NIF Imaging Session

Laura Kegelmeyer

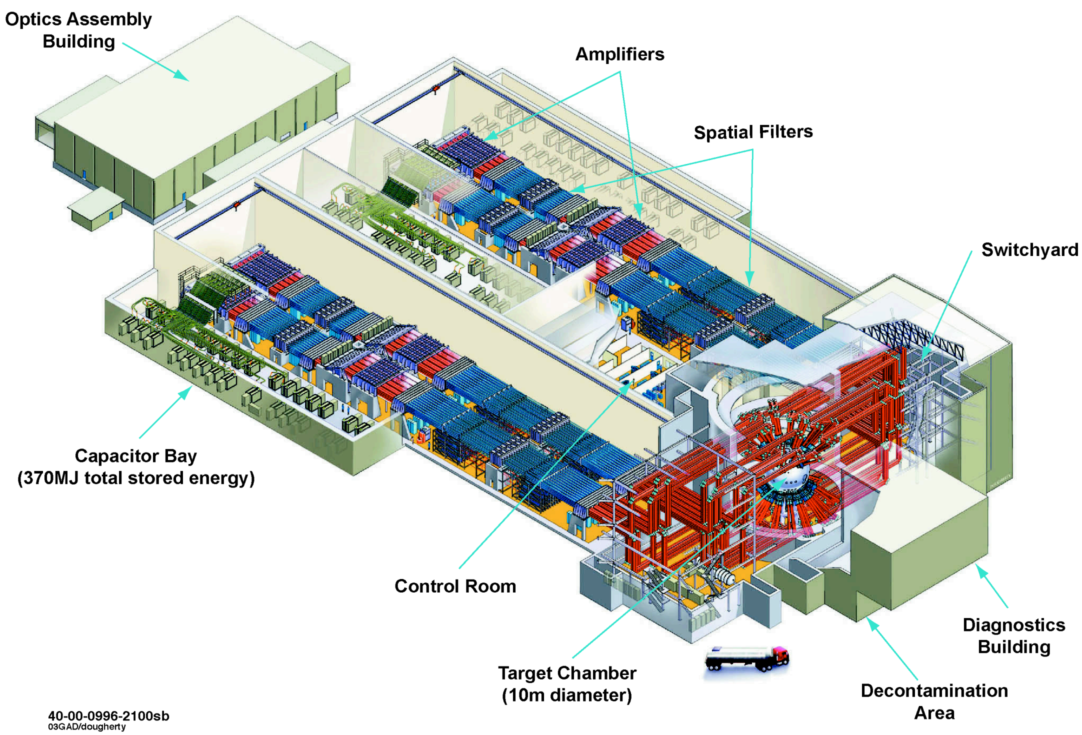
CASIS Signal and Imaging Workshop
November 18-19, 2004

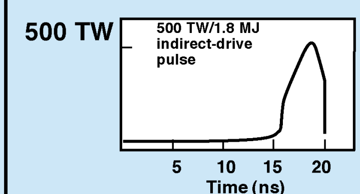
UCRL-PRES-208128

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.

The National Ignition Facility is 192-beam laser system for inertial fusion and high-energy-density physics research

The National Ignition Facility

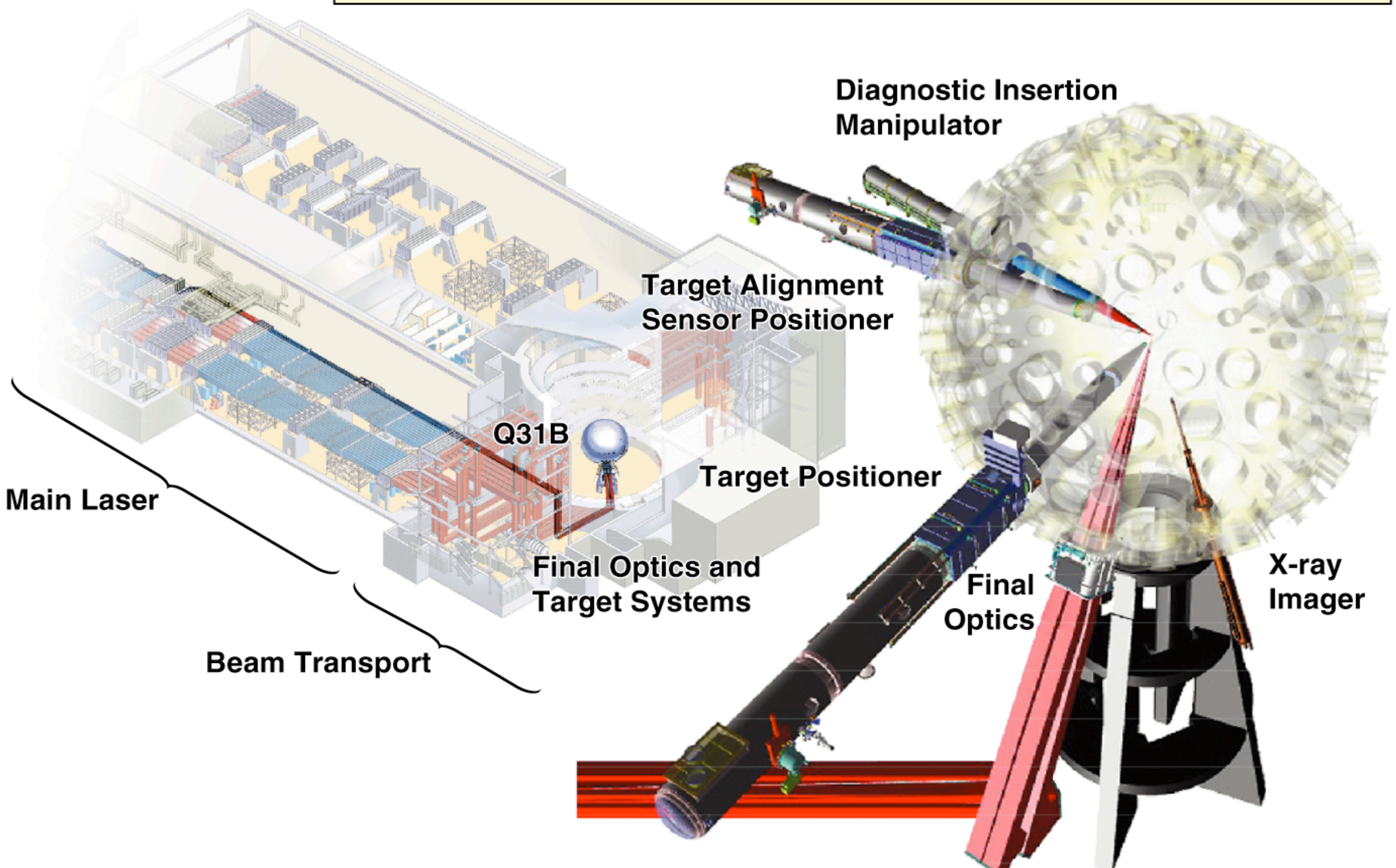


Performance	Value
Energy	1.8 Megajoules
Power	500 Terawatts
Wavelength	351 nm
Pulse length	1 to 21 nsec
Pulse shape	Flexible,
	
