Actinic inspection of EUV masks at the Advanced Light Source, Berkeley

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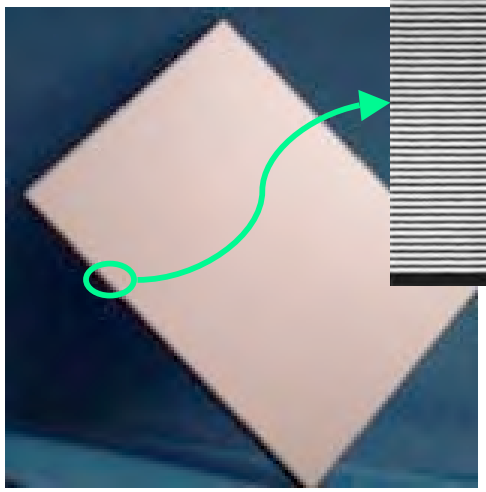
Actinic inspection of multilayer coated EUV masks at the Advanced Light Source, Berkeley

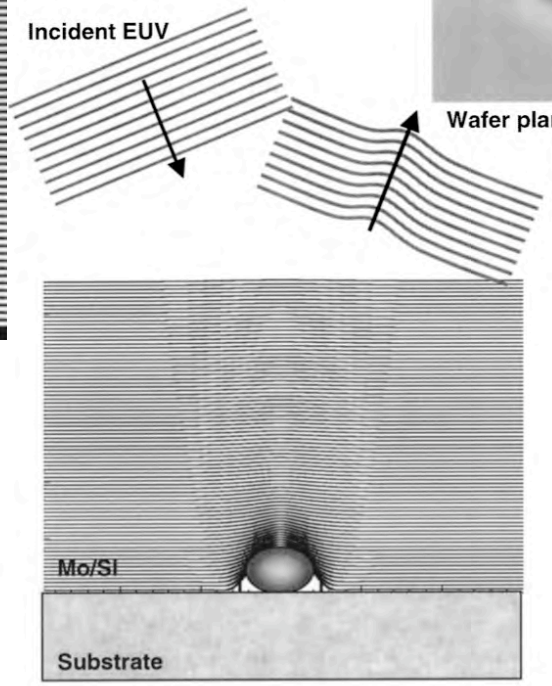
- We have a unique tool at the ALS that provides:
  - *EUV mask imaging*: emulation of printing behavior
  - *EUV mask scanning*: high speed defect detection
- A key project goal is the validation of light scattering methodology for EUV mask defect detection
- Provides at-wavelength mask imaging and inspection capability
- Funding from SEMATECH

