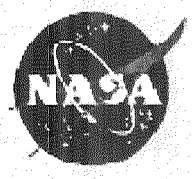


Applications of ANSYS/Multiphysics at NASA/Goddard Space Flight Center

Jim Loughlin

Mechanical Systems Analysis and Simulation Branch

Code 542

May 15, 2007

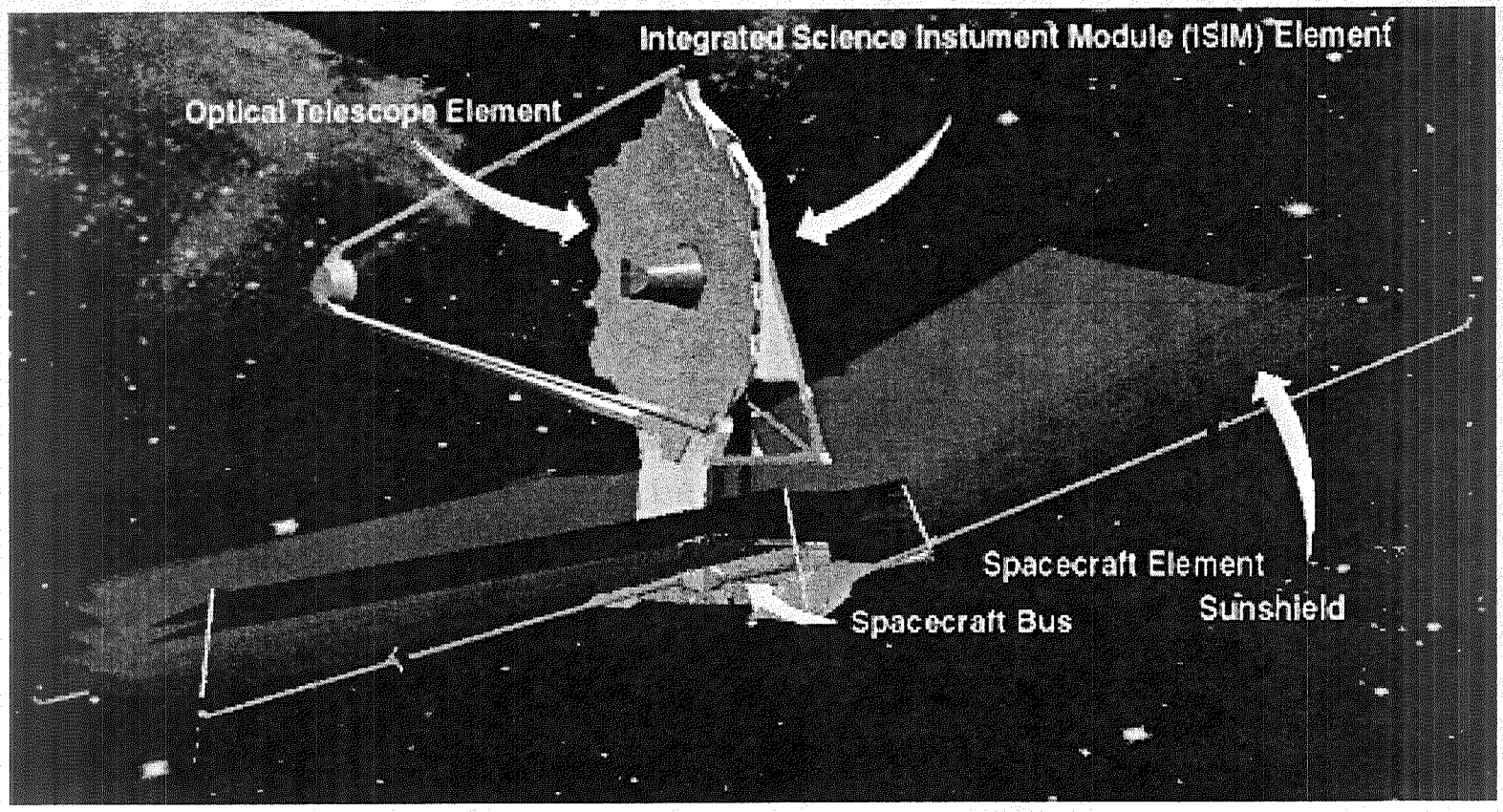
Contributors to the GSFC MEMS Analysis Efforts

- Mindy Jacobson/formerly of 542
- Jonathan Kuhn/formerly of 542
- Jim Loughlin/542
- Dan Powell/540
- Apurva Varia/592

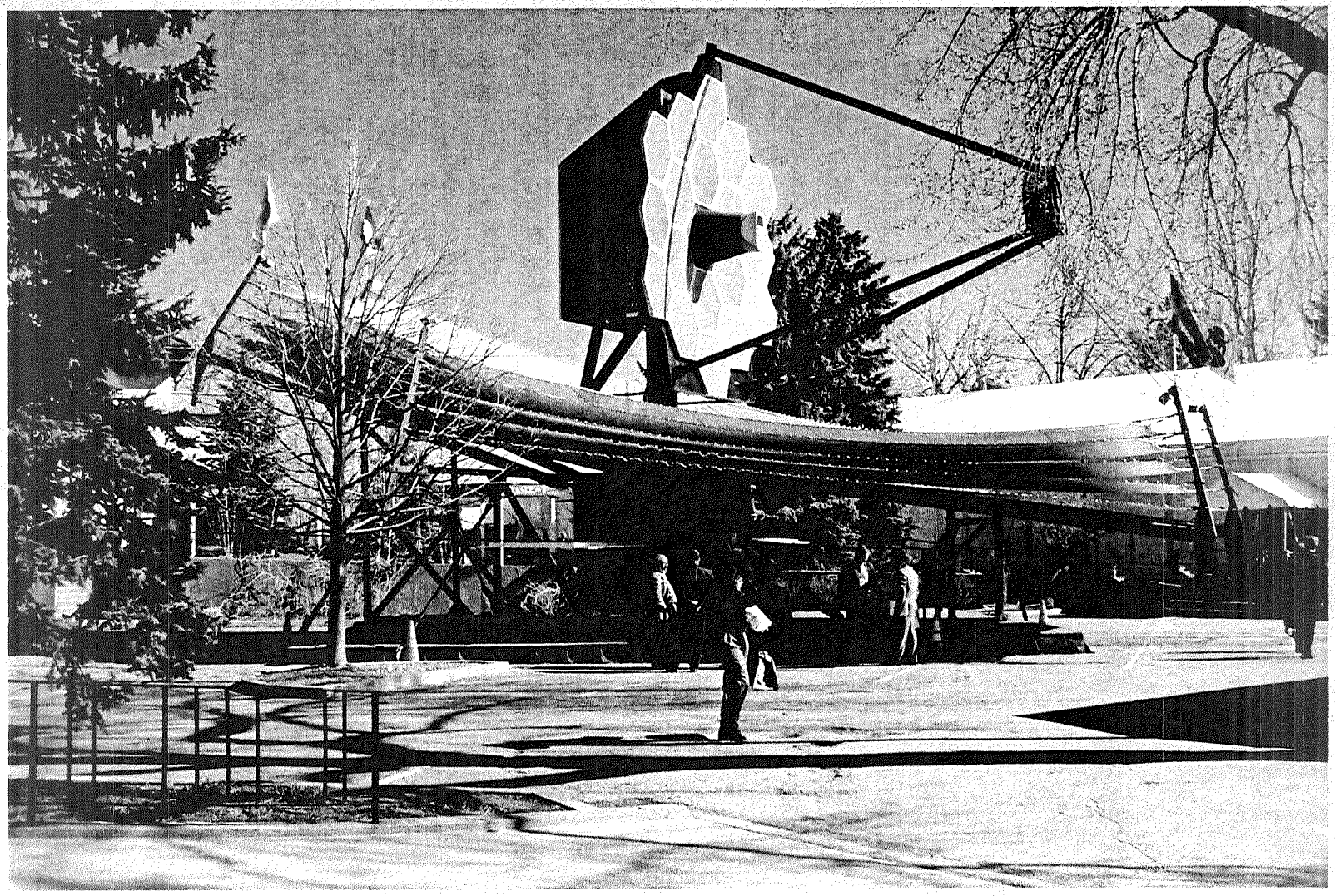
MEMS Structural Analysis

- Projects:
  - Micro-mirror Array for JWST
  - Micro-shutter Array for JWST
  - MEMS FP Tunable Filter
  - AstroE2 Micro-calorimeter
- Types of Analysis:
  - Electrostatic/Structural Interaction
  - Electromagnetic/Structural Interaction
  - Geometric and Material Nonlinear Analysis
- Software:
  - ANSYS Multiphysics

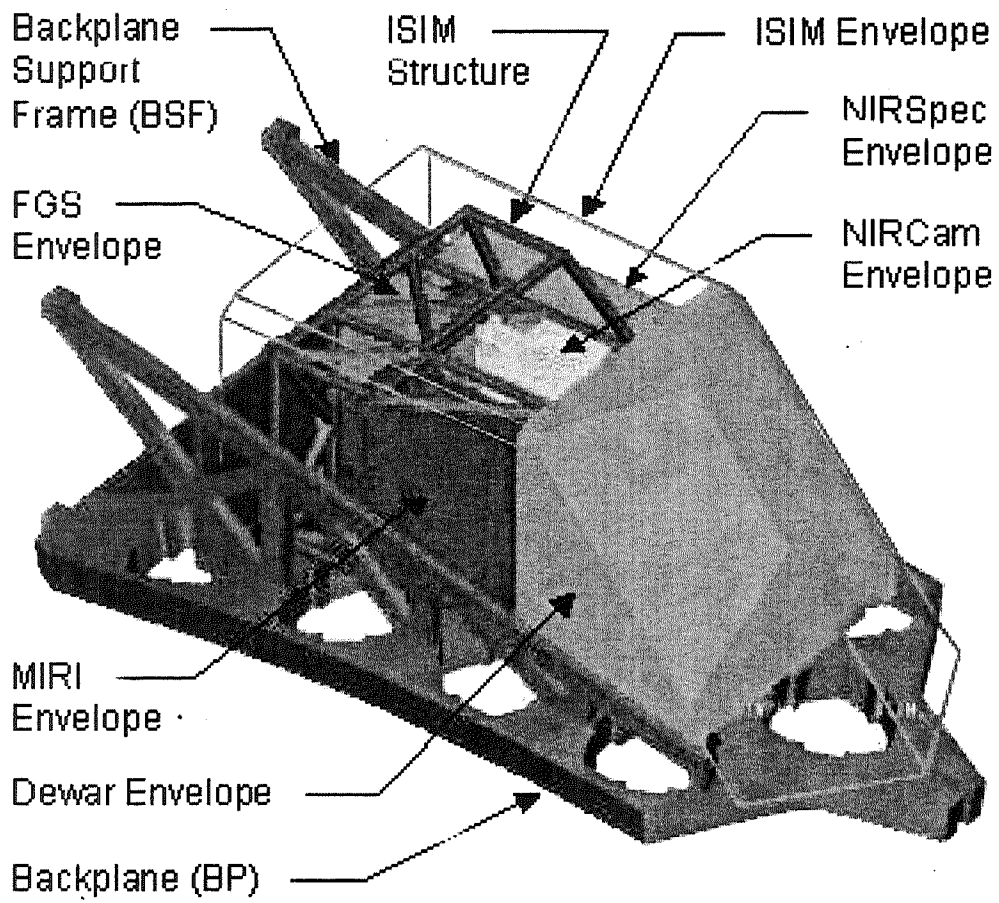
James Webb Space Telescope (JWST)