Power balance	8% in 48 beams spots
80% focal spot diameter	250 to 350 microns

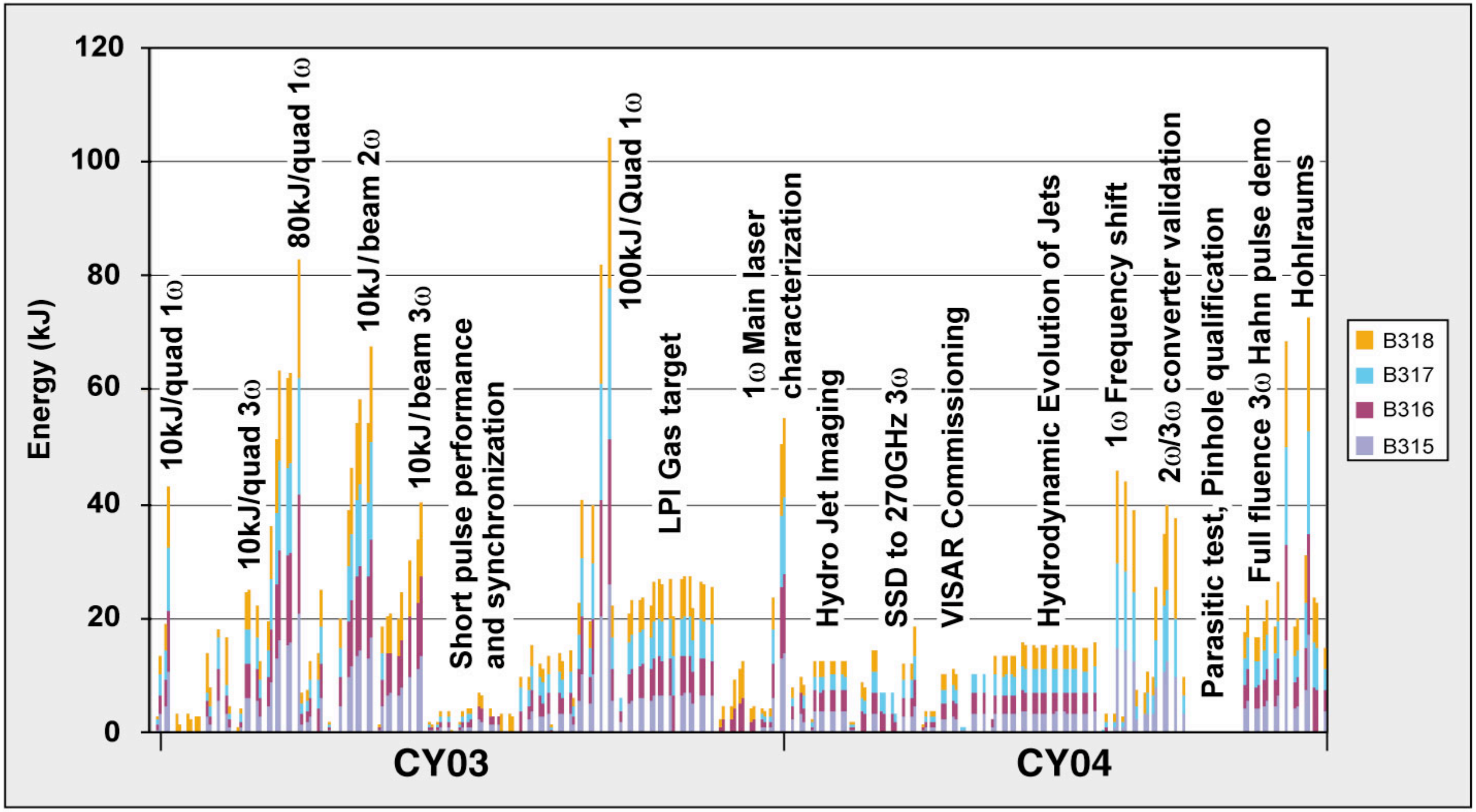
The first four NIF beamlines have been commissioned to the center of the target chamber

