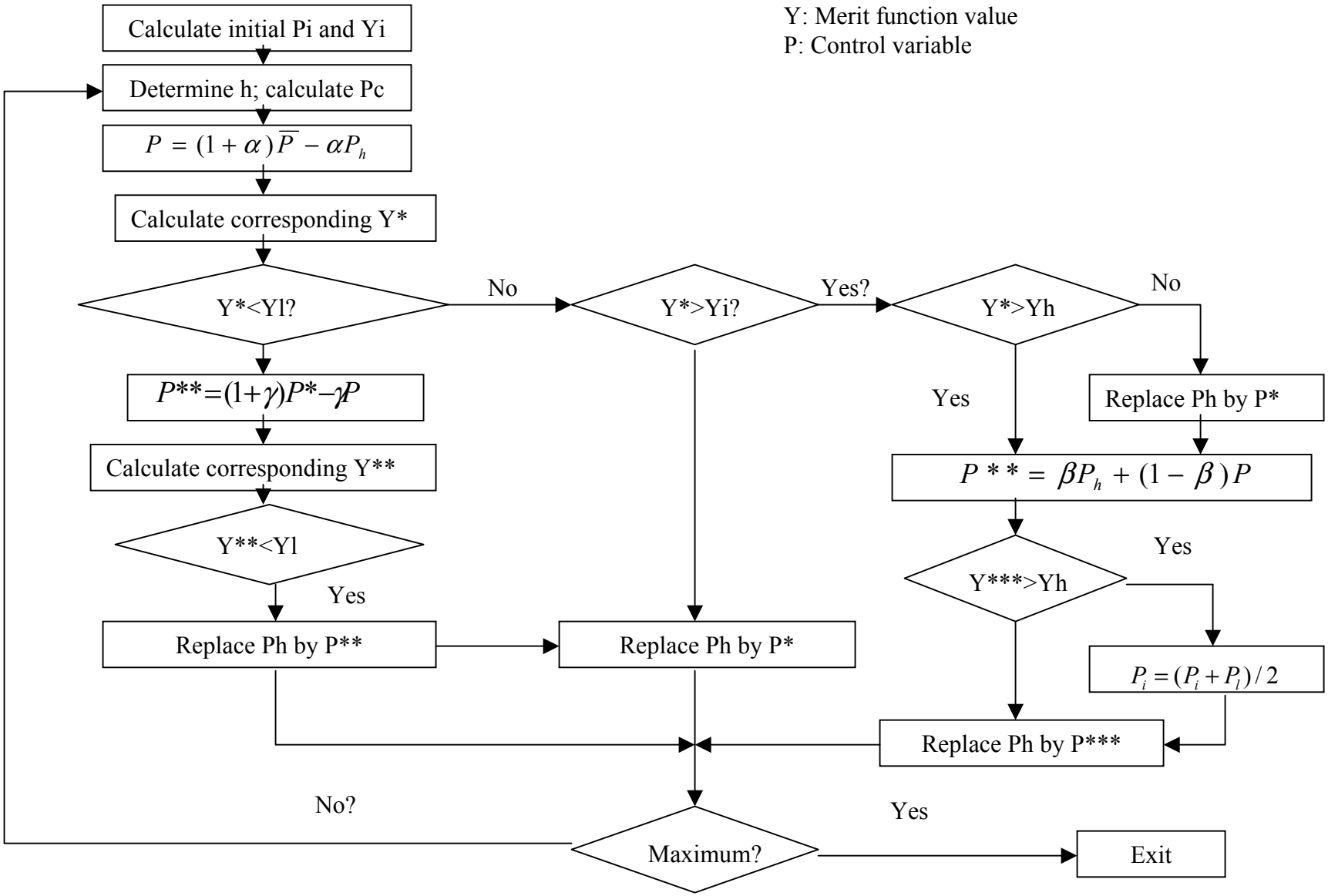




Selected Feedback Scheme for Closed Loop Alignment



Control Flow Chart



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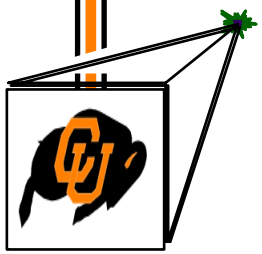


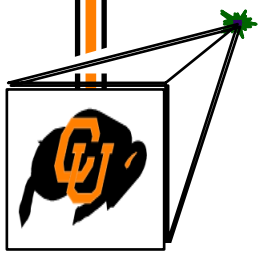
MEMS at the University of Colorado

Project Accomplishments

Future Demonstrations

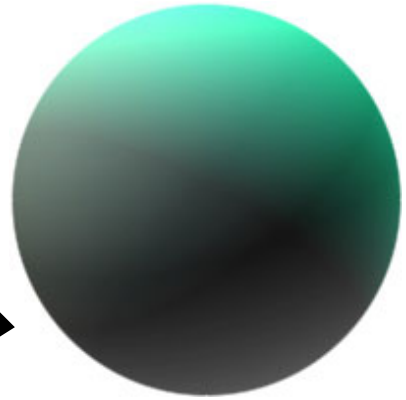
- Demonstrate glass-bead microlenses
- Demonstrate a micromirror-based folded beam path

