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Beam Quality Diagnostics and Adaptive Optics Approaches at the Z-Backlighter

THALES Petawatt Meeting

Beam Profile and Phase Front Measurements Session

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Sandia National Laboratories

Z Backlighter

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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Available Laser Systems

- λ=527nm
- τ=0.3-8ns (2ns common)
- ϕ~75μm spotsize
- E<2kJ
- I<10^{17} W/cm^2
- ~3 hr/shot
- 2 pulse MFB

- λ=1054nm
- τ=500fs min
- ϕ~30μm spotsize
- E<60J (<500J pending)
- I>10^{19} W/cm^2
- ~3 hr/shot
- Sub-ps probe @ 527nm, <20mJ

- λ=1064nm (532nm option)
- τ=150ps
- ϕ~5μm spotsize
- E<10J
- I<10^{17} W/cm^2
- ~20 min/shot
- Pending: 8-10ns operations at >100J @1ω

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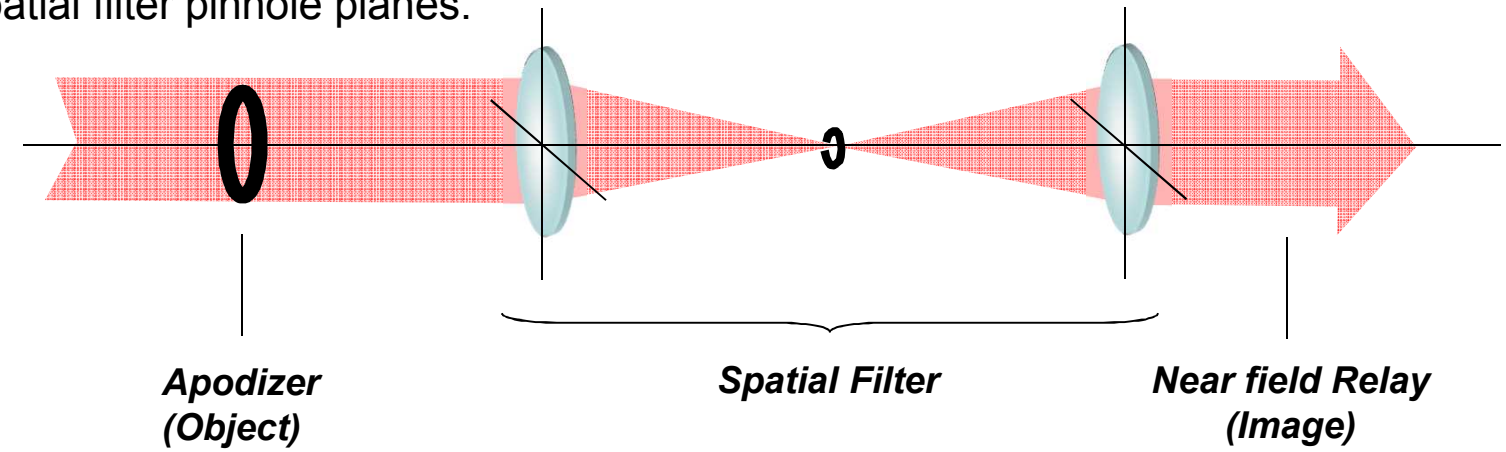
Methodology

• For efficient energy extraction in our high energy laser, a flattop beam profile is created with modest to fast edge roll-offs such that the wings of the beam profile do not clip in the amplifiers.

• The flattop is generated by clipping the beam with an apodizer followed by a spatial filter.

• The apodizer serves as an object plane for relay imaging throughout the system.

• Beam diagnostics refer back to this apodizer object plane
  • Near field sensors and wavefront sensors are images if this plane (or occasionally an object of interest nearby such as a deformable mirror).
  • Far field sensors are set to the best beam focus which should also be a relay plane to spatial filter pinhole planes.



