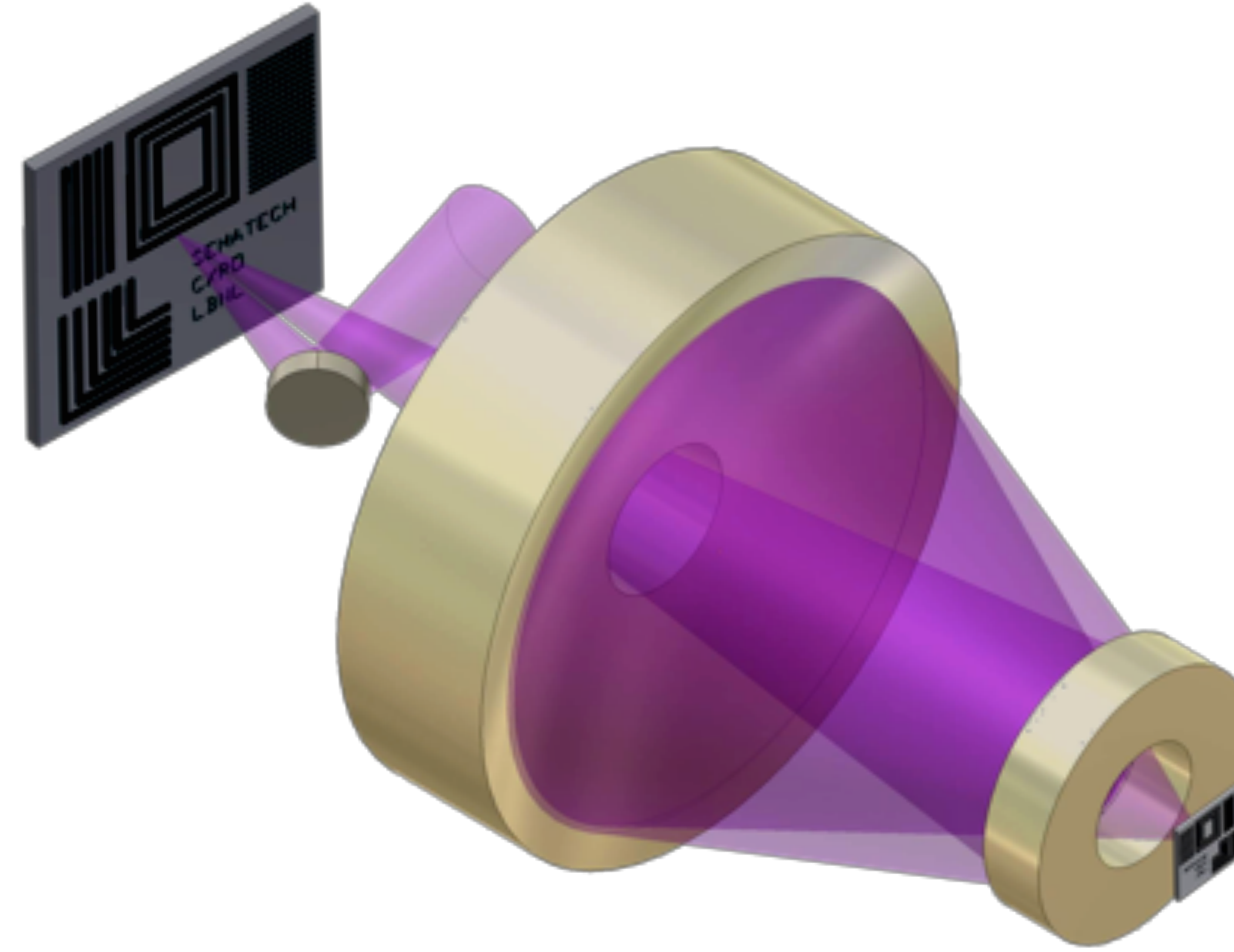
OVERVIEW STATUS AND PERFORMANCE OF THE 0.5-NA EUV MET AT BERKELEY LAB

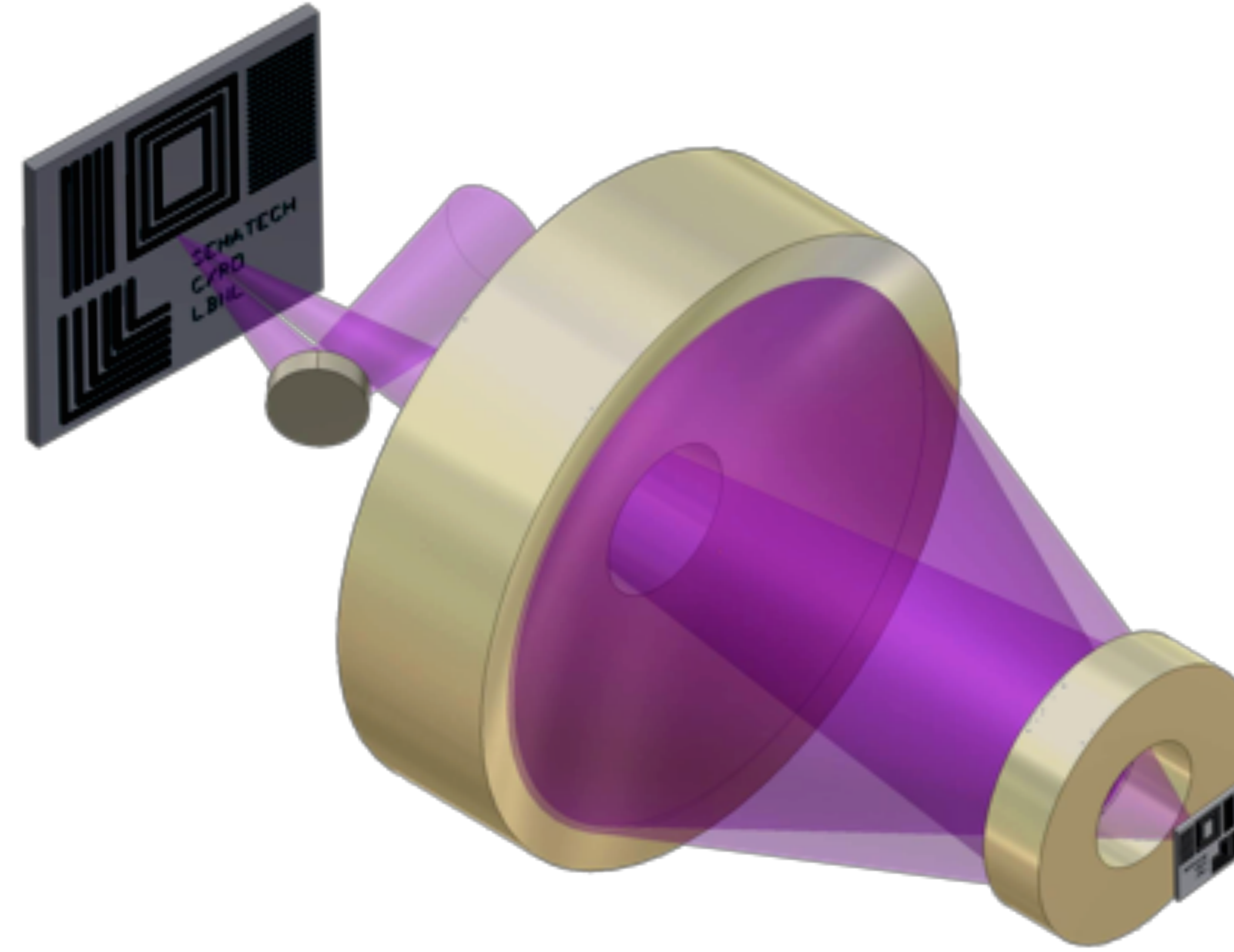
BERKELEY LAB
ARNAUD ALLEZY, **CHRIS ANDERSON**, WEILUN CHAO, CARL CORK, WILL CORK, RENE DELANO, JASON DEPONTE, MICHAEL DICKINSON, GEOFF GAINES, JEFF GAMSBY, ERIC GULLIKSON, GIDEON JONES, RYAN MIYAKAWA, PATRICK NAULLEAU, SENO REKAWA, FARHAD SALMASSI, BRANDON VOLLMER, DANIEL ZEHM, WENHUA ZHU

