Macro-Modeling of Systems Including Free-Space Optical MEMS

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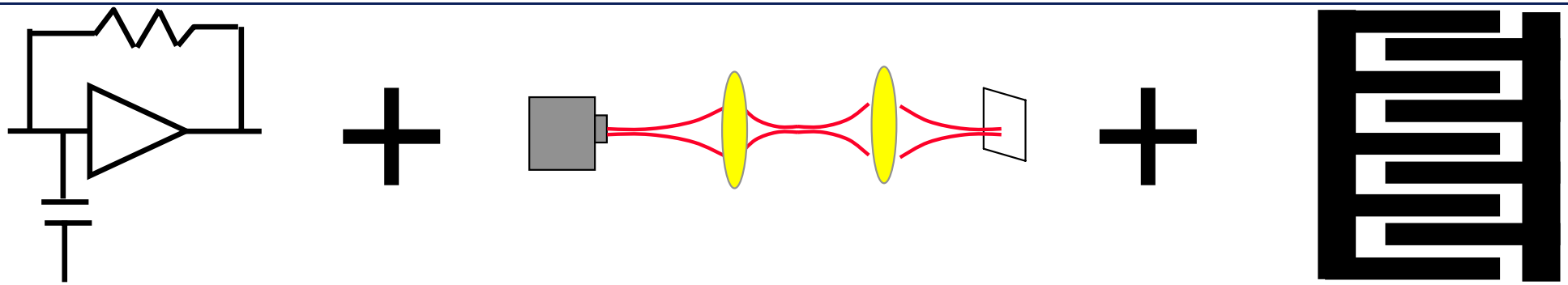
Outline

- Motivation: CAD for Optical MEMS
- System-Level Optical MEMS Modeling
  - Electromechanical macro-modeling
  - Overview of Gaussian optical modeling
  - Opto-electronic and optical components
- Example System
- Conclusions & Future Work

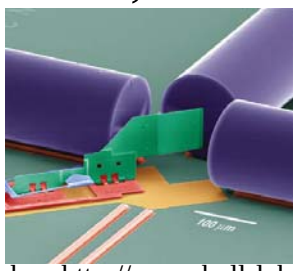
Optical MEMS



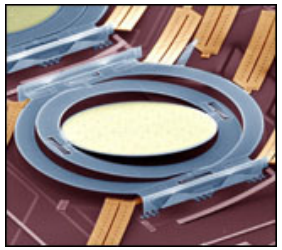
- **Electronics**
- **Optics**
- **Micromechanics**

Telecommunications

Switches, Modulators, Attenuators, Equalizers



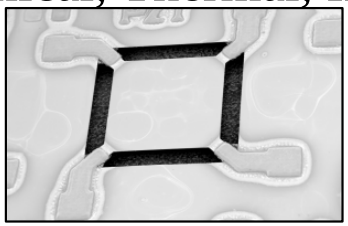
Bell Labs- http://www.bell-labs.com/



Lucent - http://www.lucent-optical.com/

Sensing

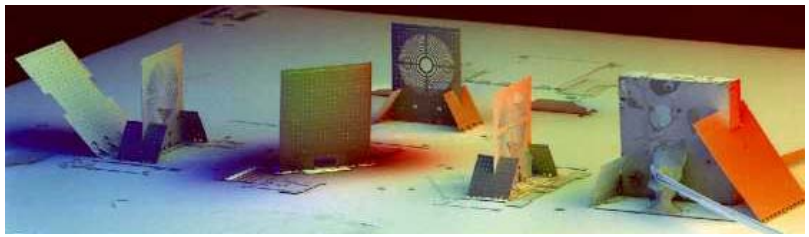
Chemical, Thermal, Inertial



Thick-Film PZT Sensing Element University of Southampton Institute of Transducer Technology - http://www.usit.ecs.soton.ac.uk/

Optical Computing

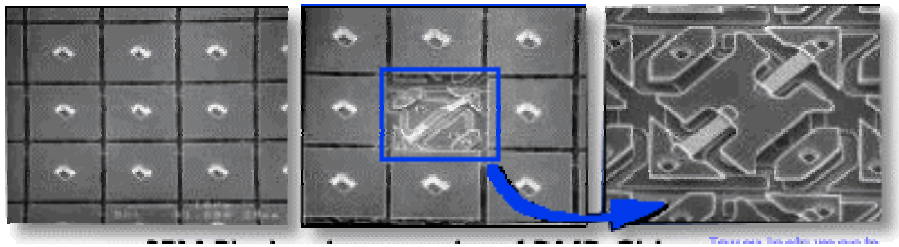
Data Storage, Backplanes, Interconnects



UCLA - Integrated Free-Space Optical Disk Pickup Head
http://www.ee.ucla.edu/labs/laser/