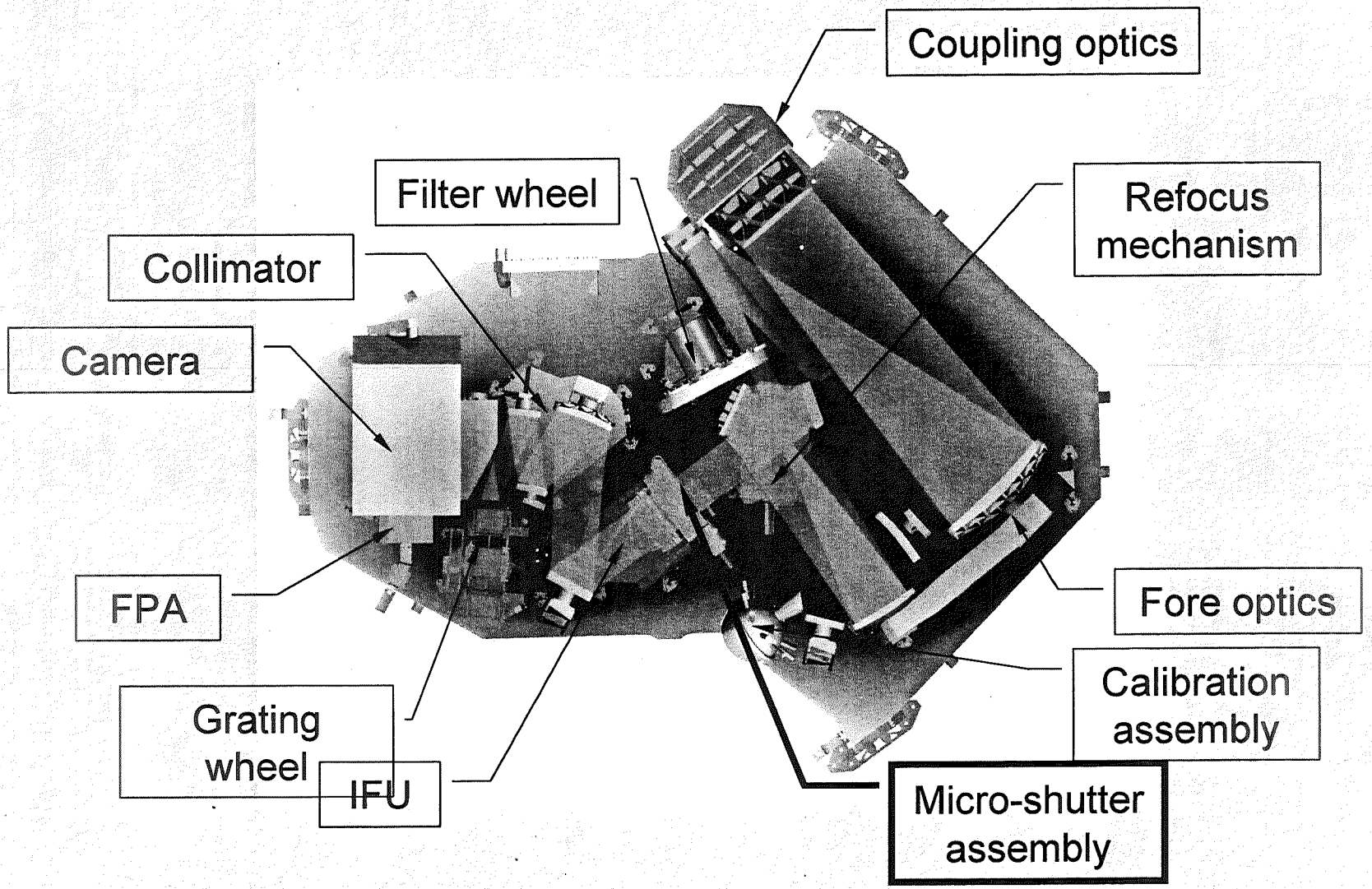
JWST Relative Size



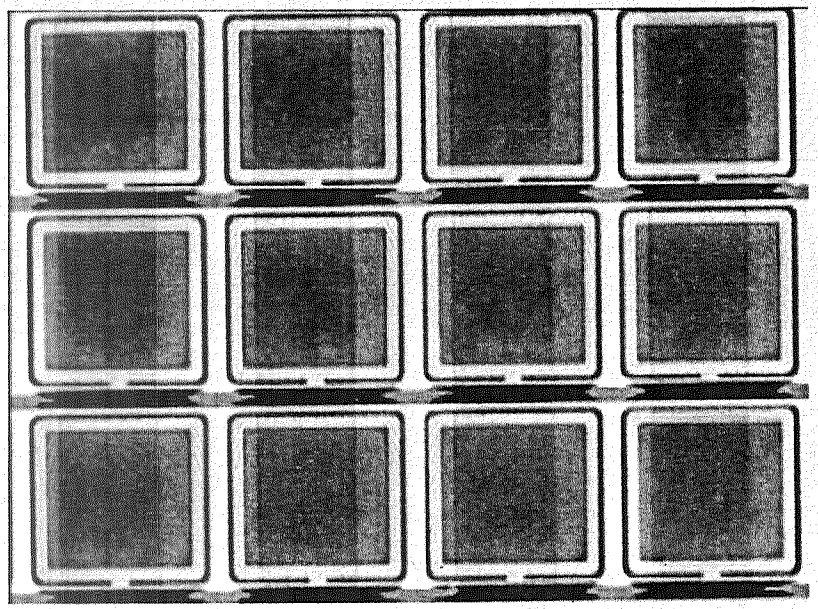
Integrated Science Instrument Module (ISIM)



