

Lawrence Berkeley National Laboratory

LBL Publications

Title

Berkeley MET5 enters mature phase of research

Permalink

<https://escholarship.org/uc/item/4wv5s0h4>

Author

Anderson, Christopher N

Publication Date

2022-11-11

DOI

10.1117/12.2643076

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at

<https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

Berkeley MET5 enters mature phase of research

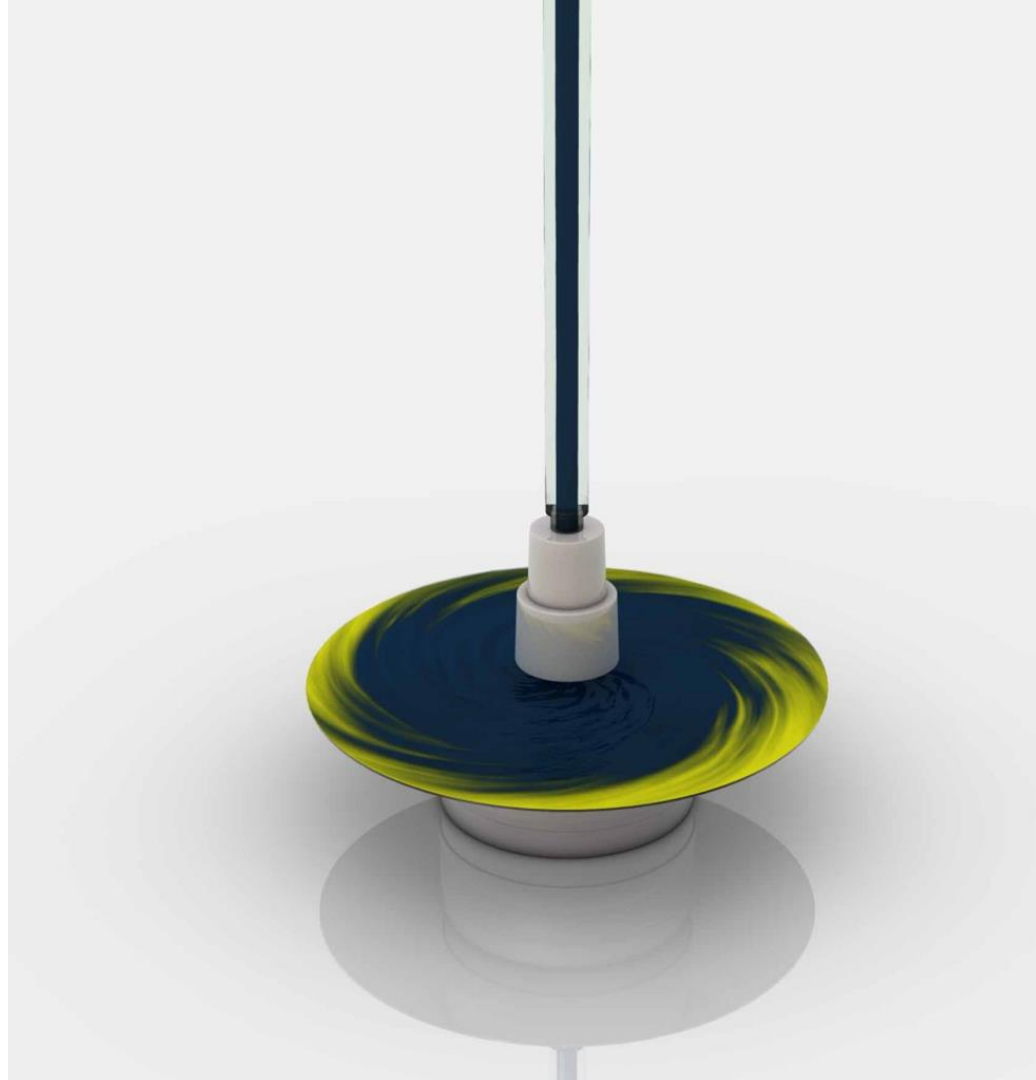
Arnaud Allezy, **Chris Anderson**, Weilun Chao, Carl Cork, Will Cork, Rene Delano, Jason DePonte, Michael Dickinson, Geoff Gaines, Jeff Gamsby, Eric Gullikson, Warren Holcomb, Martin Izquierdo, Gideon Jones, Ryan Miyakawa, Patrick Naulleau, Seno Rekawa, Farhad Salmassi, Brandon Vollmer, Jinyuan Yan, Daniel Zehm, Wenhua Zhu, Farid Zuberi.



