Wavefront Correction Technologies

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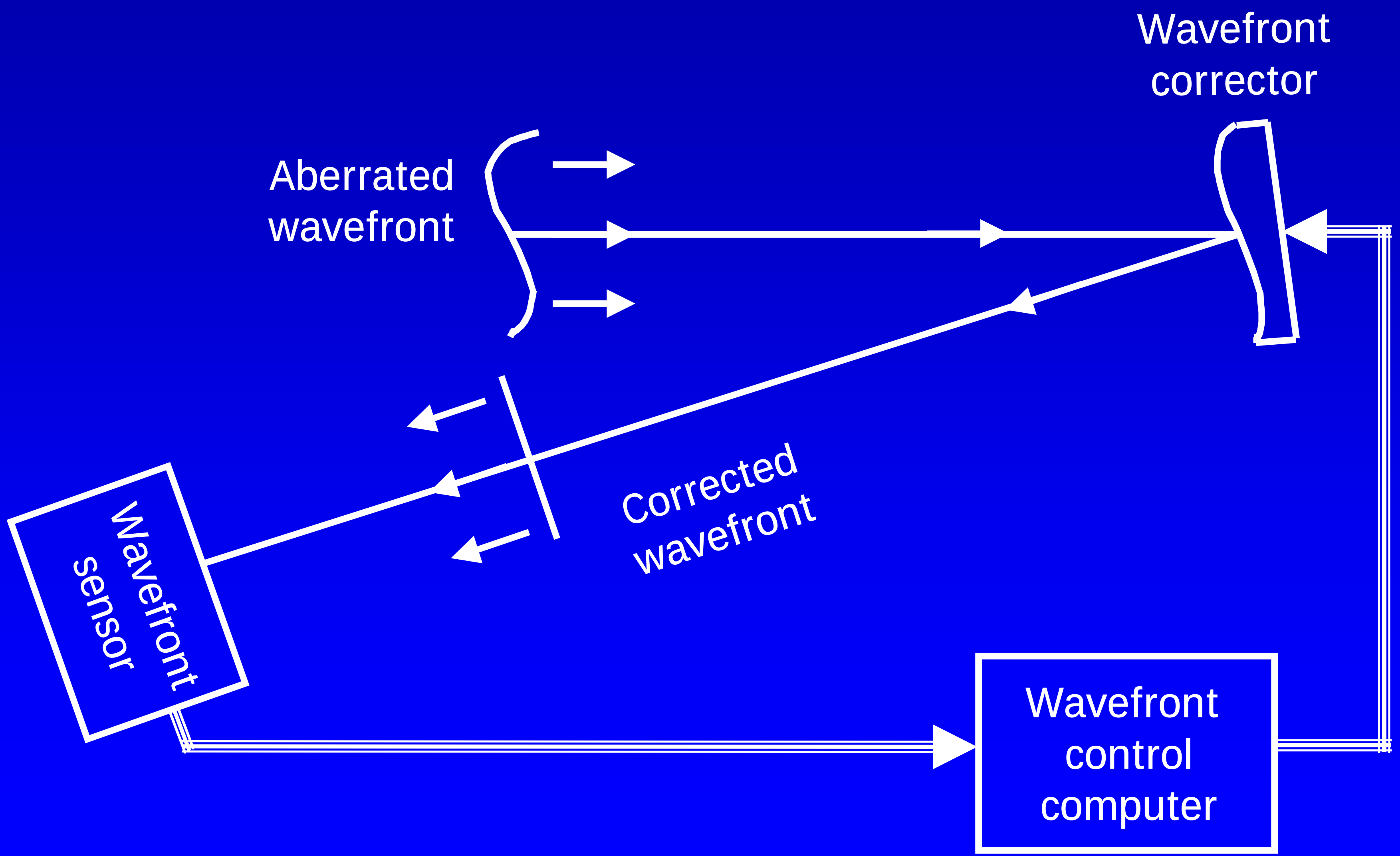
Adaptive optics control wavefront phase to compensate for optical aberrations



Outline of Presentation

- Conventional wavefront correction technologies
- Limitations of conventional adaptive optics
- Spatial light modulator technology
    - Liquid crystals
    - Micro-electro-mechanical systems (MEMS)

