



Ultra High Density Deformable Mirrors for Coronagraphic Imaging

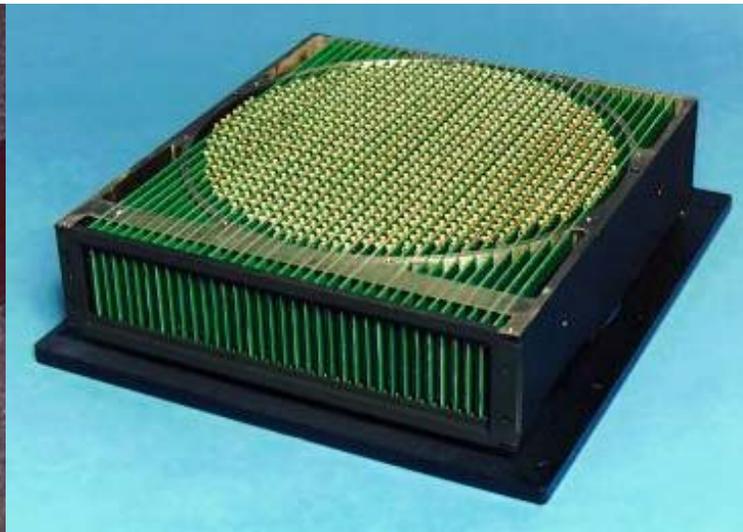
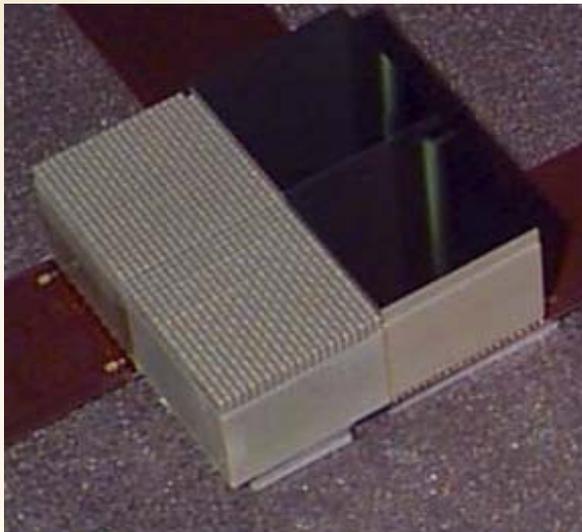
Dr. John T. Trauger
Jet Propulsion Laboratory

and

Mr. Mark A. Ealey
Xinetics Inc.



Transition from Longitudinal to Transverse ... Modular versus Discrete Actuators

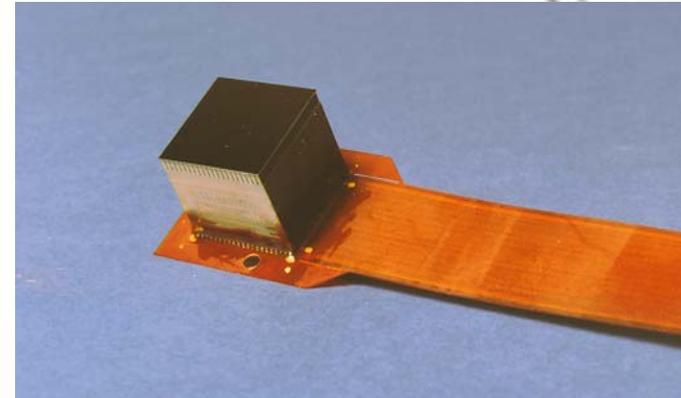




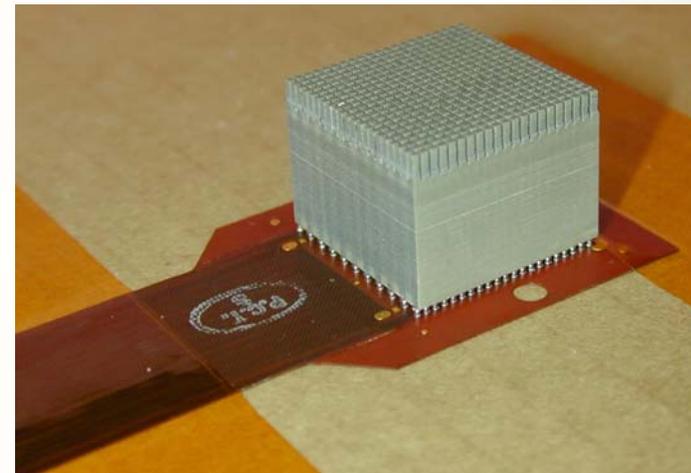
448-Channel Photonex Deformable Mirror

...Modular Mirror Technology for Scaling to High Density

- 21 x 21 1-mm Module Format
 - Modular Actuator Arrays Allow Scaling to Large Channel Counts
 - PMN-Based Electroceramic Enables Angstrom Level Dimensional Control
 - Conductive Adhesive Enables Integrated Ground of All Actuators
 - Multiple Layer Flex Circuit Replaces Thousands of Individual Wire Leads