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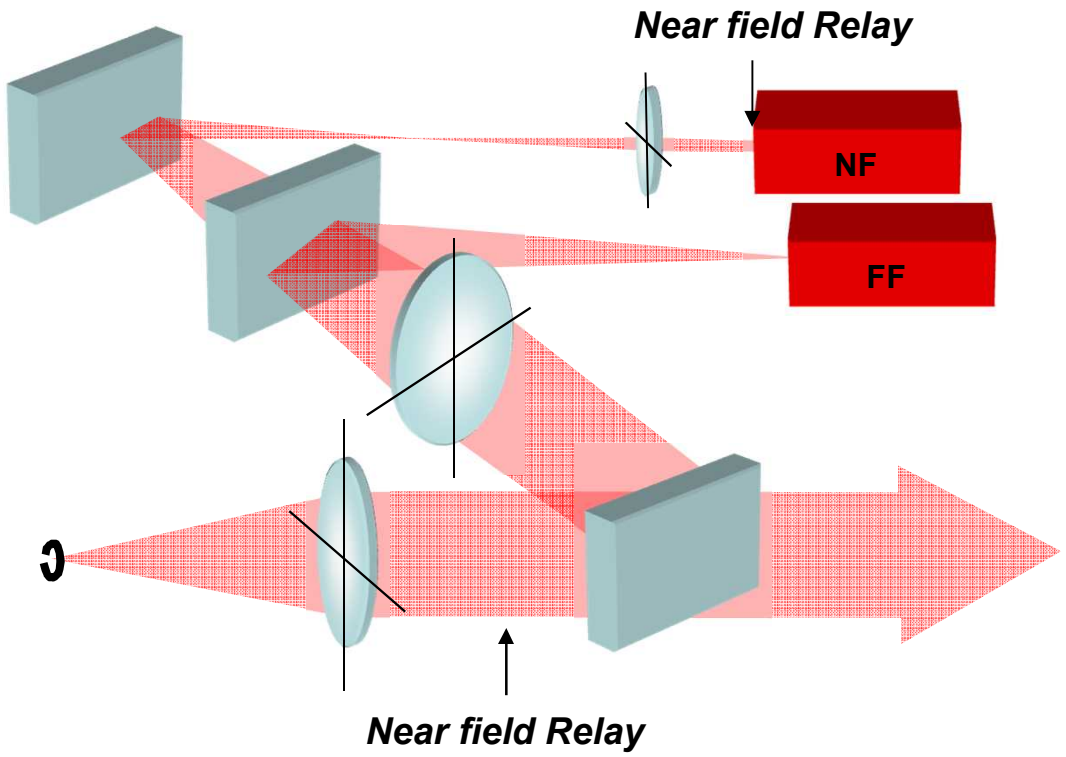
Diagnostics Packages

• Of the two main laser systems in the Z-Backlighter Facility (the ~kJ/ns Z-Beamlet and the ~500J/500fs Z-Petawatt), beam diagnostics occur:
  • After the seeder, after each stage of amplification, and after compression



• After pick-offs, beams are reduced with a collection lens

• NF's are images of preceding relays and are in collimated-space

• FF's are placed at the focus of the collection lens
  • FF's are not used in transmission at any of the diagnostic beamsplitters
  • FF magnification may be increased with a negative lens by increasing the effective focal length of the collection lens

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Near Field Diagnostics

- NF's are typically recorded with Pulnix TM-9701 cameras:
  - Triggerable
  - Progressive scan
  - → Stores frame internally for easier frame grabber DAQ
  - 2/3" Format
  - 768 (H) x 484 (V) pixels
  - 11.6μm x 13.6μm Pixel Size
  - Windowless chip option
  - 8-bit
  - Multi-pin connector interface or camera link
  - Additional video out option for monitors
  - → Facilitates alignments
  - Dimensions:
    48mm x 44mm x 136mm
    →Sometimes bulky

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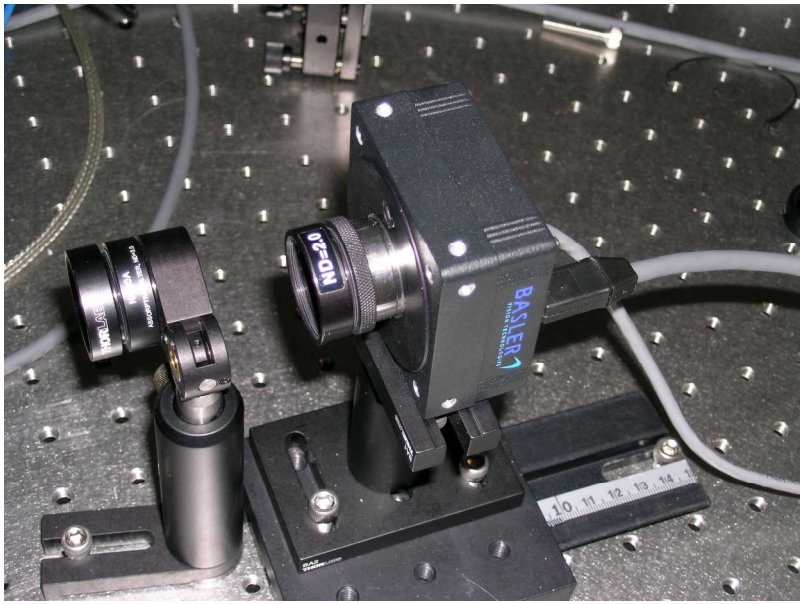
Far Field Diagnostics