The supply of defect free mask blanks remains a key risk area for EUVL

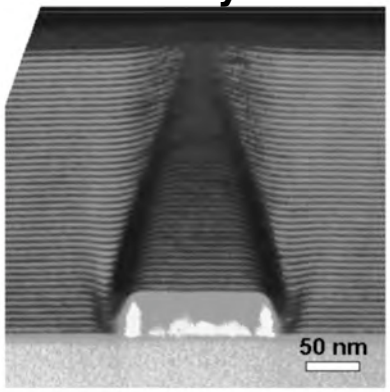
Mask blank



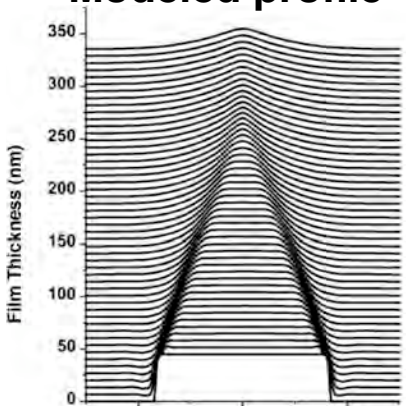
Multilayer coating



Actual multilayer defect



Modeled profile

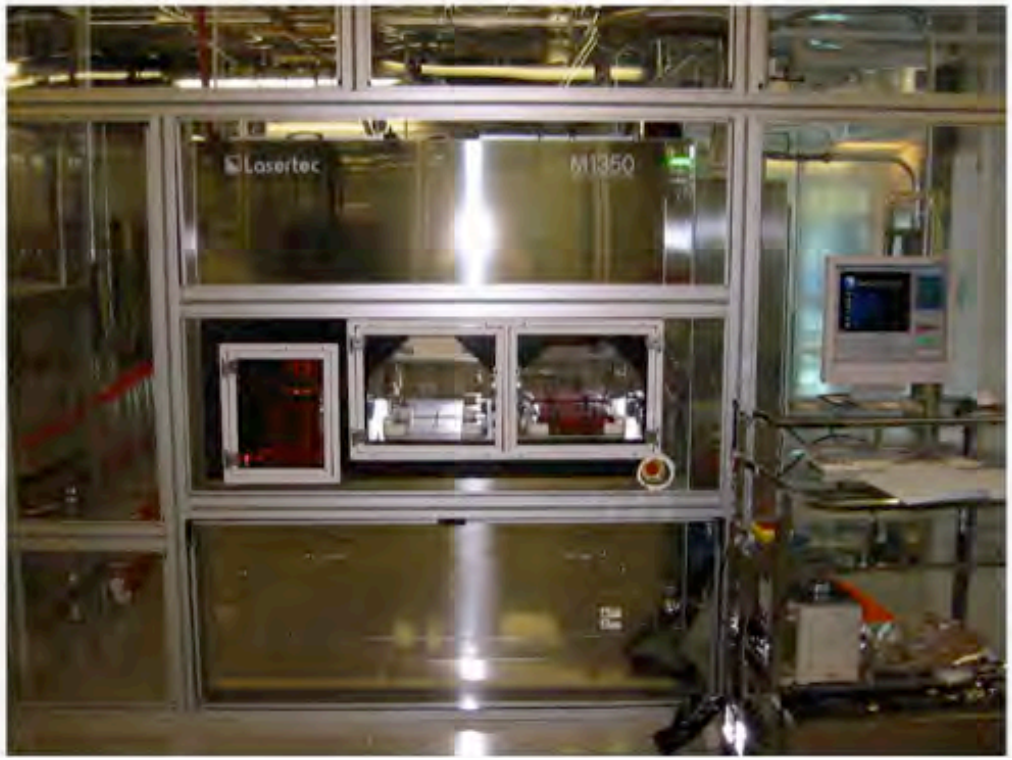


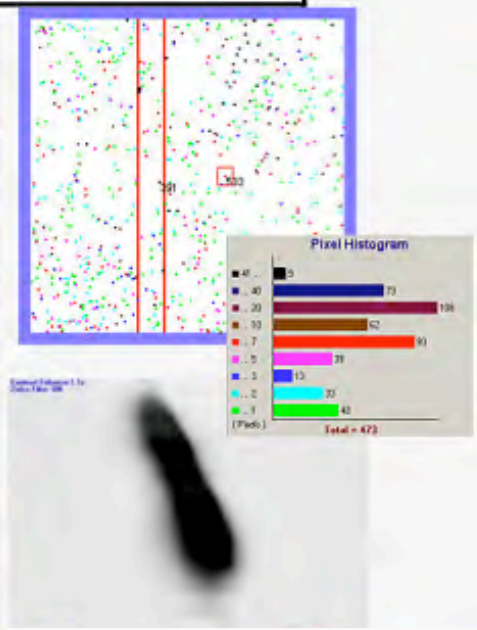
- Inspecting one mask for defects is akin to finding 2–3 randomly placed 600-μm-wide, 30 μm high dots somewhere in a 1 mile square area with no prior knowledge of their location
- Inspection must take a reasonable time (days, not years); 100% success rate required

Industry plans to use laser-based defect inspection systems for high-speed qualification of mask blanks

For example: ***Lasertec M1350***

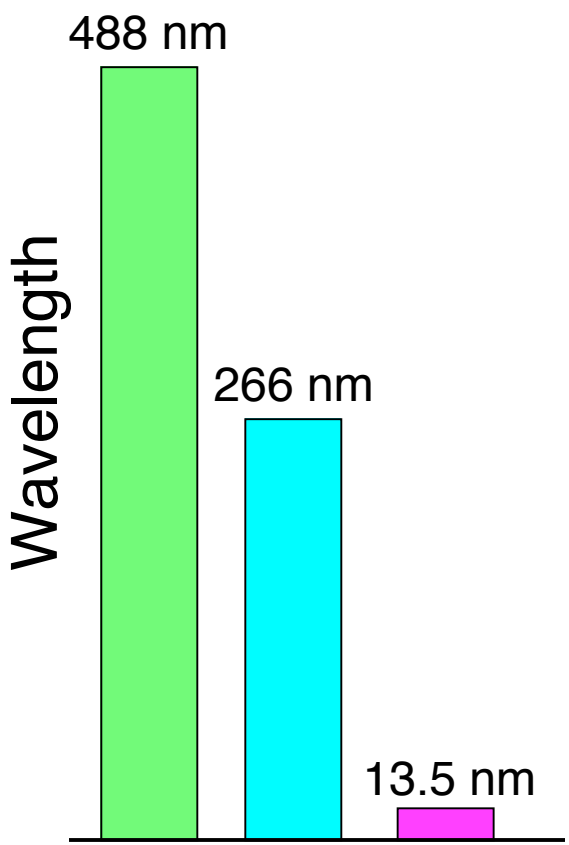
Purpose	**Measure defect density on mask blanks or substrates**
Capability	**60nm (PSL equivalent) on quartz, 80nm on ML (extending capability in late 2004)**
Usage	**In-line and end-of-line metrology**

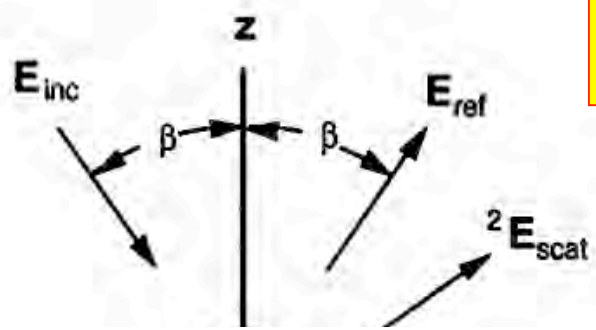


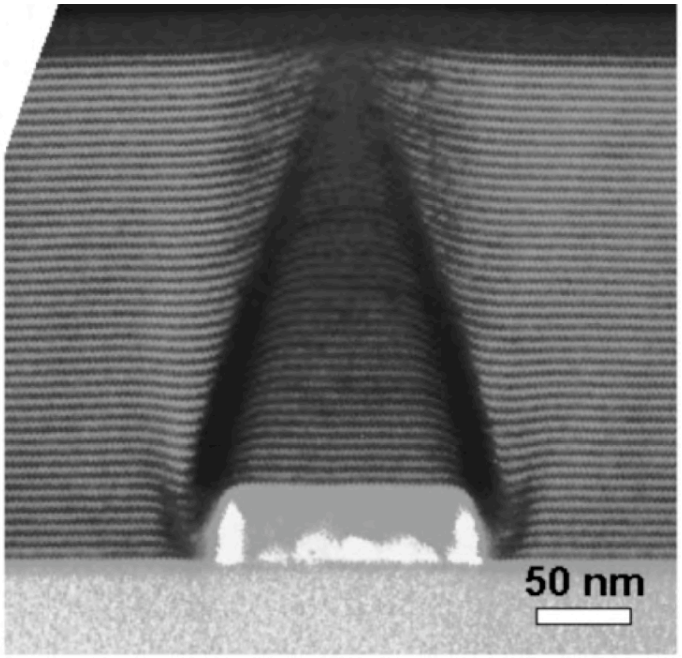


The key question is: Can visible light scattering be used to reliably detect all multilayer defects?