NIRSpec Instrument Layout

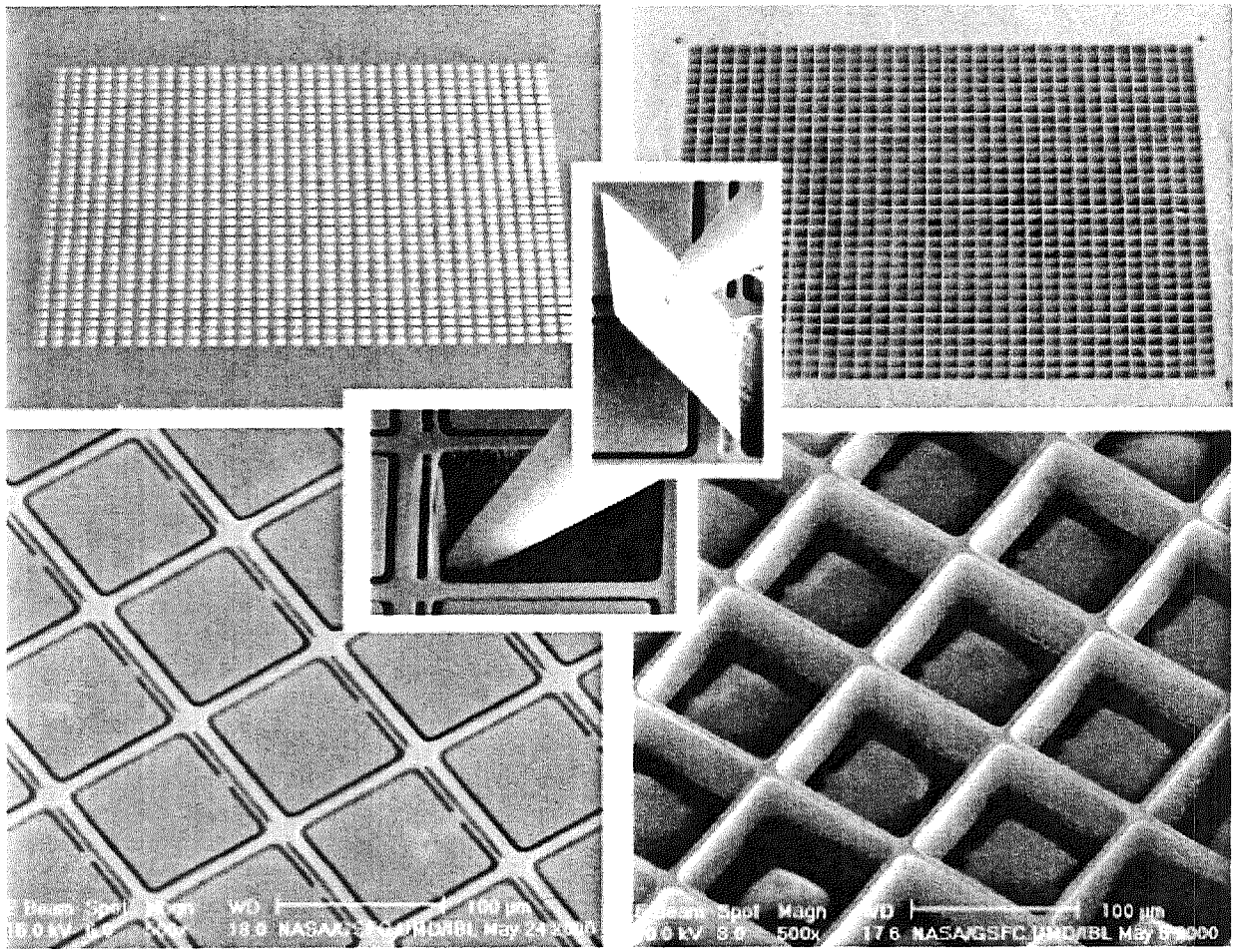


Micro-shutter Array



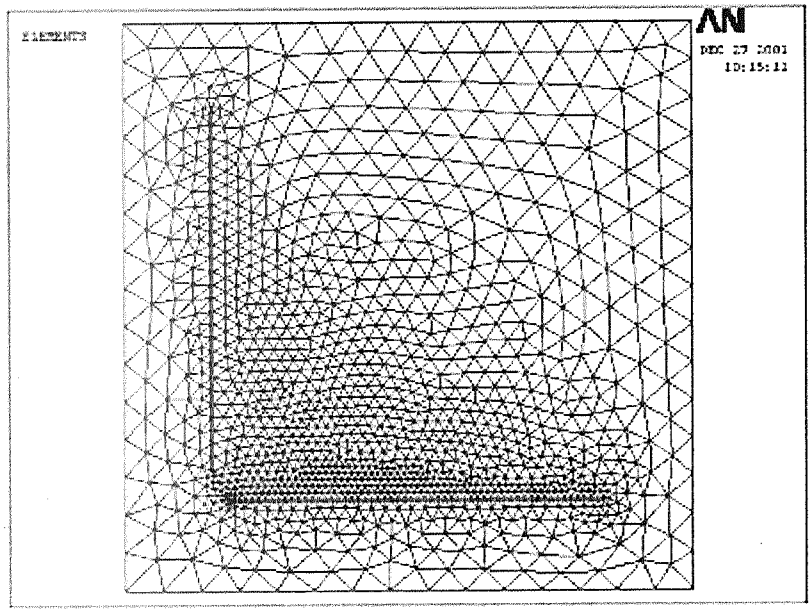
- The micro-shutter array is used as a transmissible filter in the Near Infrared Spectrometer.
- The shutter is etched from silicon nitride.
- The array grid is single crystal silicon
- Iron Cobalt is deposited onto the shutter paddle and is used for magnetic actuation.
- Aluminum is deposited onto the shutter as the ground electrode for electrostatic latching.

Micro-shutter Array

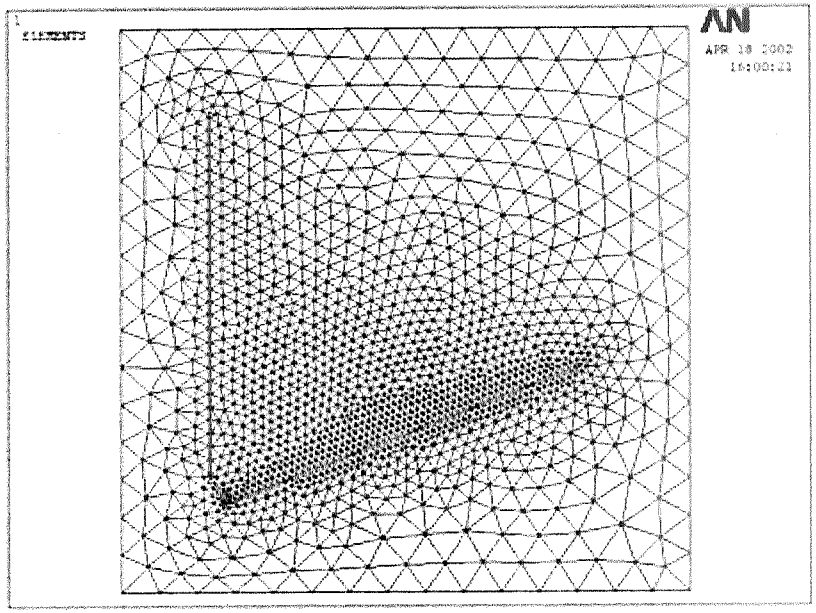


Early Micro-shutter Electrostatic Results

- 2D Structural/Electrostatic FEM Using ANSYS Multiphysics v5.7
- High voltage required for pure electrostatic actuation led to the shutter's magnetic actuation with electrostatic latching.



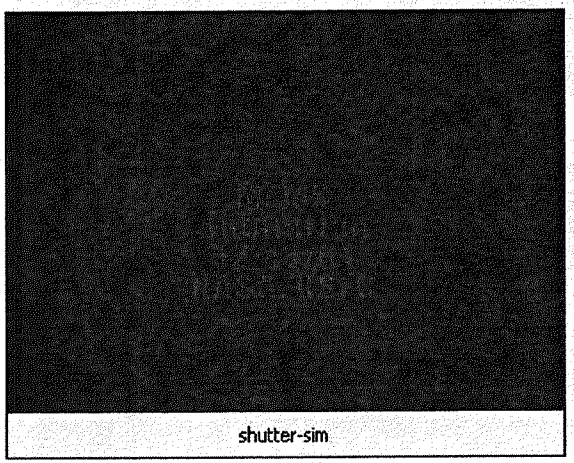
0 Volts



625 Volts

Micro-shutter Simulation

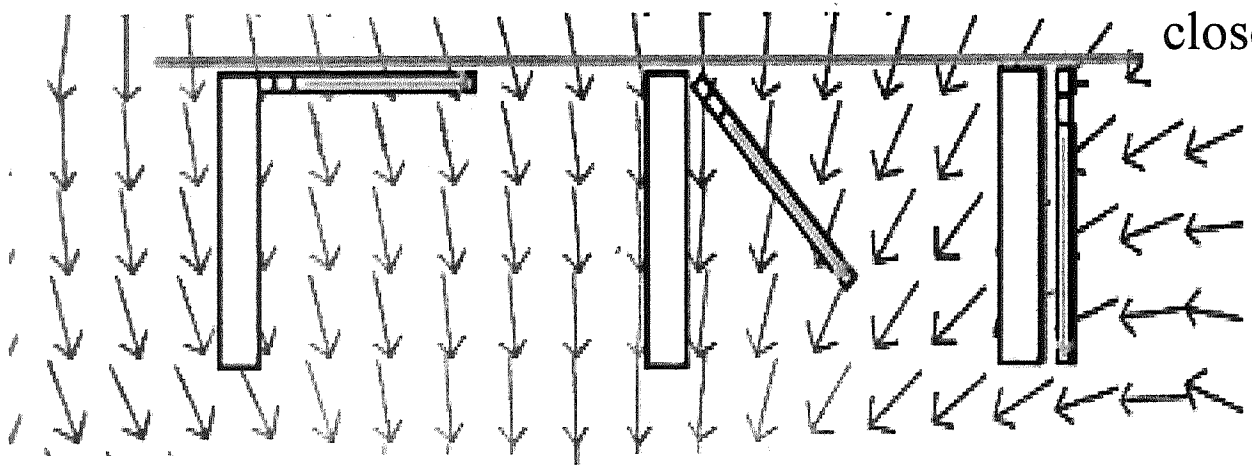
- animation created by Tim Carnahan/542



Micro-shutter Magnetic Actuation

Shutter is moved down as it is moved through magnetic field

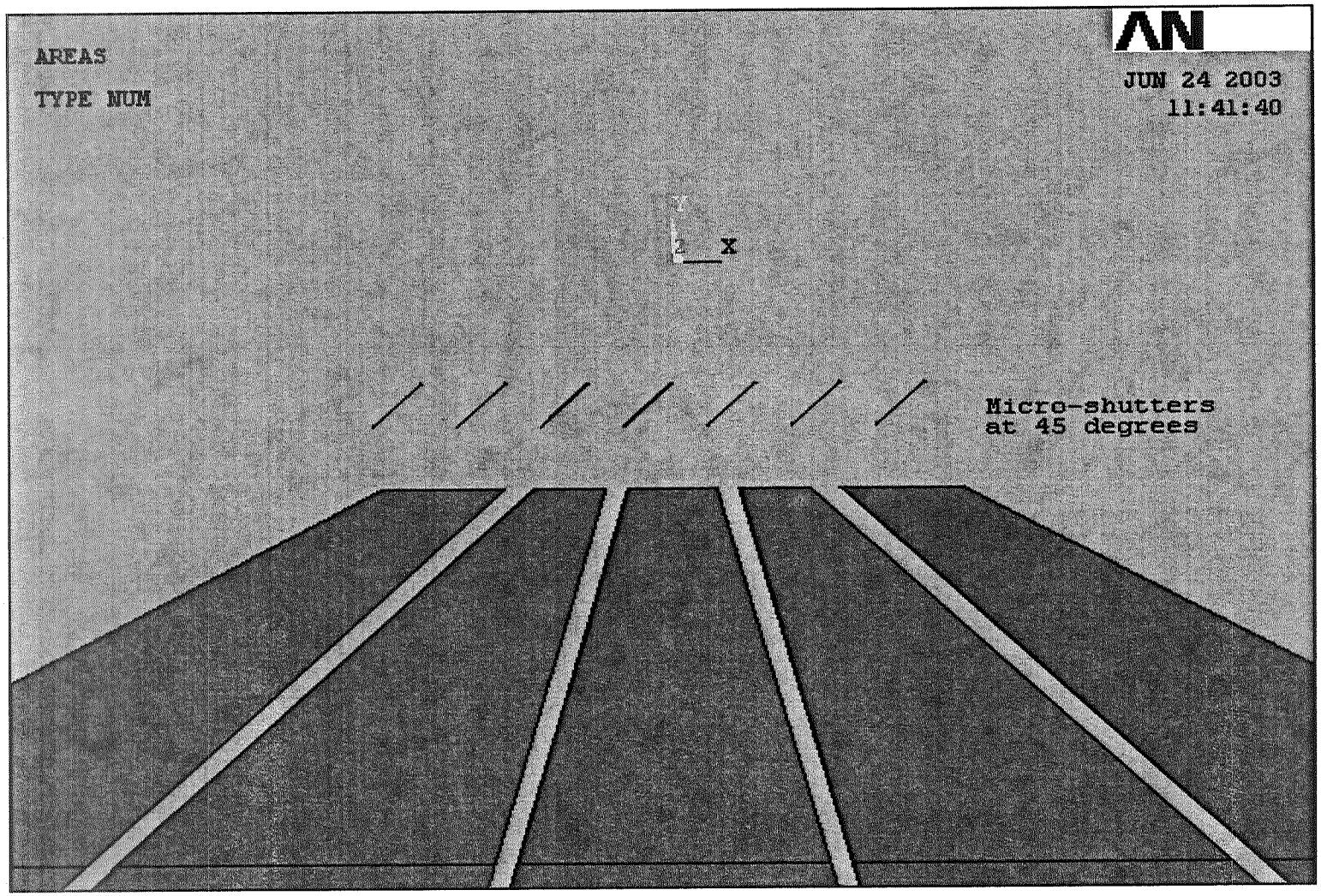
Transparent electrode holds closed shutters closed



