Projects past and present

UAHuntsville

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

CENTER FOR APPLIED OPTICS

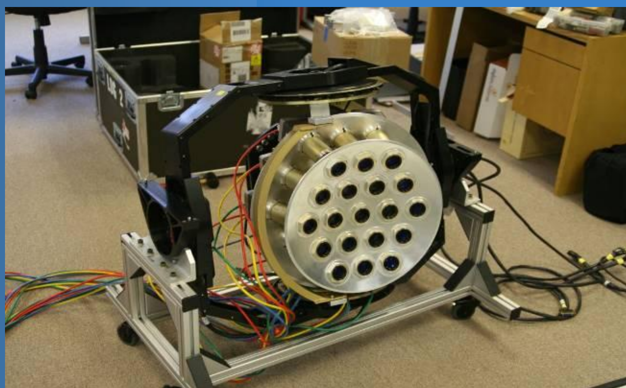
The CAO has enjoyed a rich history of optical and opto-mechanical design and fabrication since its inception.

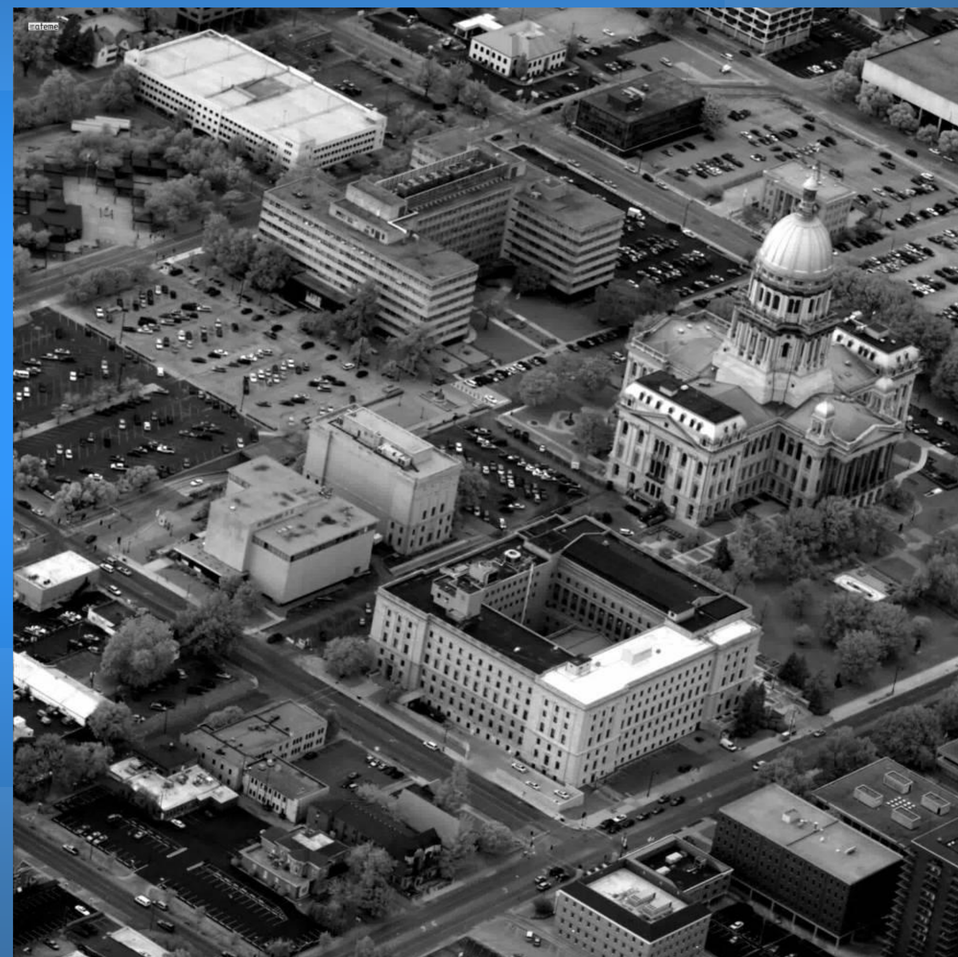
We have developed NASA flight hardware, refurbished military hardware and supported return to flight.

And we have been involved in some of the most interesting and rewarding projects.

Here is a sample of some of our recent collaborative efforts.

GiGA pixel camera
Current System : Flight Test in Springfield , IL



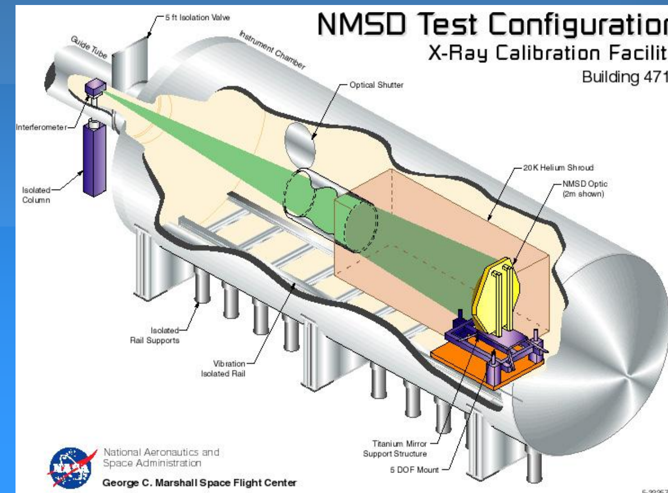


Six inch resolution

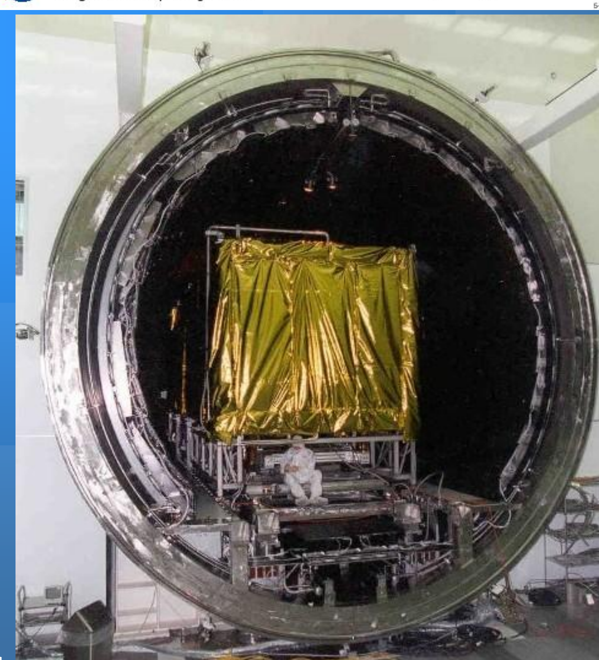
The NASA X-Ray Calibration Facility (XRCF)

For UAH testing of the JWST

Modified to test JWST mirror segments.



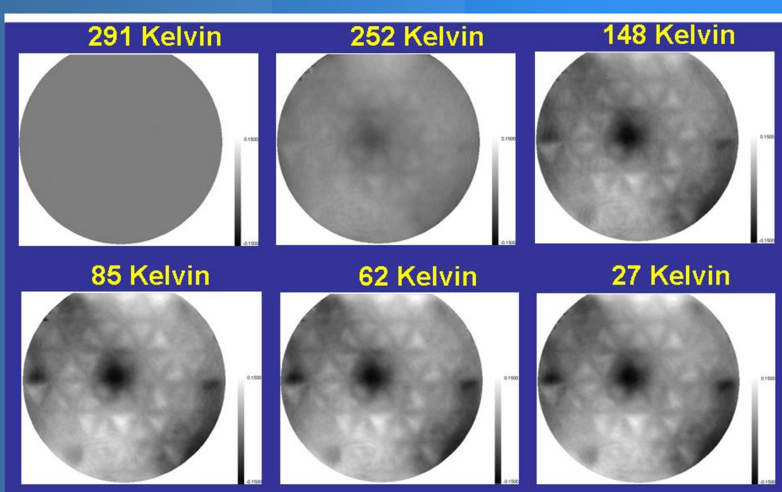
Small Chamber



Large Chamber

JWST SBMD/NMSD Testing

Cryogenic testing led, conducted



and analyzed by CAO.