INPRIA
ANDREW GRENVILLE, STEPHEN MEYERS

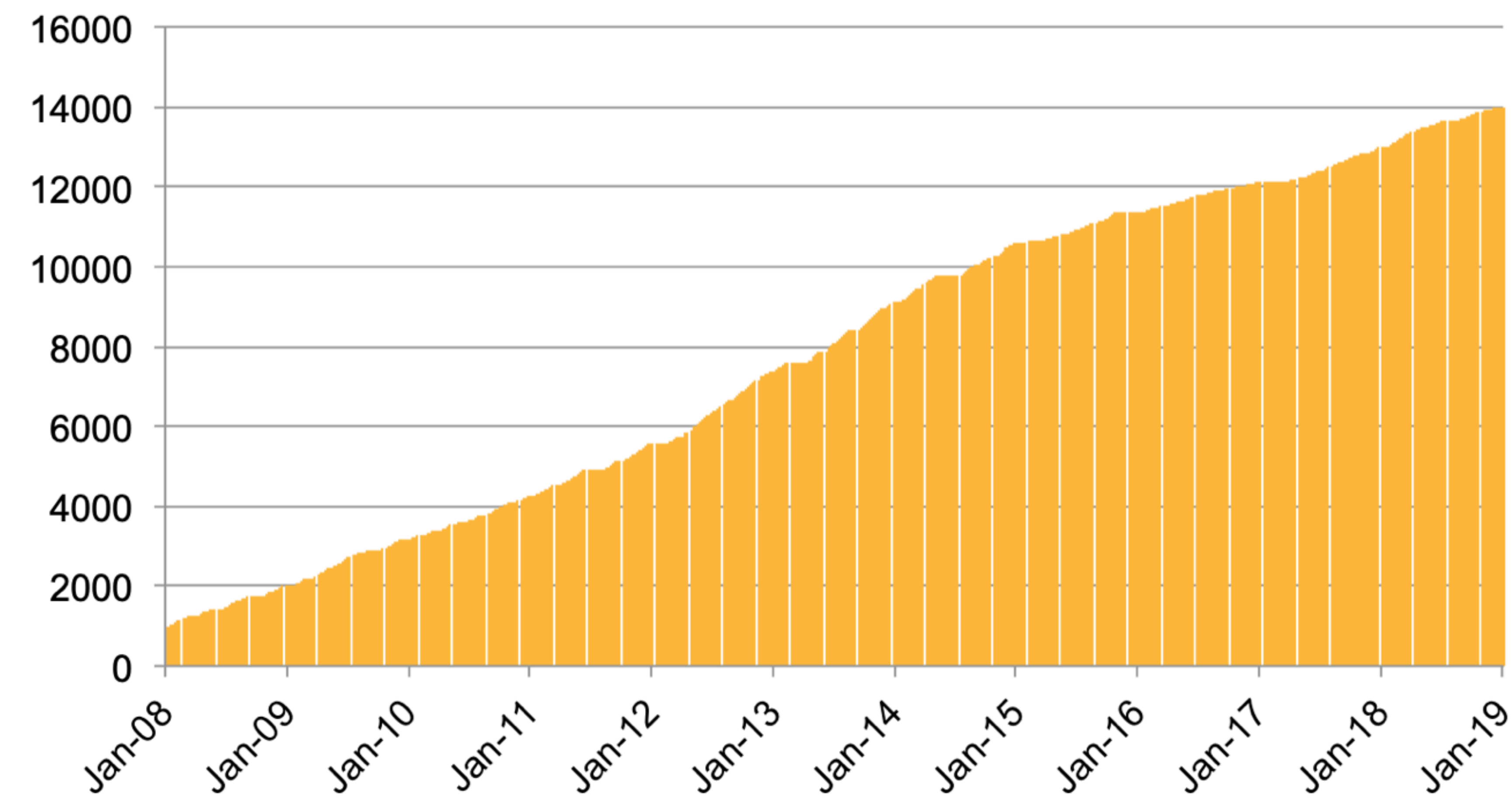
0.3 NA MET



0.3 NA MET

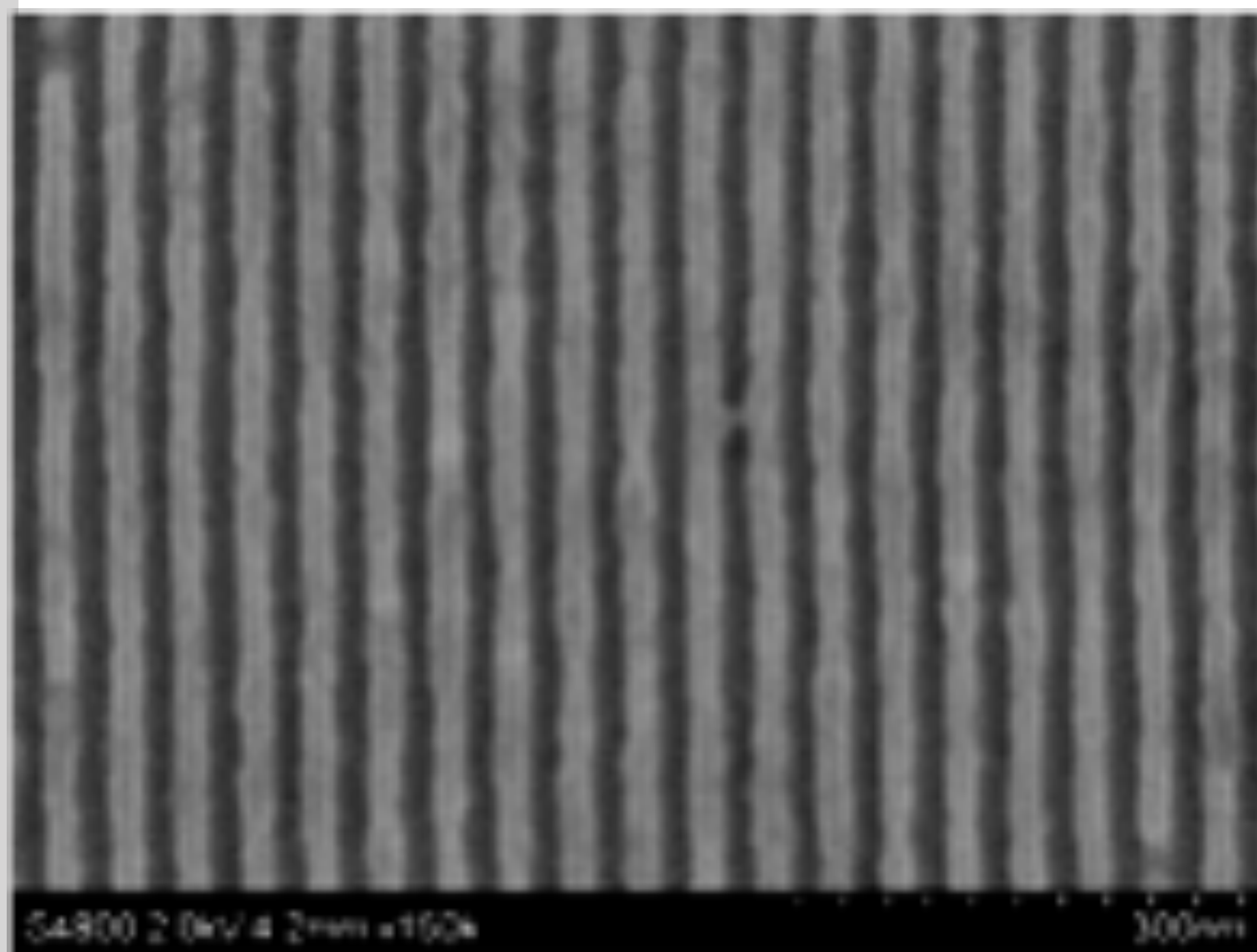


14,078 MATERIALS TESTED

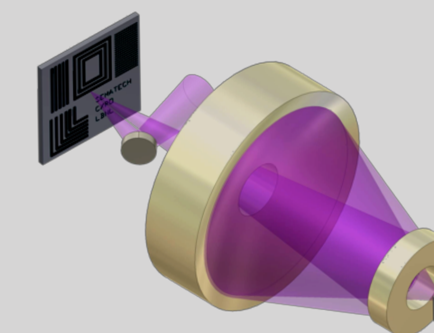


2008

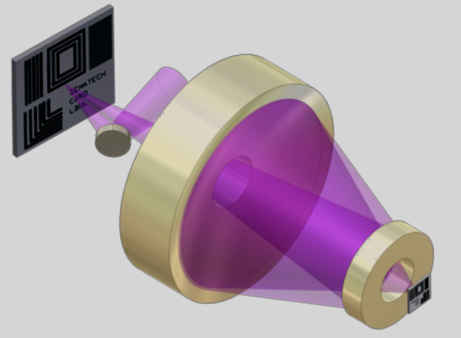
22 nm HP CAR



0.3 NA MET



0.3 NA MET

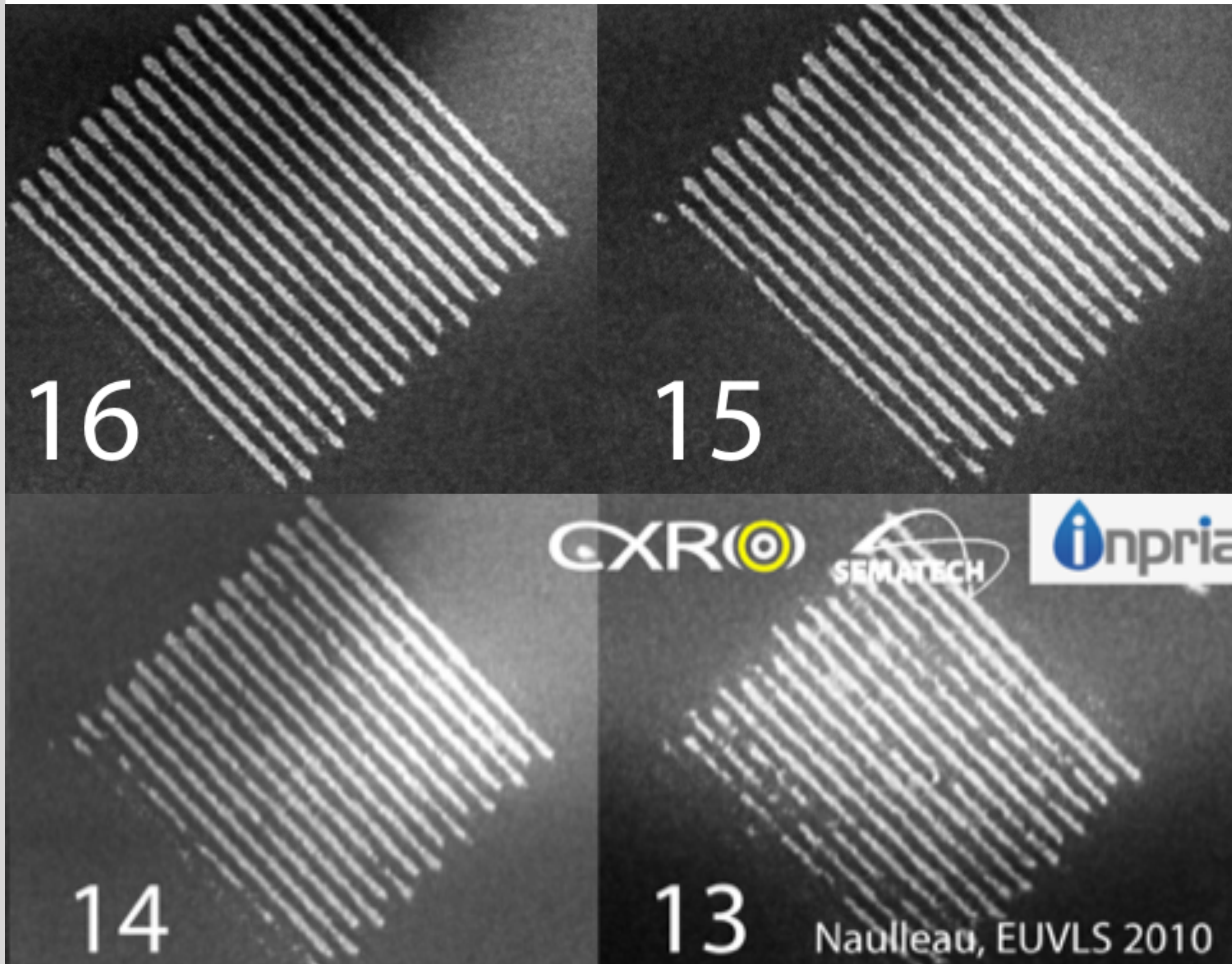


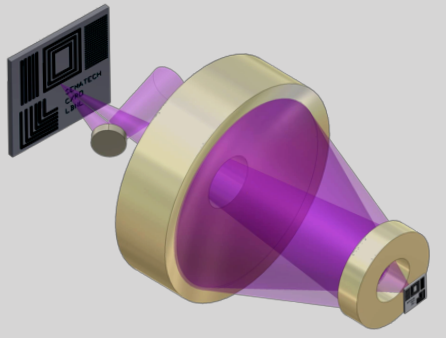
2008

22 nm HP CAR

2010

Inpria





2008
22 nm HP CAR

2010
Inpria

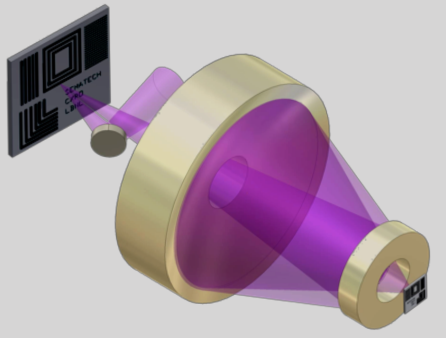
16

14

2010
16 nm HP CAR

BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:56 300nm

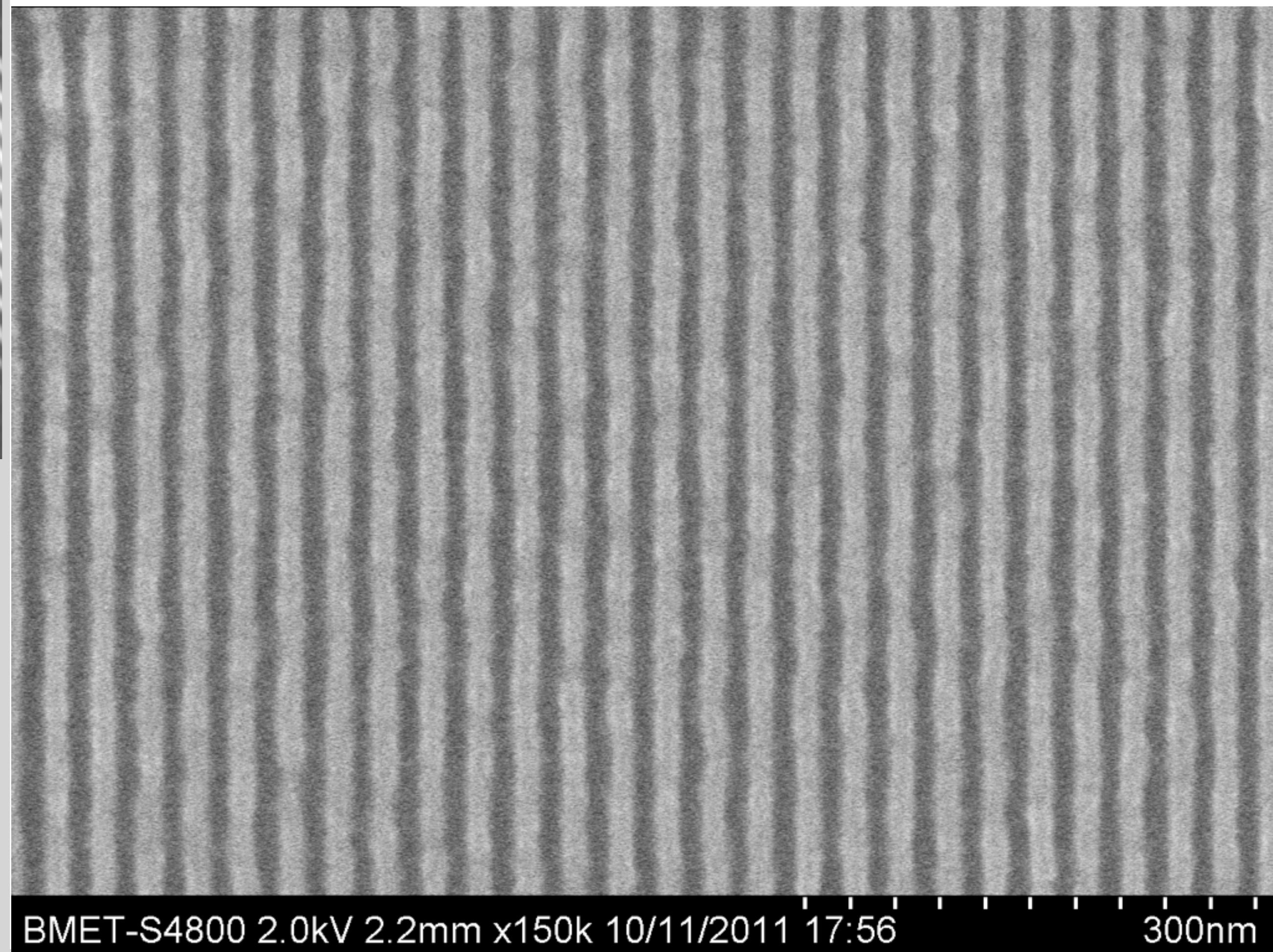
0.3 NA MET



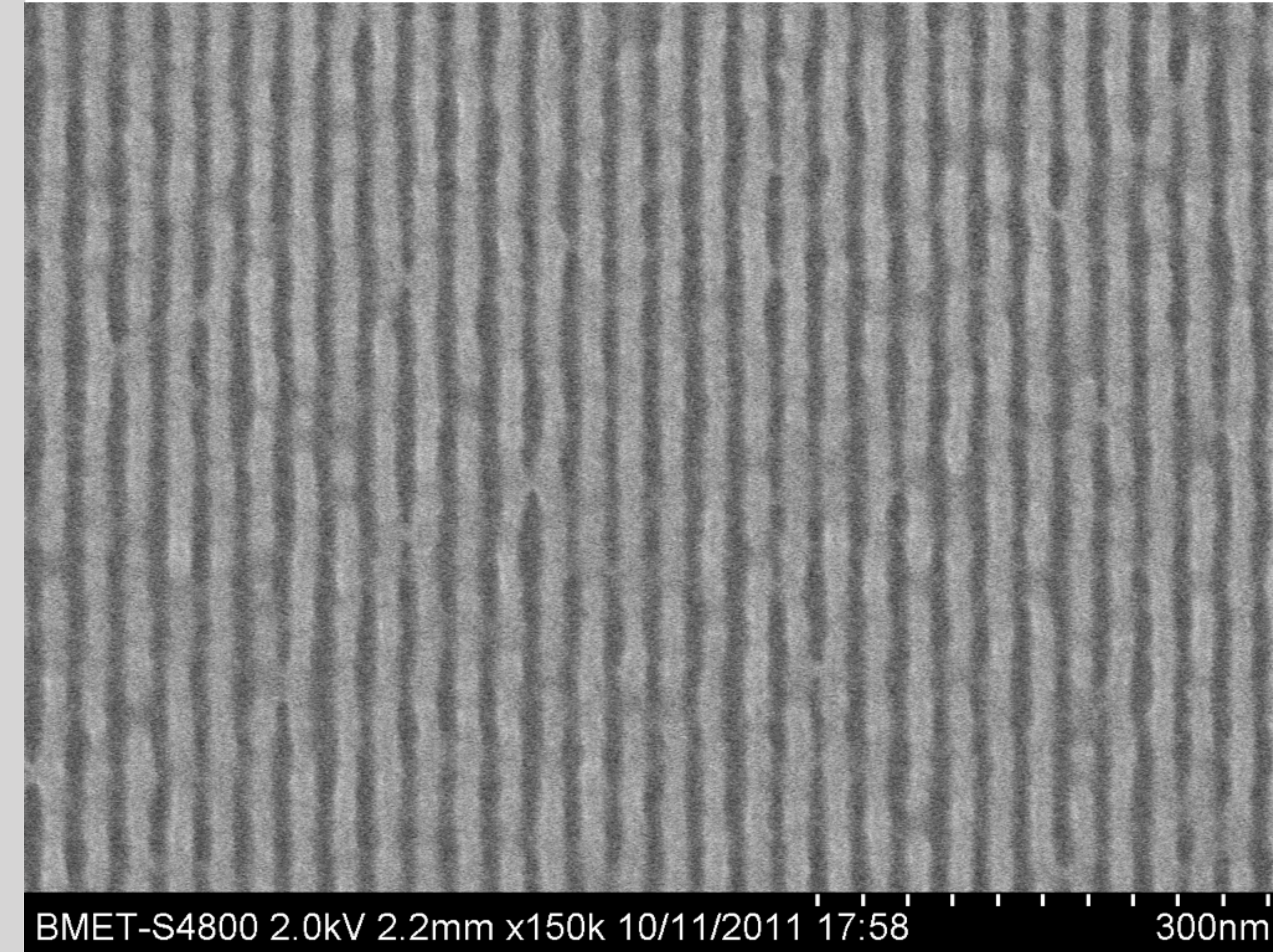
2008
22 nm HP CAR

2010
Inpria

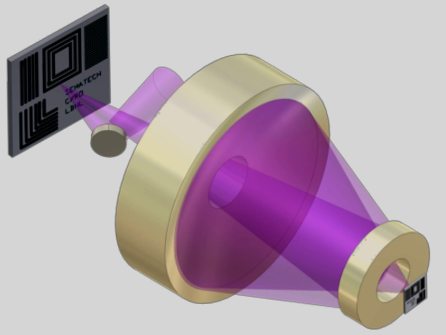
2010
16 nm HP CAR



2011
14 nm HP CAR



0.3 NA MET

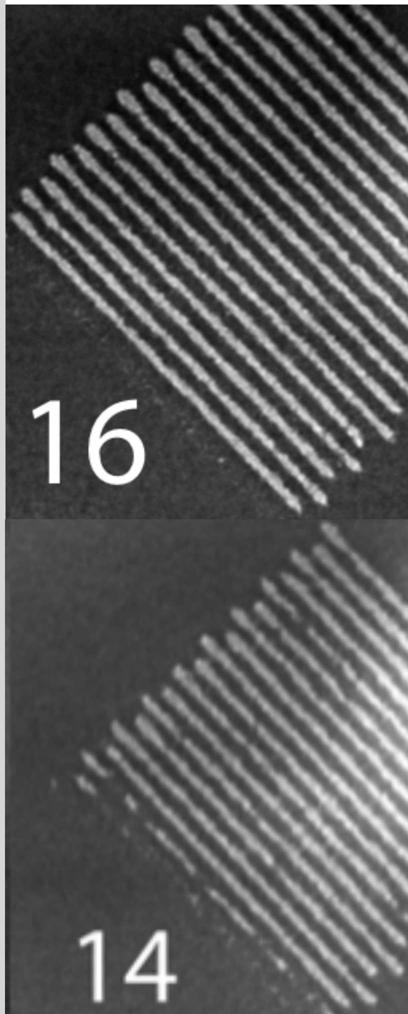


2008

22 nm HP CAR

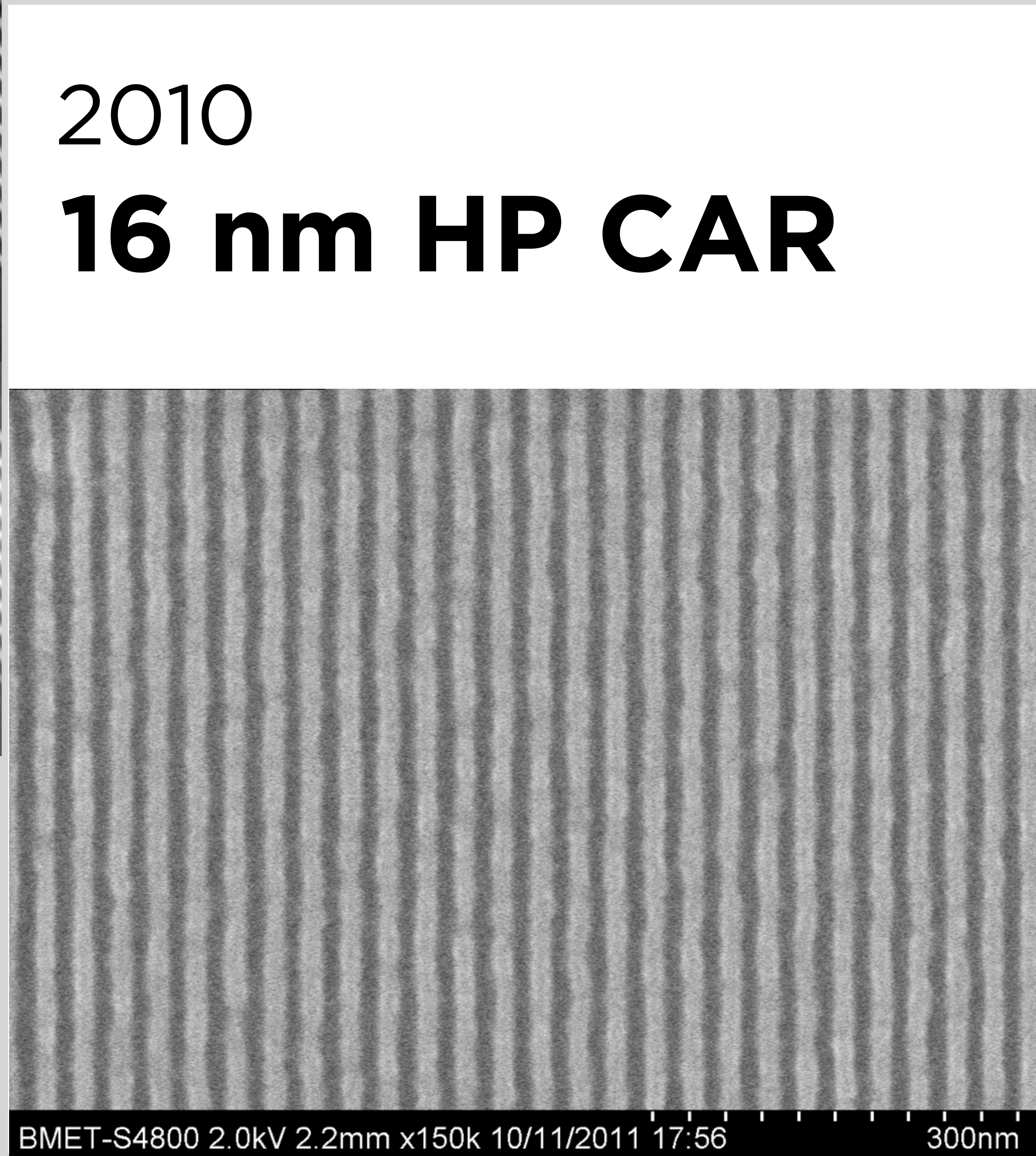
2010

Inpria



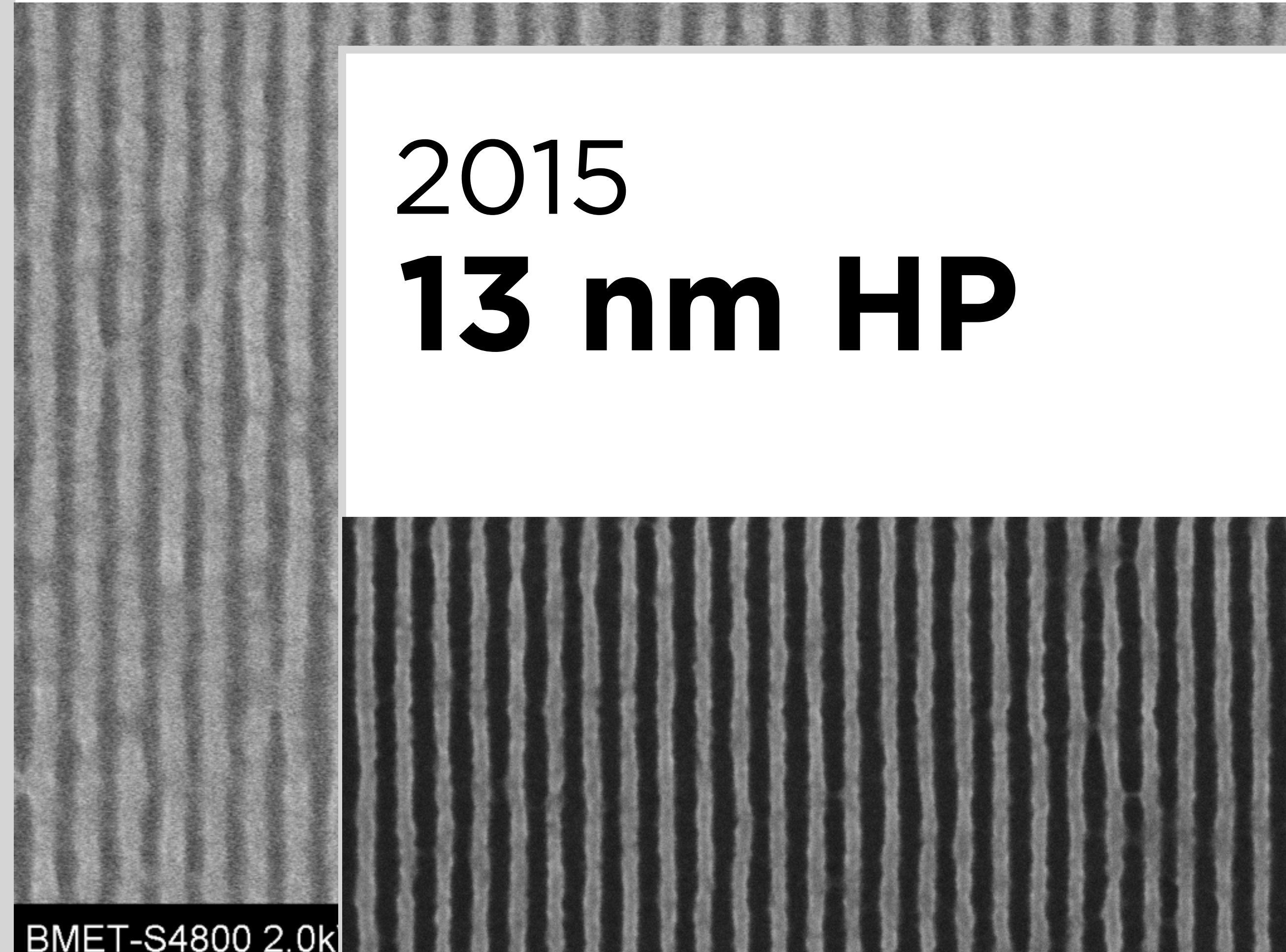
2010

16 nm HP CAR



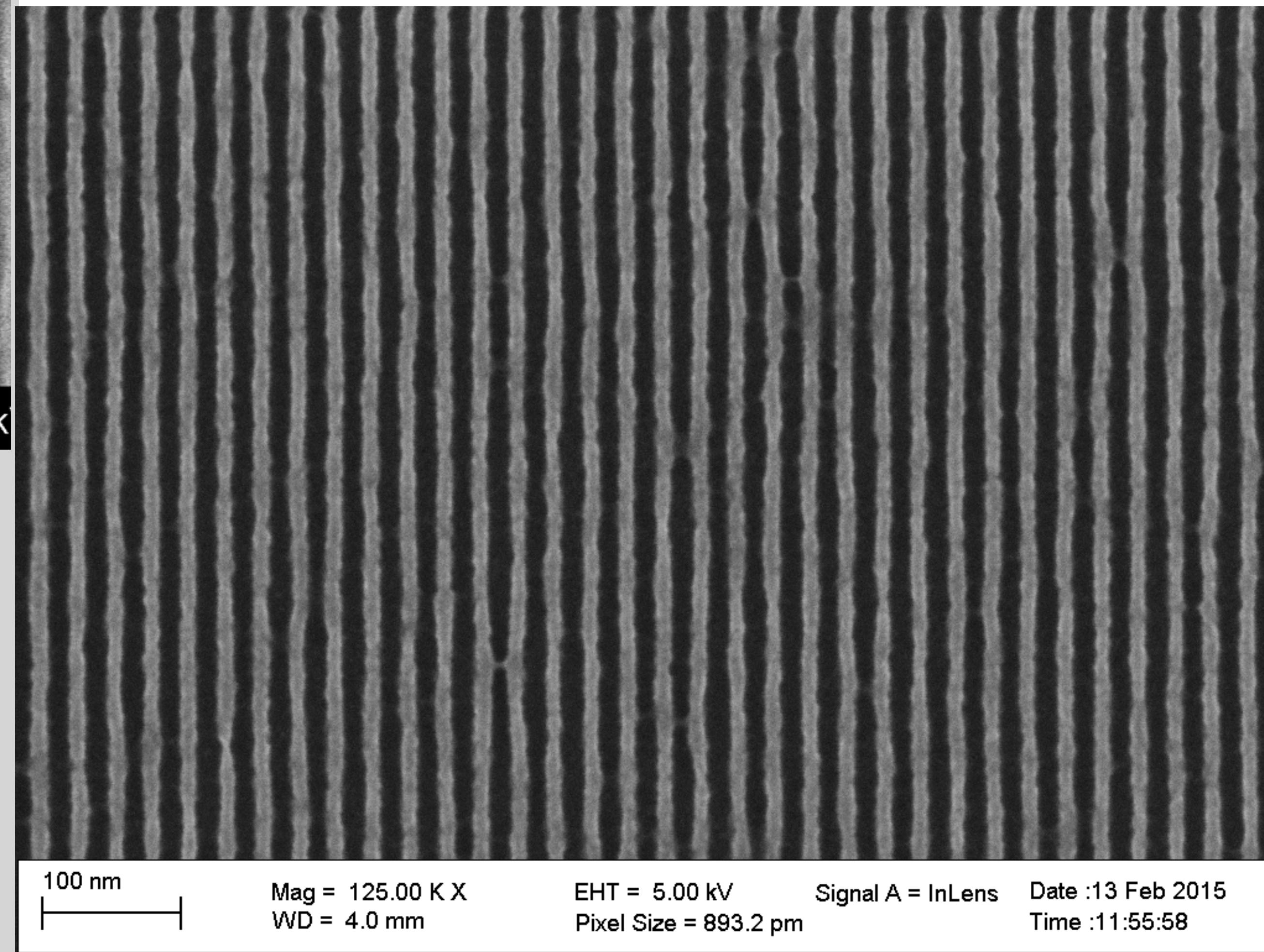
2011

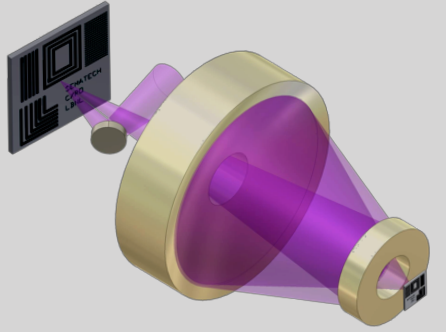
14 nm HP CAR



2015

13 nm HP





2008
22 nm HP CAR

2010
Inpria

16

14

2010
16 nm HP CAR

BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:56 300nm

2011
14 nm HP CAR

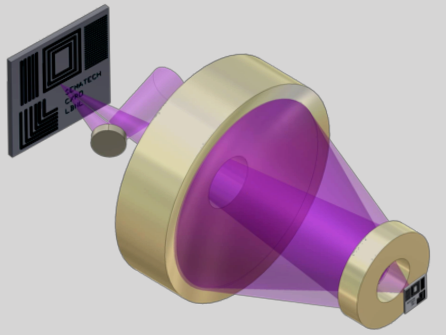
BMET-S4800 2.0k

2015
13 nm HP

100 nm

2O??
12 nm HP

0.3 NA MET



2008
22 nm HP CAR

2010
Inpria

16

14

2010
16 nm HP CAR

BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:56 300nm

2011
14 nm HP CAR

BMET-S4800 2.0k

2015
13 nm HP

100 nm

20??
12 nm HP

20??
10 nm HP

2008
22 nm HP CAR

2010
Inpria

16

14

2010
