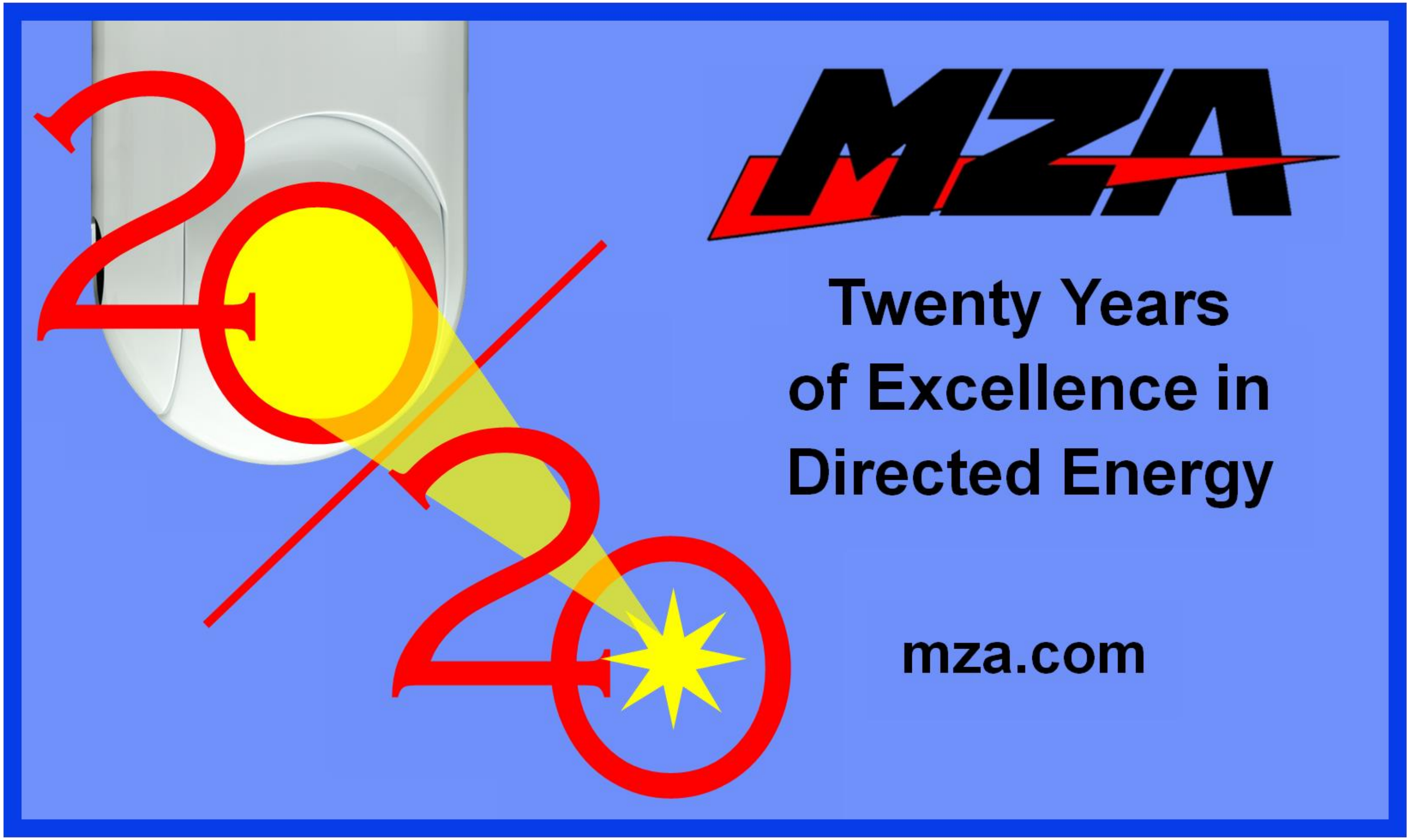
MZA Associates Corporation

Capabilities Overview



2021 Girard Blvd. SE, Suite 150
Albuquerque, NM 87106
505-245-9970

An Employee-Owned Company

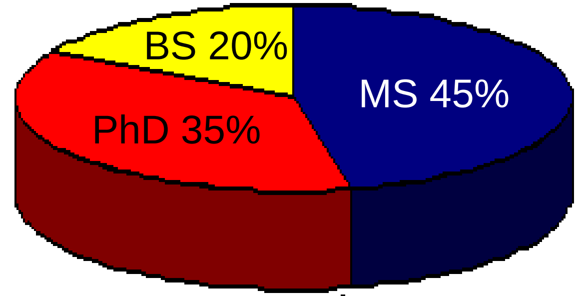
1360 Technology Ct, Suite 200
Dayton, OH 45430
937-684-4100

RWPII – 05/2013

MZA is a world leader in the modeling, analysis, and development of directed energy and imaging systems

Modeling, analysis, & development

- Beam control and imaging systems
- Solid state and gas laser resonator systems
- Adaptive optics design and implementation
- Atmospheric and aero optical effects
- DE engagement analysis
- Weapons system military utility
- Target signatures and vulnerability
- Laser communications
- LADAR applications

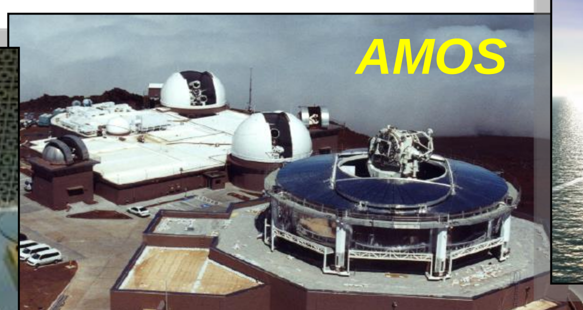


>50 employees

WaveTrain

wave optics made easy~~y~~ier

MZA's modeling and analysis software has been used on nearly every major HEL program of the past fifteen years.



MZA's Core Business Areas

- **Laser Weapon & Optical Sensor Modeling & Simulation**
  - WaveTrain - Integrated physics-based simulation
  - Atmospheric and aero-effects modeling
  - Beam control and propagation scaling models
  - Systems engineering models
  - Laser resonator device modeling
- **Laser System Testing and Integration**
  - Beam Control
  - Imaging
  - Laboratory and field experimentation
  - Experimental analysis
  - Turbulence profiling
  - Aero optics
- **Adaptive-Optics Beam Control Hardware**
  - High-speed tracking and wave front compensation devices
  - High Power Deformable Mirrors (HPDMs)
  - Real-time and distributed control systems
  - Optical telescopes and beam directors
  - Experimental optical measurement devices
  - Atmospheric measurement devices


February 11, 2010
First Boost-Phase Ballistic Missile Shootdown
USAF
ED
00-0001
U.S. AIR FORCE
MZA
Twenty Years
of Excellence in
Directed Energy
mza.com
MZA
target
atmosphericpath
platform
WaveTrain
wave optics made easy/ier

MZA Supports the Development of Major Directed Energy Weapons Systems

- Demonstrator Laser Weapons System (DLWS, AFRL/DARPA)
- High Energy Liquid Laser Area Defense System (HELLADS, DARPA)
- Laser Weapons System Module (LWSM, Lockheed/DARPA)
- Helicopter Beam Director for High Energy Fiber Laser Future Naval Capability (HEFL FNC, ONR/NAVAIR)
- Airborne Aerooptics Laboratory (AAOL, HEL-JTO)
- High Energy Laser Technology Demonstrator (HELTD, SMDC)
- Next Generation Airborne Laser (NGABL, MDA)
- WSMR Solid State Laser Test Bed (SSLTB, SMDC)
- Airborne Laser Test Bed (ALTB, MDA)
- Tactical Relay Mirror System (TRMS, AFRL)
- Joint High Power Solid State Laser (JHPSSL, HEL-JTO)
- Electric Laser on a Large Aircraft (ELLA, AFRL/DARPA)

MZA's Major & Recurring Customers

- **Air Force Research Laboratory (AFRL)**
- **High Energy Laser Joint Technology Office (HEL-JTO)**
- **Airborne Laser Test Bed (ALTB) / Missile Defense Agency (MDA)**
- **Defense Advanced Research Projects Agency (DARPA)**
- **Naval Air Systems Command (NAVAIR)**
- **Naval Research Laboratory (NRL)**
- **Office of Naval Research (ONR)**
- **Air Force Institute of Technology (AFIT)**
- **Naval Postgraduate School (NPS)**
- **Army Space & Missile Defense Command (SMDC)**
- **US Aerospace and Defense Contractors**

  Lockheed Martin, Textron, Raytheon, SAIC, Boeing, Schafer, SPARTA, Radiance
- **US Educational Institutions**

  UCLA, Notre Dame, Univ. of Dayton, Univ. of MD, Univ. of Central FL

Overview of
Hardware Development Efforts

Lightweight Compact Beam Directors

Addressing a high priority need identified by the Air Force Research Laboratory, MZA undertook the challenge to develop lightweight compact beam directors for high power laser applications.

The result has been the development of MZA's Othela line of beam directors that utilize the latest technologies in opto-mechanical materials, gimbals, optical coatings, and sensors to reduce the number of high power optics in order to institute on-gimbal beam control concepts.

- **Integrated on-gimbal beam control systems.**
- **Line-of-site stabilization and wave front compensation.**
- **< 1 cubic meter in volume**
- **< 500 lbs.**
- **Designed for high power laser applications.**
- **On-axis and off-axis telescope designs.**

Sentinal

The Practical
Laser Weapon System
Concept

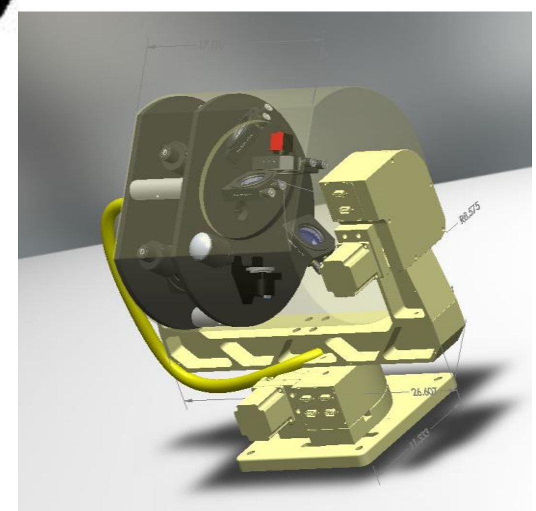
Mobile Laser Defense and Tactical Engagement

Recent developments in high power fiber lasers and advanced optical coatings enable a new class of mid-power laser weapons systems.

MZA's Laser Sentinal concept employs advanced coated optics to overlap four **1.5 kW** high-efficiency and high-quality fiber lasers to create a **22 cm** diameter output beam effective against surveillance systems and soft targets up to **10 km** away**.**

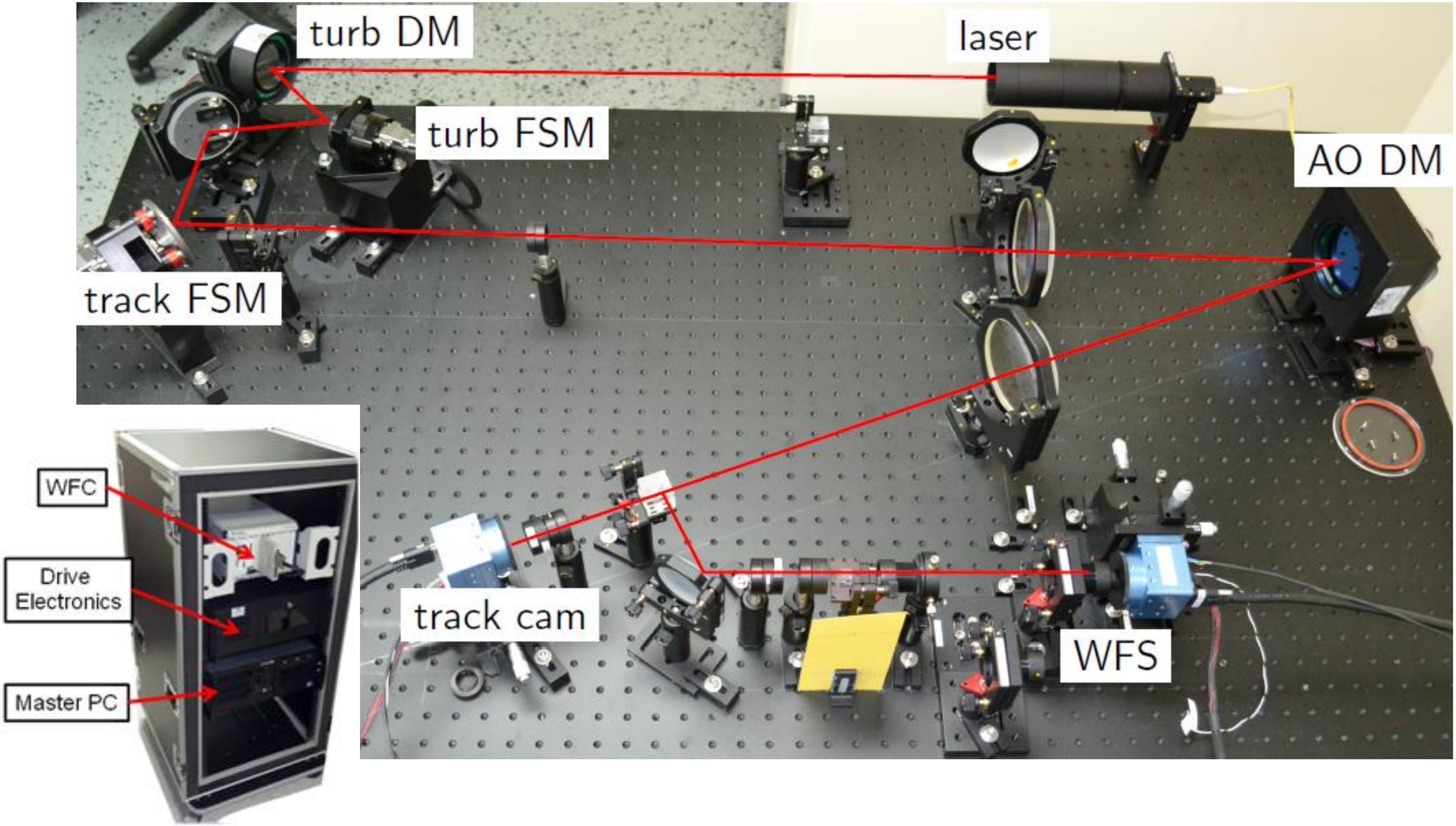
The MZA Laser Sentinal provides a real opportunity to introduce effective laser weapons to the fighting forces.