21 x 21 Photonex Mirror

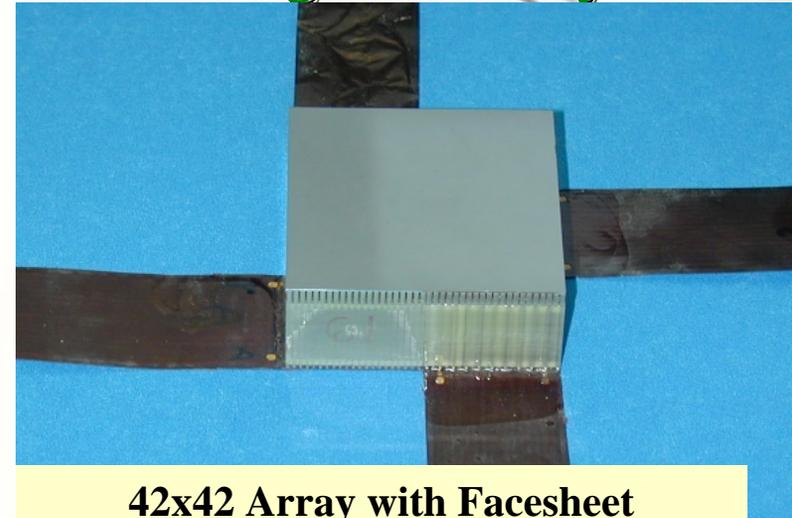


21 x 21 Module on Flex Cable

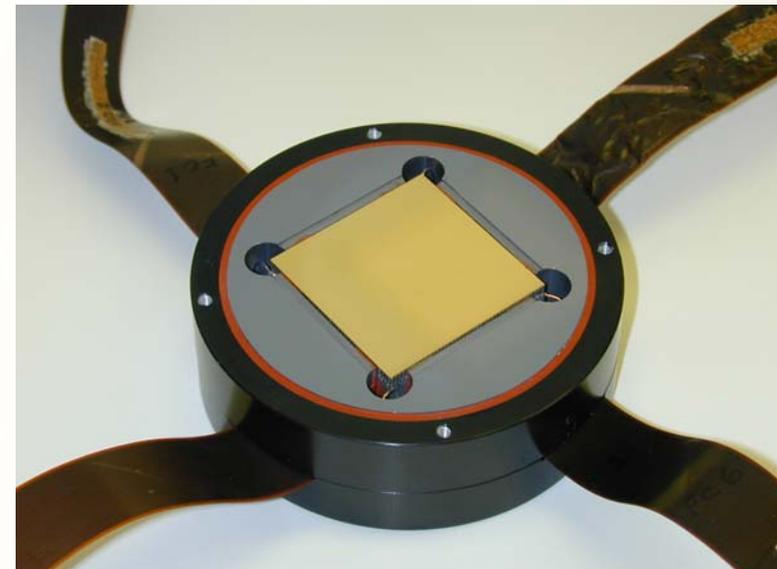


1,764-Channel Photonex Deformable Mirror ... Evolution of Module Towards Integrated Arrays

- 42 x 42 1-mm Module Format
 - 2 x 2 Array of 21 x 21 Modules Bonded with Uniform Bond Line
 - Continuous Single Crystal Silicon Facesheet with Integral Pusher Pads
 - Common Ground Enabled by Gold Coating on Back Side of Facesheet
 - Individual Modules Interconnected with Flex Circuit



