MEMS Adaptive Optics Technology and Products

Maker: Iris AO (USA)
Distributor: Moreseeker (HONGKONG) Trading Limited.
www.moreseeker.com

Key Technical Advantages

• Easy-to-use precision open-loop positioning
• Hexagonal piston/tip/tilt segments enable efficient wavefront correction
• Unique coating options
  – Protected-Silver, Gold, protected-Aluminum
  – Dielectric coatings for high pulse energies and average power
• Large operating-temperature range
• End-to-end knowledge of core components and subsystems
  – MEMS design and fabrication
• Wafer fab by Iris AO engineers at foundry
  – Electronics
  – Windows/PC software
  – Control system design

Iris AO Segmented DM

• Piston/tip/tilt electrostatic actuation

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- no hysteresis
- Hybrid fabrication process
- 3-poly surface micromachining
- Single-crystal-silicon assembled mirror
- Unit cell easily tiled to create large arrays
- Unique hybrid technology
  - Thick mirror segments
  - Enables dielectric coatings

**Adaptive Optics Beam Control**

**Actuator Control Options**
- Wavefront sensor
- Focused spot monitor and optimization algorithm

**Benefits of Using DMs**

- DMs provide dynamic
  - Aberration correction
  - Beam quality control
  - Beam shaping
  - Relaxed optical specifications
  - Precision beam steering
- Application areas
  - Laser beam quality control
  - Laser micromachining systems
  - Optical coherence tomography
  - Astronomy
  - Microscopy
  - Retinal imaging

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- Laser surgery
- Speckle reduction

Packaged DMs and Drive Electronics

- Compact DM enclosure
- High resolution
  - 14 bit, 200 V
- Factory calibration
- Simple USB interface: 140 Hz
- High-speed interface: <165 μs latency
  - > 6 kHz synchronous mode
  - >10 kHz asynchronous mode
  - > 14 kHz pre-recorded mode
  - Frame rates of 35 kHz possible
  - $f_{3d B} \geq 30$ kHz

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DM Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Dynamic Range</td>
<td>5, 8 µm mechanical</td>
</tr>
<tr>
<td>(Stroke)</td>
<td></td>
</tr>
<tr>
<td>Maximum Segment Angle</td>
<td>4, 7 mrad</td>
</tr>
<tr>
<td>Mechanical Step-Response</td>
<td>&lt; 200 µs (10-90%)</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
</tr>
<tr>
<td>Segment Positioning</td>
<td>&lt; 2 nm</td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
</tr>
<tr>
<td>Optical Coatings</td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td>Protected-Silver, Gold, Protected-Aluminum</td>
</tr>
<tr>
<td>Dielectric: Demonstrated</td>
<td>λ = 355, 532, 589, 1064, 1540 nm</td>
</tr>
<tr>
<td>Dielectric: Possible</td>
<td>188-1600 nm</td>
</tr>
<tr>
<td>Segment Flatness</td>
<td></td>
</tr>
<tr>
<td>Metal Coating</td>
<td>&lt; 20 nm rms, &lt; 7 nm rms (optional)</td>
</tr>
<tr>
<td>Dielectric Coating</td>
<td>&lt; λ/20 nm rms, &lt; λ/40 nm rms (optional)</td>
</tr>
</tbody>
</table>

AO System Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>PTT111</th>
<th>PTT489</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deformable Mirror Type</td>
<td>PTT111</td>
<td>PTT489</td>
</tr>
<tr>
<td>Software Interface</td>
<td>GUI, Console</td>
<td>Console</td>
</tr>
<tr>
<td>Wavefront Sensor Type</td>
<td>Shack Hartman</td>
<td></td>
</tr>
<tr>
<td>Wavefront Sensor Lenslets</td>
<td>37 (1 per segment)</td>
<td>163 (1 per segment)</td>
</tr>
<tr>
<td>Optical Magnification</td>
<td>1:1</td>
<td>2:1</td>
</tr>
<tr>
<td>Camera Sample Rate</td>
<td>30 Hz, 60 Hz</td>
<td></td>
</tr>
<tr>
<td>Camera Dynamic Range</td>
<td>10 bit, 12 bit</td>
<td></td>
</tr>
<tr>
<td>Wavefront Resolution</td>
<td>&lt;15 nm rms</td>
<td>&lt;15 nm rms</td>
</tr>
<tr>
<td>Wavefront Dynamic Range</td>
<td>± 14 mrad</td>
<td>± 20 mrad</td>
</tr>
<tr>
<td>AO Controller</td>
<td>Zernike-based modal</td>
<td></td>
</tr>
</tbody>
</table>