- ✓**Light-weight**
- ✓**Compact**
- ✓**Self-contained**
- ✓**Fits on a HMMWV**
- ✓**5 kW 22 cm beam**
- ✓**Surveillance**
- ✓**Tracking**
- ✓**Engagement**



The Mobile Laser Weapon of NOW

High-Speed Optical Tracker and Adaptive Optics System



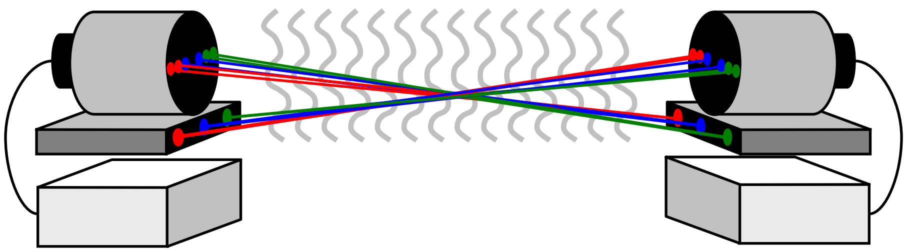
- **Full system including deformable mirror, high-speed wavefront processor, and track+AO controls built by MZA**

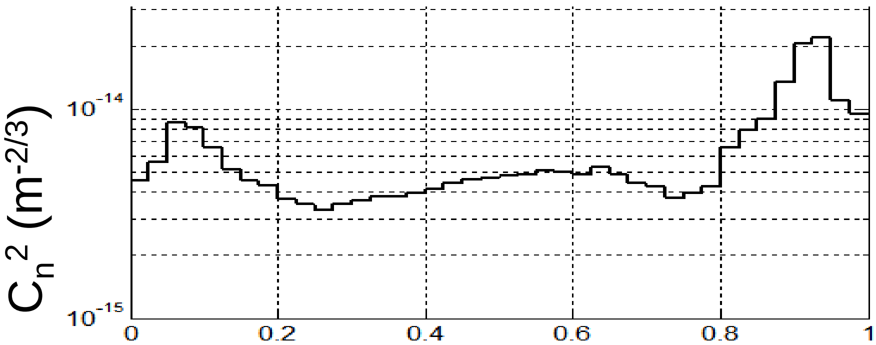
North Oscura Peak Facility

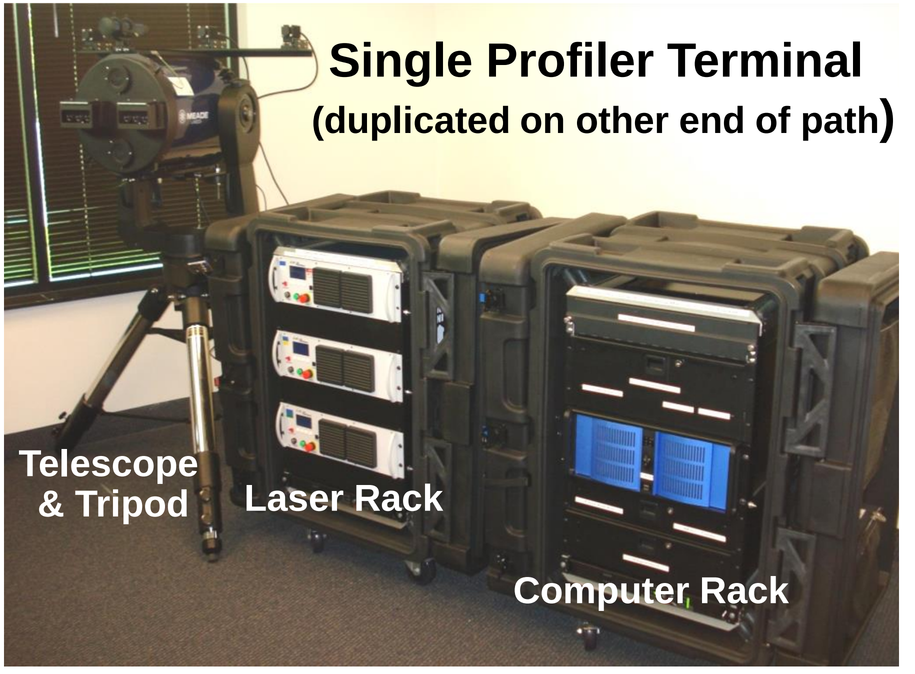
MZA…

- **Developed the specifications for the 1-meter telescope and then assisted in its procurement and installation.**
- **Designed and implemented the Coude path.**
- **Designed illuminator insertion optical path.**
- **Implemented numerous embedded systems for atmospheric characterization, system monitoring, safety, and diagnostics.**

Turbulence Profilers



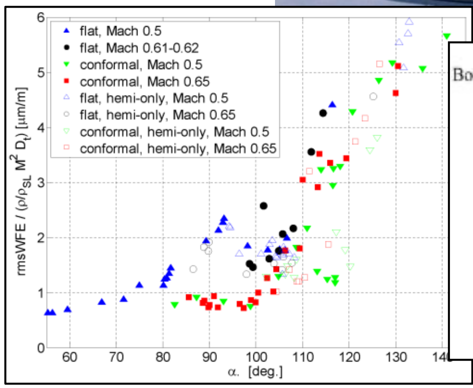


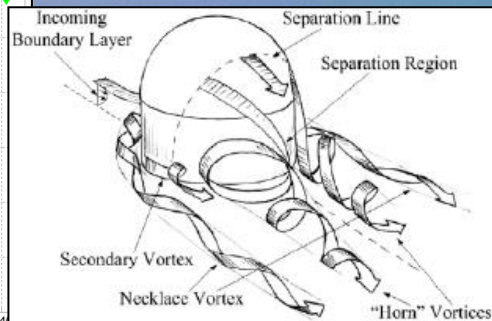


- Measures C_n^2 values in bins along a line-of- sight path of up to 200 km
- Greatly assists understanding of system performance (fades, dropouts, BER, etc.)

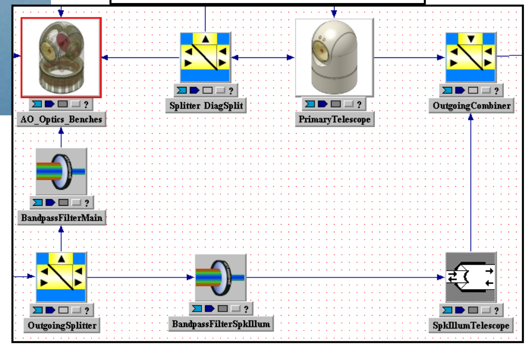
Predictive Control for AO

AAOL flight data

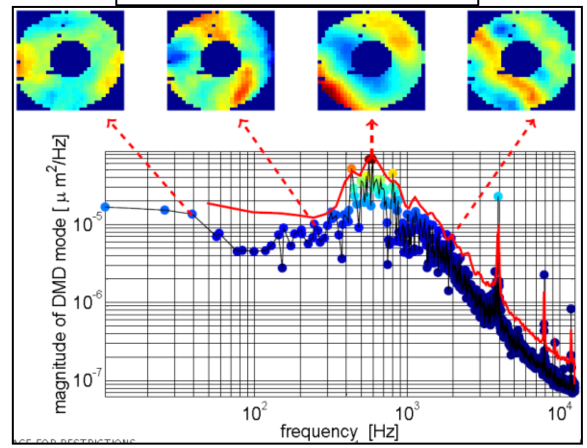




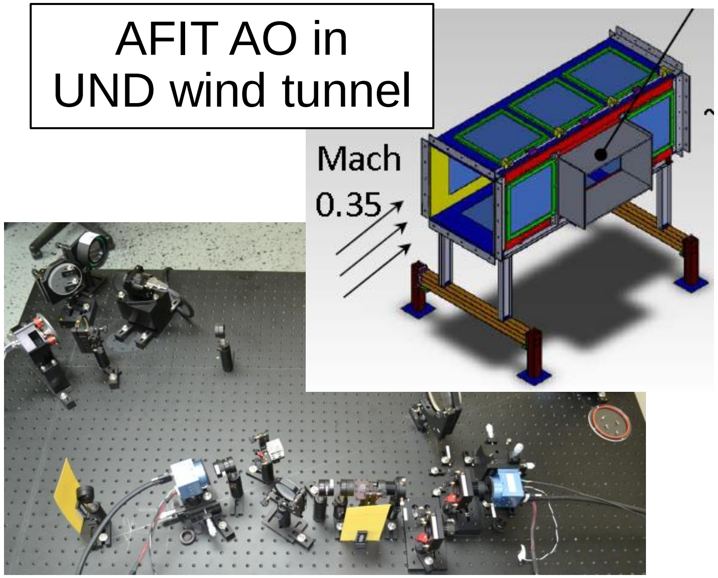
Wave-Optics Simulations



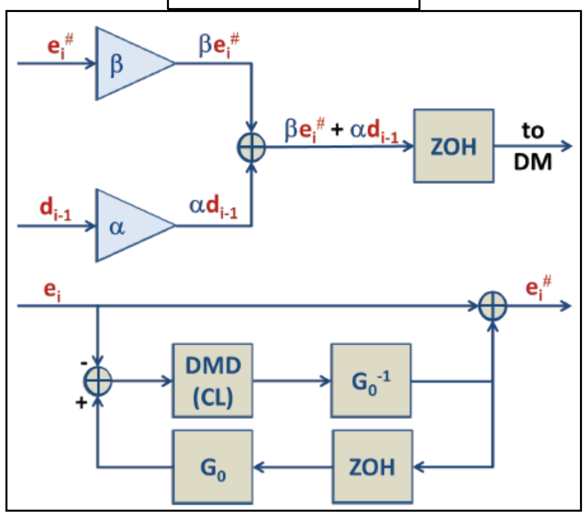
Dynamic Mode Decomposition



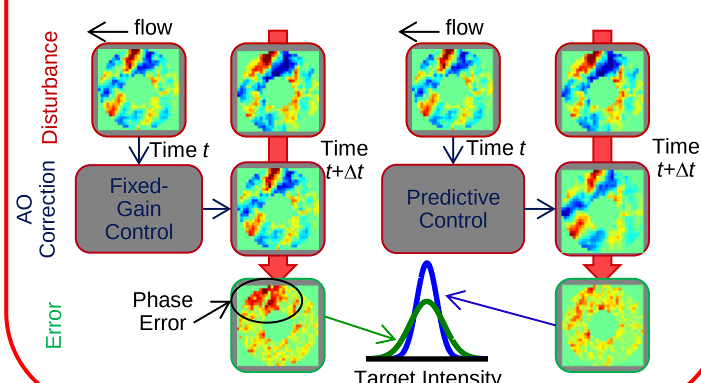
AFIT AO in UND wind tunnel



Predictive Control

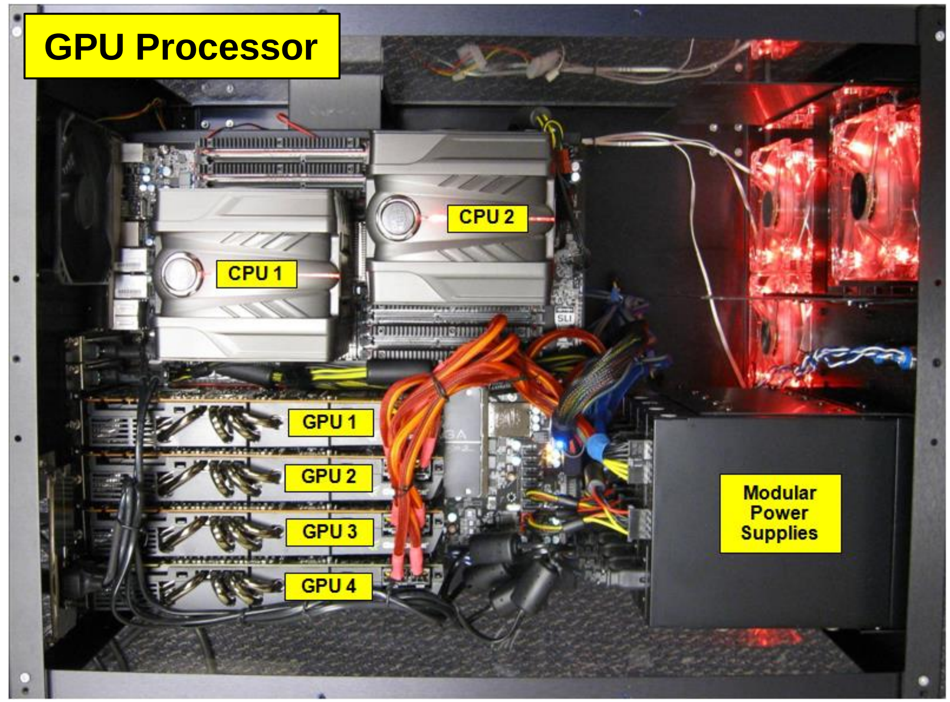


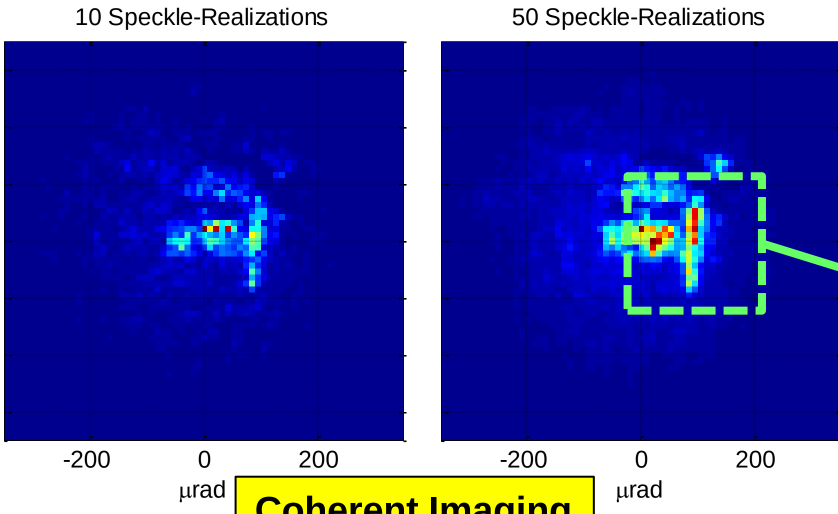
More Power on Target



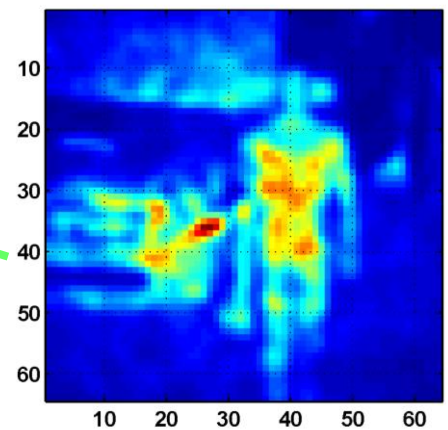
Sparse Aperture Image Synthesis, Compensation, and Tracking Processor

- High-bandwidth processing capability required for phased array imaging applications
- Spatial-heterodyne imaging provides complex field data allowing for fully digital phasing
- Parallel GPUs give significant performance boost over CPUs
- COTS hardware

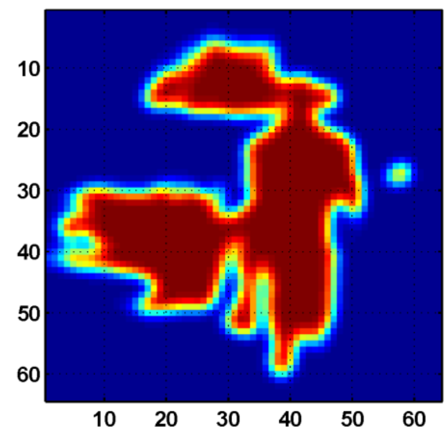




Coherent Imaging

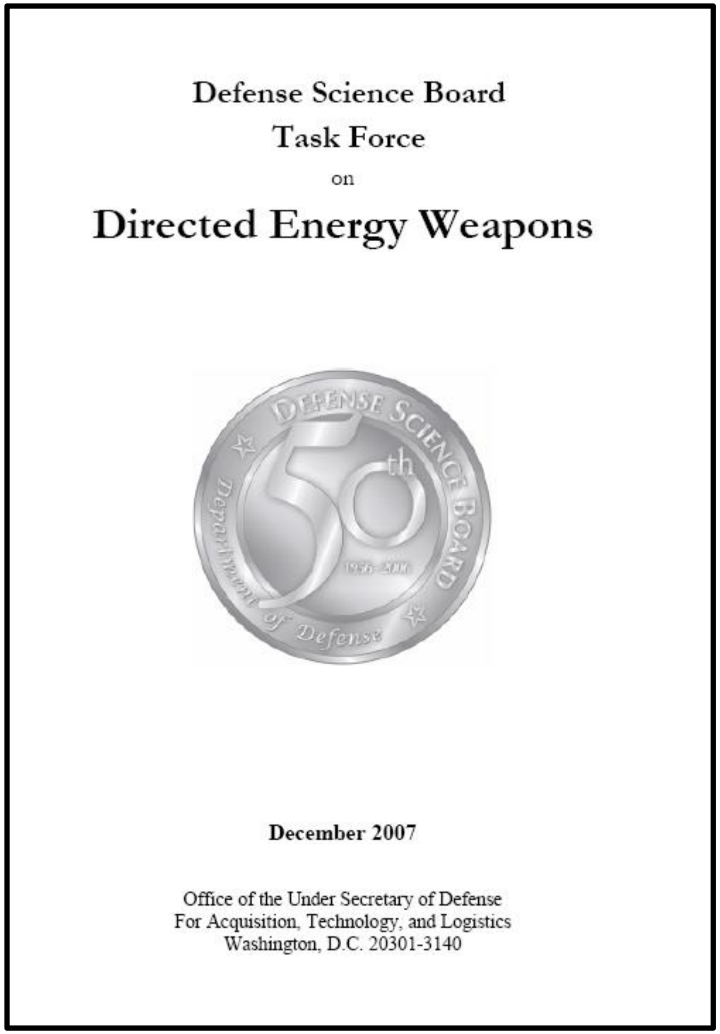


Gated Image



Segmentation

The DSB identified a need in the U.S. directed energy industrial base for beam control and deformable mirrors.



