MOEMS Manufacturing Consortia

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XEROX

OMM
OPTICAL MICRO-MACHINES, INC

MAXIM

STANDARD mems

MICROCOSM
software solutions for MEMS design

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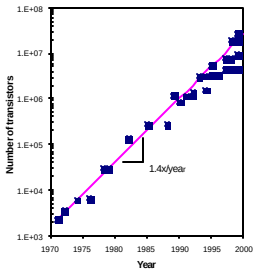
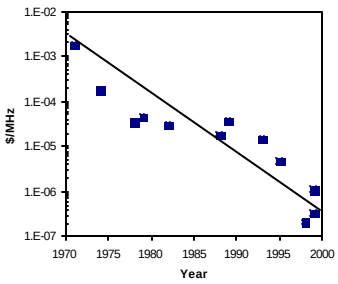
Photonics Manufacturing

Move from electro-mechanical to microelectronic industry cost curves by using IC-based manufacturing:

- Efficient high-volume IC-based batch manufacturing
- QCD's follow Moore's Law





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Photonics Packaging and Assembly

- Lower the assembly cost associated with passive alignment of optical elements by using silicon μoptical bench technology.
  - Photolithographically defined alignment, $\lambda = 2\mu m$
  - On-chip actuators for automated assembly
  - Low-cost free-space optical interconnects.

V. Bright et. al, Univ. of Colorado

M.J. Daneman et. al, UCBerkeley

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Photonics Packaging and Assembly

Decrease the high-cost of active alignment using a mechatronic approach enabled by on-chip sensors, actuators and control systems.

V. Bright et. al, Univ. of Colorado

M.J. Daneman et. al, UCBerkeley

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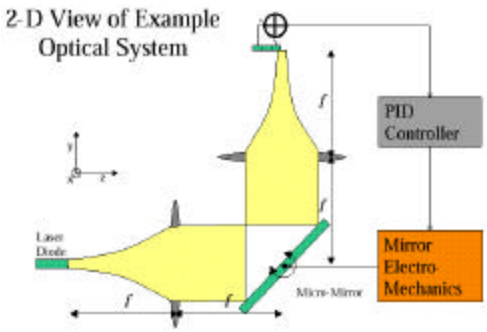
Photonics Packaging and Assembly

- Increase long-term dimensional stability using on-chip closed-loop feedback control.



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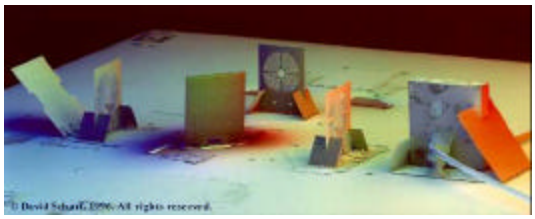
Photonics Packaging and Assembly

- Decrease the packaging cost associated with the integration of photonic and electronic components using MOEMS technology:
  - Monolithic integration of optical, electrical, and mechanical components on a silicon die.



Micro-opto-electro-mechanical systems on a chip

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Objectives:

- Robust MOEMS manufacturing process
- Integration of light sources and detectors with optical and electromechanical components
- Automated self-assembly and alignment
- Modeling design tools
- Prototype applications
- Commercial silicon foundry

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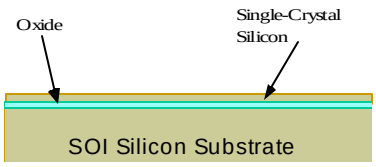
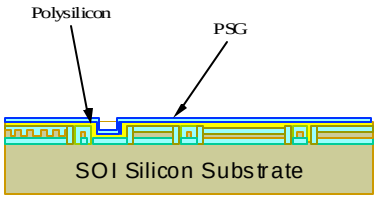
Challenges:

- Manufacturability of surface micromachining process
  - Materials properties (E, ν)
  - Optical (λ, r, t)
- Integration of light sources
  - Si good for micro-electro-mechanical
  - GaAs good for light emission
- Integration of microelectronics
  - Processing tradeoffs

SCS-SMM Process:

- Implement a polysilicon surface micromachining process on top of a SOI wafer.
- Use SCS device layer of the SOI wafer for critical optical, electrical, and mechanical applications.
- Use polysilicon layers for non-critical applications such as hinges and guides.