Imaging

Scanning, Display, Printing, Adaptive

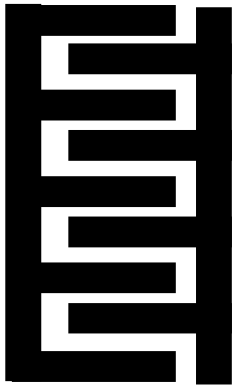


Texas Instruments - DMD - From Darpa
http://www.darpa.mil/ETO/MOEMS/DMD/index.html

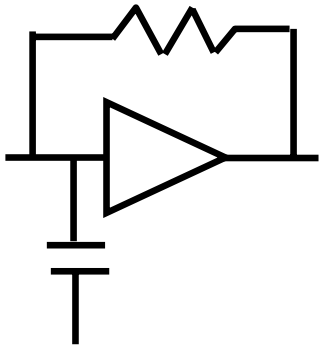
System Level Design Tools

- Support all 3 domains in single framework
- Reduce costly prototyping
- Architecture vs. technology trade-offs
- Extract device macro-models
- Device evaluation in system-level context

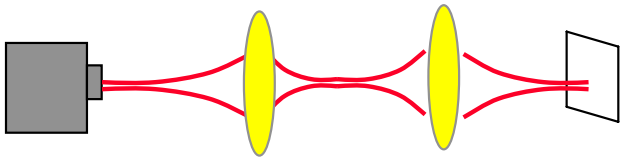
CAD for System-Level Design



MEMCAD



MEMSys

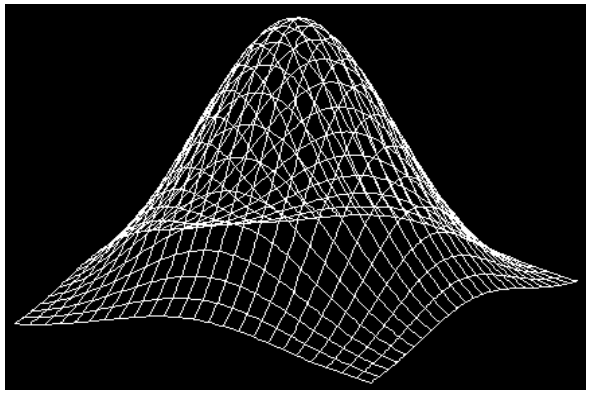


???

- *MEMSys* - established platform for MEMS system design
  - Dynamic electro-mechanics
  - Damping
  - Packaging effects
  - Models extracted into *MEMSys* from *MEMCAD*
- Extend *MEMSys* for optical analysis
  - Gaussian optical propagation
  - Written in MAST (*Saber's* AHDL)

Gaussian Optical Propagation

- ☺ Good approximation in many systems
- ☺ Fast simulations
- ☺ 11 scalar parameters
  - position: x,y,z; orientation: ρ, θ, γ; peak intensity: I_0; Rayleigh range: z_0; distance to next minimum waist: z_{w0}; wavelength: λ; phase: p



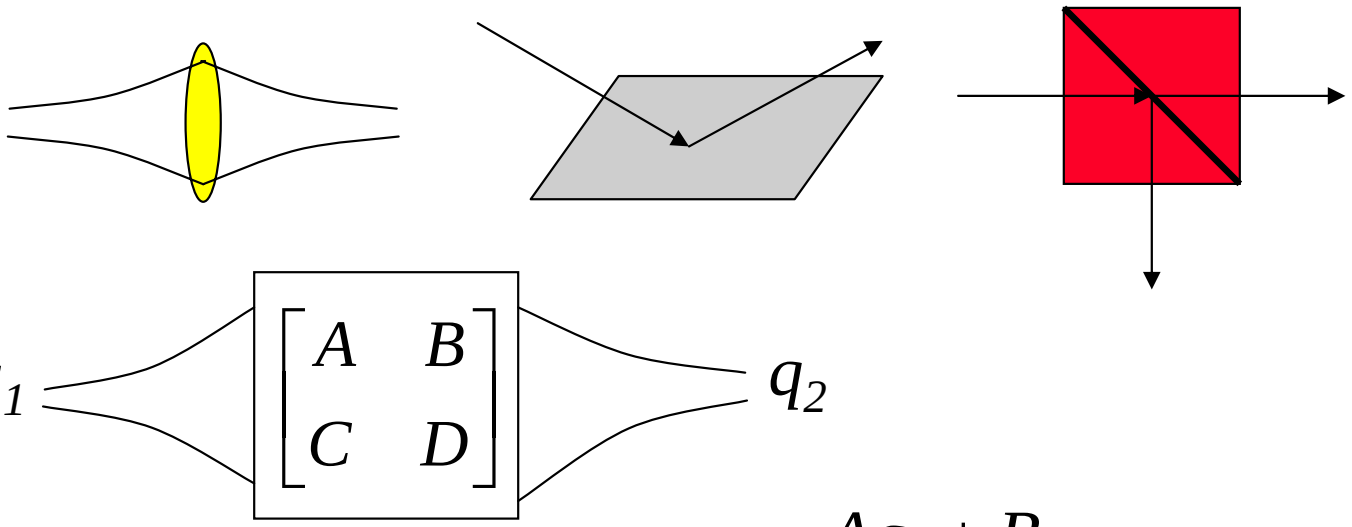
- ☺ No explicit integration of wavefront