Defense Science Board
Task Force
on
Directed Energy Weapons

December 2007

Office of the Under Secretary of Defense
For Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

- The lack of directed energy production programs or the serious prospect of significant production programs has jeopardized the supporting industrial base. There is essentially one U.S. vendor capable of supplying deformable mirrors.

  - *The Deputy Secretary of Defense should direct the military departments to provide overall vision and strategic plans for developing relevant directed energy capabilities that can provide visibility into the likely future business case for sustaining directed energy industry capabilities.*

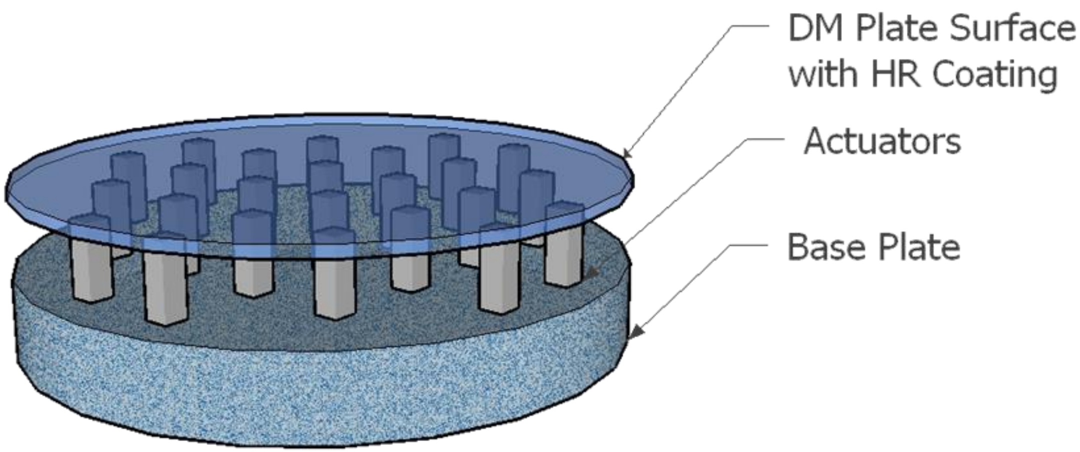
- The nation's technical capabilities in HEL components and sub-systems are thin and have, in some cases, atrophied. The situation in large high-power optics and beam control is particularly fragile depending on a single vendor at best.

  USD (AT&L) should direct a survey of laser component capability and produce a plan for sustaining access to the required capability.

MZA and AOS have stepped up to this challenge. We are now the second US provider of high power deformable mirrors. We have also significantly improved the state-of-the-art in beam control systems engineering.

MZA High Power Deformable Mirrors

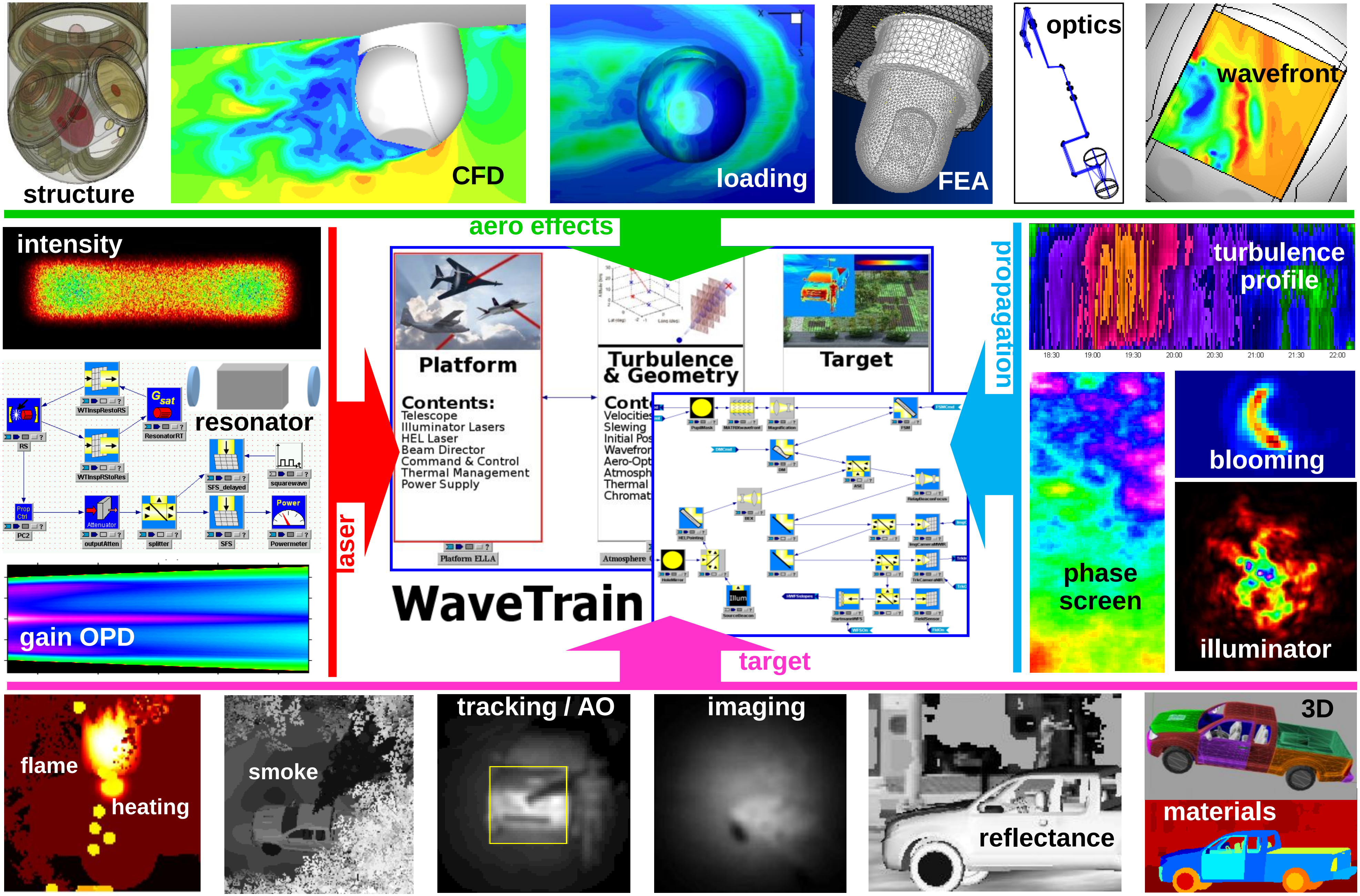
- 100 kW average power for up to 5 seconds over a 6 cm^2 area with < 1 deg. C temperature increase.
- Tested up to 250 kW CW.
- Rapid fabrication possible.
- More than 20 high power DMs delivered



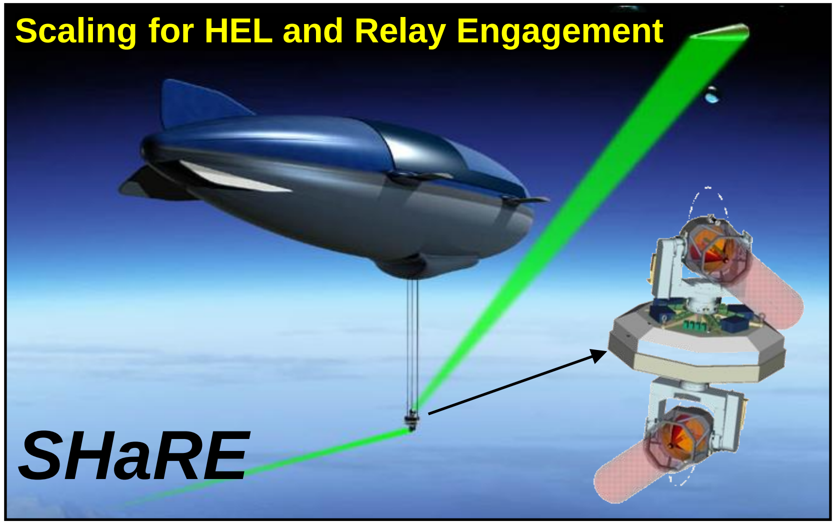
We offer complete systems that include the DM, compact high-voltage drive electronics and full adaptive optic feedback control systems.

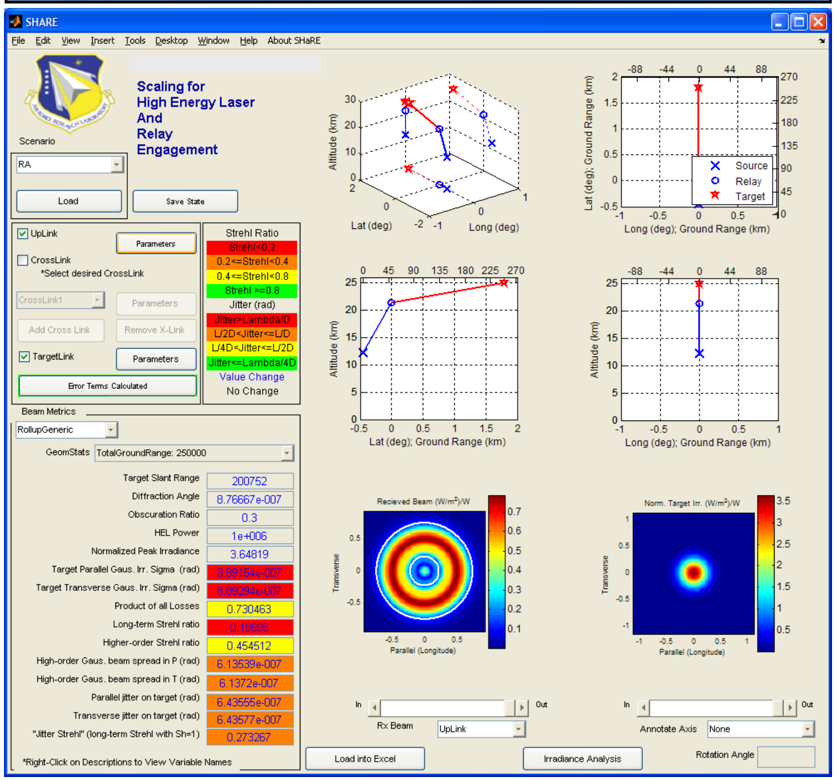
Overview of Modeling & Analysis Capabilities

Integrated End-to-End Modeling



Scaling for High Energy Laser and Relay Engagement (SHaRE)

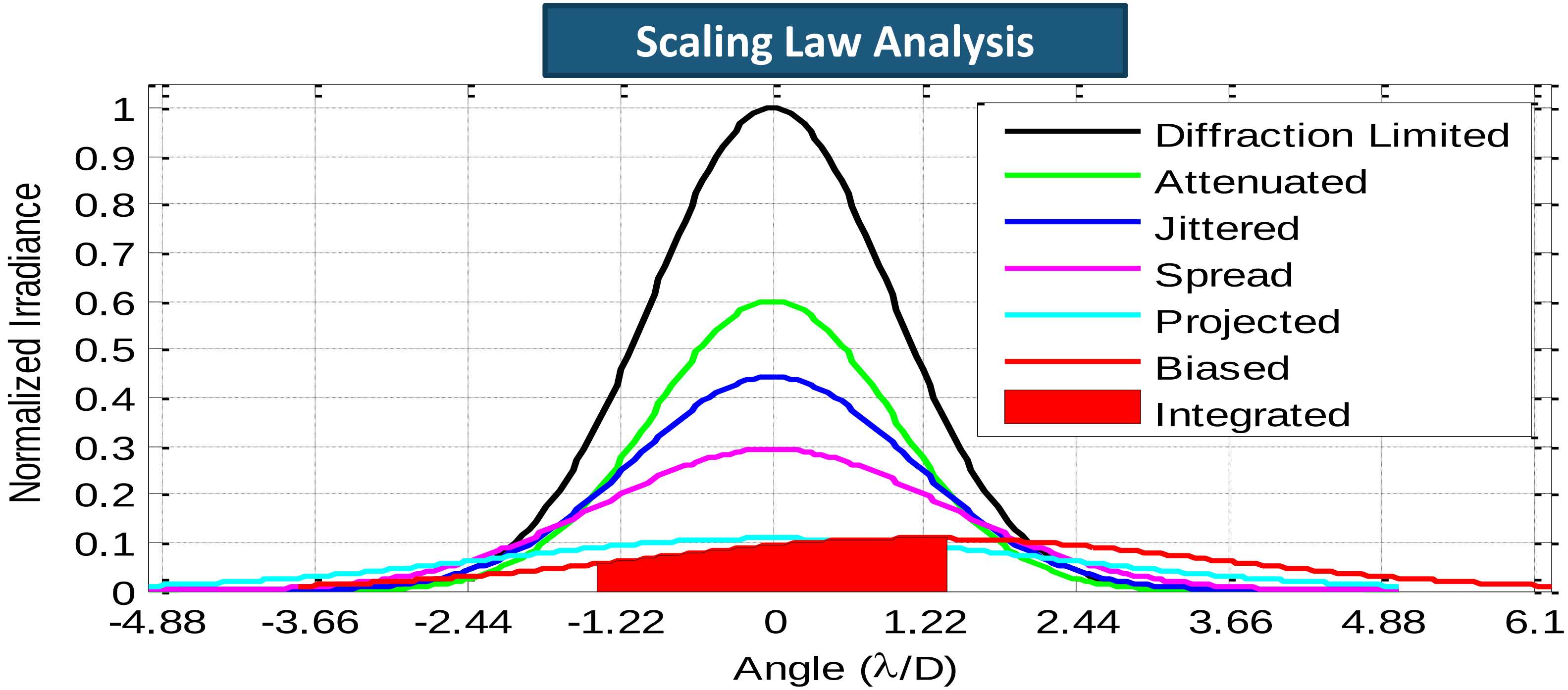




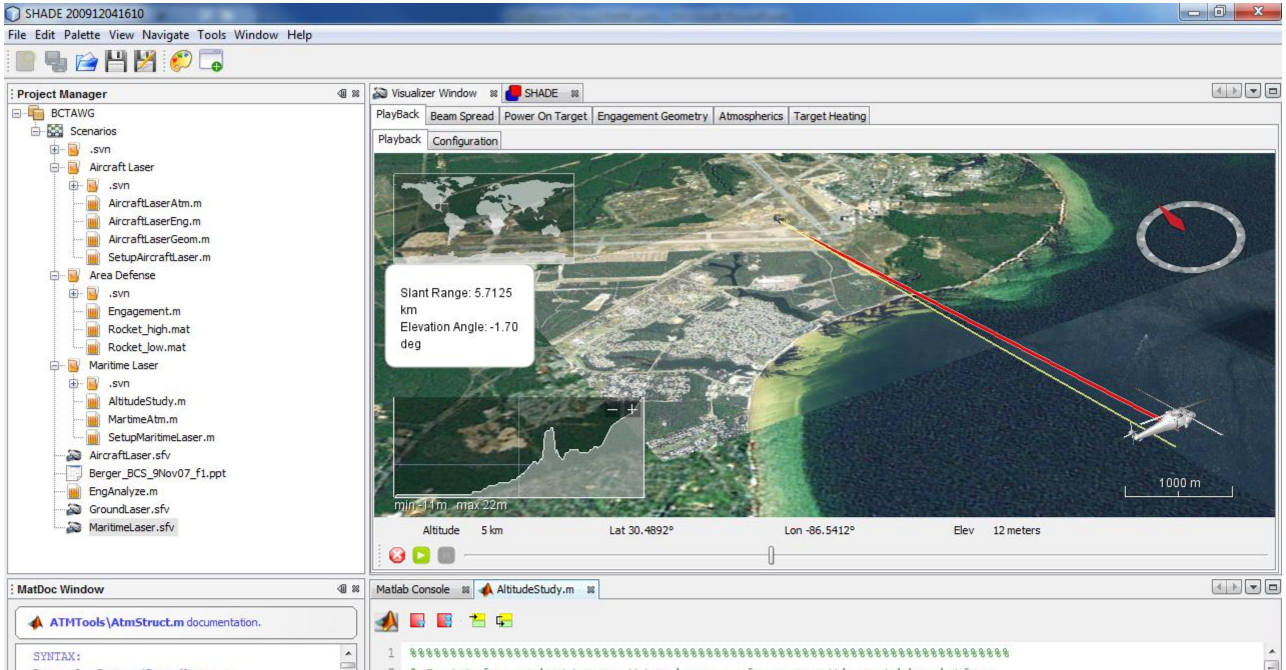
- **Original development sponsored by AFRL/DE Relay Mirror Program**
  - AFRL/RD approves distribution
  - MATLAB toolbox for Govt & Govt Contractors
- **Used to model strategic, tactical, ground-based, and maritime direct attack and relay HEL systems**
  - Based on work for MDA (BMDO), 2001
  - Built on ~10 years of scaling law modeling for ABL
  - Scaling law approaches augmented or innovated for relay uplink
- **Modularity supports the addition of new effects and anchoring of isolated and composite relations to both wave-optics and experimental results.**
- **Enables consideration of wide range of physical effects on laser performance**
  - Laser: power, wavelength, beam quality
  - Platform: transmitter, jitter, aero-optical
  - Atmosphere: extinction, turbulence, thermal blooming
  - Beam control: finite bandwidth, anisoplanatism, sensor SNR
  - Target: velocity, engagement geometry