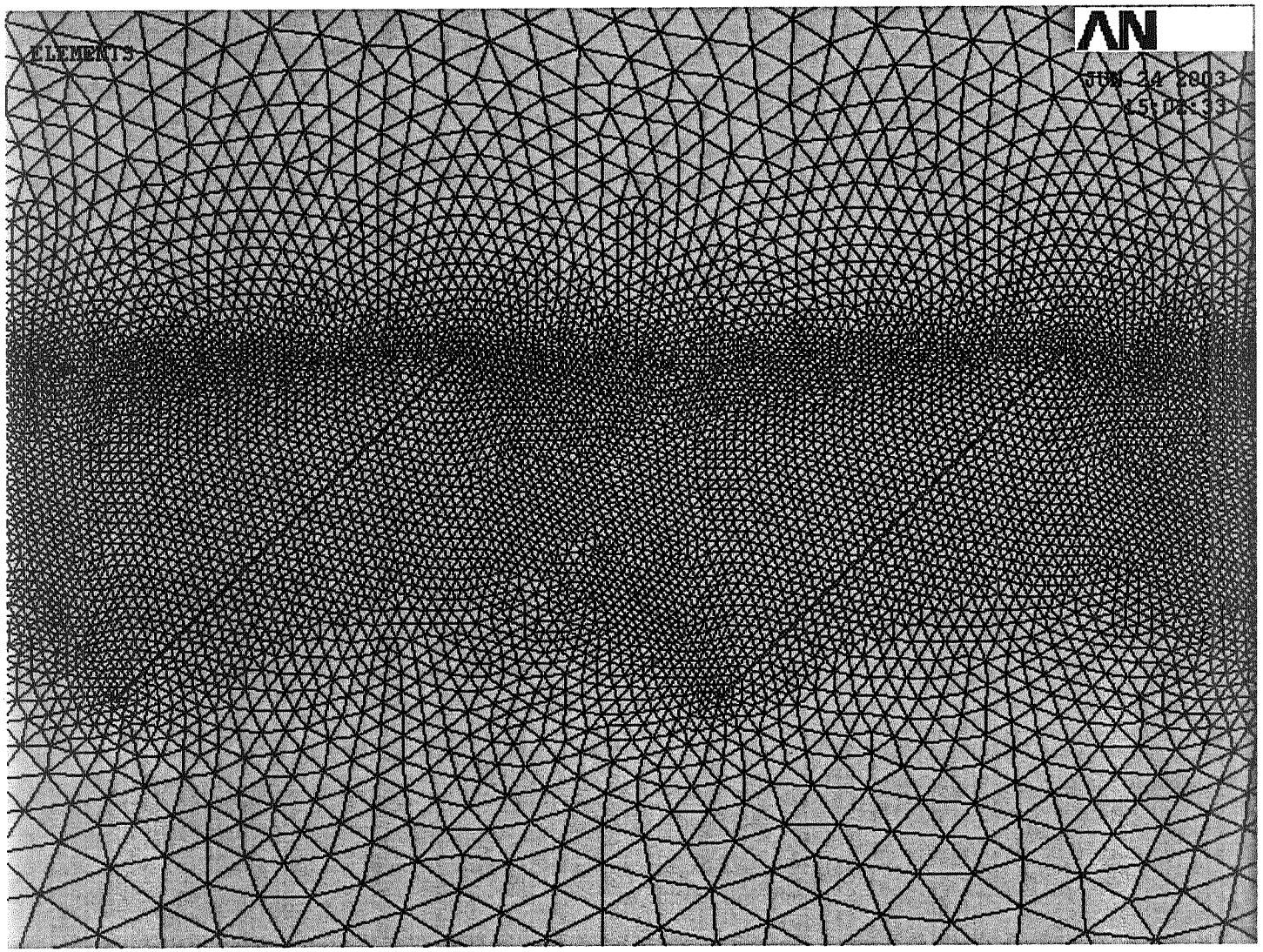
Magnetic metal on shutter is magnetized

Shutter is electrostatically captured and held in vertical position

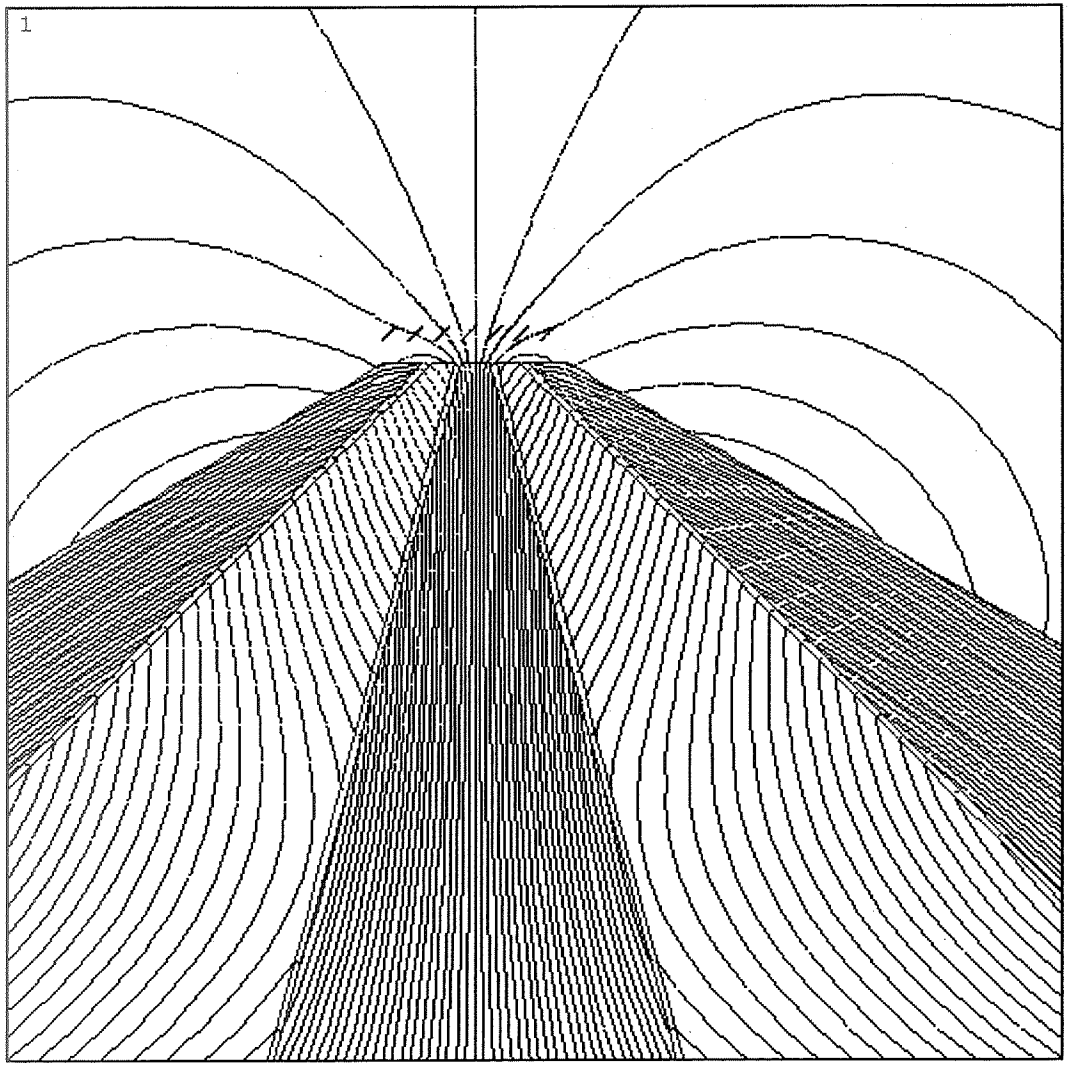