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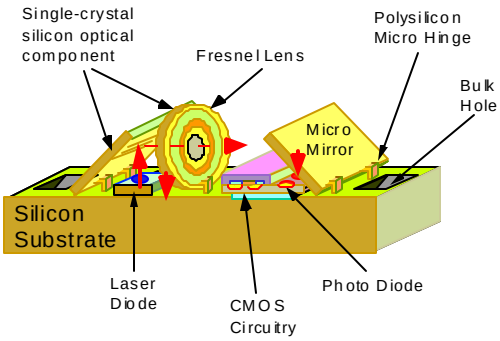
SCS-SMM Process



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Milestones:

- **Mask Set 0** 3 layer polysilicon surface micromachining
- **Mask Set 1** bulk + surface micromachining on SOI wafers
- **Mask Set 2** add integrated light sources
- **Mask Set 3** add integrated microelectronics

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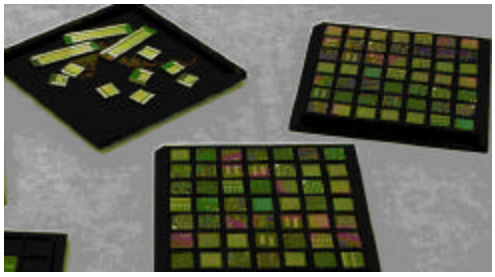
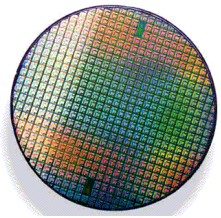
Mask Set 0





- Started Run 4/15/99
- Completed Run 9/1/99
- Diced 9/22/99
- Testing 10/4/99

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Mask Set 1 Unit Process Development

- In plane optical element in SCS device layer 2Q99
- 3 layer poly SMM on SOI wafer 3Q99
- Out of plane release of SCS optical element 4Q99

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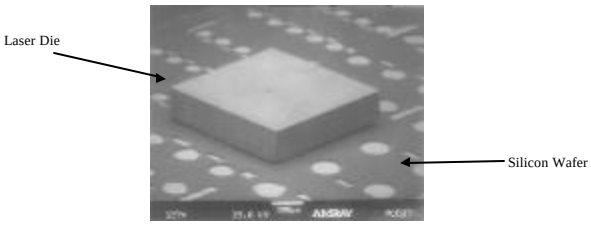
Integration of light sources



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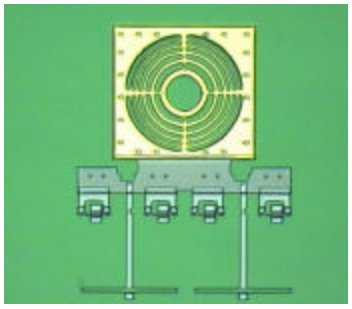
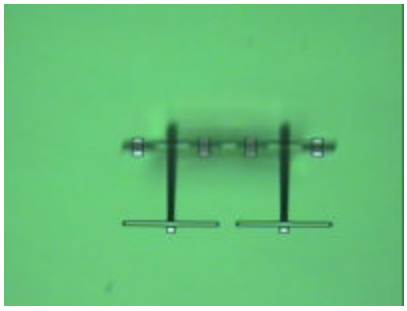
Assembly





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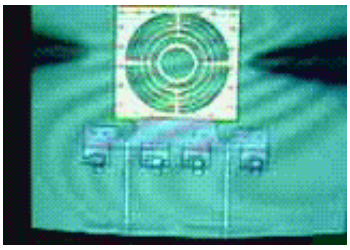
Assembly



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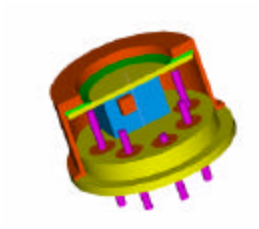
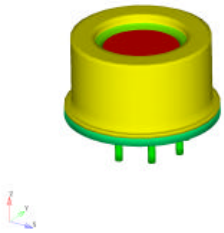
Optical package simulation

- A 3-D solid model of a typical optical package in MEMCAD



Cross-section of a solid model of the optical package from Xerox. A small red block on a heat sink (blue) represents a die.



Meshed model of the package in MEMCAD visualizer

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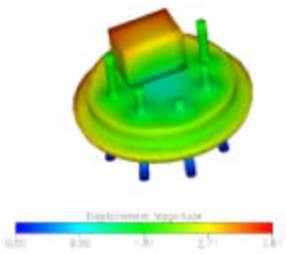
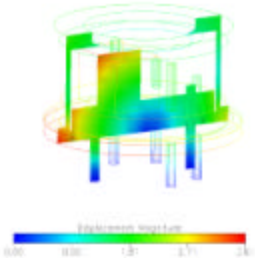
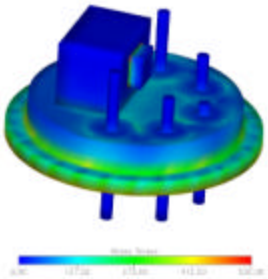
Thermo-mechanical analysis of optical packages



Resulting displacement fields inside the package for the temperature of -40^{0}C. A zero stress temperature for all materials was assumed to be 0^{0}C.