42x42 Array with Facesheet

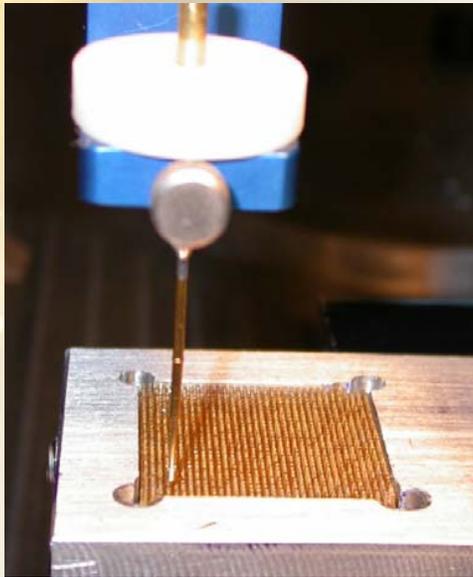


Polished and Gold Coated 42x42 Mirror

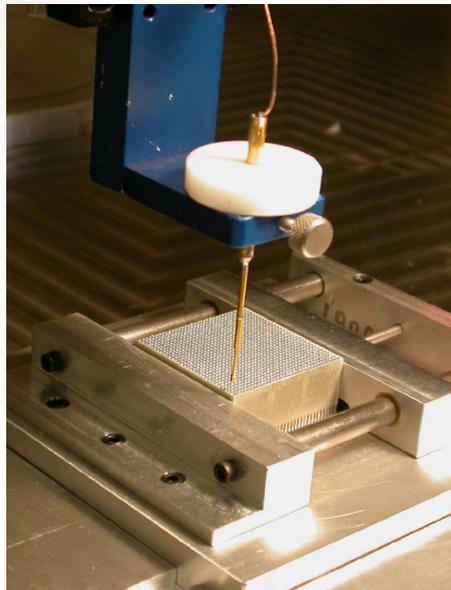


Automated Testing

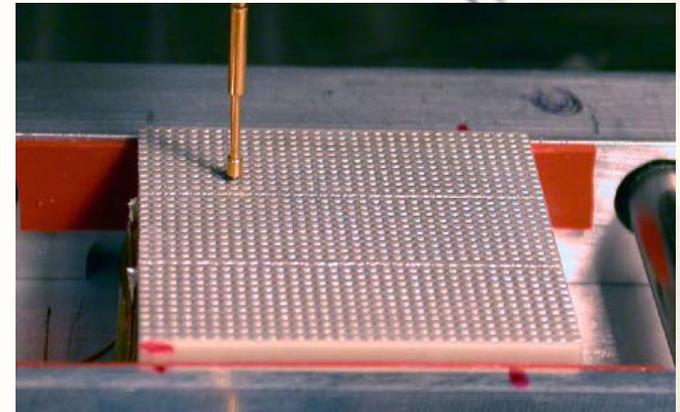
...Enabling Qualification of Complex Components



32 x 34 1-mm Flex Testing



32 x 32 1-mm Module Testing



1-mm Module Reliability Testing

- Flex – qualify continuity of all connections in flex and confirm that no shorts exist.
- Module – confirm that all actuators are active and individually addressable, connector pads are correctly printed.
- Flex to Module Interface – establish integrity of bond between flex and module, confirm that no shorts exist between actuators or from signal to ground



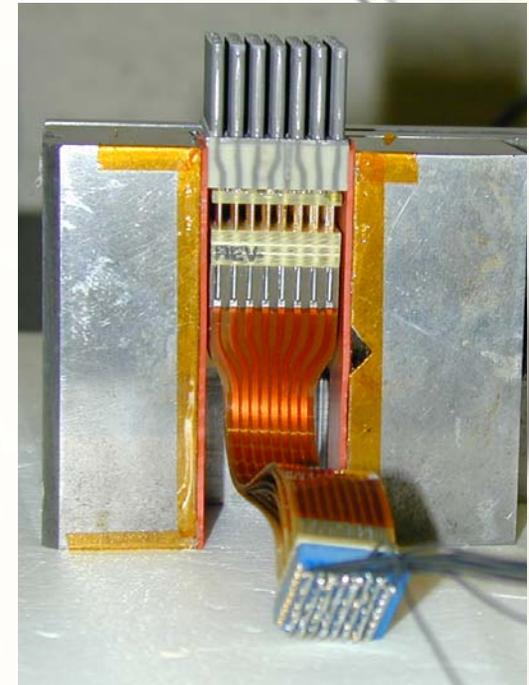
High Authority Demo At Elevated Fields ... Proof Test, Cycle Life & Bandwidth

Cycle Testing Parameters

- 70 V DC, ± 16 V AC, 500 Hz, 30 minutes
(900,000 cycles)
- 120 V DC, ± 30 V AC, 500 Hz, 30 minutes
(900,000 cycles)
- 70V DC, ± 2 V AC, 4 kHz, 30 minutes
(7.2 million cycles)

Results:

- No Noticeable Change in Stroke, Capacitance or Parallel Resistance After Several Million Cycles
- No Visual Sign of Degradation
- Only 1 Degree Temperature Increase During Most Intense Testing.



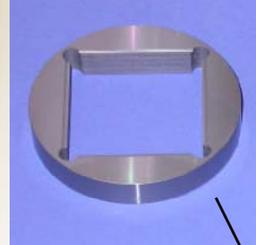
Module Cycle Testing



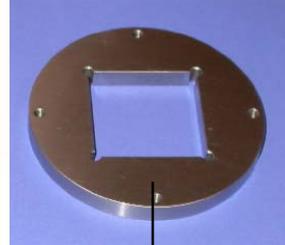
1,024-Channel Single Module Mirror

... Delivery in June 2003

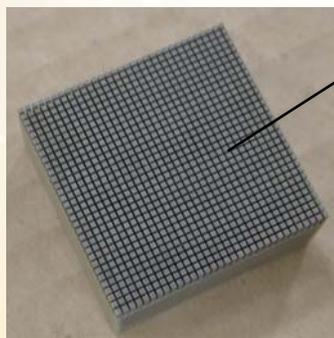
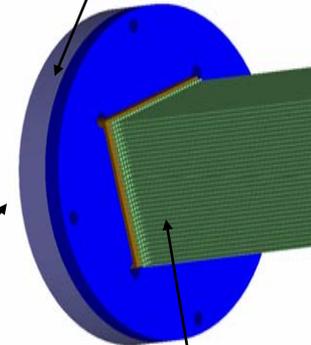
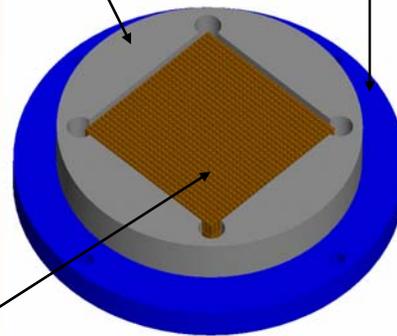
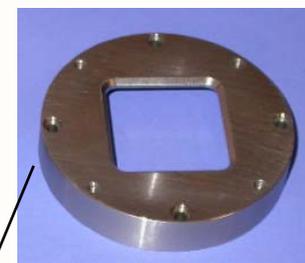
Polishing Ring