ANSYS Electromagnetic/Structural Model



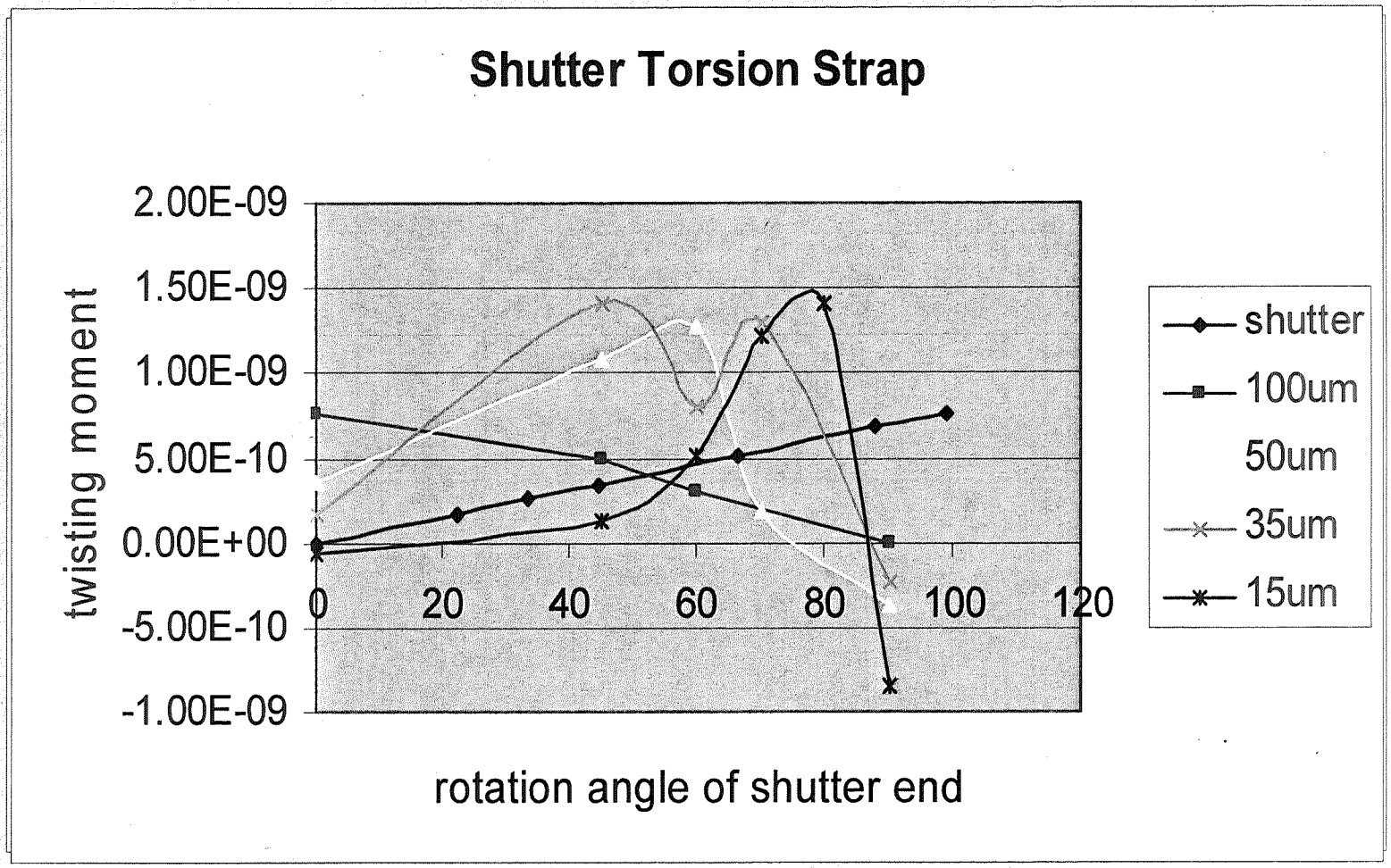
ANSYS Electromagnetic/Structural Model



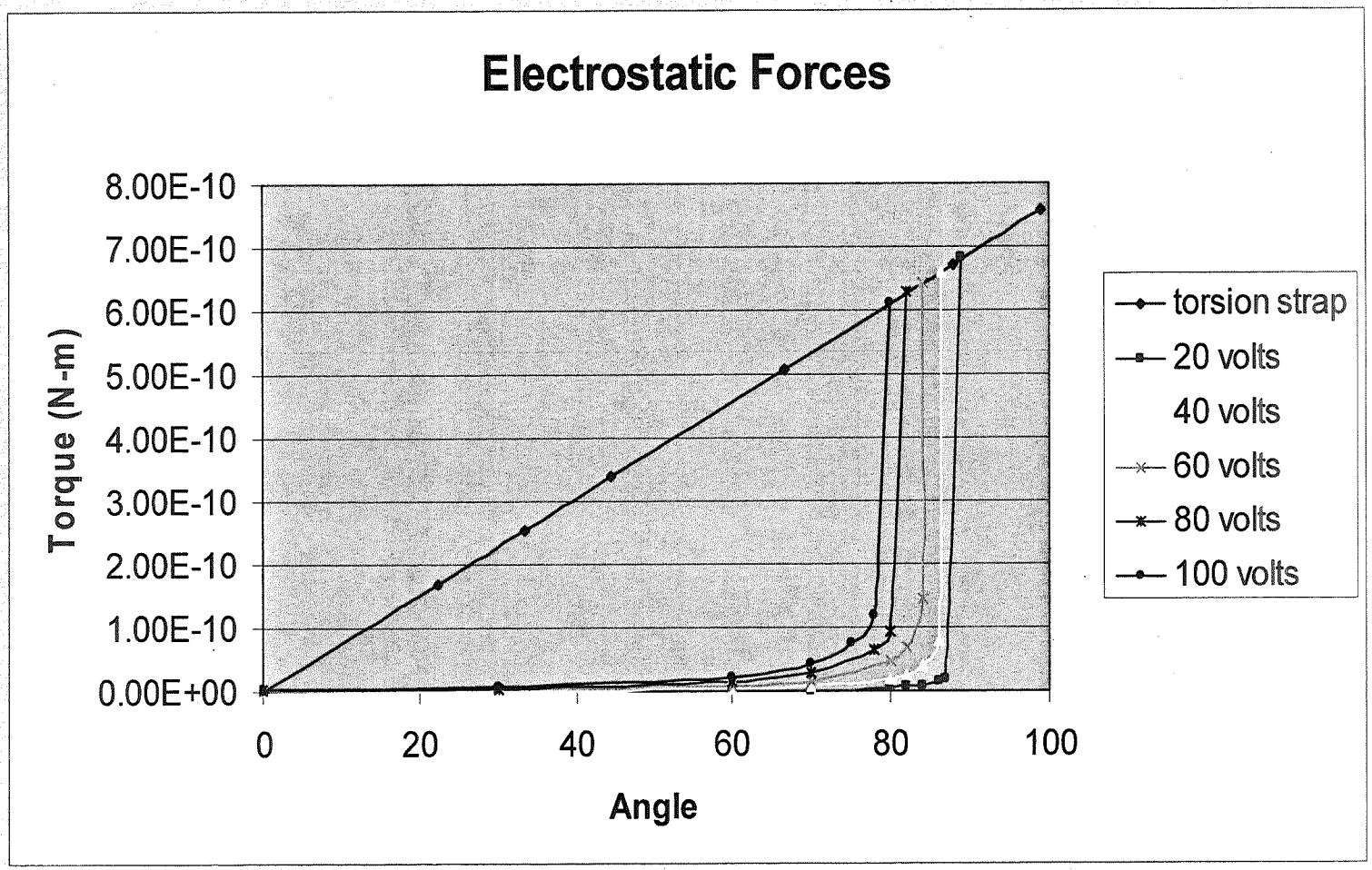
Magnetic Flux Lines from the Ansys Magnetic Solve