16 nm HP CAR

BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:56 300nm

2011
14 nm HP CAR

BMET-S4800 2.0k

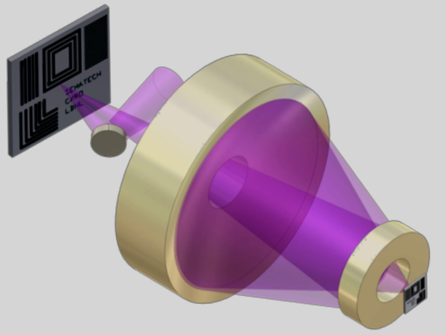
2015
13 nm HP

100 nm

20??
12 nm HP

20??
10 nm HP

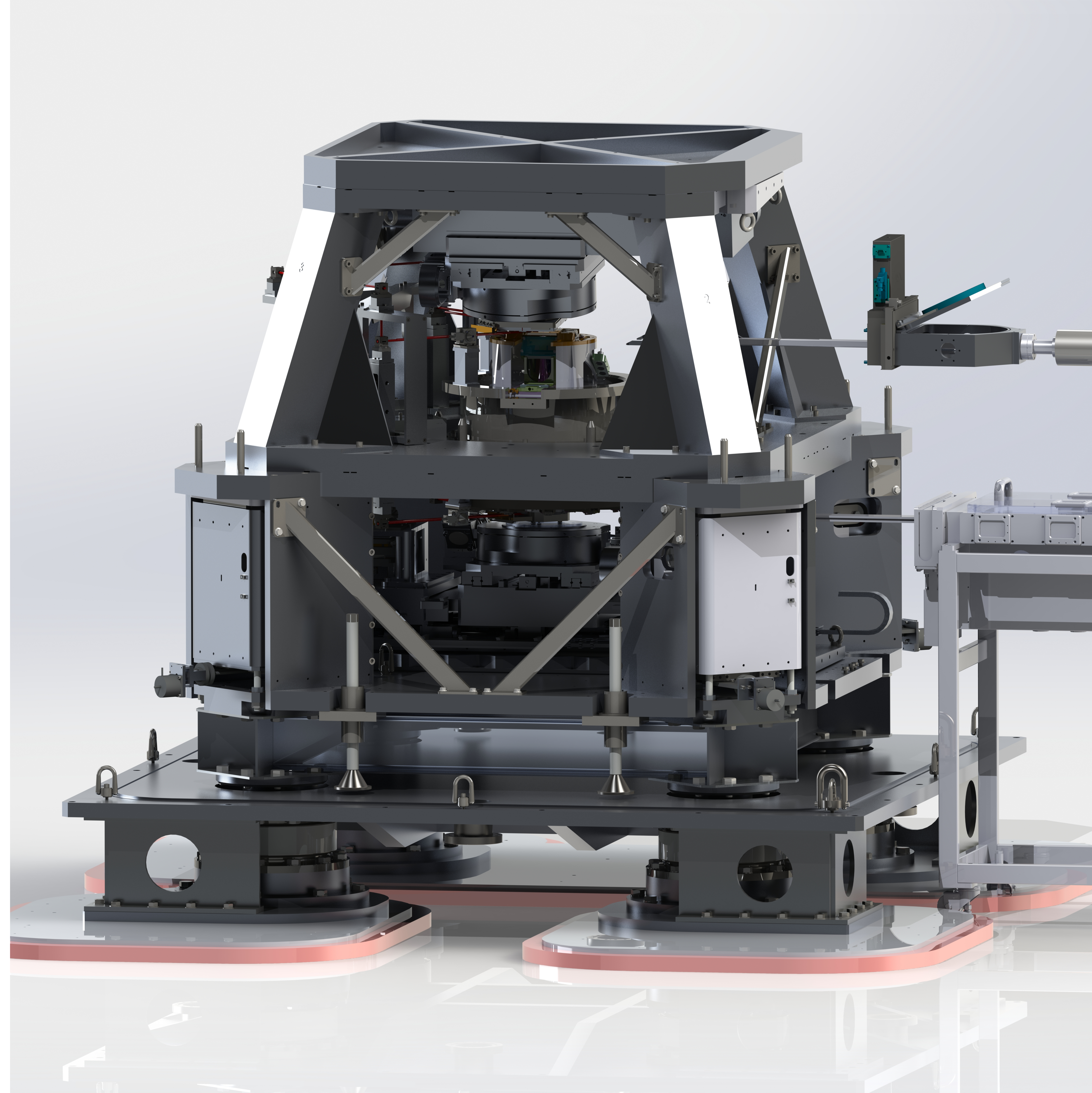
20??
8 nm HP



MET5

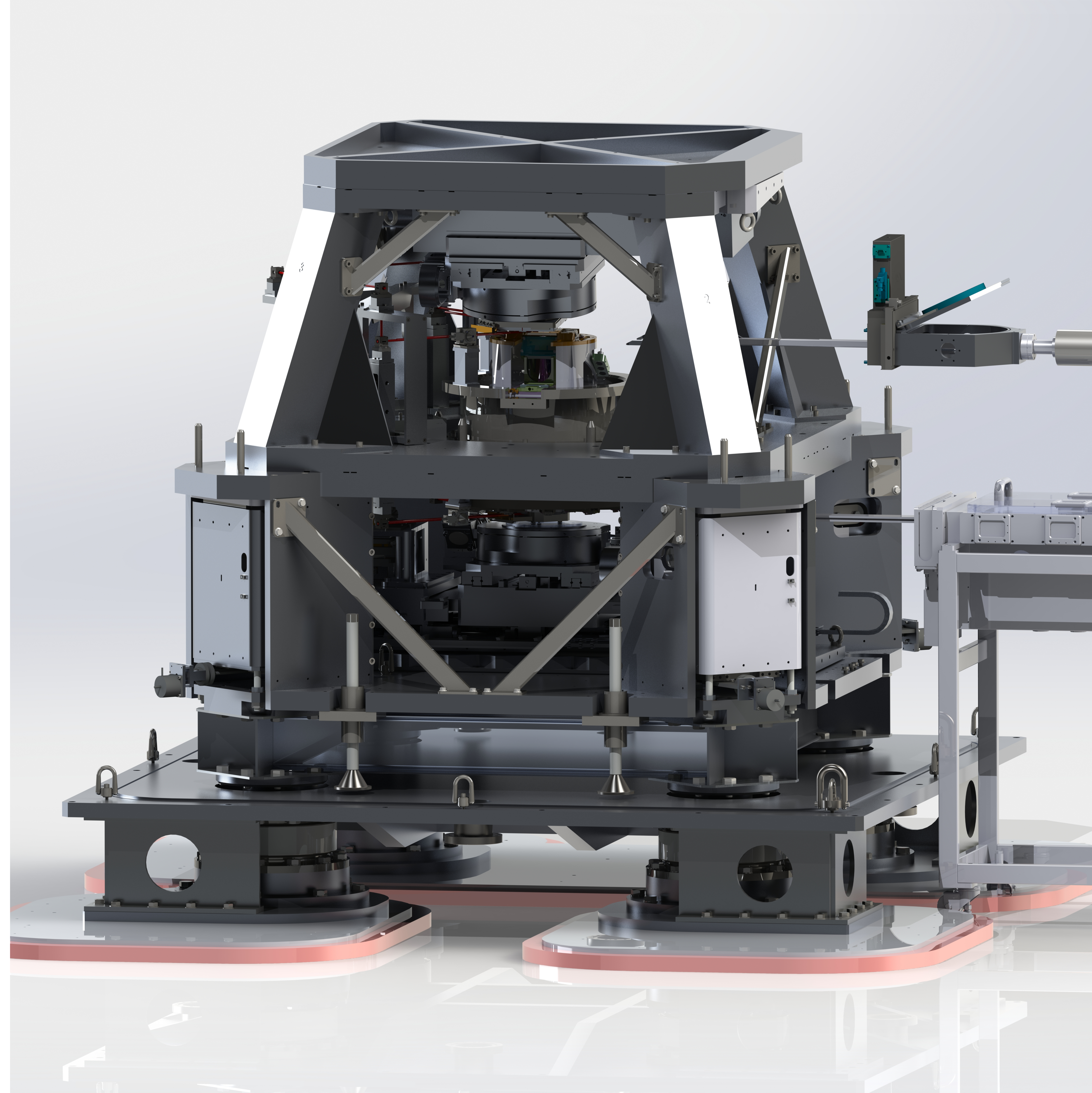
MET5

NA 0.5



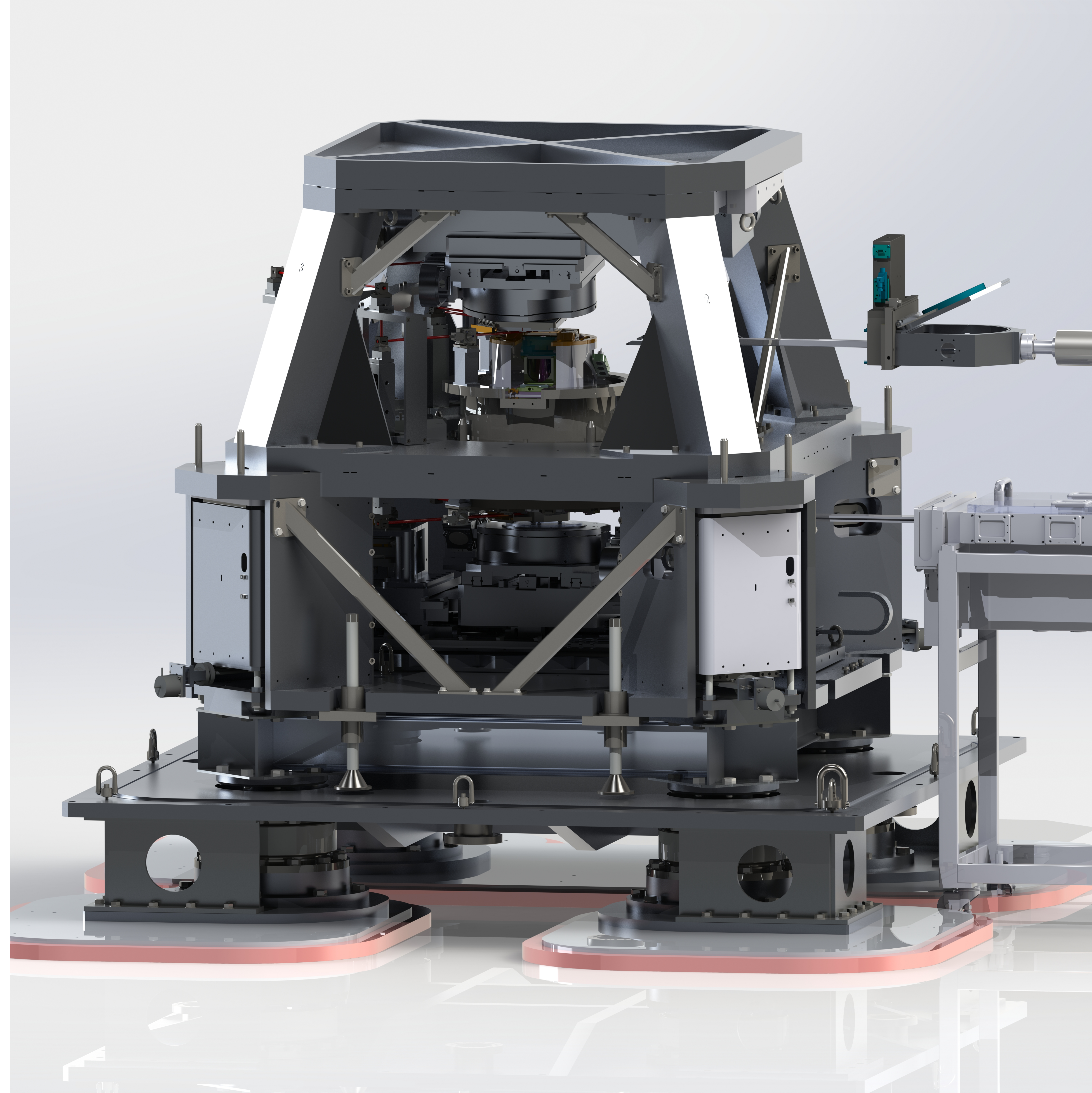
MET5

NA	0.5
RESOLUTION	8 nm



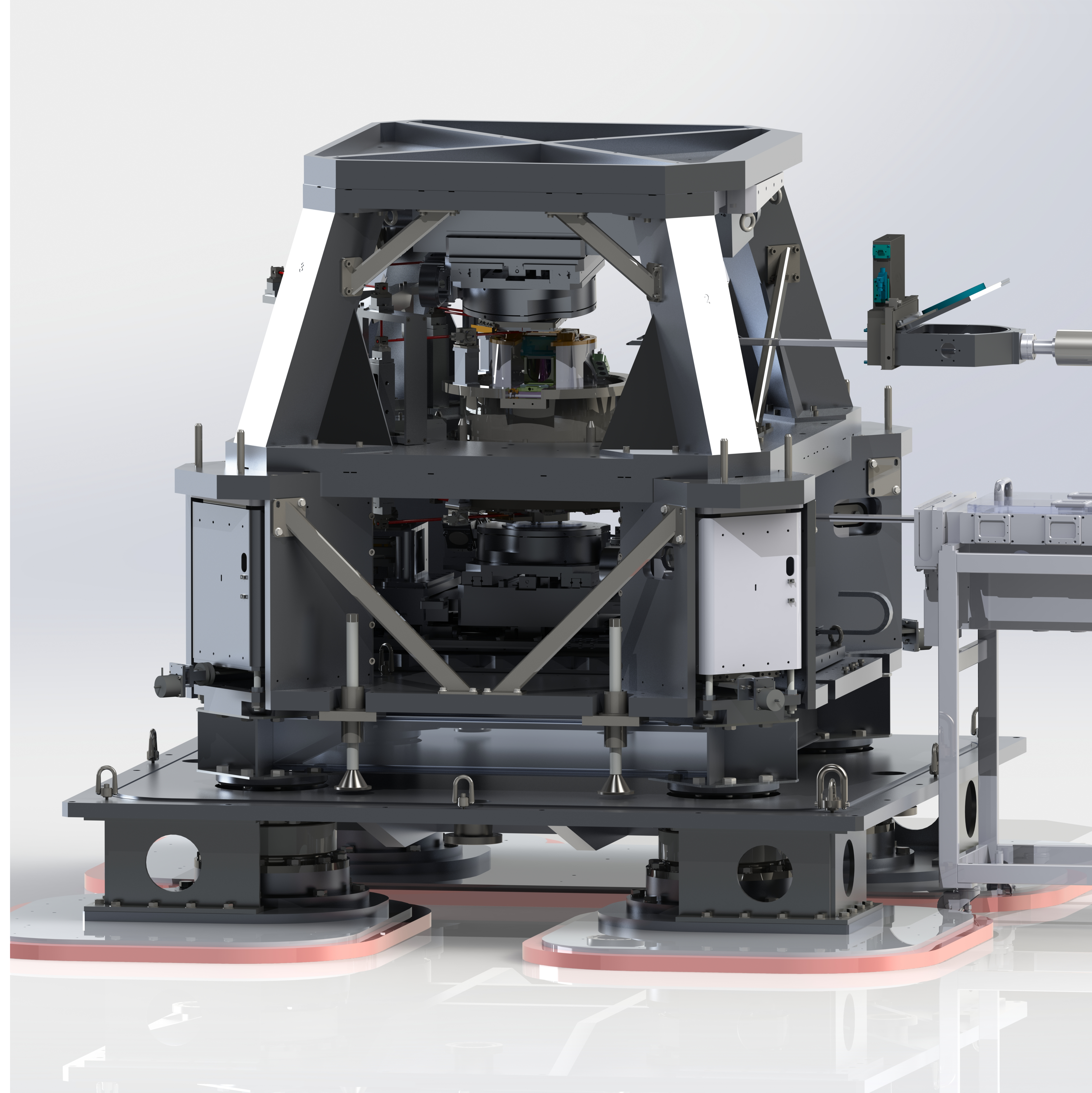
MET5

NA	0.5
RESOLUTION	8 nm
SOURCE	Synchrotron



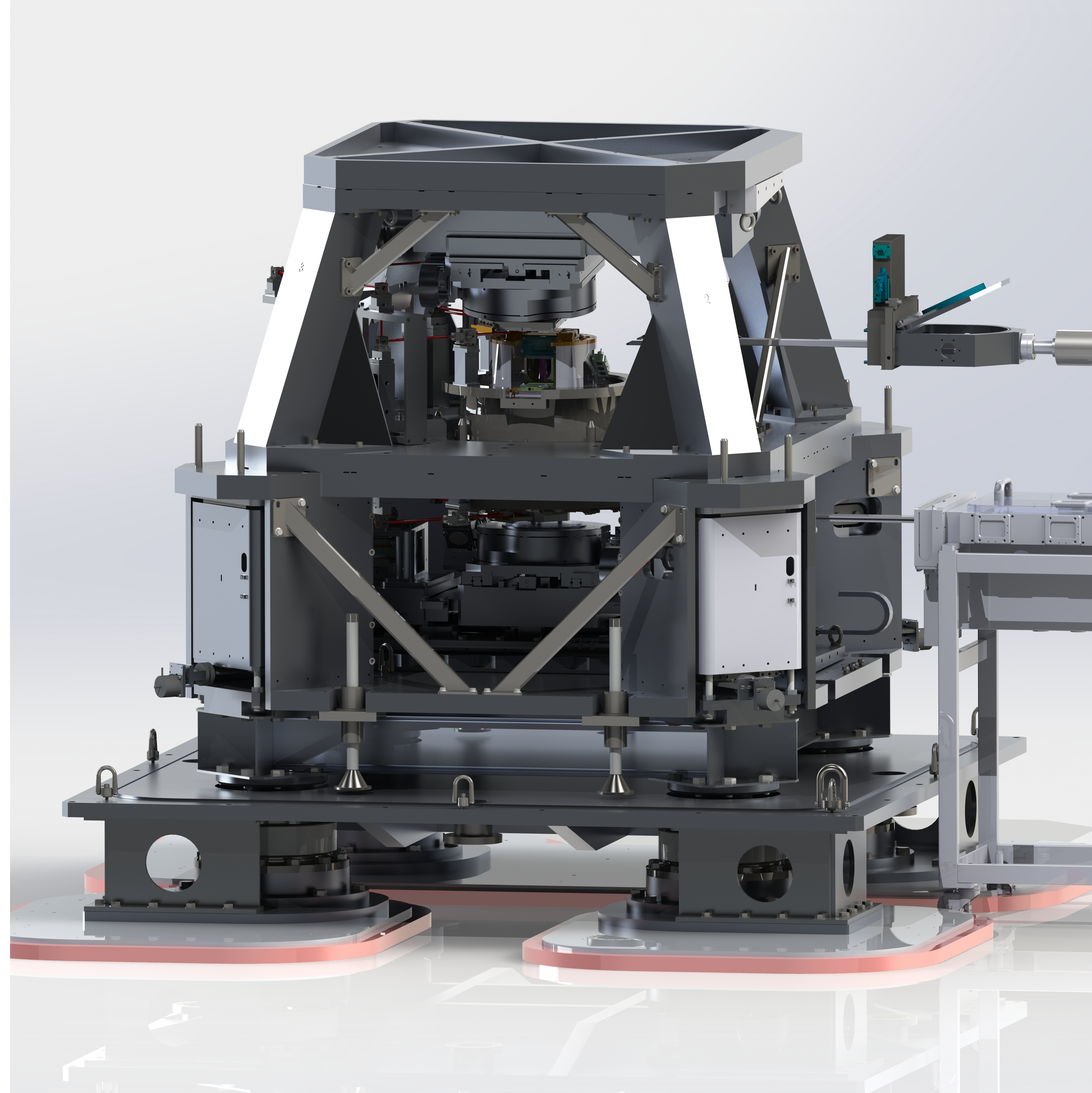
MET5

NA	0.5
RESOLUTION	8 nm
SOURCE	Synchrotron
PRODUCTIVITY	1 WPH 9 x 9 FEM up to 200 mJ/cm2



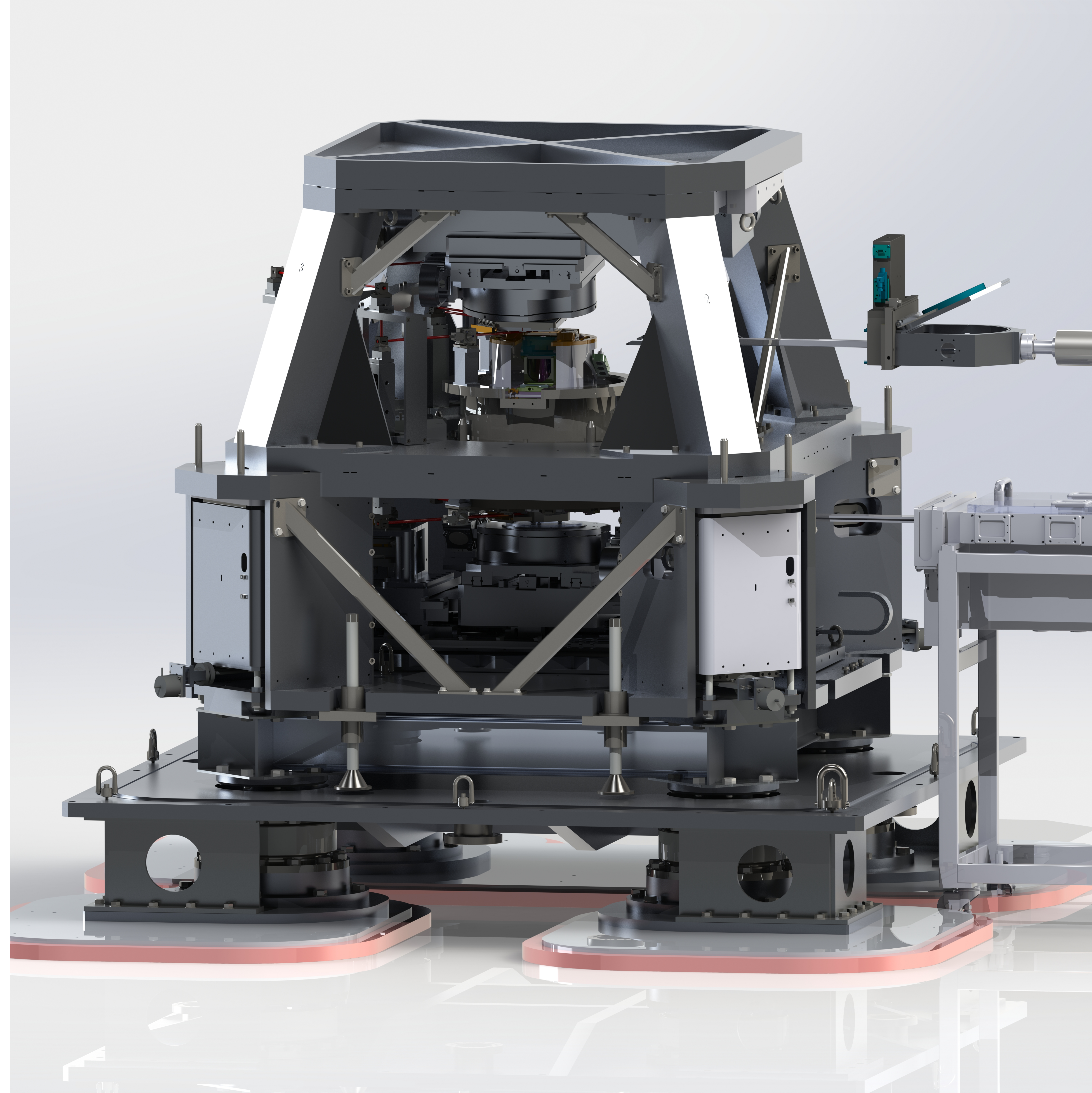
MET5

NA	0.5
RESOLUTION	8 nm
SOURCE	Synchrotron
PRODUCTIVITY	1 WPH 9 x 9 FEM up to 200 mJ/cm2
FIELD SIZE	200 um (x) 30 um (y)



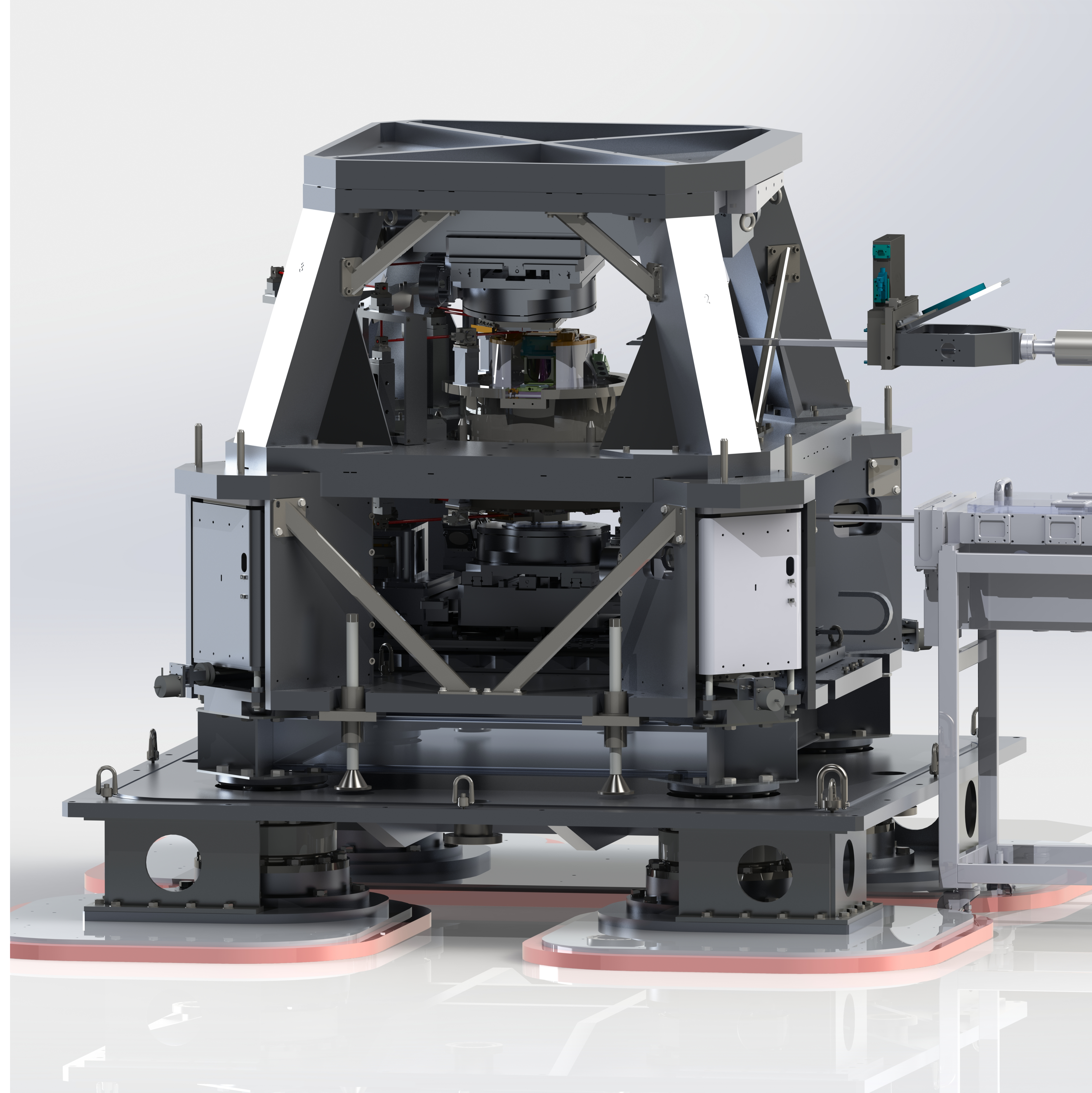
MET5

NA	0.5
RESOLUTION	8 nm
SOURCE	Synchrotron
PRODUCTIVITY	1 WPH 9 x 9 FEM up to 200 mJ/cm2
FIELD SIZE	200 um (x) 30 um (y)
WAFER SIZE	200 mm



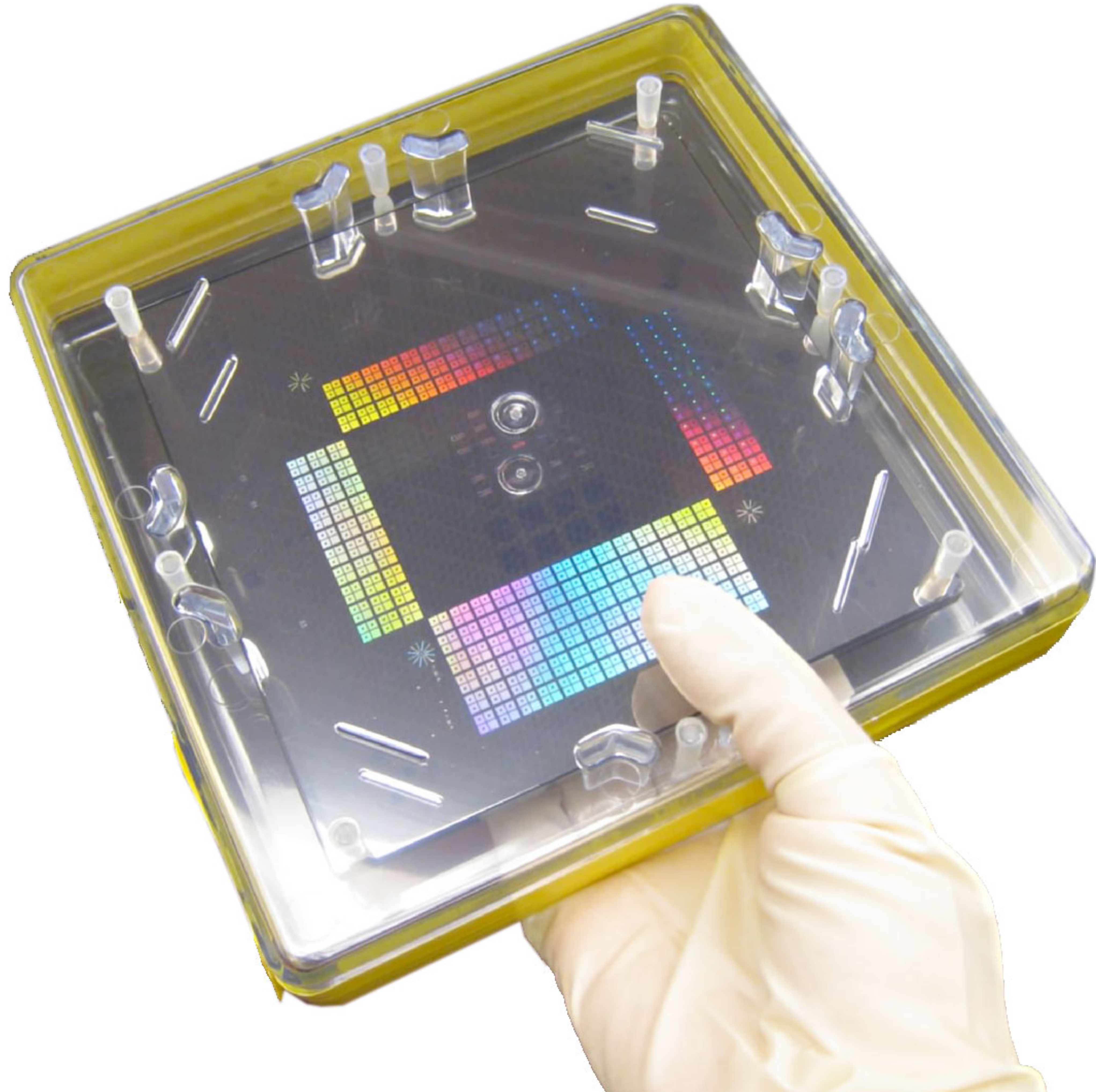
MET5

NA	0.5
RESOLUTION	8 nm
SOURCE	Synchrotron
PRODUCTIVITY	1 WPH 9 x 9 FEM up to 200 mJ/cm2
FIELD SIZE	200 um (x) 30 um (y)
WAFER SIZE	200 mm
PROCESSING	Robotic tailored for research



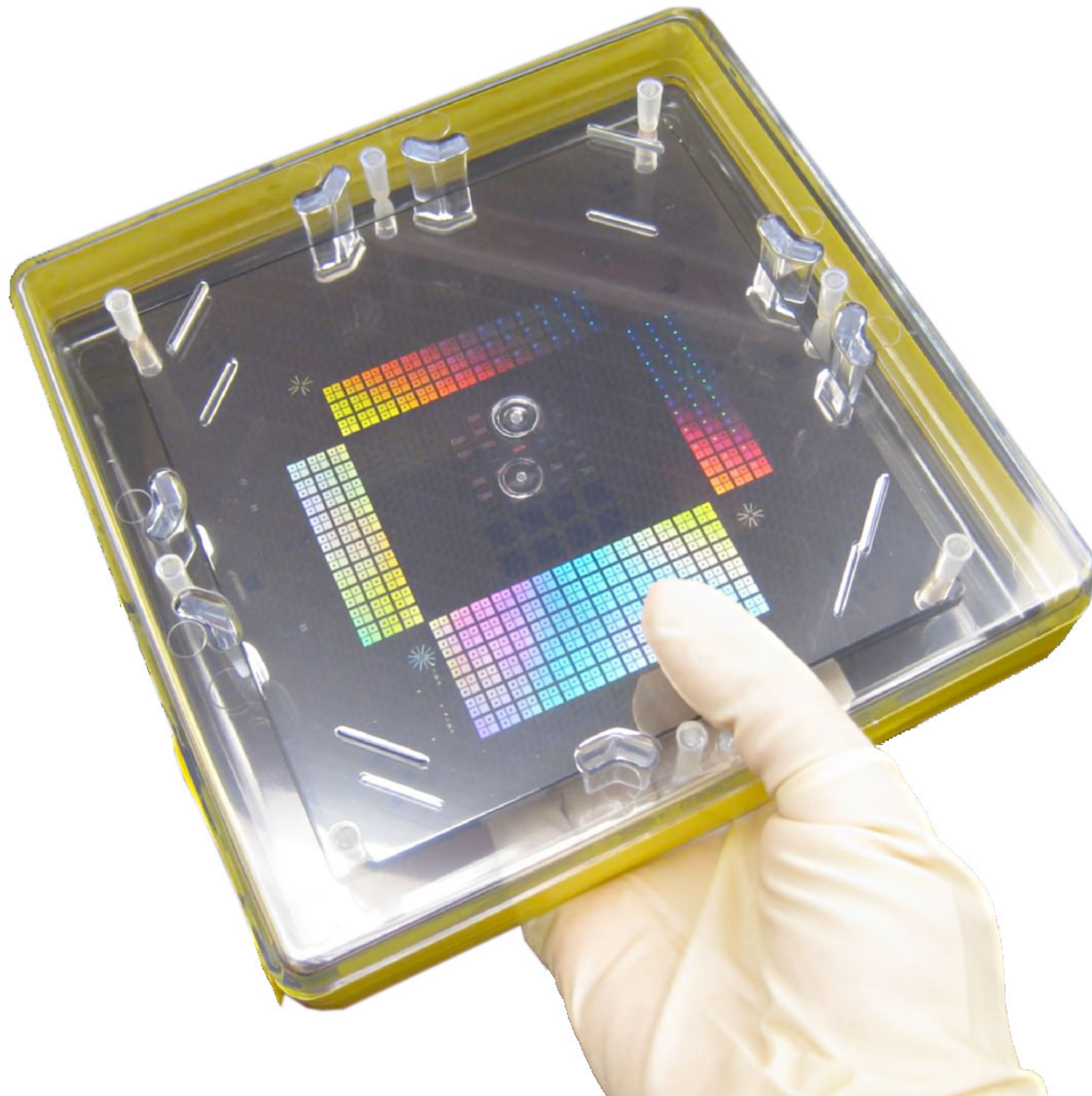
0.5-NA PRINTING RESULTS

RESOLUTION



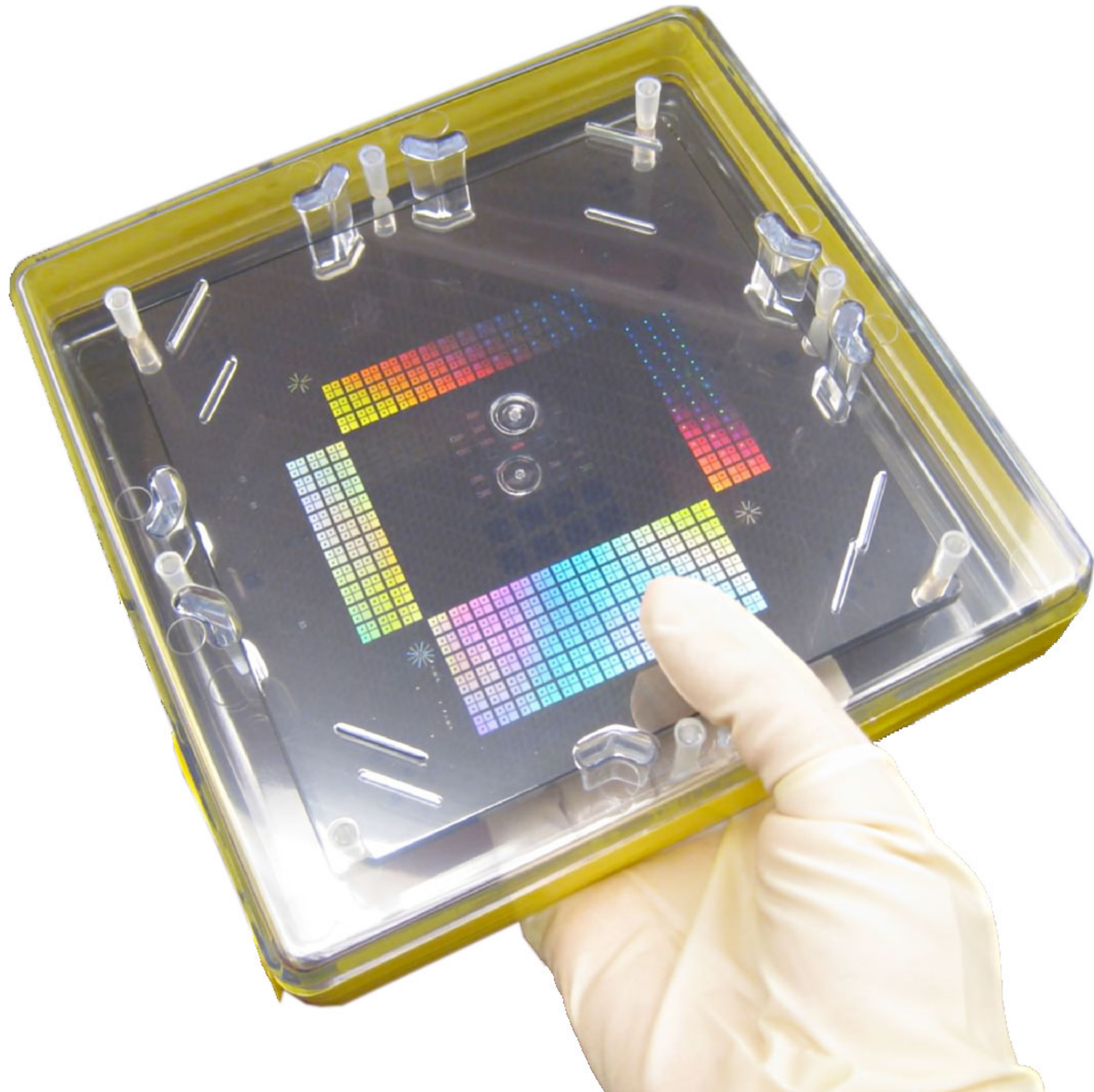
REFLECTIVITY OF MULTILAYER @6°

63%



THICKNESS
OF ABSORBER

62 nm



REFLECTIVITY OF ABSORBER @6°

1.5%

Modeled contrast of vertical lines in MET5 with annular 35-55 illumination.

Contrast

Half pitch (nm)

Annular 35-55

Modeled contrast of vertical lines in MET5 with annular 35-55 illumination.