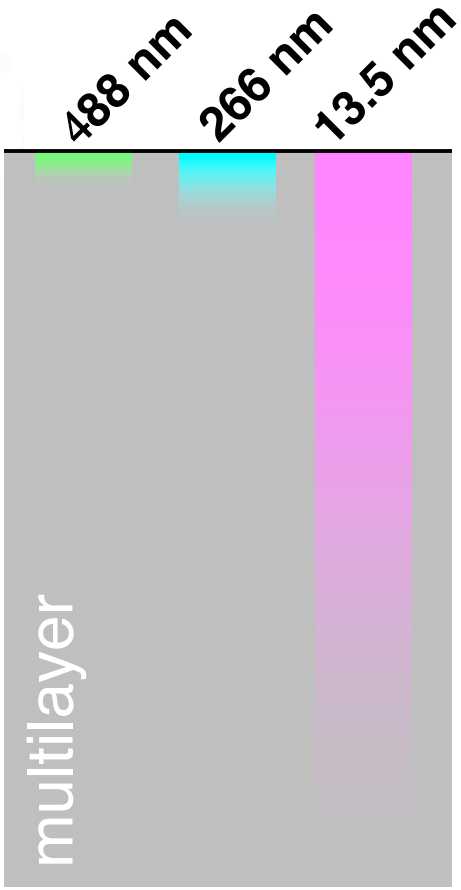
Scattering amplitude typically varies as $\sim\lambda^{-4}$







EUV penetrates the multilayer structure



Validation of laser-based mask inspection is a key goal of this project

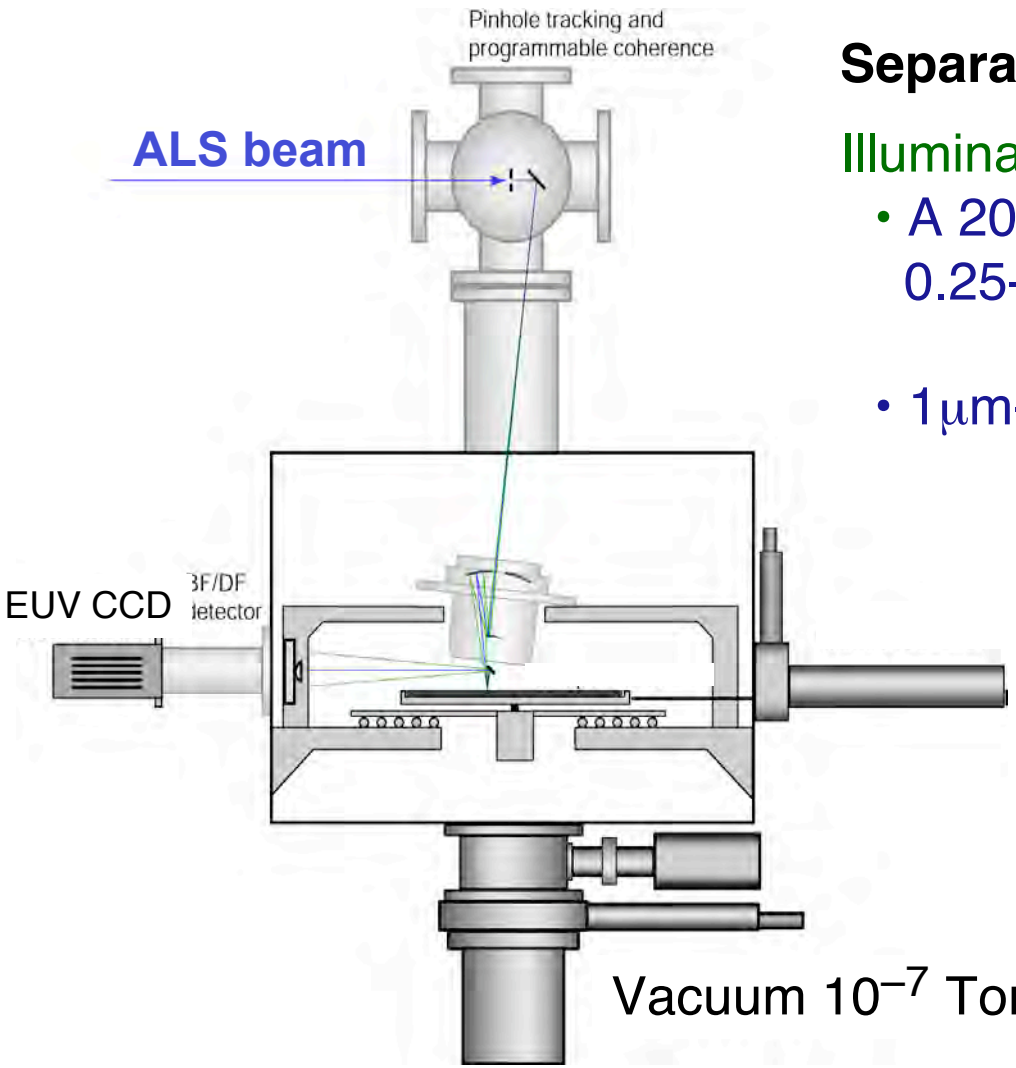
Key questions for tool validation:

- Can a non-EUV inspection system find all printable EUV defects?
- Is the defect detection rate of laser-based scattering tools adequate?
- Will inspection tools be able to ensure an acceptable yield of delivered, useable mask blanks?

To answer this question:

- You can only obtain an answer by printing or by EUV inspection
- The answer depends on the specific mask design, and inspection tool used.