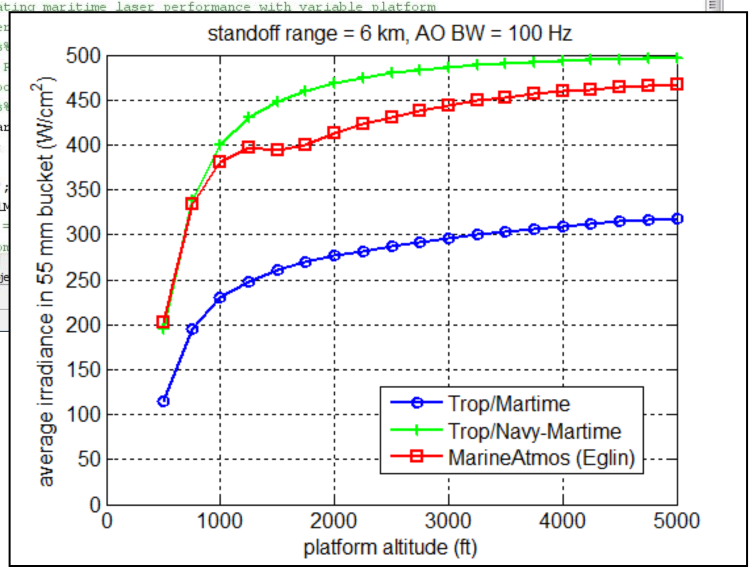
Scaling Law Analysis

- **Beam control metrics take into account the transmission losses, aimpoint error, and beam spread due to jitter and higher-order effects.**
- **The instantaneous power is projected onto the vulnerable region of the target.**
- **The power is then integrated in space and time to compute a fluence on target.**
- **Target vulnerability criteria are applied to determine whether and when sufficient fluence has been deposited on target.**



SHaRE *Development Environment*

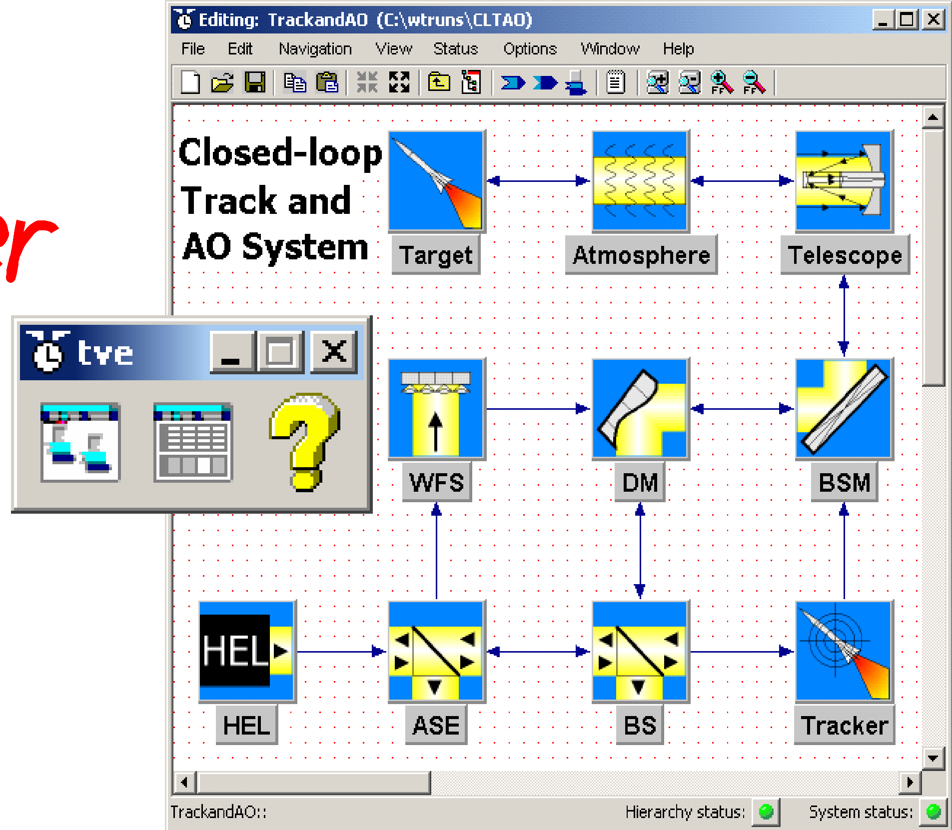




- ✓ **SHaRE** enables comprehensive system analysis for ground-based, aircraft, and maritime laser systems in direct engagement or with relay mirrors
- ✓ **SHADE** extends MATLAB capability with visualization and graphical interface

WaveTrain

wave optics made eas~~y~~ier

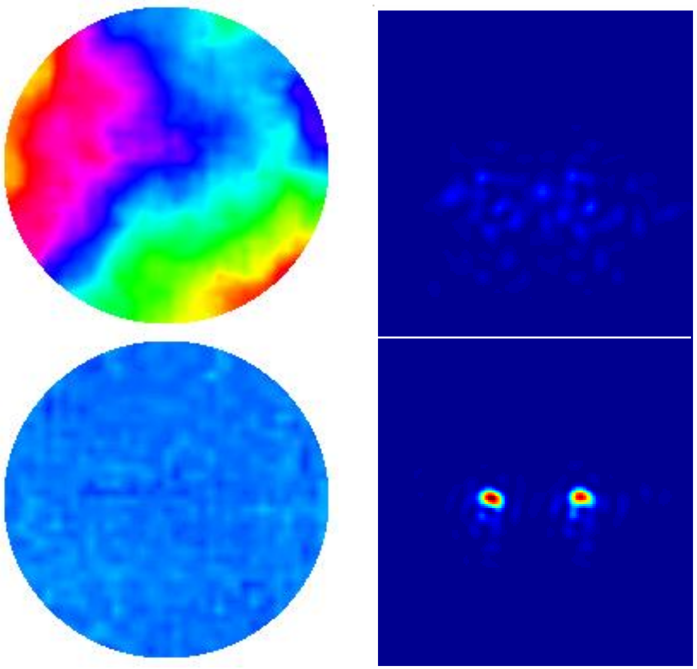


The Challenge of Wave Optics Simulation

Wave optics simulation is a crucial technology for the design and development for advanced optical systems. Until now it has been the sole province of a handful of specialists because the available codes were extraordinarily complicated, difficult to use, and they often required supercomputing resources.

Without Adaptive Optics

With Adaptive Optics



Phase **Image**

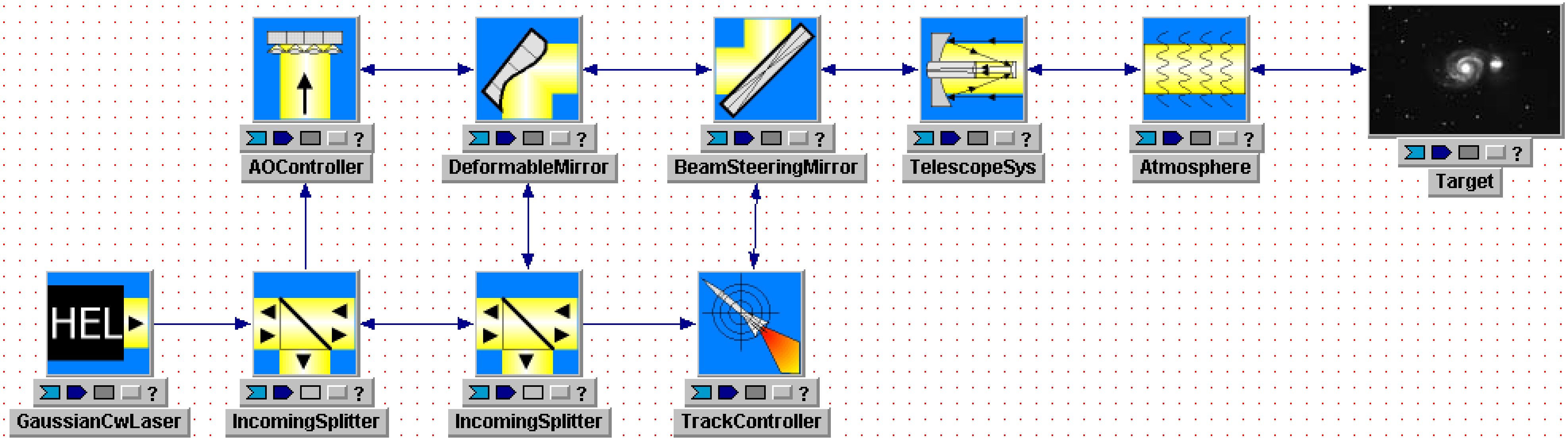
The Solution is WaveTrain

WaveTrain puts the power of wave optics simulation on your PC. Through an intuitive connect-the-blocks visual programming environment, you can assemble beam lines, control loops, and complete system models, including closed-loop adaptive optics (AO) systems.

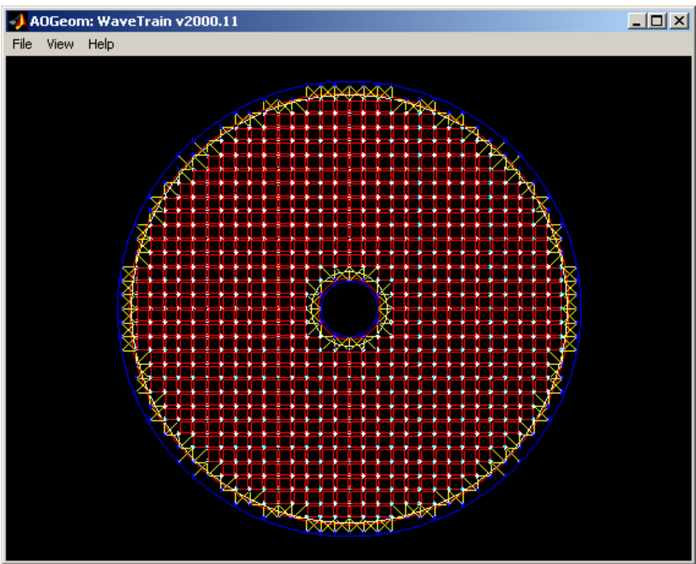
MZA Associates Corporation

For more information:
wavetrain@mza.com
www.mza.com
(505) 245-9970

A Basic WaveTrain Model



Starfire Optical Range 3.5 meter Telescope Model (Version 1.0)



Starfire Optical Range (SOR) imaging and adaptive optics model.

Dynamic Runs

Track and Science

Major Parameters:

Runsets:
SOR3501Runbs1

1 x Clear-1 atmosphere.

Wind was 5 m/s at low altitudes and 15 m/s at high altitudes.

10 phase screens.

256x256 propagations with 0.04 cm spacing.

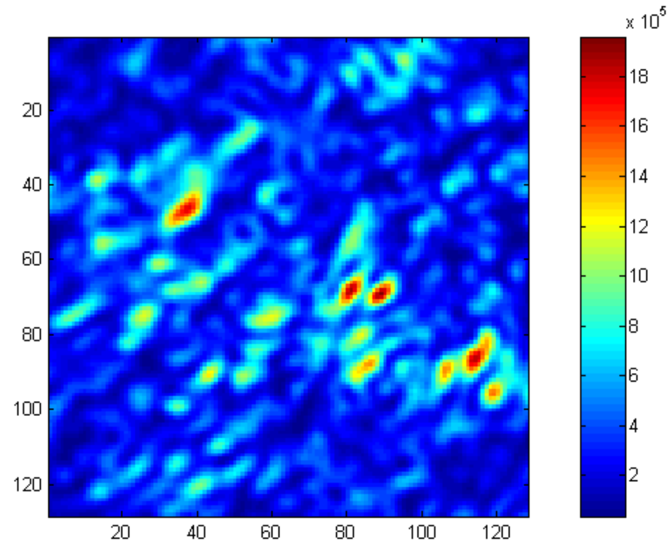
Point source beacon

Dual point sources separated at 0.3 arcsec. as celestial objects.

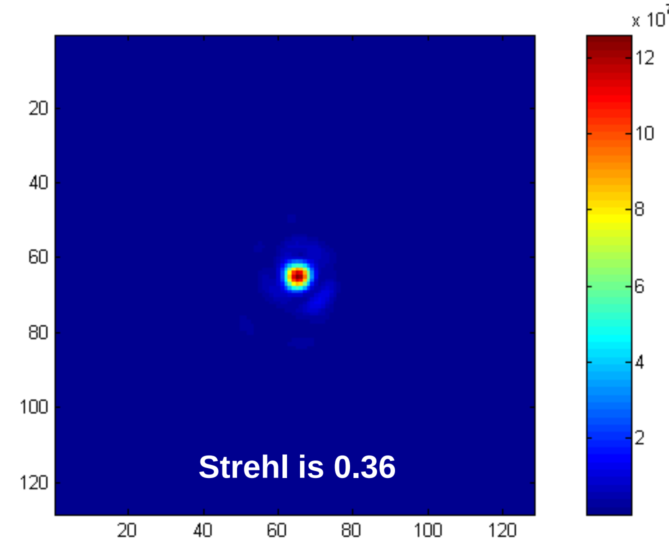
Resolved wavefront sensor (instead of 2x2 quad cell)

Est. AO closed-loop system bandwidth is about 50 Hz at -3dB

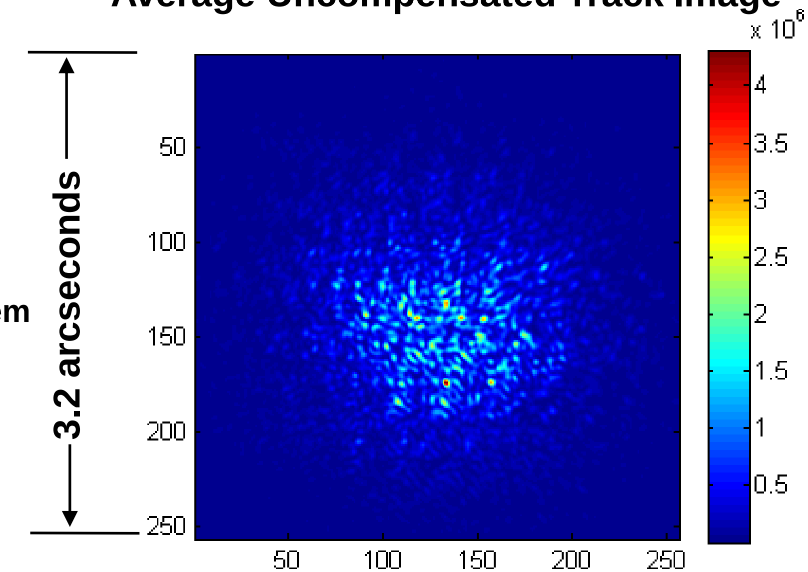
Est. Track closed-loop system bandwidth is about 240 Hz at -3dB.