12 nm HP cutoff

Contrast

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

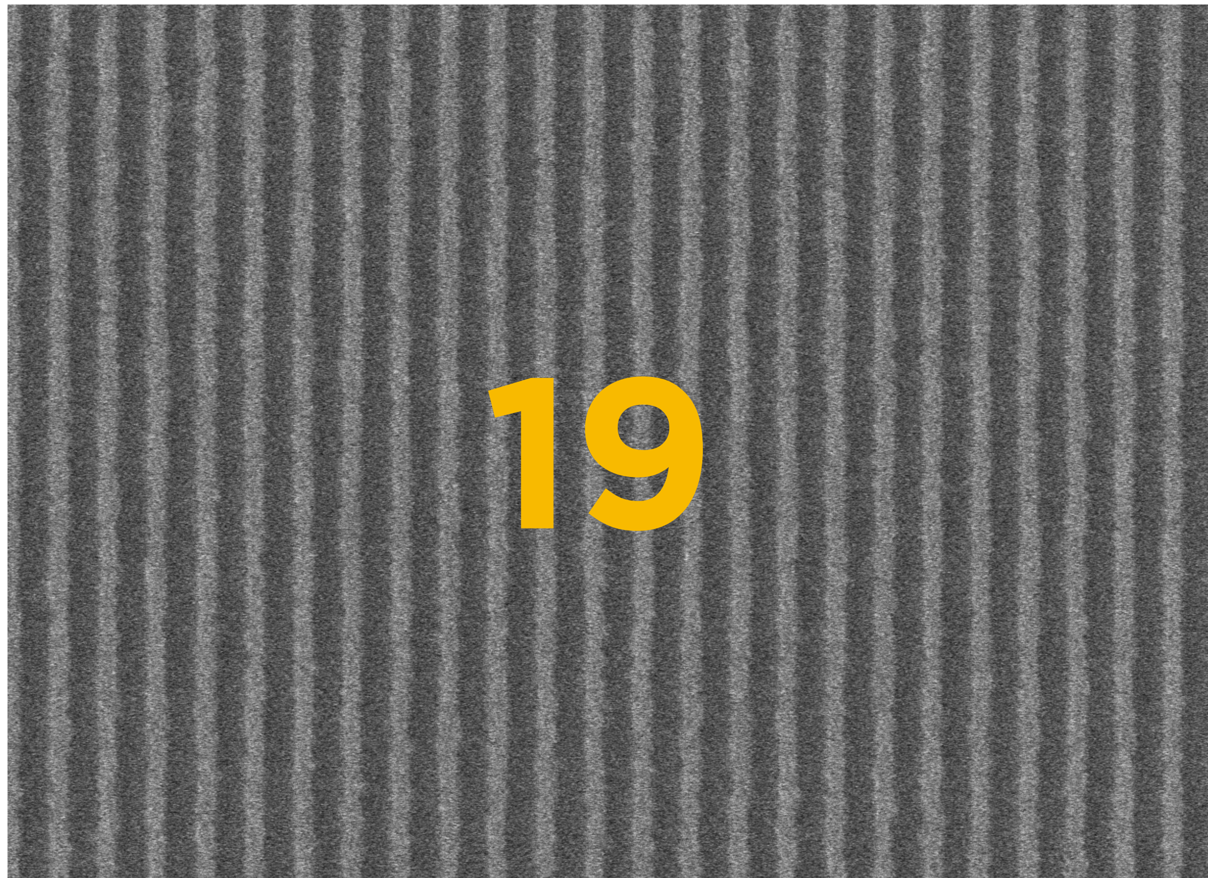
5 10 15 20 25 30 35

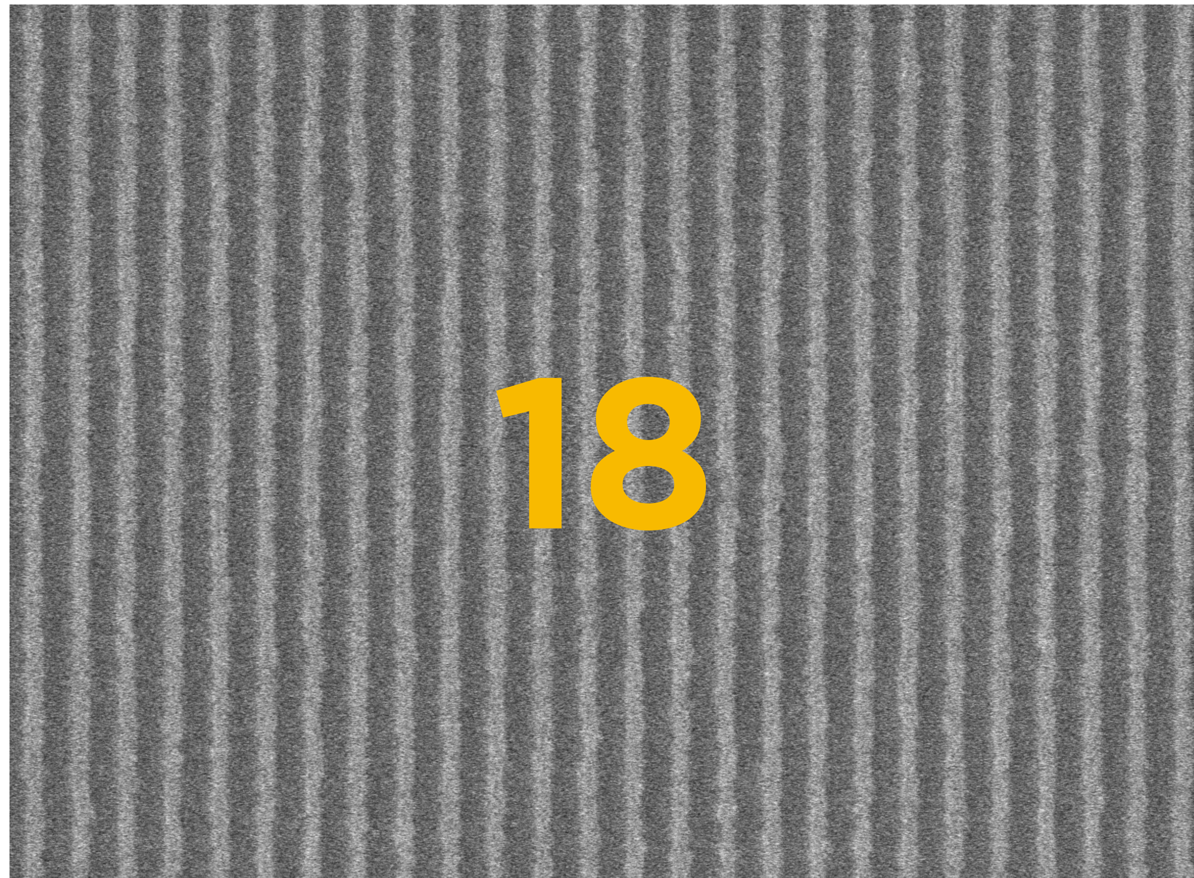
Half pitch (nm)

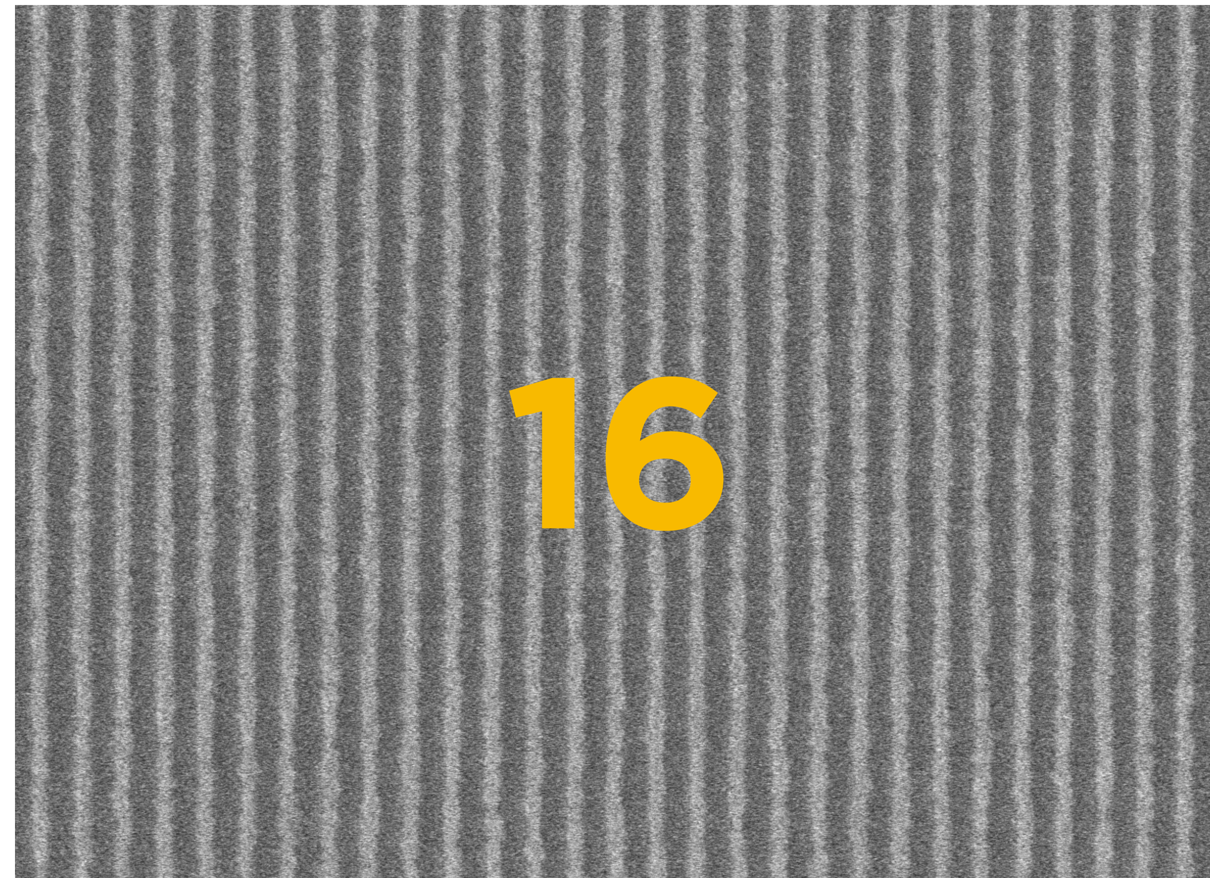
Annular 35-55

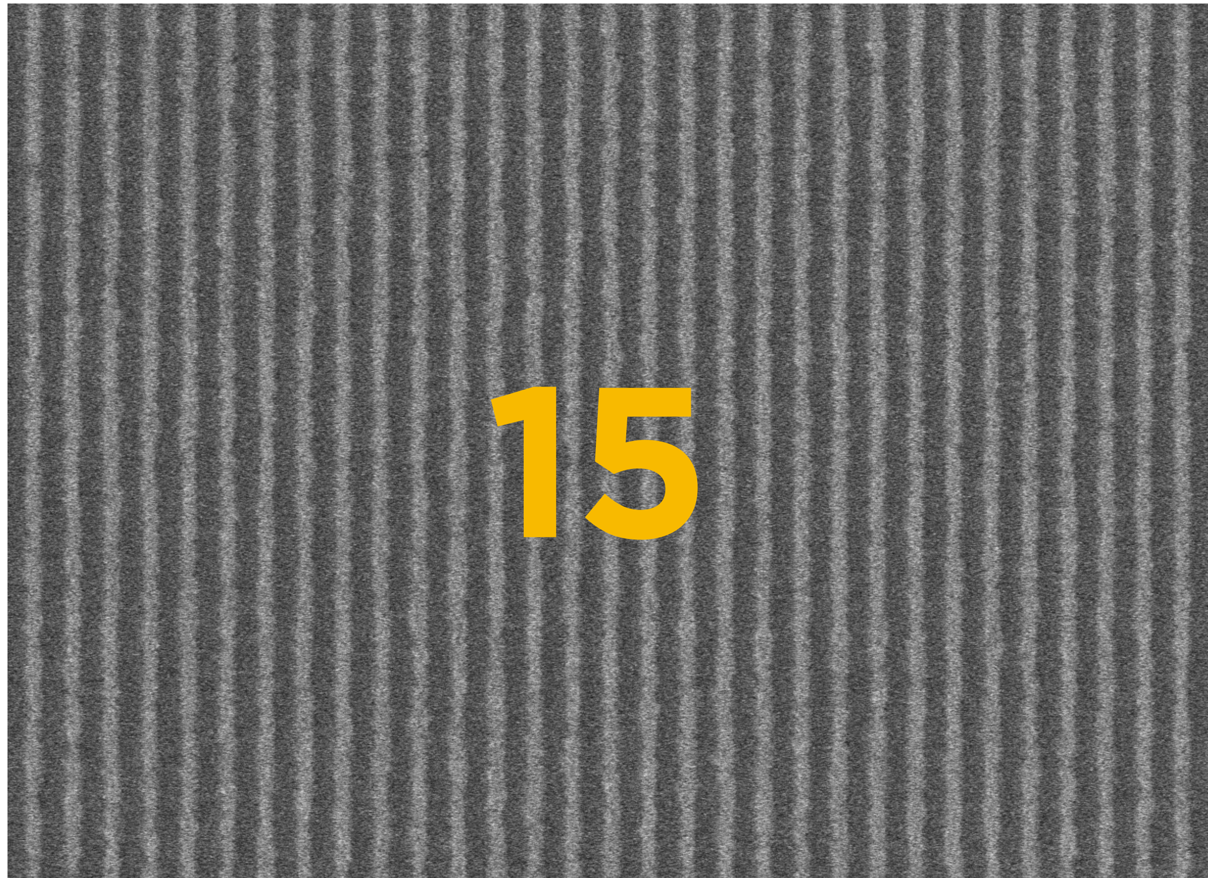
Below the line won’t print. Contrast too low.

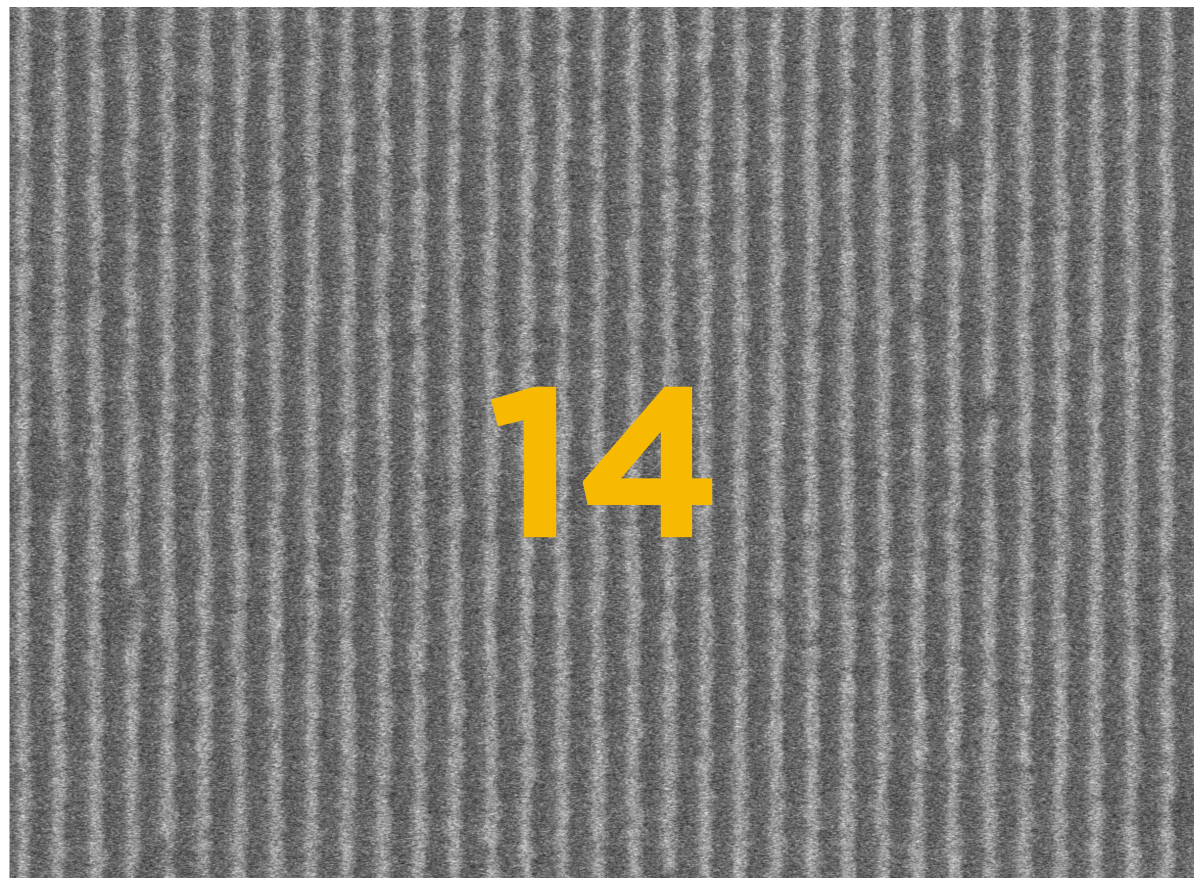
Vertical lines in MET5 with annular 35-55 illumination. Numbers are half-pitch.

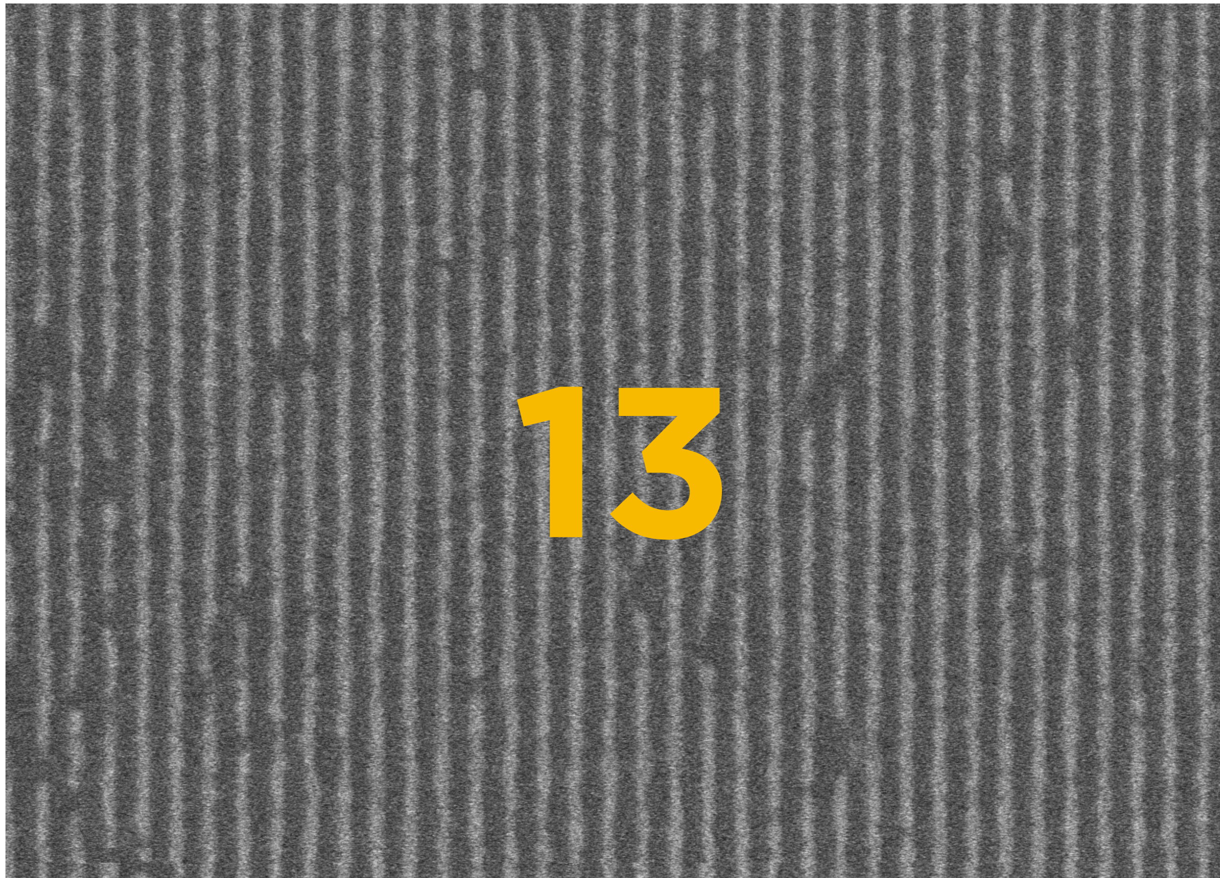


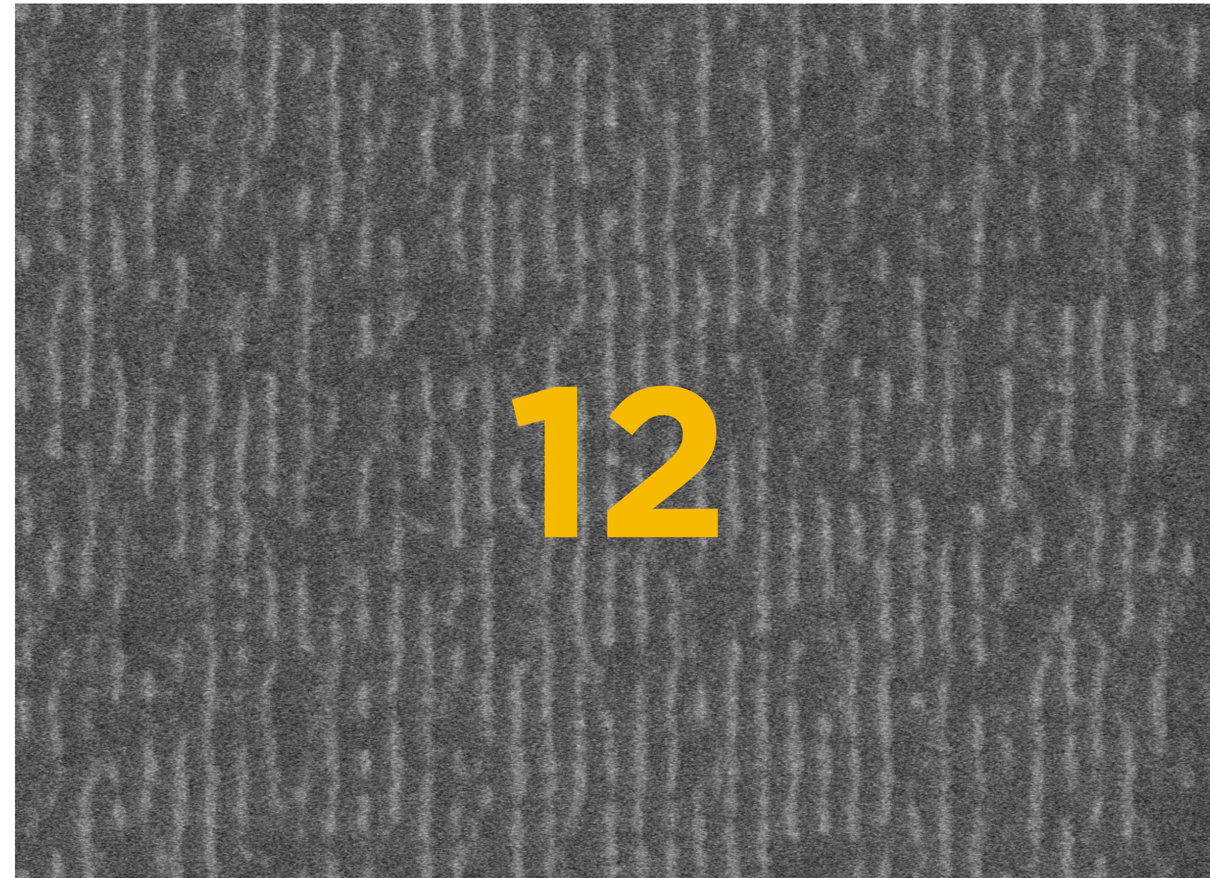






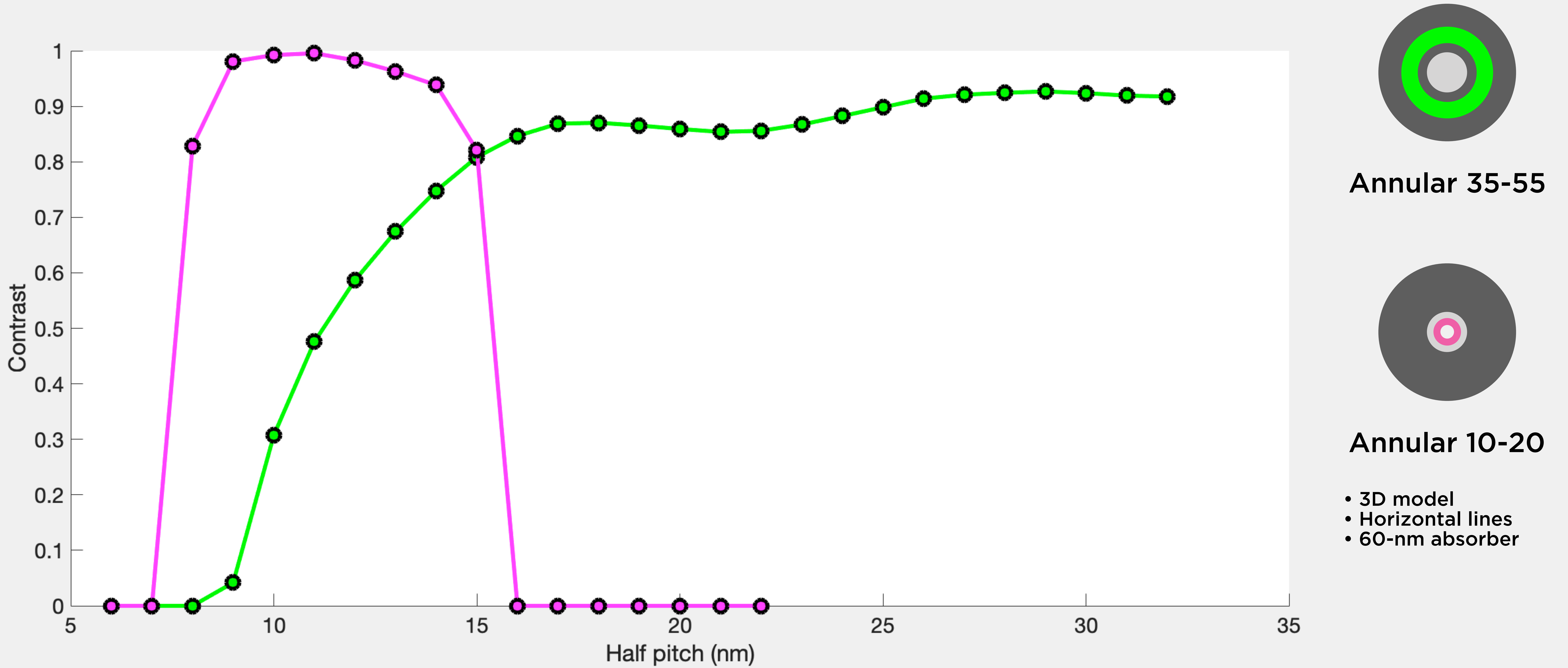




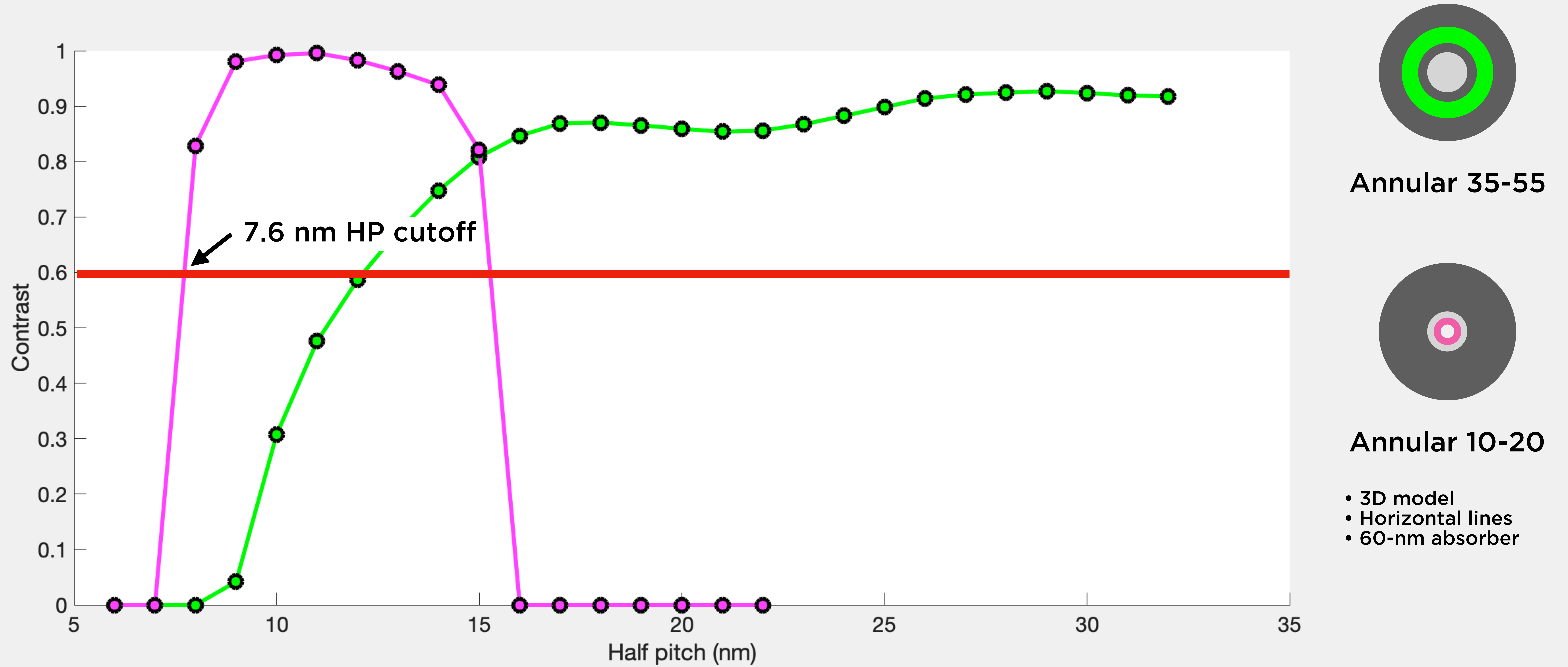


Wafer ID: 2018-12-05-002
Dose: 48 mJ/cm2
FT: 20 nm

Modeled contrast of frequency doubled horizontal lines in MET5 with annular 10-20 illumination.