Research areas

Research areas

EUV materials & process

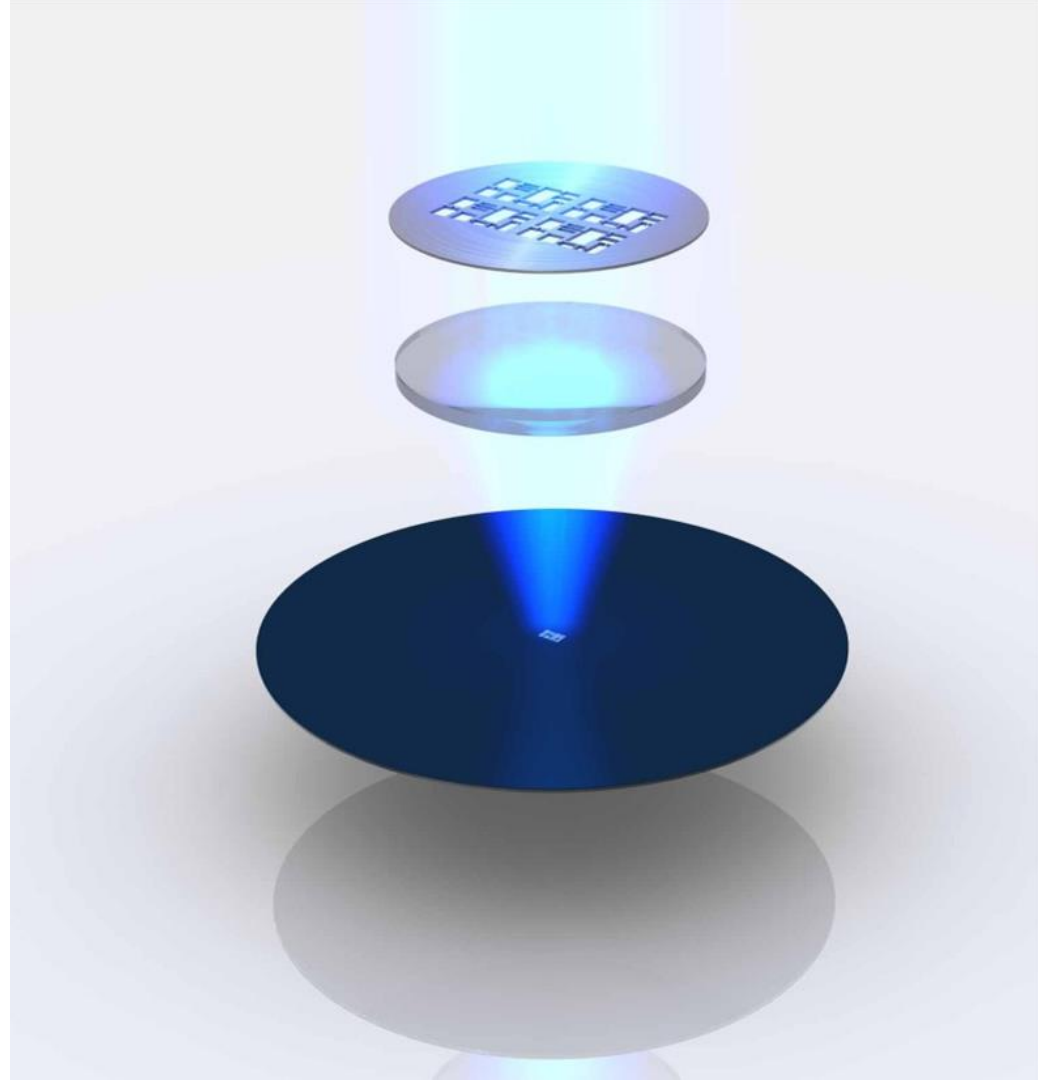


Research areas

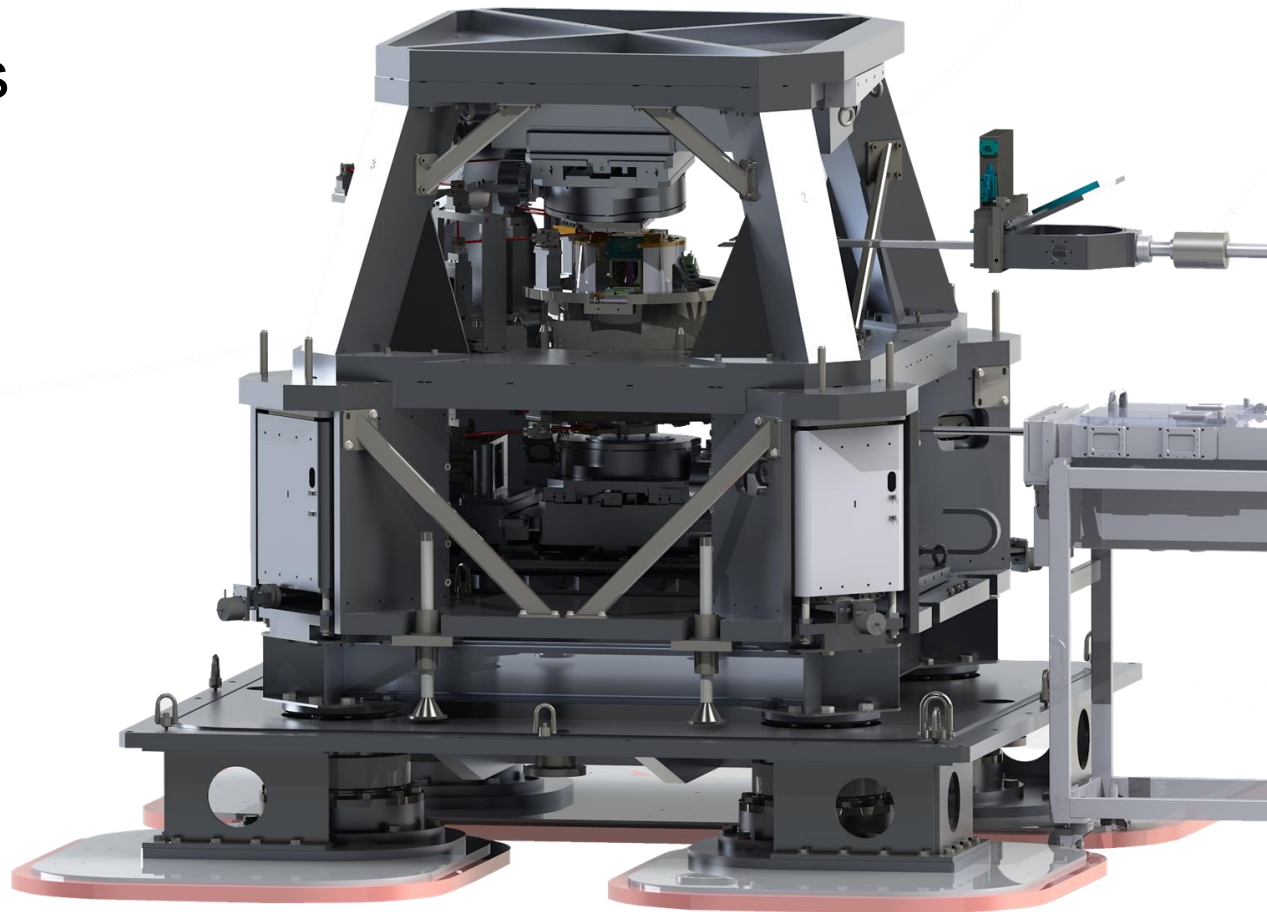
EUV materials & process

0.5-NA Imaging

- Image modeling validation
- Polarization effects
- Reduced depth of focus



Features & benefits



Features & benefits

Synchrotron light source

- Linearly polarized in X
- 1/100 spectral purity



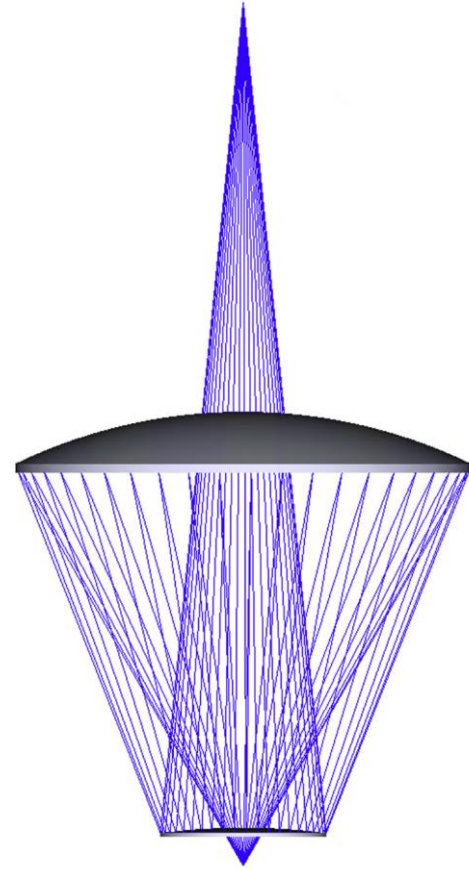
Features & benefits

Synchrotron light source

- Linearly polarized in X
- 1/100 spectral purity

0.5 numerical aperture

- Aspheric Schwarzschild



Features & benefits

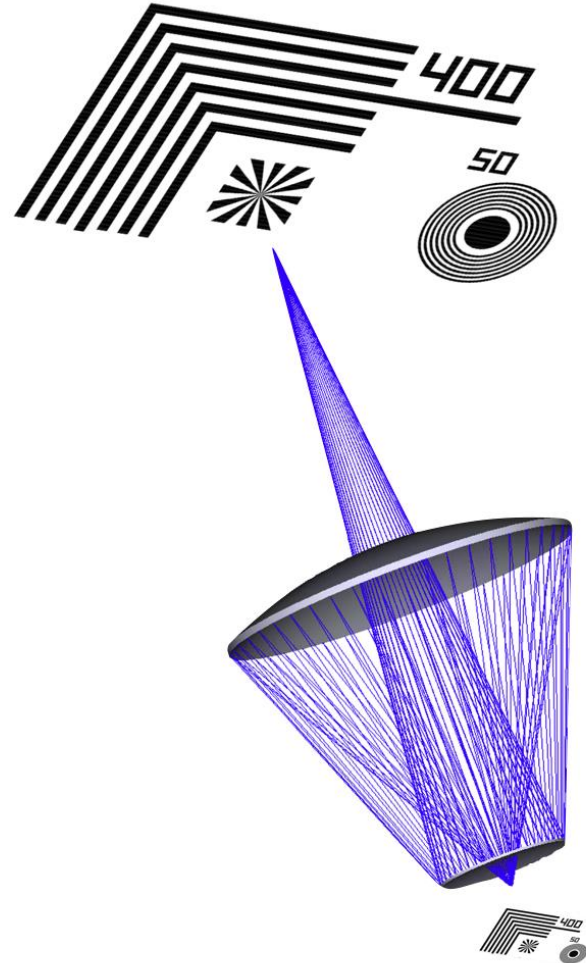
Synchrotron light source

- Linearly polarized in X
- 1/100 spectral purity

0.5 numerical aperture

- Aspheric Schwarzschild

5X demag



Features & benefits

Synchrotron light source

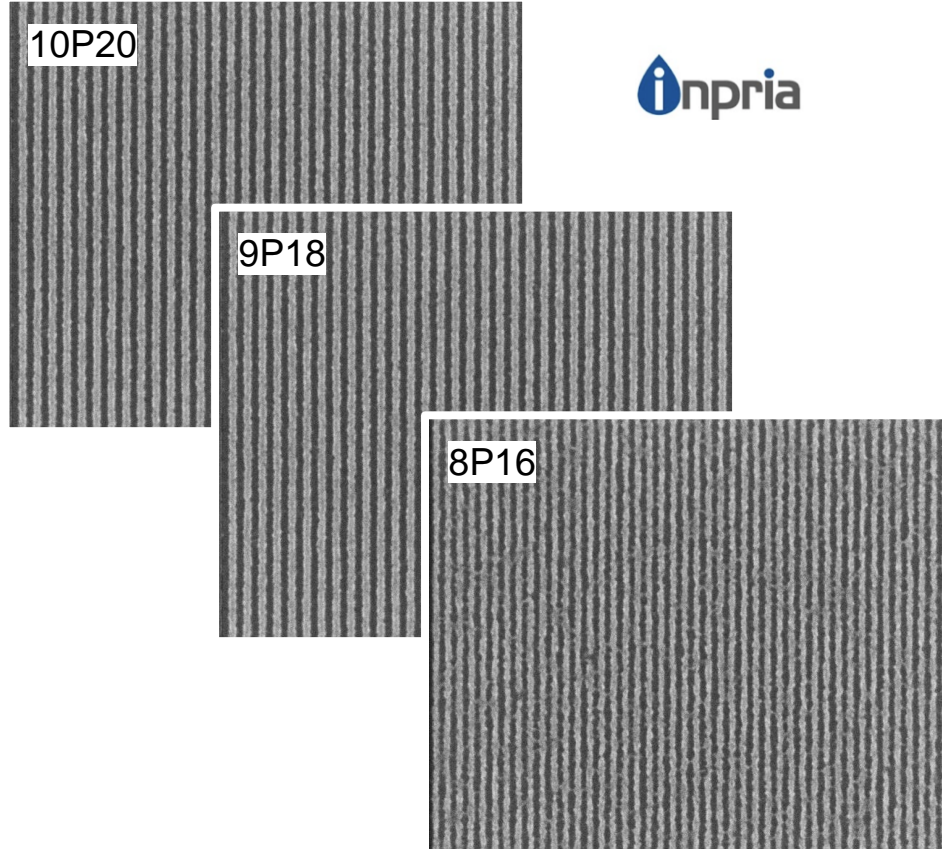
- Linearly polarized in X
- 1/100 spectral purity

0.5 numerical aperture

- Aspheric Schwarzschild

5X demag

9 nm resolution proven



Features & benefits

Synchrotron light source

- Linearly polarized in X
- 1/100 spectral purity

0.5 numerical aperture

- Aspheric Schwarzschild

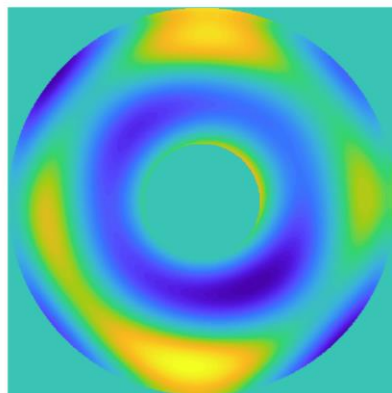
5X demag

9 nm resolution proven

$\lambda/43$ wavefront error

- Measured with built-in EUV shearing interferometer
- Substrate is $\lambda/58$

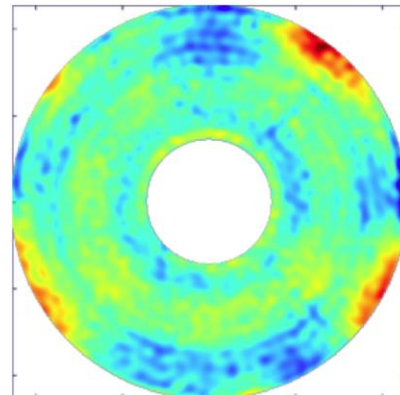
AFTER ALIGN



0.31 nm

RMS wavefront error

SUBSTRATE

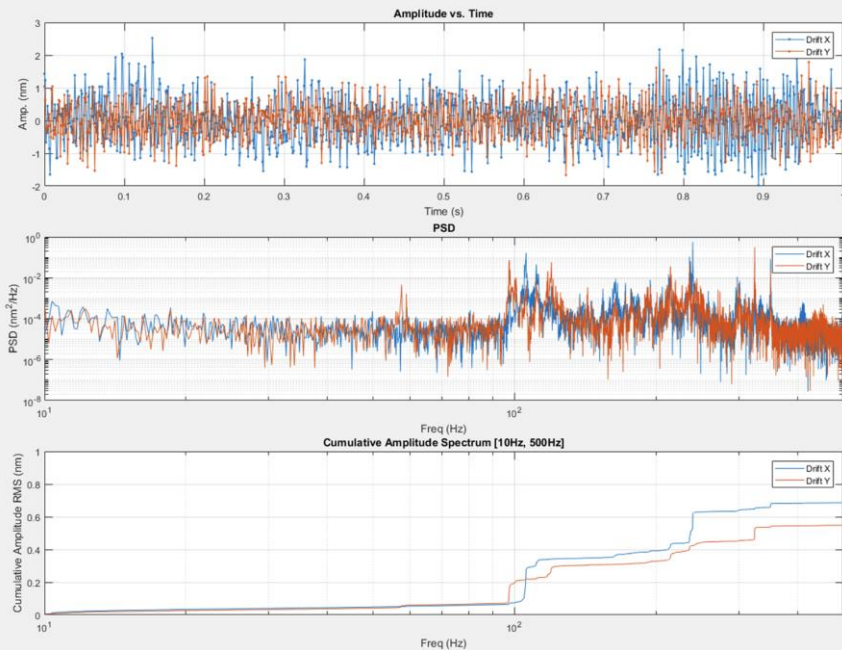


0.23 nm

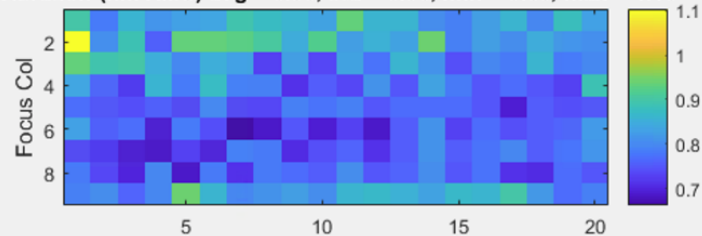
RMS wavefront error

Features & benefits (cont.)

0.8 nm image stabilization



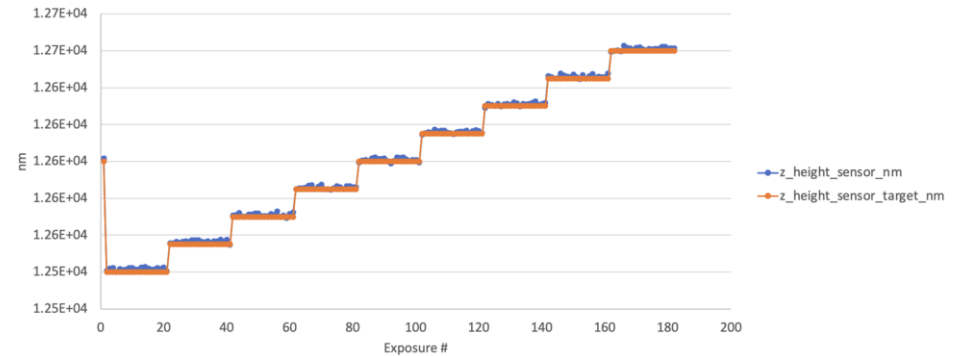
Vibration (nm RMS) avg = 0.80, std = 0.06, min = 0.66, max = 1.10



Features & benefits (cont.)

0.8 nm image stabilization

0.9 nm focus lock to target (1σ)



15 nm focus steps

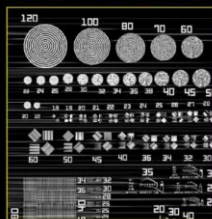
Features & benefits (cont.)