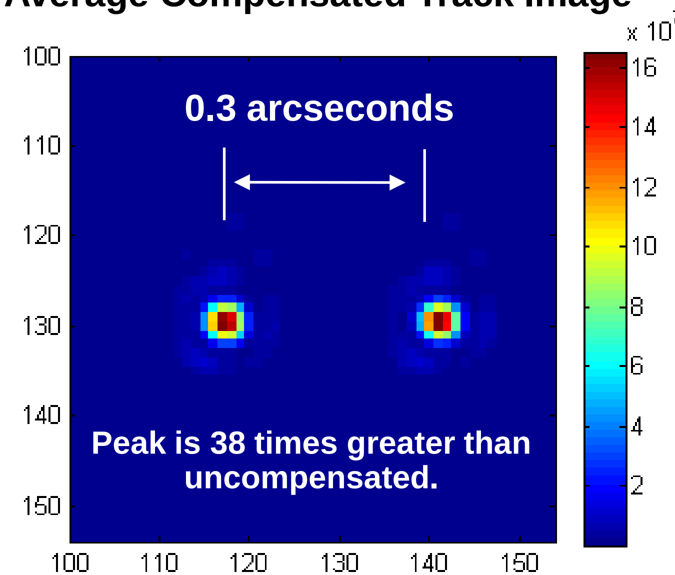
Average Uncompensated Track Image



Average Compensated Track Image



Average Uncompensated Science Image



Average Compensated Science Image (zoomed)

Wavefront Compensation

Static Run – Field and DM

Major Parameters:

Runset:
SOR3501Runa1w0

1 x Clear-1 atmosphere with no wind.

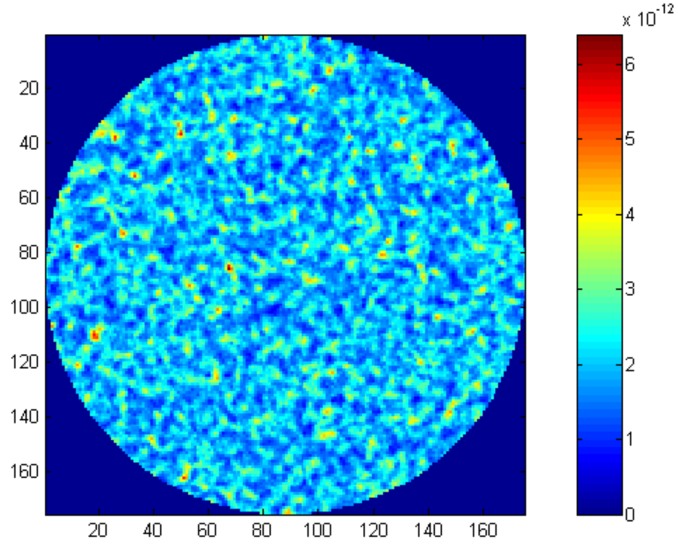
10 phase screens.

512x512 propagations with 0.02 cm spacing.

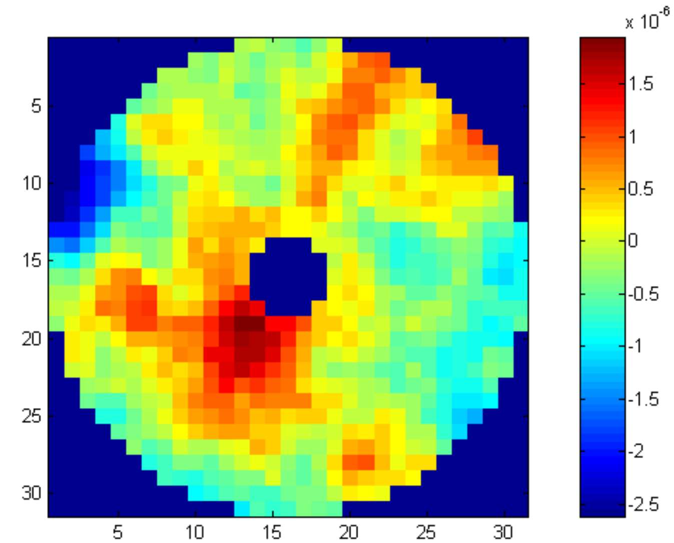
Point source beacon

Dual point sources separated at 0.3 arcsec. as celestial objects.

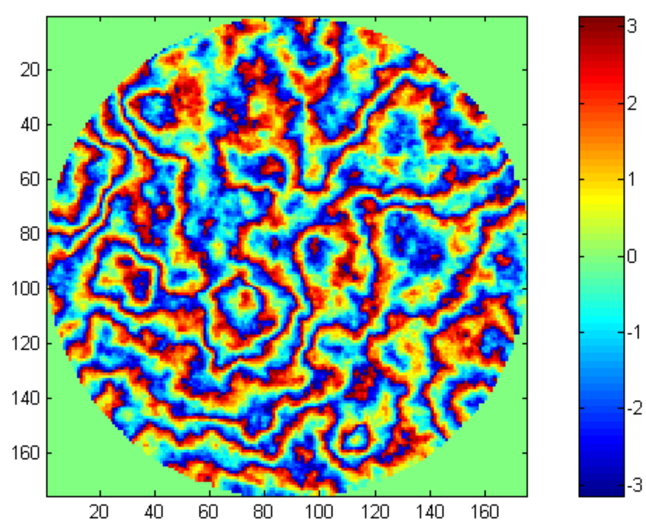
Resolved wavefront sensor (instead of 2x2 quad cell)



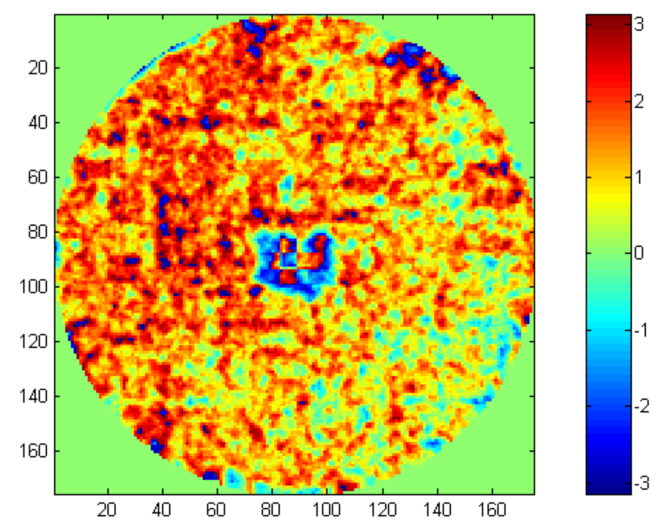
Pupil Irradiance



Final DM Actuator Positions



Initial Uncompensated Pupil Phase



Final Compensated Pupil Phase

Wavefront Sensor Model

Static Run – WFS

Major Parameters:

Runset:
SOR3501Runa1w0

1 x Clear-1 atmosphere with no wind.

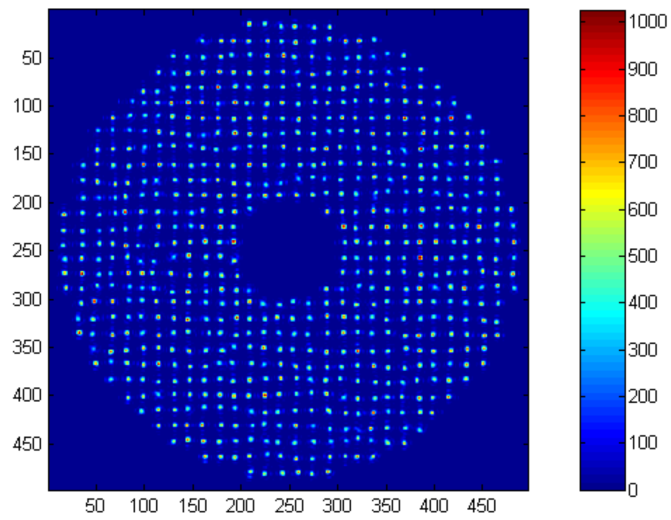
10 phase screens.

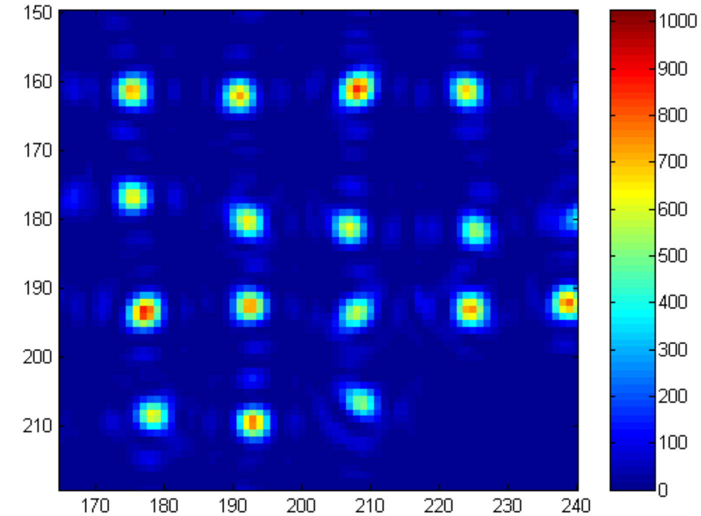
512x512 propagations with 0.02 cm spacing.

Point source beacon

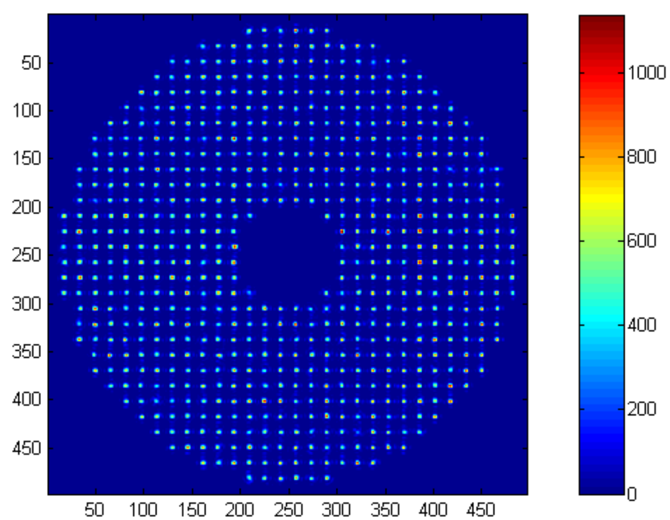
Dual point sources separated at 0.3 arcsec. as celestial objects.

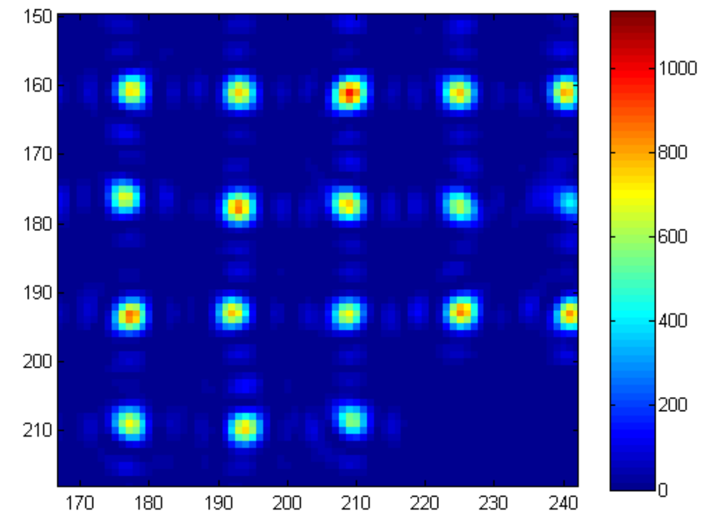
Resolved wavefront sensor (instead of 2x2 quad cell)





Initial Uncompensated WFS Subaperture Spots **Zoomed**





Final Compensated WFS Subaperture Spots

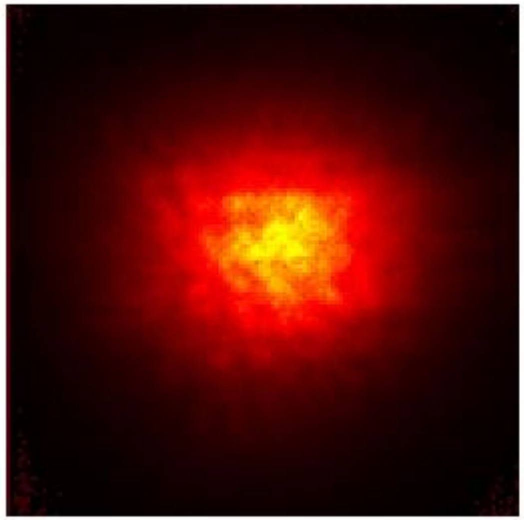
Comparison with Published SOR Results

First light for the adaptive optics system on the 3.5-m telescope at the Starfire Optical Range occurred in September, 1997. This astronomical I Band compensated image of the binary star k-Peg was generated using the 756 active actuator adaptive optics system.

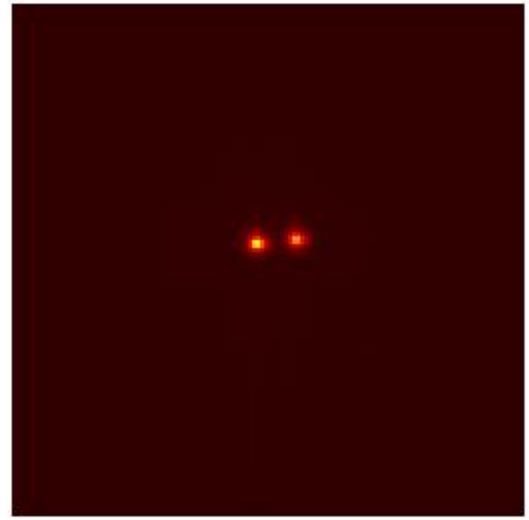
Actual Data

From the SOR website.

Atmospheric conditions, camera characteristics, and control loop parameters are not available.



Uncompensated Image



Compensated Image. 0.3 arcsec separation

Simulated Data

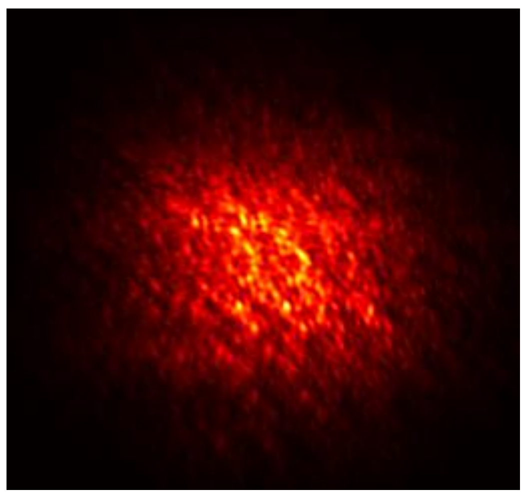
Runsets:
SOR3501Runa1w20 &
SOR3501Runa1w20ol

1 x Clear-1 atmosphere.

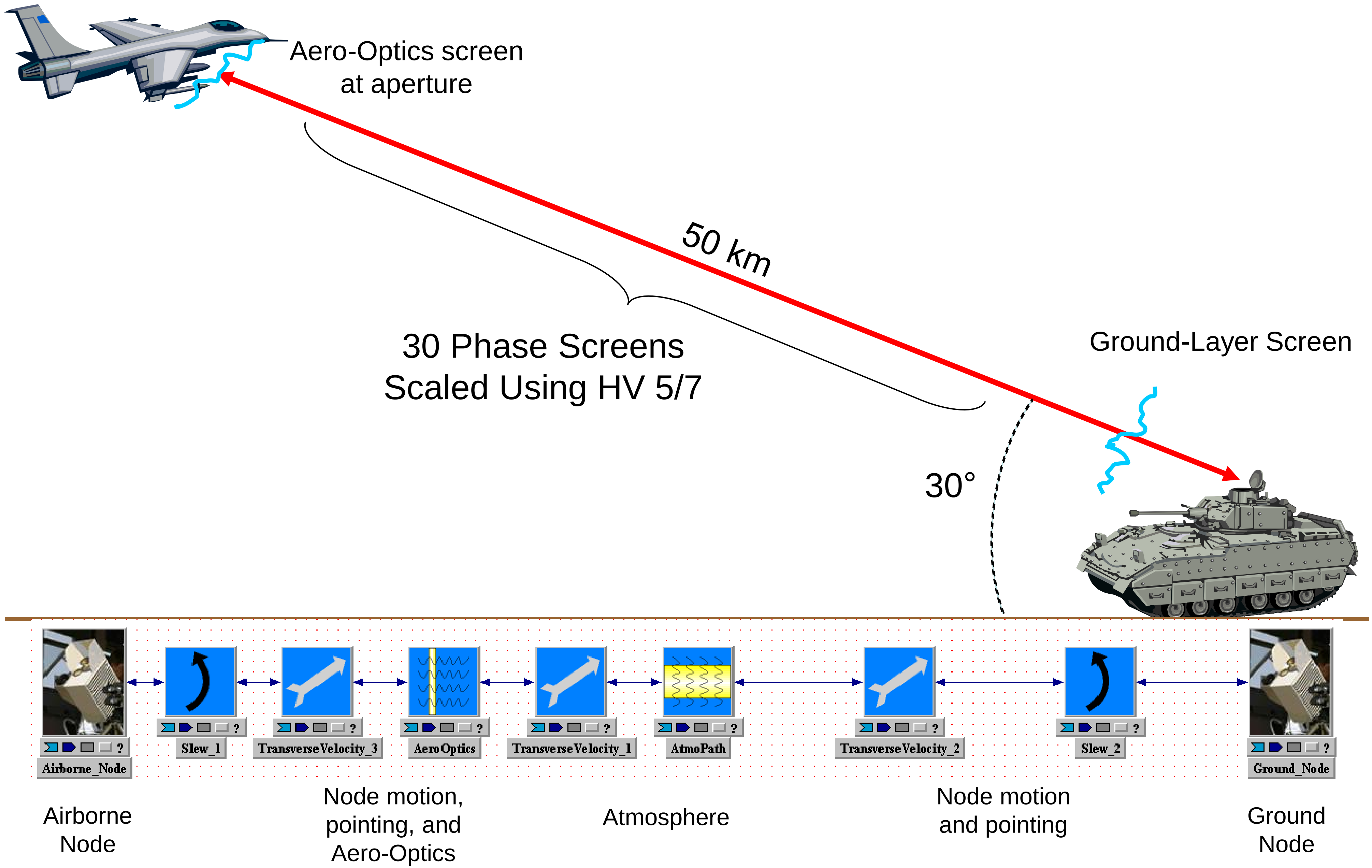
Wind was 20 m/s at all altitudes.