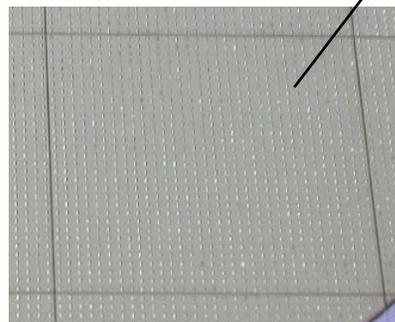
Support Structure



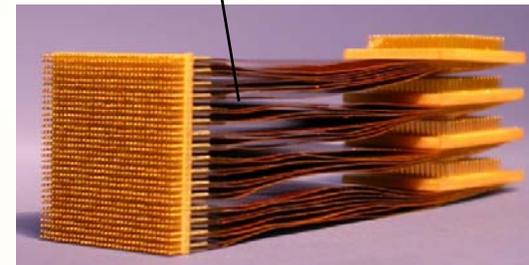
Aperture Mask



32 x 32 Module



32 x 32 Facesheet

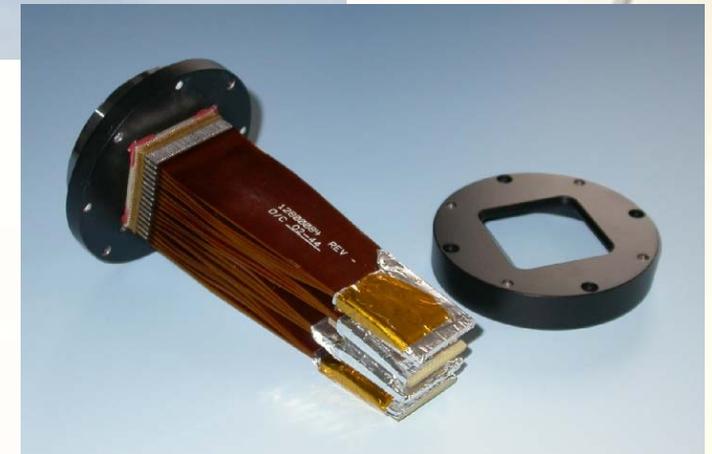


32 x 34 Interconnect



1,024-Ch Deformable Mirror

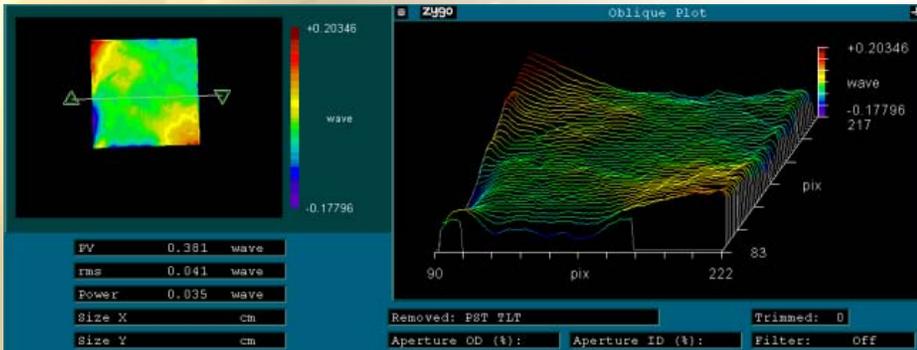
... Angstrom Level Precision for $\lambda/1000$ Telescopes