The National Ignition Facility

End-to-end functionality of all major subsystems demonstrated

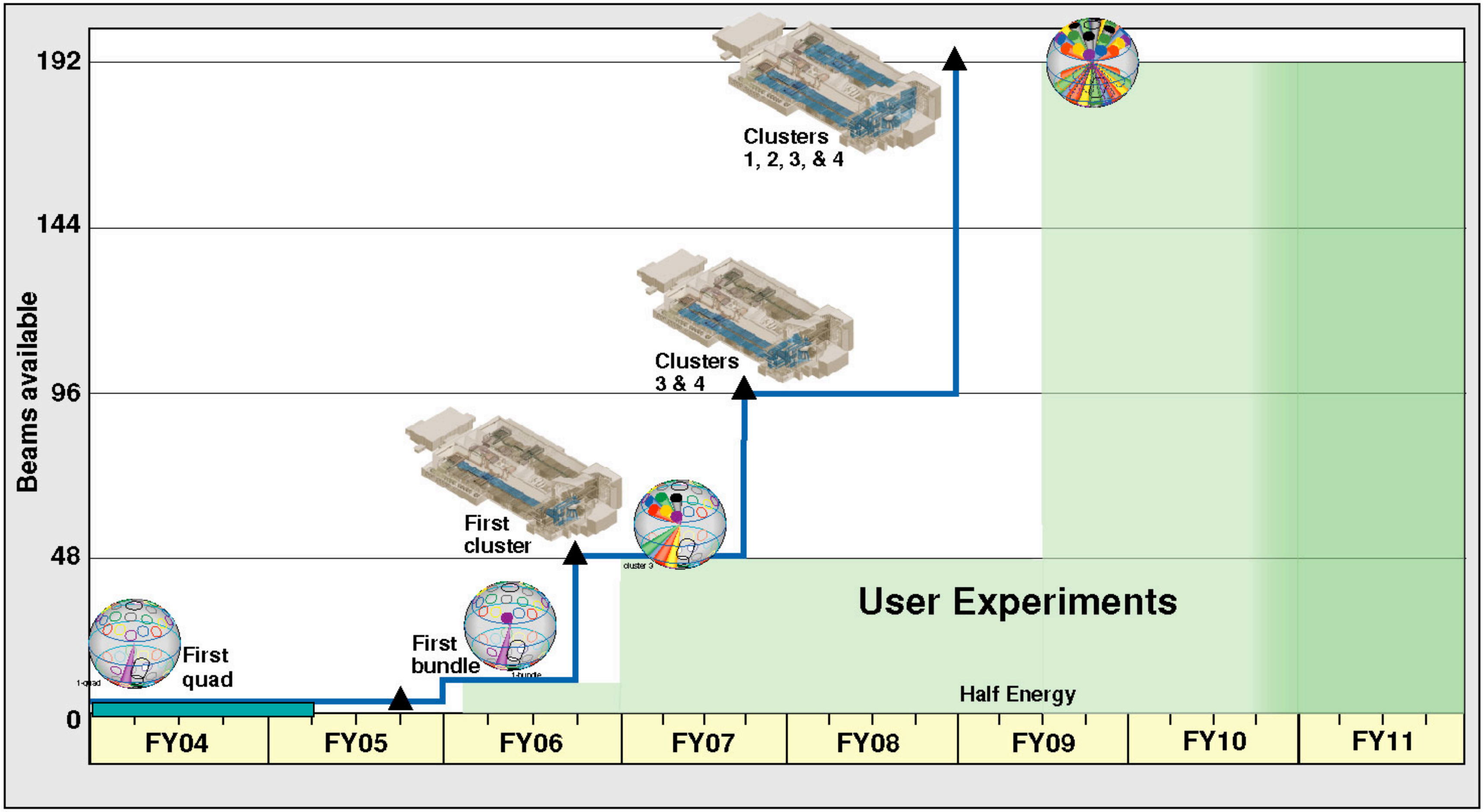


We have taken data on over 380 shots on NIF's first quad



NIF operations have supported a variety of users and covered a wide operational range

NIF Commissioning Plan



NIF Optics Inspection Overview

Laura Kegelmeyer

CASIS, Signal and Imaging Sciences Workshop

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UCRL-PRES-

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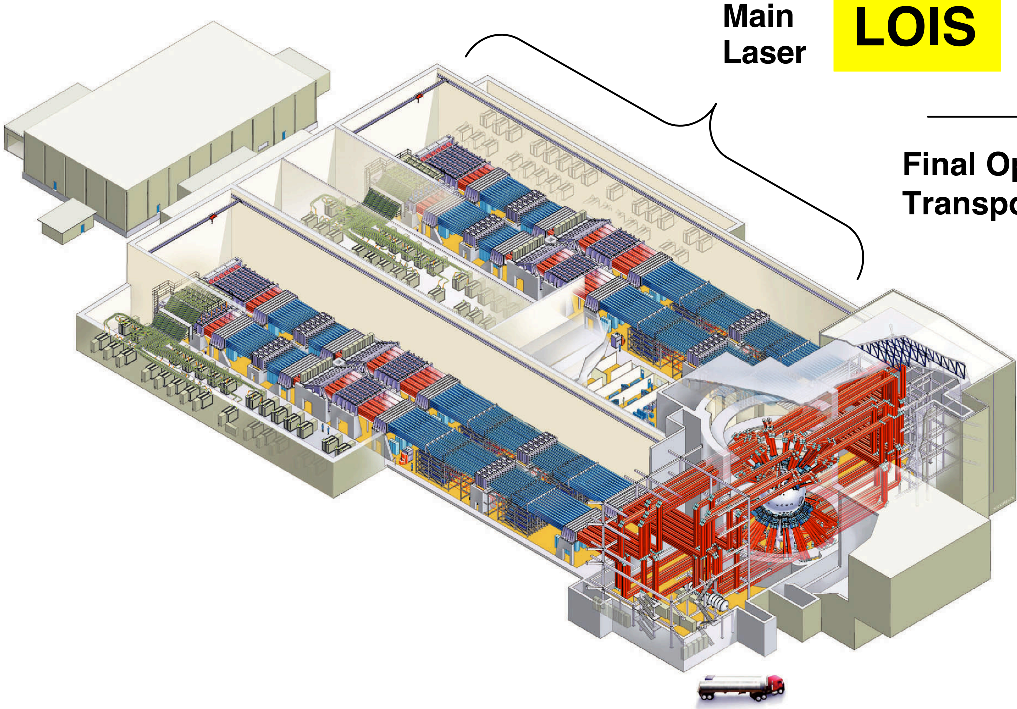
Optics Inspection: Interdisciplinary effort merges engineering, computer science, physical optics theory, and customer interface

- Algorithms & Application Development: Marijn Bezuijen, Steve Glenn, Judy Liebman
- Data Acquisition Software: Vicki Miller-Kamm
- Physical Optics theory: Erlan Bliss and Thad Salmon
- Systems Engineering: Steve Azevedo, Scott Burkhart, Walter Ferguson
- Web, Database, GUI Development: Stephanie Daveler, Guy Bayes
- Eng/Scientists/Customers: Jim Chang, Charlie Cerjan, Chris Choate, Alan Conder, Chris Haynam, Mike Nostrand, Tom Parham, Rahul Prasad, Mary Spaeth, Shot Directors and Control Room Operators.
- Support & feedback: testers, configuration management team, system administrators

We're developing an integrated image analysis inspection system for images from 5 areas of the NIF beamline and 3 labs off-line