Deformable Mirror Technology

Xinetics Deformable Mirrors

LLNL Deformable Mirror

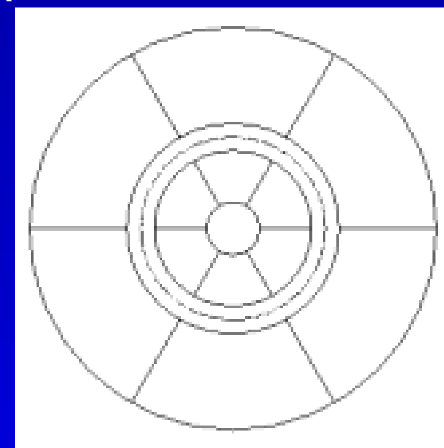
U. Chicago Deformable Mirror

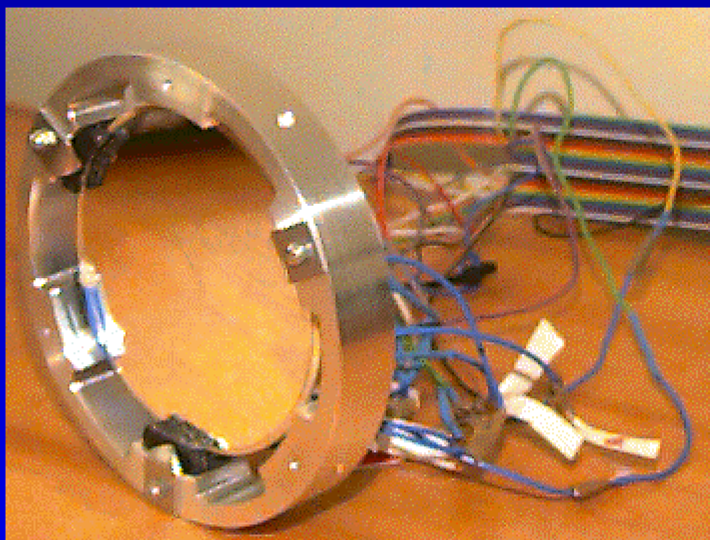
New photonics modules under development at Xinetics

Bimorph deformable mirrors developed by CILAS, et al.

Bimorph Deformable Mirror Technology

Bimorph mirror electrode sketch





AAT bimorph mirror

Bimorph deformable mirrors developed by CILAS, et al.

CFHT AO Bonnette

Deformable Mirror

Rear View

349 Actuators
on 7 mm spacing

Front View

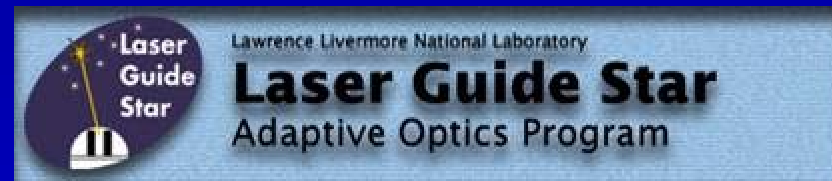
146 mm diameter
clear aperture

Large Deformable Mirror Technology

University of Arizona Deformable Secondary Reference Body

LLNL National Ignition Facility Deformable Mirror

Adaptive optics are a key enabling technology for LLNL projects in laser beam control and imaging

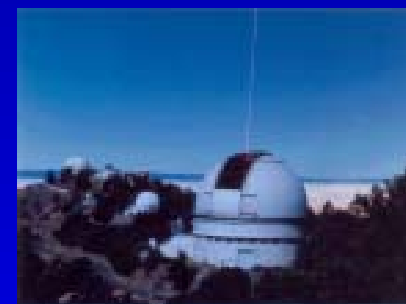


Wavefront control capabilities are crucial for many LLNL projects involving high power lasers

Army SSHC 10KW laser

- NIF requires AO on all 192 beams
- SSHC laser requires intra-cavity AO

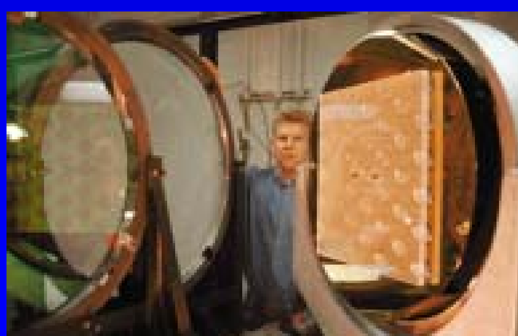
LLNL-built sodium-layer laser guide star AO system at Lick Observatory is world's first