Stress field distribution for the same ambient temperature. In coupled package/device simulation device was represented by silicon die.

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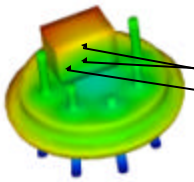
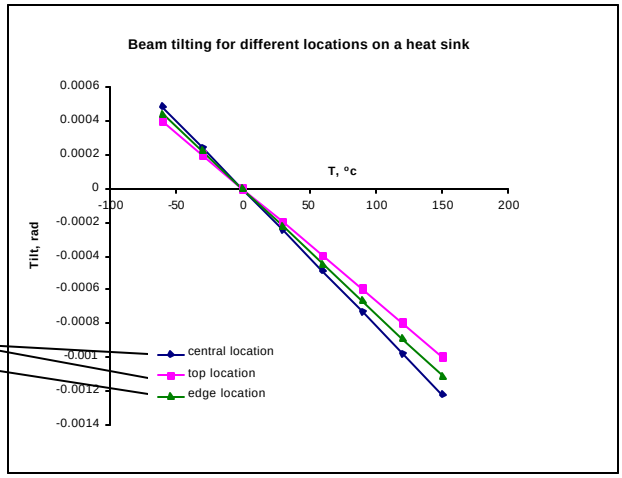
Estimation of beam direction variation due to thermal expansion/contraction of the package





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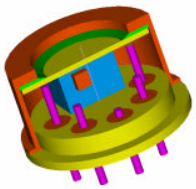
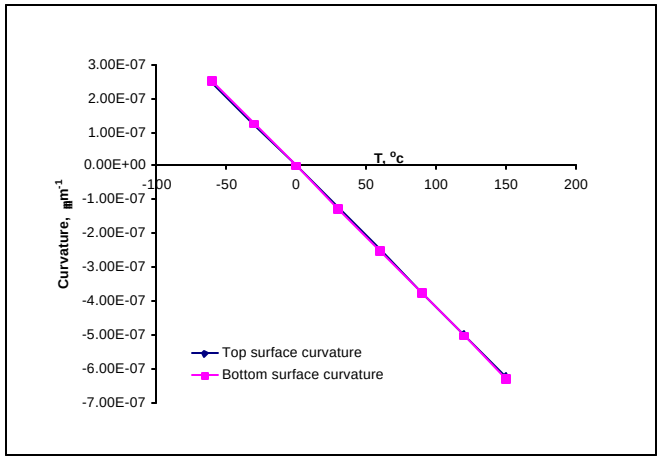
Variation of the window surface curvature with temperature





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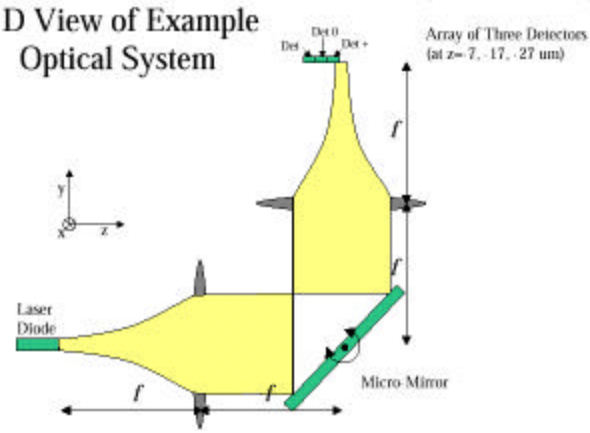
Optical Macro Modeling

2-D View of Example Optical System



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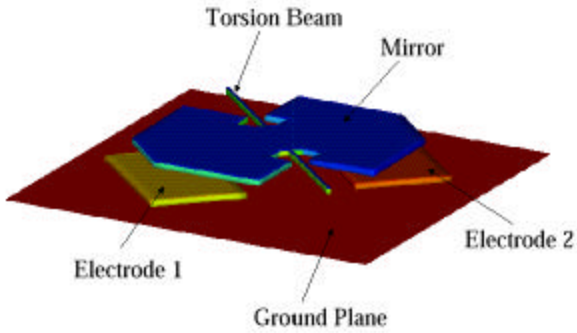
Optical Macro Modeling