WAVE : Response to Columbia Accident Investigation Board

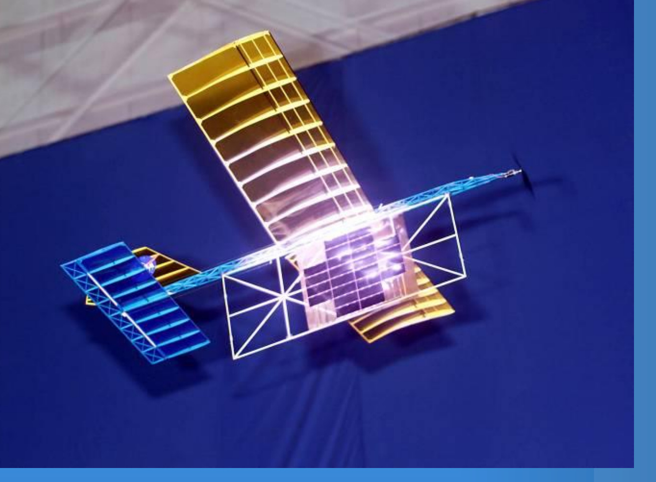
A Collaboration with NASA MSFC to design and build a telescope

on a mobile platform

to observe the Shuttle launch as never seen before.

Laser – Powered Flight

A collaboration of UAH, NASA
to demonstrate
wireless transmission of power



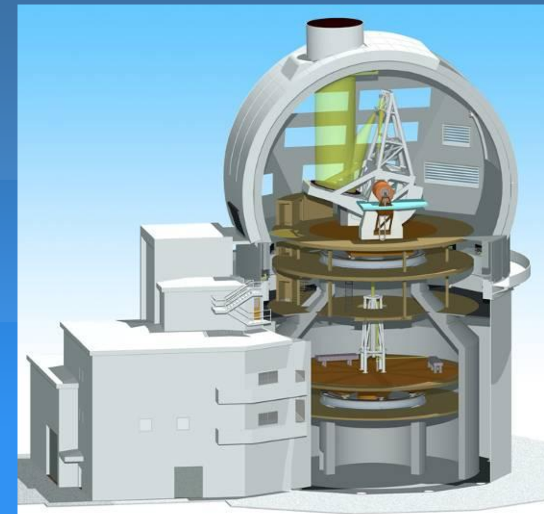
the first ever flight

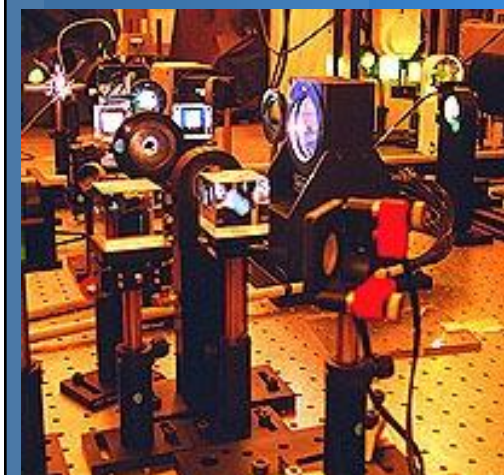
powered solely by laser power.

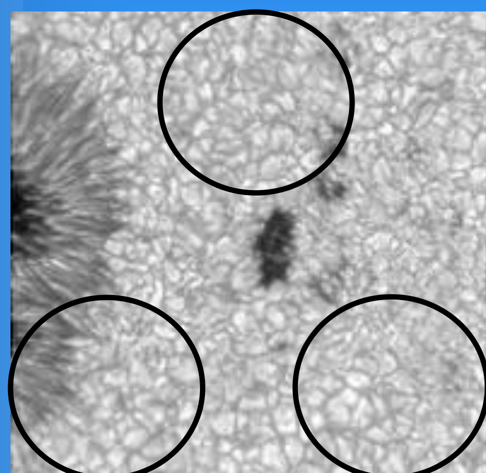
Potential use:
100Kft cell phone “floating tower”
Short range areal survey

Adaptive Optics

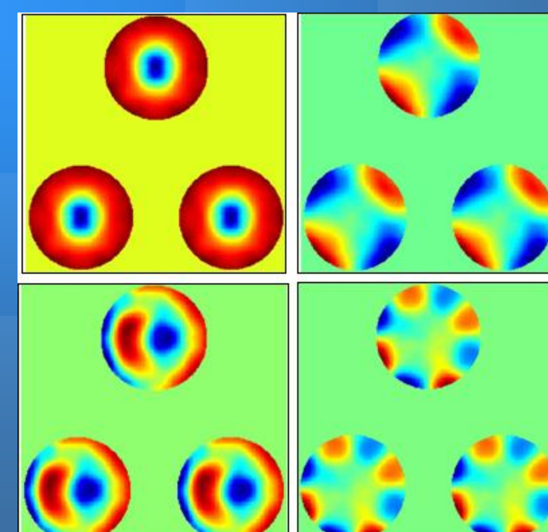
Assisted National Solar Observatory (NSO)





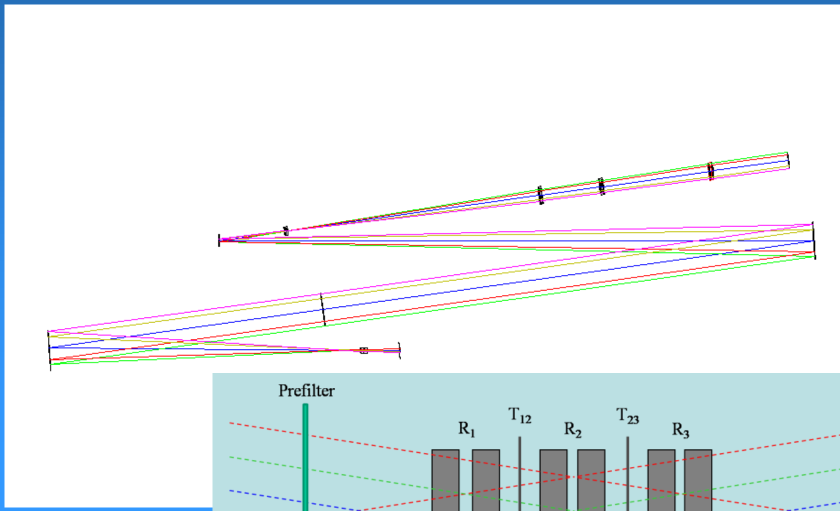


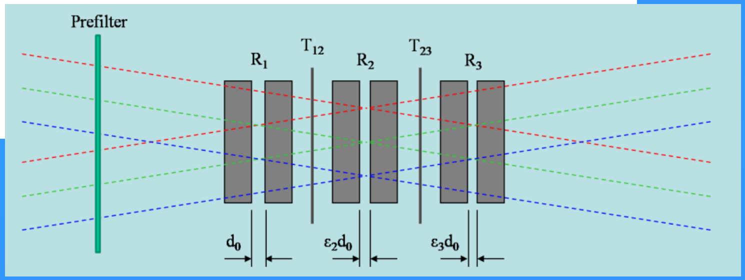
with the analysis and testing of adaptive optics (AO) and



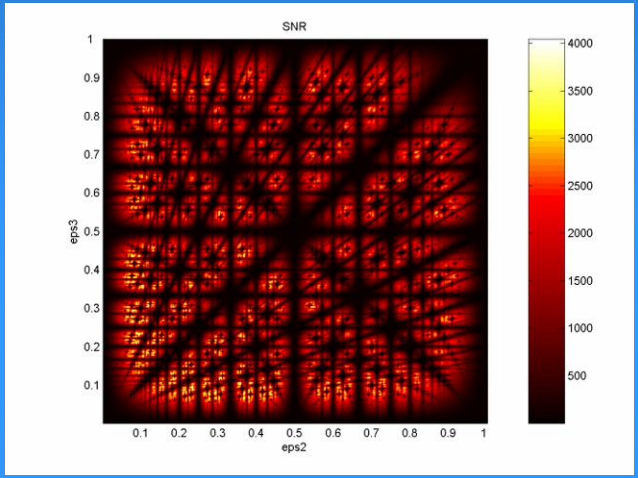
of multi-conjugate adaptive optics (MCAO) for the Advanced Technology Solar Telescope (ATST).