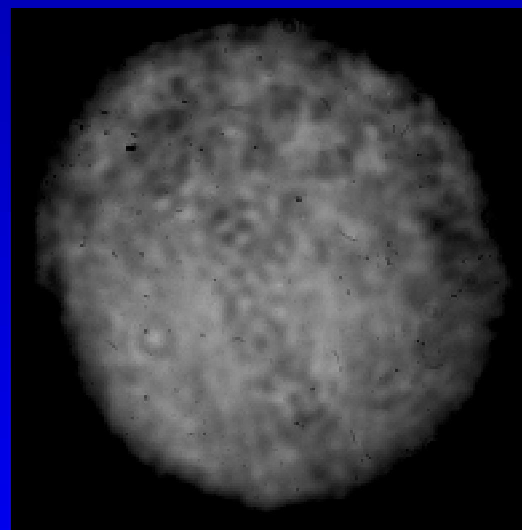
LLNL-built AO system at Keck Observatory is world's most powerful

A major science thrust with NIF is connected to the future development of a short-pulse capability

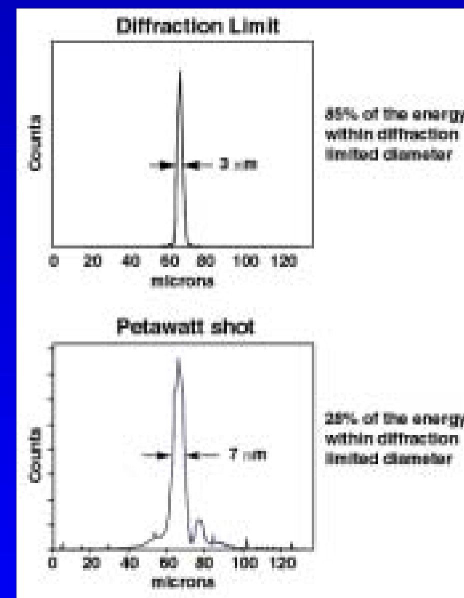
Current NIF deformable mirror with ~40 actuators corrects for aberrations at low resolution



Previous experience with short-pulse capability on NOVA (“Petawatt Laser”) revealed need to control beam at high resolution



Petawatt beam profile showed high resolution fluctuations -



- resulting in 3x decrease in power density

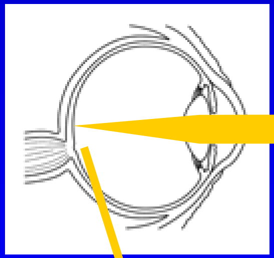
The short-pulse-based science program on NIF will benefit from new, high-resolution, affordable deformable mirror technology.

Center for Adaptive Optics

An NSF Science & Technology Center

CfAO

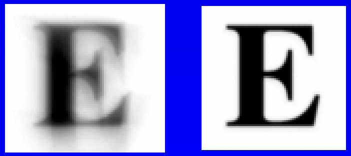
- Headquarters at UC Santa Cruz
- 11 university nodes
  - 3 primarily vision science (Rochester, Houston, Indiana)
- ~25 participating institutions (research, edu., gov., industry)
- Combines research and development in three main areas:



Visual acuity and retinal imaging degraded by aberrations in cornea and lens

Without AO

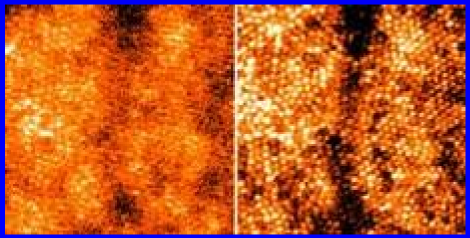
With AO



Effect of AO aberration correction on the image quality of the 20/20 E

Without AO

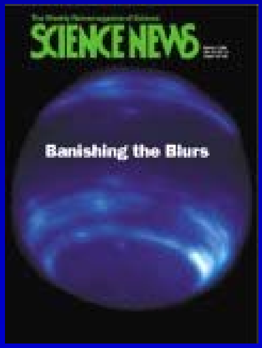
With AO



Images of single cells in the living human retina

VISION SCIENCE

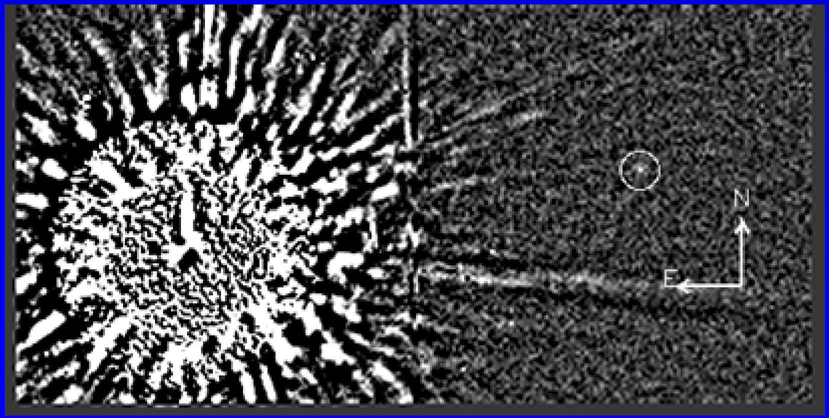
ASTRONOMY



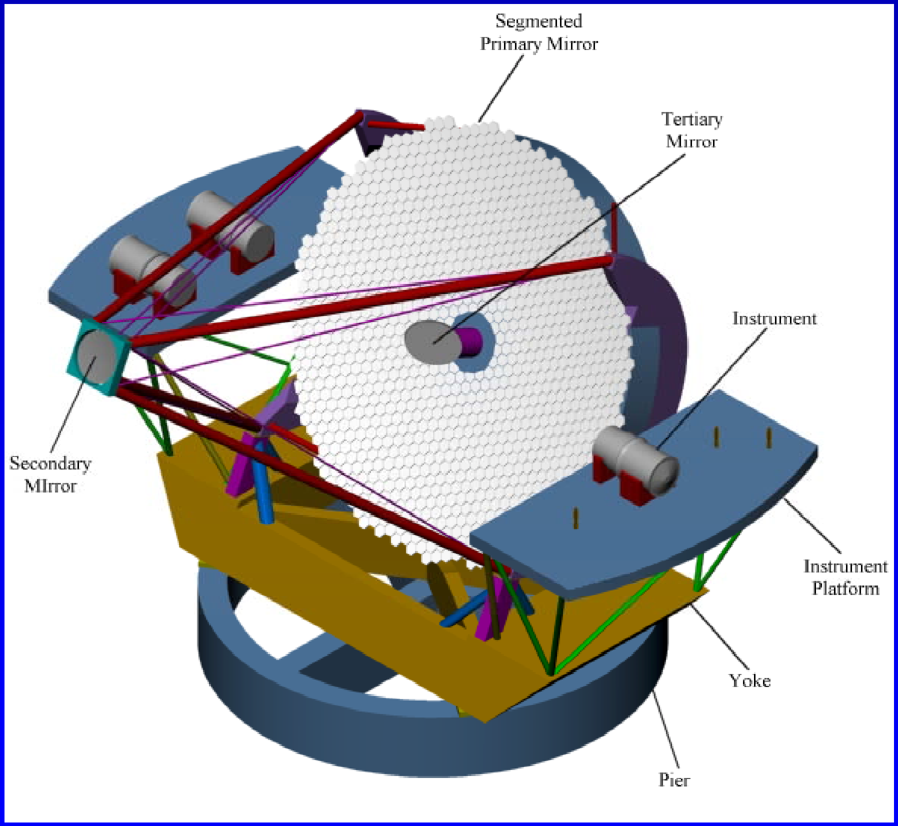
ADVANCED TECHNOLOGY

The Center for Adaptive Optics has two main science themes in astronomy

Extremely high resolution adaptive optics to enable observations of the origins of planetary systems



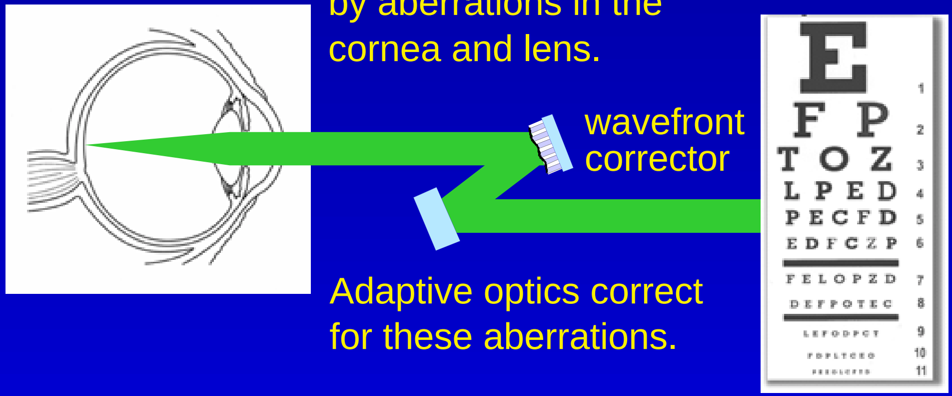
Adaptive optics for extremely large telescopes to enable observations of the origins of the universe



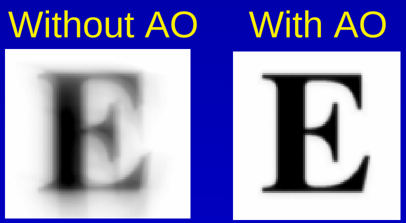
Development of adaptive optics systems for these applications requires new, high-resolution, affordable wavefront corrector technology.