Unique Capability: Dielectric Coatings

- Metal coatings are standard
- Dielectric coatings enable large power handling
  - High reflectance > 99.9%
  - High damage threshold
- Iris AO unique stress-compensation approach enables dielectric coatings
- Thick segments resist CTE mismatches and coating stress changes
- Dielectric coatings from UV to IR possible
  - 355, 532, 589, 1064, and 1540 demonstrated

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Projected Power Handling (≤λ/20 rms Limit)

CW (532nm)
- 300 W/cm² w/o heatsink
- 2,800 W/cm² with heatsink and 2nd generation DM
- Future Potential >10kW/cm²

Pulsed (No damage detected)
- 355 nm: 130 MW/cm², 2 mJ/cm² peak fluence, 15 ps, 50 μm diameter straddling segment gap
- 1540 nm: ~75 MW/cm², 4.2 mJ, 7 ns, 1mm diameter, 1540 nm

DM Application Areas

Benefits of Using DMs in Laser Systems:
- Improve spot quality (resolution and intensity) in laser micromachining systems
  - Compensate for field aberrations in F-theta scan lenses
- Enable dynamic focus correction and beam shaping
- Increase beam quality and laser power
  - Correct thermal lensing and other aberrations
- Broaden pulse-repetition rate operating range
  - Compensate for thermal drift in cavity
- Extend laser lifetimes
  - Compensate for optical drift
- Simplify manufacture of lasers
  - Adds servo control of laser beam
- Improve fs pulse widths
  - Correct group delay

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Industrial Laser Micromachining

- **DM focus correction**
  - Track fine focus over topography and scanning path-length differences
  - Fast focus (kHz rates) for high throughput
  - Enables higher NA system for better resolution
- **Adaptive Optics**
  - Improve resolution by correcting for beam train aberrations
    - Increases power to the laser spot
  - Enables simple on-the-fly beam shaping
    - Round, square
    - Super Gaussian, annulus

Retinal Imaging

- Scanning laser ophthalmoscope
- Iris AO PT111 and AO Engine
- Shack-Hartmann wavefront sensor
- Imaged as close as 0.25 degree


Astronomy: Laser Guide Star Correction

- Sodium laser-guide-star (LGS) uplink correction
- Demonstrated at Lick Observatory
  - Compensates for laser and beam train optics
  - Produces smaller and brighter LGS spot

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Results in improved science images

- PTT489 DM: Enables ability to create and position multiple LGS spots


Astronomy: Segmented-Aperture Testbed

- DMs enable testing AO concepts with a segmented aperture
- PTT111 and PTT111L DMs have been used to test concepts for JWST phasing

Optical Coherence Tomography in vivo imaging Using Sensorless Iris AO DM

- Simplifies optical design
- No wavefront sensor, rapid convergence
- High image quality for arbitrarily selected retinal layers, greater depths

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3D Adaptive Optics Microscopy

• Single plane illumination microscope
• Imaging fluorescent protein in a zebra fish
• High image quality for arbitrarily selected layers, greater depths
• Wavefront sensorless optimization possible
• Recorded 3-D z-stack
• Researchers using Iris AO DM technology

C. Bourgenot, et al., Optics Express, 20, 2012

Optical Vortex Generation

Tyson et al., APPLIED OPTICS / Vol. 47, No. 33 / 20 November 2008

Summary

• Iris AO MEMS DMs
  - Precision open-loop control
  - Dielectric coatings for laser applications, UV to NIR
  - Efficient wavefront correction

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- Robust over large operating conditions (temperature)
- DMs provide exquisite, dynamic beam control
- Beam control improves laser system performance
  - Better beam quality, increased power
  - Spatial / intensity beam shaping for laser micromachining
- Aberration corrected imaging for
  - Microscopy
  - Optical coherence tomography
  - Retinal imaging
  - Astronomy

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