Micro-Mirror Geometry



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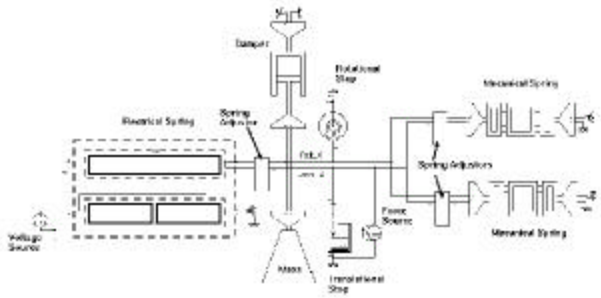
Optical Macro Modeling

Mirror Mechanical Macro-Model



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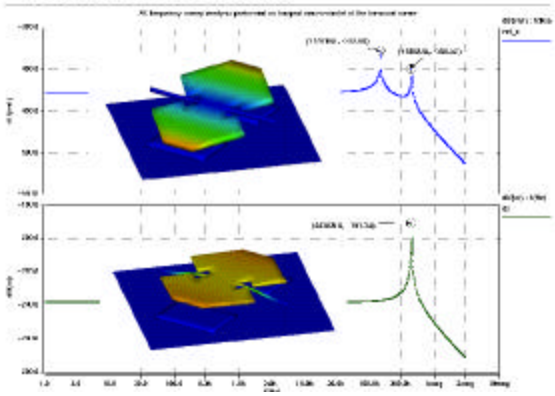
Optical Macro Modeling

Micro-Mirror Modes



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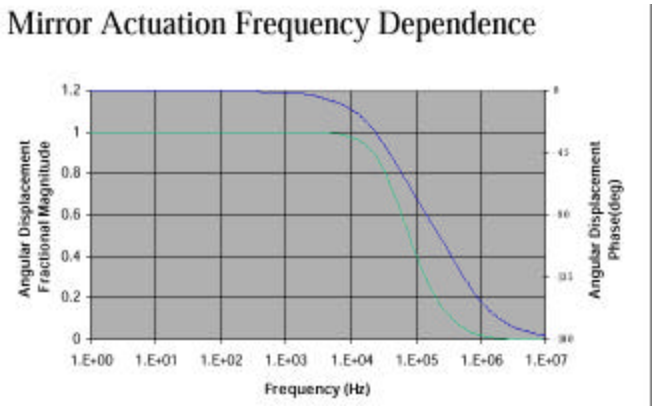
Optical Macro Modeling



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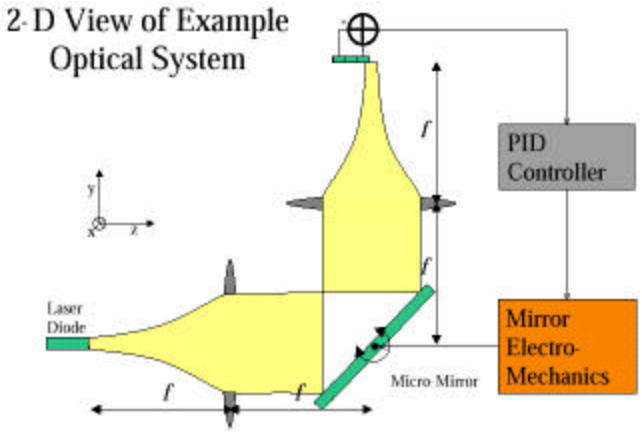
Optical Macro Modeling



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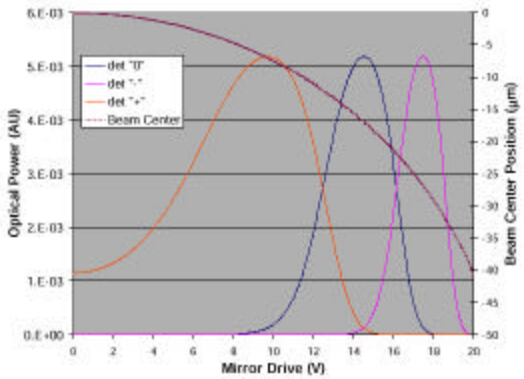
Optical Macro Modeling

Beam Motion vs. Applied Voltage



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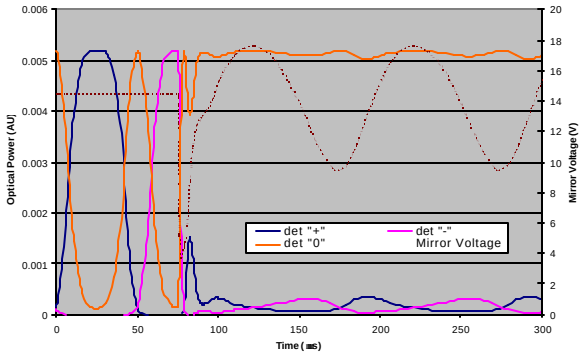
Optical Macro Modeling