ATST Triple Fabry-Pérot Étalon Tunable Filter

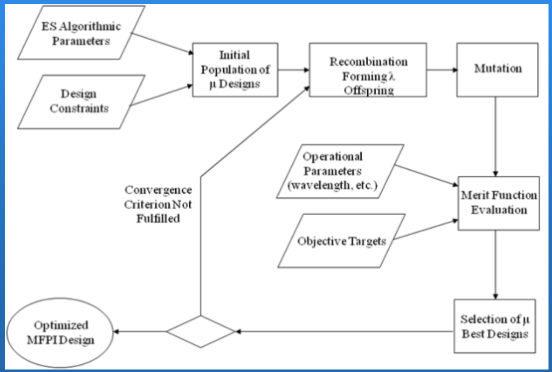


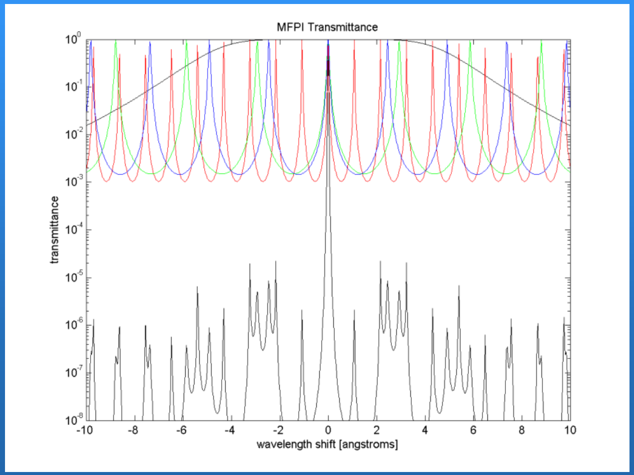


Zemax lens design of optics supporting triple F-P in telecentric mounting configuration.



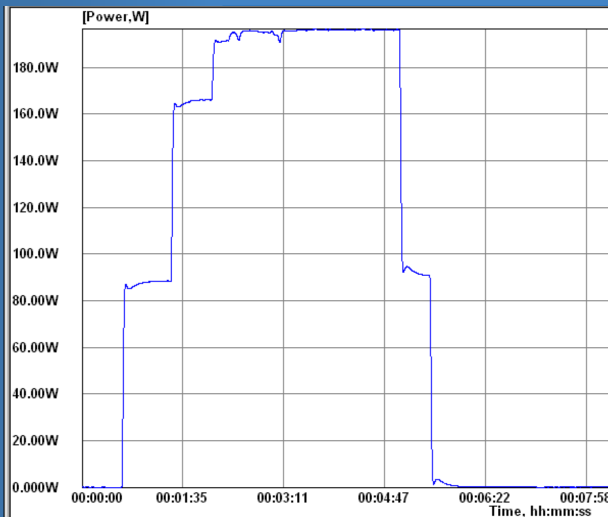
Evolutionary algorithm developed at CAO for optimization of triple etalon system



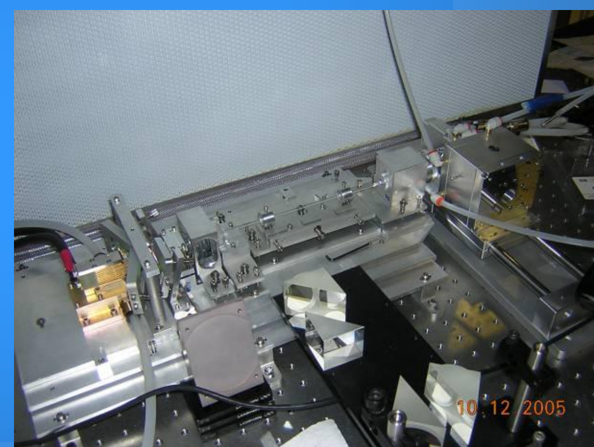


Thin Disk Laser

Technology licensed by inventor Dr. Adolf Giesen



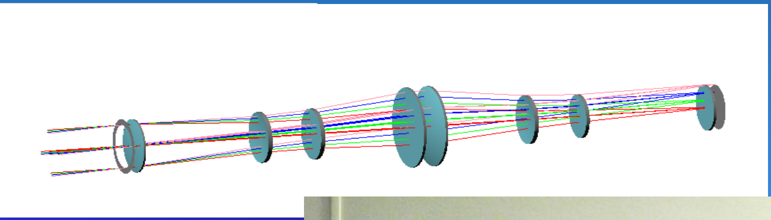
A collaboration of UAH and NASA to design, analyze, fabricate and assemble working TDL

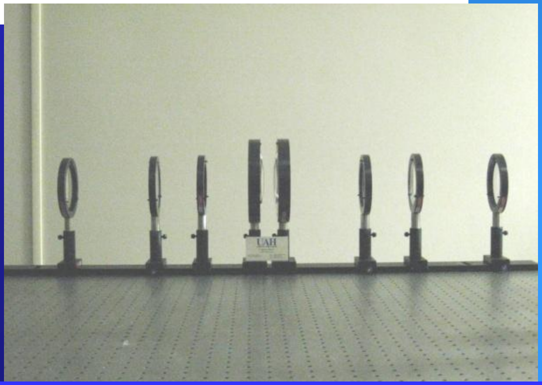


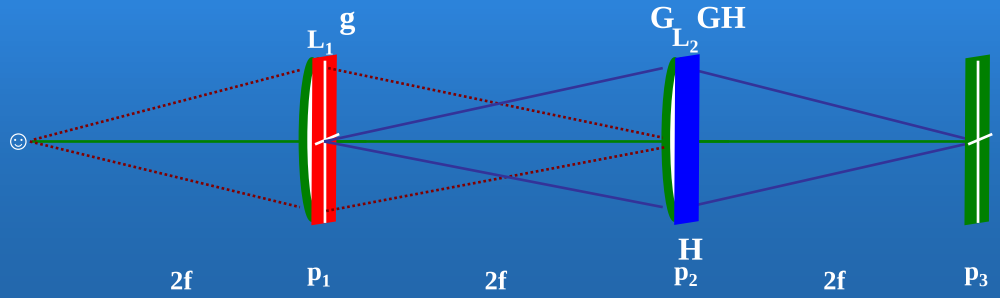
First group in US to achieve lasing.
System transferred to CAO for student research.
We have hosted three teams of Mechanical Engineering students

Automatic Target Recognition Technology

- Target scene searching
- Region of interest tracking
- Low latency target tracking (ms)
- Real time aim point selection
- Target-relative Shift invariance
- Range and rotation invariants built into optical filters
- Range relative accuracy increase







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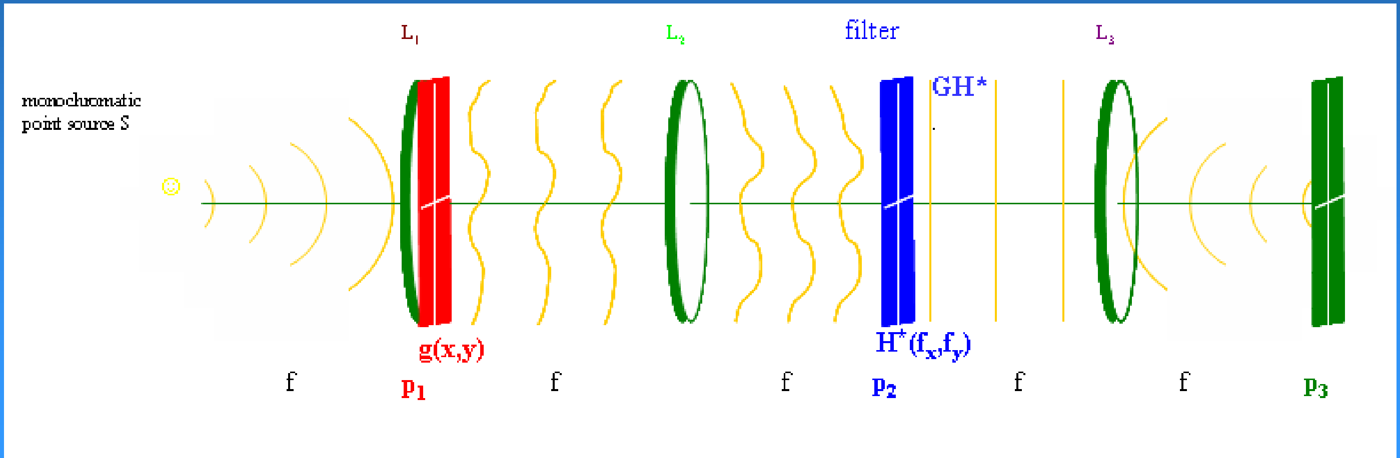
Optical Signal Processing 101 (OSP 101)
Two FTL's yield pattern recognition/tracking