0.8 nm image stabilization

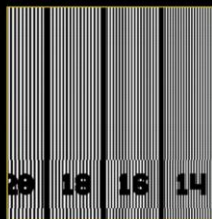
0.9 nm focus lock to target (1σ)

Programmable pupil fill for fine-tuning image properties

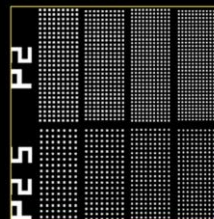
GENERAL PURPOSE



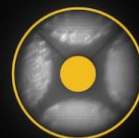
LINES



CONTACTS



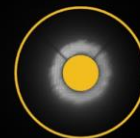
ETC.



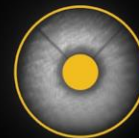
"LEAF" QUAD



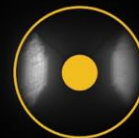
QUASAR



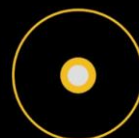
GRIDDED ANNULAR



GRIDDED ANNULAR



"LEAF" DIPOLE



FREQUENCY DOUBLING
*NOT REAL IMAGE



HEXAPOLE



QUASAR 2

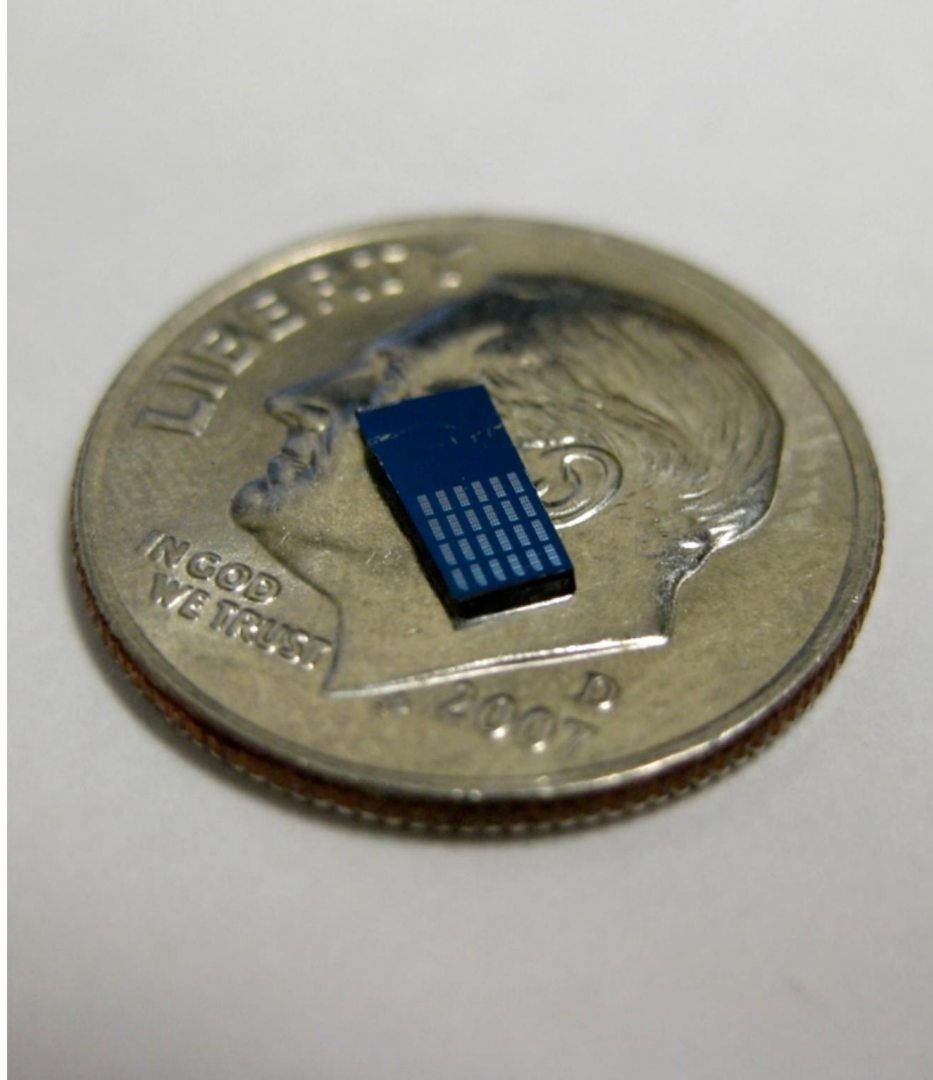
Features & benefits (cont.)

0.8 nm image stabilization

0.9 nm focus lock to target (1σ)

Programmable pupil fill for fine-tuning image properties

200 μm x 30 μm field



Features & benefits (cont.)

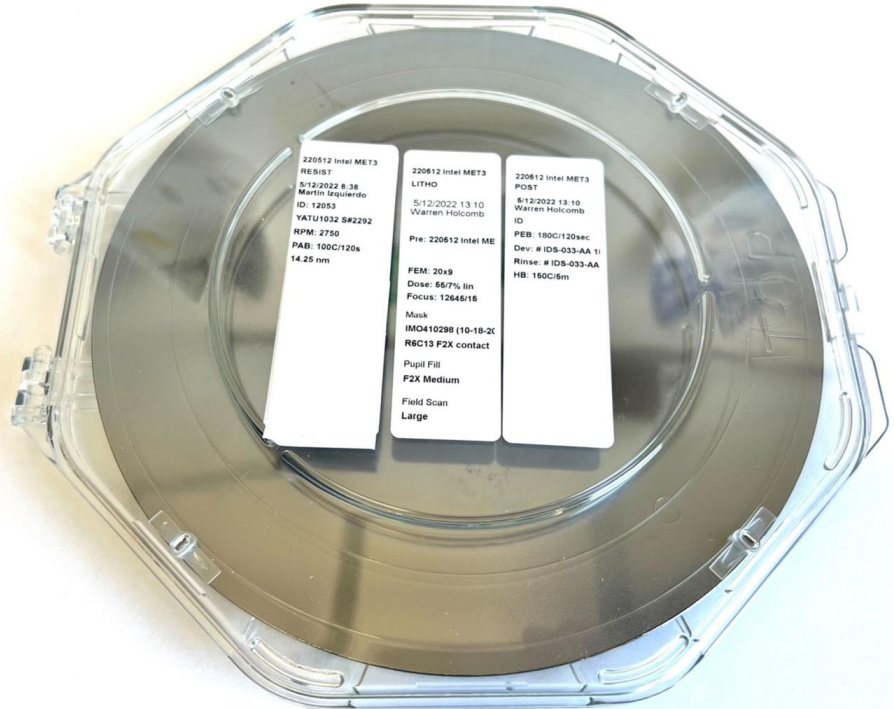
0.8 nm image stabilization

0.9 nm focus lock to target (1σ)

Programmable pupil fill for fine-tuning image properties

200 μm x 30 μm field

200 mm wafers



Features & benefits (cont.)

0.8 nm image stabilization

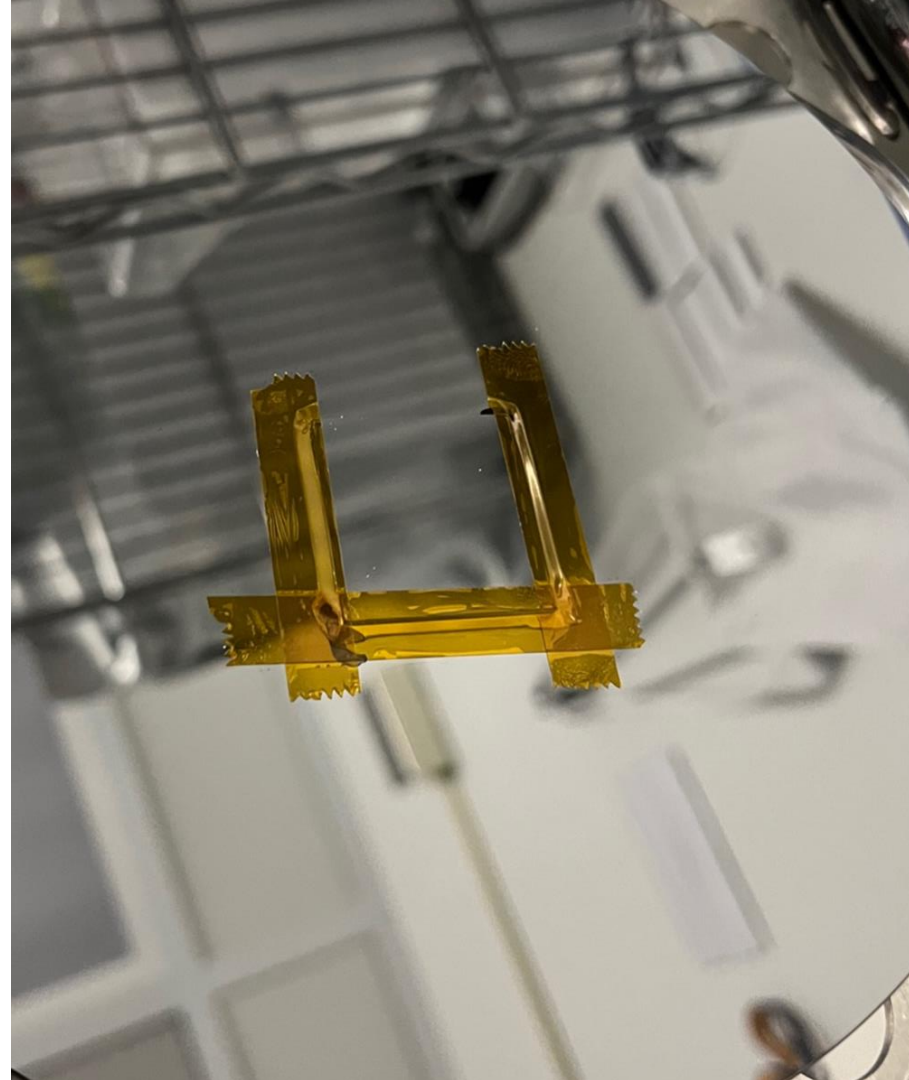
0.9 nm focus lock to target (1σ)

Programmable pupil fill for fine-tuning
image properties

200 μm x 30 μm field

200 mm wafers

Coupons OK



Features & benefits (cont.)

Material-based dose calibration

- Can transfer doses between tools, e.g. NXE

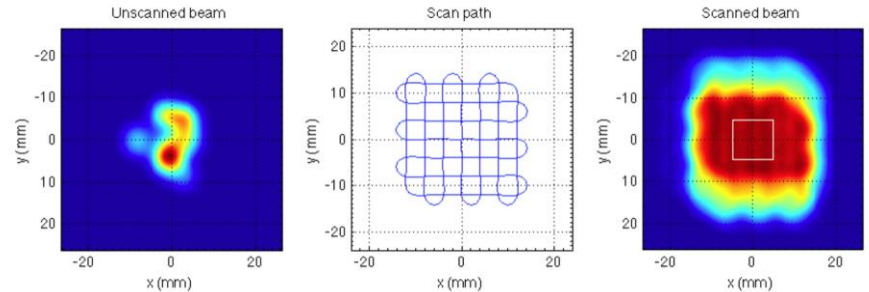
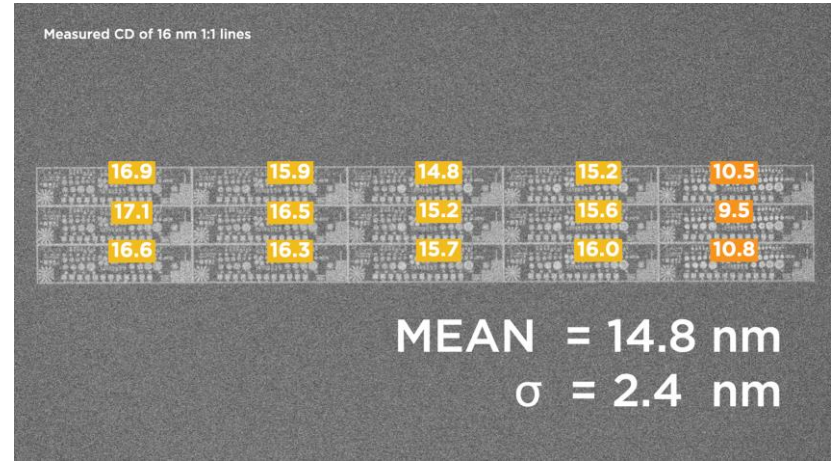


Features & benefits (cont.)