10 phase screens.

512x512 grid with 0.02 cm spacing.



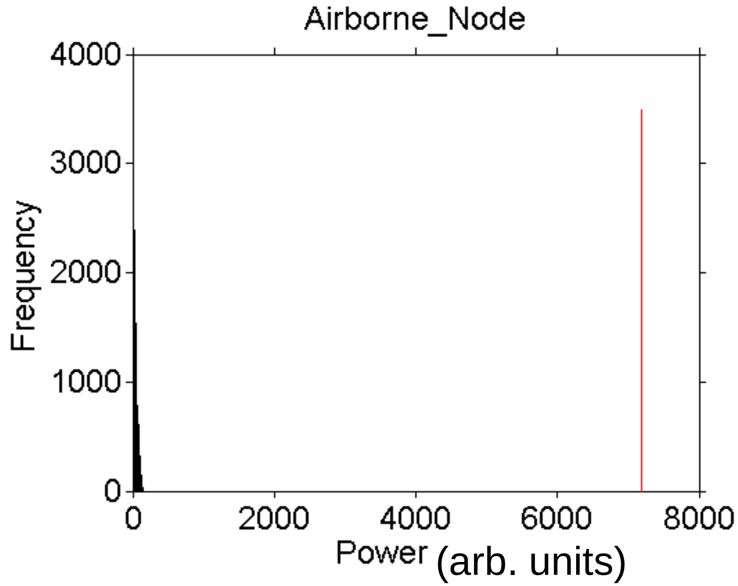
Air-to-Ground Laser Comm System

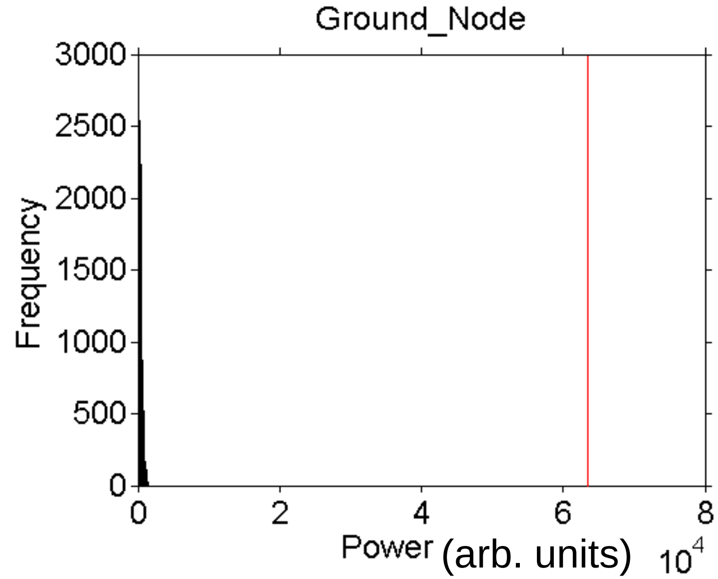


Laser Comm Terminal

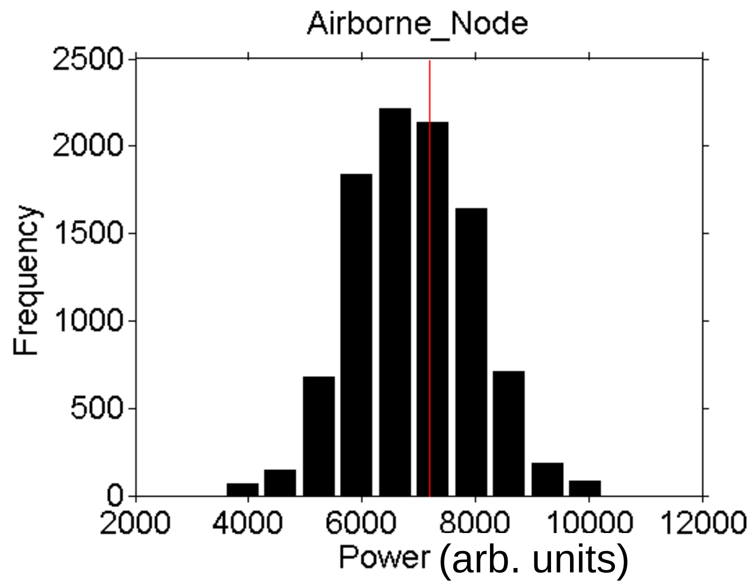
Adaptive Optics Increases Power Transmission from Transmitter to Receiver

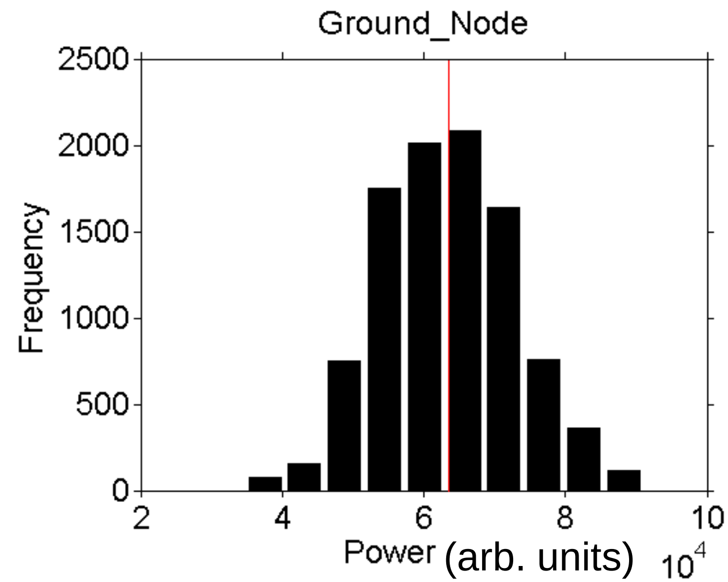
Transmission to Receiver without AO





Transmission to Receiver with AO



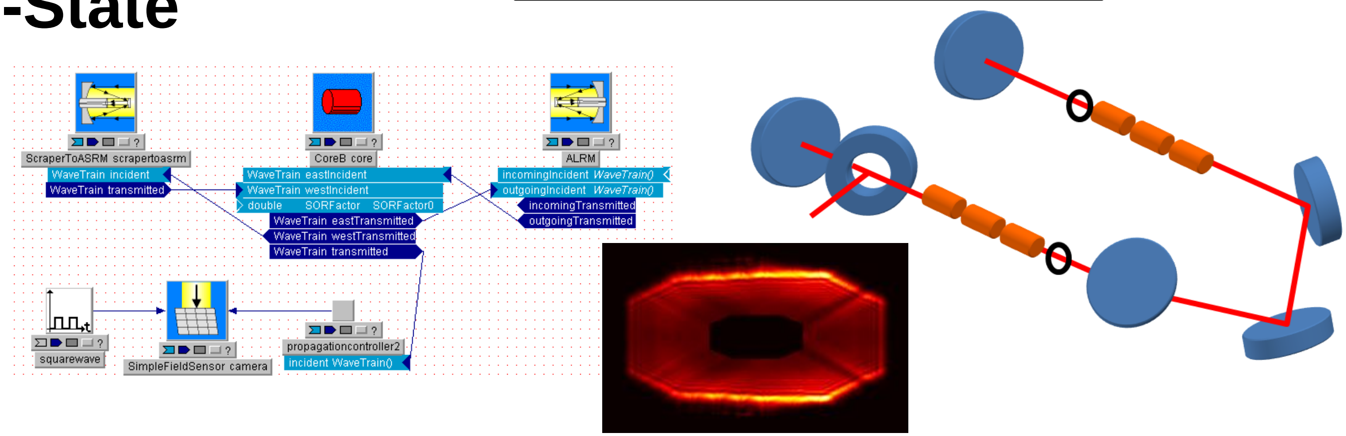


RED LINE = Diffraction-Limited

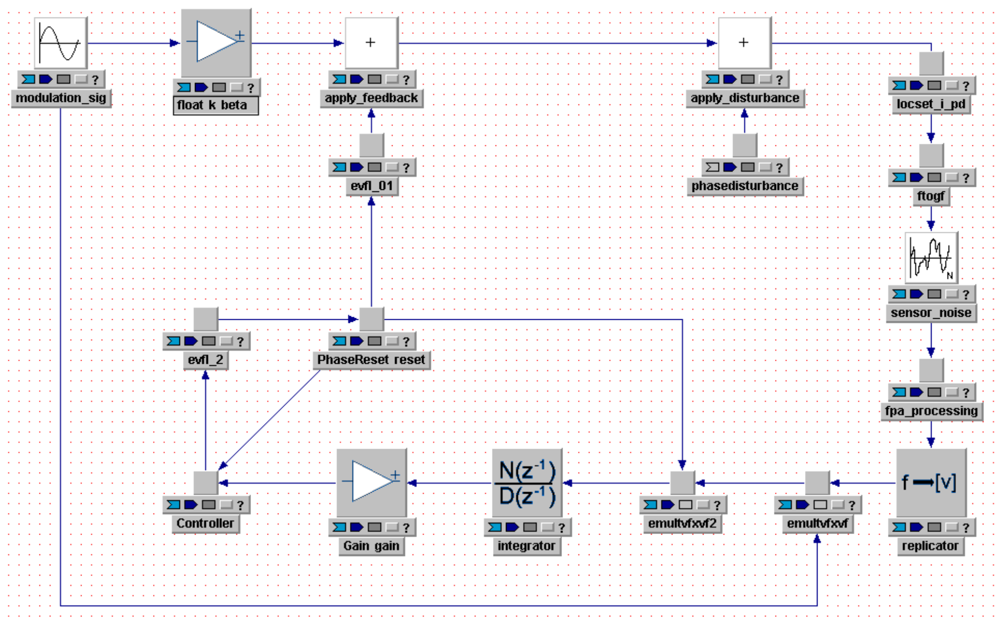
Laser Modeling with WaveTrain

- **High Power Solid-State Laser Modeling**
  - Slab lasers
  - Fiber lasers
- **COIL Modeling**
- **Diode Pumped Alkali Laser (DPAL) Modeling**