$$W(z) = W_0\sqrt{1+\left(\frac{z}{z_0}\right)^2}, \quad R(z) = z\left[1+\left(\frac{z_0}{z}\right)^2\right], \quad \zeta(z) = \tan^{-1}\frac{z}{z_0}, \quad W_0 = \sqrt{\frac{\lambda z_0}{\pi}}$$

- ☹ Limited diffraction modeling

Initial Optical Devices Implemented

- Optical Components
  - Thin Lens
  - Mirror
  - Beam Splitter

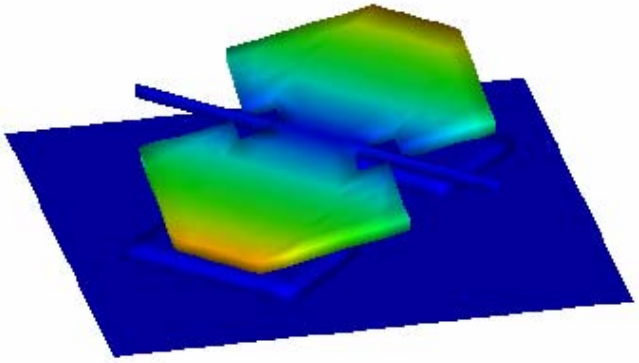


$$y_2 = Ay_1 + B\theta_1 \qquad \theta_2 = Cy_1 + D\theta_1 \qquad q_2 = \frac{Aq_1 + B}{Cq_1 + D}$$

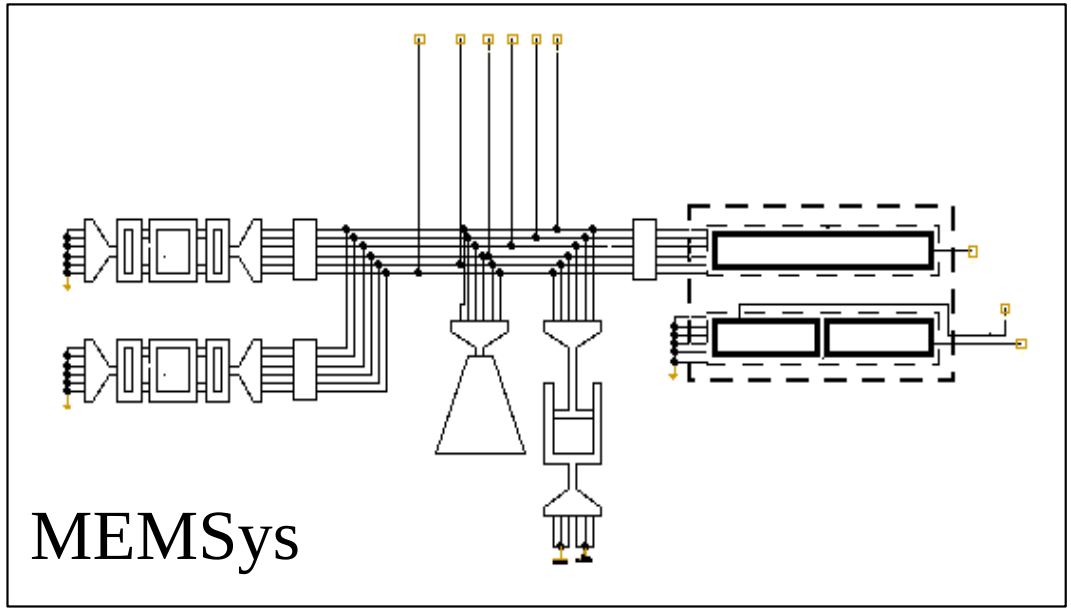
(Position) (Rotation) (Intensity, Rayleigh Range)