Dual mode inspection system incorporates high-speed scanning and an imaging defect review microscope



Separate Scanning and Imaging modes

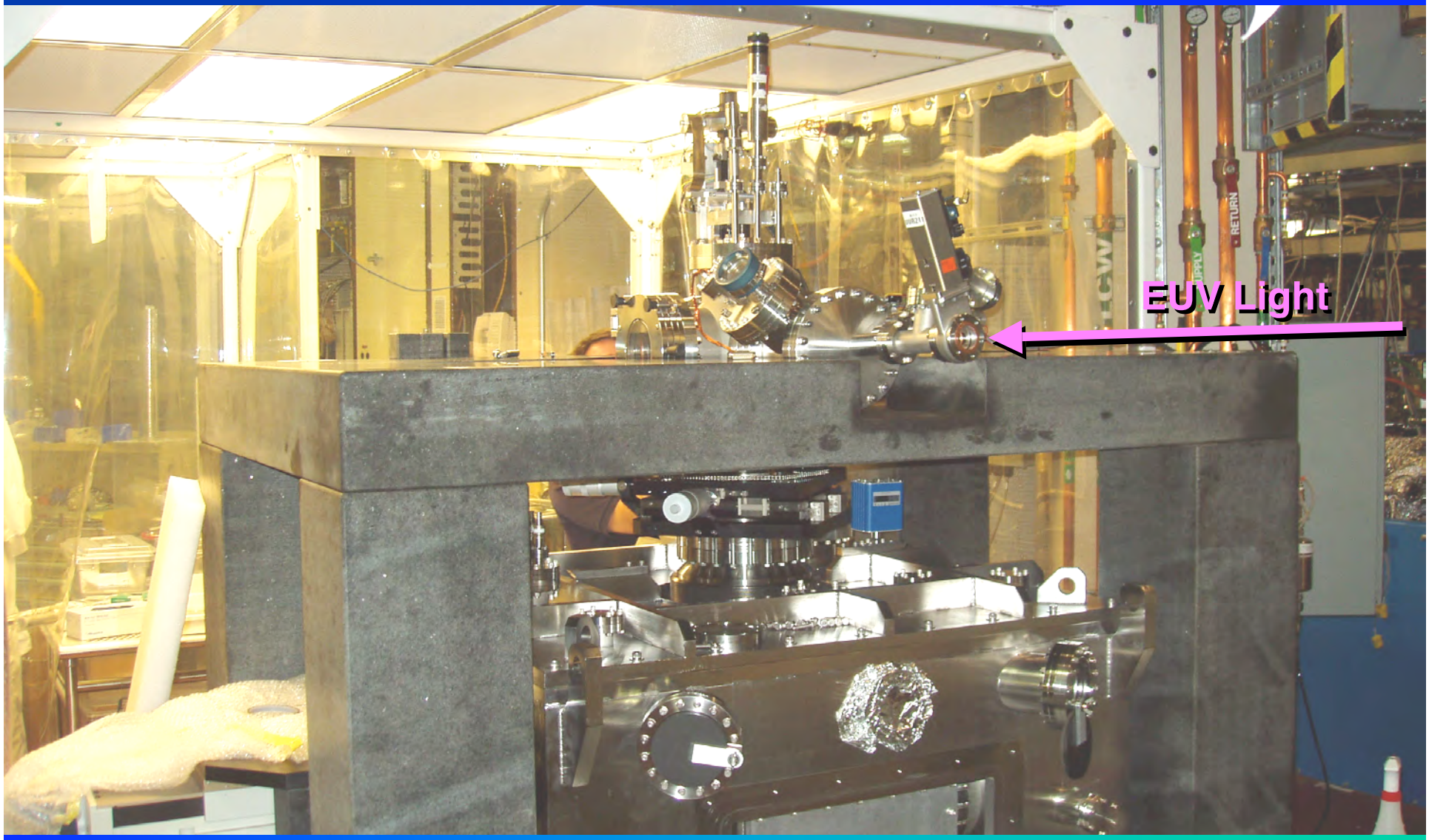
Illumination Optics:

- A 20x Schwarzschild emulates a 0.25-NA EUVL Stepper
- 1μm-diameter spot on mask

