• tight environment
• high radiation area
• non-serviceable area
• passive components
• optics only, no active electronics
• back illuminated with a single fiber laser - pulsed laser
• transmit image through flexible fiber bundle
Optical Diagnostics
Nov, 2004 @ Princeton

Field of view

Test target

lens

fiber bundle
Optical Diagnostics

More imaging fibers

old fiber bundle

New imaging fiber bundle
Core size: 24 µm, Diameter: 1/4"

New imaging fiber bundle
Core size: 12 µm, diameter: 1/8"

SMD camera

CCD size: 13.4 x 13.4 mm
Pixels: 960x960
Single frame: 240x240 pixels
Reduced pixel size: 56 x 56 um

Total fiber counts ~50,000 in 3.17 mm diameter
Imaging ~243 x 243 fibers on 960 x 960 CCD array

~1 imaging fiber on ~4x4 pixels on full frame
~1 imaging fiber on ~1 pixel on a single frame
Optical Diagnostics
Simple back illumination?
Optical Diagnostics
Backlight illumination results

- Fiber backlight
- Laser light input

Need >500 pulse/frame

~mJ/pulse in 1-MHz rate!!

Test target on cm scale

Field-of-view: back illuminated light strip
NIR laser illuminated at 1000 pulses/frame
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Conventional shadow illumination approach?

>12-inch away

Can NOT be implemented in this tight environment!
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retroreflected illumination

Spherical mirror

laser illumination

image collection

cm scale

test target

Works OK in this tight environment
**Optical Components**

- 50/50 beam splitter: Edmund, 0.5 cm cube
- Spherical mirror: Edmund, f=3-in, D=3in < Au coated
- Small prism mirror: Edmund, 1x1x1.4 cm, Au coated
- Large prism mirror: Edmund, 2.5x2.5x3.54 cm, Au coated
- Imaging fiber Edmund: ⅛-in diameter, 12-µm core, 0.55 NA
- Illumination fiber: ThorLabs, 0.22 NA, SMA-905 840-µm core
- Imaging lens: Sunex, f=0.38-cm, f/# 2.6, diagonal FOV 54°, φ1.4-cm x 2.0 cm
Optical Diagnostics

Field of view - imaging
Optical Diagnostics

Field of view – NIR laser illumination & imaging

- Target shifted 1.5 cm upstream
- Field of view
  - NIR illumination
  - 0.01 ms frame rate
- Target shifted 1.5 cm downstream
Optical Diagnostics

optical design in secondary containment

One set of optics per viewport
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An optical chopper in motion @ 4 kHz

Stationary image

Velocity @ ~40 meter/sec

100 µs/frame

10 µs/frame
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Other issues:

1. Laser power increase to ~40 W/pulse (instead of 10 Watt/pulse)
2. ~50-m long flexible, square shaped imaging fiber – Schott
3. Depth of focus → apparent image size variation
4. 3-in dia. spherical mirror (lens/mirror) with the right focal length
5. Anti-reflection coated (@ 800 nm) viewports
6. Number of viewports ?
7. Location of the viewports ?
8. How many fast CCD camera ?
9. Switch from one viewport to the next with one laser/camera system ?
10. Glass rather than fused silica optics ok ?
11. …