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CASIS Signal and Imaging Workshop
November 16-17, 2006

UCRL-PRES-226124
This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Optics Inspection: Interdisciplinary effort merges engineering, computer science, physical optics theory, and customer interface

- Algorithms & Application Development: Steve Glenn, Judy Liebman
- FRODO TechBase: Anthony Azevedo, Mina Bionta, Barry Chen, Aseneth Lopez
- Summer Projects: Ketrina Yim, Jack Tzeng, Philip Fong, Dan Potter, John Pate
- Image Acquisition Software: Vicki Miller Kamm
- Physical Optics theory: Eran Bliss and Thad Salmon
- Systems Engineering: Steve Azevedo, Scott Burkhart, Walter Ferguson
- Web, Java GUI Development: John Carlson, Stephanie Daveler
- Eng/Scientists/Customers: Jim Chang, Chris Choate, Alan Conder, Chris Haynam, Mike Nostrand, Tom Parham, Rahul Prasad, Mary Spaeth, Pam Whitman, Shot Directors and Control Room Operators.
- Support & feedback: testers, configuration management team, system administrators, database administrators
NIF has thousands of optics on the beamlines which must be inspected after every shot.

On-beamline inspections can be like looking through a house of mirrors.
- Focusing on clear glass can be tricky.
- Images are relayed to camera through mirrors/periscope, spatial filters and other lenses and optics.
- Must keep track of orientation.
In addition, every optic is inspected (off-beamline) before and after going on the beamline.

The LOIS inspection system for the Main Laser has mirrors, relay optics and intervening glass. Light scattering sites can still be detected.

We must detect the site, identify the optic on which it resides and estimate its size.

Analysis software is capable of detecting very small imperfections; we track these over time to ensure quality performance of the laser system.

In addition, every optic is inspected (off-beamline) before and after going on the beamline.

- Verify manufacturing specifications
- Pass/Fail quality of coatings
- Confirm Conditioning
- Mitigation
- Refurbishment

To track the evolution of a defect requires tracking a variety of conditions:
- Illumination settings
- Exposure times
- Operator-specific methods
- Orientation!
Most on-beamline and off-beamline images go through the same “one” algorithm (Local SNR for each pixel in image) with specified parameters.

- Detect tiny flaws online
- Interface to prediction codes for recycling optics

Example of 1 (manufactured) defect imaged from online to offline inspections

SIDE (Online image of TCVW)
- Check for damage exceeding 1 mm.

DMS-OPL (Damage Mapping System - Optics Processing Lab)
- Confirm size and location of surface flaws - 97 microns per pixel

CIM (Conditioning, Initiation & Mitigation)
- Test and condition the optic with increasing laser energies
- Scattering sites smoothed (mitigated) with a CO2 laser

Micrographs
- Evaluate “true” size of flaws for calibration and validation - 6 microns per pixel
We may be able to find some defects by using their out-of-focus rings to estimate location and size -- Finding Rings Of Damage on Optics

Simulated images with 15 defects on different “optics”

FRODO (based on ICE GDM*) was able to find diffraction rings on NIF Final Optics by tuning 4 adjustable parameters

*Image Content Engine Gradient Direction Matching
APPSPACK® optimized FRODO parameters; Receiver Operating Characteristic curves provided performance metrics.

APPSPACK (G Gray, T Kolda; Sandia, CA): derivative-free optimization software for solving nonlinear unconstrained and bound-constrained optimization problems, with possibly noisy and expensive objective functions.

How OI Analysis is used in practice for NIF....

Our client-server design is a robust and flexible tool that allows many customers to access/display results as needed for many different purposes.
A java-based visualization application allows users to view inspection results from a birds-eye view or in great detail.
O1 Scaling to NIF: The amount of data storage will quickly become large

<table>
<thead>
<tr>
<th>Inspection Type</th>
<th>Images per dataset</th>
<th>Estimated Image Size (GB)</th>
<th>Size per dataset (GB)</th>
<th>Anticipated no. datasets</th>
<th>Interval</th>
<th>Inspections Per Month</th>
<th>Size per beam per Month (GB)</th>
<th>Partial NIF Total for one year (GB)</th>
<th>Full NIF Total for one year (GB) *</th>
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</thead>
<tbody>
<tr>
<td>FODI</td>
<td>16</td>
<td>0.032</td>
<td>0.512</td>
<td>2 shot week</td>
<td>20</td>
<td>0.02</td>
<td>2.5</td>
<td>24.6</td>
<td>493.6</td>
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<tr>
<td>IDM</td>
<td>16</td>
<td>0.032</td>
<td>0.512</td>
<td>2 shot week</td>
<td>20</td>
<td>0.02</td>
<td>2.2</td>
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<td>IDI</td>
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<td>0.005</td>
<td>0.301</td>
<td>8 shot week</td>
<td>20</td>
<td>0.01</td>
<td>2.9</td>
<td>24.6</td>
<td>493.6</td>
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<tr>
<td>LDI</td>
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<td>0.150</td>
<td>8 shot week</td>
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<td>0.20</td>
<td>18.8</td>
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<td>HDL (EPS, EPC)</td>
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<td>0.010</td>
<td>8 shot week</td>
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<td>0.20</td>
<td>18.8</td>
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<td>DPL (CMS maps+)</td>
<td>2</td>
<td>0.032</td>
<td>0.964</td>
<td>500 per year</td>
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<td>IMF</td>
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<td>0.032</td>
<td>0.364</td>
<td>250 per year</td>
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<td>SDFI</td>
<td>15</td>
<td>0.100</td>
<td>350 per year</td>
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<td>RMS</td>
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<td>(whole tomography)</td>
<td>18</td>
<td>0.001</td>
<td>0.310</td>
<td>450 per year</td>
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<td><strong>Total Storage Needed</strong></td>
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<td>1,616.6</td>
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* Size estimates are for early NIF (FY ‘09 - FY ‘10)

**Summary**
- 27 TBytes/year (50 if full FODI) – ~6000 DVD’s
- NIF Ops (nif) has ~6 TByte now
- 300 GB drives are $300 now (Maxtor or $1/GB
- Archival plans are being made with NIF IT

O1 Analysis supports on-beamline inspections for shot readiness and optics recycling as well as off-beamline for QA, conditioning, validation...

- Automated inspection for images from 9 camera systems on the NIF beamline and 11 offline. (One fundamental algorithm to analyze them all.)

- Track defects on thousands of optics through their lifetime (across different camera systems). Detect and measure defects over a range of sizes to assure quality performance and safety.

- We can keep up with speed requirements by expanding our Linux cluster for parallel analysis of all on-beamline and offline systems.

- Image analysis runs on an application server and all images and results are stored in a database.

- Java-based visualization application can be downloaded from any browser. It allows each customer to review results appropriately via dynamic database queries.