Manual load-lock
for Reticle exchange

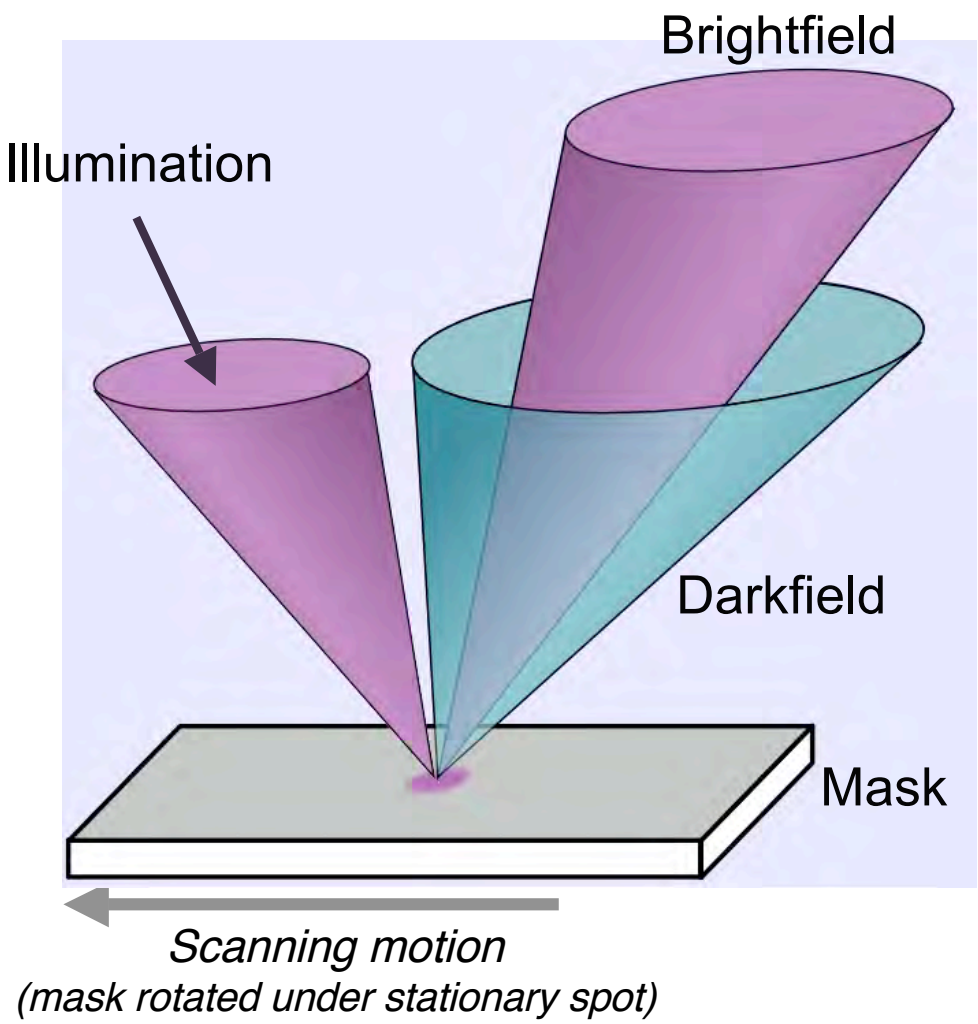
Vacuum 10^{-7} Torr

Our dual-mode EUV mask inspection system is installed at Berkeley's Advanced Light Source (ALS)



Anton Barty
October 20, 2005

High-speed scanning inspection mode collects both brightfield and darkfield signals to disk in real time



Scanning Spot:

- 1μm diameter spot on mask
- 0.1 to 2cm^2/hr Scan Speed
- 10 μm or better defect location across a 6" square reticle

High Speed Detectors:

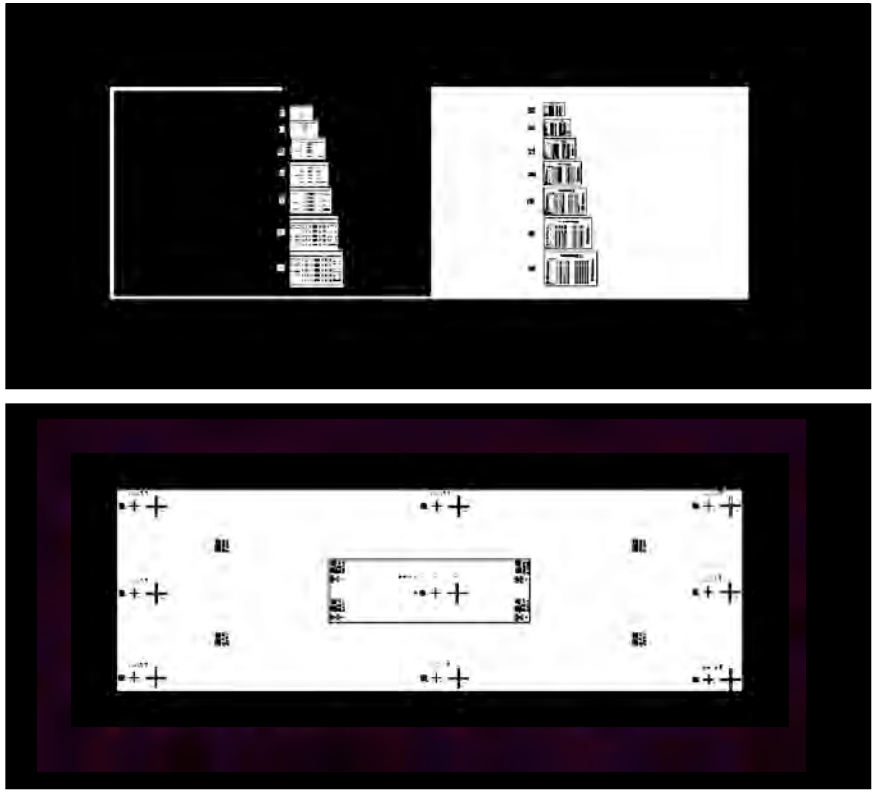
- Brightfield: Photodiode
- Darkfield: Micro-Channelplate

  Up to 100 kHz data collection *saved in real-time*

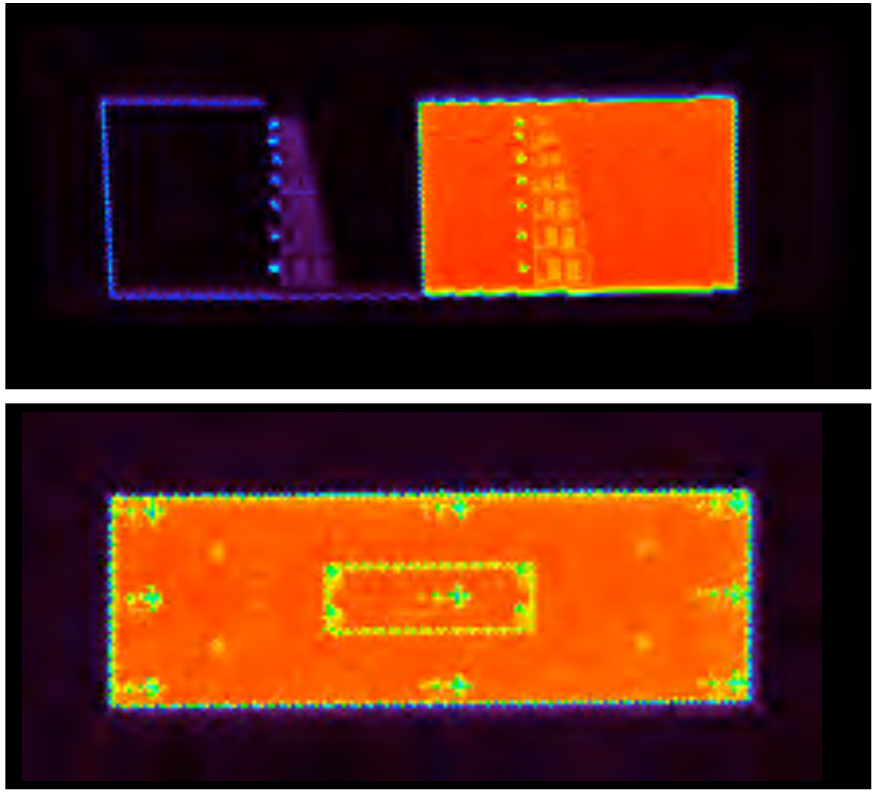
500 cm^2 Scanned in 3 Weeks

Scanning mode can be used to identify features and coordinates for microscope review