A first FTL creates the spectrum of the input scene (P1) at P2,

FTL1{g} => G

A matched filter, H, is placed in plane P2

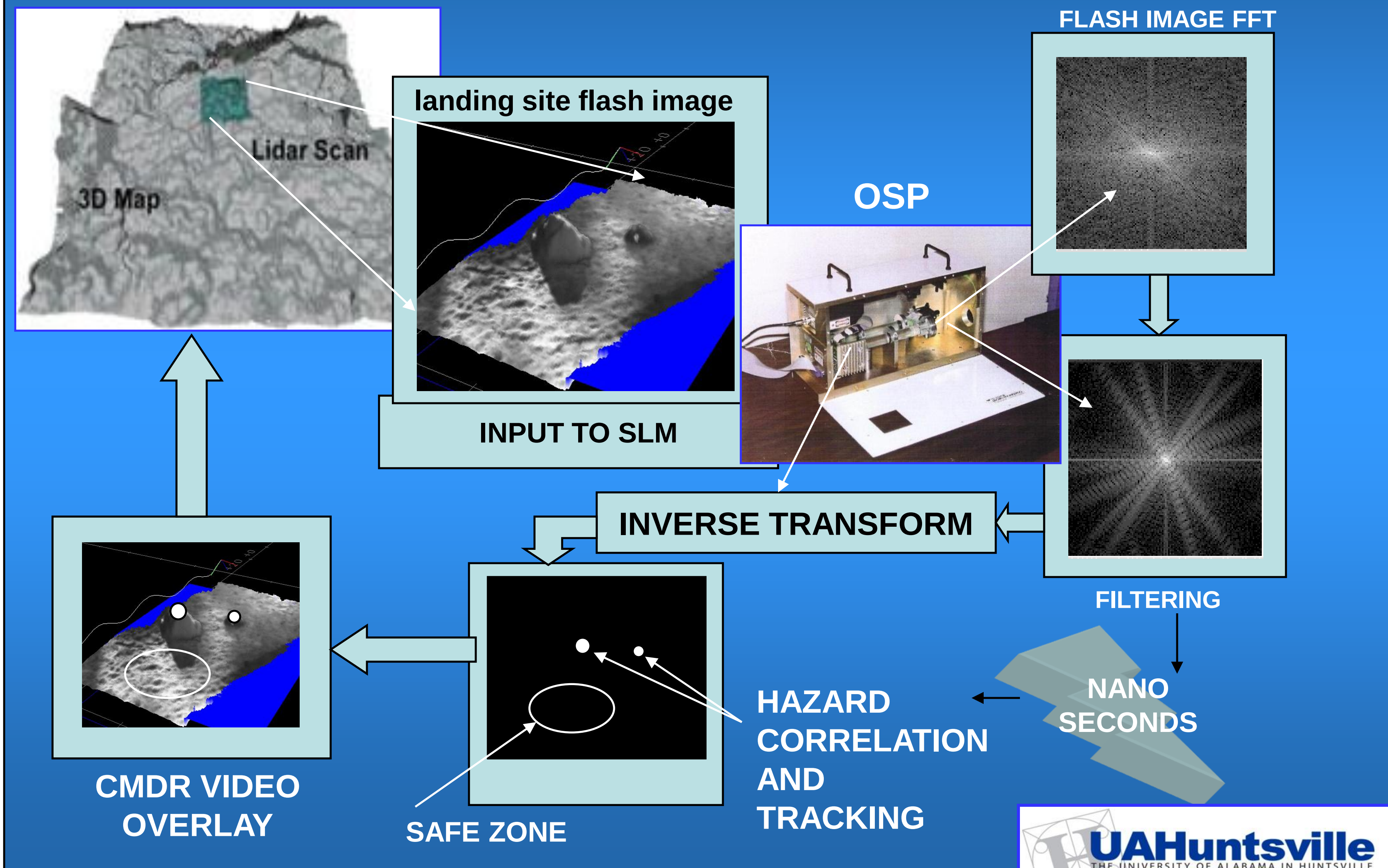
A second FTL creates the FT of the product of the matched filter and the FT of the input scene.

P3 = FTL2{G x H}

Cross correlation of g and h

If G* = H, the result is a bright correlation peak which moves with the motion of the input.

OPTICAL CLASSIFICATION / IDENTIFICATION PROCESSING PARADIGM
Application example



OPTICAL MODELING

CRITICAL COMPONENTS OF OPTICAL DESIGN/MODELING/FABRICATION

AN EFFECTIVE OPTICAL DESIGN HAS TO:

- EFFICENTLY USE DESIRED SCIENCE PERFORMANCE REQUIREMENTS
- ESTABLISH SYSTEM LEVEL OPTICAL SPECIFICATIONS FROM THOSE REQUIREMENTS
- OPTIMIZE OPTICAL SYSTEM DESIGNS
- DEVELOP OPTICAL ELEMENT ALIGNMENT AND FABRICATION TOLERANCES
- FEDUCIALIZE REFERENCE SURFACES FOR EASE OF ALIGNMENT
- ACCOUNT FOR HEAT LOADING OF OPTICS IN THE SYSTEM
- VALIDATE MODELS WITH HARDWARE EXPERIMENTS
- VERIFY OPTO-MECHANICAL CONSTRAINTS FOR FABRICATION
- DEVELOP ERGONOMIC COST EFFECTIVE MECHANICAL STRUCTURES FOR OPTICS

The UAH THIN DISK LASER IS A GOOD EXAMPLE OF OUR OPTICAL MODELING

DIODE ARRAY REDIRECTION
- CONTROL OF THE BEAM PARAMETER PRODUCT
- EFFICIENT HOMOGENIZER TUBE LAUNCH
- MONITOR IRRADIANCE AT OPTICAL ELEMENT SURFACES

OPTICAL PUMP CAVITY
- COMPLEX SET OF TURNING MIRRORS
- DELACITE ALIGNMENT TO PARABOLA
- PARABOLA TO DISK BPP REQUIREMENTS

Modeling of the Thin Disk Laser Hardware at the CAO

THE TDL IS A VERY COMPLEX LASER DESIGN

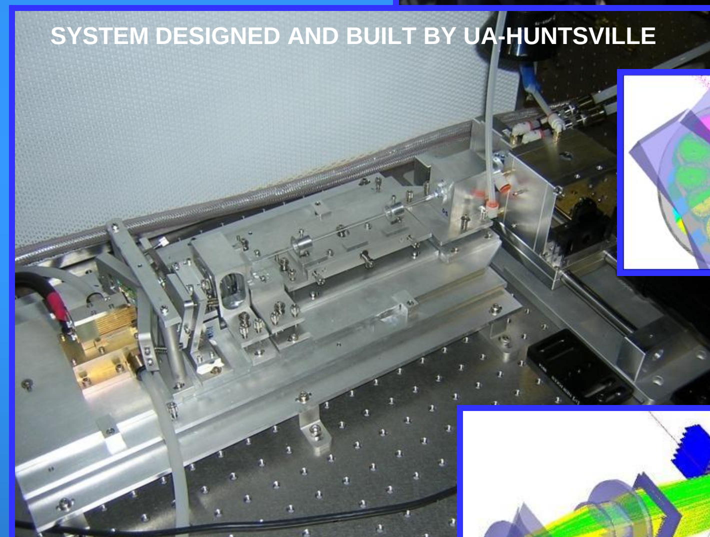
THE TDL HAS NUMEROUS TOLERANCING ISSUES

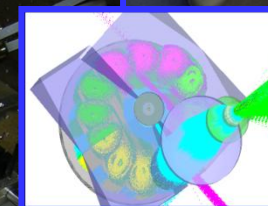
MODELING ACHIEVED WITH PHOTON ENGINEERING'S FRED
- -NON SEQUENTIAL MODEL
- -RIGEROUS, NOT A RAY TRACE PROGRAM