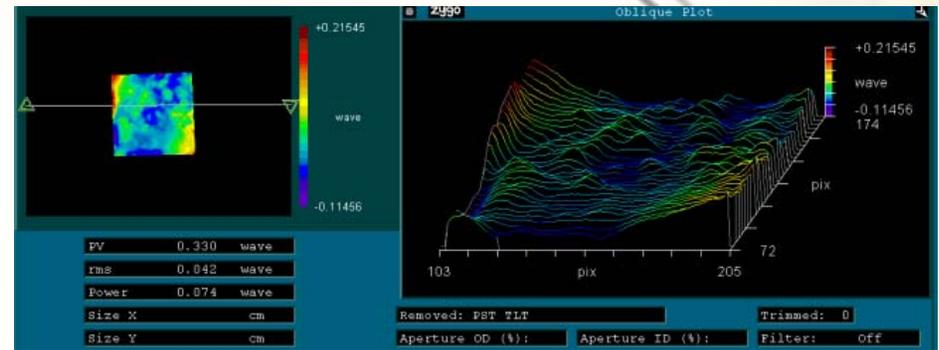
Demonstrated Polish Stability

... Time line: Square Aperture Comparisons



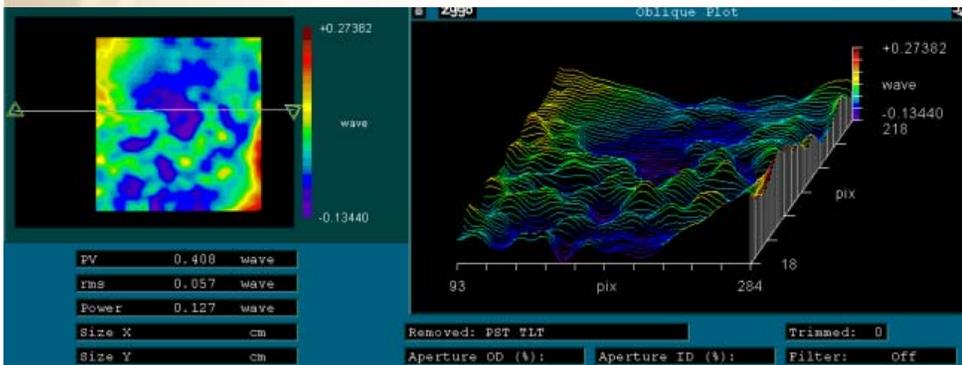
6-13-03
Mirror face-sheet is sealed
Humidity: 40%

P/V: 0.381 waves
RMS: 0.041 waves



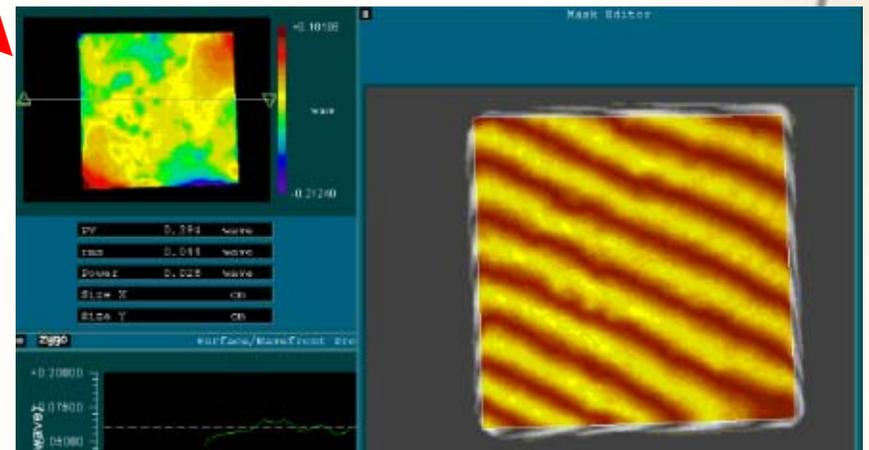
6-18-03
Polishing housing removed
Humidity: 51%