Mask patterns from design



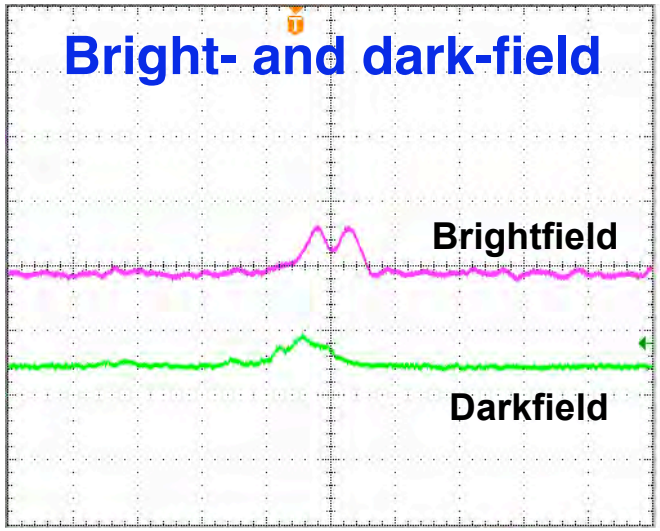
At-wavelength scans

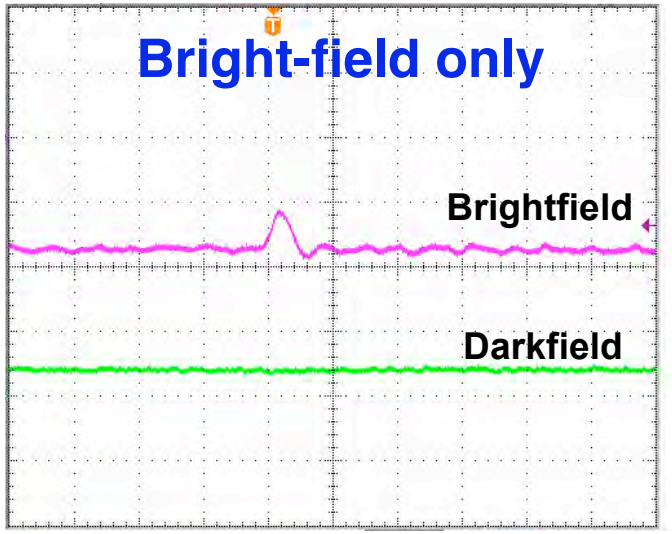


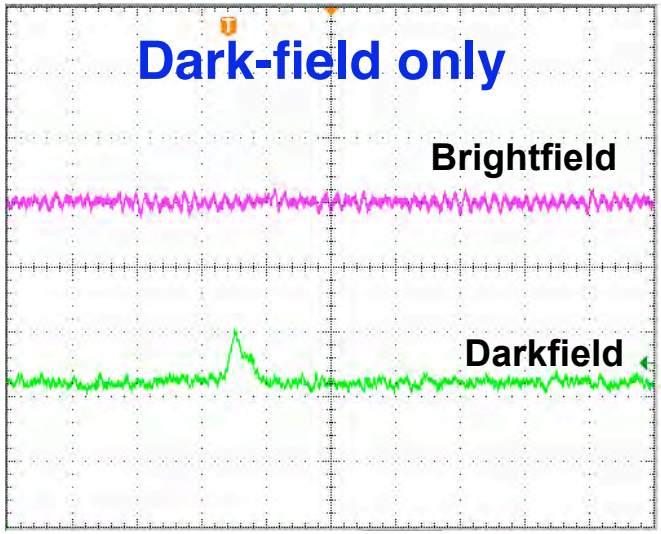
3x1 mm fields

We have observed that some defects appear in both channels, whilst others appear on one channel or the other