- Optoelectronic Components
  - VCSEL
  - Detector

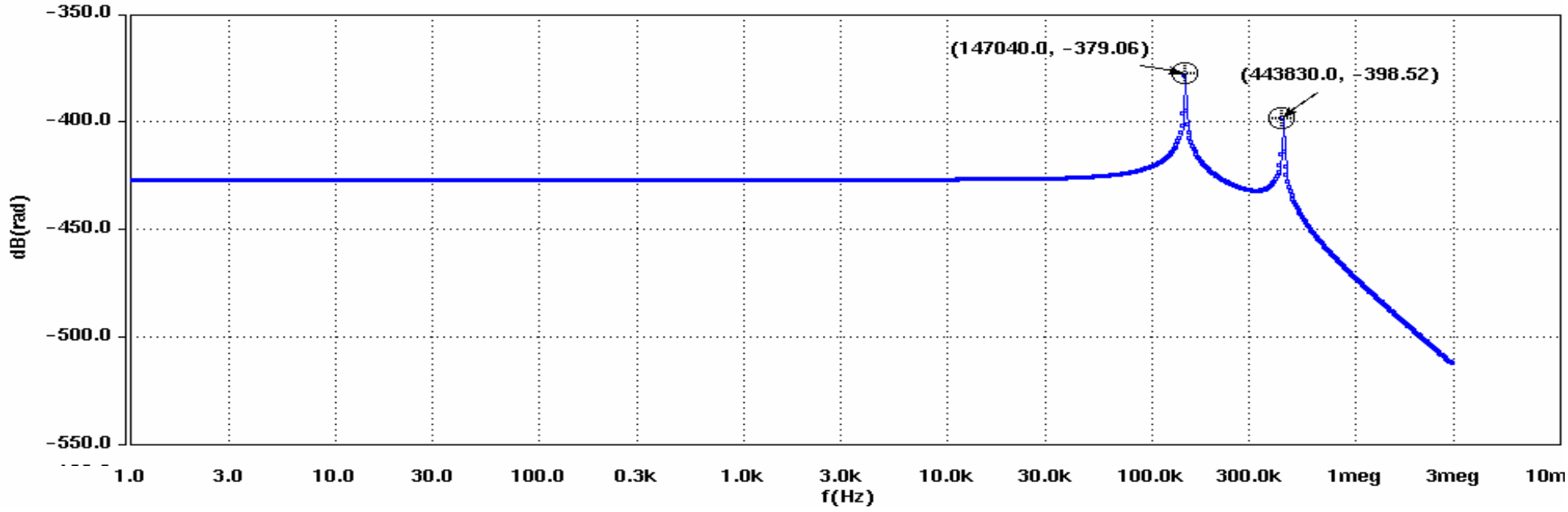
Micro-Mirror Model Extraction



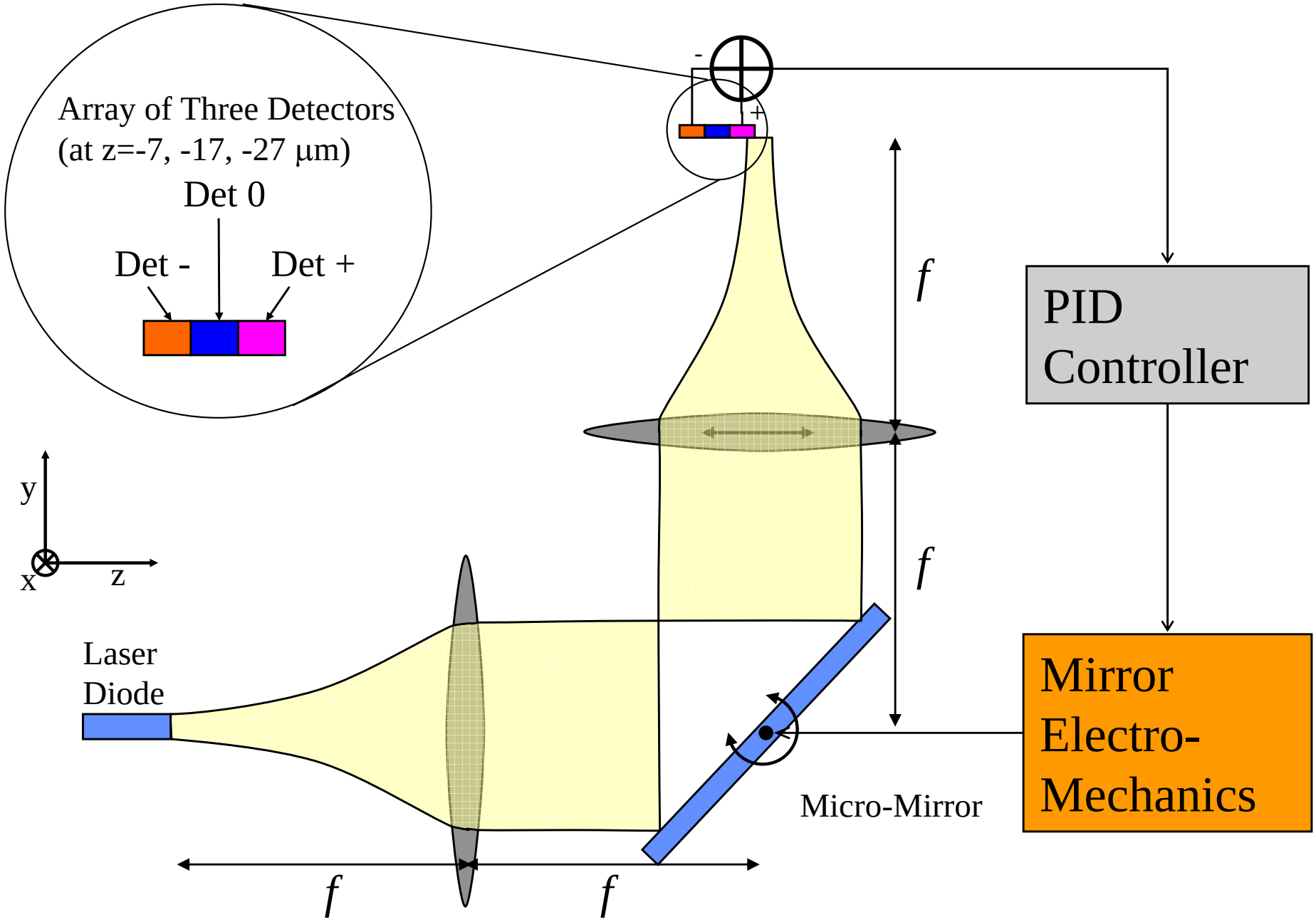
MEMCAD



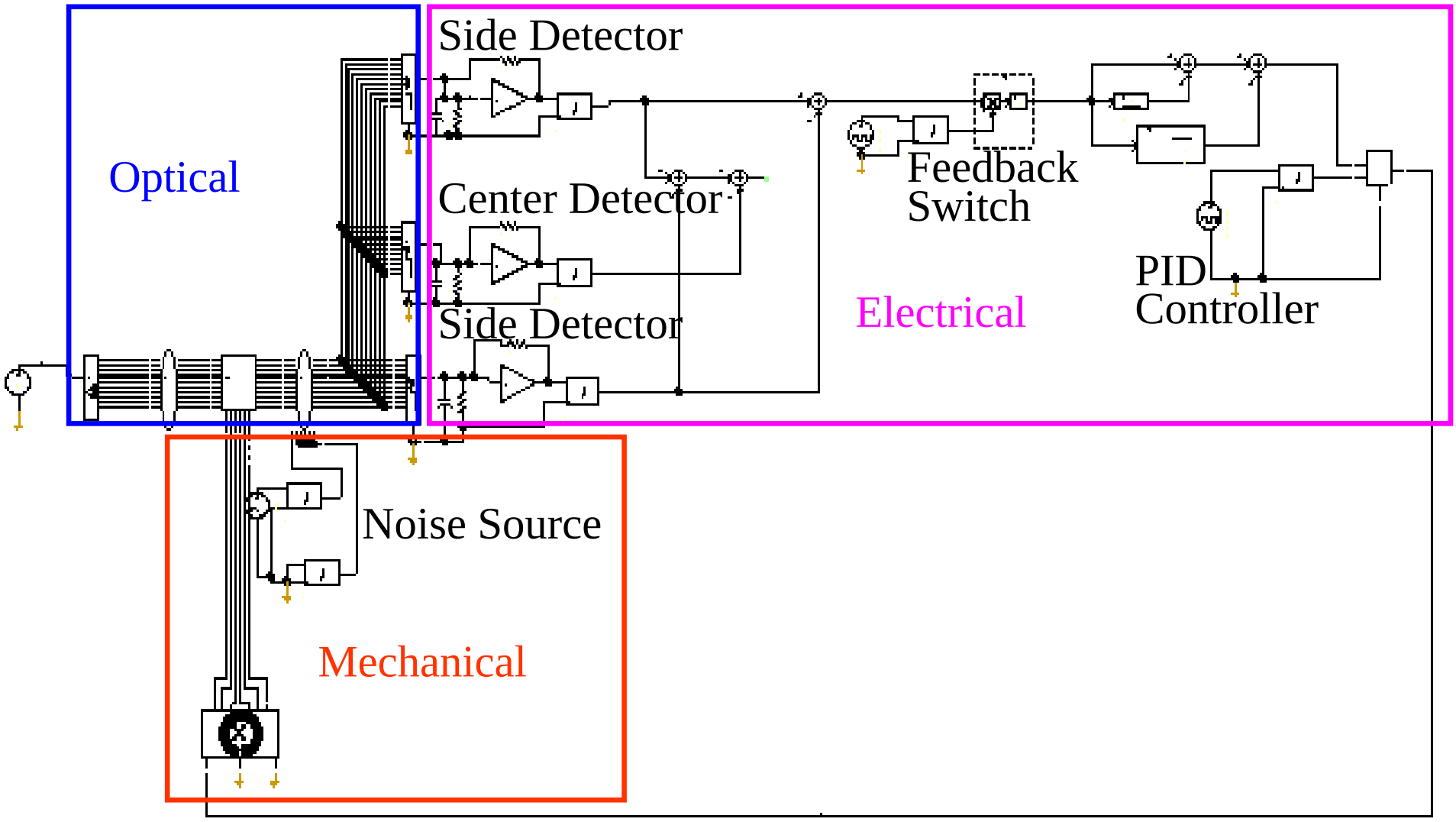
