UAHuntsville
Center for Applied Optics

Research advancing optical science, optical design, fabrication and testing

Building complex optical systems and components for environments from the lab to space
CAO Background

- Established in 1985 as a focal point of optics at UAH & in Alabama.

- Primary mission: advance research and education in applied optics and optical engineering.

- Primarily Research Staff with many affiliated faculty and graduate students.

- 110,000 ft² Optics Building completed in 1991 with vibration-isolated laboratory core, including numerous clean rooms.
CAO and NMDC Merged in 2008

- **CAO: Research Staff**
  - Dr. Patrick J. Reardon, Interim Dir., CAO
  - Dr. James Hadaway
  - Dr. Brian Robinson
  - Mr. Darell Engelhaupt (OC)
  - Dr. Joe Geary
  - Dr. Lisa Blackwell (OC)
  - Mr. Dave Pollock (OC)
  - Mr. Ken Pitalo (OC)
  - Mr. Ted Rogers
  - Mr. Chris Underwood

- **NMDC; Faculty**
  - Dr. John Williams, Assoc. Dir, NMDC
  - Dr. Yongbin Lin, NMDC staff
  - Frank Berisford, NMDC staff
  - Dr. Robert Lindquist, ECE
  - Dr. Junpeng Guo, ECE
  - Dr. Emanuel Waddell, Chem.
  - Dr. Jeffrey Weimer, ChE
  - Dr. Jennifer English, ECE
  - Dr. David Coe, ECE
  - Dr. Seyed Sadeghi, Physics
CAO: Classical Optics

- **Research Areas**
  - Optical and Opto-mechanical System Design
  - Optical Fabrication, Testing, Integration and Deployment
  - Laser Technology, Power Beaming and Lidar
  - Adaptive Optics and Wavefront Sensing
  - Radiometry, Radiometric Calibration & Polarimetry
  - Optics for UAS’s

- **Experience**
  - Gamma-ray to THz
  - Meter-class to micro-optics
  - DoD, NASA, NSF and commercial customers
  - Basic research through product development
  - Education
Optical and Optomechanical Design

- ZEMAX
- CODE V
- Pro E
- UG
- Rhino

Three Mirror Anastigmat

Thin Disk Laser

SPARCLE
Analysis

- ZEMAX
- CODE-V
- ASAP
- FRED
- NASTRAN

NSO: MCAO Modeling

NASA: Shuttle Camera

NASA: WAVE

NASA: SPARCLE
Fabrication

Components to Systems
Optical Testing
• Surface Metrology
• Component Quality
• Optical System Performance
CAO Example Programs
WAVE : Response to Columbia Accident Investigation Board

A collaboration with NASA MSFC to design and build a telescope on a mobile platform to observe the Shuttle launch as never seen before.
Gigapixel Camera Program

- **UAH-CAO Role**
  - Provide Optics Expertise to Ipix, Inc
    - Ipix Inc. provided virtual tour technology to the real-estate industry
    - Won DARPA proposal in 2005 to build Gigapixel Camera

- **Program Goals**
  - Persistent daylight surveillance at 25kft, 10km diameter area, 0.5m resolution, for a forensic tool
Gigapixel Camera Program
Technology Readiness

Development

2005 2006 2007 2008 2009

9/18/05 Knoxvillle, TN 7.6° x 7.6°

3/30/06 Milwaukee, WI > 21°

2007 - 2009
Springfield, IL – FW, Gimbal
Yuma, AZ – FW & Rotary
> 34°

Fully Operational Data Collection

Gigapixel Camera Program
Technology Readiness

CAO
The Center for Applied Optics

UAHuntsville
The University of Alabama in Huntsville

Argusight
76MPix Movie Camera over Springfield, IL
35 degree FoV, 3500ft, Stabilized gimbal
~5" resolution, ~0.5mile diameter
Primary Mirror Segment Assemblies

- **Ball/UAH**: lead; design; actuators; integration; cryo testing.
- **Brush-Wellman**: Blank manufacture
- **Axsys**: Blank machining
- **Tinsley**: Mirror surface figuring.
- **Denton**: Gold coating.
- **MSFC**: Cryo testing facility.
The NASA X-Ray Calibration Facility (XRCF)