Main Laser **LOIS** Laser Optic Inspection System

Final Optics Assembly, Transport Optics **FODI** Final Optic Defect Inspection

Target Chamber Window **SIDE** Side-illuminated Defect Evaluation

Precision Diagnostic System **PODI** PDS Optics Damage Inspection

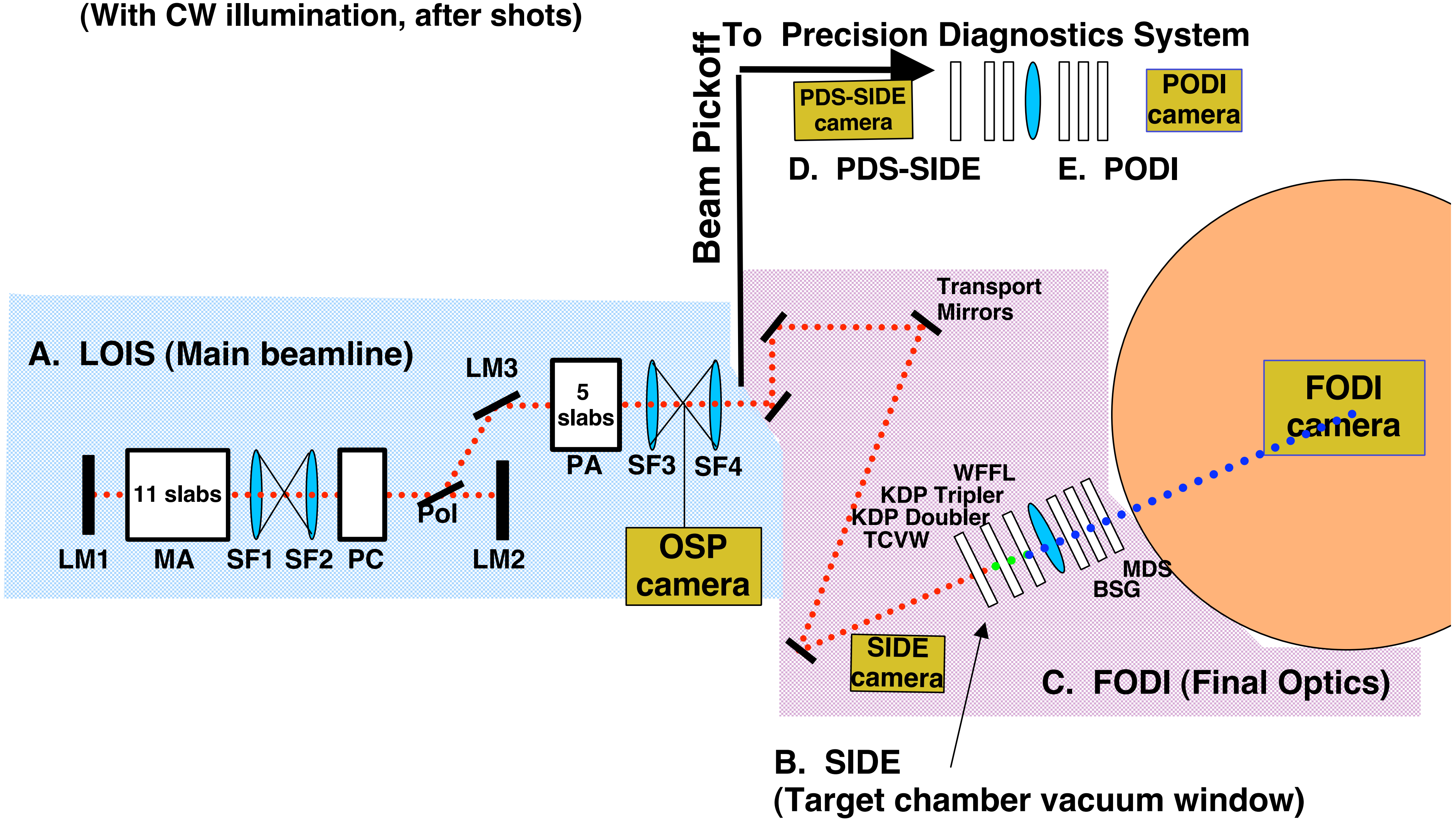
Precision Diagnostic System Vacuum Window **PDS-SIDE**

Thousands of optics must be inspected for quality control and safety

Automated image analysis inspects optics on the beamline

1. **On-the-beamline (single beamline shown x 192 on NIF)**

   (With CW illumination, after shots)

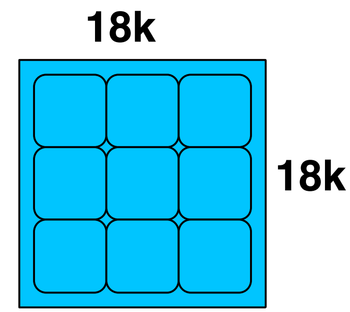


… and off the beamline

2. **Before installation on beamline**

IMS (Inclusion Mapping System)

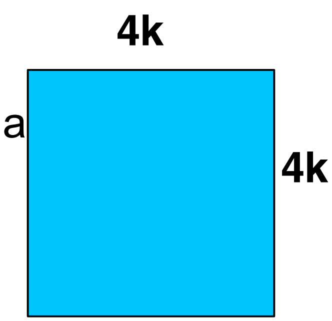
– Checks quality of manufacturing process; inclusions indicate non-dissolved Zirconia or other material)



CIM (Conditioning Initiation & Mitigation)