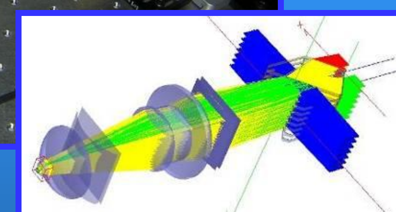
MODEL VALIDATED AS BUILT LASER

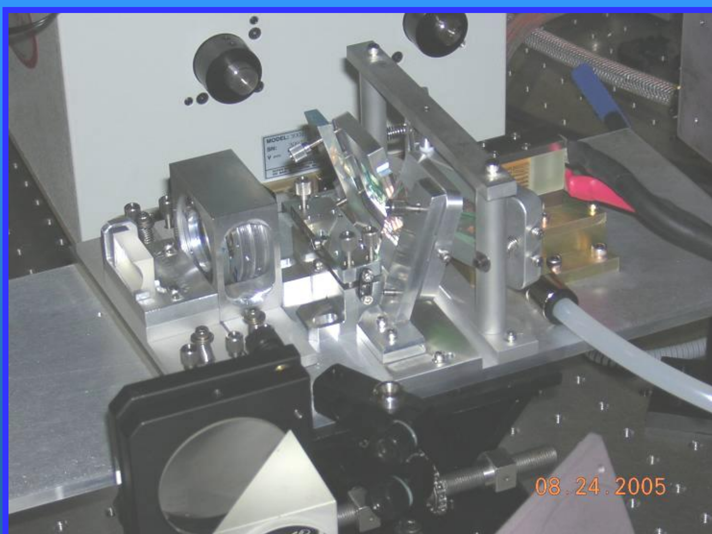
ANCHORED MODEL WAS USED FOR TOLERANCE STUDIES

LASER BUILT AND PERFORMED AS PREDICTED









TDL Bench unit designed to:
Anchor models
Establish requirements and tolerances
Scale the output power
Flight Qualification issues

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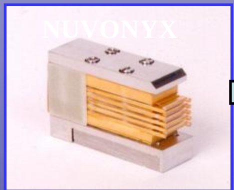
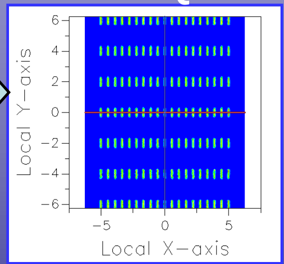
DIODE ARRAY DESIGN AND MODELING -REDUCING FACTORY BPP

COMPLEX OPTICAL PROBLEM:
- BPP TOO BIG FOR LASER
- HOW TO BEST MEET REQUIREMENT



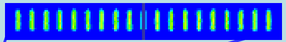


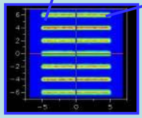
Total power = 286W
λ= 940 nm
425.5 mm*mrad
Need 232mm*mrad

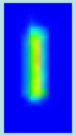
BPP = 425.5

Single emitter

Array Bar

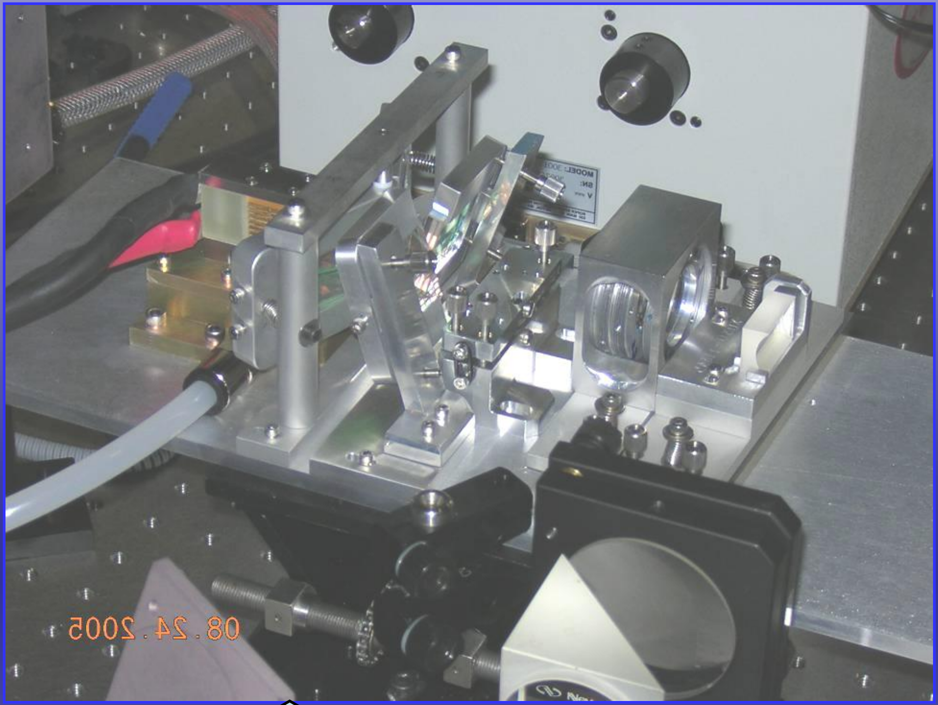


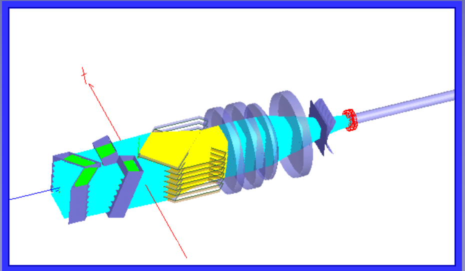


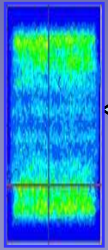


Array = 7 Bars

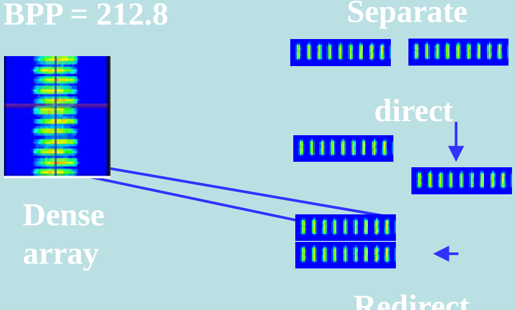
251 Watts max







BPP = 212.8



Dense array

ϕ =3mm
α = 70 mrad

Design results

$\phi * \alpha = 212.8$

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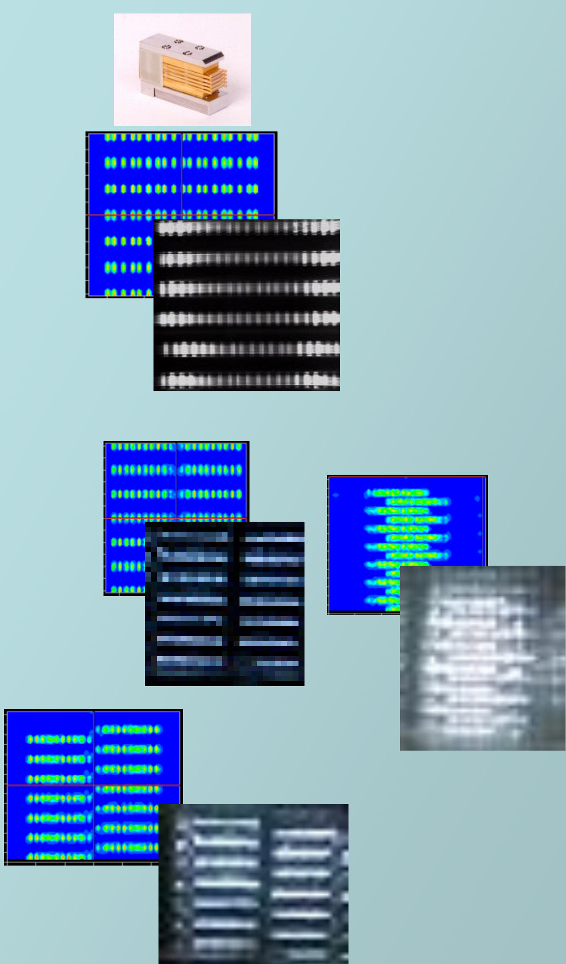
TOLERANCING AND ANCHORING OPTICAL DESIGN MODELS