- FF's are recorded with either Pulnix TM-9701 (mainly for pointing) or Basler A102f
  - Triggerable
  - Progressive scan
  - Fire wire
  - 12 bit
  - 2/3" Format
  - 1392 (H) x 1040 (V) pixels
  - 6.45µm x 6.45µm Pixel Size
  - No additional video out option

  →Only computer interface
  - Dimensions:

  32mm x 62mm x 62mm

  →Compact



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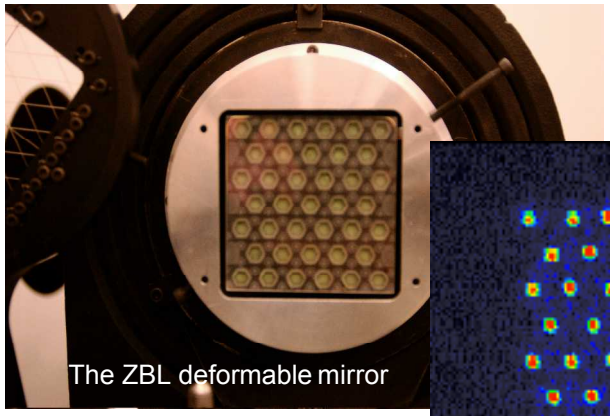
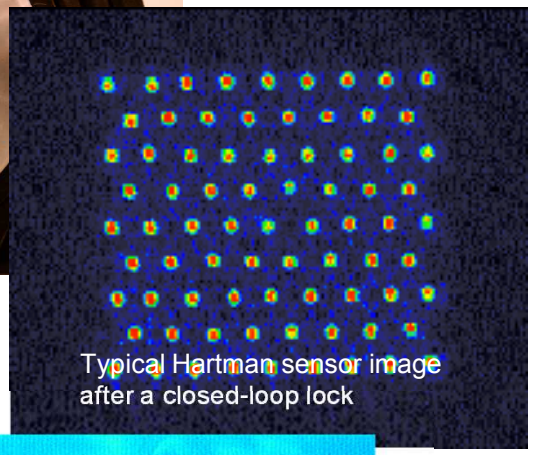
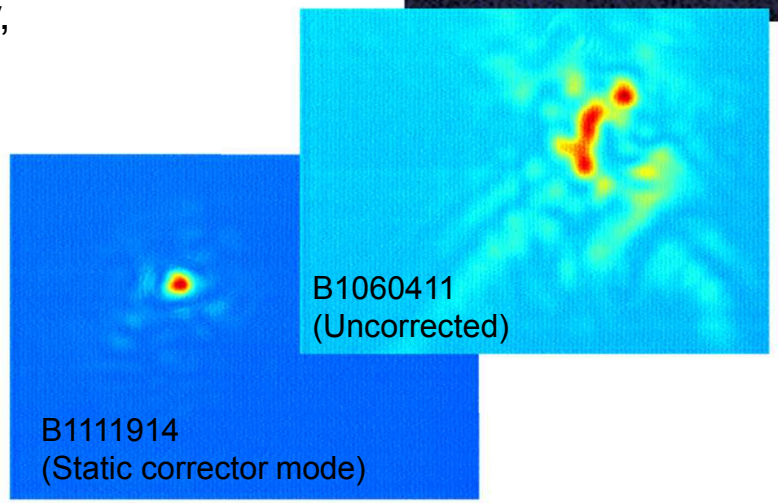
Adaptive Optic Approaches

- Over the course of the facility, several AO approaches have been tried or investigated:
  - **Custom LLNL legacy solution**
  →Worked to some degree, problems with legacy codes and hardware
  - OKO system solution
  → Small sizes and delamination issues with mirrors, code not a smooth fit
  - AOA sensors with custom mirrors (OKO,CILAS, in-house)
  → AOA hardware works but can be tricky, Software interface issues
  → Used effectively open-loop with in-house developed deformable mirrors
  - Phasics system solution
  → Nice flexible sensor with working AO loop
  → Minor mirror communications issues being worked out


The ZBL deformable mirror


Typical Hartman sensor image after a closed-loop lock



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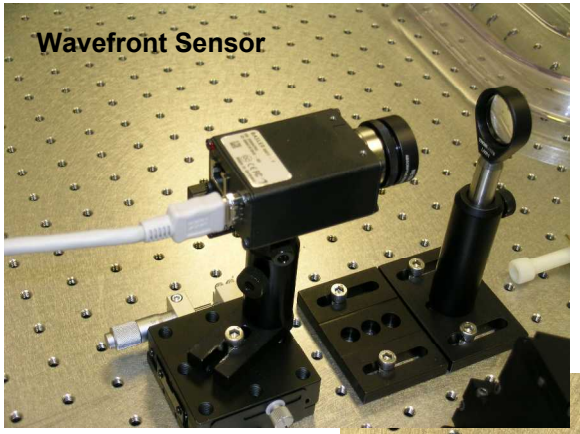