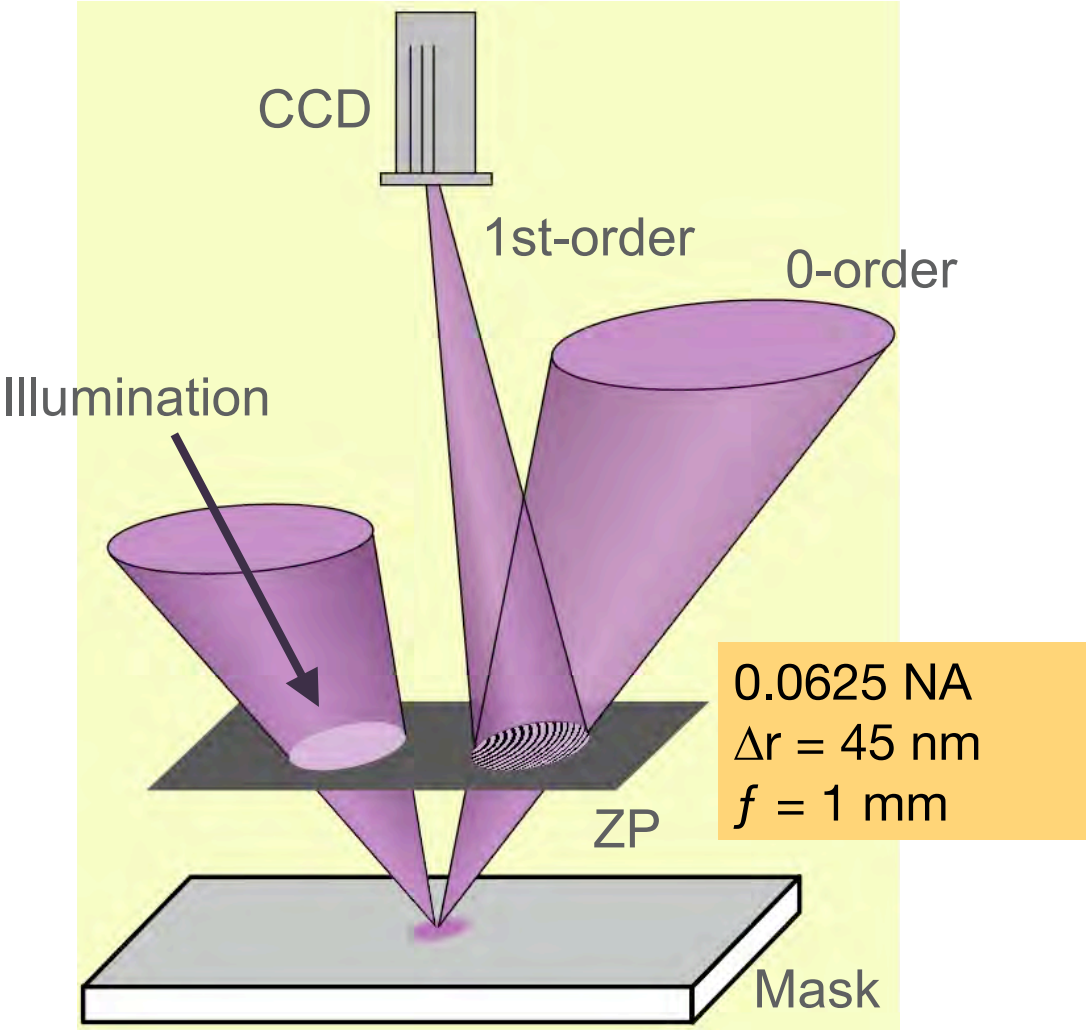
- Scanning mode signals reveal different bright-field and dark-field signatures for different types of defects.
- Review mode may help understand the differences.



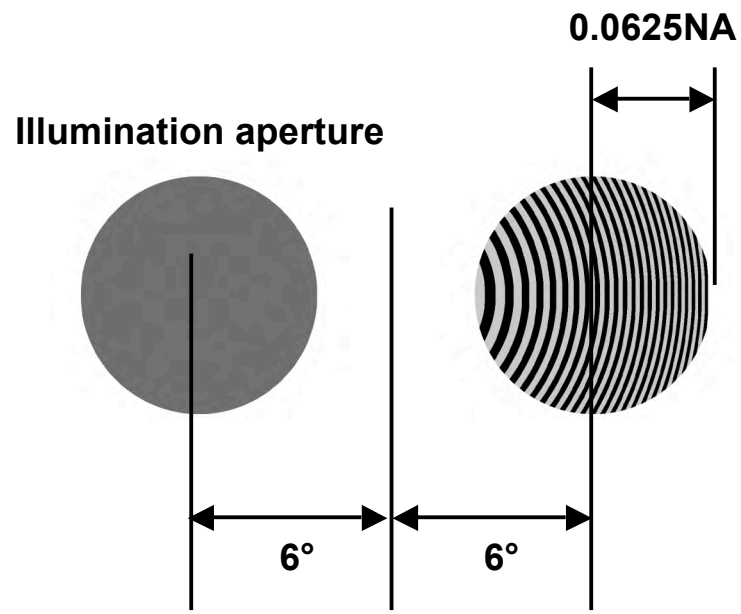




Zone plate microscope (600–1000x magnification) used for at-wavelength defect imaging and review



Zone plate for defect review imaging



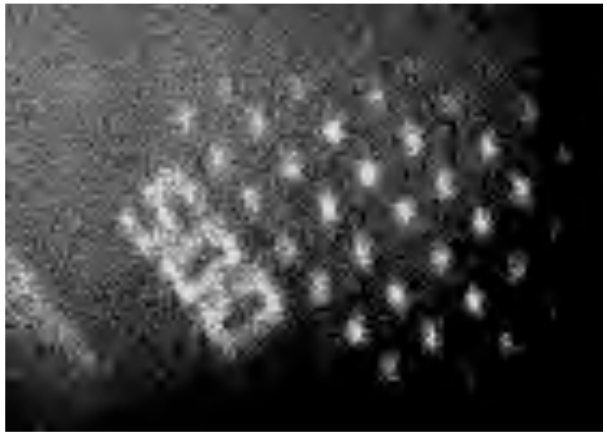
Emulates 0.25 NA EUVL stepper

5 μm field of view
(1340x1024 pixels)

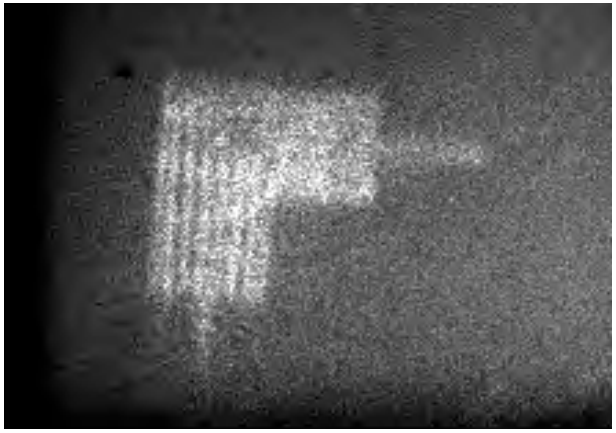
5 sec – 1 min exposure time

Tool's first zone plate microscope images were recorded 22 September, 2005

Resolution Test Patterns from a MET mask



Contacts
(200nm printed)



Elbows
(70-80nm printed)

