tight environment

- high radiation area
- non-serviceable area
- passive components
- optics only, no active electronics
- transmit image through flexible fiber bundle
**Optical diagnostic tool:**
high-speed camera to fast record transient phenomena

- back illuminated laser shadow photography technique
- freeze the image of events using high speed camera (up to 1 µs/frame)
- synchronized arrival of short laser light pulses illuminate onto the target
- the motion of the target after proton impact is freezeed by high intensity short (150 ns) laser pulses
- 2-dimensional image
Sumitomo imaging fibers – **used in our setup**

### Product Lineup

<table>
<thead>
<tr>
<th></th>
<th>IGN-02/03</th>
<th>IGN-028/06</th>
<th>IGN-035/06</th>
<th>IGN-037/10</th>
<th>IGN-05/10</th>
<th>IGN-08/30</th>
<th>IGN-15/30</th>
<th>IGN-20/50</th>
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</thead>
<tbody>
<tr>
<td>Number of picture elements</td>
<td>3,000</td>
<td>6,000</td>
<td>6,000</td>
<td>10,000</td>
<td>10,000</td>
<td>30,000</td>
<td>30,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Jacketing diameter (μm)</td>
<td>200</td>
<td>280</td>
<td>350</td>
<td>370</td>
<td>500</td>
<td>800</td>
<td>1,500</td>
<td>2,000</td>
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<tr>
<td>Picture elements area diameter (μm)</td>
<td>180</td>
<td>252</td>
<td>315</td>
<td>333</td>
<td>450</td>
<td>720</td>
<td>1,350</td>
<td>1,800</td>
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<tr>
<td>Coating diameter (Primary) (μm)</td>
<td>250</td>
<td>340</td>
<td>420</td>
<td>450</td>
<td>590</td>
<td>960</td>
<td>1,900</td>
<td>2,400</td>
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<tr>
<td>Coating diameter (Secondary) (μm)</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Circularity</td>
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<tr>
<td>Core material</td>
<td>GeO2 Containing Silica</td>
<td>F Containing Silica</td>
<td>Pure Silica</td>
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<tr>
<td>Cladding material</td>
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<td></td>
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<tr>
<td>Coating material</td>
<td>Silicone</td>
<td>Silicone + PFA</td>
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<tr>
<td>Numerical aperture</td>
<td>0.35</td>
<td>0.30</td>
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<td>Lattice defect (%)</td>
<td>&lt;= 0.1</td>
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<tr>
<td>Allowable bending radius (mm)</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>40</td>
<td>75</td>
<td>100</td>
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<td>Allowable max temp. (°C)</td>
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<td></td>
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<tr>
<td>Rad-hard to 1 Mrad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Cost Per Foot**: $78

**Cost in 10 meter**: $2574

**Total Cost for 4 fibers (40 meter)**: $10.3k
Optical Diagnostics in secondary containment

One set of optics per viewport

Conceptual design completed
All-in-one optical setup

Grin objective lens
imaging fiber – 1 mm
illumination fiber
fiber holder
glass lens
## Optical components irradiation using radiation sources #1 & #2

Source #1: CERN proton beam: 1.4 GeV, 5x10^15 protons, 320 krad, equivalent to 40 pulses of 24 GeV proton
Source #2: BNL Co60: 30 krad & 3 Mrad equivalent to 3.7 & ~370 pulses of 24 GeV proton
measurements wavelength ~ 800 nm

<table>
<thead>
<tr>
<th>item #</th>
<th>components</th>
<th>radiation source</th>
<th>equivalent proton pulse</th>
<th>before</th>
<th>after</th>
<th>results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>gold mirror reflector</td>
<td>#1</td>
<td>40</td>
<td>0.910</td>
<td>0.920</td>
<td>no change</td>
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<tr>
<td>2</td>
<td>1-mm thick sapphire window (&amp; ball lens)</td>
<td>#1</td>
<td>40</td>
<td>0.863</td>
<td>0.867</td>
<td>no change</td>
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<tr>
<td>3</td>
<td>5-meter multimode low-OH fiber</td>
<td>#1</td>
<td>40</td>
<td>1.000</td>
<td>1.020</td>
<td>no change</td>
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<tr>
<td>4</td>
<td>30-cm long Sumitomo imaging fiber</td>
<td>#1</td>
<td>40</td>
<td>0.670</td>
<td>0.710</td>
<td>no change</td>
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<tr>
<td>5</td>
<td>Grin objective lens, 2.43 mm long</td>
<td>#2</td>
<td>~4</td>
<td>0.900</td>
<td>0.860</td>
<td>T=95%</td>
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<tr>
<td>5</td>
<td>Grin objective lens, 2.43 mm long</td>
<td>#2</td>
<td>370</td>
<td>0.900</td>
<td>0.657</td>
<td>T=73%</td>
</tr>
</tbody>
</table>
Stainless steel primary: significant leak

Sept., 28, 2006 welding defect on the SS primary
10/06/06 - large leak detected, all gaskets are not good

10/10/06 - new gaskets installed, small leak detected, in 17 hrs pressure drop from 21 to 8 psi, fixed viewport #4 gasket.

10/11/06 – small leak in 21 hrs pressure drops from 21 to 19 psi leak rate of ~1.4 mTorr/sec

10/12/06 - Leak check using Metheson 8850 flammable gas sniffer, 5 ppm sensitivity, 15 psi of Ar/Methane (90%/10%) several tap holes aren’t deep enough on viewport #4, shorten a few screws and tighten the viewport.

10/13/06: No leak detected, 21 psi holds for over 17 hrs
Optical Diagnostics on SS Primary

Viewport #1 Viewport #2 Viewport #3 Viewport #4

identification on window exterior

home-made mini-choppers
canventional video camera
SMD camera
FastVision camera
1x2 fiber splitter
laser diode
pulsed laser driver
Optical Diagnostics – complete setup
Multi-Pulse Train for SMD and FastVision Cameras

- **SMD Camera**
  - (17-pulse, 80 μs/frame)

- **FastVision Camera**
  - (220-pulse, 2 ms/frame)
Optical Diagnostics on SS Primary

cw NIR light
conventional video camera
30 frame/sec, 1sec. movie

pulsed NIR light
SMD camera
80 us/frame, 16 frames

pulsed NIR light
FastVision camera
2 ms/frame, 250 frames
(only 16 frames showing)
Summary

- two 10-meter and one 1.5 meter (temporary) long imaging fibers assembled on SS primary
- SS primary are pressure tight (20 psi)
- dynamic image collection on all viewports were tested
- dis-mount and re-mounting optical base plate requires little or no realignment
- camera ↔ viewport are inter-changeable but the field of view on all viewports are fixed

- 3 more 10-meter imaging fibers just arrived for the remaining viewports and backup
- 2nd FastVision camera on its way for 4th viewport
- all optical diagnostic equipment headed to ORNL