Material-based dose calibration

- Can transfer doses between tools, e.g. NXE

18% dose variation across field



Features & benefits (cont.)

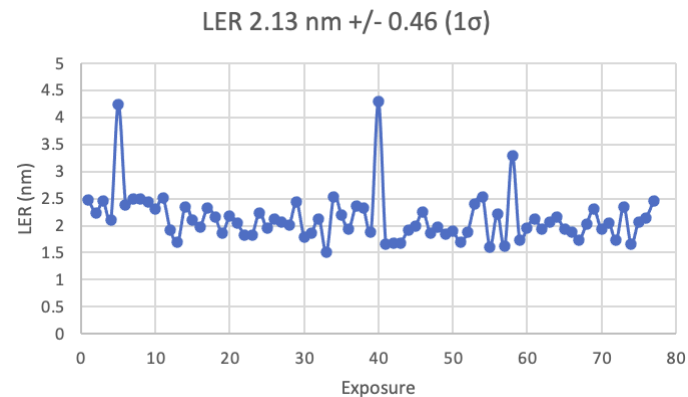
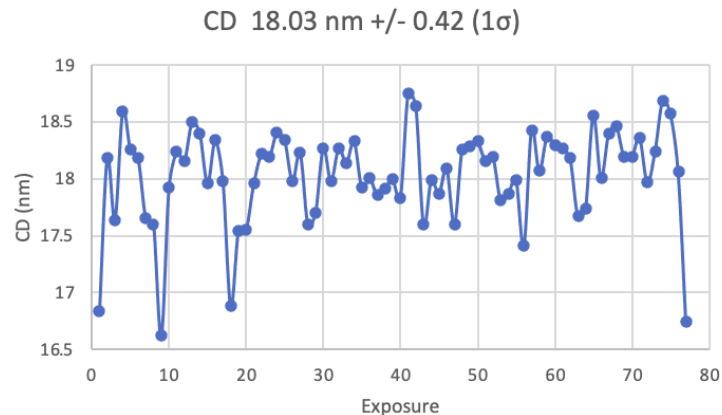
Material-based dose calibration

- Can transfer doses between tools, e.g. NXE

18% dose variation across field

2.3% CDU

- Constant dose/focus FEM, plot CD vs. exposure 16 nm 1:1 lines



Features & benefits (cont.)

Material-based dose calibration

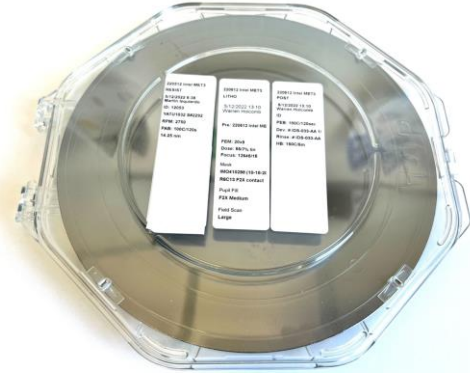
- Can transfer doses between tools, e.g. NXE

18% dose variation across field

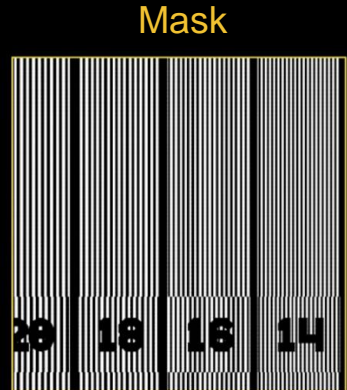
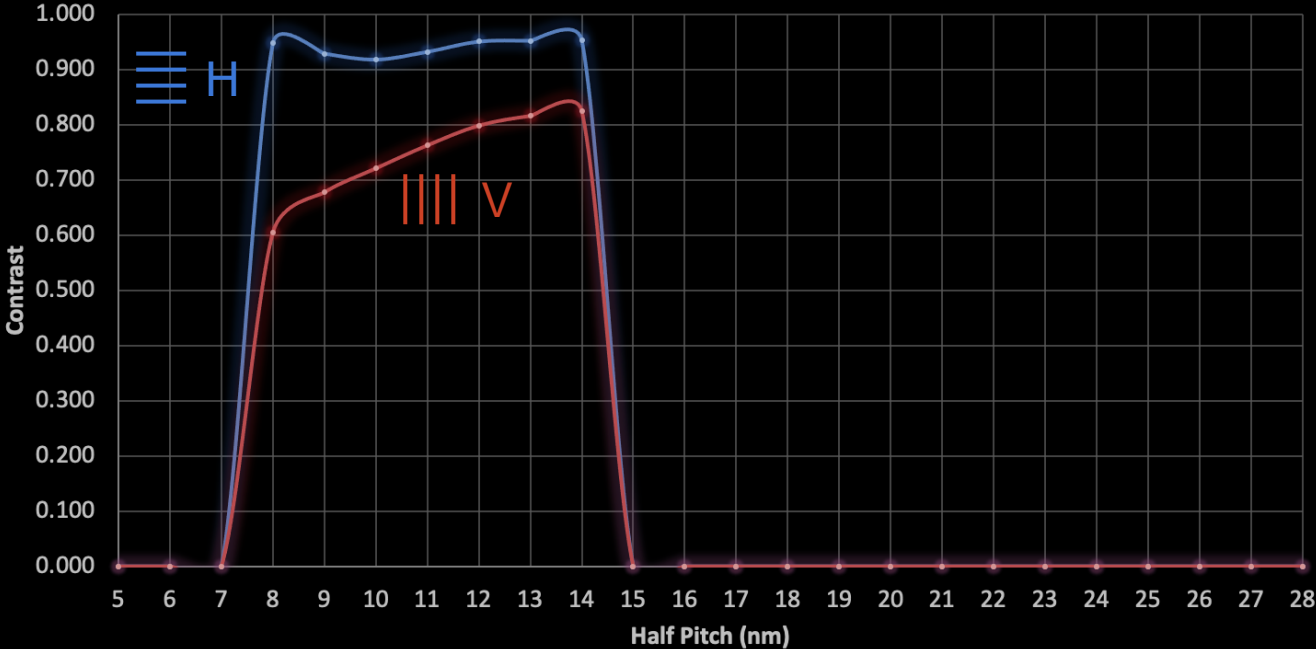
2.3% CDU

- Constant dose/focus FEM, plot CD vs. exposure 16 nm 1:1 lines

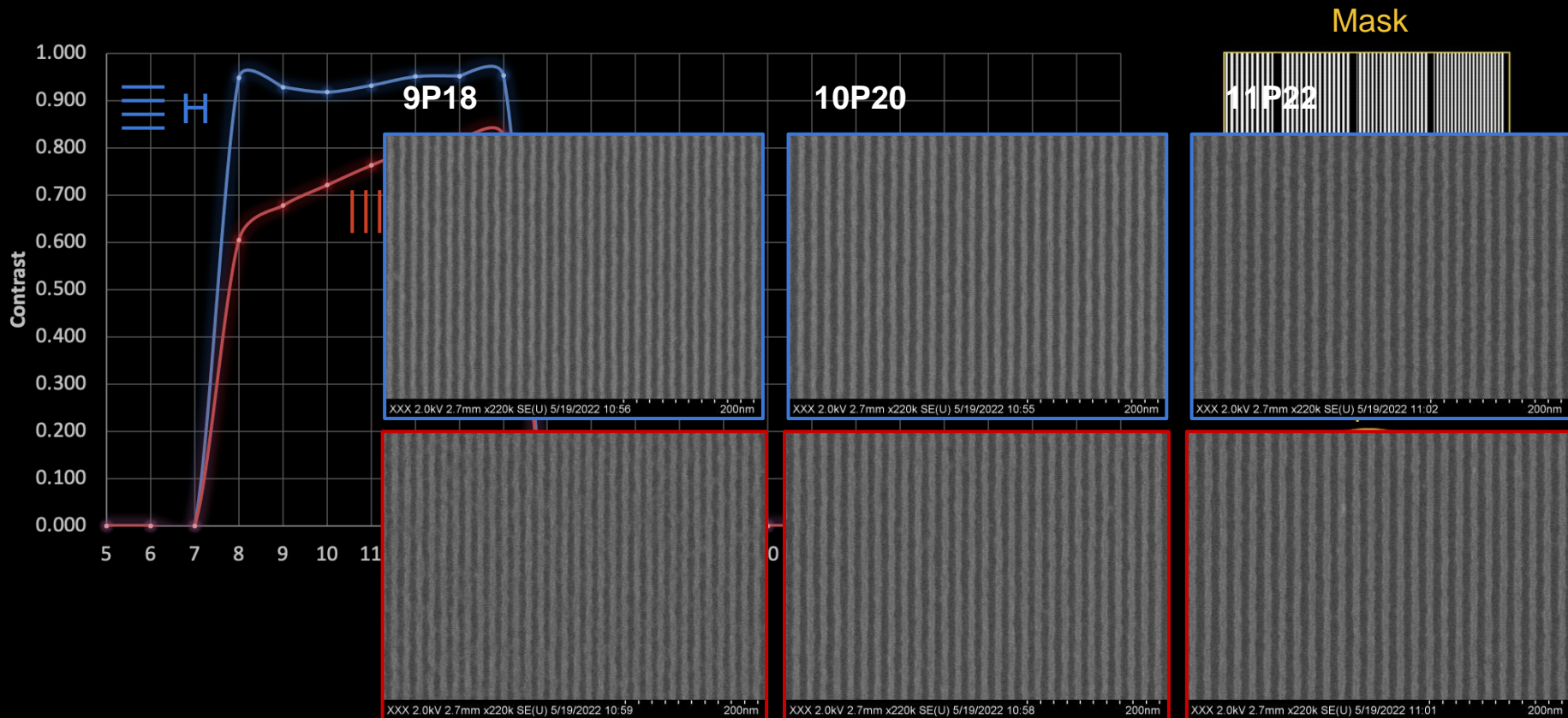
~1 wafer per hour (9x11 FEM)