MEMSys



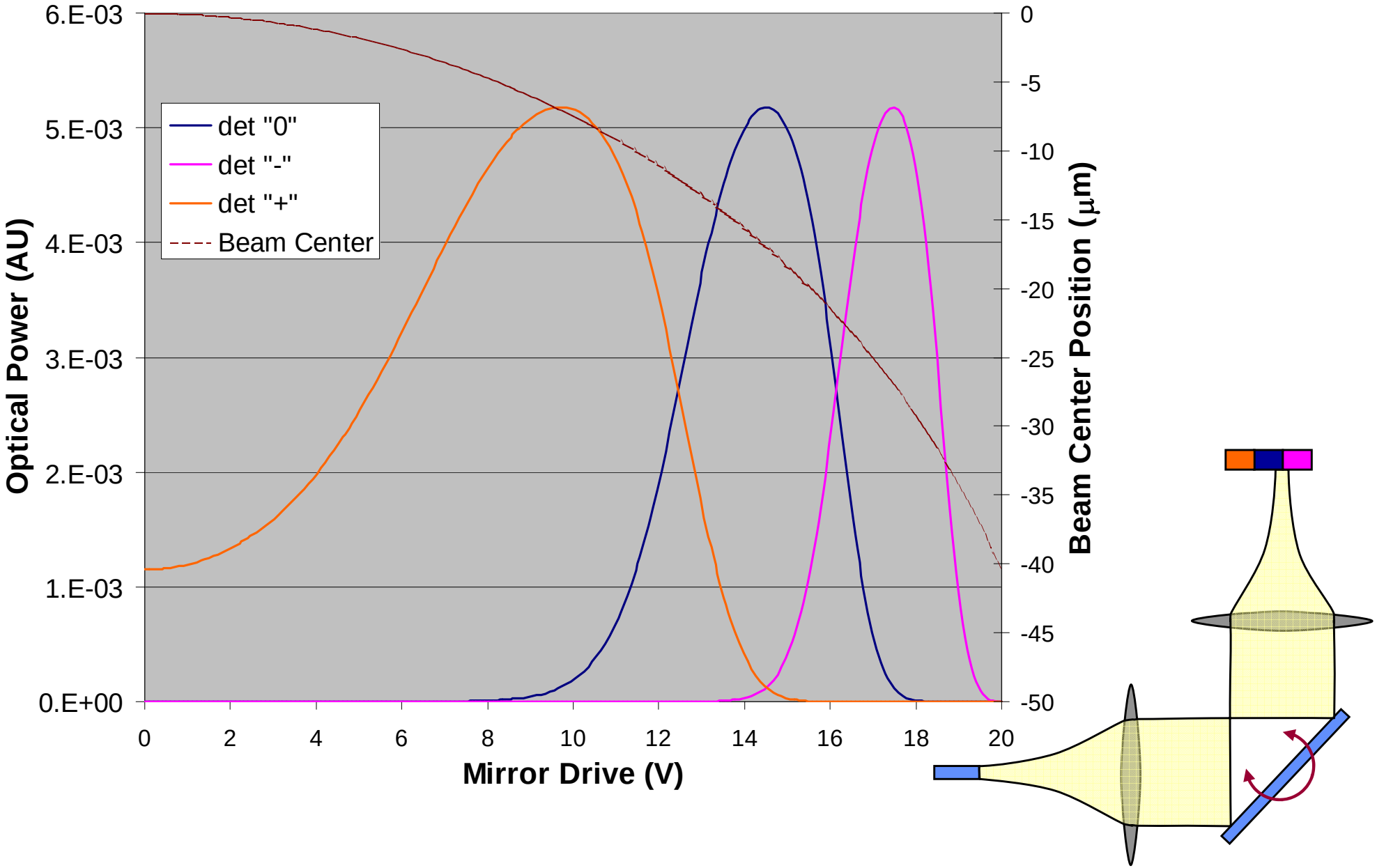
MOEM Noise Suppression System



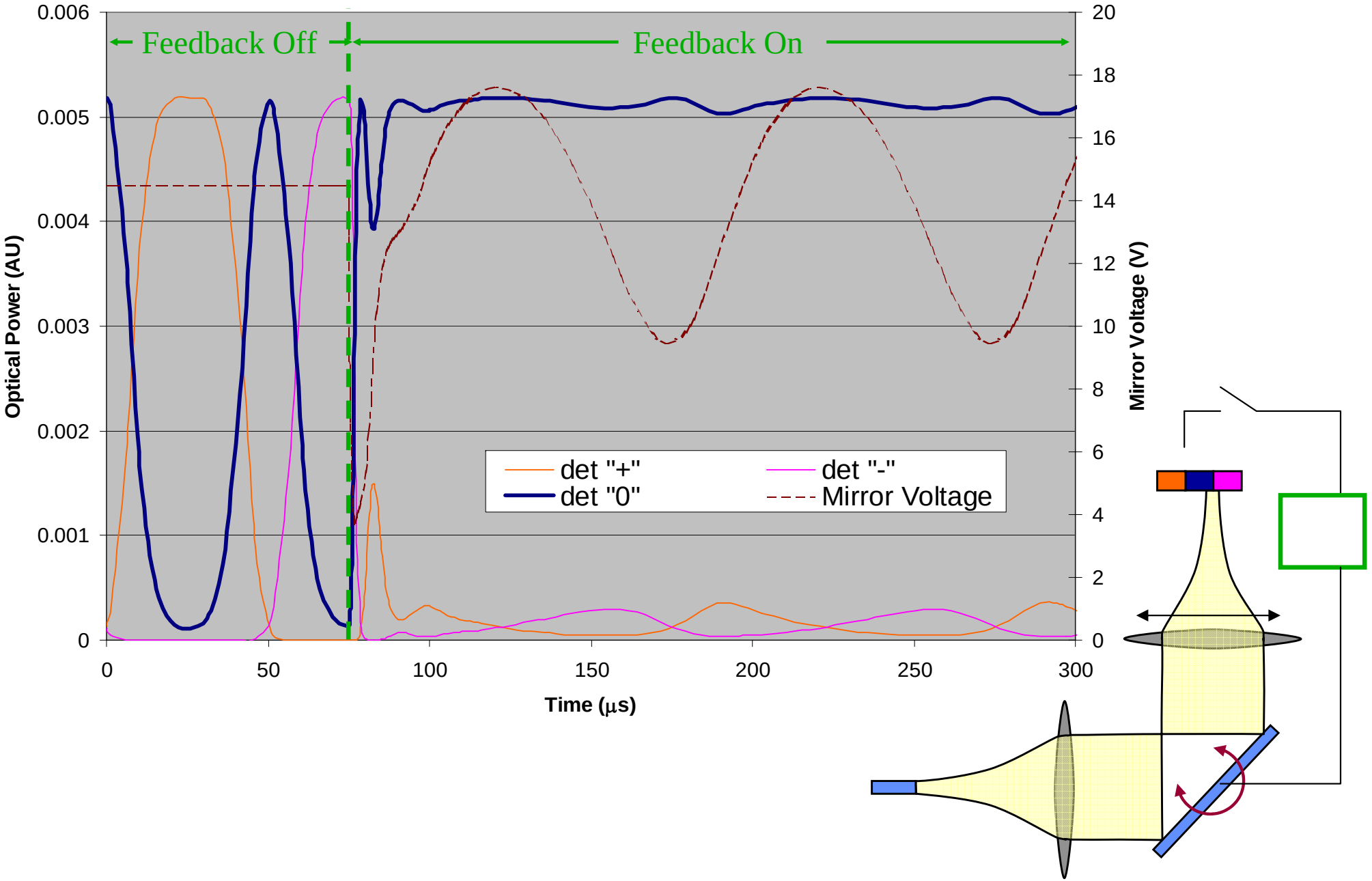
Noise Suppression System in *MEMSys*



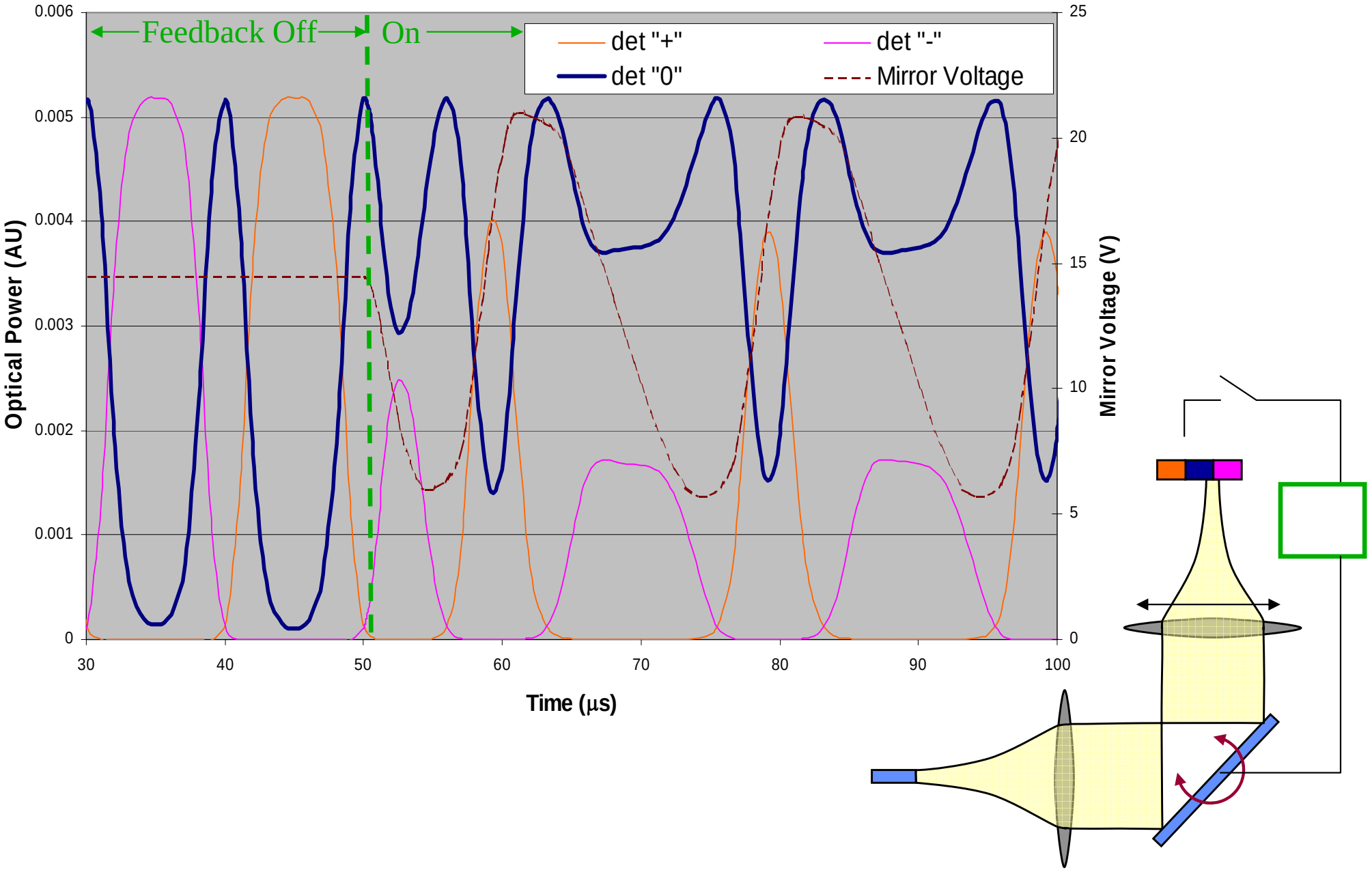
Beam Motion vs. Applied Voltage



10kHz Lens Vibration Compensation



50kHz Lens Vibration Compensation



Conclusions

- CAD Needed for System Design of Optical MEMS
  - Simultaneous simulation of electronics, mechanics, and optics
  - Reduce costly prototyping
- Promising Tool for the Design and Optimization of Systems Utilizing Optical MEMS
  - Mechanical and electrical domains exist in *MEMSys*
  - Added optical models based on Gaussian optics
    - fast simulation
    - accurate for systems not heavily diffractive
  - Closed loop control system simulated
    - Intuitive results obtained