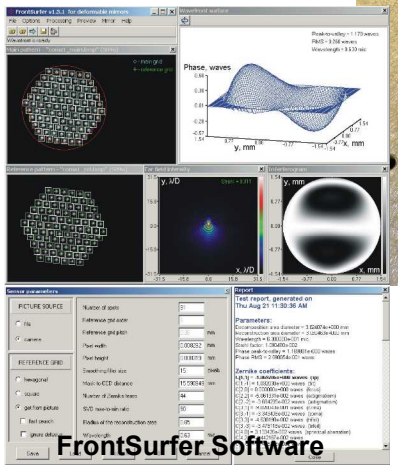

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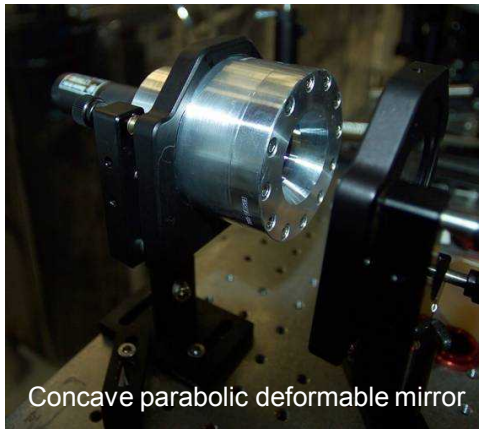
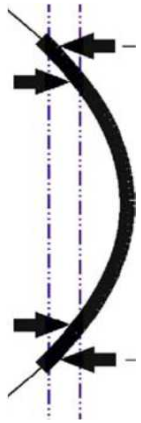
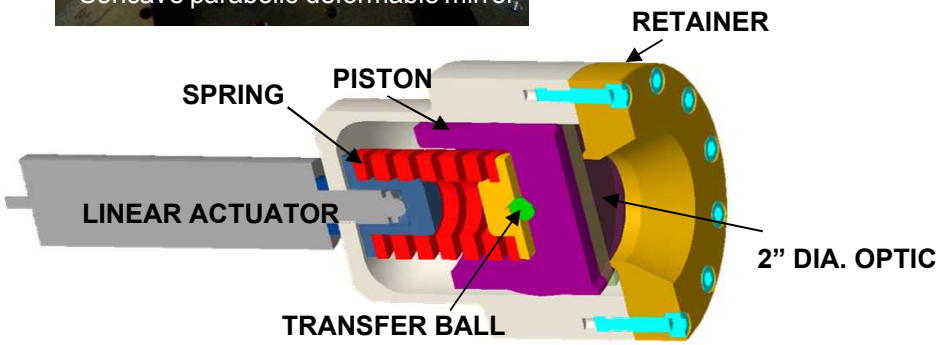
- Custom single-actuator mirrors can be:
  → Convex parabolic [Schwarz, AppPhysB v82 (2006)]
  → Concave parabolic [Schwarz, OptExp v14 (2006)]
  → Cylindrical concave [Schwarz, OptComm v264 (2006)]
  → Off-axis parabolic


Concave parabolic deformable mirror





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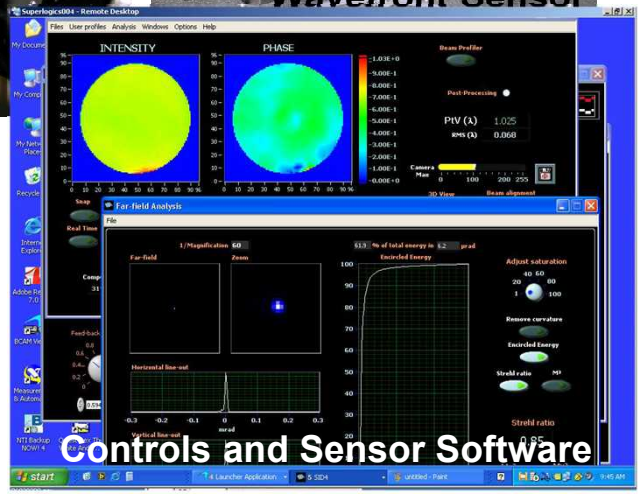

- **Compensated full system shot:**
  PV: 1.03 waves
  RMS: 0.07 waves
  Strehl ratio: 0.85.

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Conclusions

• The sensor package approach meets our beam diagnostics needs.

• Our cameras selections work well but some camera models may need replaced in the future as part of long-term maintenance and support.

• We have had a modest effort over the last 9 years since the facility has been established looking at a variety of adaptive optics and wavefront sensors

- •ThorLabs wavefront sensor with LabView interface recently purchased

• Long-term goals:

- • Integration of AO subsystem into shot control operation
- • Integrated diagnostics analysis for rapid detailed diagnostics feedback

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