DIODE RESHAPING

ENABLES:

REFINED OPTICAL TOLERANCING

BROAD BAND COATING DESIGN

SCALABILITY STUDIES

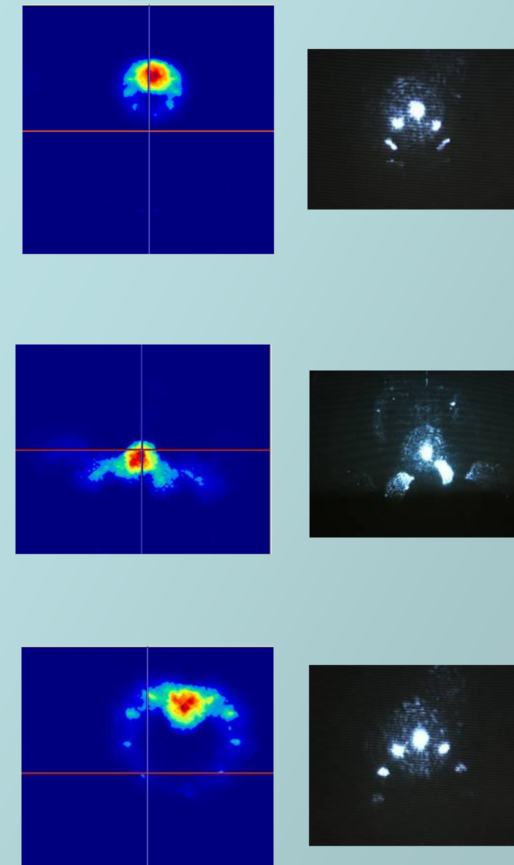
PERFORMANCE PREDICTIONS
- OPTICAL COMPONENTS
- MULTIPLE DIODE ARRAYS

OPTICAL INTENSITY LOADING

IGS FORMATING FOR CAD

THERMAL LOADING ESTIMATES

STRAY LIGHT



PUMP CAVITY MISALIGNMENT

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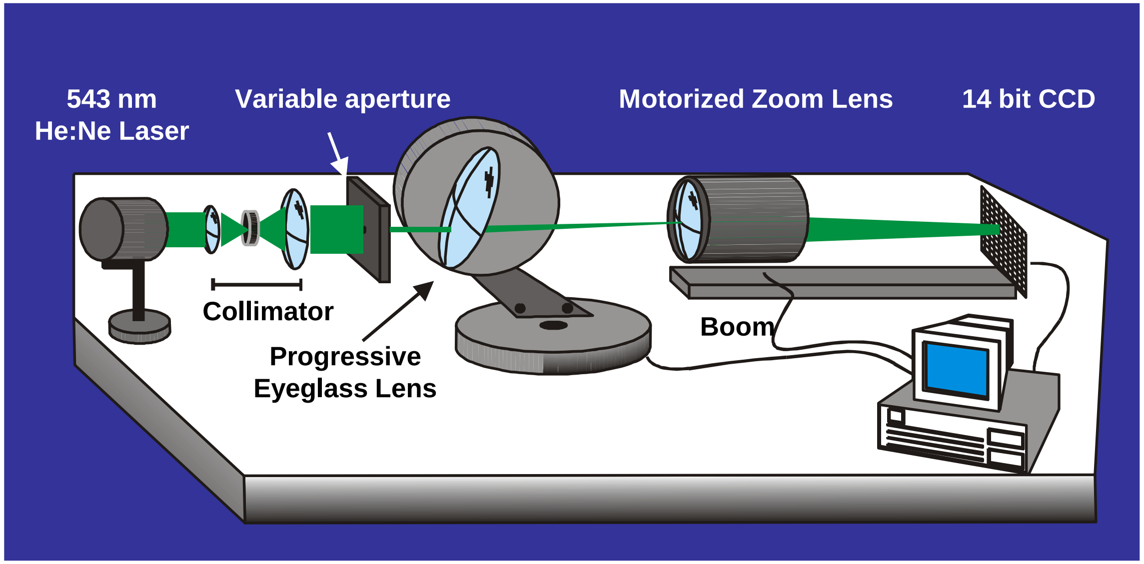
Select Programs Worked on by Current CAO Staff

NASA	MILITARY	INDUSTRY
Multi-Spectral Solar Telescope Array	Airborne Laser Lab	All-Reflective Zoom Telescope
Solar Vector Magnetographs	MIRACL/HELSTF	Fiber-Optic Fusion Monitor
Solar X-Ray Imager	AMOR Optics Support	Aircraft Glass Strain Measurement
Chandra X-Ray Telescope	Lightweight, Dual-Aperture Collimator	Aircraft Window Laminate Thickness Measurement
Ultraviolet Imager on POLAR Orbiter	Midcourse Space Experiment	Lightweight Electro-Optical Test-Set
Long-Duration Exposure Facility	AST	IR Scene Projection System
Total Integrated Scatter Instrument on MIR	HALO/IRIS & HALO II	Small, Low-Cost Missile Seeker
Lightning Mapper	MOSTT	Automobile Lane Position Monitor
Two-Color Holography	Project PRESS	Oil-Sheen Measurement
PAMELA Segmented Telescope	TOW Missile Trainer	Speckle-Based Residual Stress Measurement
Space Readiness Coherent LIDAR Exp	Improved Target Acquisition System	Spectacle Lens Image Mapper
Replicated Optics	Eye Oximeter	
James Webb Space Telescope	Advanced Optical System	
Orbiting Wide-Angle Fresnel Lens	IR Detector Development/Modeling	