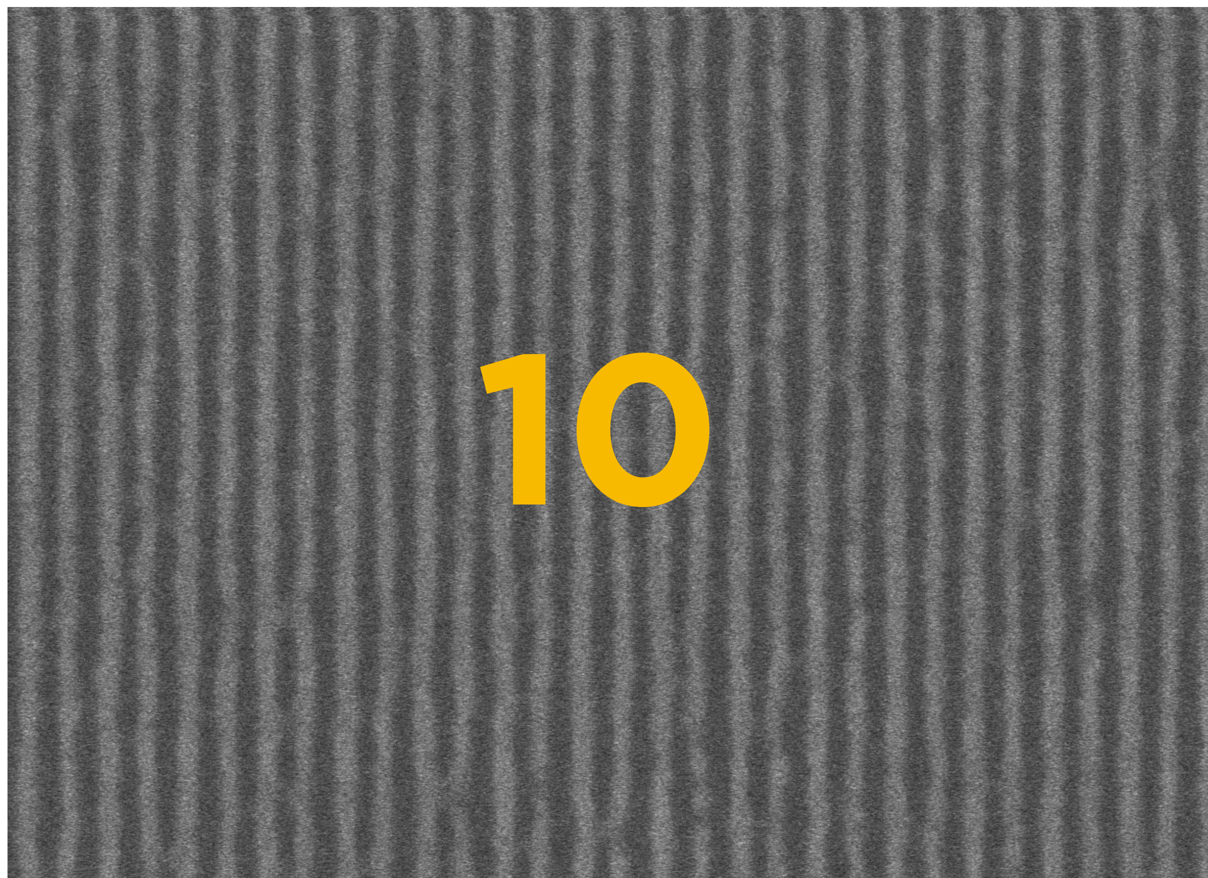


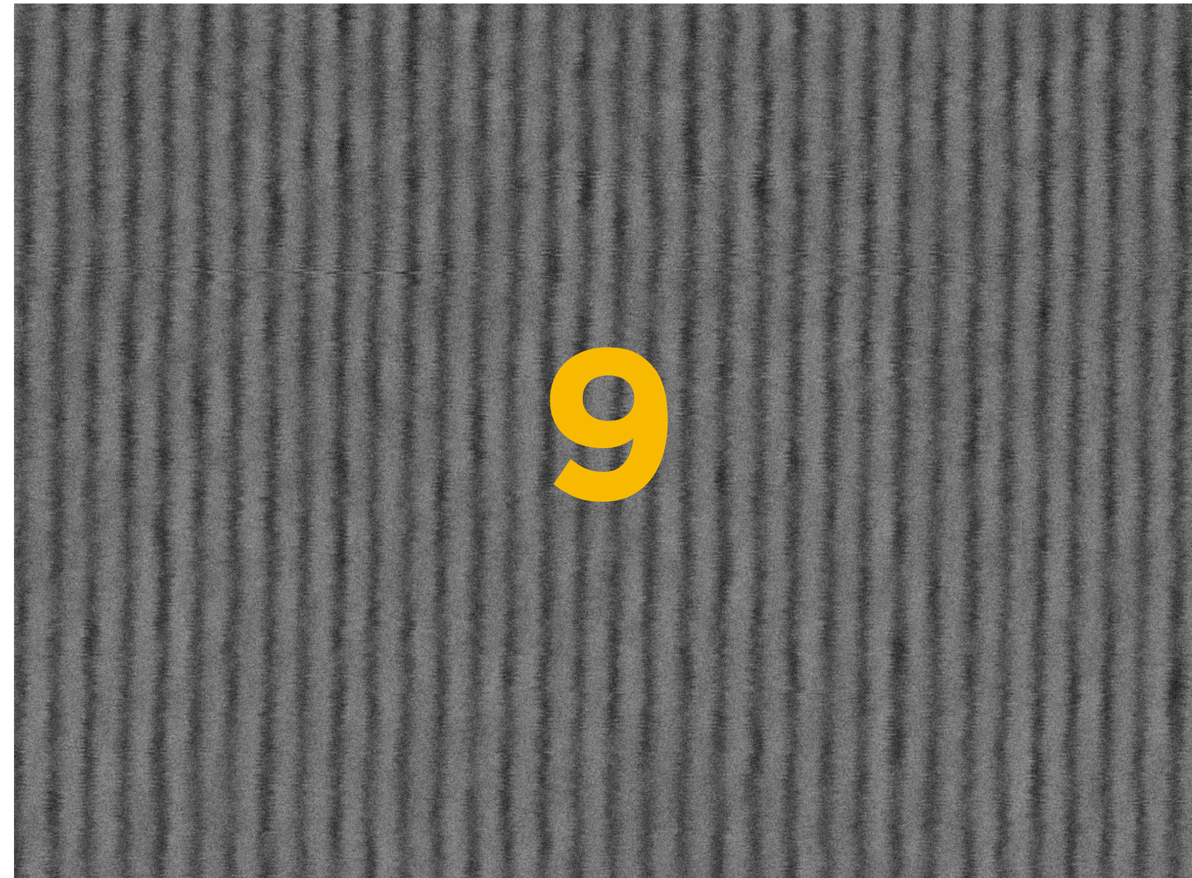
Modeled contrast of frequency doubled horizontal lines in MET5 with annular 10-20 illumination.

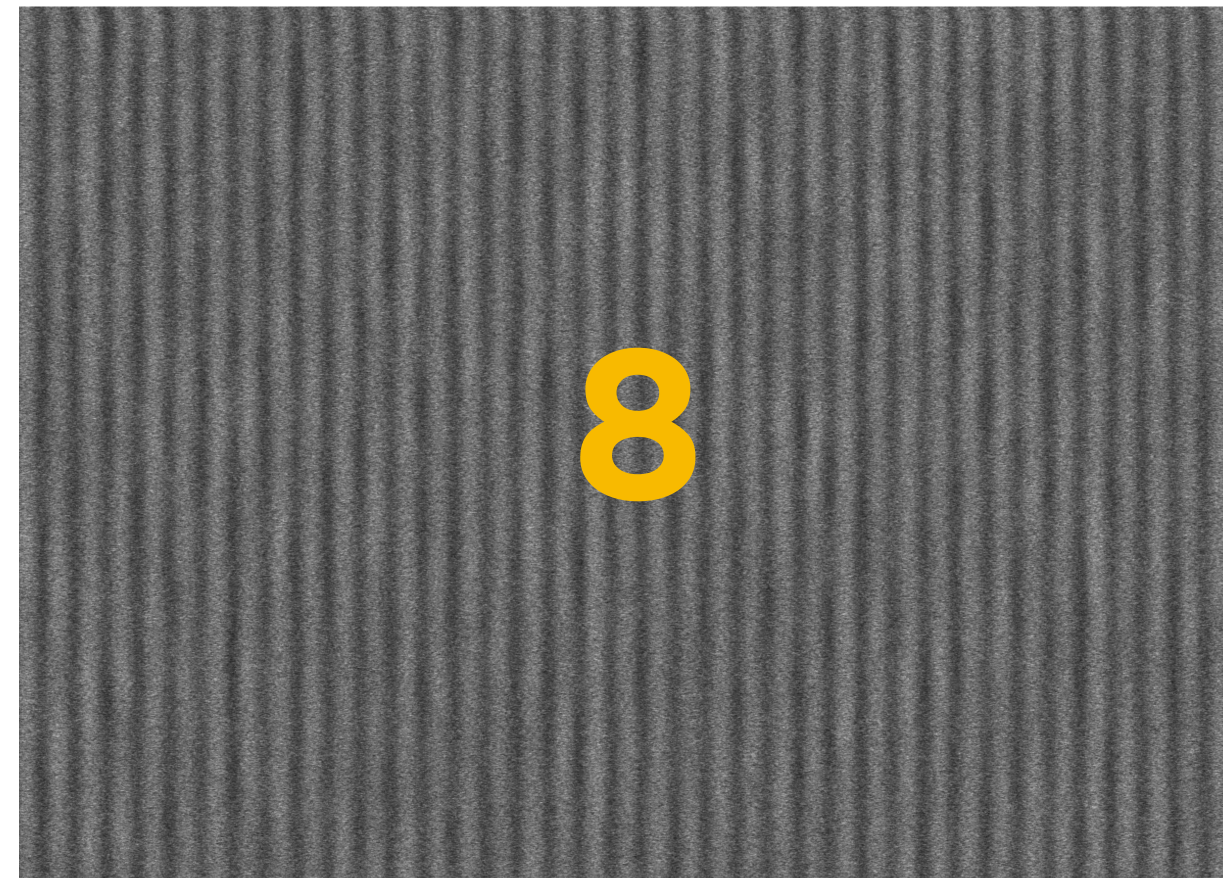


Below the line won't print. Contrast too low.

Frequency doubled horizontal lines in MET5 with annular 10-20 illumination. Numbers are half-pitch.







Wafer ID: 2018-12-05-002
Dose: 96 mJ/cm2
FT: 20 nm

inpria™

8 nm HP

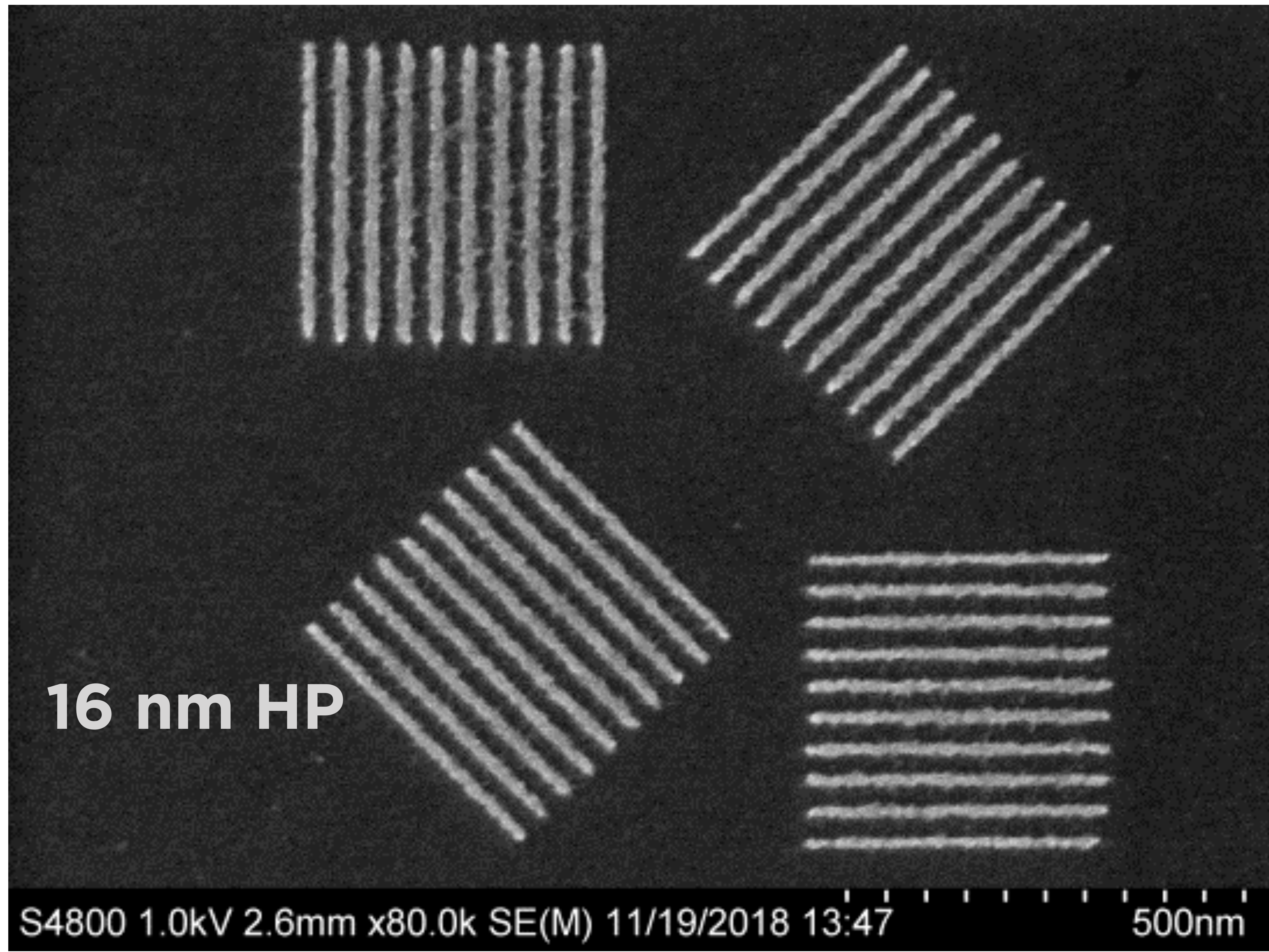
Annular 10-20 (F2X)

Wafer ID: 2018-12-05-002
Dose: 47 mJ/cm2
FT: 20 nm

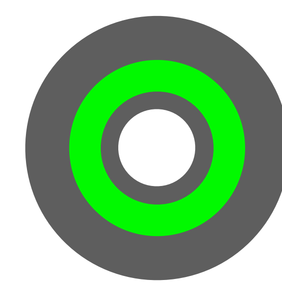
inpria™

0.5-NA PRINTING RESULTS

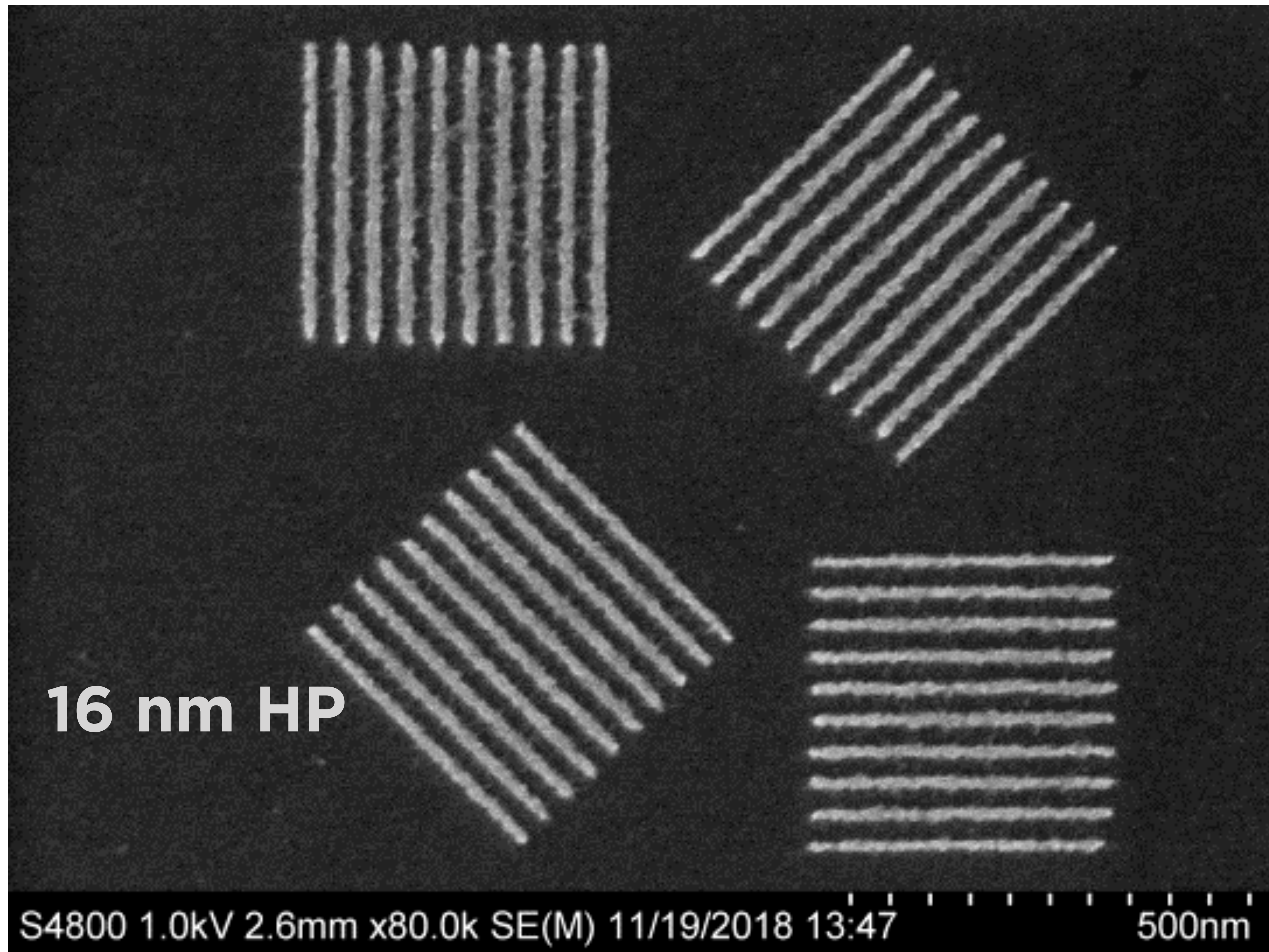
ASTIGMATISM

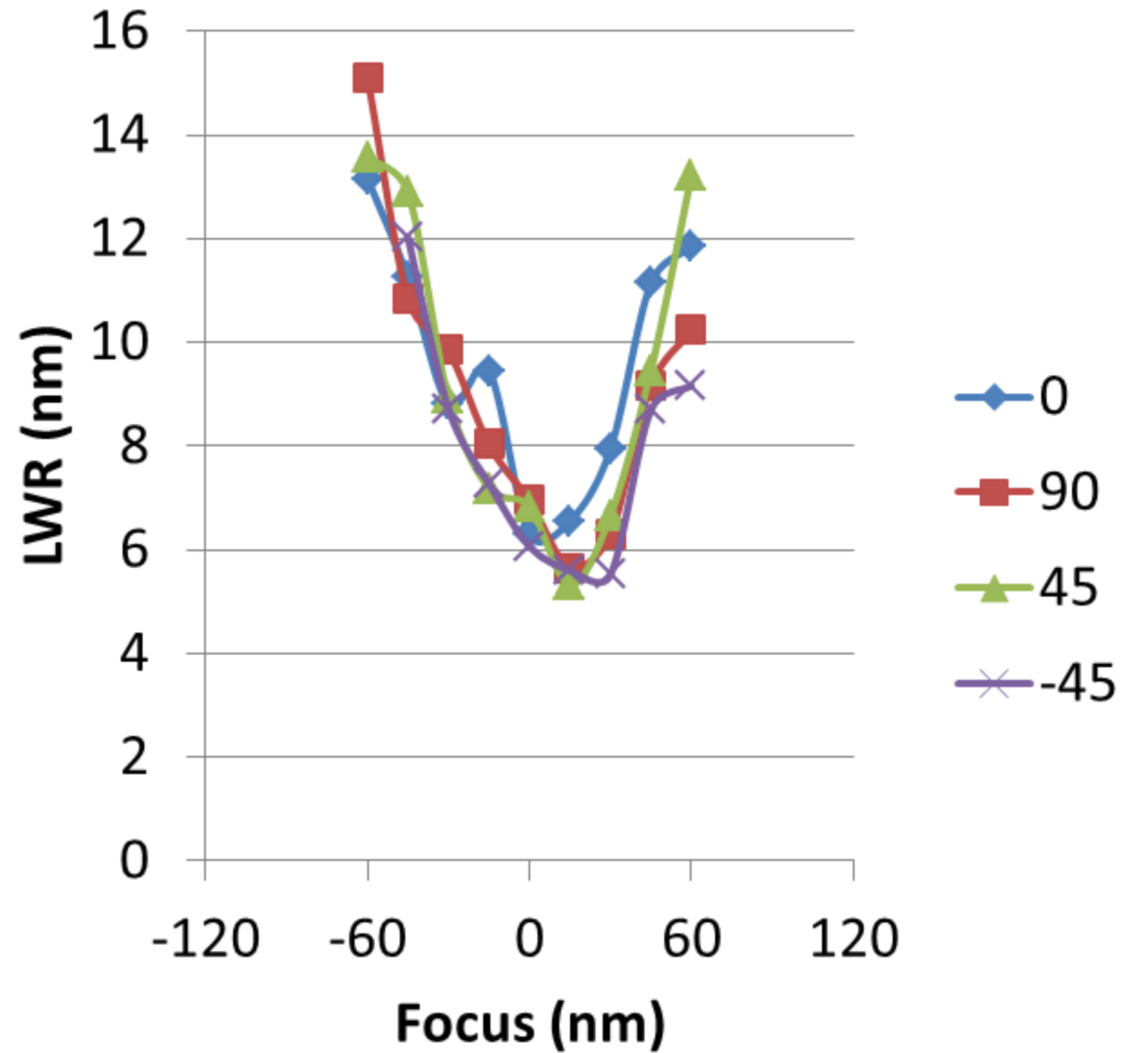


Wafer ID: 2018-11-02-02
Dose: 23 mJ/cm2
FT: 20 nm

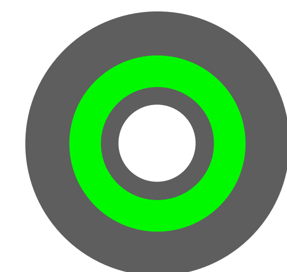


Annular 35-55





Wafer ID: 2018-11-02-02
Dose: 23 mJ/cm2
FT: 20 nm



Annular 35-55

0.5-NA PRINTING RESULTS

FOCUS CONTROL

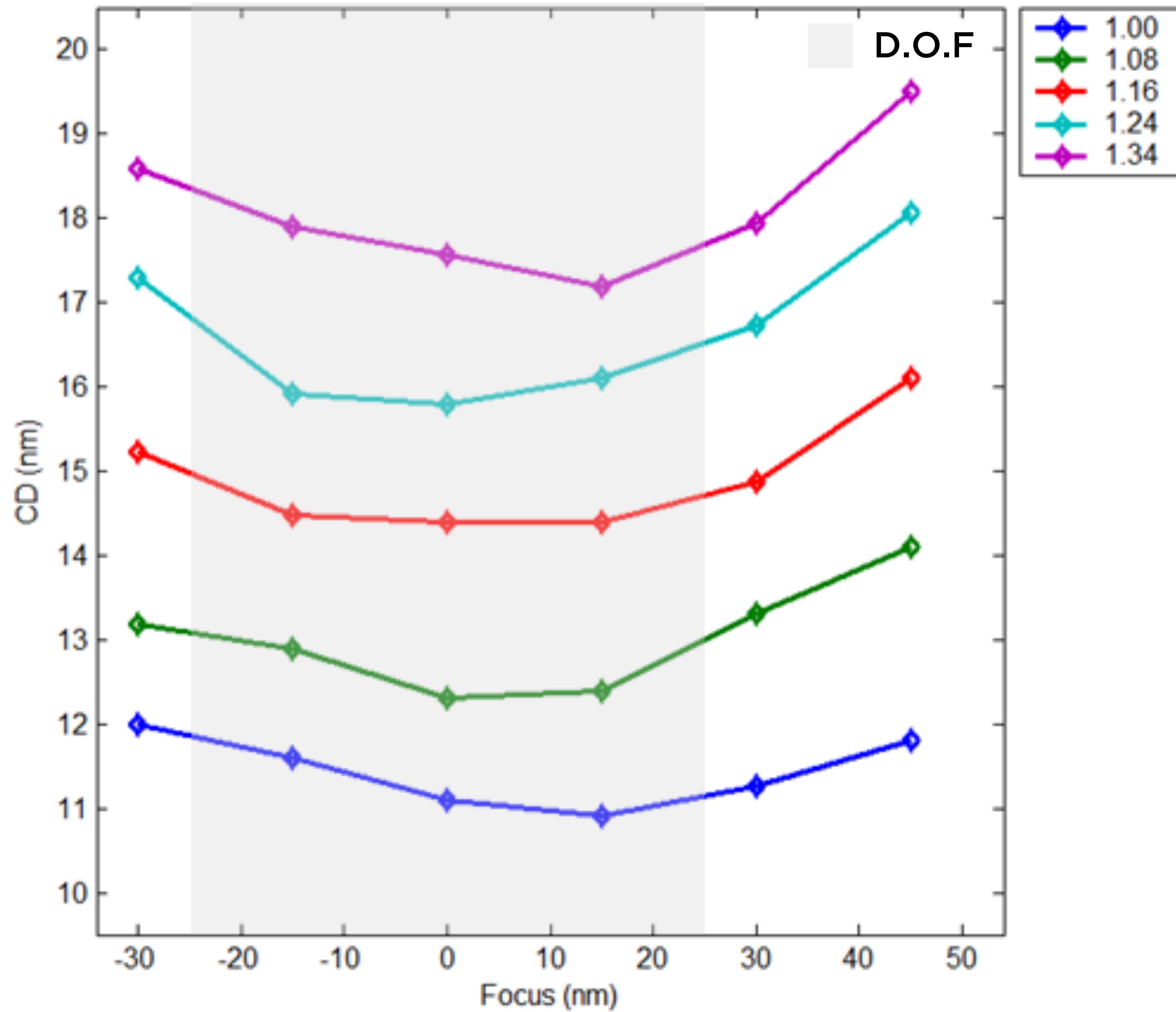
mJ/cm²

FOCUS

mJ/cm²

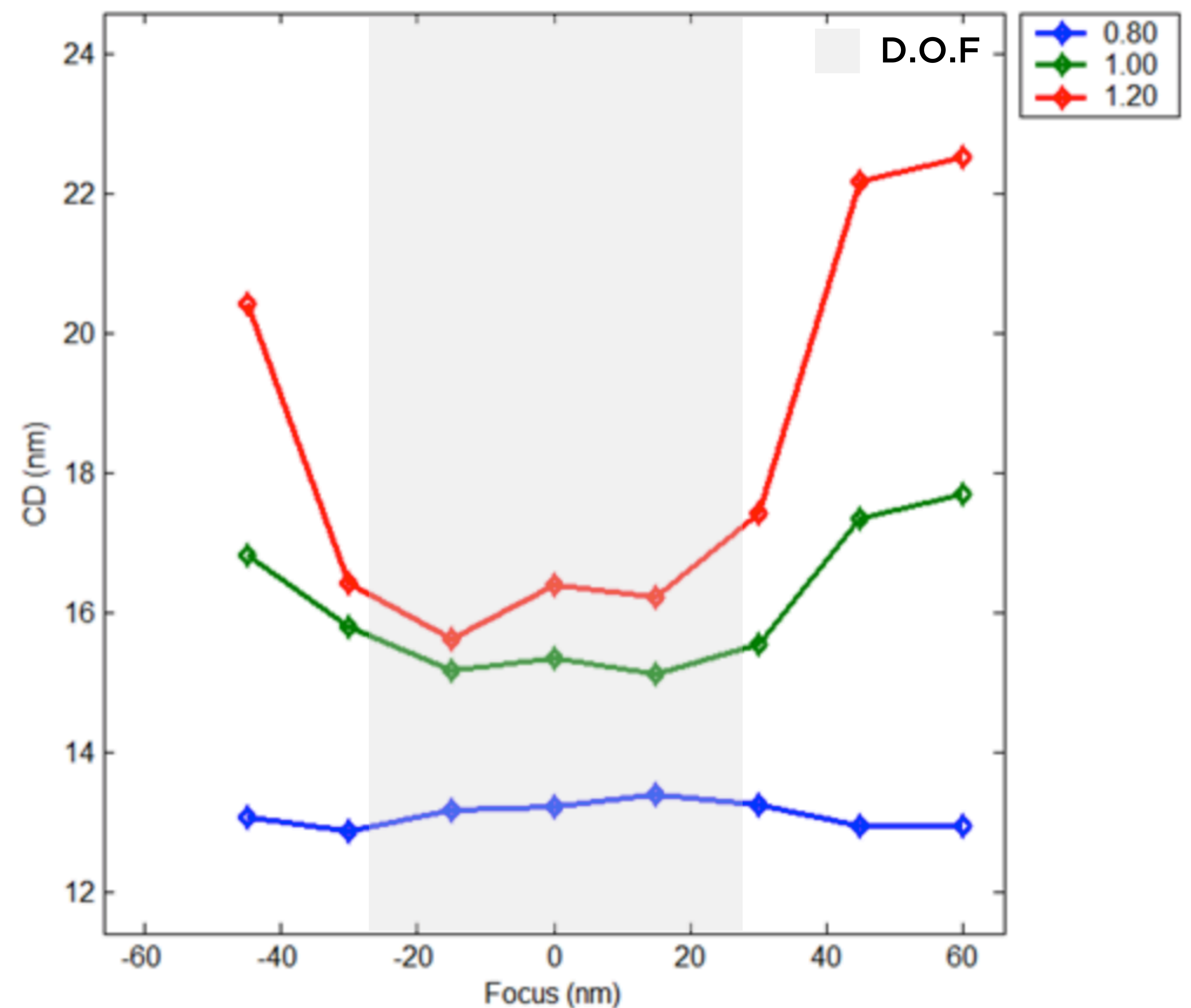
FOCUS

Bossung Curves for 14 nm 1:1 vertical lines (nominal) in MET5 with annular 40-80 illumination.