Adaptive optics can provide a unique diagnostic capability for effects of vision correction and for high resolution retinal imaging

Visual acuity is degraded by aberrations in the cornea and lens.



Adaptive optics correct for these aberrations.



Effect of AO aberration correction on the image quality of the 20/20 E.

An adaptive optics system can be used to sense and correct aberrations in a subject's eye, enabling detailed studies of visual performance and retinal structure under a variety of conditions

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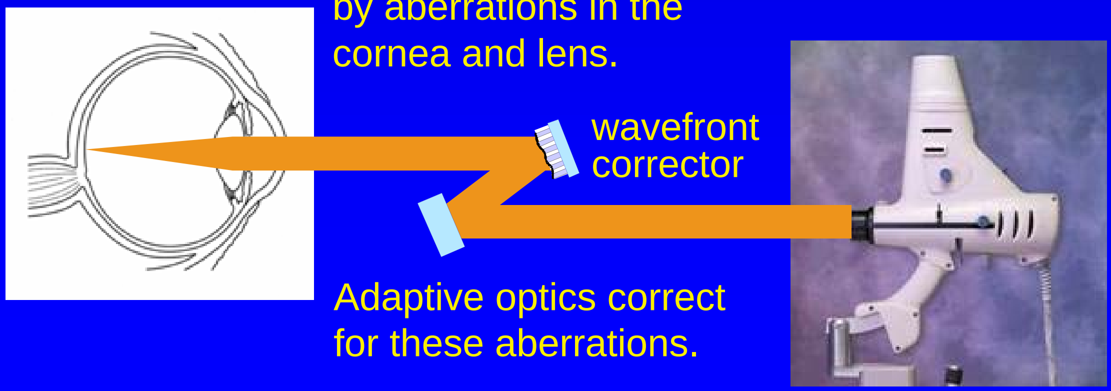

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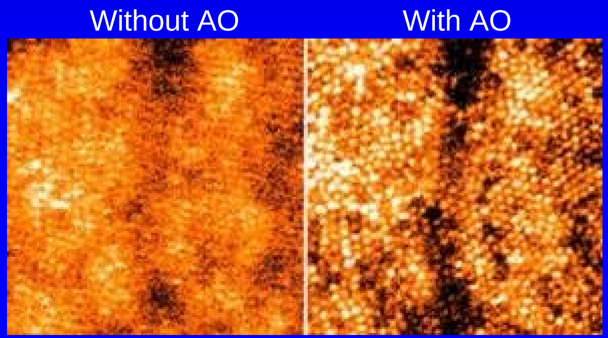
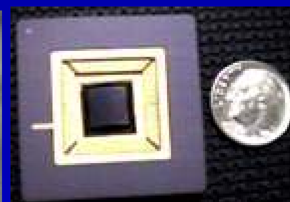


Images of single cells in the living human retina

CfAO has catalyzed a national effort to use new AO technologies to develop prototype high-resolution clinical ophthalmic imaging systems