– Test and condition the optic for increasing laser energies

– Scattering sites are identified and smoother (mitigated) with a CO_2 laser

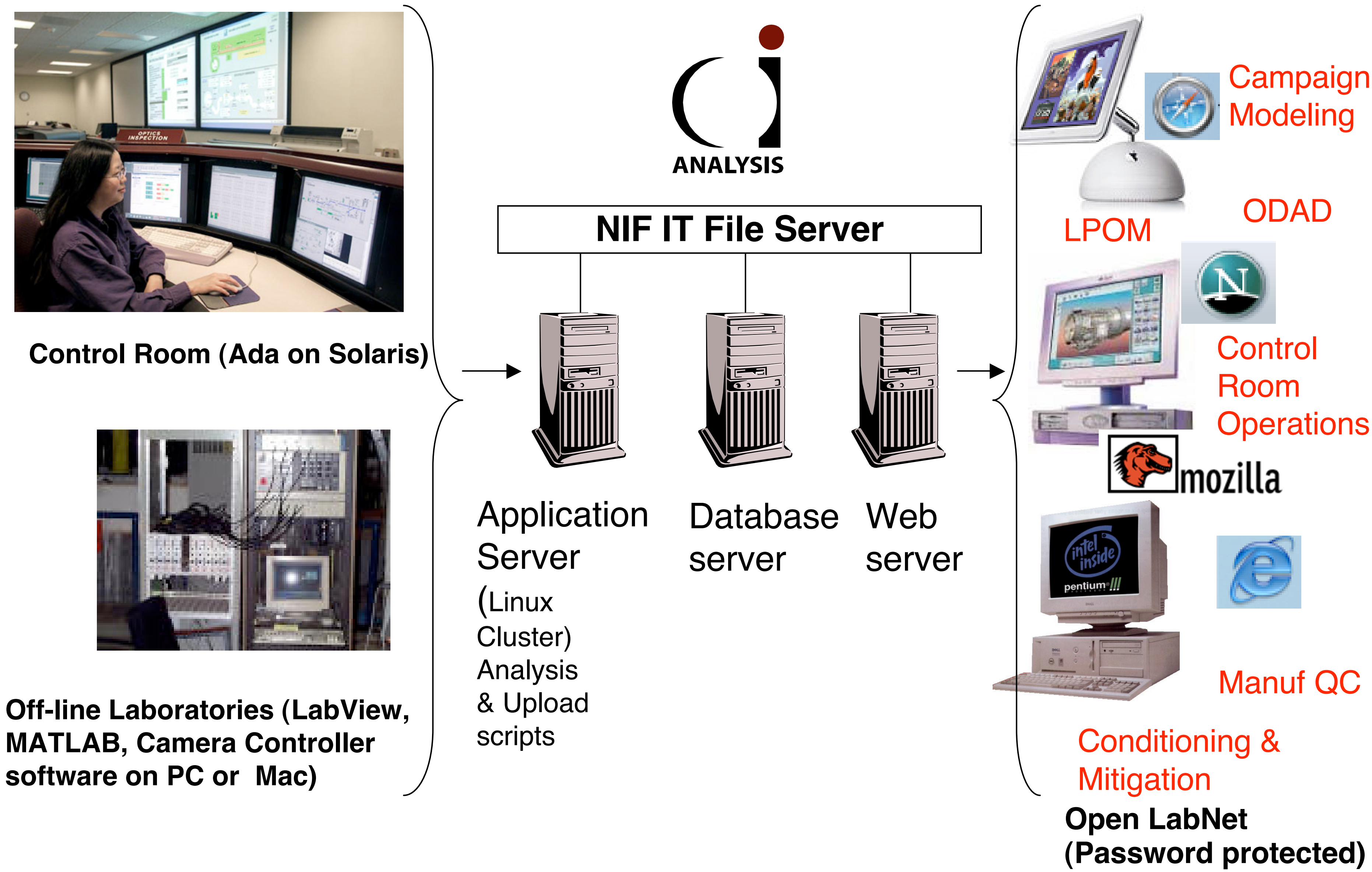


3. **After removal from beamline - “truthing”**

– Image Analysis (similar to above) & Physical inspection on optics removed from beamline provides “truth” for size and location of features

Analysis software provides a unified solution to detect very small imperfections from a variety of inspection systems and track these throughout the life of the optic to ensure quality performance of the laser system.

Our client-server design is a robust and flexible tool that allows many customers to access/display results as needed for many different purposes



Client / Server architecture has many advantages

•Persistent (maintained 24/7)

•Standardized: All authorized users have access to same software, versions and data

•Automated
•Distributed workload
•Scalable

•Web browser allows anyone to generate dynamic queries to view the data of interest

•Test environment mirrors production environment
•Formal Configuration Management - can roll back to previous release
•Testers - confirm new changes and previous results
•Operators can monitor progress through web pages.

•Regression tests

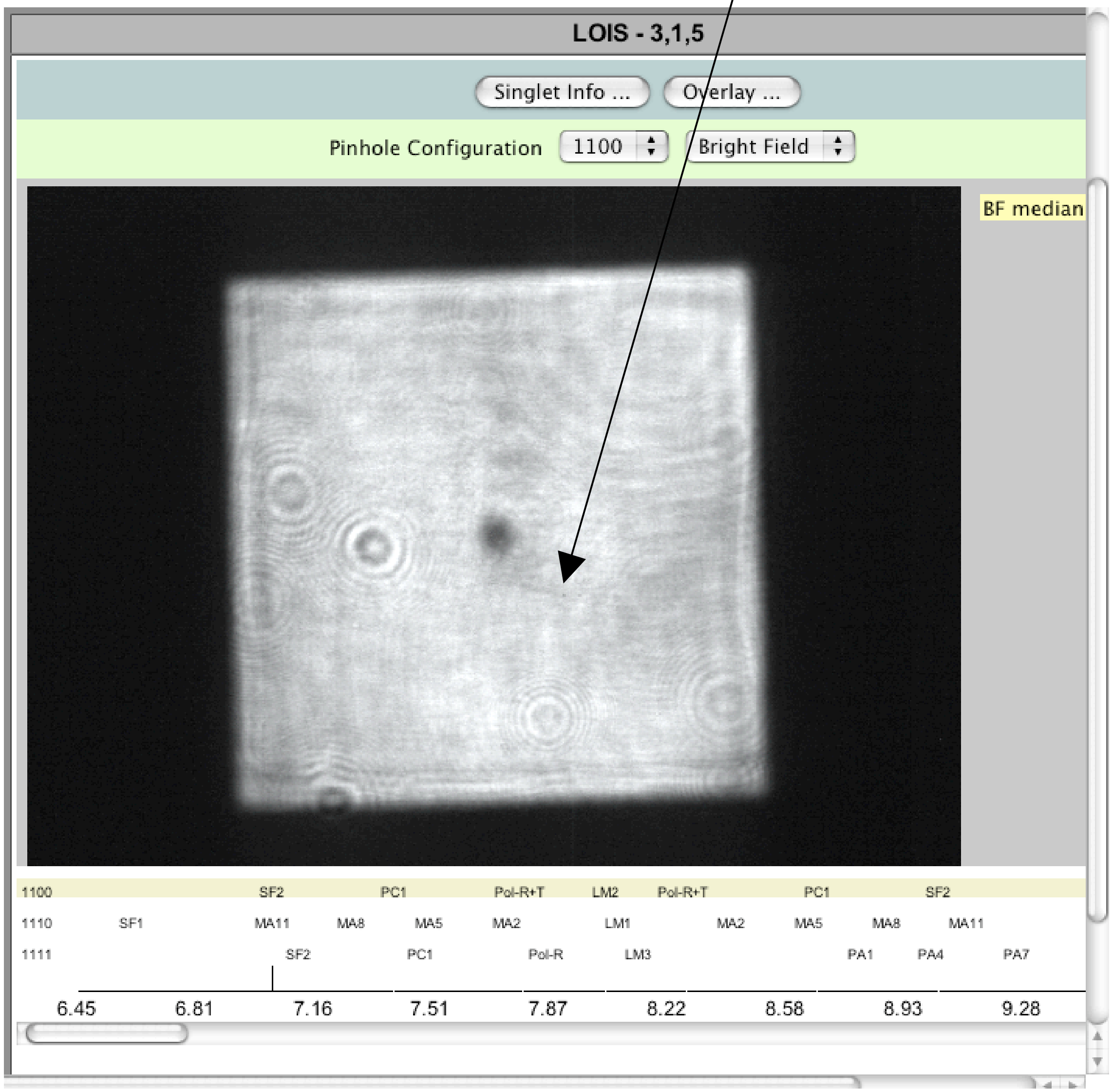
Database allows maximal connectivity, safe storage and flexible retrieval

- Database storage is safer than filesystem; redundancy; back-up
- Transactions are all logged
- Can store all intermediate results in db and make decisions afterwards
- Can produce data summaries independent of image processing/analysis
- Can share data with others
  (We link to NIF-parts db for optics serial numbers)
  (NIF IT ODAD event logs link to our pages and results)
- Must decide image storage: blob vs filesystem

Live database queries via our web browser optimizes flexibility for retrieval and display.