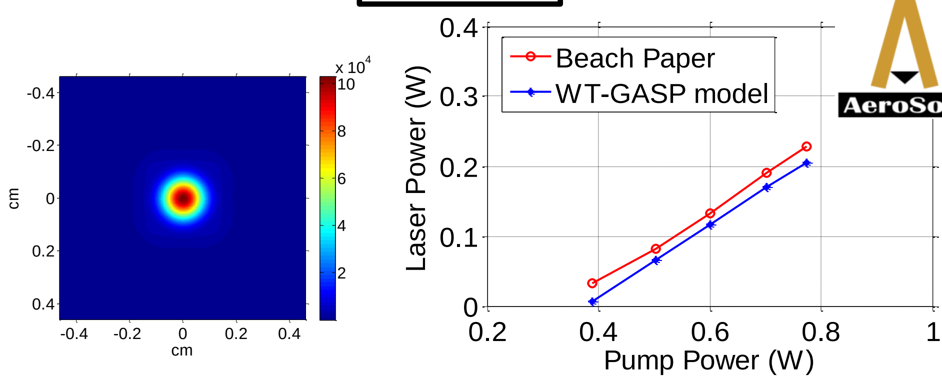
COIL RESONATOR MODELING



LOCSET FIBER PHASING

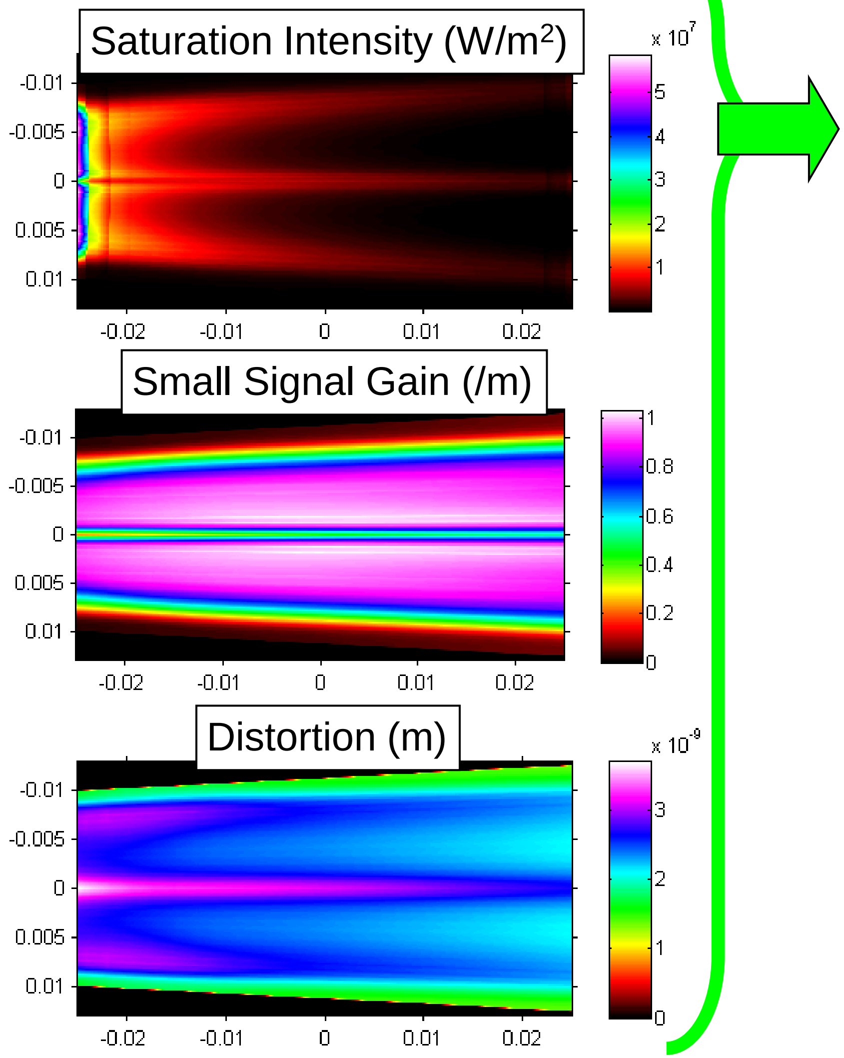


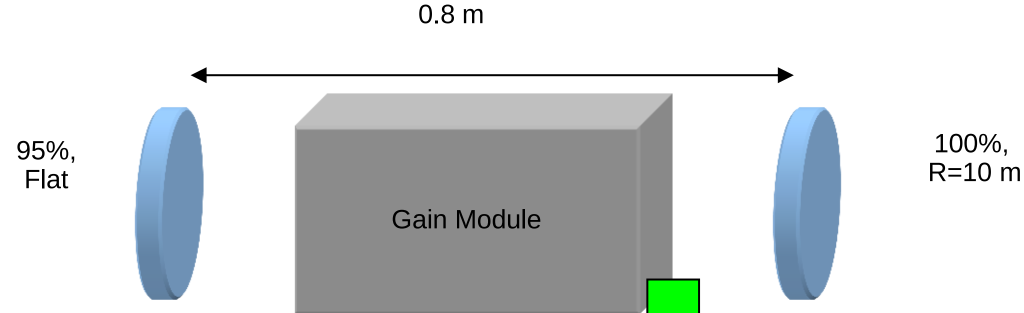
DPAL

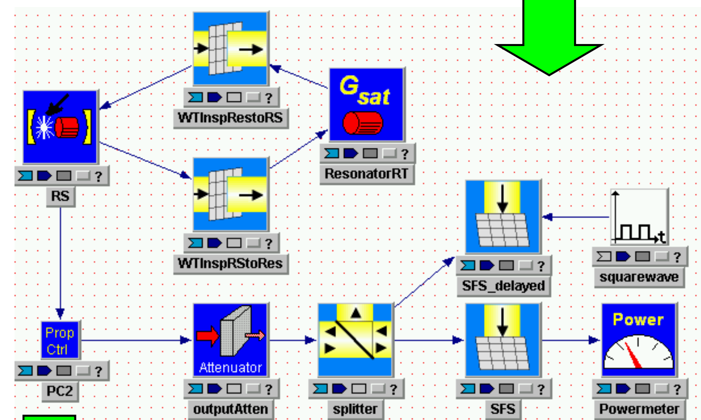


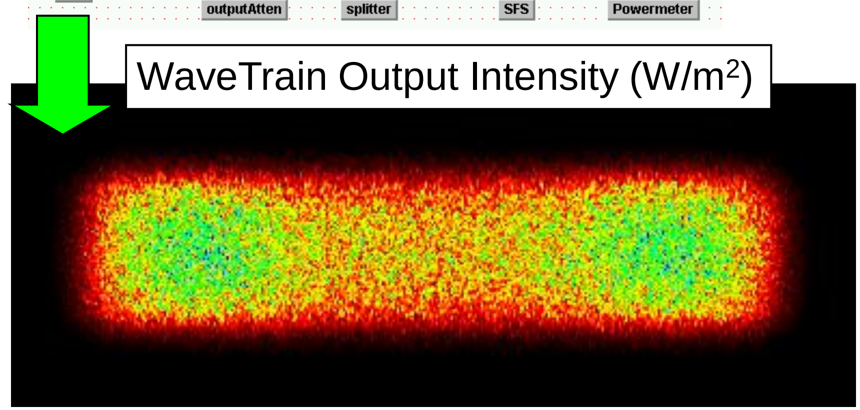
RADICL Stable Resonator Modeling with GASP CFD

GASP Inputs





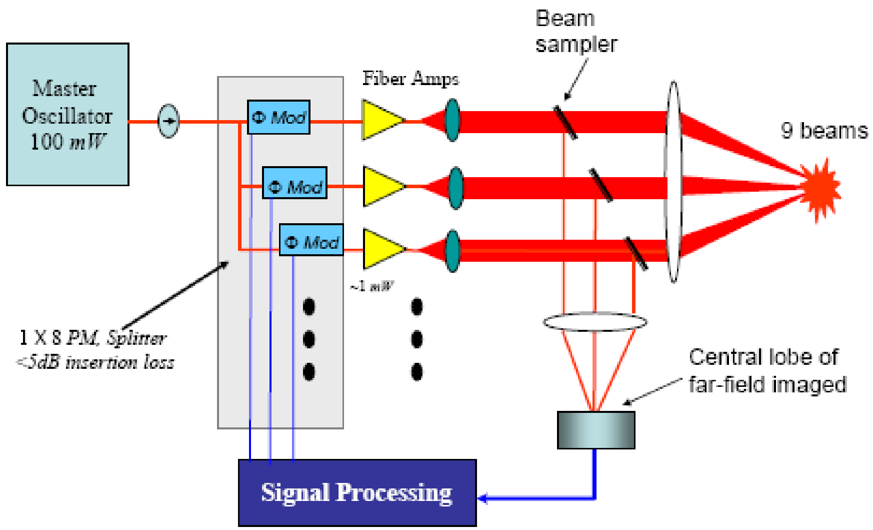




LOCSET Fiber Phasing Concept

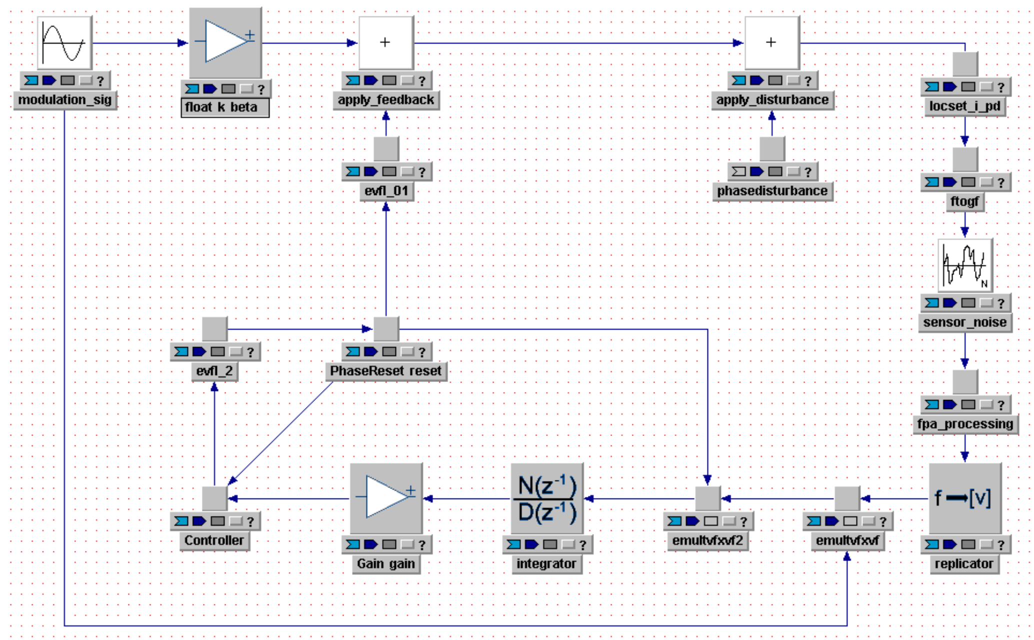
First Experimental Demonstration of Self-Synchronous Locking of Optical Coherence by Single-detector Electronic-frequency Tagging of Fiber Amplifiers

T. M. Shay[a], Vincent Benham[b], J. T. Baker[c], Capt. Benjamin Ward[a], Anthony D. Sanchez[a], Mark A. Culpepper[a], Sgt. D. Pilkington[a], Lt. Justin Spring[a], Lt. Douglas J. Nelson[a], and Lt. Chunte A. Lu[a]



Fiber Phasing Schematic

WaveTrain Model



Overview
of
Adaptive Optics and Wavefront Compensation
for
High Energy Laser Weapons Systems
(HELWS)
and
Optical Surveillance Systems

Adaptive Optics Systems Make HELWS More Lethal and Cost Effective

- **High Energy Laser Weapons Systems must…**
  - employ a Laser Source of sufficient power to be lethal, and
  - be projected from a Beam Director of sufficient diameter.
- **The Laser Source and the Beam Director make up nearly all of the Size, Weight, and Power required by a HELWS**
  - The logistical footprint of a HELWS can become significant.
- **The addition of Adaptive Optics to a HELWS allows…**
  - A lower power Laser Source to achieve the same lethality as that of a system with a lower laser power source.
  - A smaller Beam Director to achieve the same lethality and better surveillance capabilities as that of a system with a larger Beam Director.
- **The most cost effective High Energy Laser Weapons Systems will employ Adaptive Optics.**

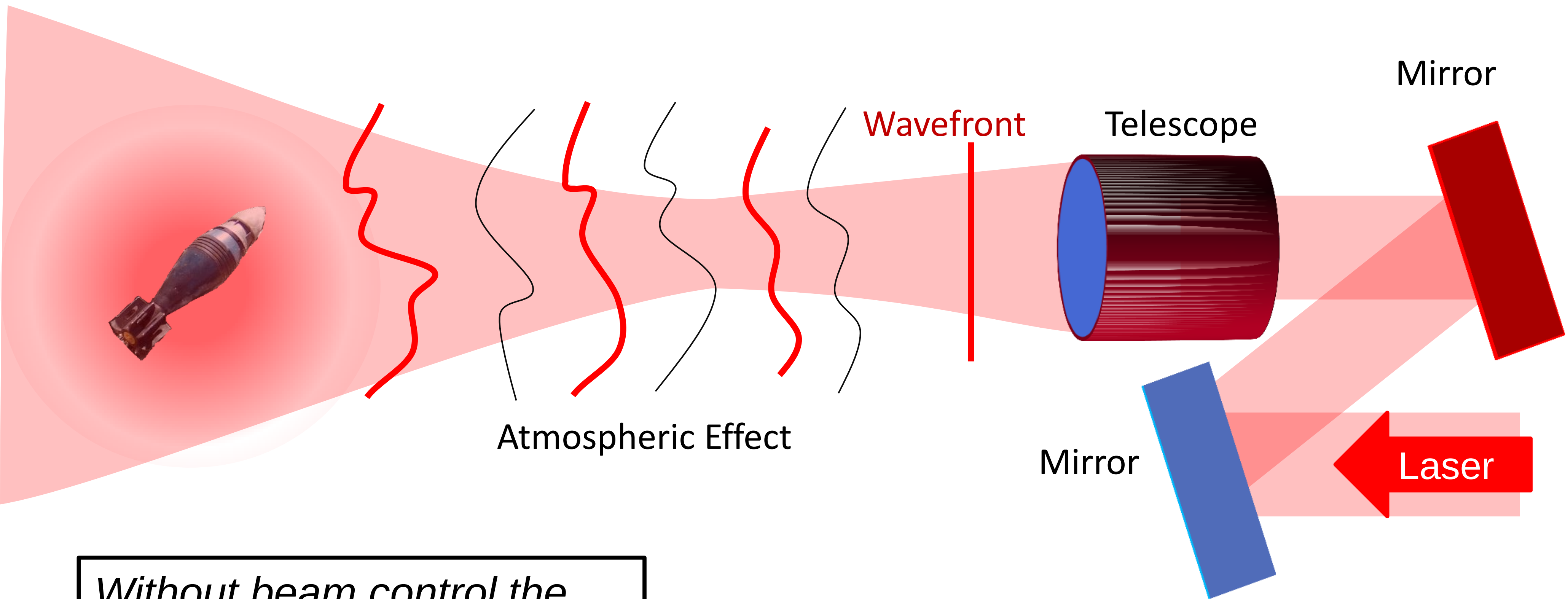
What Does Adaptive Optics do for High Energy Laser Weapons Systems?

- **Extend the range**
  - Adaptive Optics Wavefront Compensation delivers more power to a target vulnerable region at longer ranges.
- **Reduce the time-to-kill**
  - More power on the target vulnerable region means that it takes less time to kill the target
  - This allows greater margin in the system and possibly increases the number of defeated targets in a salvo.
- **Reduce the total number of systems in an area defense**
  - Increased range and decreased time means that fewer total weapons system might be used to defend the same area.
- **Increase system robustness**
  - The presence of an adaptive optics system potentially increases the range of environmental conditions under which the system can be effective.
- **Improve surveillance range and quality**
  - Adaptive optics improves image quality when the system is used for surveillance purposes.

Adaptive Optics Systems Increase the Resolution and Quality of ISR Systems

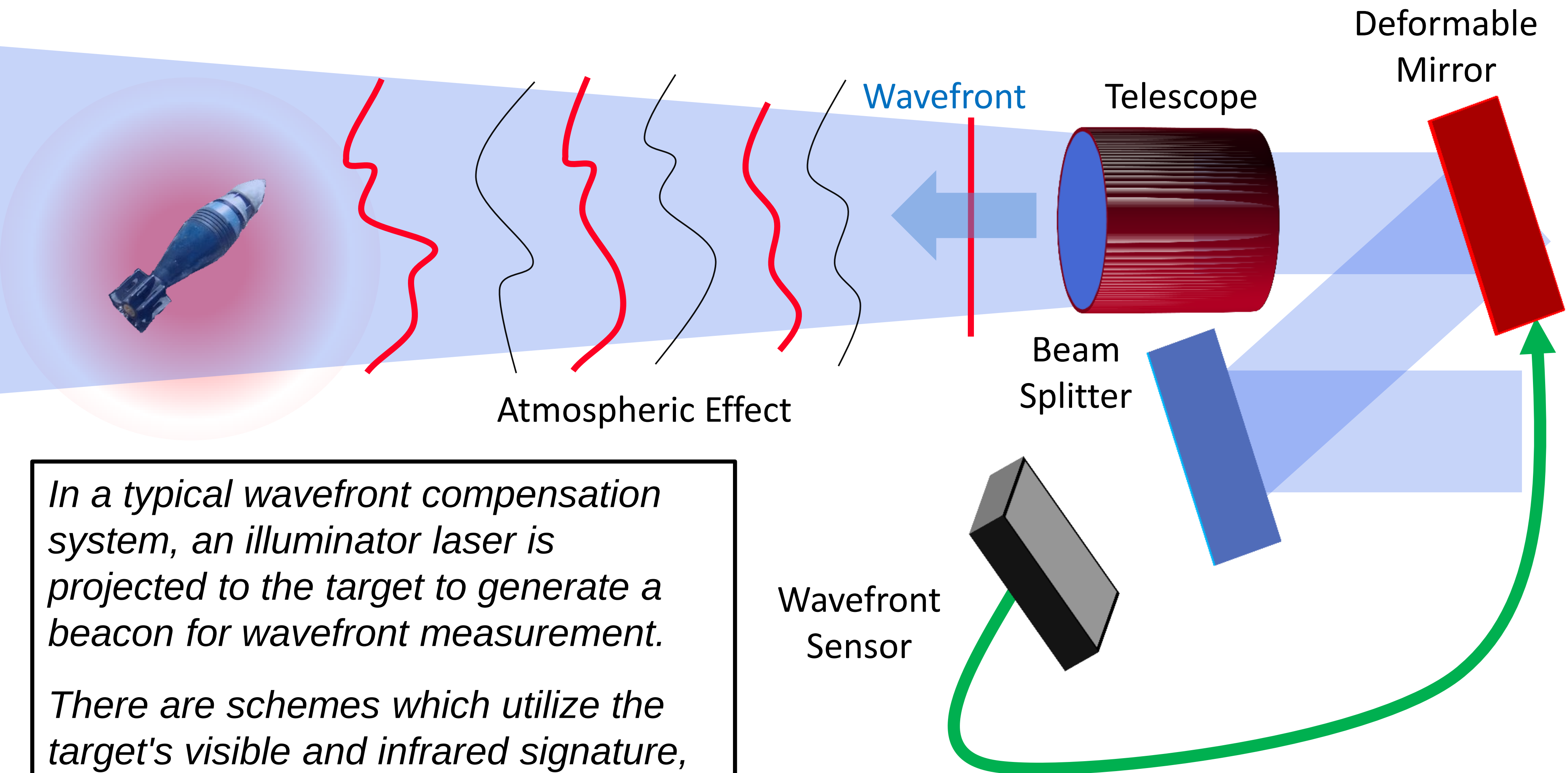
- **Optical surveillance systems must…**
  - contend with intervening atmospheric distortions,
  - and operate under a range of vibration and thermal conditions.
- **The typical approach to improving such systems is to…**
  - increase the aperture diameter,
  - constrain the operational environment, and
  - employ more expensive sensors.
- **These approaches all increase the cost, complexity, and logistical footprint.**
- **The addition of Adaptive Optics to such systems allows…**
  - the same aperture diameter to achieve greater effective resolution, and
  - increase the signal-to-noise ratio on the optical sensors.
- **The most capable future ISR systems will employ Adaptive Optics.**

The Need for Wavefront Compensation



Without beam control the weapons beam spreads and less power reaches the target vulnerable region.