MEMS deformable mirror

Liquid crystal spatial light modulator

MEMS-based adaptive phoropter

Liquid crystal adaptive phoropter

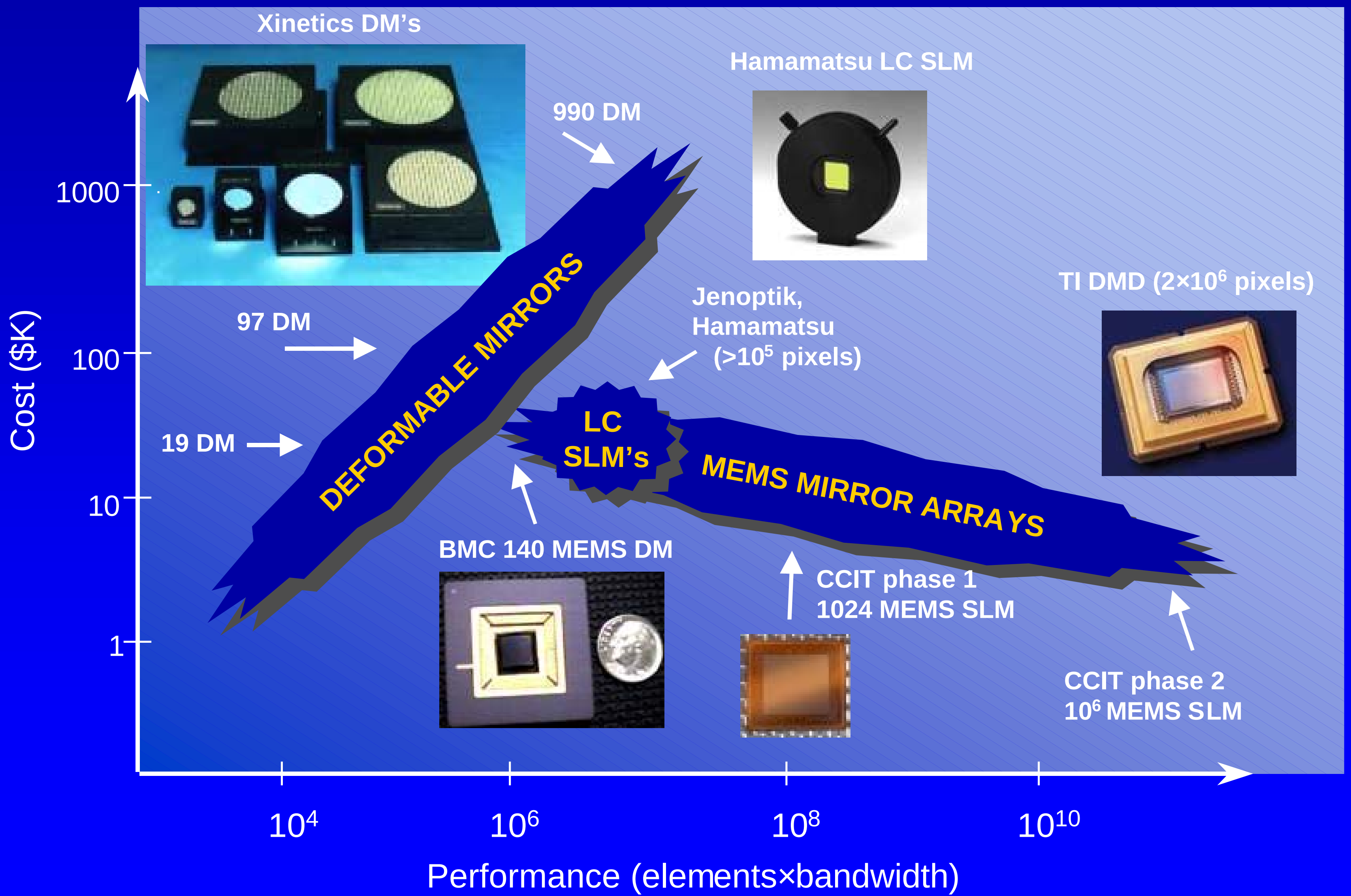
These systems will aid in the diagnosis and treatment of diseases causing blindness and the development of new techniques for vision correction in the general population

Development of viable clinical ophthalmic adaptive optics instrumentation requires continued enhancement of enabling wavefront corrector technologies that are: *compact, robust and inexpensive*.

- Greater range of motion
- Lower drive voltages
- Integrated drive electronics

U.S. Department of Energy—DOE
OFFICE OF SCIENCE
Biological and Environmental Research—BER

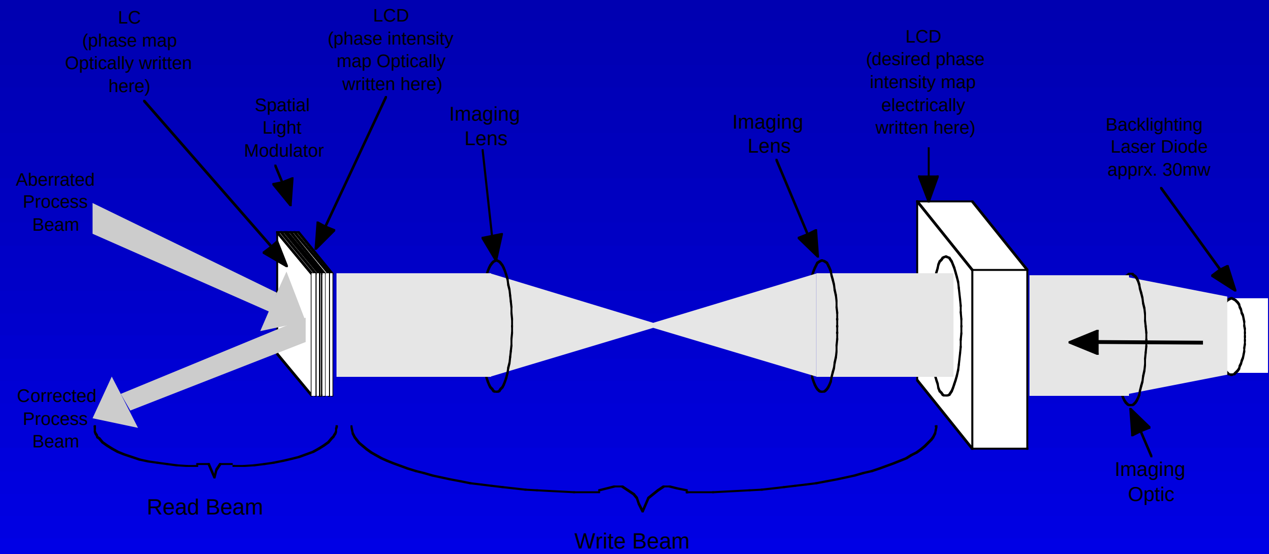
New wavefront control devices provide dramatically increased capabilities at lower cost