For UAH testing of the JWST
Modified to test JWST mirror segments.
SiC Polishing Project

- MSFC – Xray Mirror Fabrication
  - Produce a precision mandrel in aluminum
    - Diamond turned and polished
  - Plate on a nickel replica
SiC X-ray Mandrel
Metrology and Polishing

Developed

- New metrology approach for testing a near-cylinder with cylindrical wavefronts
- New optic yielding 20X improvement in metrology
- New process for figuring SiC on Zeeko polisher
- New surface analysis for rect. apertures
Misalignment or Misfigure: X-ray testing

2-D Chebychev decomposition reveals misalignment errors
Dissertations

- Differential metrology
  - Regressing surface shape from many known misalignments
  - Brian Robinson, Ph.D.
Dissertations

- Interferometric Phasing of Segments
  - William Lightsey, Ph.D.
Parent Radius and Conic Constant with a Spherical Reference Wave

- No null optics required,
- Ying Pi, Ph.D.

\[ R_S = \sqrt{R^2 - Ky^2} \]

\[ R_T = \sqrt{\left( R^2 - Ky^2 \right)^3} \left( \frac{R}{R^2} = \frac{R_S^3}{R^2} \right) \]

\[ \Delta R_{TS} = R_T - R_S = -Ky^2 \frac{\sqrt{R^2 - Ky^2}}{R} \]

\[ R = \sqrt{R_S^2 + 8(f/#)^2 R_s w_{22-s}} \quad \text{when} \quad R_{rs} = R_s \]

\[ K = \frac{Q^2}{P^2 - 1} + P^2 - 1 \quad \left\{ \begin{array}{l} Q = \frac{32(f/#)^3 w_{31-s}}{R_S \left( 3P^2 + 1 \right)} \\ P = \frac{R}{R_S} \end{array} \right. \quad \text{when} \quad R_{rs} = R_s \]
Interferograms of Off-Axis Paraboloid

Parent Vertex

Ying Pi
New Fabrication Equipment

- NSF-MRI
  - Zeeko IRP-600X Free-form Polisher
    - Any shape or material
    - 600mm diameter
    - Operational, August 2011

- NASA Grant
  - Nanotech 250UPL Diamond Turning Lathe
    - Free form surfaces
    - 350mm diameter
    - Rotary B-axis
Nanotech Activities
Current Zeeko Activities

- X-ray mirror stave (MSFC)
- Process development for new optical materials (Industry x 3)
- Optical testing calibration tools
Rapid Optical System Results

- Optical Systems from COTS Optics
- Diamond turned mirrors and plastics
- Modify COTS glass optics with Zeeko Free-form polisher
Optical Design/COTS

High Speed Wavefront Sensor

AMOR Zoom Optics
- Original 10km
- Optimized 10km

25X Beam Expander (ERC)

LOCAD (MSFC)
Current Fabrication / Testing Research Efforts

- **MaGIXS (NASA-MSFC, Robinson)**
  - Fabricate an x-ray telescope stave in Zerodur
    - 3 Diffractive Nulls
      - Paraboloid, Hyperboloid, Both for relative alignment
    - Stitching multiple interferograms
  - Parallel, non-critical path student research
    - Use a cylindrical null
    - Use differential measurements
      - Despace, tilt,
    - Use Chebyshev decompositions
Future Research

- Optical instrument design, fabrication, test, assembly, deployment
  - Enhanced by new fabrication capabilities
- Zeeko/Nanotech based
  - Free form metrology
    - Interferometer test plates for calibration
  - Generic Null
- Zeeko based
  - ZeekoJet Process Development
  - Process optimization
    - SiC
  - Extend Freeform diameter range
Infrared Point Diffraction Interferometer (PDI)
- Vendors provide IR optics to customers who can not test them
- PDI allows simple interferometric verification
- Many made on a single ZnSe plate
- Covers broad spectrum and quality

Computational Imaging: Thin optics
CAO/NMDC Summary

- Optical design, analysis, fabrication, assembly and testing
- THz, IR, visible, UV, X-ray, Gamma-ray
- Meter class to microoptics
- Advanced photonics and microwave modeling and fabrication
- Basic research, rapid prototype, deployed systems
- Experience in delivering results
Contact

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