• 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

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 µm

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?

Lumitex® Inc.

Secondary Containment Flange
Optical Diagnostics

Backlight illumination results

- Fiber backlight
- Laser light input
- Need >500 pulse/frame
- ~mJ/pulse in 1-MHz rate!!
Optical Diagnostics

Conventional shadow illumination approach?

>12-inch away

Can NOT be implemented in this tight environment!
Optical Diagnostics

retroreflected illumination

Spherical mirror

laser illumination

image collection

cm scale

test target

Works OK in this tight environment
Optical Diagnostics

Exp test setup

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

Conceptual design completed
Optical Diagnostics

An optical chopper in motion @ 4 kHz

Stationary image

100 µs/frame

10 µs/frame

1 µs/frame

Velocity @ ~40 m/s
Optical Diagnostics

An optical chopper in motion @ 4 kHz cont'

Velocity @ ~40 m/s

100 μs/frame with reflective mask

frame #12
1. Laser power increase to ~40 W/pulse (instead of 10 Watt/pulse)
2. Depth of focus → apparent image size variation
3. 3-in dia. spherical mirror (lens/mirror) with the right focal length
4. Anti-reflection coated (@ 800 nm) viewports
5. ~50-m? long flexible, square shaped imaging fiber bundles – Schott Optics

Wound Fiber Optic Image Bundles

IG-154, 10 µm size
4 mm x 4 mm
4.5 meter long
$5.7K

6. Radiation resistance of imaging fiber bundles and optics ? to be tested.
7. Number of viewports ? minimum of 3
8. Location of the viewports ? 5-inches apart
9. How many fast CCD camera ? 1 fast (1 µs) camera, 1 slower (250 µs) camera ?
10. Switch from one viewport to the next with one laser/camera system ?
11. …