P/V: 0.33 waves
RMS: 0.042 waves



6-23-03
Prior to coating
Humidity: 58%

P/V: 0.41 waves,
RMS: 0.057 waves

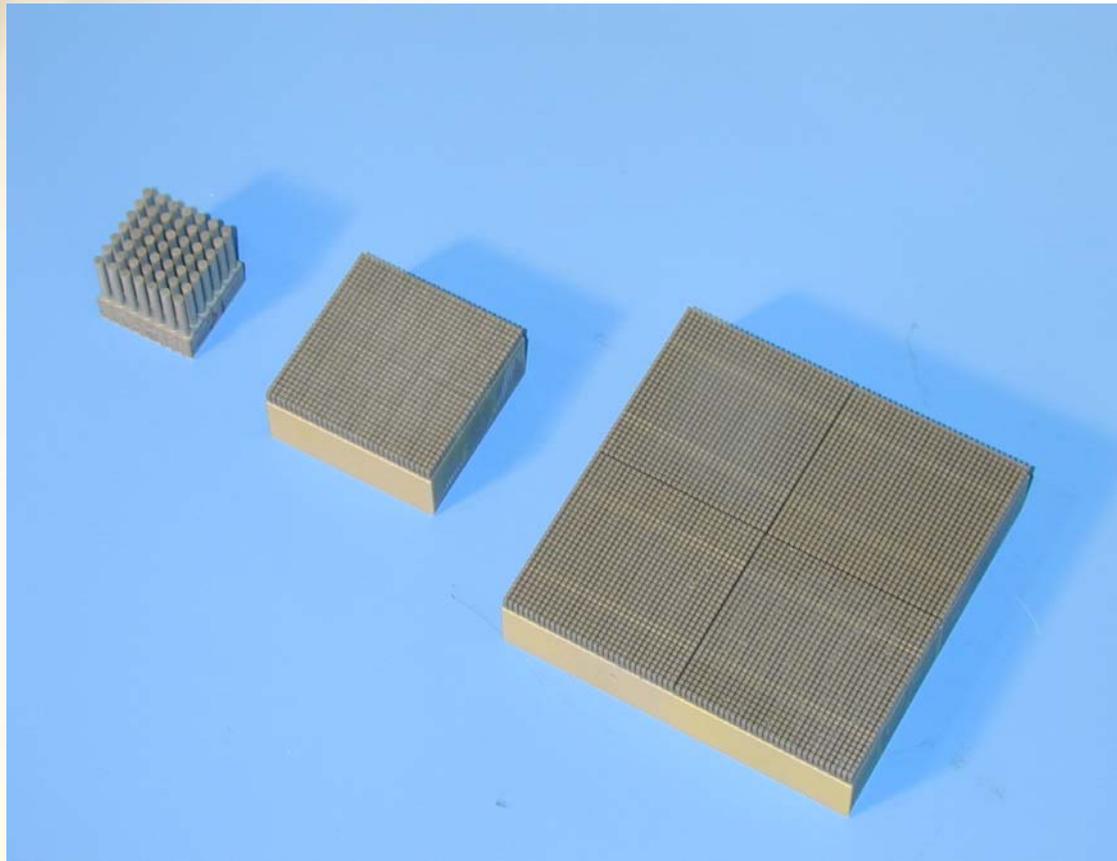


6-25-03
After coating

P/V: 0.394 waves
RMS: 0.044 waves

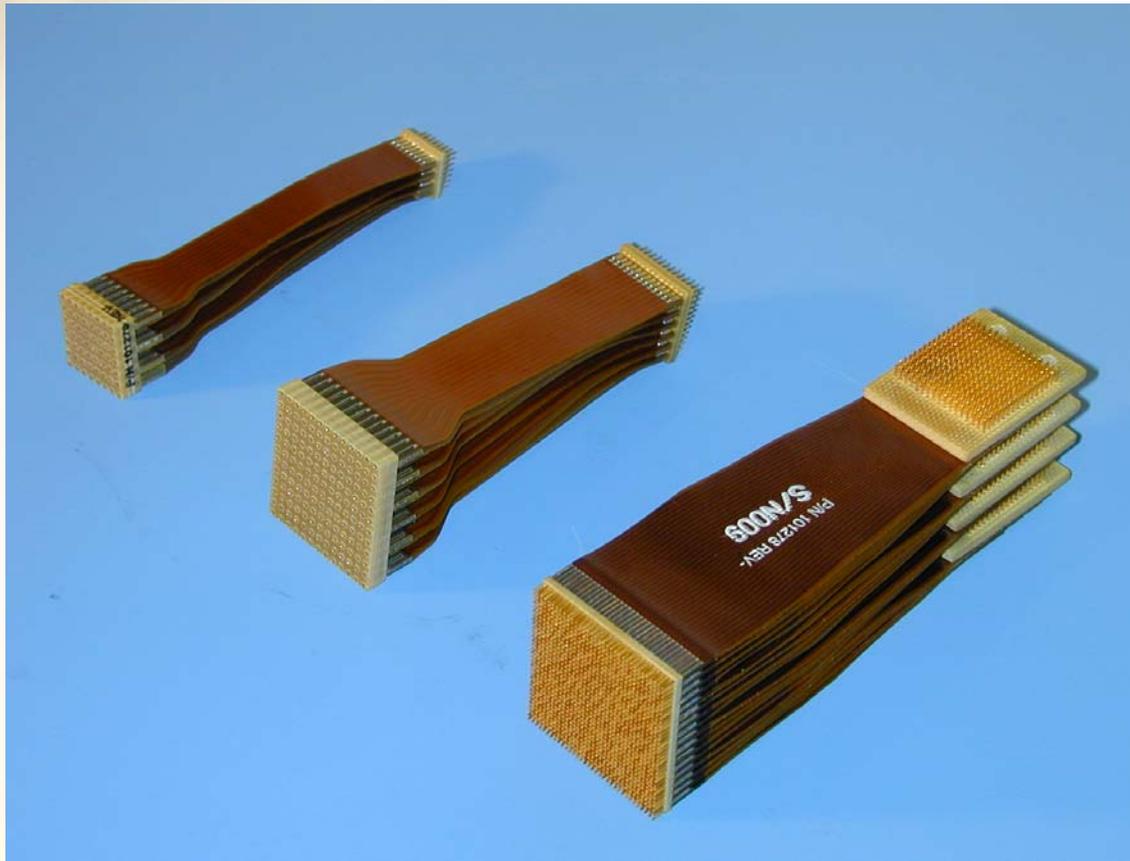


Photonex Modules: Multilayer Capacitor Scaling ... Integral Electrodes for High Density Connections