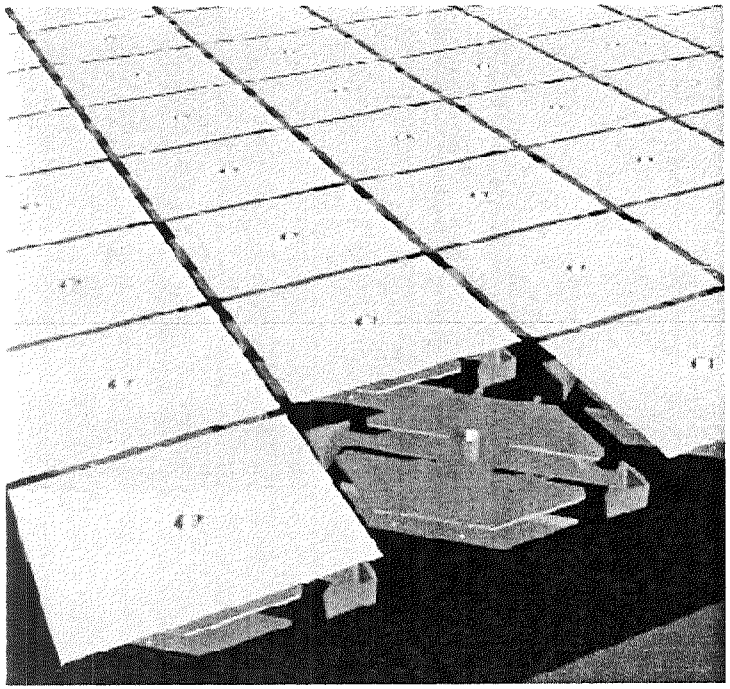
ANSYS Electromagnetic Results



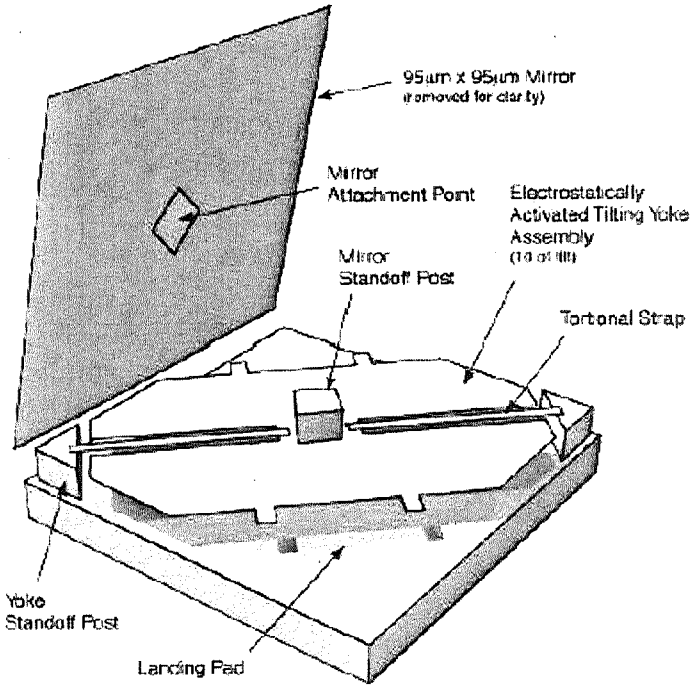
ANSYS Electrostatic Results



Micro-Mirror Schematic

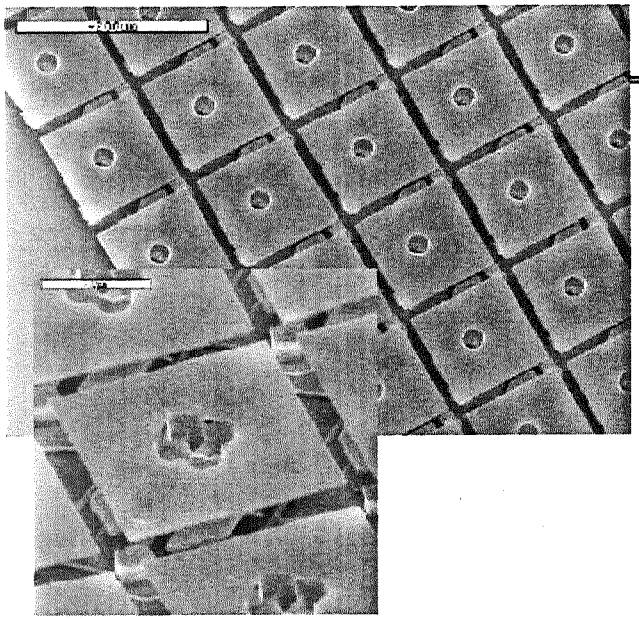


Artist's concept of the MMA

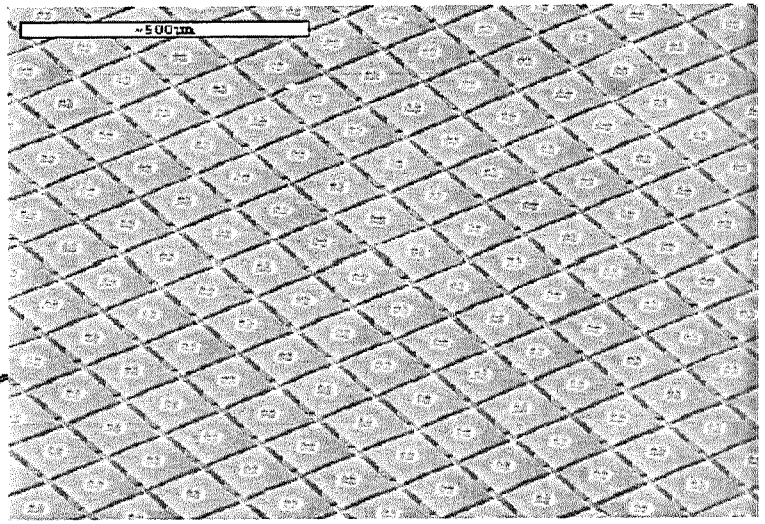


Artist's concept of a single mirror

Micro-Mirror-Array



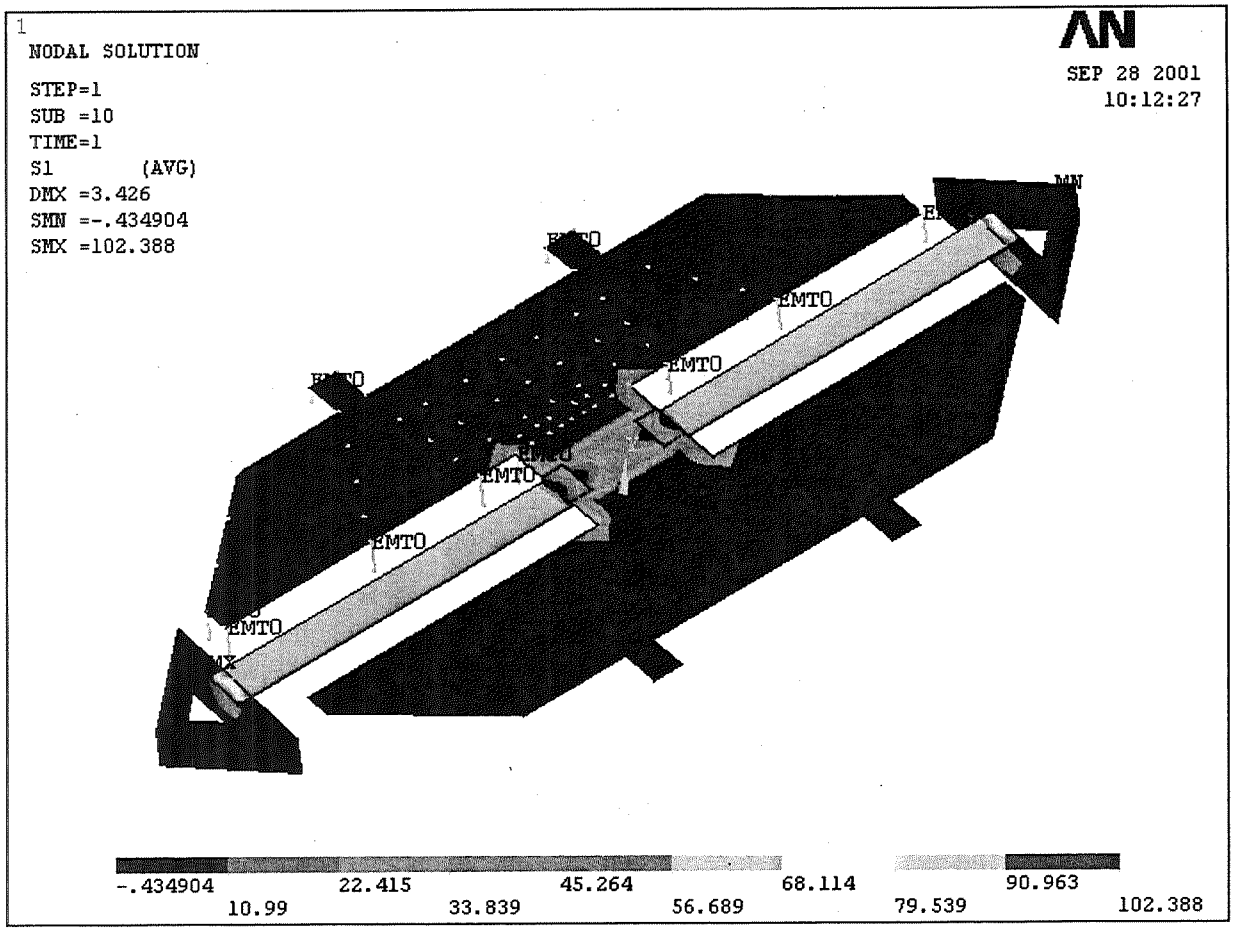
Dry Release of the Micro-Mirror-Array



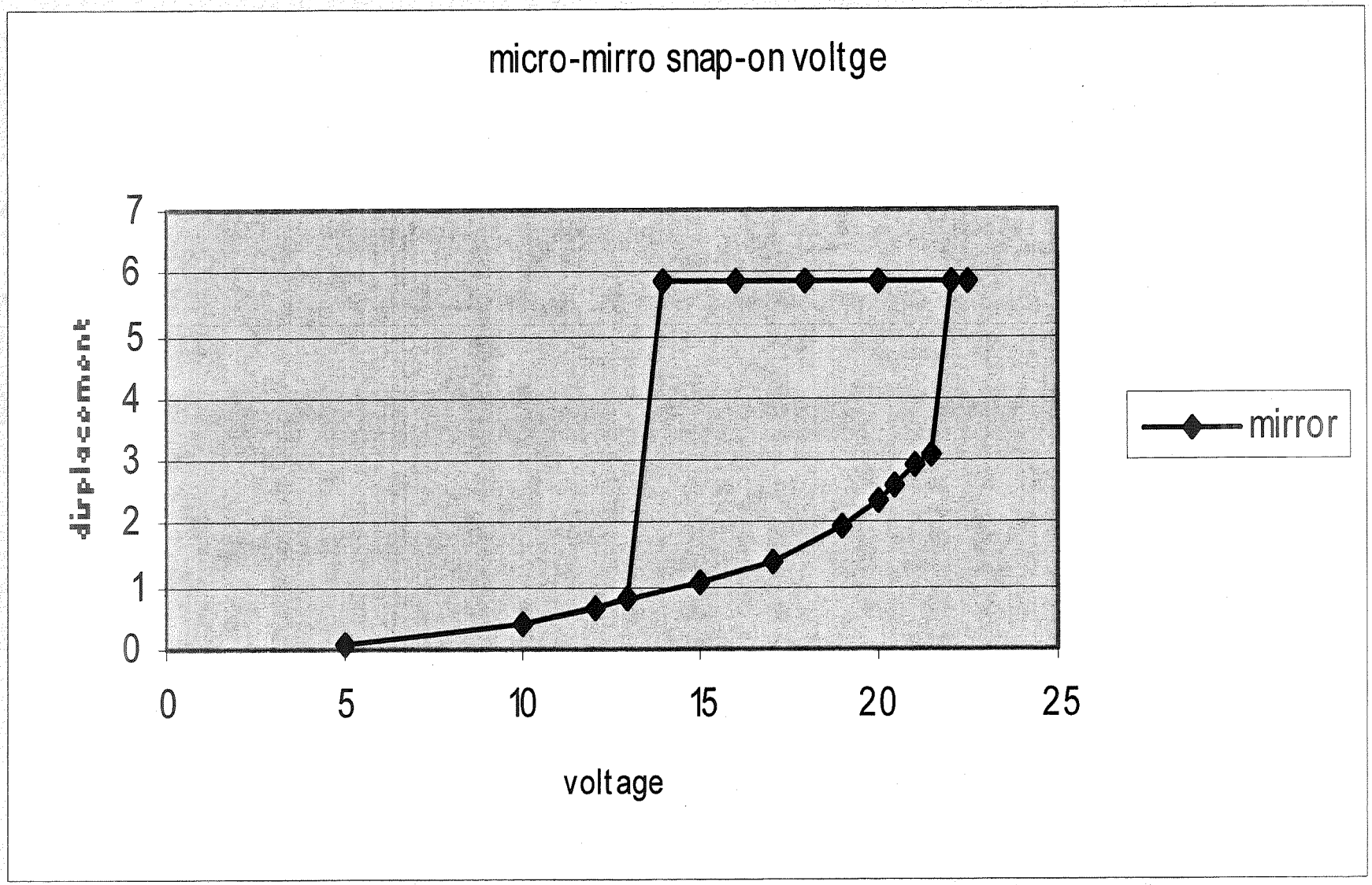
Recent improvement in the array size

3-D Micro-mirror Results

- 100μm x 100μm mirror electrostatically actuated at 50°K using nonlinear 1100 series Al properties