WaferID: 2018-11-04-02

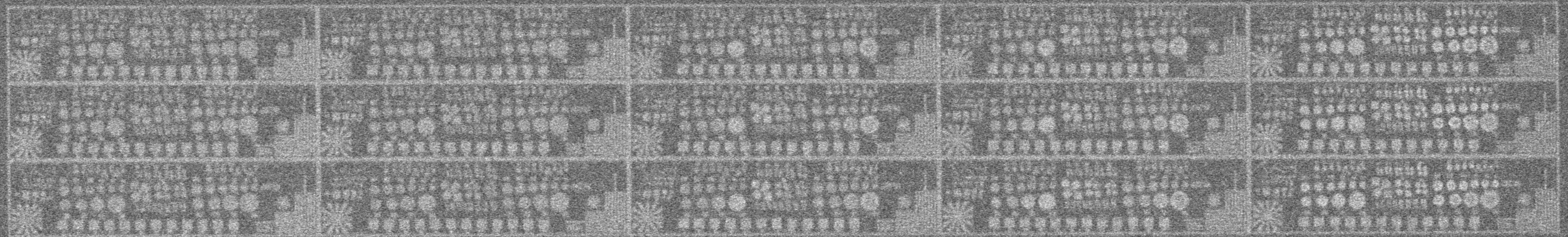
Bossung Curves for 15 nm 1:1 vertical lines (nominal) in MET5 with annular 40-80 illumination.