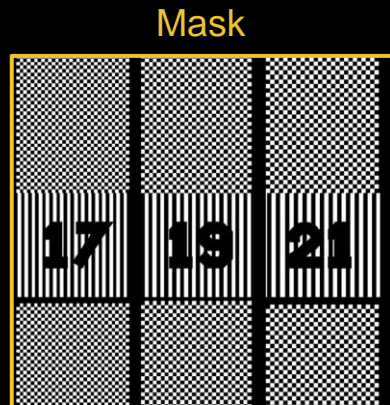
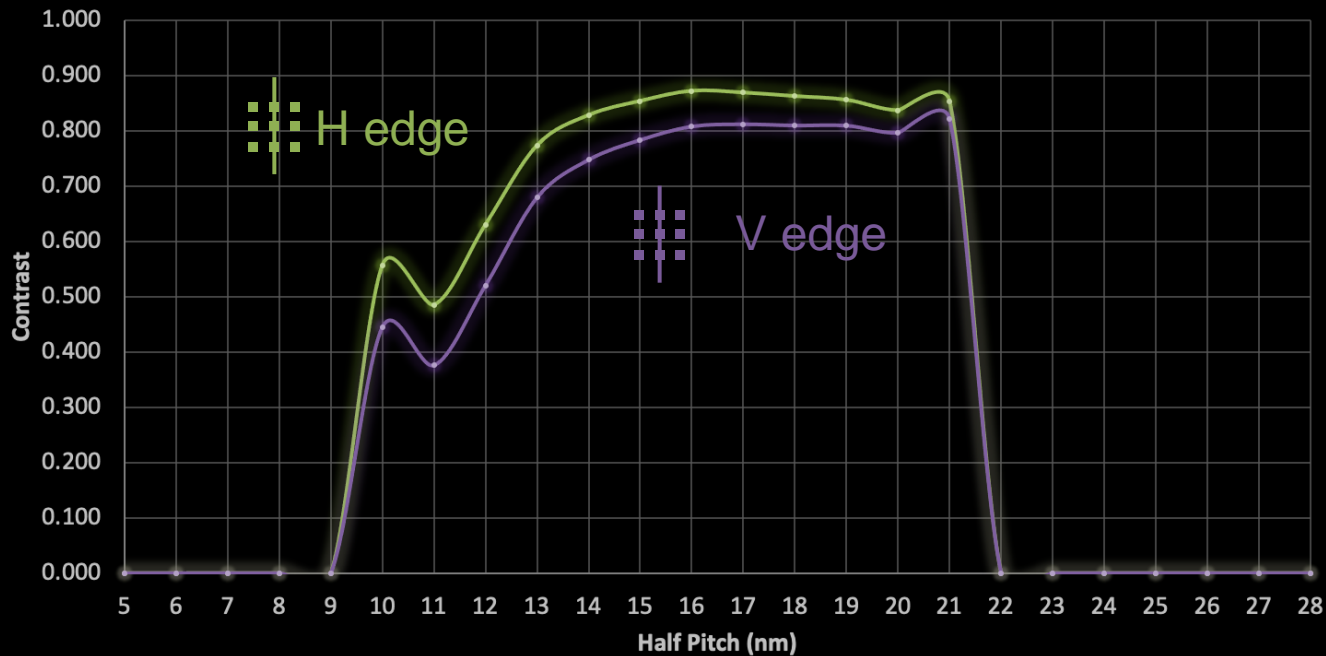
Best resolution lines



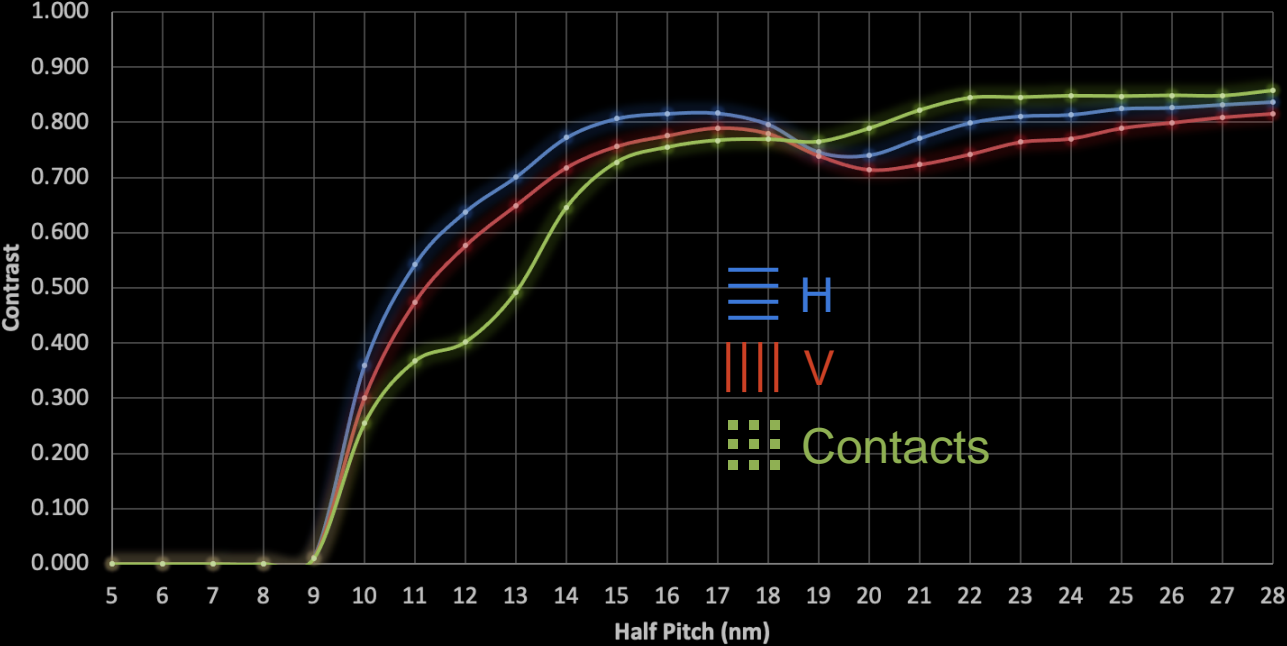
Best resolution lines



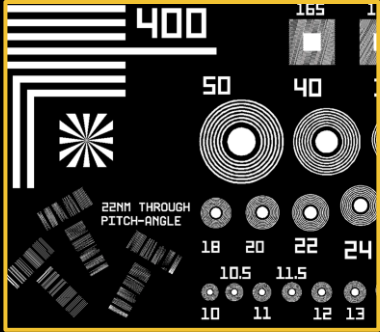
Best resolution contacts



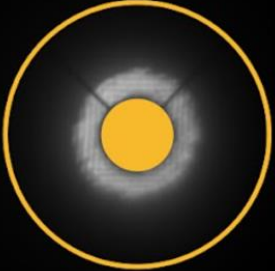
General purpose imaging



Mask



Pupil fill



CEE XPro-II Processing Modules Coming Soon



Solvent
Spin/Coat



Aqueous
TMAH develop



Bake X4
400C

CEE XPro-II Processing Modules Coming Soon



Mature logistics infrastructure

Sample Inventory

My Samples SUBMIT NEW SAMPLES / PACKAGE

Find where: Name contains 5308 Extra: N/A Hide Disposed

3 records. Page 1 of 1 Previous Next Results per page: 25

DYMO Printer:

Company	User	Collaborators	Date Submitted	ID	Name	Vol. Shipped	Vol. Current	Wafers	Bin	Comments
LBNL	Martin Izquierdo	Edit	3/22/2022, 9:25:02 AM	11894	EUVJ5308	100 mL	100 mL (3/22/2022, 9:25:02 AM) 100 mL	220504-CXRO_CAL 220504-CAL2 220505-CXRO_CAL 220504-CAL2 220505-CAL2 220506_CXRO_CAL_1 220509-CAL 220511-CAL1 220511-CAL2 220511-CAL1 220512-CAL1 2nd Fine FEM on CAL 220513 CXRO MET2 220517-CAL1 220517-CAL1 220519-CXRO_CAL 220519-CXRO_CAL 220518-CAL2 220519-CAL1 220519-CAL2	231	Write a Comment Save
LBNL	Martin Izquierdo	Edit	3/22/2022, 9:25:02 AM	11893	EUVJ5308	100 mL	100 mL (3/22/2022, 9:25:02 AM) 100 mL	220503-CAL1	231	Write a Comment Save
LBNL	Martin Izquierdo	Edit	9/21/2021, 6:34:08 AM	11338	EUVJ5308	100 mL	75 mL (4/14/2022, 1:58:01 PM) 75 mL	220315 CAL 3 220330-CAL1 220330-CAL2 220330-CAL3 220330-CAL4 220401-CXRO-Cal3-POTemp-22.851C 220331-CAL2	231	Write a Comment Save

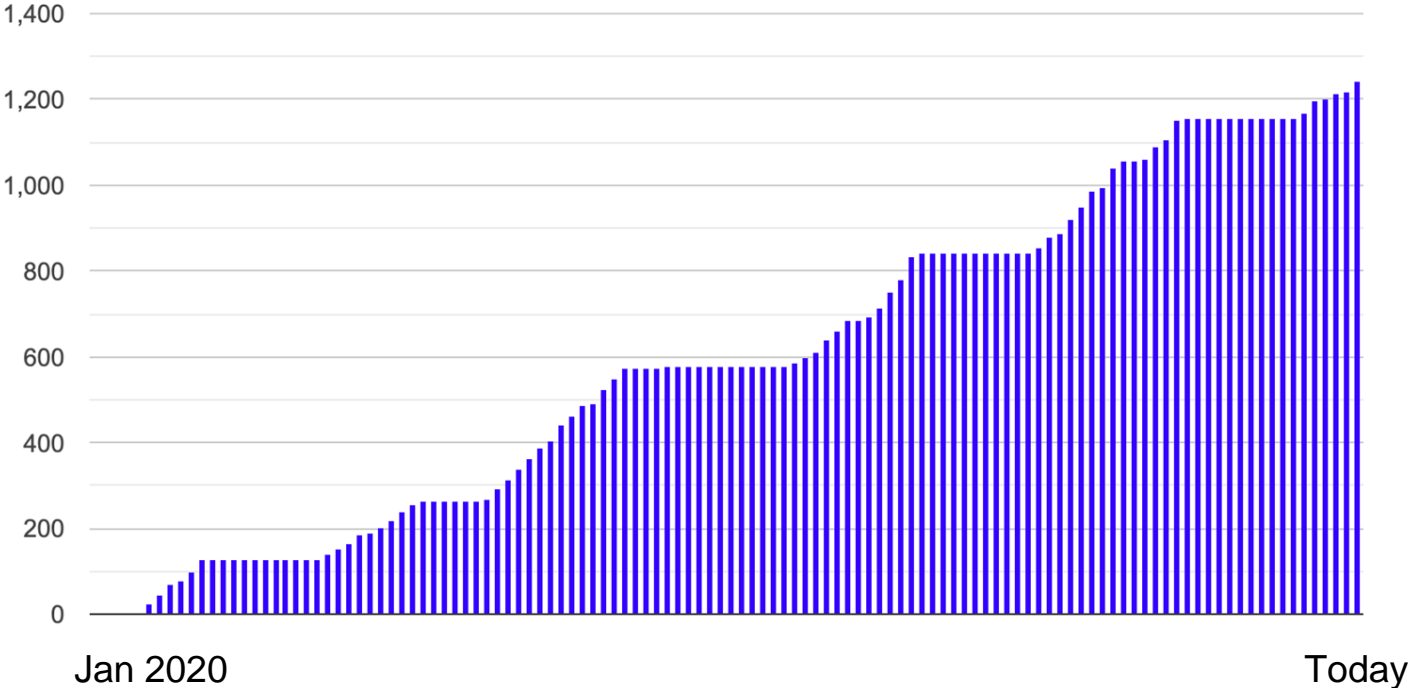
Wafer Database

Find where: Resist contains 5308 where contains

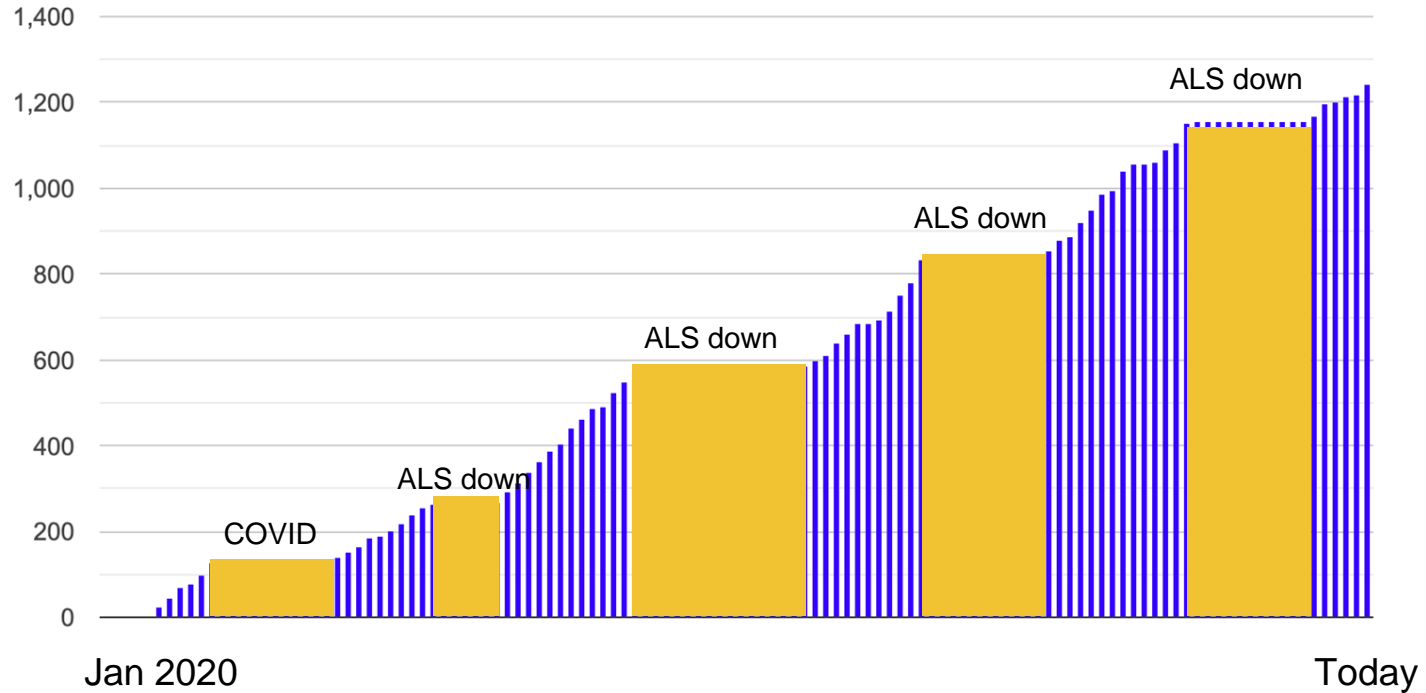
266 records. Page 1 of 6 Previous Next Results per page: 50