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Applications

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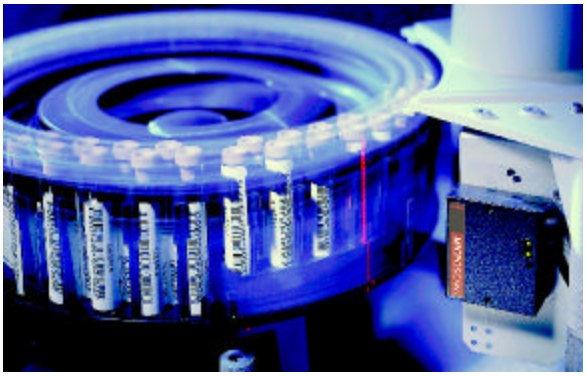
VS 310 Application

- Test Tube



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MS 520 High Speed Application

- Sort, Verify and Process

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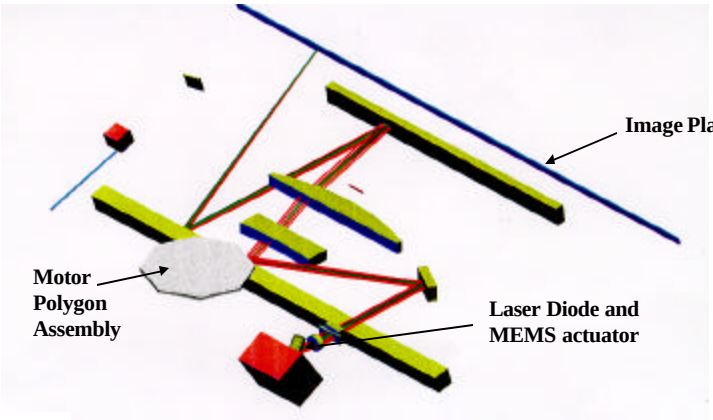
Agile Beam ROS



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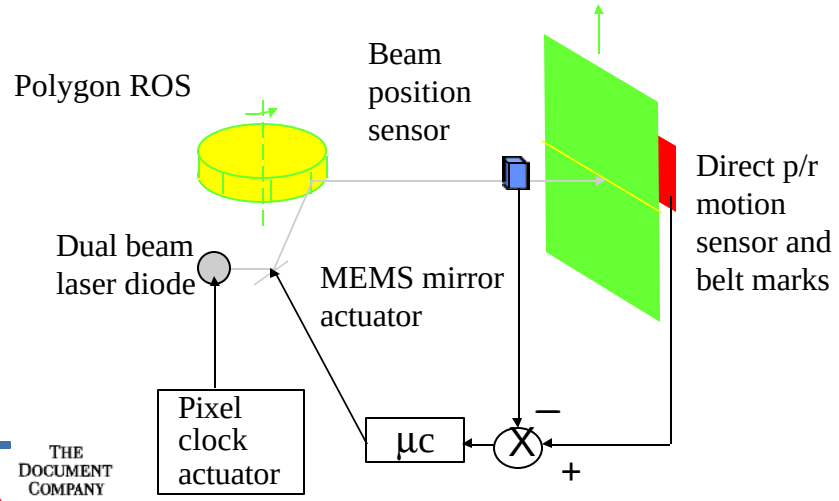
Agile Beam ROS



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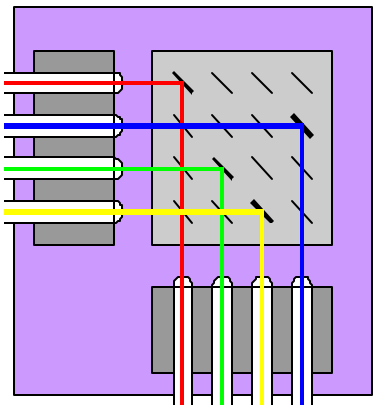
Optical Switch



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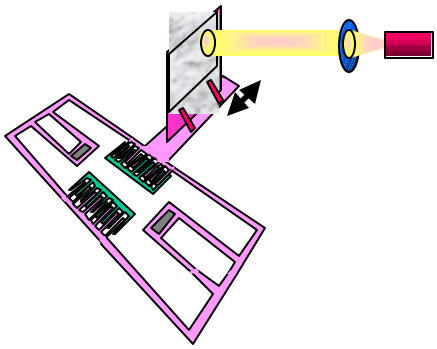
Optical Switch



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Summary

- Mask Set 0 completed, testing underway
- Mask Set 1 unit process development ongoing
- Mask Set 1 scheduled to start 1Q00