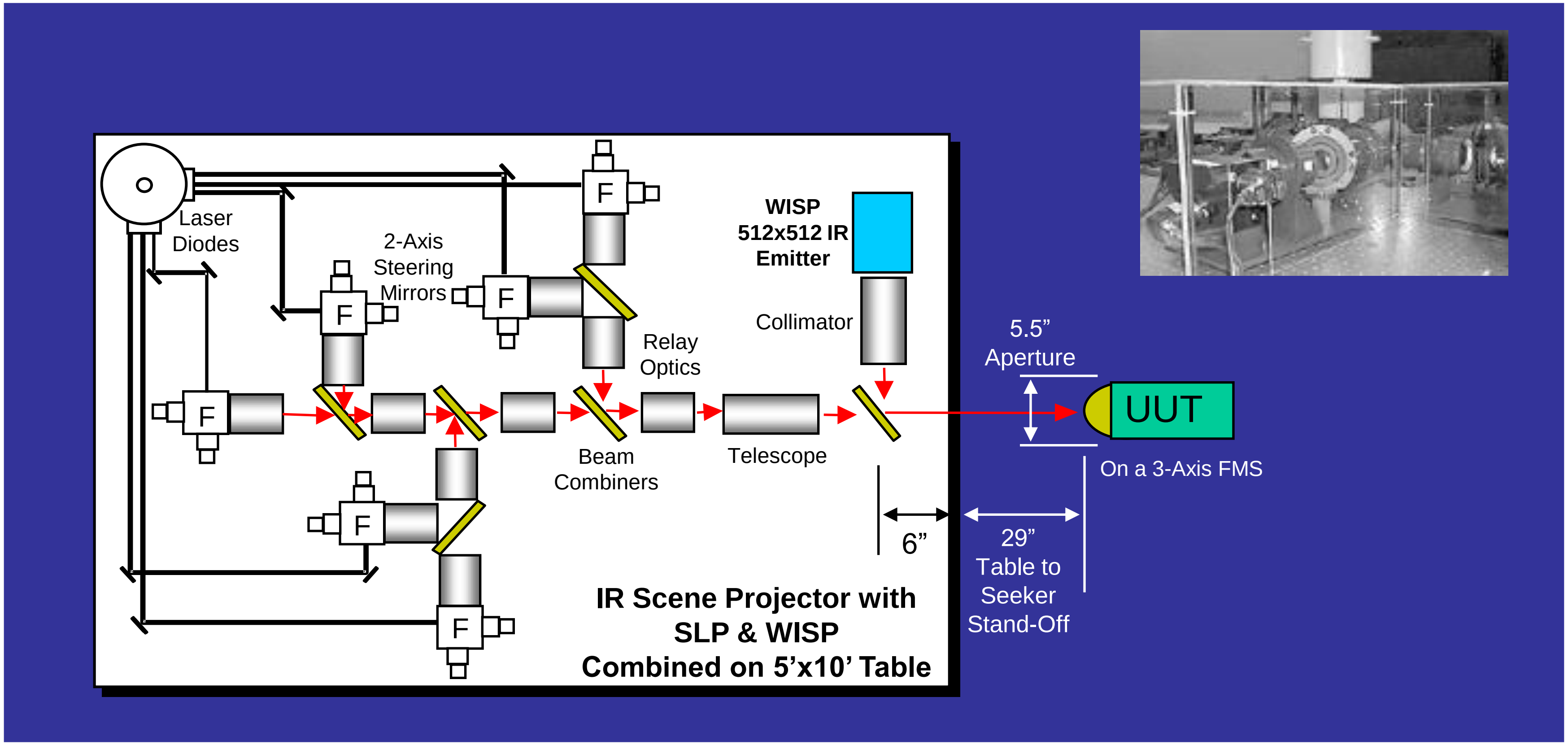
The Spectacle Lens Image Mapper



- **Direct optical measurements on lenses.**
- **Mimics wearer geometry.**
- **Measures PSF at best-focus using high-resolution CCD.**
- **Fourier transforms PSF to MTF.**
- **Predicts lens-limited visual acuity.**
- **Also measures power, cylinder, & prism.**
- **Automatic test produces data over full aperture of lens.**

- The Issue: Optical quality assessment methods have not kept pace with the increasing complexity of Progressive Addition Lenses (PALs).
- The Need: Objective measure of PAL image quality over the entire usable aperture of the lens.
- CAO developed & patented the Spectacle Lens Image Mapper for Johnson & Johnson Vision Products.

The Steerable Laser Projector

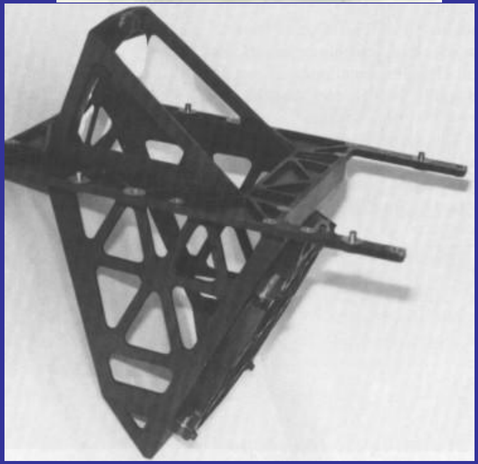


CAO, working for Aegis Research, performed all optical & mechanical design (excluding WISP & WISP collimator) for this KHILS IR projector (Eglin AFB).

EOA AN/PSM-80 Collimator

Pentastar Electronics, Inc. - Collimator Development

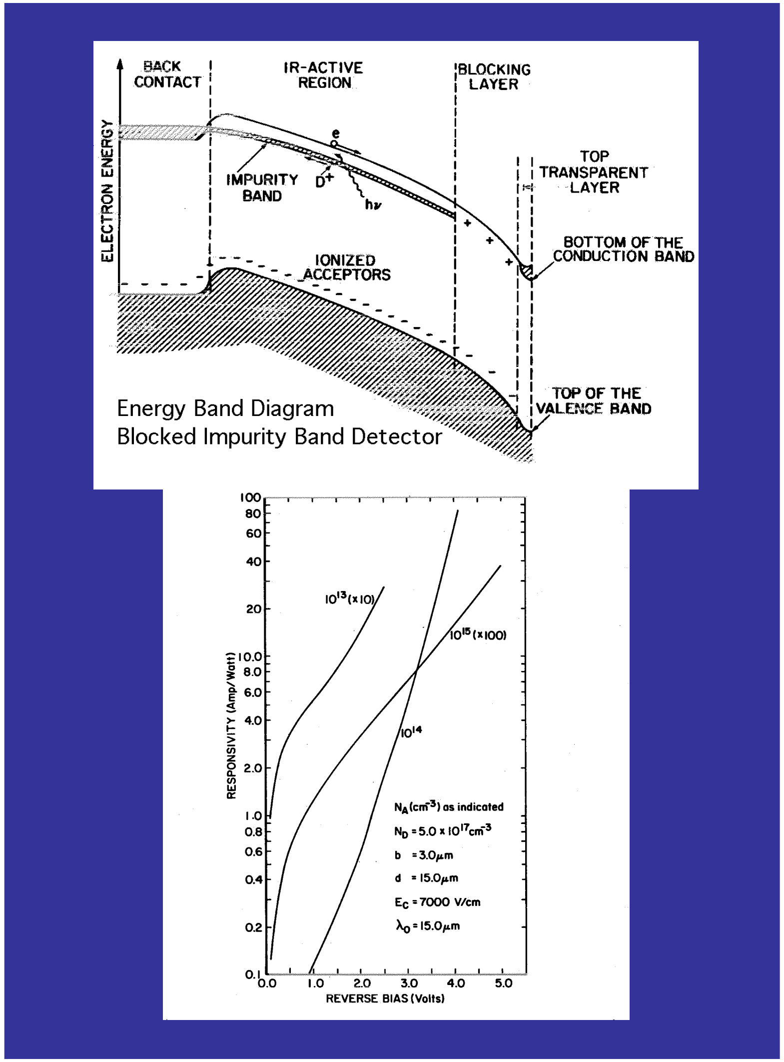
- Materials selection by CAO
    - Light weight – 1 man portable
    - Versatile – 45 calibrations of 18 systems
    - Rugged – 365 day cal cycle
- Aluminum – Silicon (Vanasil)
    - High elastic strength
    - Low density
    - Machinable
    - Thermally stable fielded design
    - Low cost, non-toxic Be substitute
    - Prototype, process development by CAO
- Manufacturing process development
    - Optical – mechanical design of collimator
    - Precision casting process
    - Thermal treatment cycles
    - Coating process and surface preparation
- Unit still in production



Electro-Optical Materials & Devices

Materials and Device Modeling

- **Infrared Detectors--Parametric Modeling/Figures of Merit**
  - Photoconductive
  - Photovoltaic
  - Blocked Impurity Band
- **HgCdTe Heterojunctions/Detectors**
- **Multiple Quantum Well Detectors**
- **Electronic & Optical Properties of Quantum Confined Structure**
- **Electronic & Thermal Transport in Semiconductor Alloys**
- **Optical Waveguides**



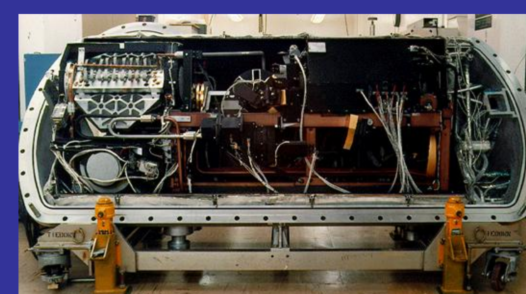
Significant Strategic Sensor Work

- AST Replacement Study
- MSX
  - Co-PI 1990 to 2001
  - Tech-transfer to MDA programs
- POST Calibration Chamber
  - Design, fabrication, test, & optical modifications
  - Calibration traced to NIST
- HALO - IRIS
  - Sensor performance tests