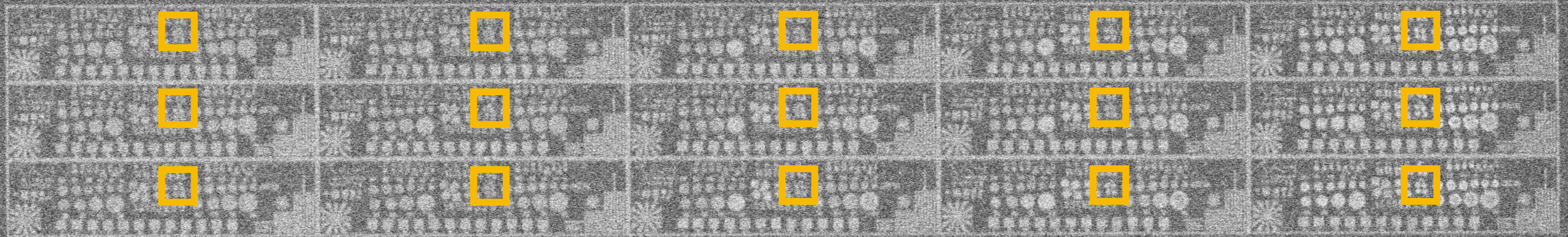


WaferID: 2018-12-05-02

0.5-NA PRINTING RESULTS

DOSE UNIFORMITY



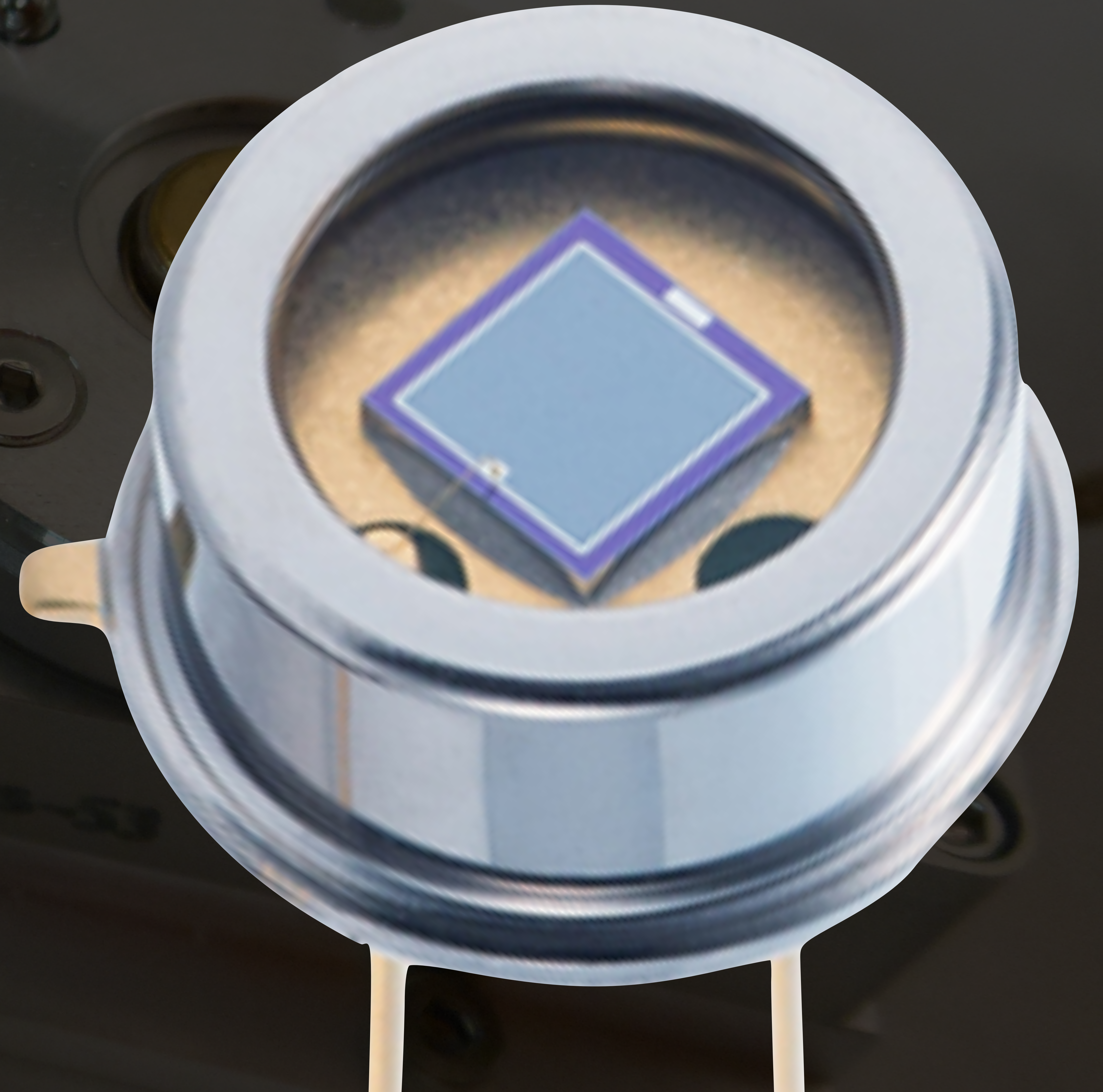


Measured CD of 16 nm 1:1 lines

MEAN = 15.9 nm

σ = 0.7 nm

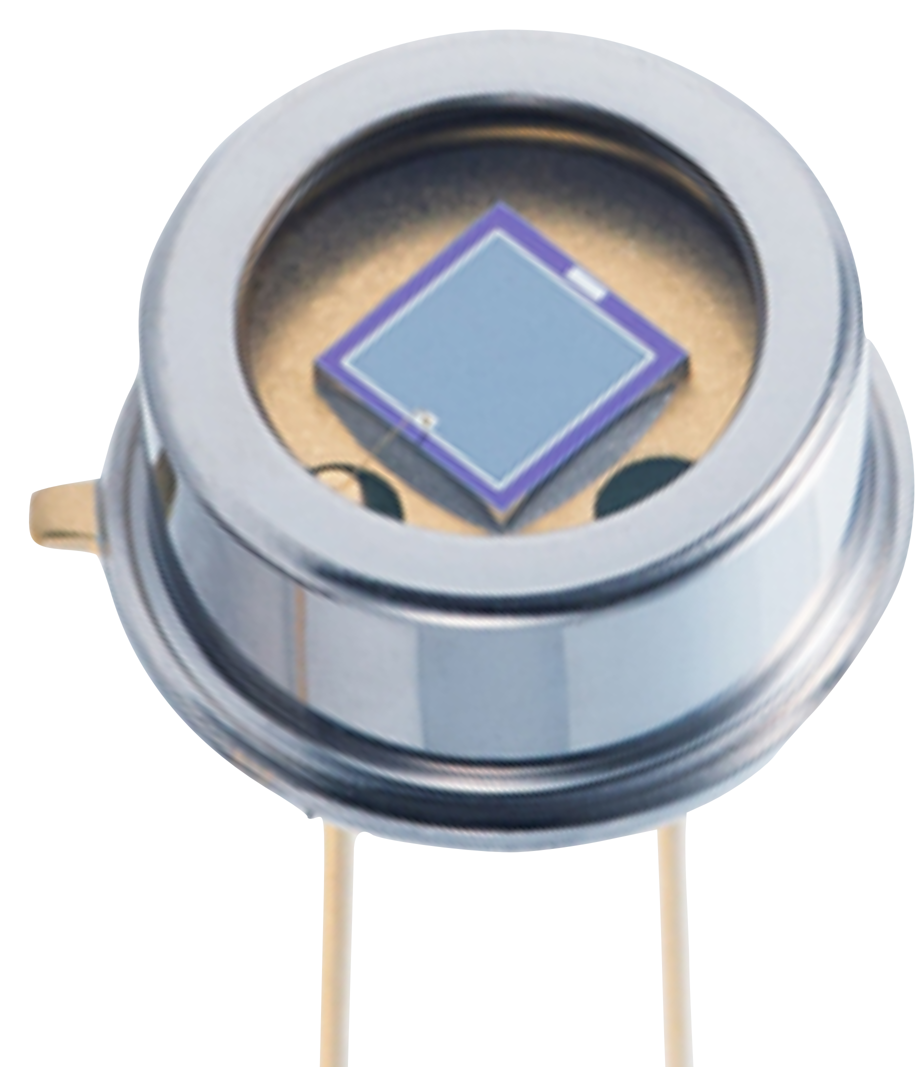
DOSE CONTROL



Hamamatsu
GaAsP Photodiode
2.3 mm x 2.3 mm

DOSE CONTROL

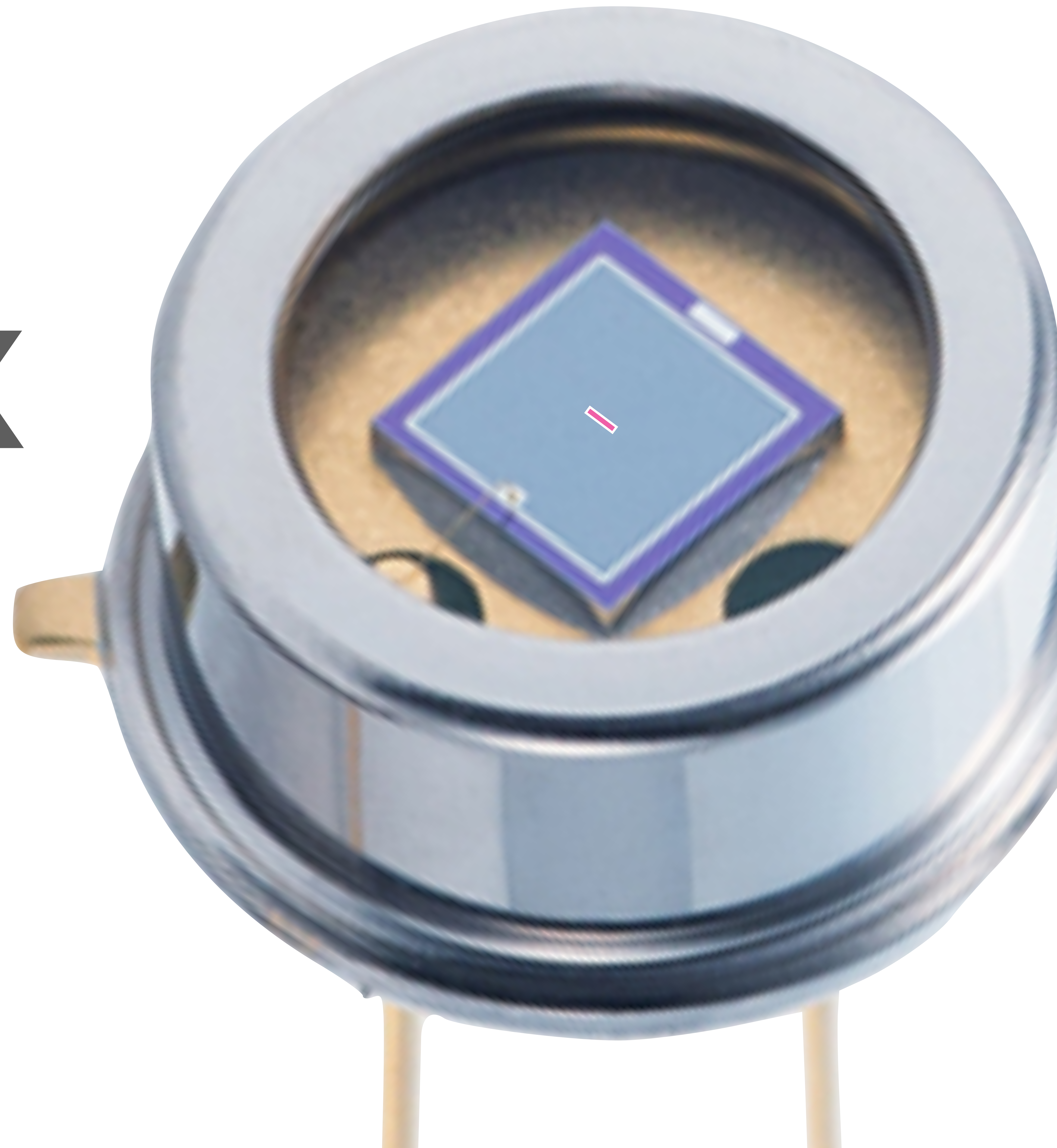
NOT TO SCALE



CLEAR FIELD IMAGED TO DIODE

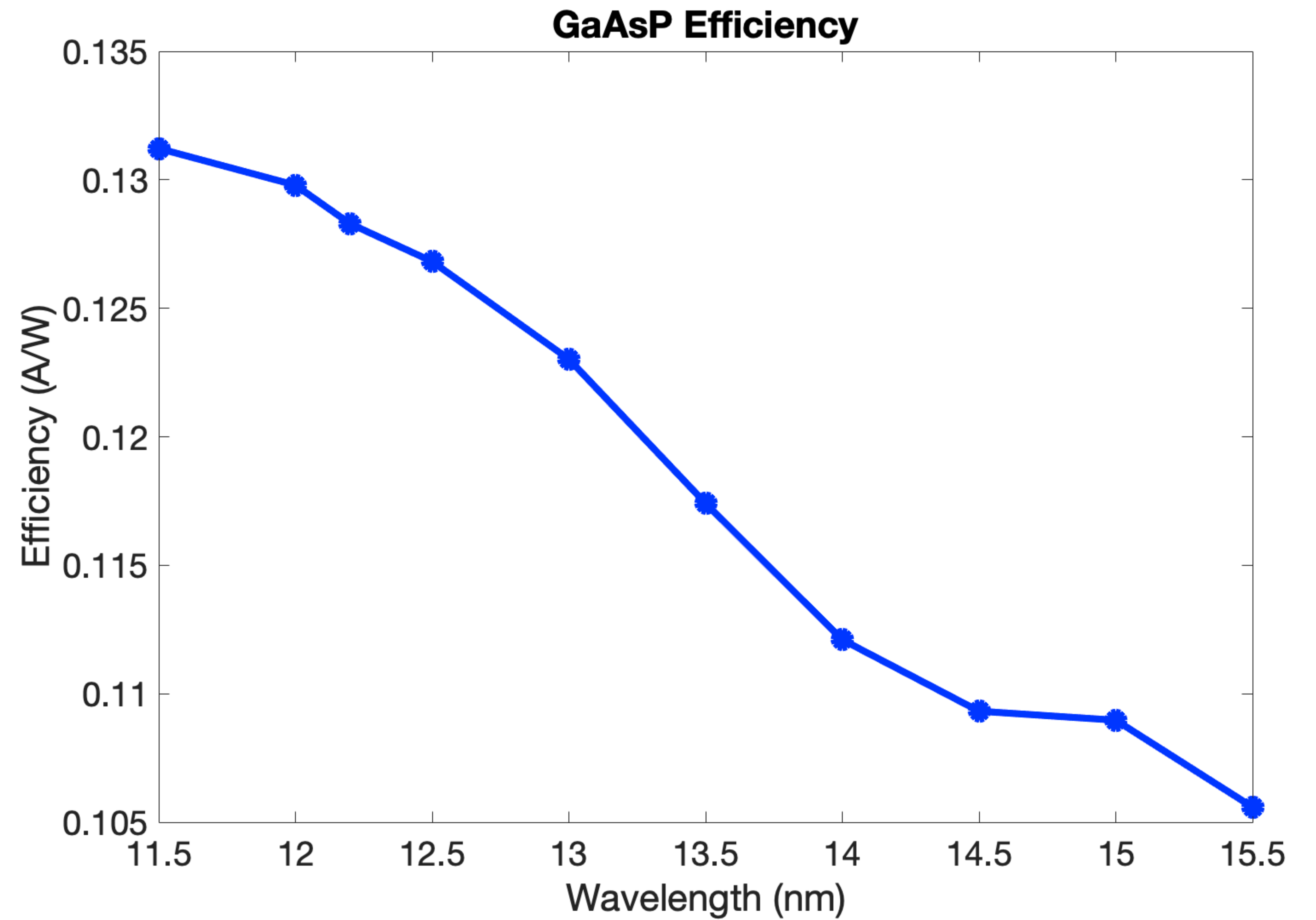
AREA

200 um x 30 um



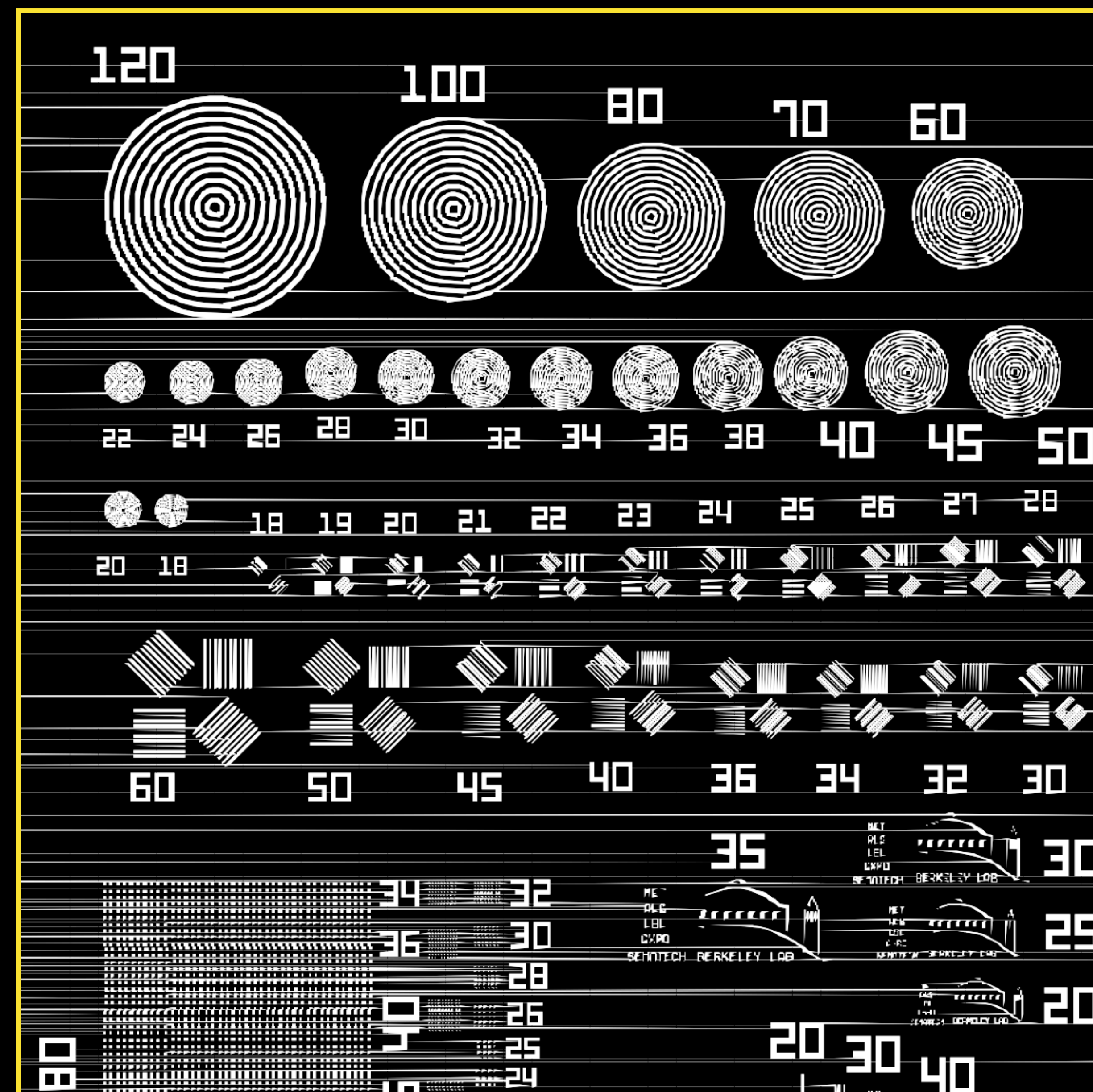
AMPS/WATT

0.117

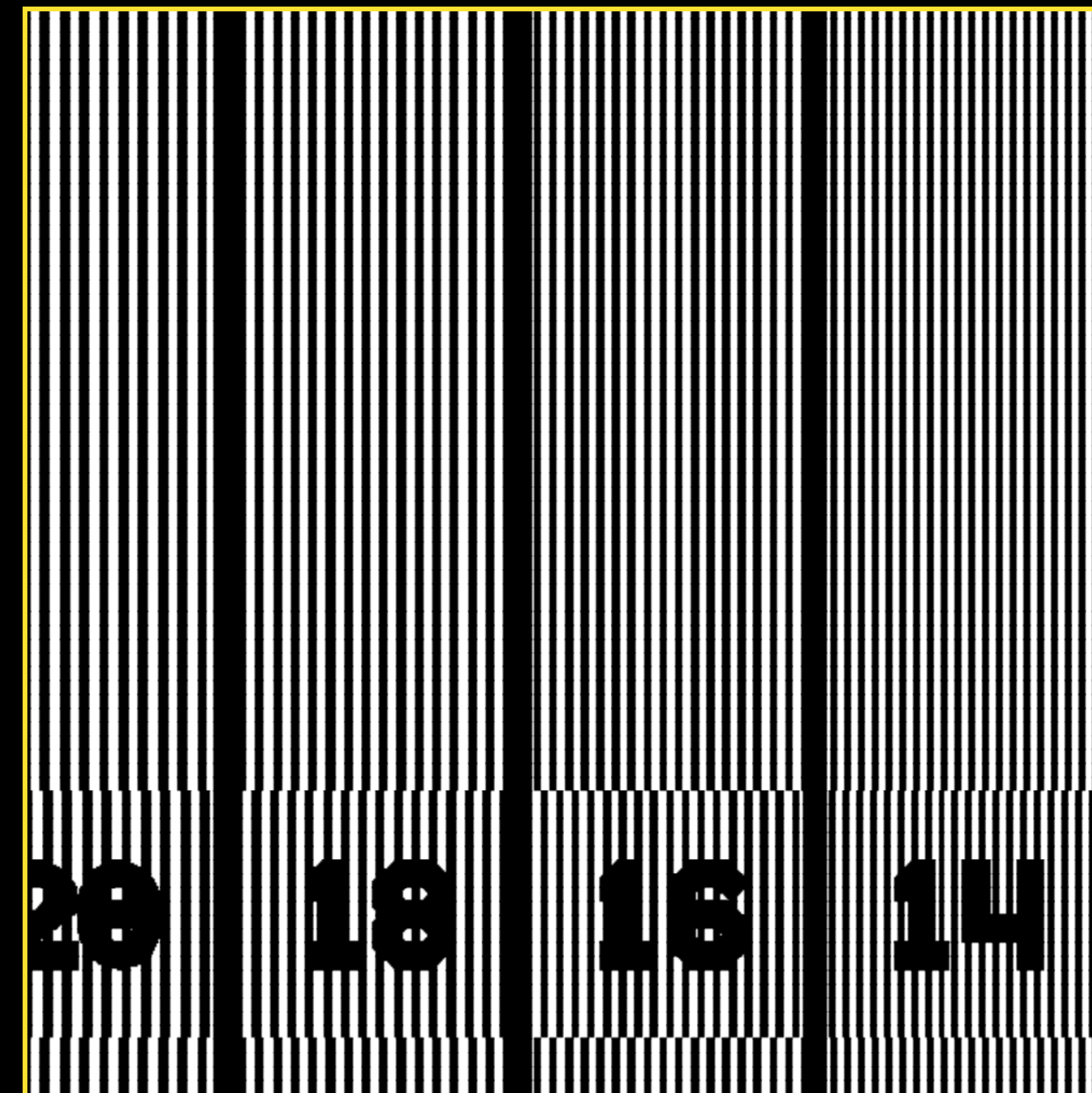


CAN FINE-TUNE AERIAL IMAGE FOR DIFFERENT FEATURES

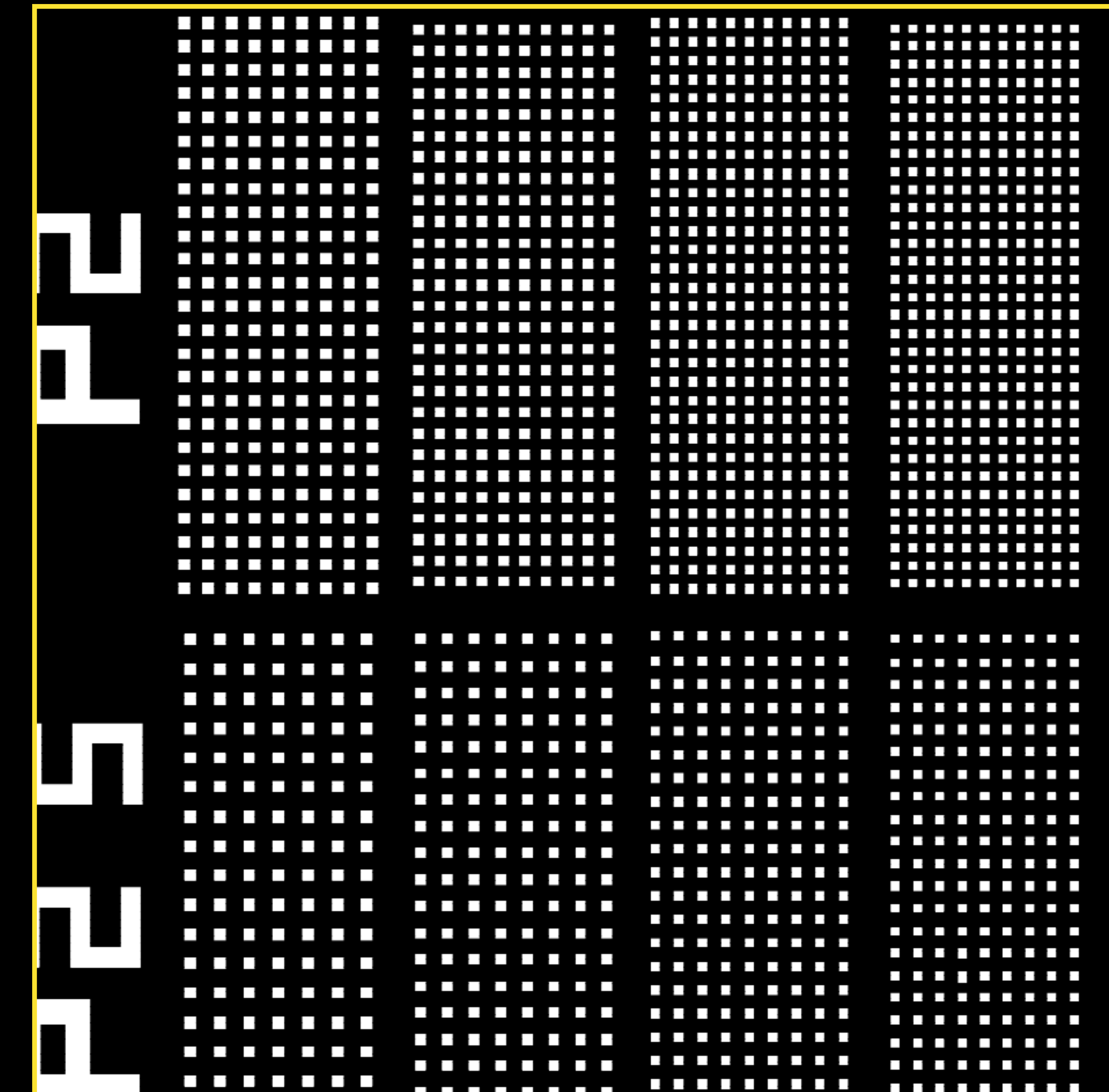
GENERAL PURPOSE



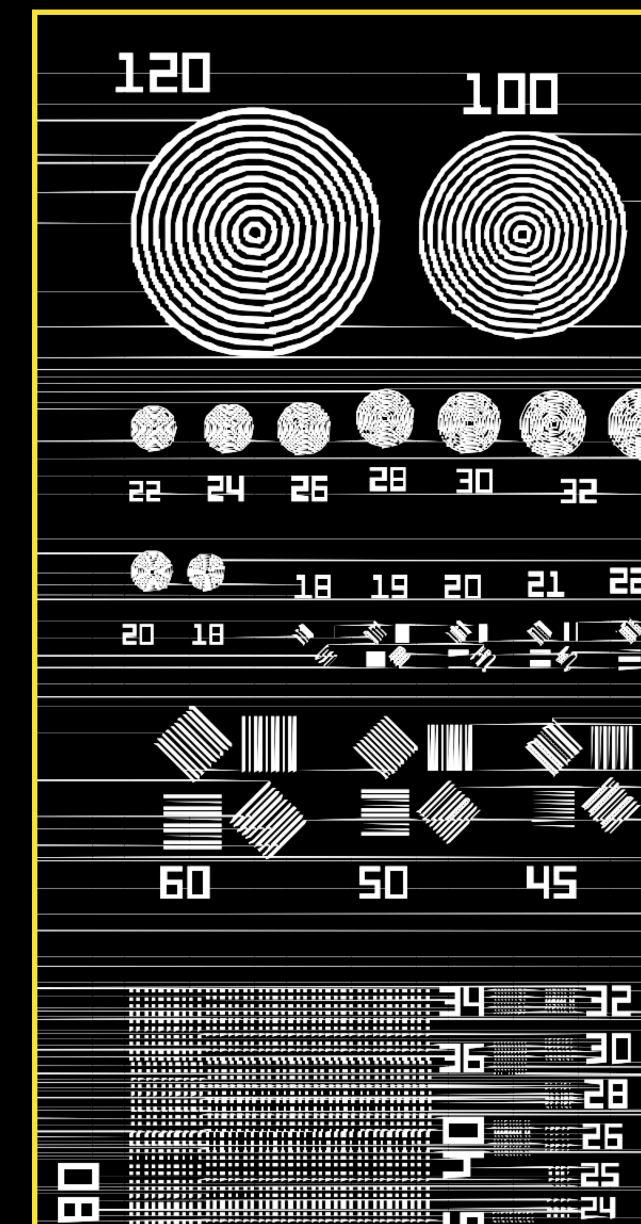
LINES



CONTACTS

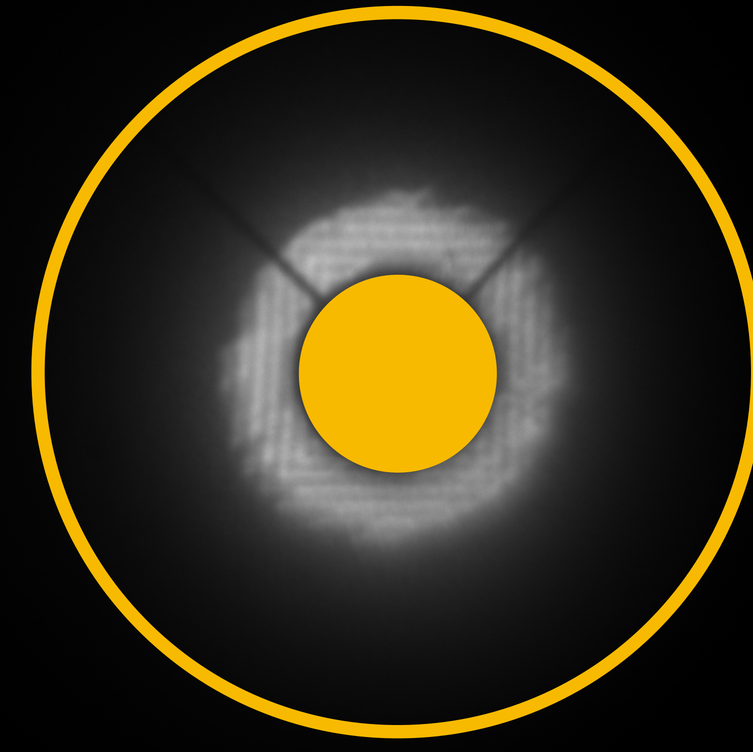


ETC.



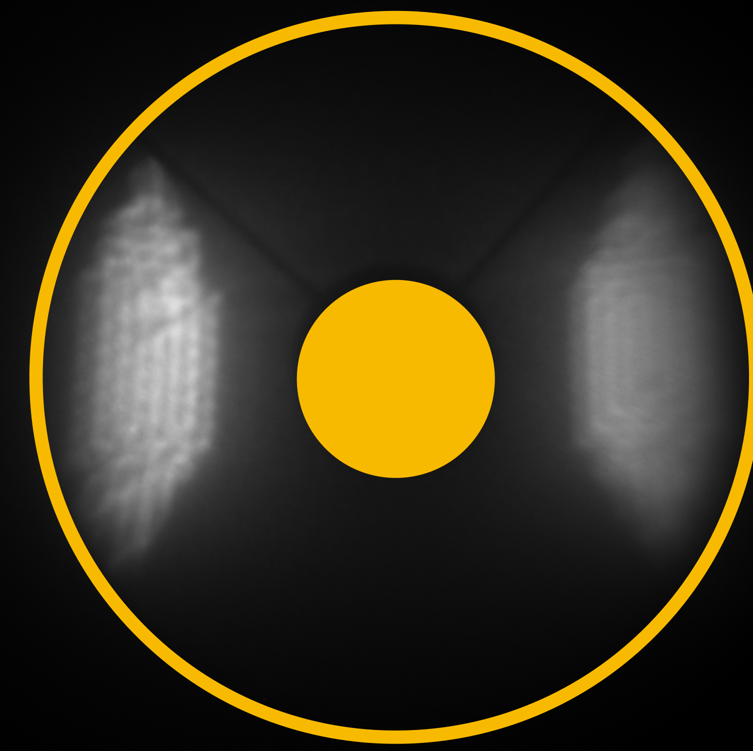
“LEAF” QUAD

QUASAR

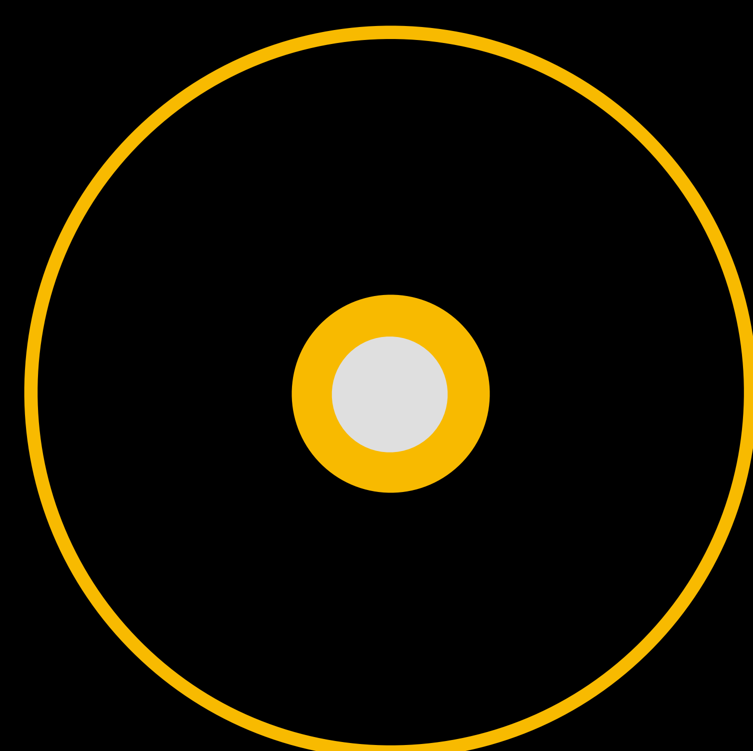


GRIDDED ANNULAR

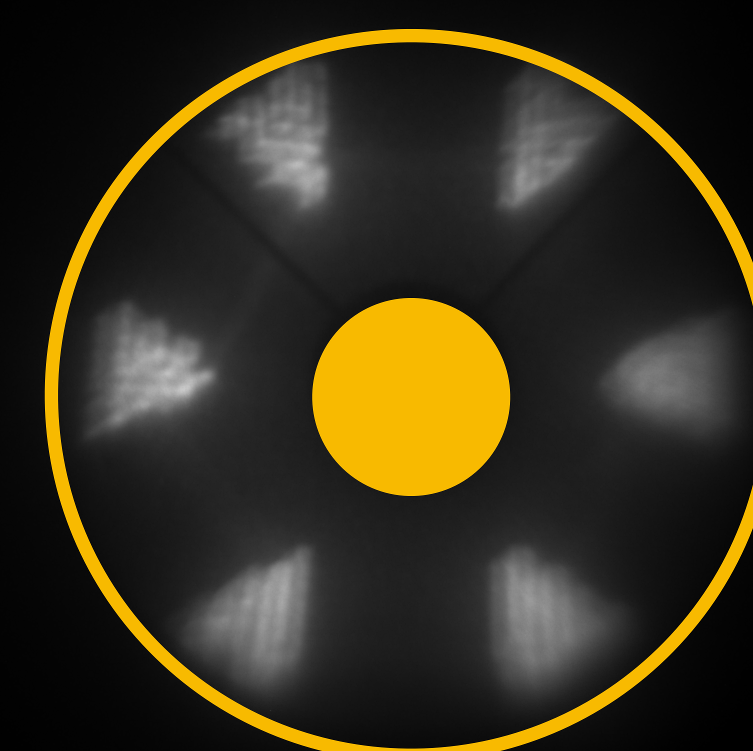
GRIDDED ANNULAR



“LEAF” DIPOLE



FREQUENCY DOUBLING
*NOT REAL IMAGE

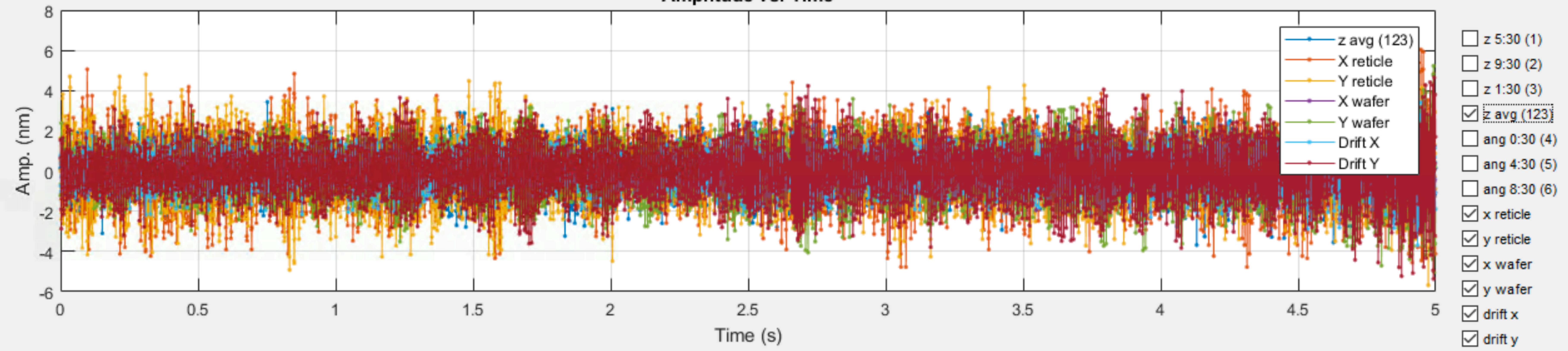


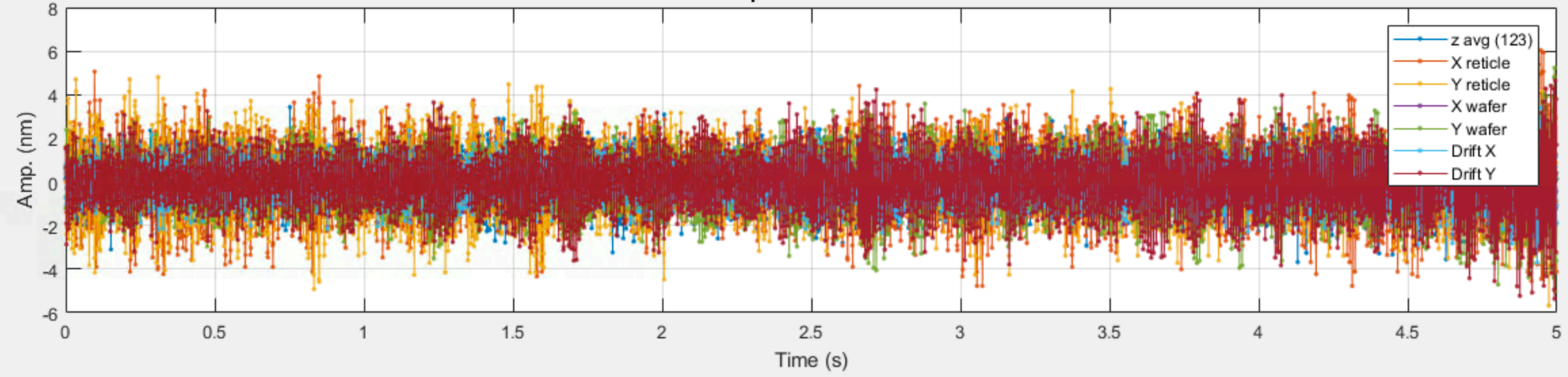
HEXAPOLE

QUASAR 2

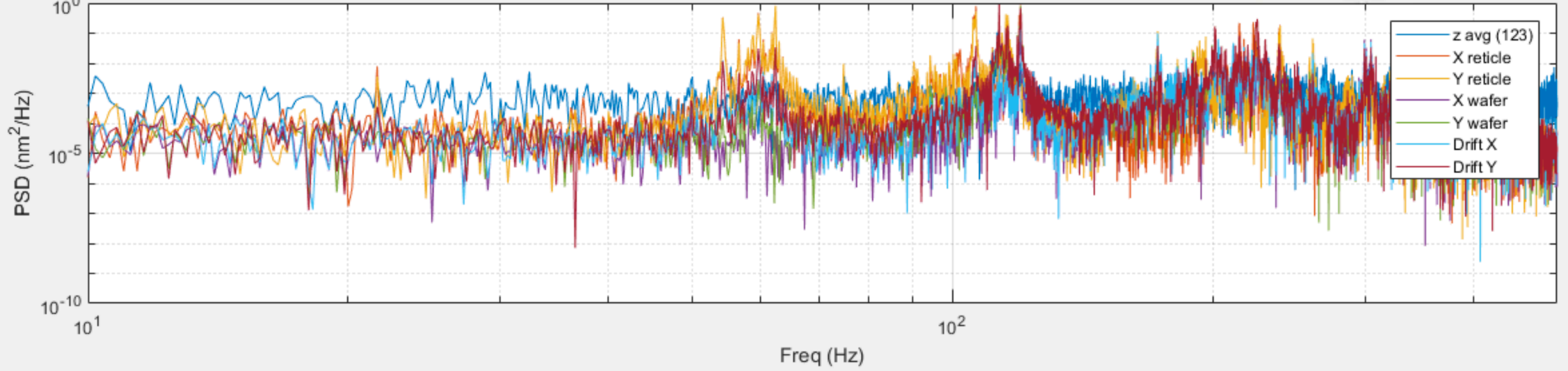
YAG scintillator is placed 10 mm below focus and imaged to an air-side CCD camera. Some vignetting in that imaging relay occurs.

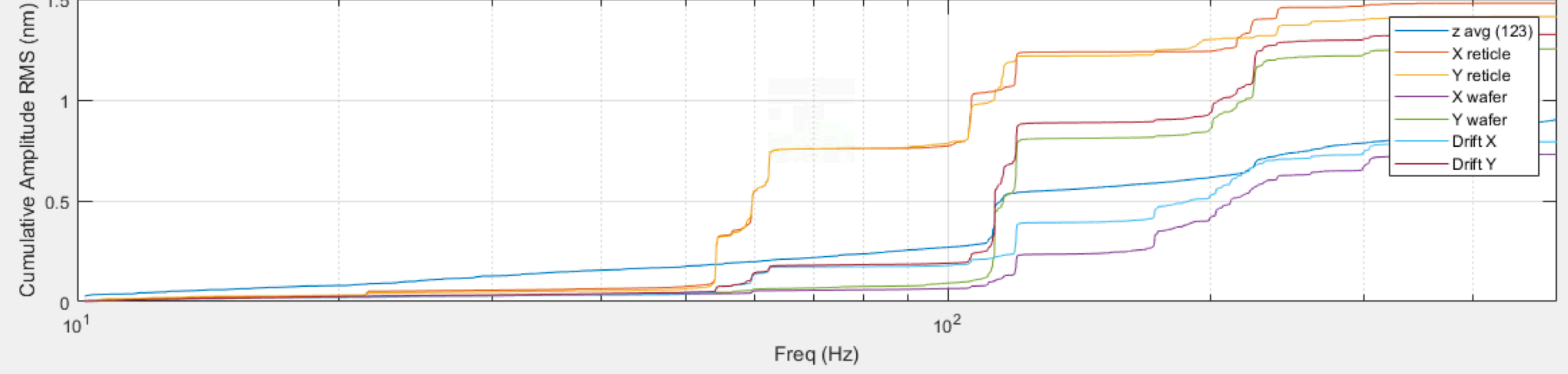
AERIAL IMAGE VIBRATION LOGS FOR EVERY EXPOSURE


Amplitude vs. Time
Amp. (nm)
Time (s)
z avg (123)
X reticle
Y reticle
X wafer
Y wafer
Drift X
Drift Y
z 5:30 (1)
z 9:30 (2)
z 1:30 (3)
z avg (123)
ang 0:30 (4)
ang 4:30 (5)
ang 8:30 (6)
x reticle
y reticle
x wafer
y wafer
drift x
drift y

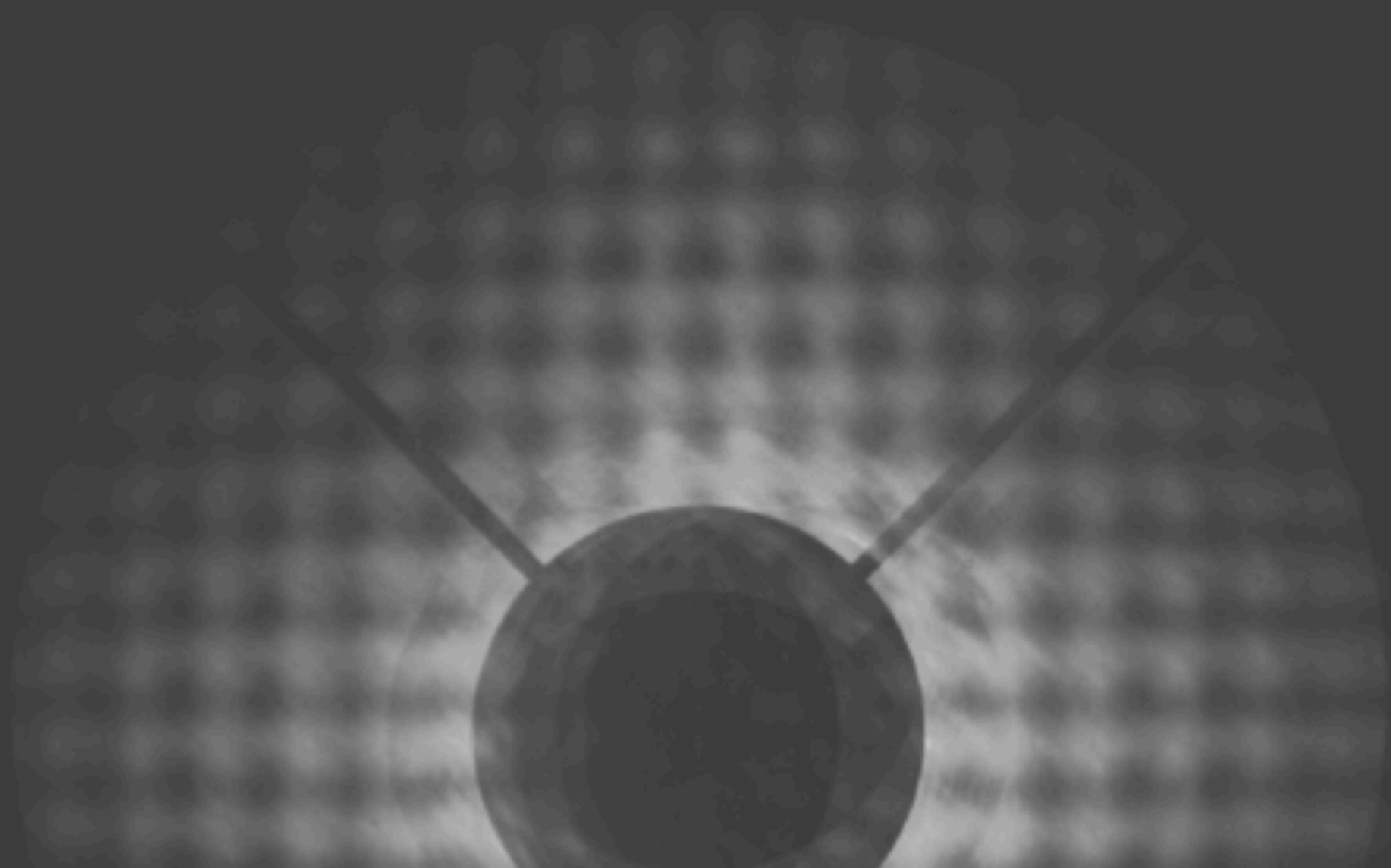


- [ ] z 5:30 (1)
- [ ] z 9:30 (2)
- [ ] z 1:30 (3)
- [x] z avg (123)
- [ ] ang 0:30 (4)
- [ ] ang 4:30 (5)
- [ ] ang 8:30 (6)
- [x] x reticle
- [x] y reticle
- [x] x wafer
- [x] y wafer
- [x] drift x
- [x] drift y