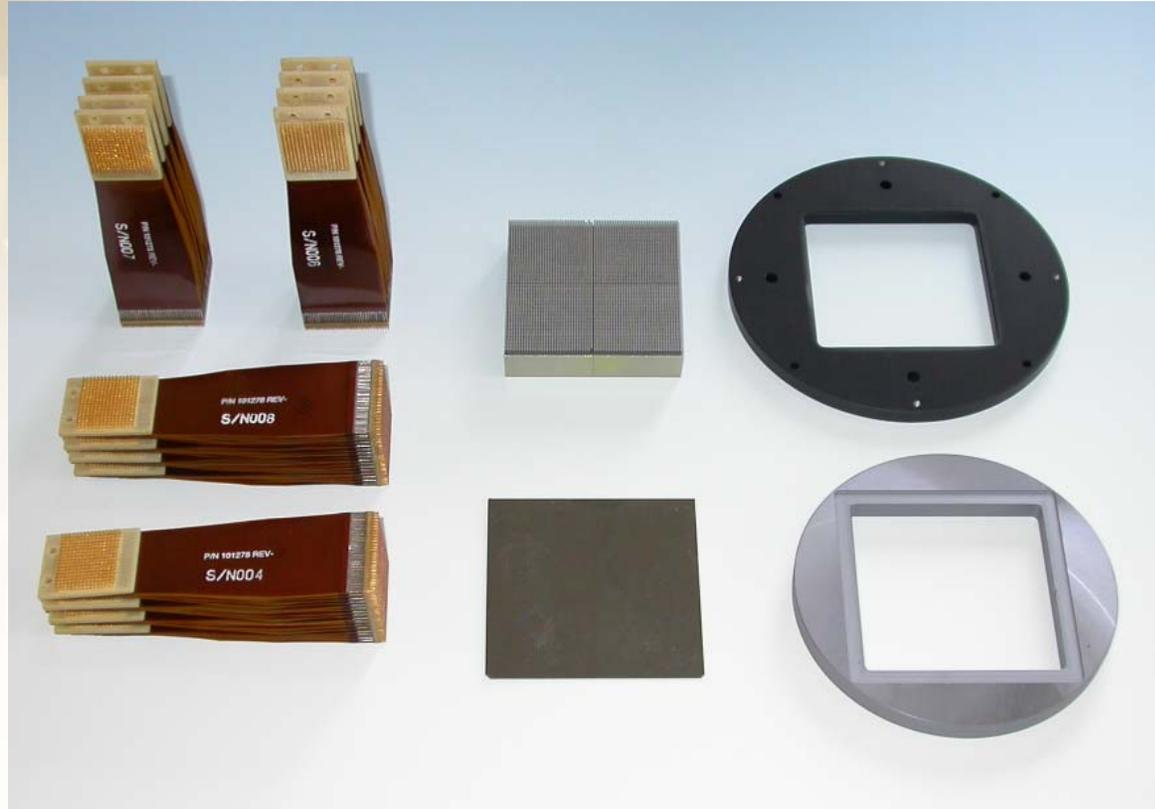
Pin and Ball Grid Arrays: High Density IO ... Map Actuator Spacing to Commercial Connectors





4,096-Channel 1-mm Deformable Mirror

... Delivery in August 2003



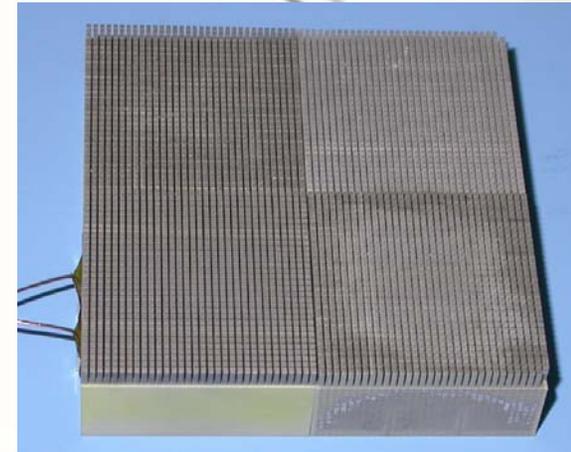
- **Facesheet Modified to Assist in Sealing**
- **High Temperature Cured Adhesive**
- **Polishing & Coating**
- **Interconnect Attachment**



4,096-Channel 1-mm Deformable Mirror

... Delivery in August 2003

- 4,096-Channel Deformable Mirror
 - Establishes Component and System Technology to TRL Level 6 in JPL Test Bed Simulations
- Roadmap Towards ECLIPSE & TPF: Pre-Planned Product Improvements
 - Modular Array Size Increased to 32 x 32 Format to Enable Direct Scaling to 64 x 64 Array
 - Structural Adhesive Replaces Conductive Adhesive and Enables Angstrom Level Dimensional Stability
 - Ground Connectivity at Modular Interconnect Enables In-Process Testing
 - Large Format Interconnect Allows Simple, Actuator Line Addressing