Limitations of Our Current Laboratory Demonstrator



- Quality of the polymer lenslets is marginal
- Interconnect channels are open loop
- Steering angle is only 4 degrees
- Lenslet schemes may not be easily manufacturable

Optical Element Improvement

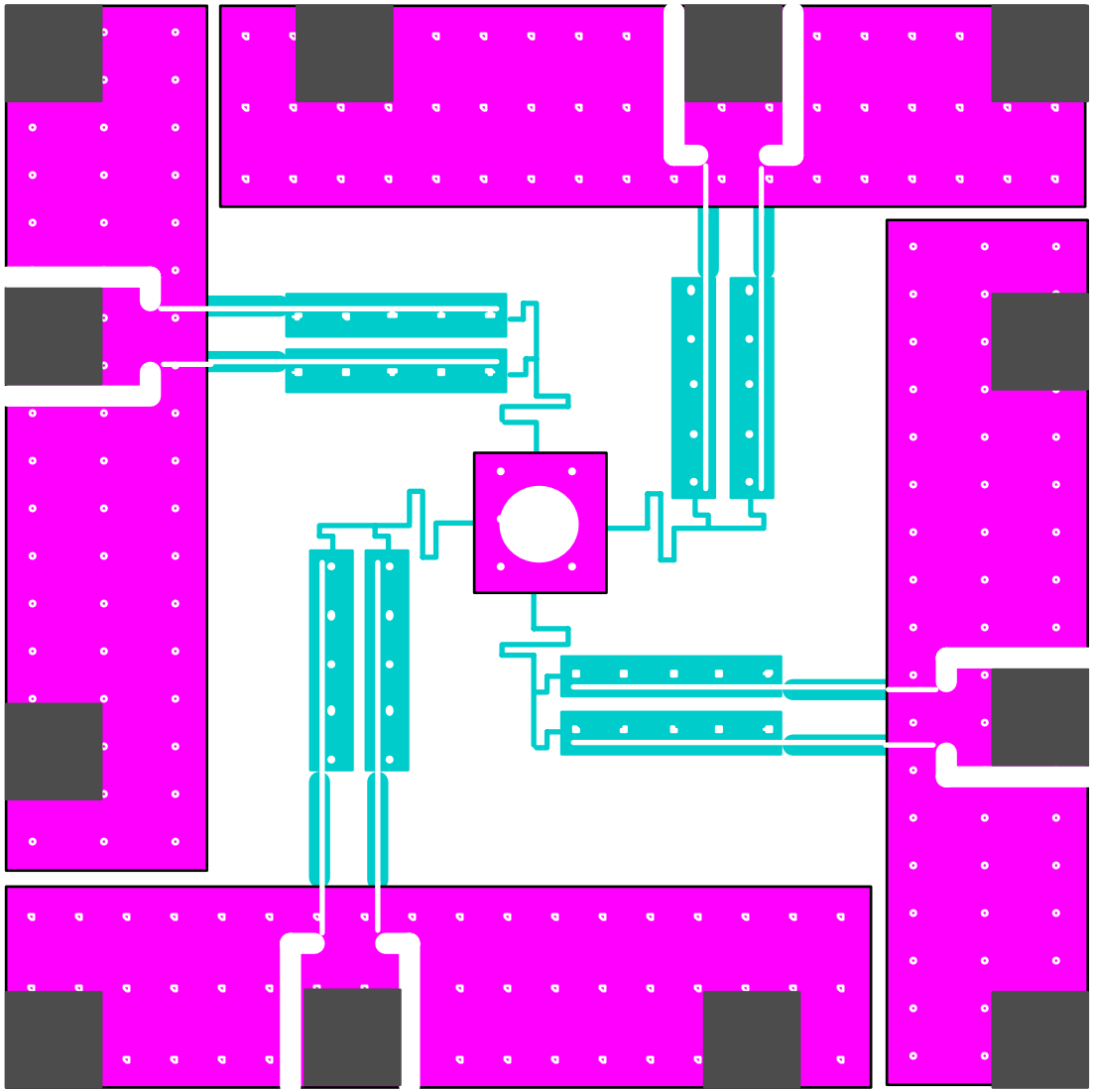


MEMS Polysilicon
Moveable Plate
With Lenslet
Aperture

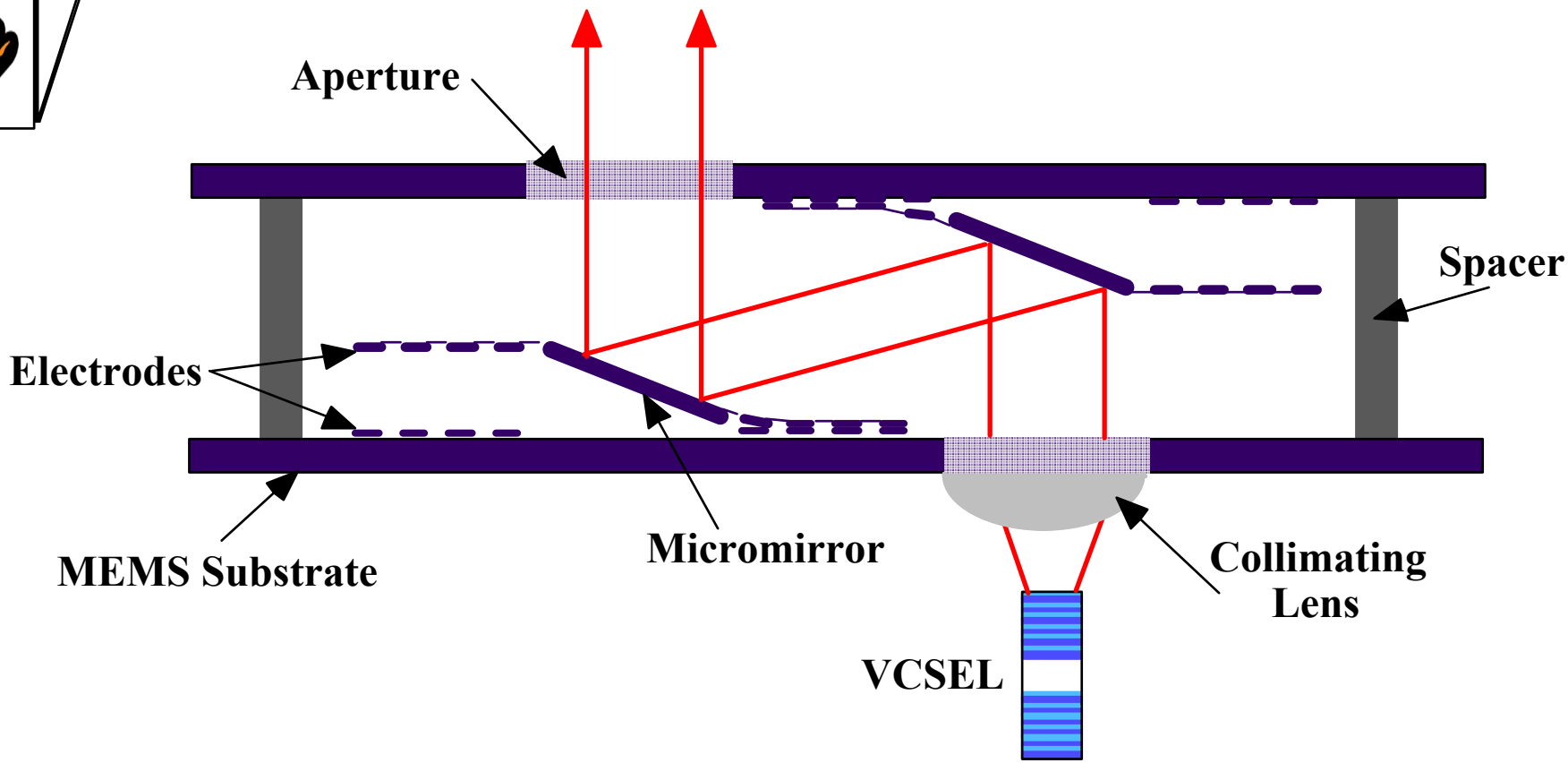
Spherical Glass Bead
(60-90 µm diameter)

VCSEL

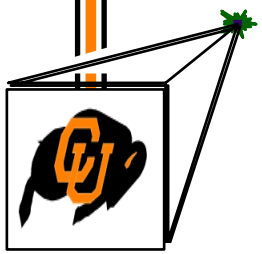
Layout for Modified MEMS-Controllable Microlens



Proposed Micro-Mirror Approach



Summary



- Demonstrated accurate electrostatic positioning and fixing.
- Accomplished only known demonstration of MEMS-based lenslet beam steering.
- Initiated development of feedback for beam-steering control.
- Are about to demonstrate optical beads as replacement for polymer lenslets.
- Have redesigned flexure structure to achieve larger steering angles.
- Have designed and planned demonstration of a folded-beam micro-mirror scanner.