High-resolution wavefront control with optically addressed liquid crystal spatial light modulators

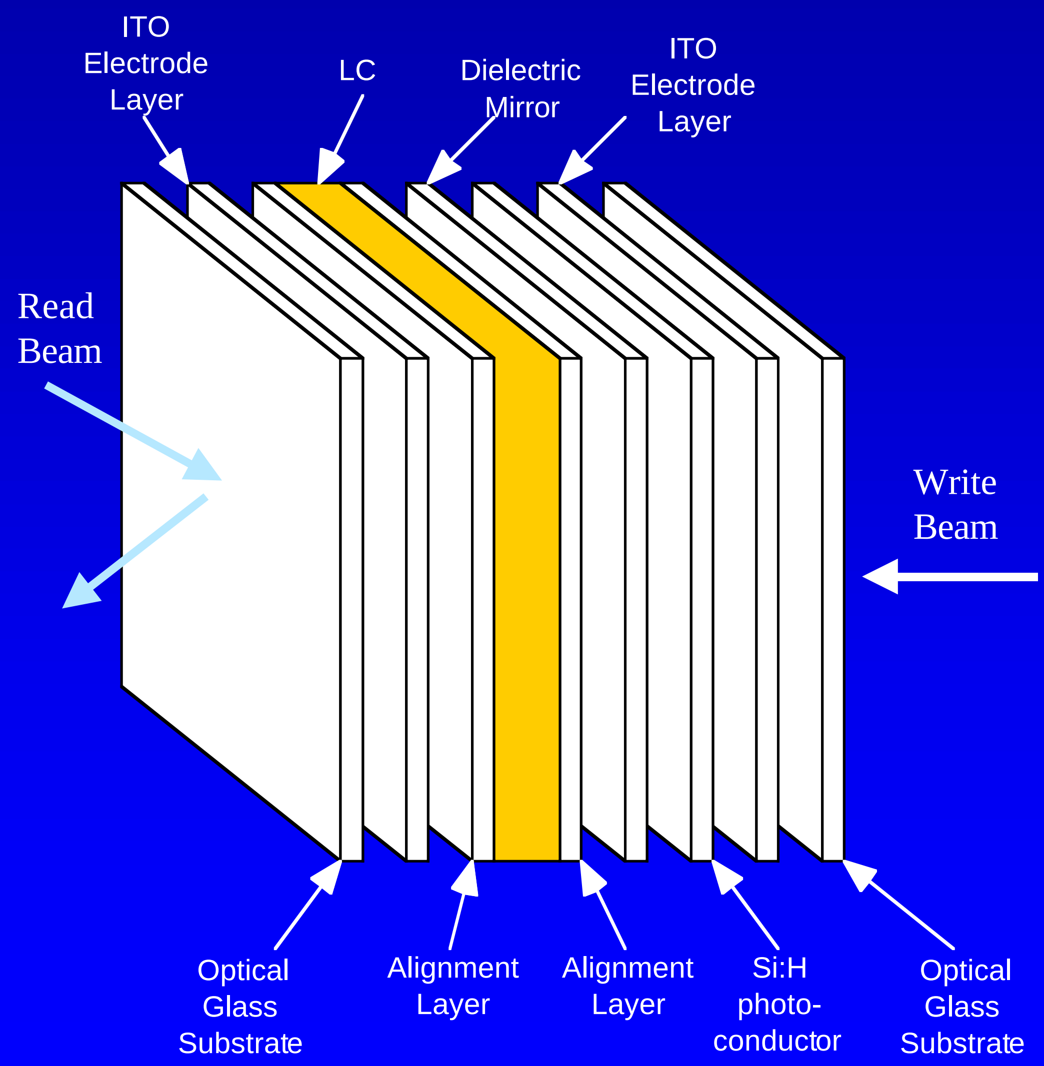
Optically addressed nematic liquid crystal spatial light modulators