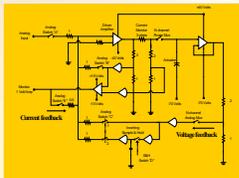
64 x 64 Modular Actuator Array





XiMux Development Path

... Low Power & Vacuum Compatible



Concept



Breadboard
37 Channels



P.C. Board
112 Channels



1 Bd. Backplane



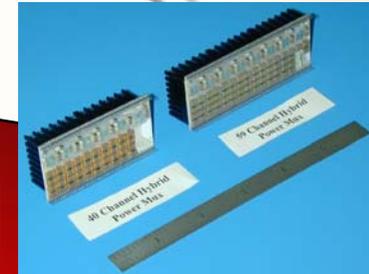
1 Bd. System



4 Bd. System
448 Channels



4 Bd. Backplane



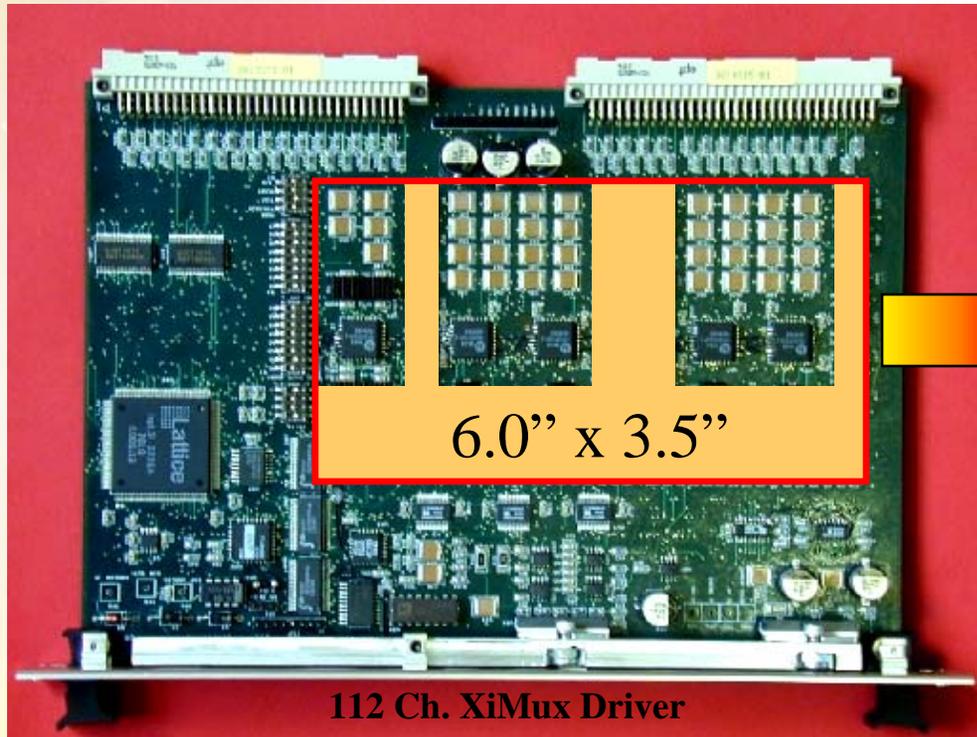
Power Mux Hybrid
40 and 59 Channels



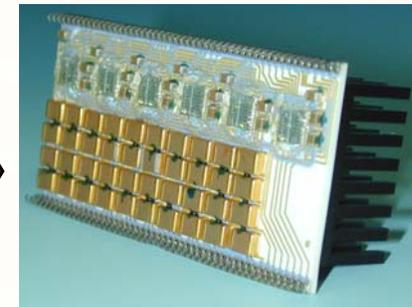
40 Channel Hybrid Power Mux

... Size reduced by 86% with Hybrid XiMux

The Hybrid Is Functionally 21 Sq. In.
of a Ximux Board Space



40 Ch. Hybrid
First Article

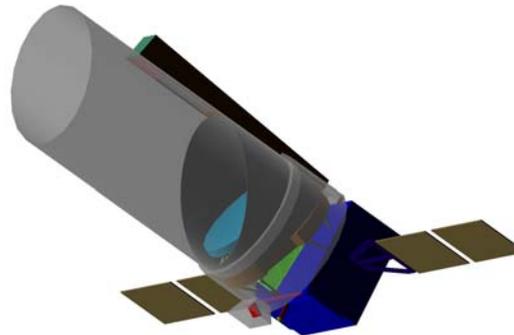


1.2" x 2.4"

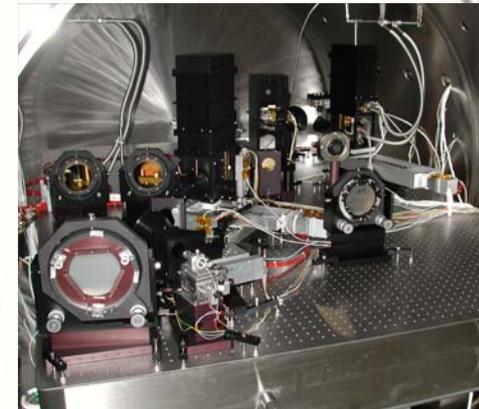


ECLIPSE High Contrast Space Telescope

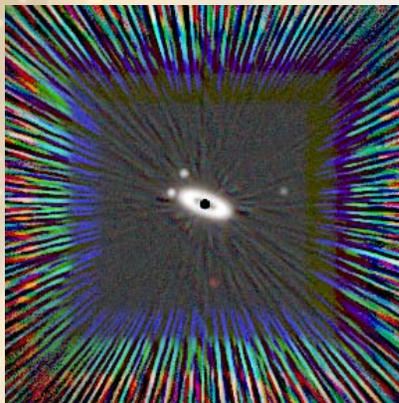
... Towards 96 x 96 Arrays & Angstrom Level Telescopes



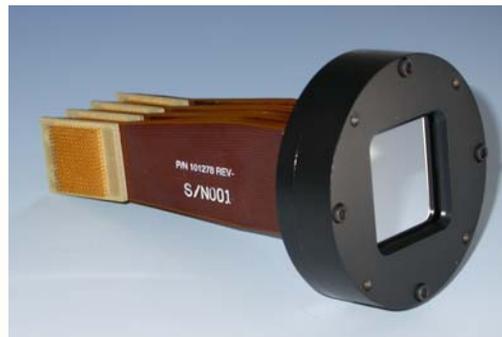
**1.8-meter Off-Axis Telescope
Coronagraphic Camera
with Active Wavefront Correction**



**High Contrast Imaging Testbed
Validation of Models &
Technology**



**Survey for Extrasolar Planets
Long Duration Exposure
Altair Simulation**



**1,024-ch Photonex Deformable Mirror
Angstrom Level Dimensional Stability**