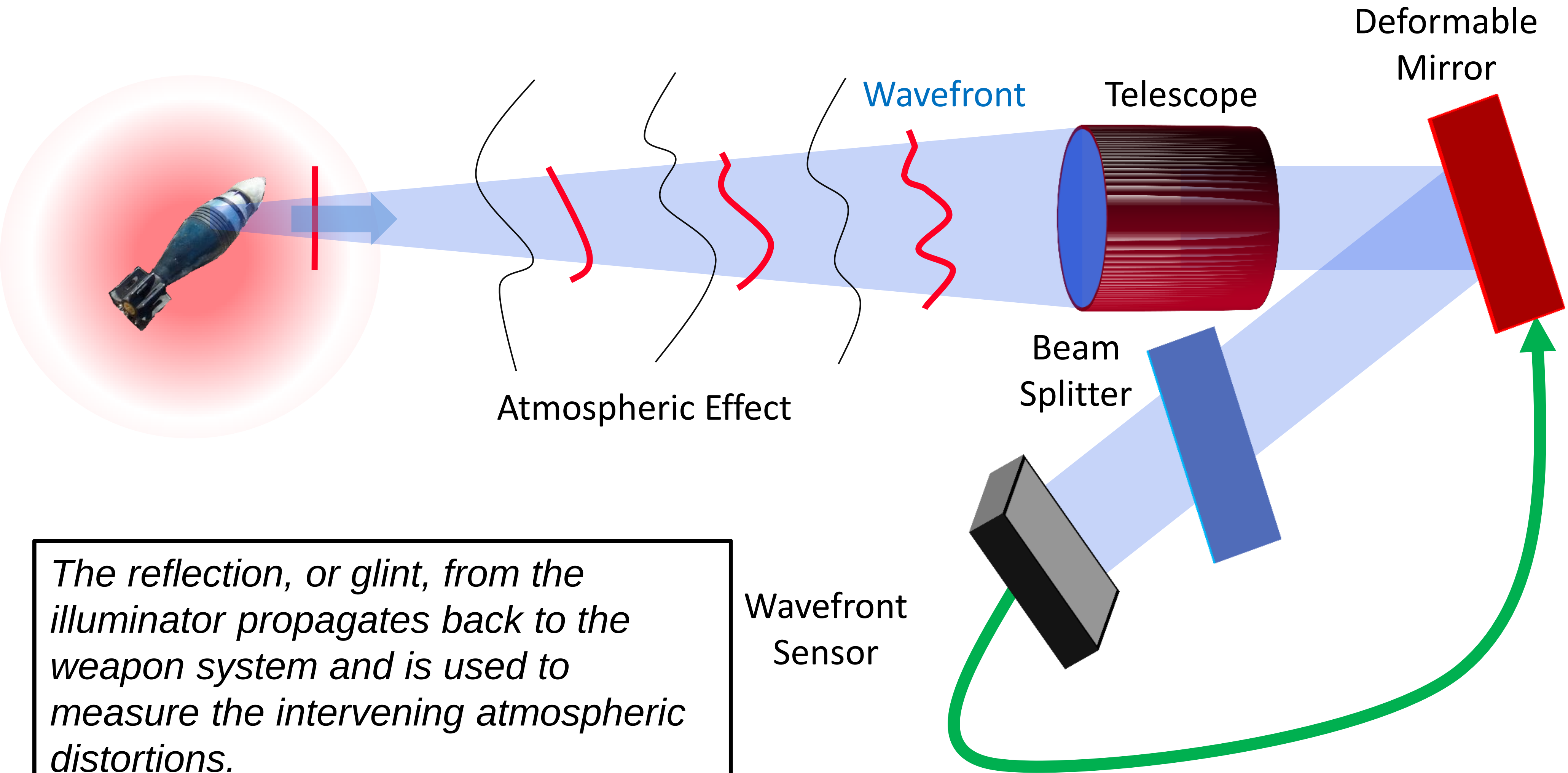
Target Illumination



In a typical wavefront compensation system, an illuminator laser is projected to the target to generate a beacon for wavefront measurement.

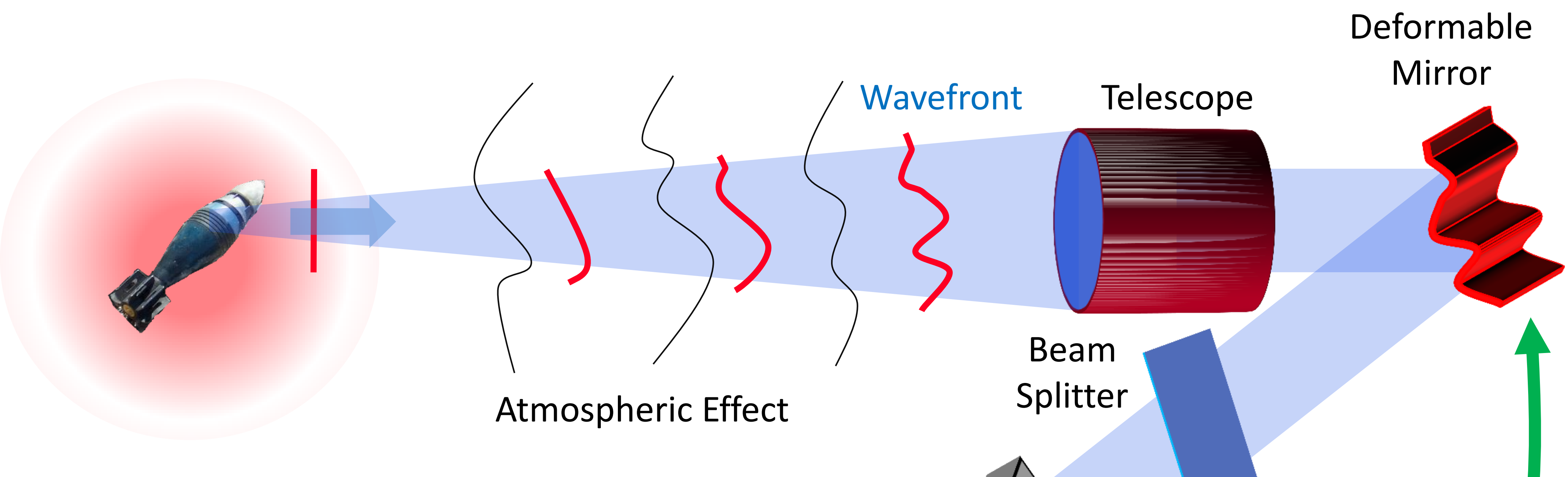
There are schemes which utilize the target's visible and infrared signature, rather than an active illuminator, to obtain this measurement.

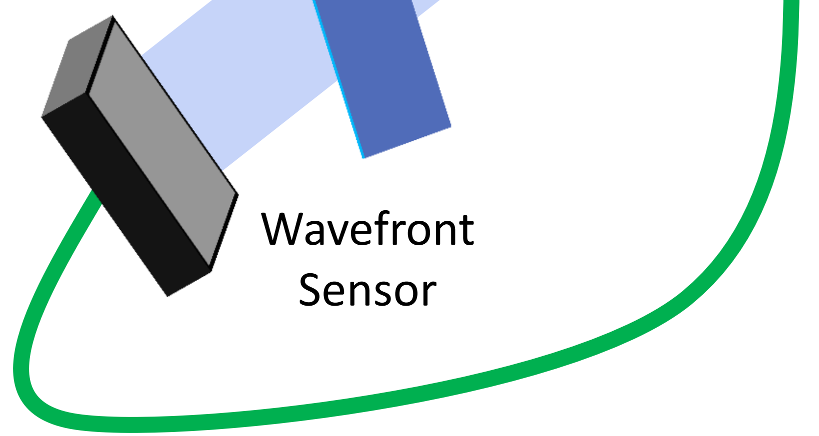
Wavefront Measurement



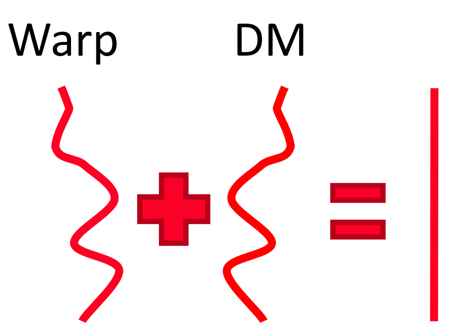
The reflection, or glint, from the illuminator propagates back to the weapon system and is used to measure the intervening atmospheric distortions.

Deformable Mirror Shaping

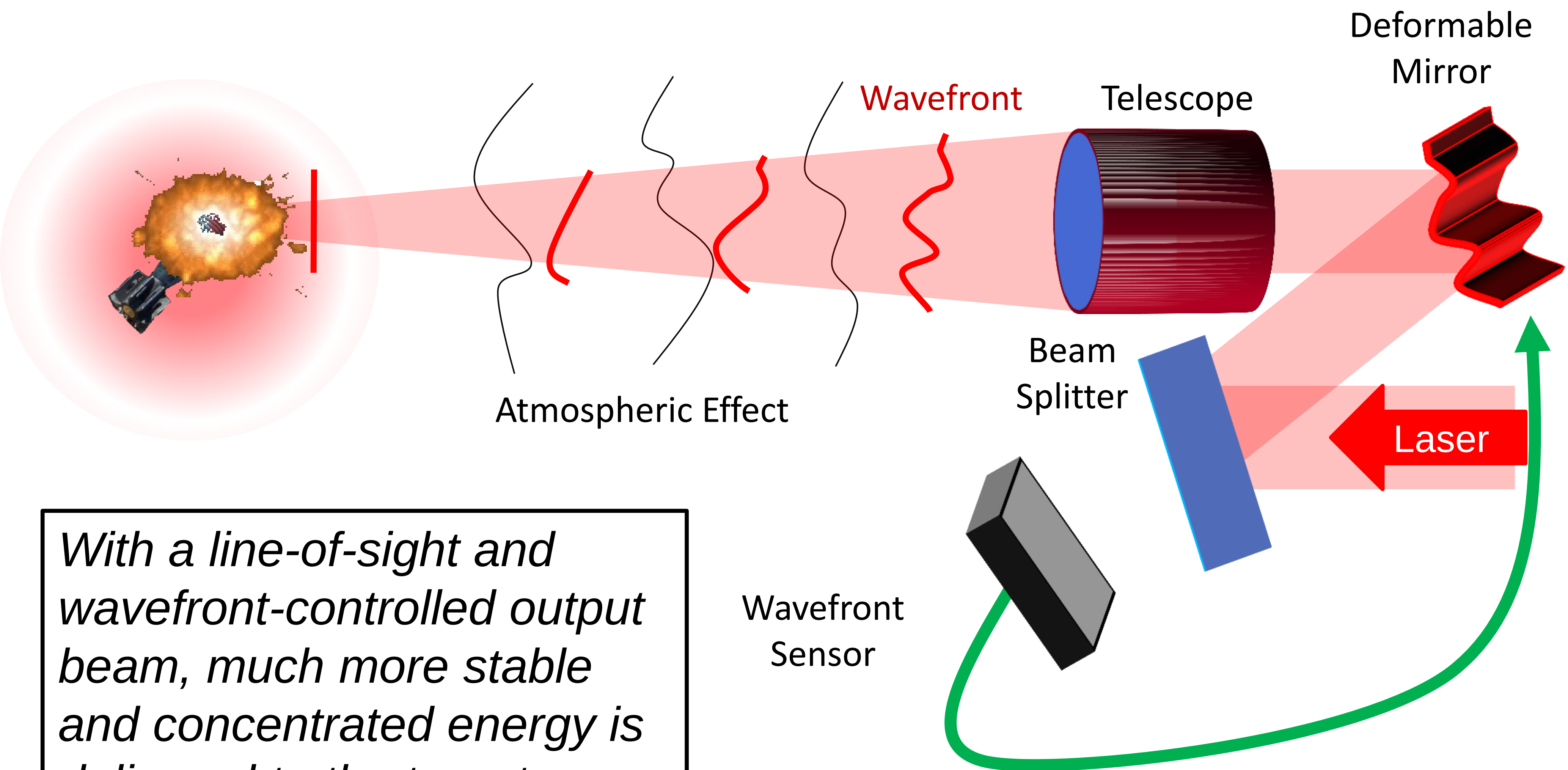




At very high speed, the wavefront controller commands a deformable mirror to warp the wave-front in the opposite shape as the measured warp.

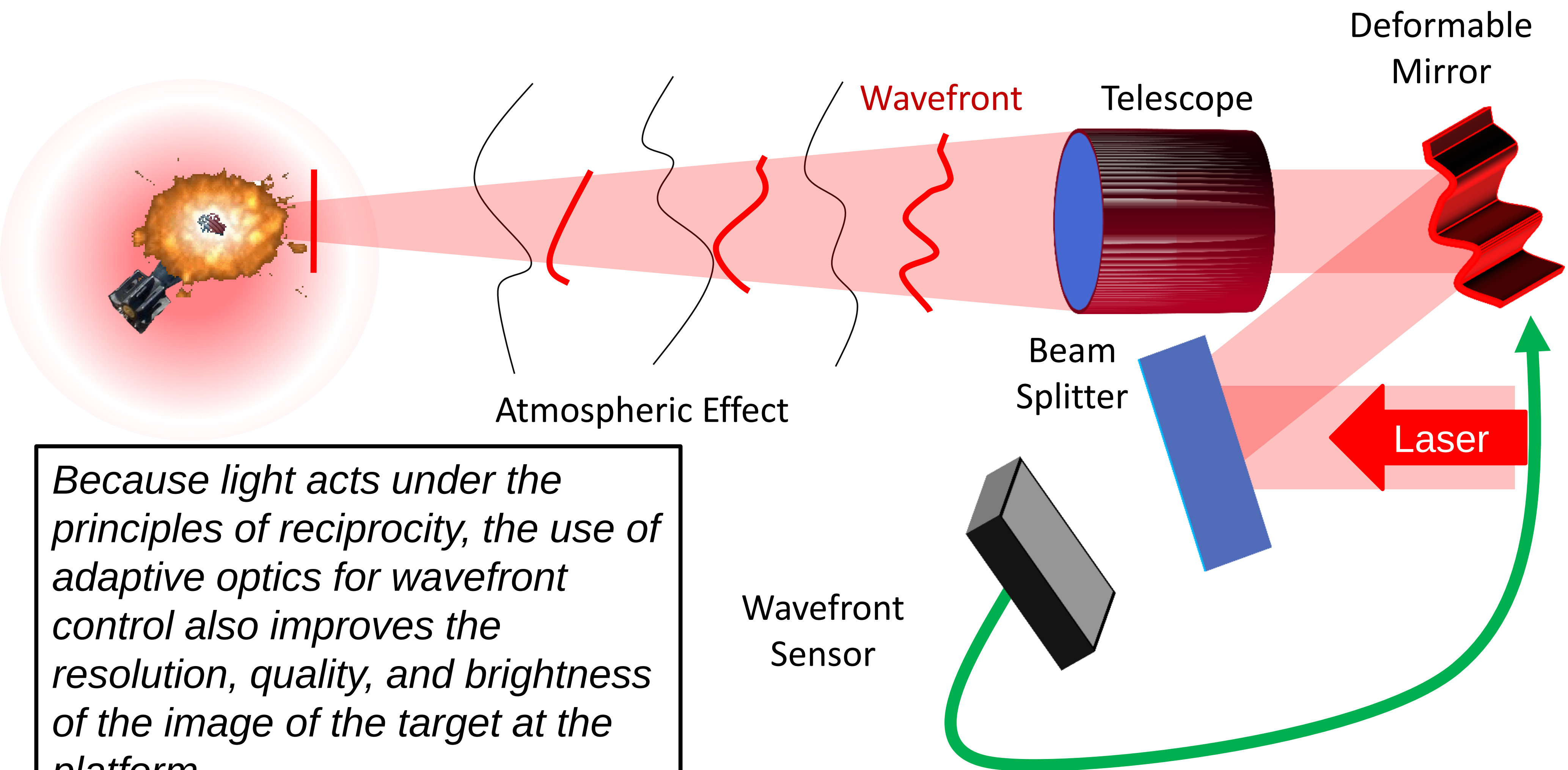


High Energy Laser Illumination



With a line-of-sight and wavefront-controlled output beam, much more stable and concentrated energy is delivered to the target.

Surveillance and Imaging



Because light acts under the principles of reciprocity, the use of adaptive optics for wavefront control also improves the resolution, quality, and brightness of the image of the target at the platform.

MZA Associates Corporation

An Employee-Owned Company

Laser Weapon & Sensing Modeling and Simulation

Laser System Testing and Integration

Adaptive-Optics Beam Control Hardware

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