Edit	ID	Company	UL				Resist					Litho			
			ID	Name	RPM	Thick	PAB	Notes	ID	Name	RPM		Thick	PAB	Notes
...	220519-CAL2	CXRO X		HMD5-59						11894	EUVJ5308	1900	18.77	130C/60Sec	
...	220519-CAL1	CXRO X		HMD5-59						11894	EUVJ5308	1900	18.70	130C/60Sec	
...	220518-CAL2	CXRO X		HMD5-59						11894	EUVJ5308	2135	18.0	130C/60Sec	
...	220519-CXRO_CAL	CXRO X		HMD5-59						11894	EUVJ5308	2135	18.28	130C/60Sec	220519-CXRO_CAL
...	220518-CXRO_CAL	CXRO X		HMD5-59						11894	EUVJ5308	1900	18.35	130C/60Sec	220518-CXRO_CAL
...	220517-CAL1	CXRO X		HMD5-59						11894	EUVJ5308	1900	18.35	130C/60Sec	
...	220517-CAL1	CXRO X		HMD5-59						11894	EUVJ5308	1900	18.26	130C/60Sec	220517-CXRO_CAL
...	220513 CXRO MET2	CXRO X		HMD5-59				150		11894	EUVJ5308	1700	18.26	130C/60s	220513 CXRO MET2
...	2nd Fine FEM on CAL	CXRO X		HMD5-59						11894	EUVJ5308	1700	18.0	130C/60Sec	220513-CXRO-CAL_Fine
...	220512-CAL1	CXRO X		HMD5-59						11894	EUVJ5308	1700	18	130C/60Sec	220512-CXRO-CAL
...	220511-CAL1	CXRO X		HMD5-59				150		11894	EUVJ5308	1900	18	130C/60s	220511-CXRO_CAL
...	220511-CAL2	CXRO X		HMD5-59						11894	EUVJ5308	1900	18.0	130C/60Sec	
...	220511-CAL1	CXRO X		HMD5-59						11894	EUVJ5308	1900	18	130C/60Sec	
...	220506-CAL	CXRO X		HMD5-59						11894	EUVJ5308	1950	18.34	130C/60Sec	
...	220506_CXRO_CAL_1	CXRO X		HMD5-59						11894	EUVJ5308	1950	18.17	130C/60s	220506_CXRO_CAL_1
...	220505-CAL2	CXRO X		HMD5-59						11894	EUVJ5308	1950	18.04	130C/60Sec	
...	220504-CAL2	CXRO X		HMD5-59						11894	EUVJ5308	1950	18.04	130C/60Sec	
...	220505-CXRO_CAL	CXRO X		HMD5-59						11894	EUVJ5308	1950	18.18	130C/60Sec	220505-CXRO_CAL
...	220503-CAL2	CXRO X		HMD5-63						11894	EUVJ5308	2078	18.0	130C/60Sec	
...	220504-CXRO_CAL	CXRO X		HMD5-63						11894	EUVJ5308	2650	17	130C/60Sec	220504-CXRO_CAL
...	220503-CAL1	CXRO X		HMD5-63						11893	EUVJ5308	1870	18.44	130C/60Sec	220503-CXRO_Cal
...	220428-CAL1	CXRO X		HMD5-66						11338	EUVJ5308	4450	19.0	130C/60Sec	220428-CXRO_CAL
...	220427-CAL1	CXRO X		HMD5-63						11338	EUVJ5308	2650	19.0	130C/60Sec	220427-CAL1