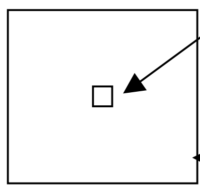
Light scattering sites on the beamline are difficult to see; we must detect the site, identify the optic on which it resides and accurately estimate its size

Real light scattering sight



Our custom algorithm robustly detects sites on optics from a variety of inspection systems

For every pixel in the normalized, background-subtracted image, calculate signal-to-noise ratio (SNR) at various scales:



Sum {signal pixel - test window mean} / Number of signal pixels

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Stdev Background (Test) Window

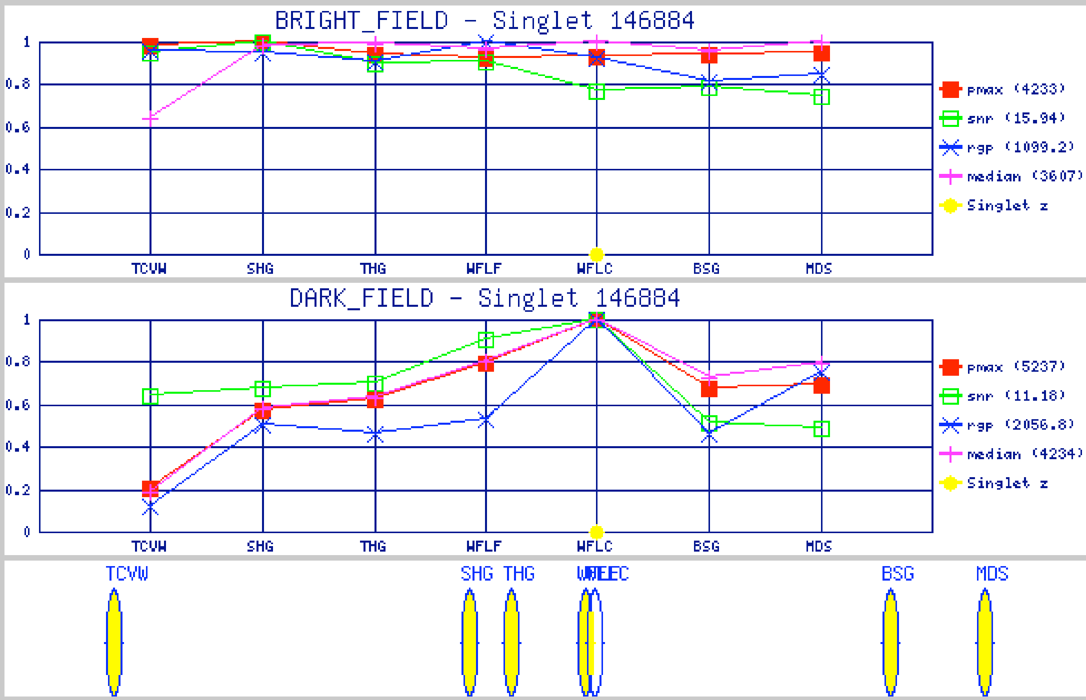
1. **Select pixels over predetermined SNR => seeds**
2. **Revisit each seed and allow it to grow to 75% max intensity**
3. **Compute 17 measurements for each detection**

Marijn Bezuijen will present details on the CSNR / GSNR later in this session.

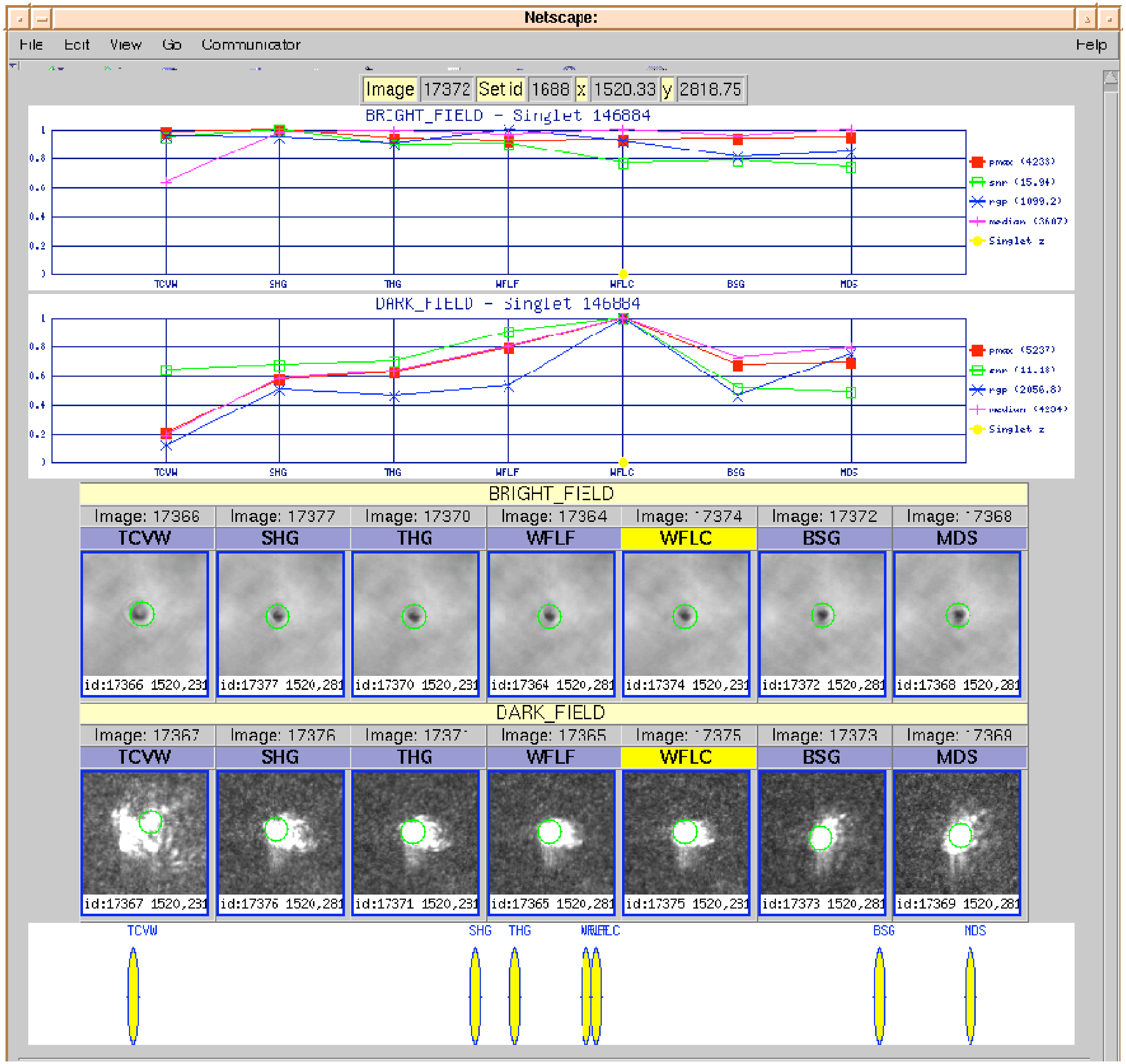
For each detection, compute edge strength, SNR, and max and median pixel intensity per focal plane to find best focus and thus most likely optic- or z-position