AST Replacement

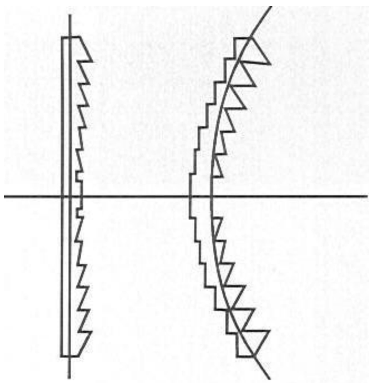
MSX

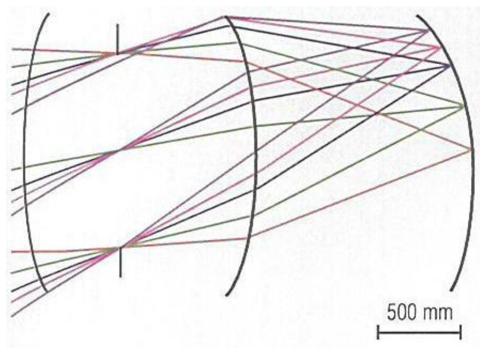
HALO

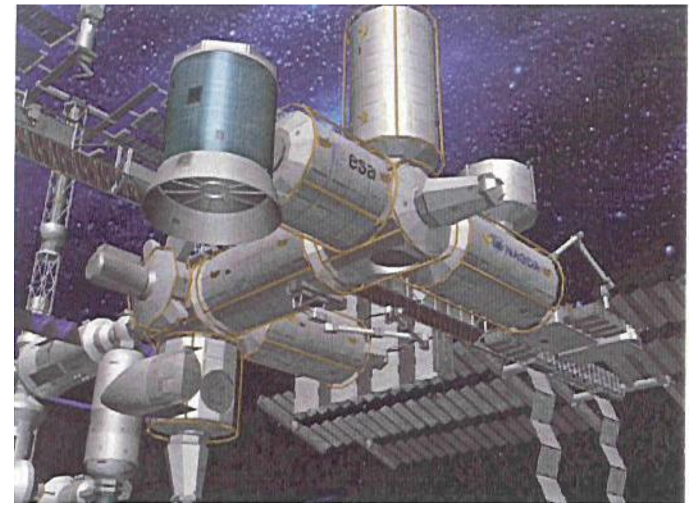


POST

Optical Wide-angle Lens (OWL)







Instrument and large Fresnel optics developed at CAO along with the Physics department.

Earth-Viewing Satellite for the Highest Energy Cosmic Particles
OWL's view area: ~1000 - 6000 km^2
Wide-angle Fresnel Optics: FOV ~ 60° / unit to cover ~120° x 360°
Observable Energy Range: $10^{19} \leq E \leq 10^{22+}$ eV ,~ 10^{3-4} Nuclei per year greater than 10^{20} eV
Angular resolution ~ 0.1°
Identify Topological Defects and/or Gamma Ray Bursts.

Watches earth's night sky for air shower-flashes caused by energetic cosmic rays.

Led to the EUSO designs

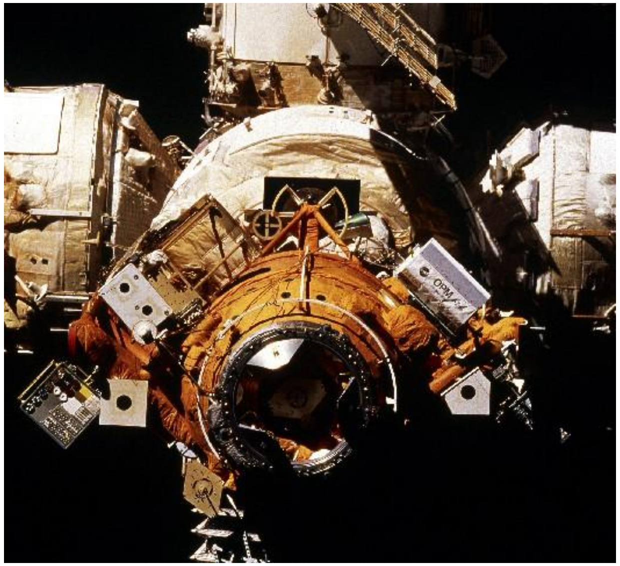
Anticipate metrology work from EUSO

NASA Imaging X-ray Optics

Manufacturing R & D

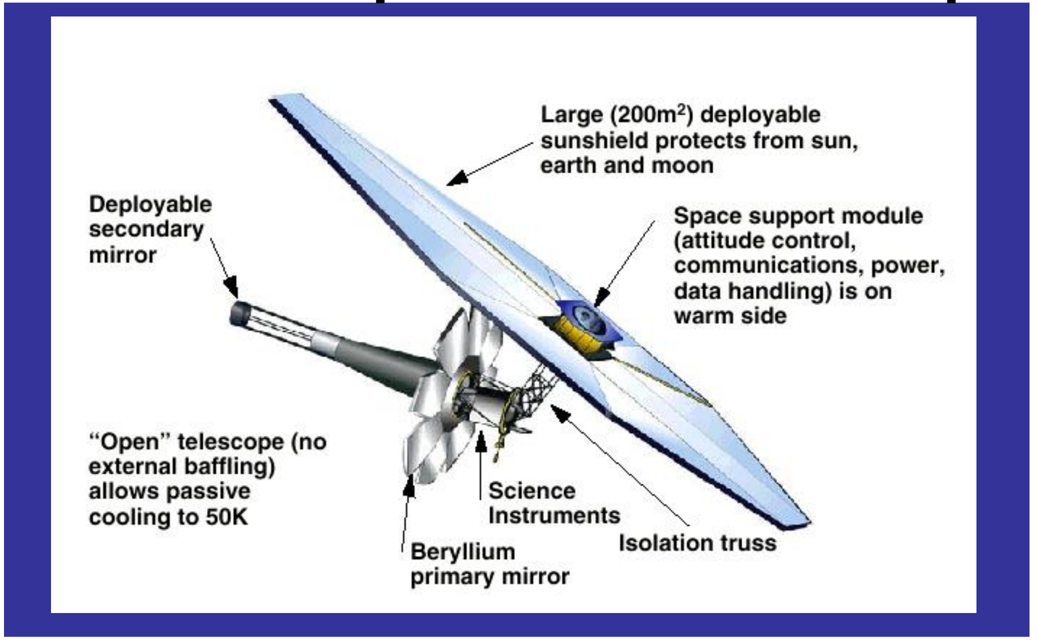
- AXAF-S, SXI, HERO, Constellation X
- Replicated optics by electro-chemical processes
- Performance requires innovative materials
  - 3 – 4 Å finish
  - High quality figure
  - Low weight
  - Ultra-high elasticity
  - Low residual stress
- Nickel alloy development
  - Fine grain structure nickel
  - Nickel cobalt
  - Nickel cobalt phosphorous
- Electromechanical developments
  - Low stress replicated optics
  - High elastic strength alloys developed

Total Integrated Scatter Instrument



Part of the Optical Properties Monitor experiment. Flew on exterior of MIR from Apr 29 to Dec 26, 1997. Measured space environmental effects on various materials as a function of exposure time.

Support of NASA's James Webb Space Telescope



- CAO led telescope optical design for pre-Phase A study & supports continuing optical design analyses.
- CAO supported alignment & phasing studies for segmented apertures using MSFC's PAMELA test-bed.
- CAO led opto-mechanical modeling & analysis of one advanced mirror concept.
- CAO led optical testing of JWST technology-development mirrors at Marshall's X-Ray & Cryogenic Facility (XRCF).
- CAO currently supporting preparations for testing flight PM segments at XRCF.

JWST Optical Testing

Cryogenic Large Optic Testing:

- Several large (0.5-2 m), lightweight (<15 kg/m^2) mirror technology programs conducted. Vendors included Ball, Kodak, Goodrich, COI, & U of AZ.
- Materials: SiO_2, ULE, Be, SiC, Composite.
- XRCF at MSFC upgraded for optical testing of meter-class mirrors at cryo-temperatures (to 20 K).
- CAO led modification of facility.
- Main chamber is 7 m x 23 m. Also 1 m x 2 m chamber.
- CAO led optical testing of the mirrors.
- Instrumentation: Shack-Hartmann sensor, 2 instantaneous phase-shifting interferometers, diffractive nulls, 6-DOF hexapod, & 2 absolute distance meters.