1.2k unique materials since Jan 2020



ALS down ~50%



50% unavailable next three years



Closed min 1 year starting Q4 2025



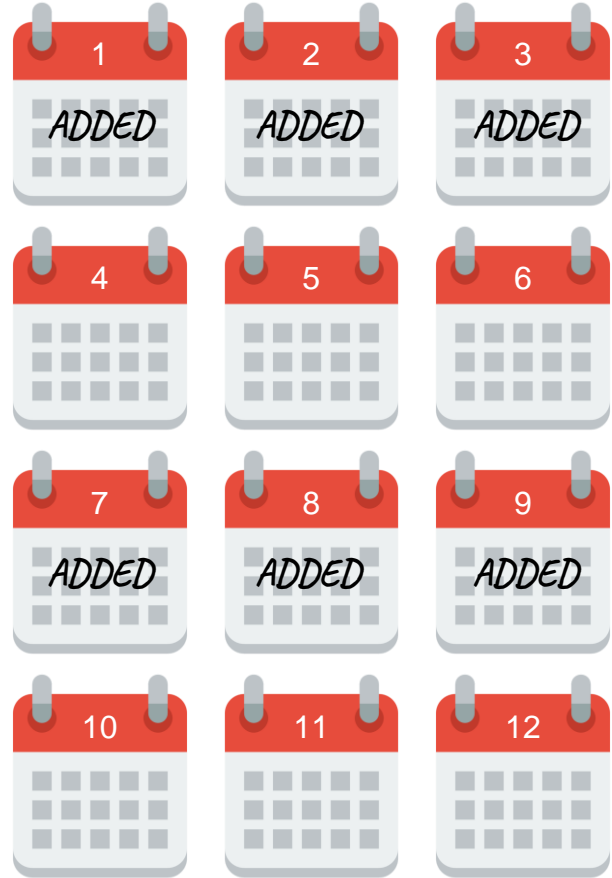
Stand alone source Q4 2021



Features & benefits

Doubles shift supply

- Immune to ALS outages
- Consistent operation Tue-Fri

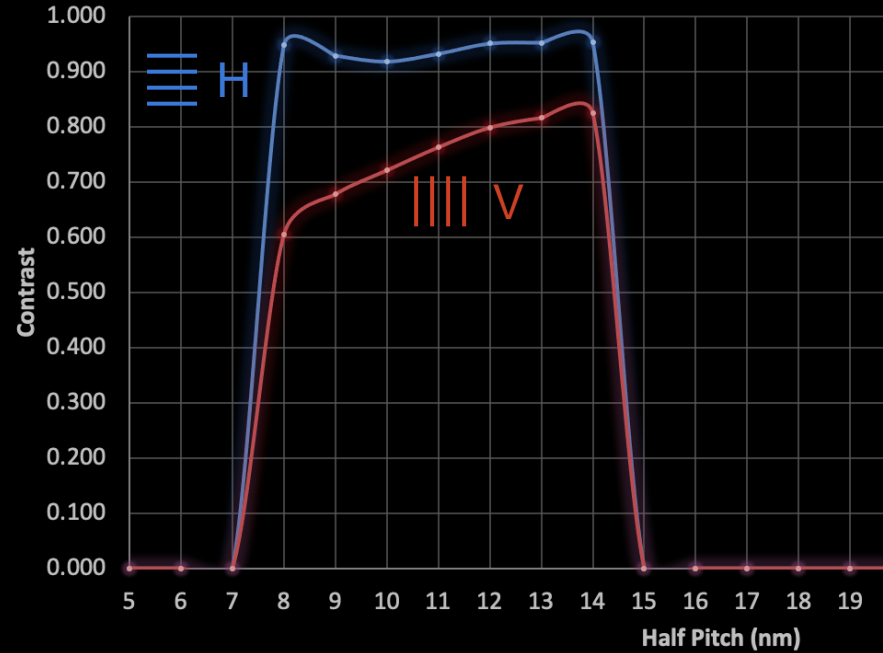


Features & benefits

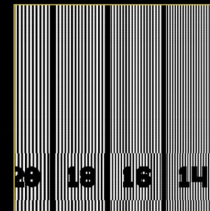
Doubles shift supply

- Immune to ALS outages
- Consistent operation Tue-Fri

Polarizer preserves 8 nm resolution



Mask



Pupil fill



Features & benefits

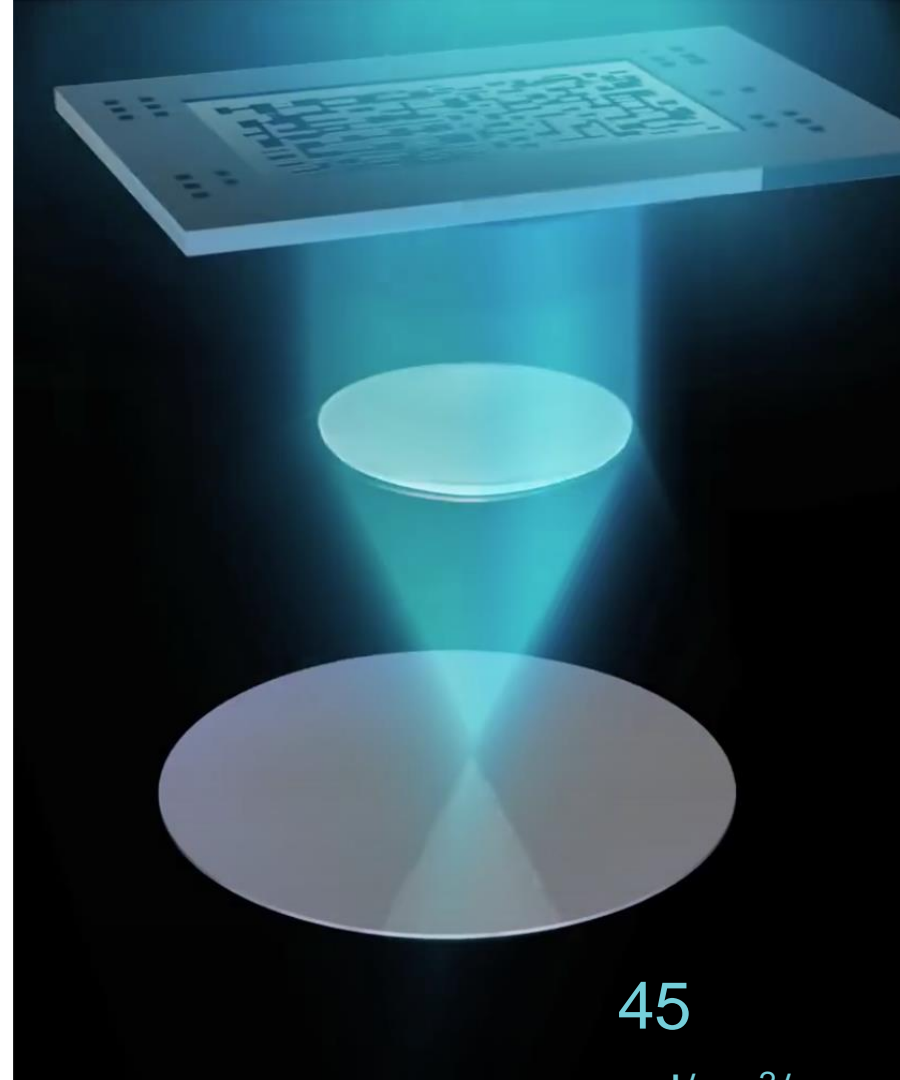
Doubles shift supply

- Immune to ALS outages
- Consistent operation Tue-Fri

Polarizer preserves 8 nm resolution

Same throughput as ALS

- 45 mJ/cm²/s @ wafer



45

Features & benefits

Doubles shift supply

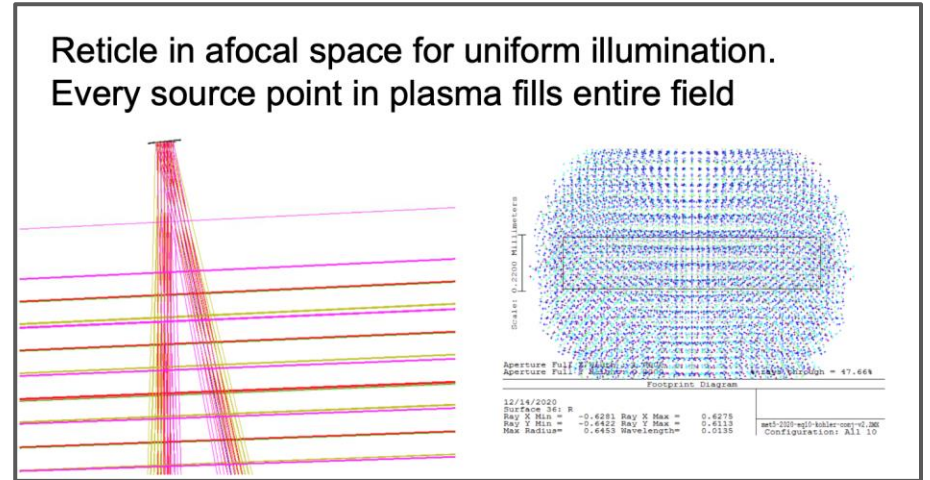
- Immune to ALS outages
- Consistent operation Tue-Fri

Polarizer preserves 8 nm resolution

Same throughput as ALS

- 45 mJ/cm²/s @ wafer

Excellent field uniformity



Features & benefits

Doubles shift supply

- Immune to ALS outages
- Consistent operation Tue-Fri

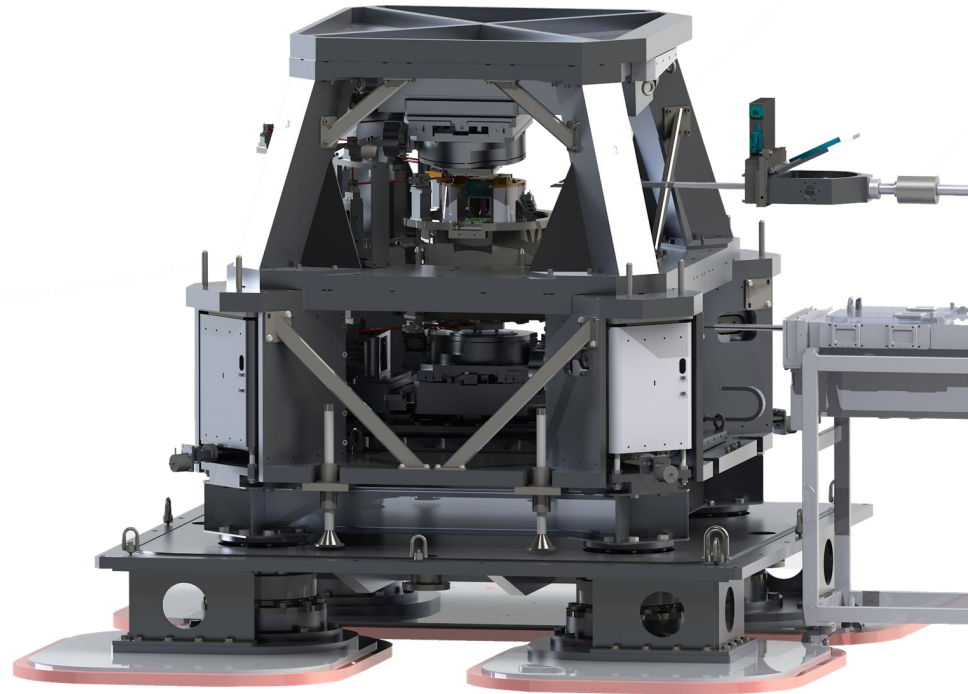
Polarizer preserves 8 nm resolution

Same throughput as ALS

- 45 mJ/cm²/s @ wafer

Excellent field uniformity

No modifications to existing tool core



Features & benefits

Doubles shift supply

- Immune to ALS outages
- Consistent operation Tue-Fri

Polarizer preserves 8 nm resolution

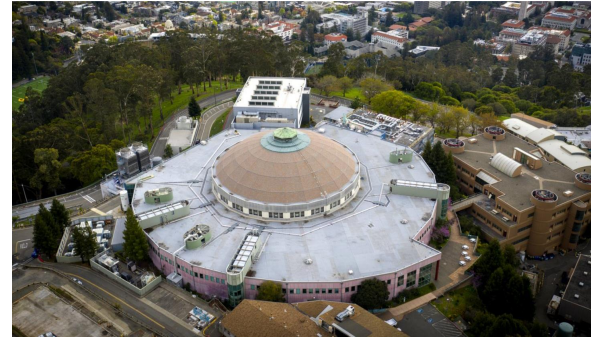
Same throughput as ALS

- 45 mJ/cm²/s @ wafer

Excellent field uniformity

No modifications to existing tool core

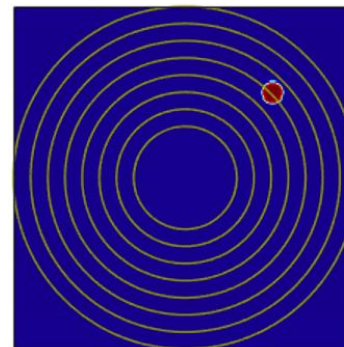
½ day swap back to synchrotron



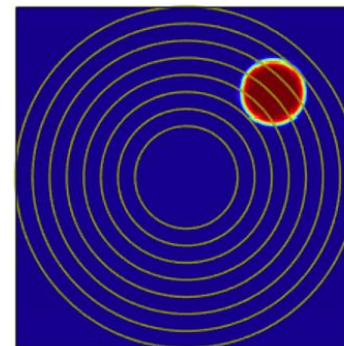
Downsides

3X less coherence

- Reduced pupil fill flexibility



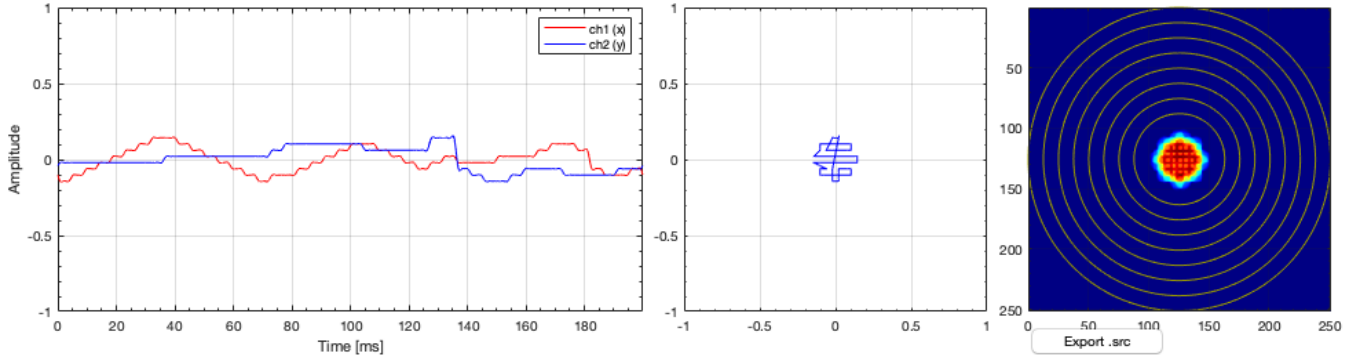
$\sigma_{\text{ALS}} = 0.05$



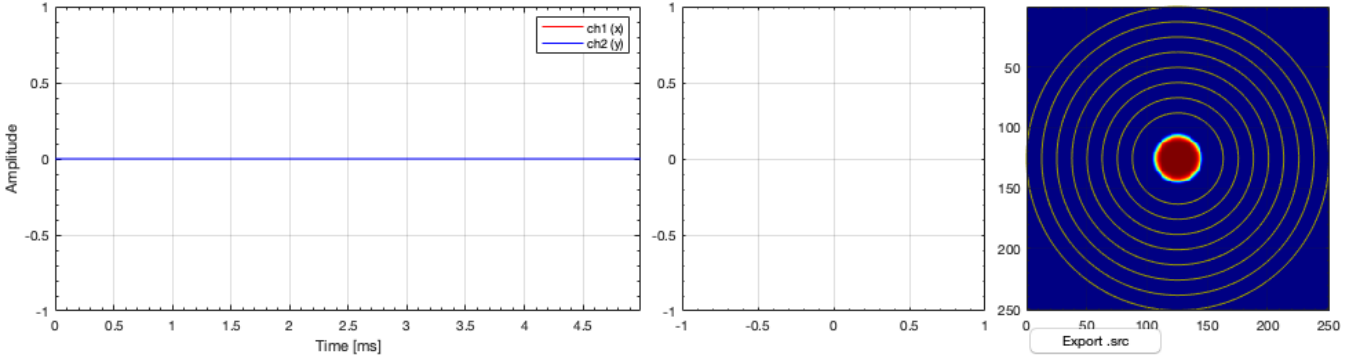
$\sigma_{\text{EQ10}} = 0.15$

Frequency doubling (F2X)