FODI:
Final Optics

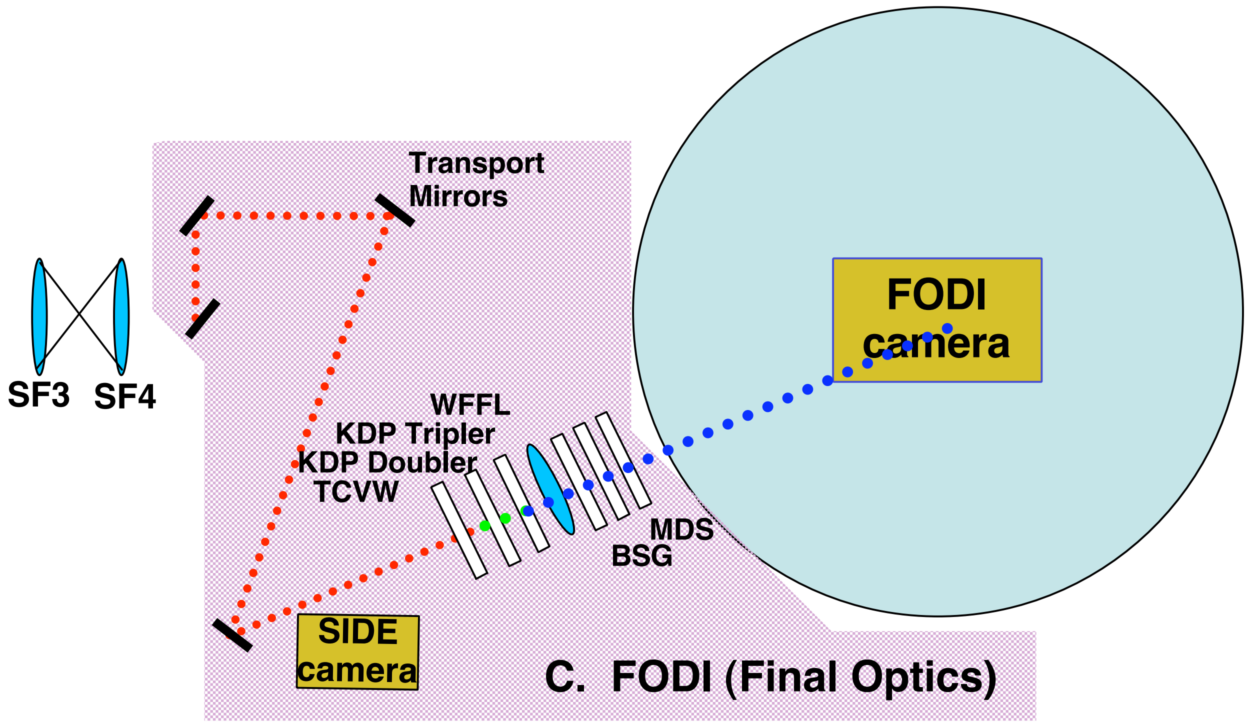
Detection: **271852**									
Area	PMAX	SNR	RGP	Cgintx	Cginty	Laxis	Saxis	Angle	Image Id
24	3961	12.6	888.43	1520.33	2818.75	2.973	2.587	4.429	17372



View mosaic (Single date – all focal planes)
View mosaic (All dates – single focal plane)
View defect at full resolution
Defect Details


Netscape:
File Edit View Go Communicator Help
Image 17372 Set id 1688 x 1520.33 y 2818.75
BRIGHT_FIELD - Singlet 146884
pmax (4233)
snr (15.94)
rgp (1099.2)
median (3607)
Singlet z
TCVW SHG THG WFLF WFLC BSG MDS
DARK_FIELD - Singlet 146884
pmax (5237)
snr (11.18)
rgp (2056.8)
median (4234)
Singlet z
BRIGHT_FIELD
Image: 17366 Image: 17377 Image: 17370 Image: 17364 Image: 17374 Image: 17372 Image: 17368
TCVW SHG THG WFLF WFLC BSG MDS
id:17366 1520,281 id:17377 1520,281 id:17370 1520,281 id:17364 1520,281 id:17374 1520,281 id:17372 1520,281 id:17368 1520,281
DARK_FIELD
Image: 17367 Image: 17376 Image: 17371 Image: 17365 Image: 17375 Image: 17373 Image: 17369
TCVW SHG THG WFLF WFLC BSG MDS
id:17367 1520,281 id:17376 1520,281 id:17371 1520,281 id:17365 1520,281 id:17375 1520,281 id:17373 1520,281 id:17369 1520,281
TCVW SHG THG WFLF WFLC BSG MDS

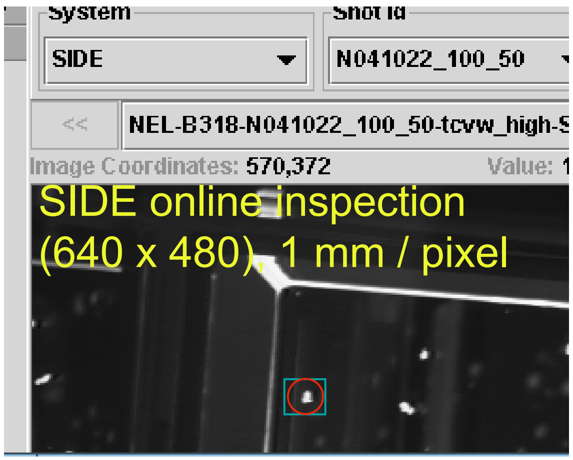
In order to do this, we must first register the stack of 32 MB images, by correcting magnification, rotation and shift.