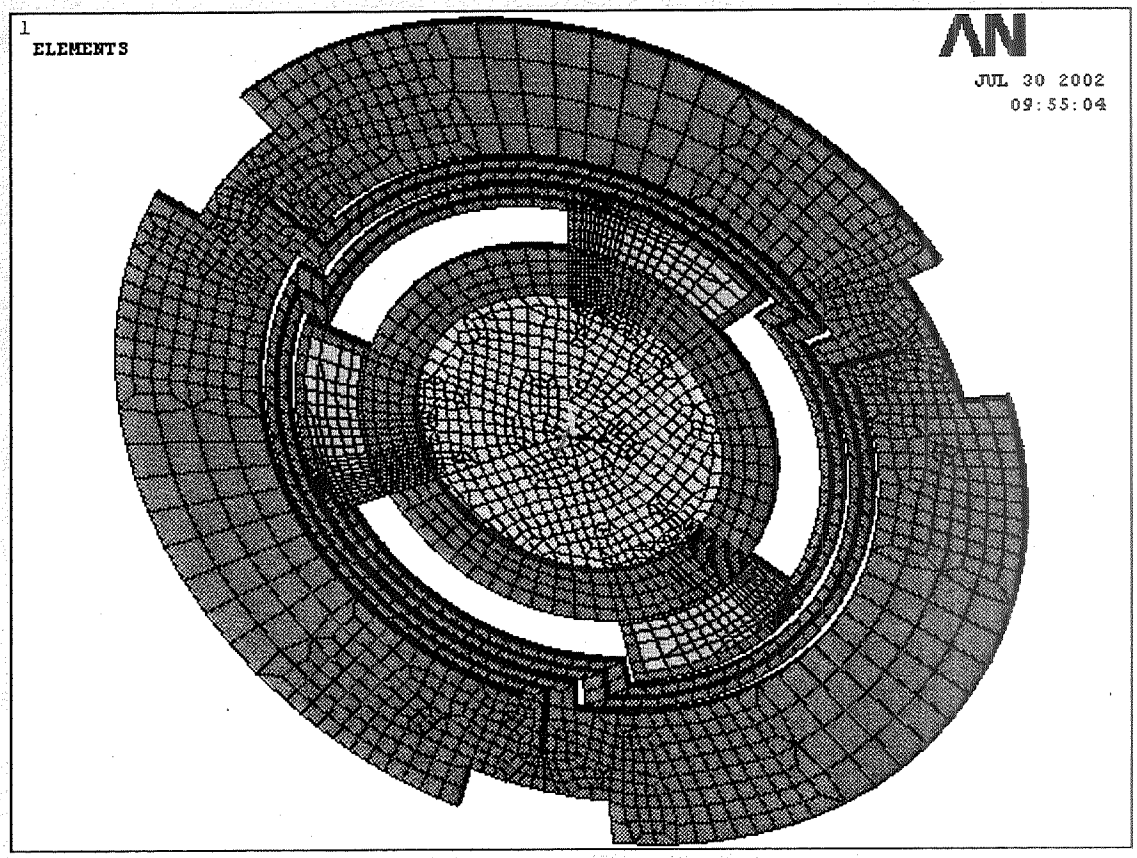
2-D Micro-mirror Electrostatic Snap-on and Release Voltages



MEMS Electrostatically Actuated Fabry-Perot Tunable Filter

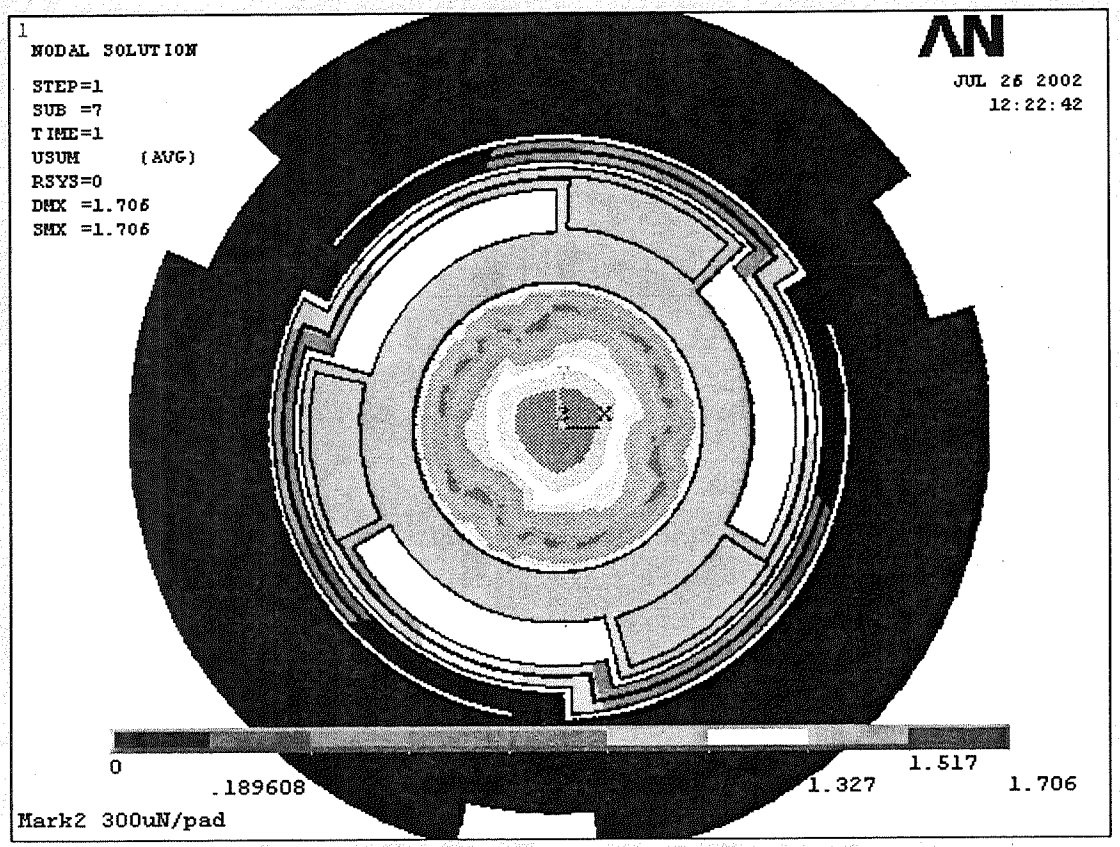
Micro-Scale Fabry-Perot

- Current 3D FEM: Top Etalon Plate (t=325μm)
  - 11.000mm Aperture
  - 32.650mm O.D.
  - Spring Width = 800μm
  - Optical Gap = 17.5μm