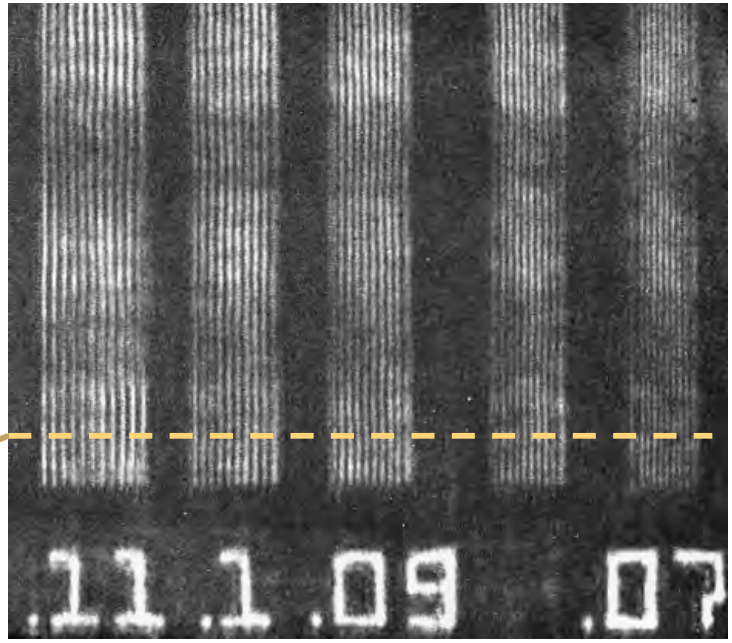
Star pattern

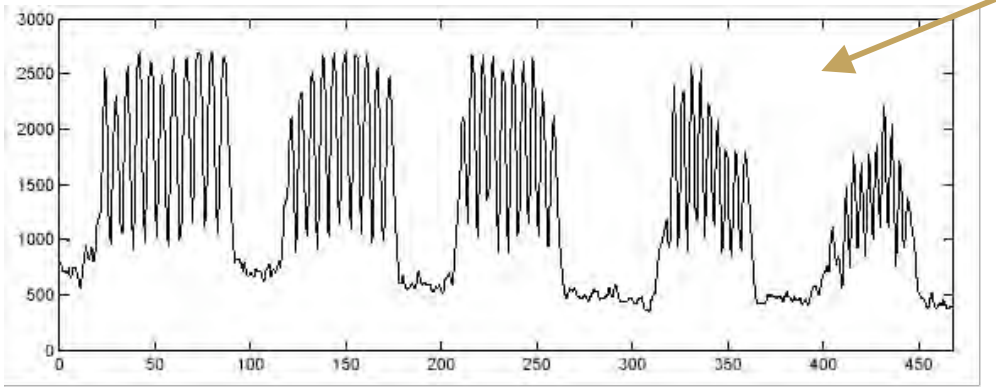
Early demonstration of 80-nm resolution (on the mask) using an EUV zone plate microscope.

Proof-of-principle experiments, 2003

250 nm – 175 nm at mask
62 nm – 44 nm at wafer

110 nm – 70 nm at the mask
27.5 nm – 17.5 nm at the wafer





Lineout shows 80-nm dense lines resolved

Unique EUV mask inspection capabilities at the ALS, Berkeley is coming online now

We have a unique tool at the ALS that provides:

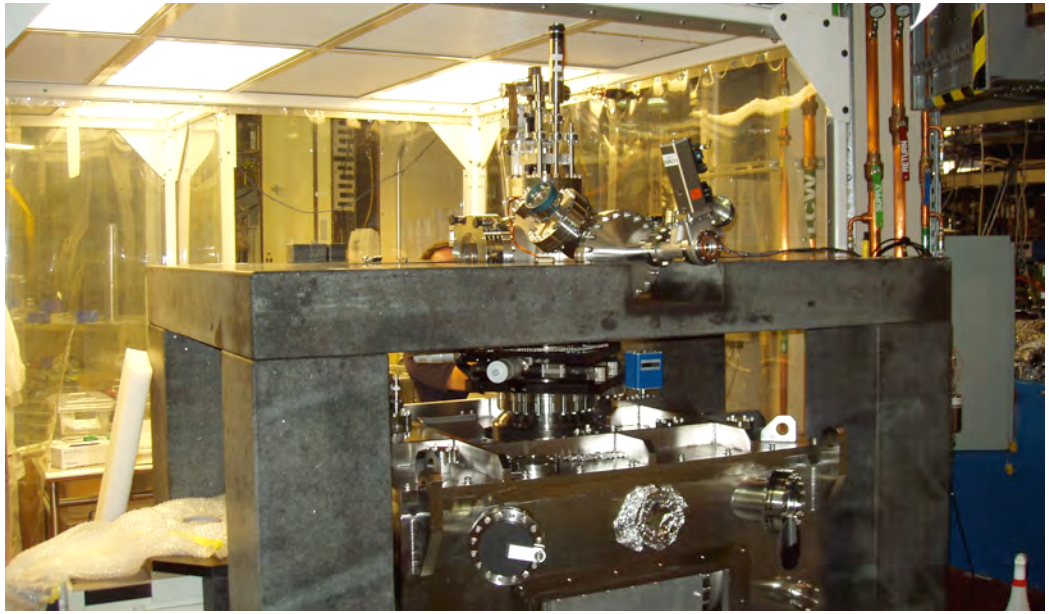
– *EUV mask imaging*: emulation of printing behavior

– *EUV mask scanning*: high speed defect detection

- System installed at the ALS

- First images recently acquired

- Goal is to validate defect detection methodology



This project is a combined effort spanning SEMATECH, Lawrence Livermore and Lawrence Berkeley National Labs

SEMATECH

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  project manager

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LBNL

- Yanwei Liu
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- Eric Gullikson
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- Ron Tackaberry
- J. Alexander Liddle
- C. Drew Kemp
- Paul Barale
- …and the CXRO team

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- Jay Ayers
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- David Thompson
- Jeff Budd
- Jeff Rosino

The end

Thank–you

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