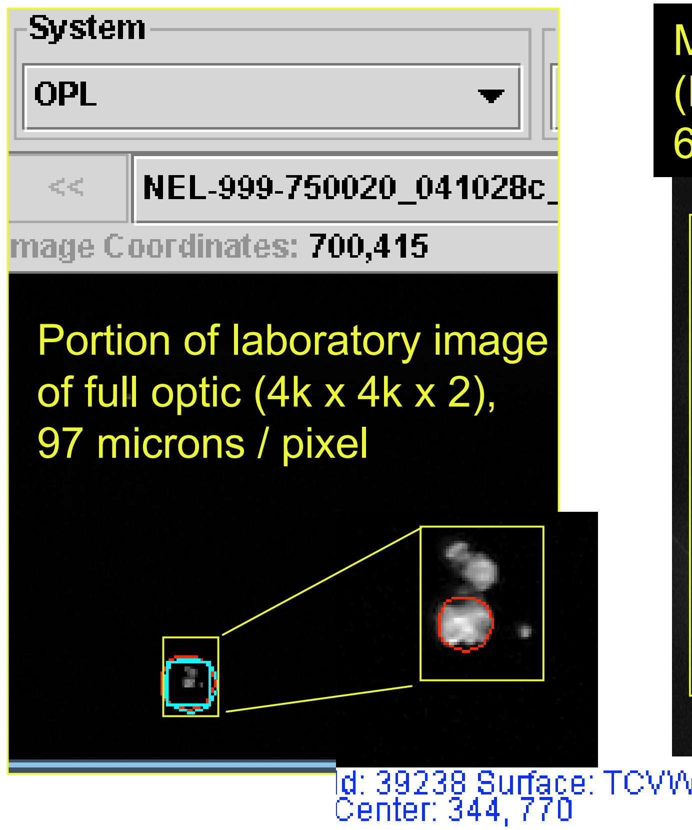


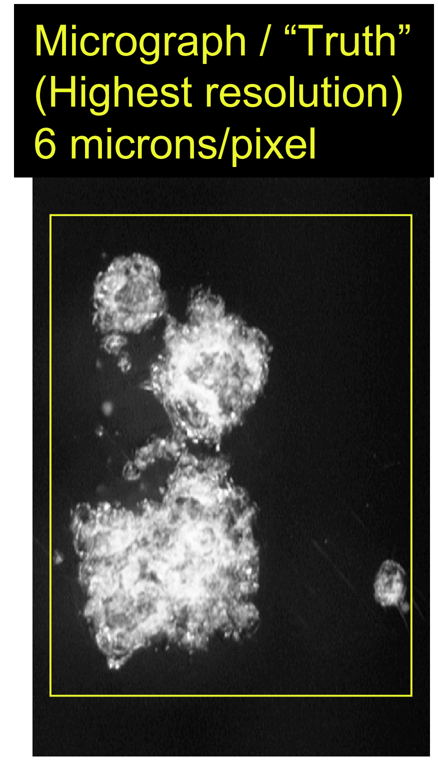
- Mostly non-overlapping sets of defects on closely spaced optics
- Large magnification changes on distantly spaced optics

Judy Liebman will present details on registration later in this session.

Currently: Adding capability to calibrate and validate on-line inspection systems with laboratory “truth” data (micrographs)



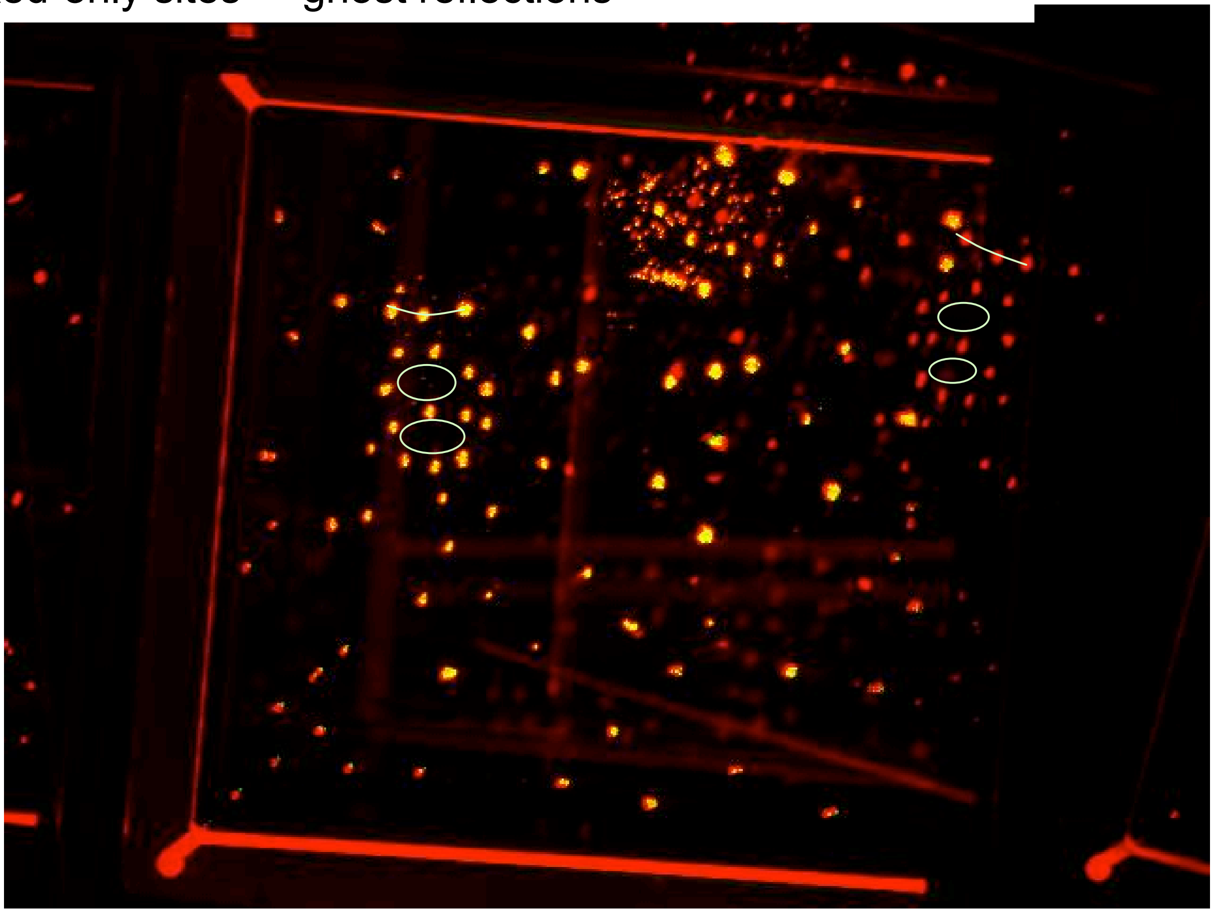




In the future, optics removed from beamline will undergo laboratory inspection, which we can use to continually calibrate our on-line analysis software.

A test optic with manually induced sites can help us train our software to recognize ghost reflections for a side-illuminated final optic.

- Yellow = green + red → real sites (manually induced)
- Red-only sites = ghost reflections



OI Analysis is preparing for terabytes, petabytes

1. The Signal-to-Noise based detection algorithm is the core of our system and is robust enough to be effective on images from various inspection systems, all with different illumination, resolution, etc.

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

3. Web-based visualization allows each customer to review results appropriately via dynamic database queries, from any browser.

4. Laboratory “truth” data will allow us to verify performance (true positive and false alarm rates) and size calibration to meet requirements.