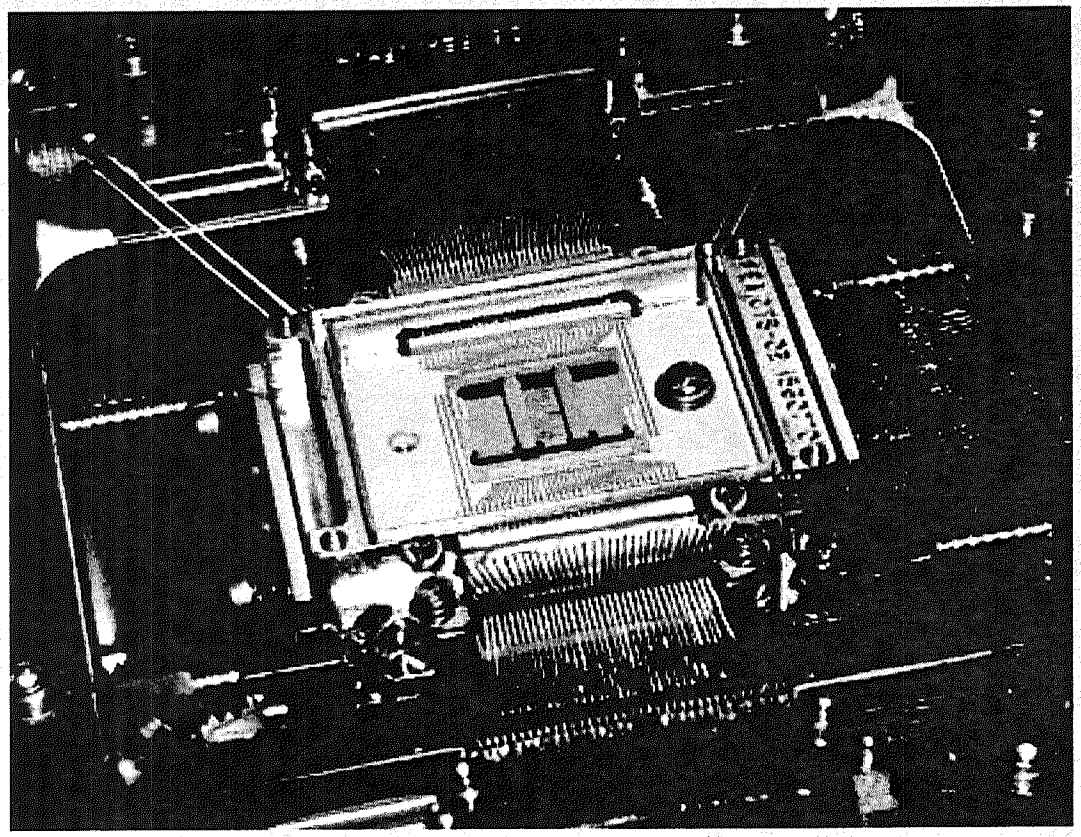
Micro-Scale Fabry-Perot

- Static Non-Linear Force-Deflection FEA



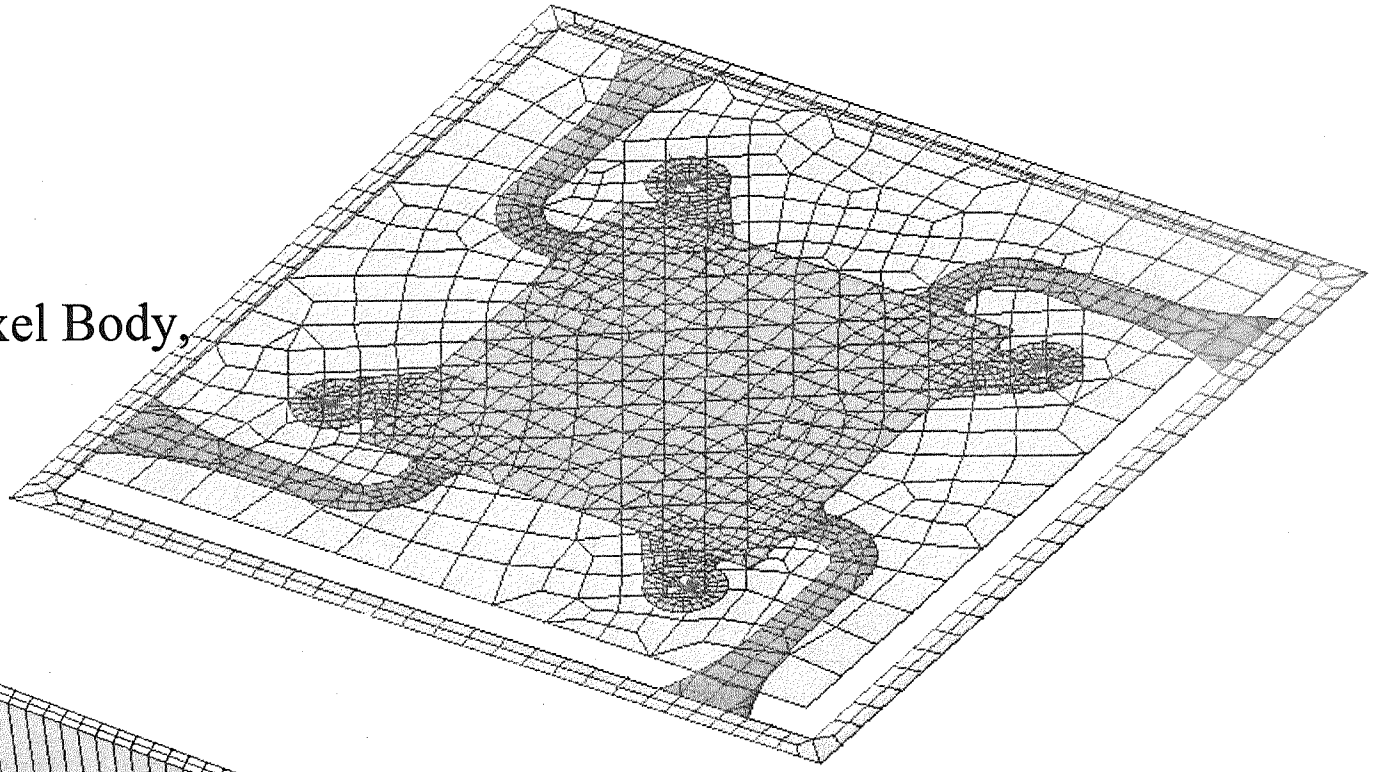
F_{app} = 300μN/pad = 900μN; K_{mech} = ~630μN/μm

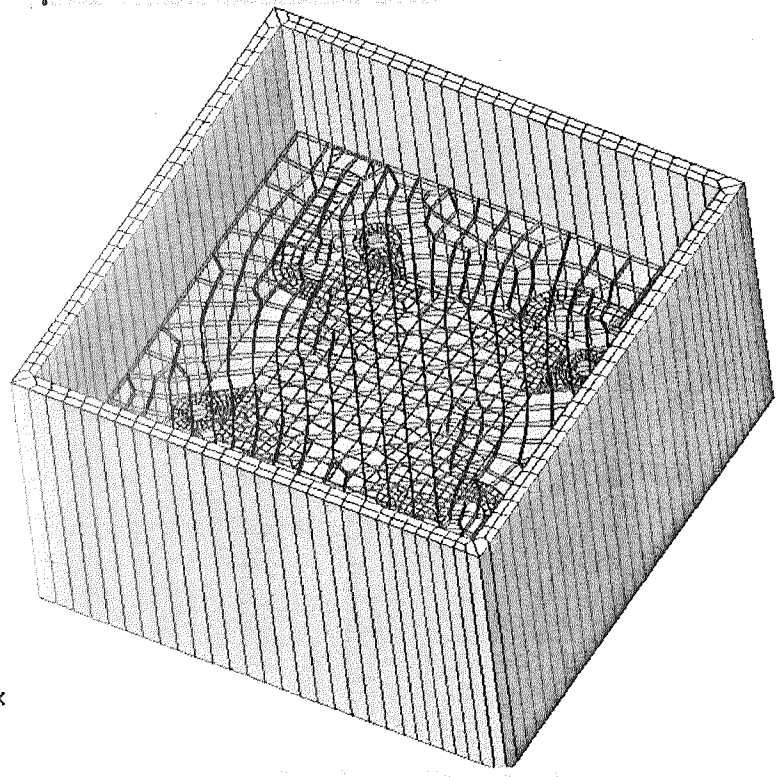
AstroE2 Micro-calorimeter

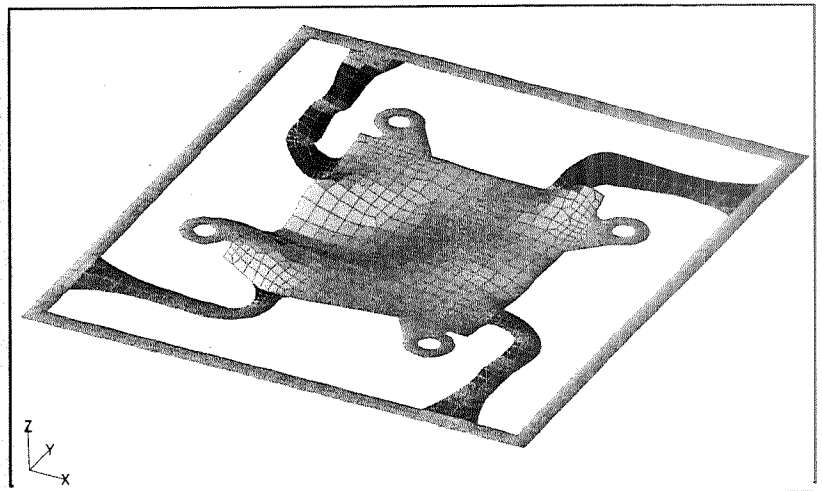


300μm² Si Pixel Body,
1.5um Thick

DRIE Etch From
385μm Thick Frame



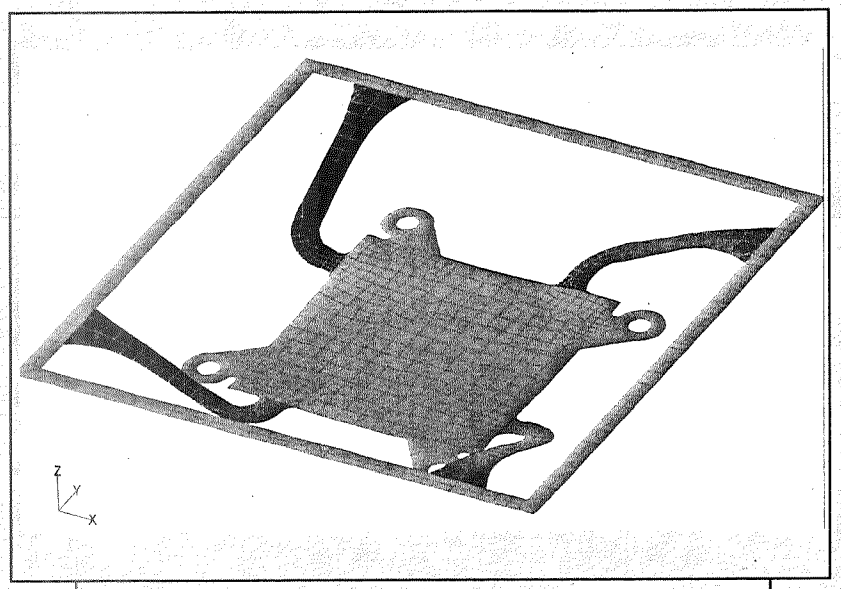




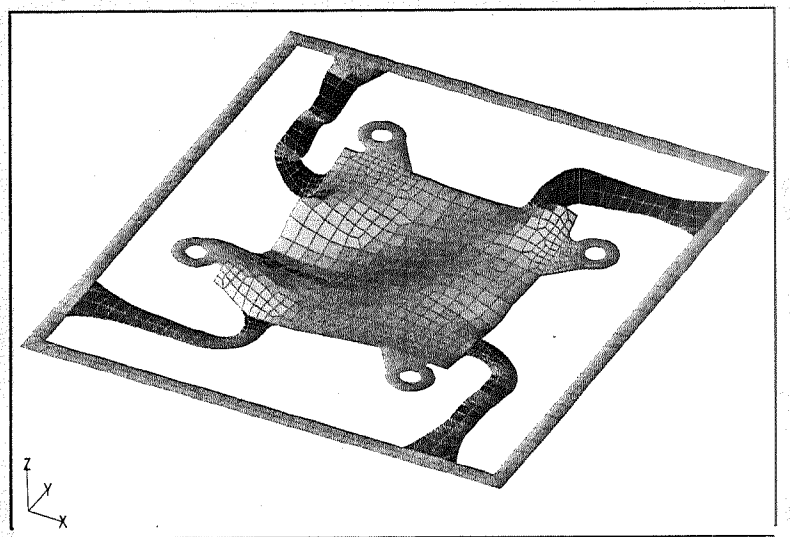
(c) Pre-Stressed Fundamental Mode Shape: f_n = 6964 Hz

Detailed Pixel Dynamics Analysis

- Prestressed Modal Analysis



(a) f_n = 2823 Hz; with 4 SU8 Tab Attachments to Absorber



(c) Pre-Stressed Fundamental Mode Shape: f_n = 6964 Hz