ALS

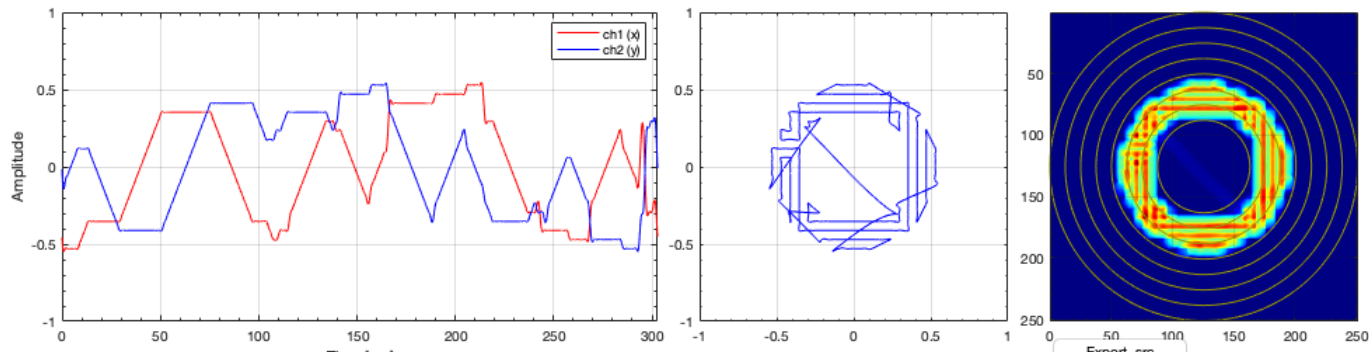


EQ10

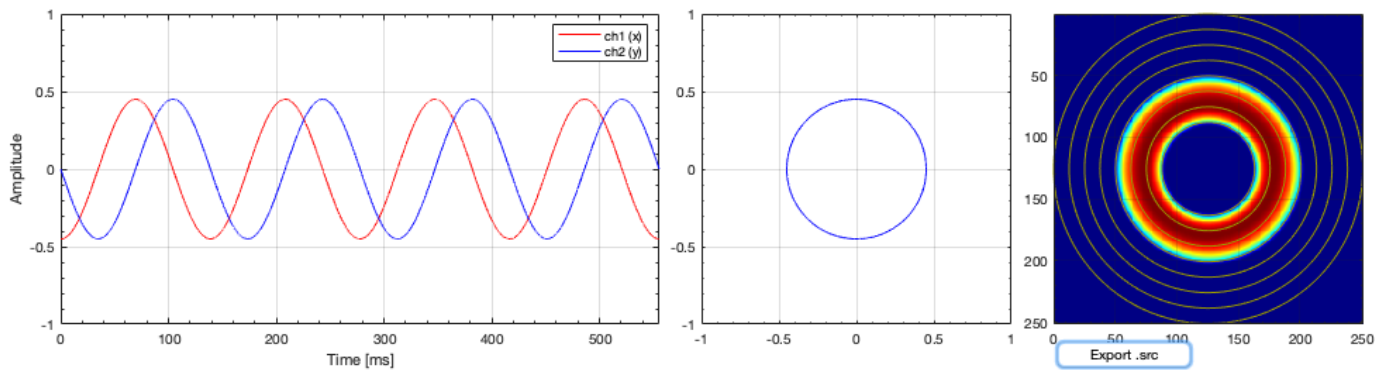


Annular 35-55

ALS

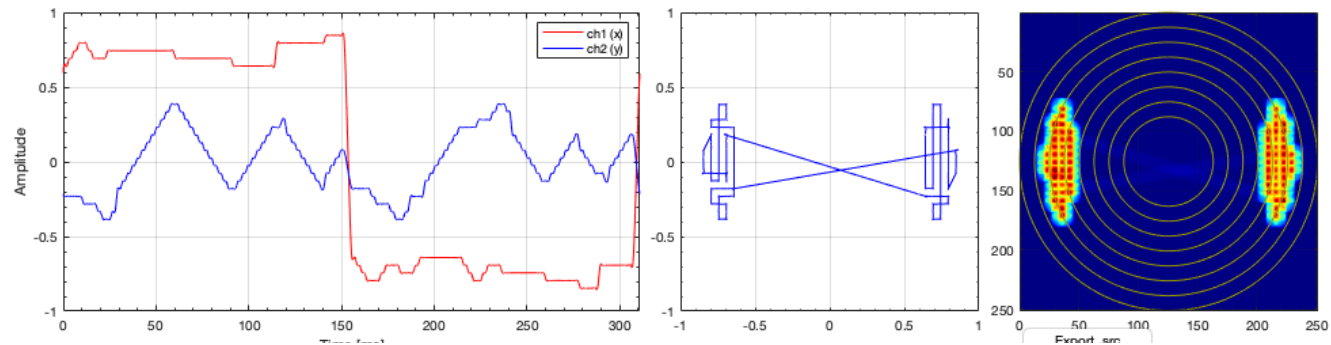


EQ10

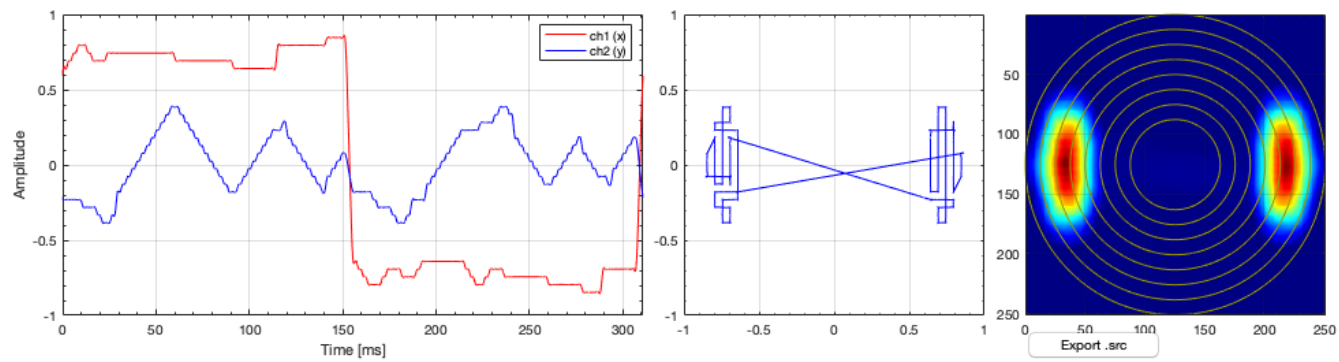


Leaf Dipole

ALS

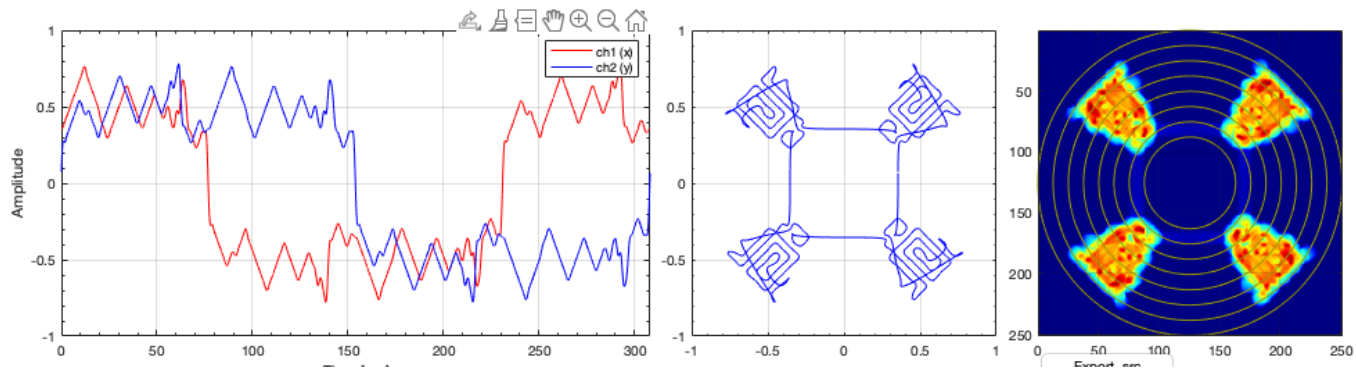


EQ10

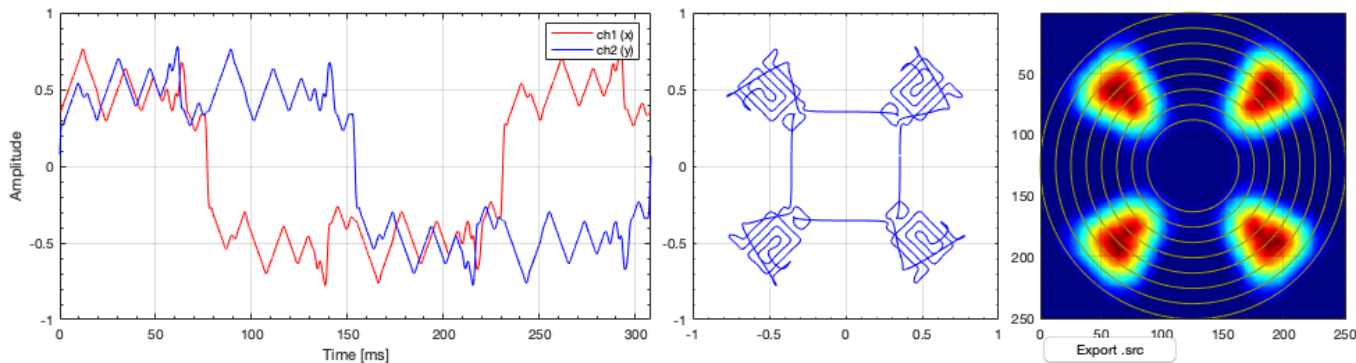


Quasar 0.4-0.9

ALS



EQ10



Downsides

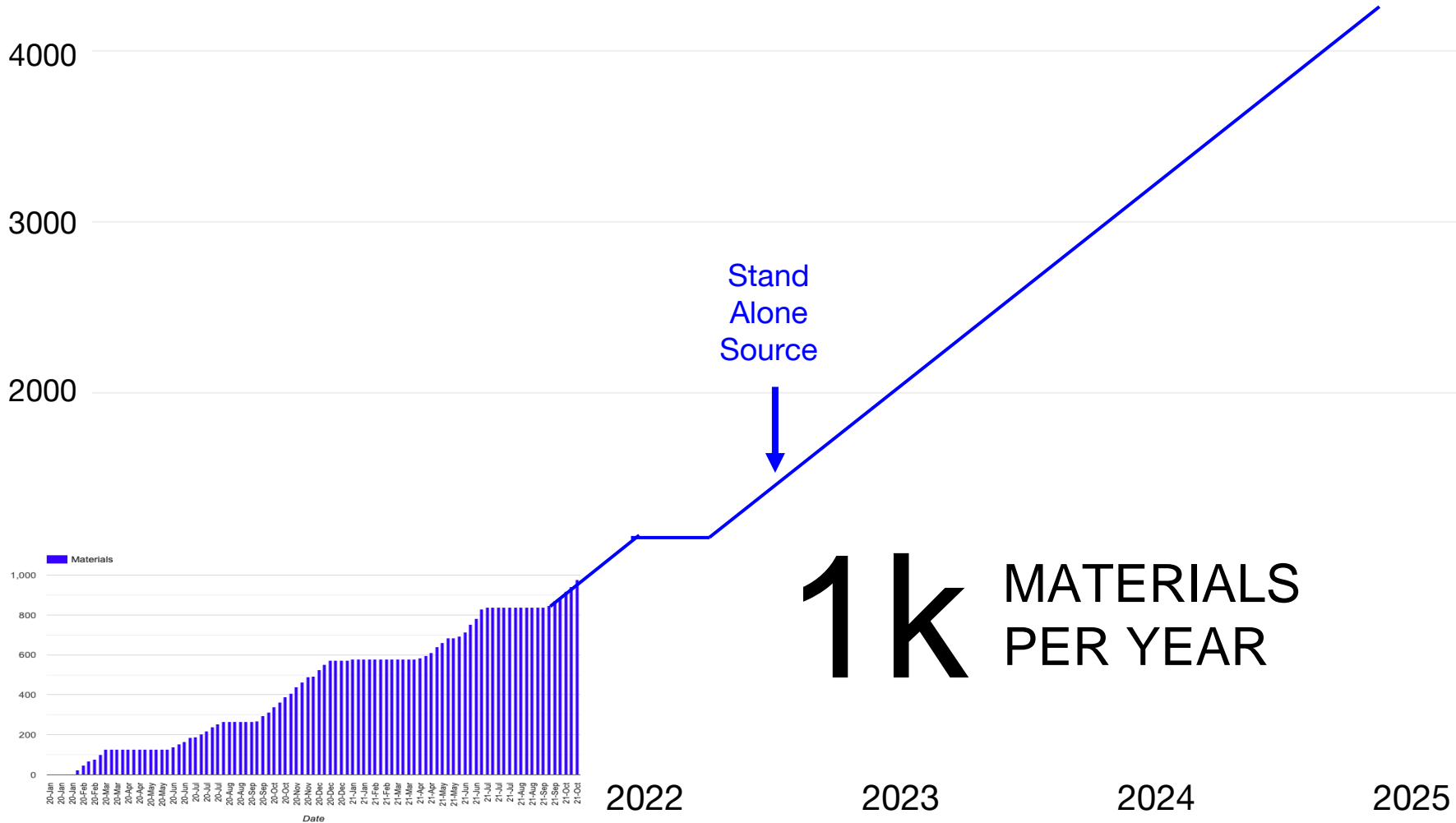
3X less coherence

- Reduced pupil fill flexibility

Regular maintenance

- Replace EQ10 bore (weekly)
- Replace sacrificial mirror (every other day)





Thank you



EUREKA



euv▼tech

KLA+

ASML FST

DUPONT

inpria



tok