JENOPTIK LC SLM
832 × 624 pixels
30 ms response time



HAMAMATSU LC SLM
640 × 480 pixels
30 ms response time

The anatomy of an optically addressed liquid crystal spatial light modulator



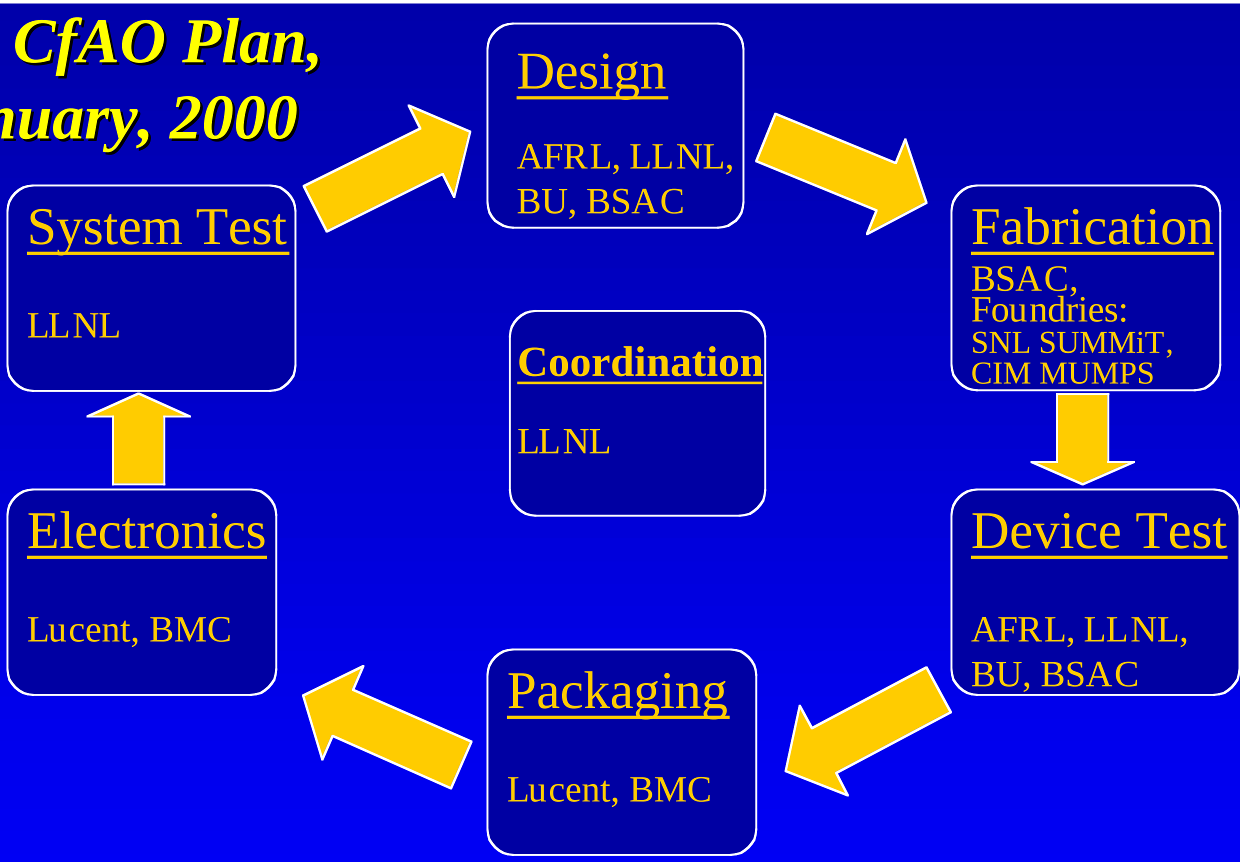
Spatial Light Modulator Technology

- **Liquid crystal spatial light modulators**
  - Advantage: Capable of high spatial frequency correction
    Commercially available today
    Compact size
  - Disadvantage: Slow, limited stroke, polarization and temperature sensitivity

- **Micro-electro-mechanical spatial light modulators**
  - Advantage: Capable of high frequency corrections (x, t),
    Light weight, lower cost (batch fabrication),
    Compact size, integration of addressing electronics
  - Disadvantage: *Limited commercial availability with specifications needed for adaptive optics*

Center for Adaptive Optics MEMS development

Original CfAO Plan, from January, 2000



- Two primary parallel paths based on AFRL and BU device designs
- Third path at BSAC investigating new designs for higher stroke actuators

- Phase 1: 256 elements
- Phase 2: 1024 elements
- Phase 3: 4096 elements

OKO Technologies micromachined membrane deformable mirror system