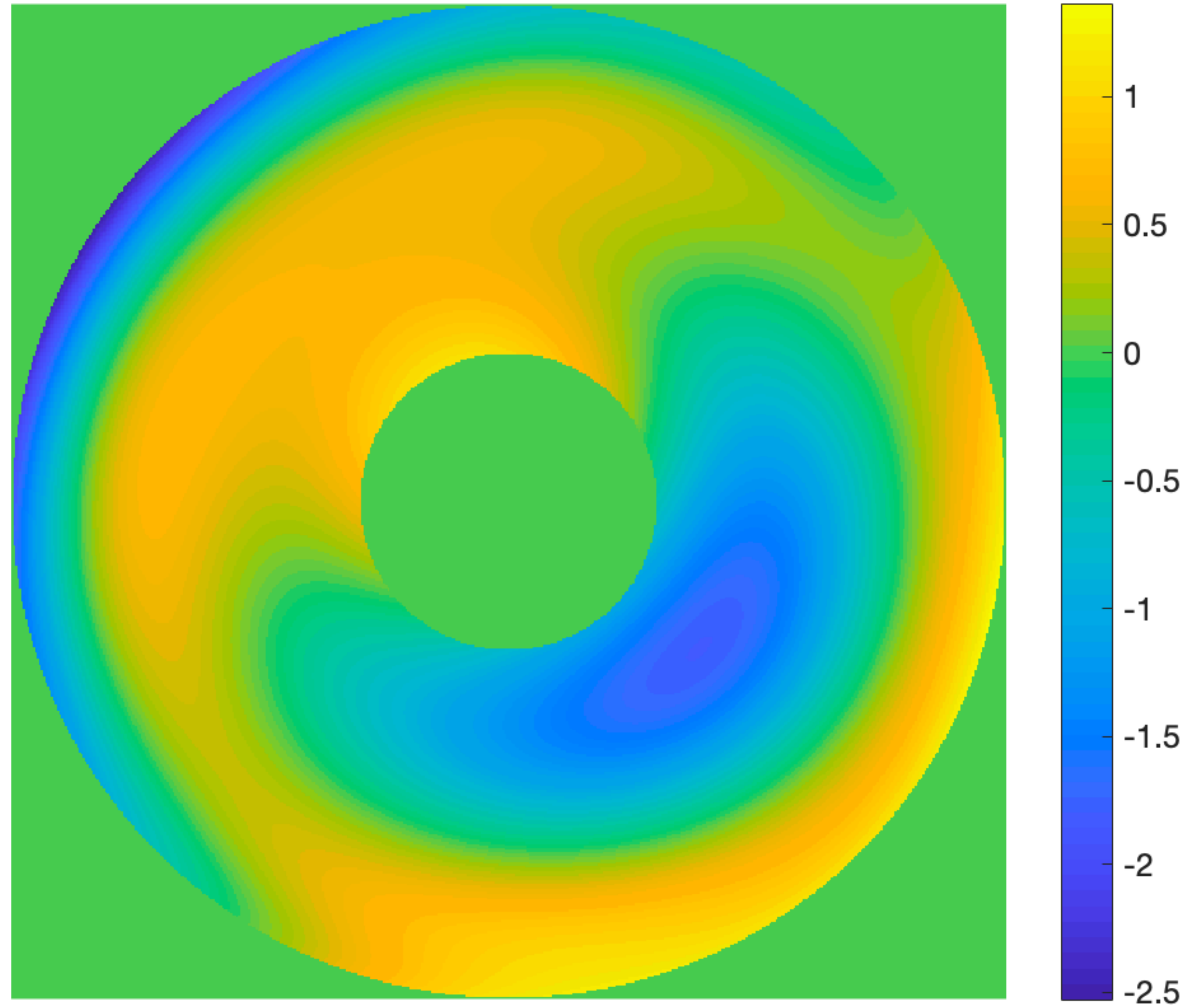




IN-SITU ALIGNMENT MONITOR



BEFORE ALIGN



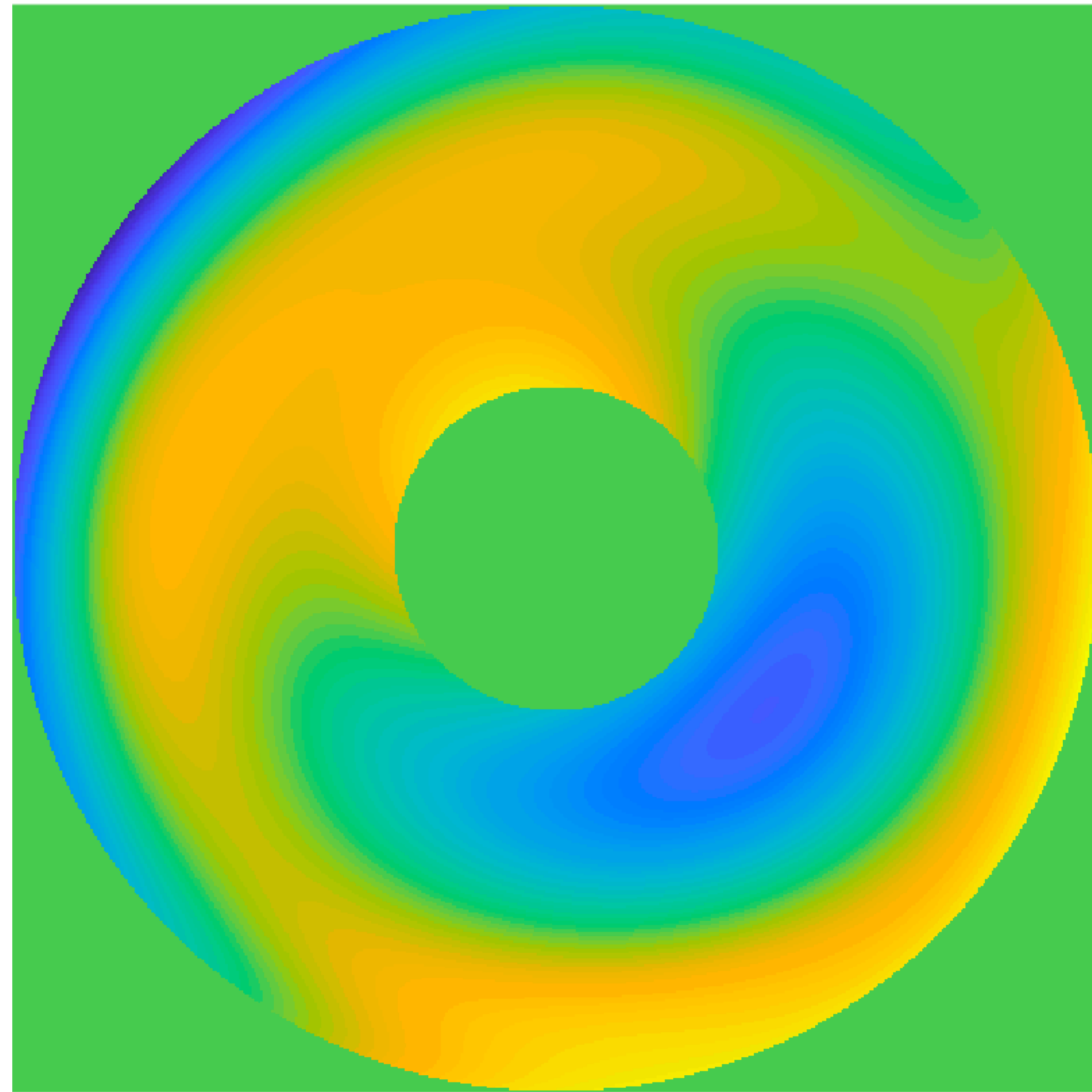
0.69 nm

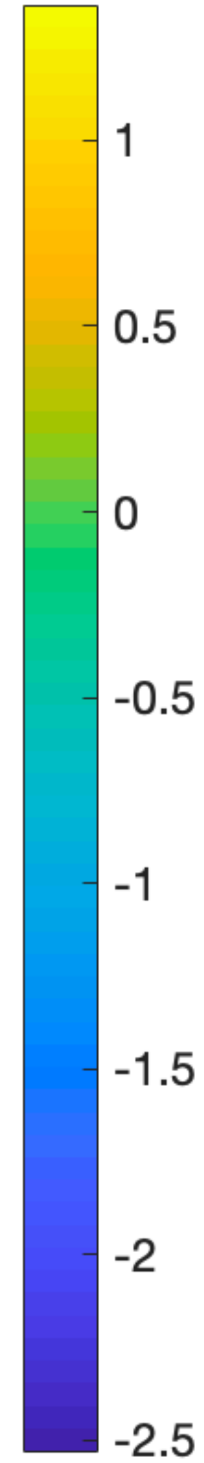
RMS wavefront error

Specification is 0.5 nm

Measurements taken at center of the field

BEFORE ALIGN





0.69 nm

RMS wavefront error

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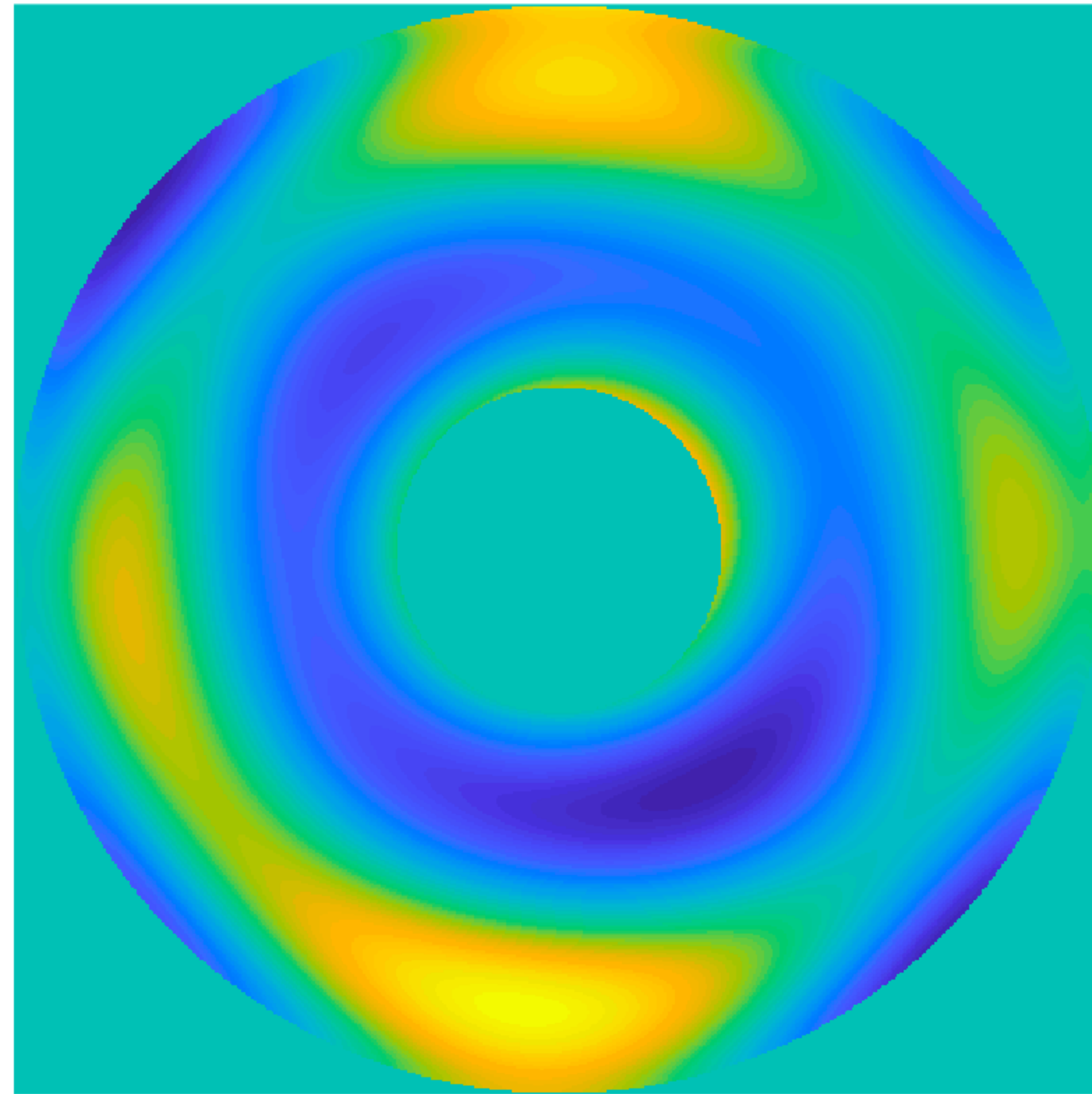
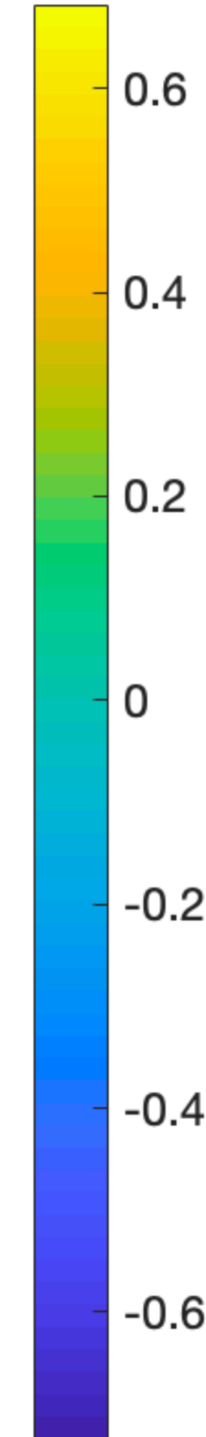
AFTER ALIGN



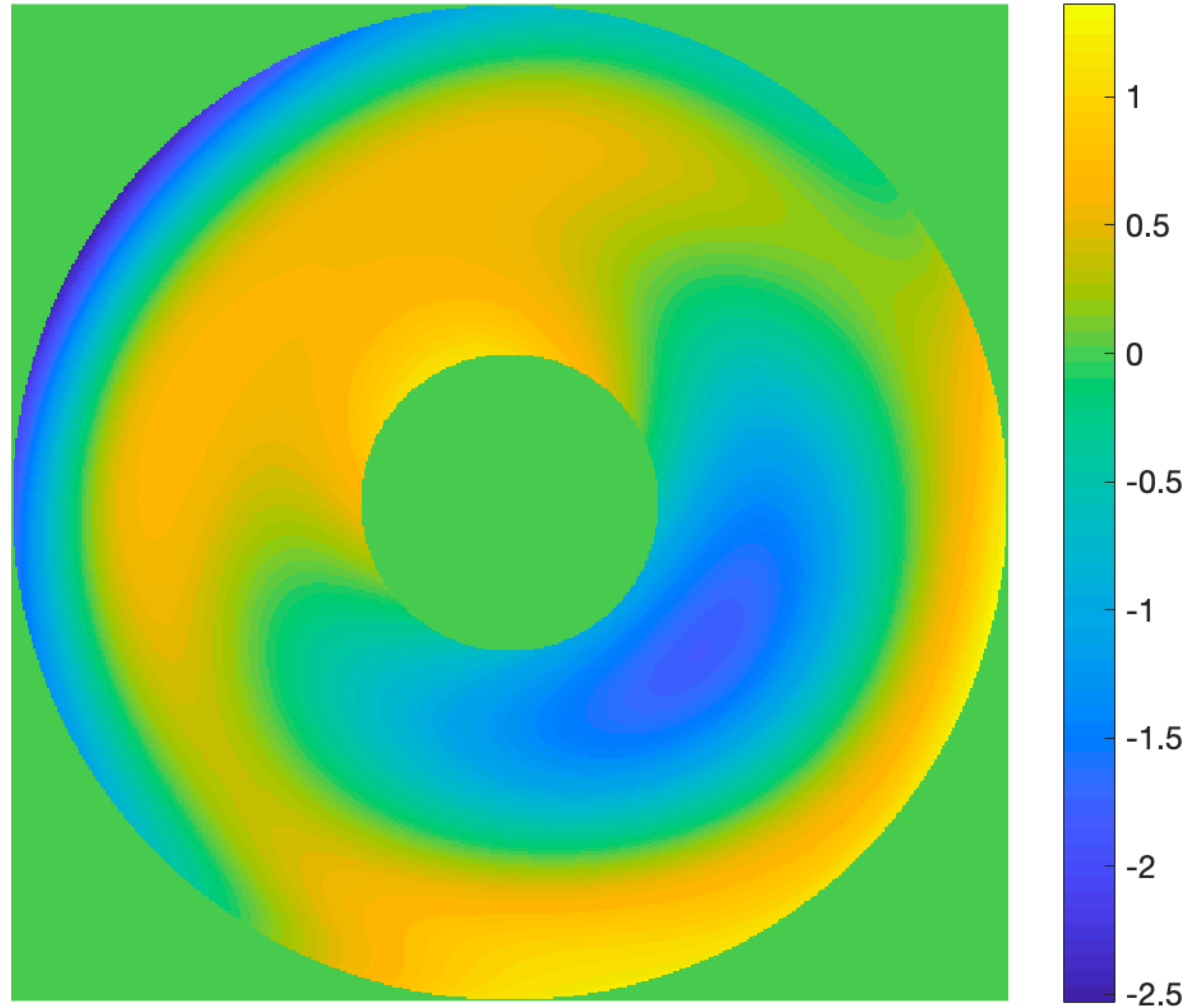


0.31 nm

RMS wavefront error

Measurements taken at center of the field

BEFORE ALIGN

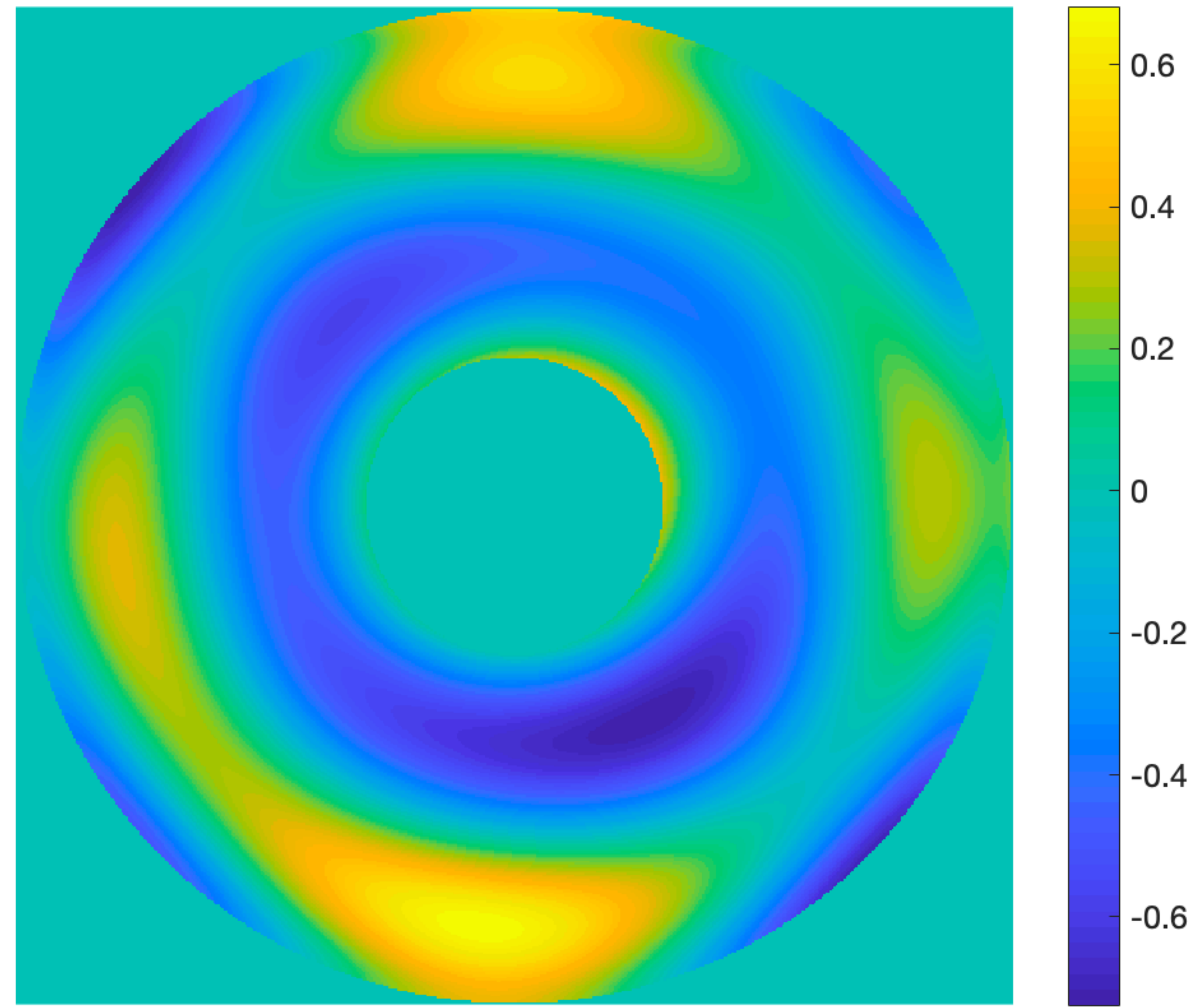


0.69 nm

RMS wavefront error

Specification is 0.5 nm

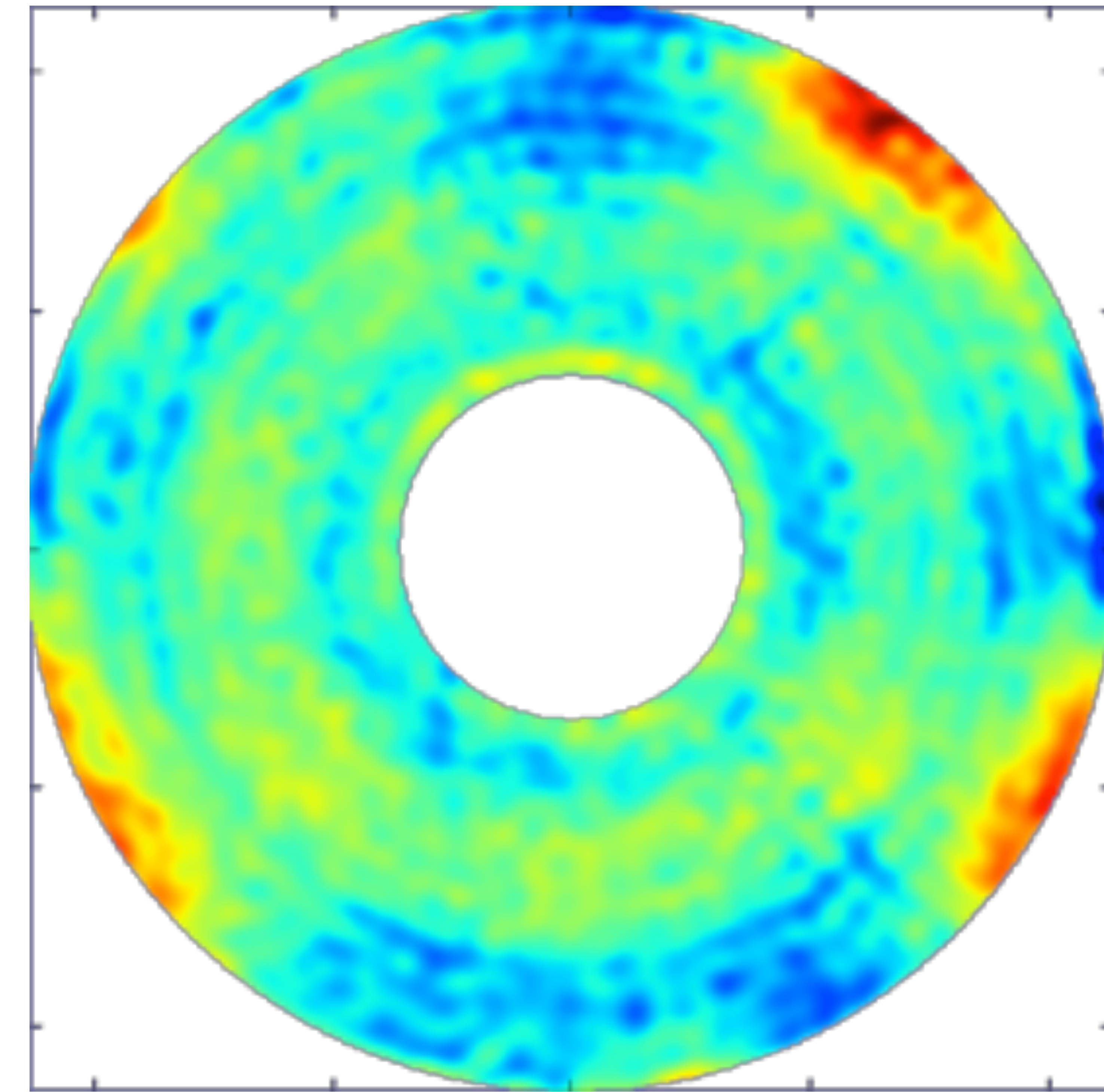
AFTER ALIGN



0.31 nm

RMS wavefront error

SUBSTRATE



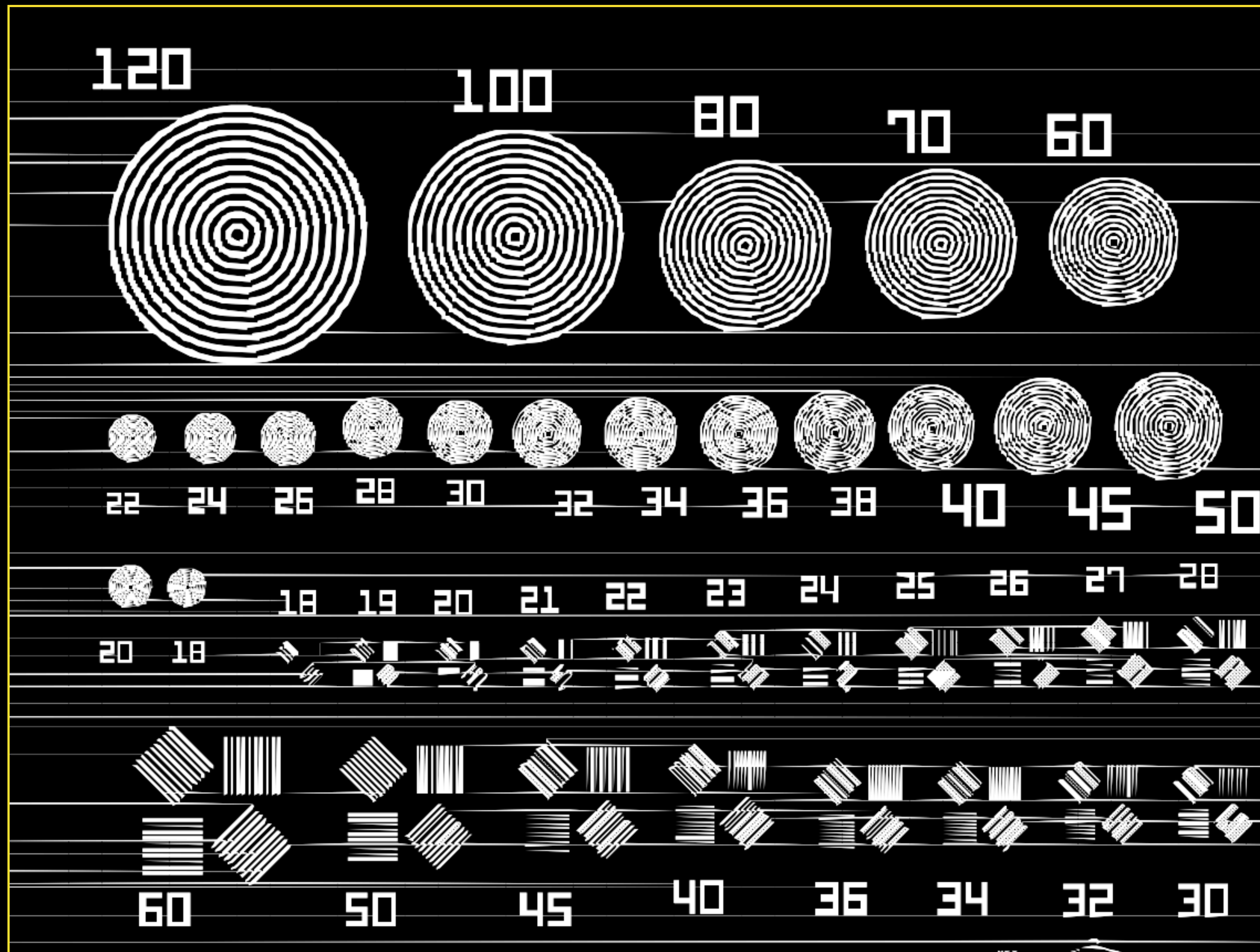
0.23 nm

RMS wavefront error

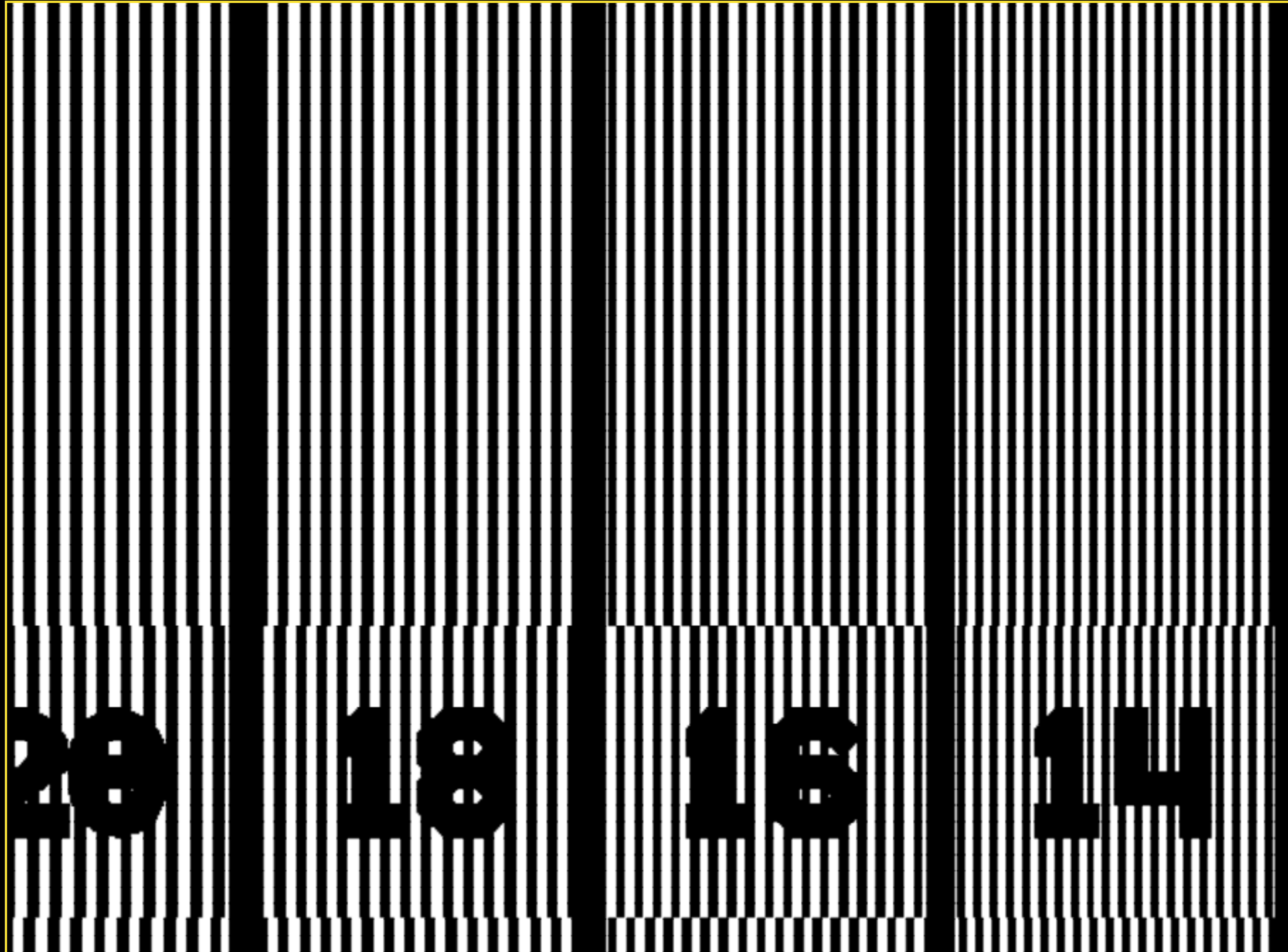
Measurements taken at center of the field

RETICLE

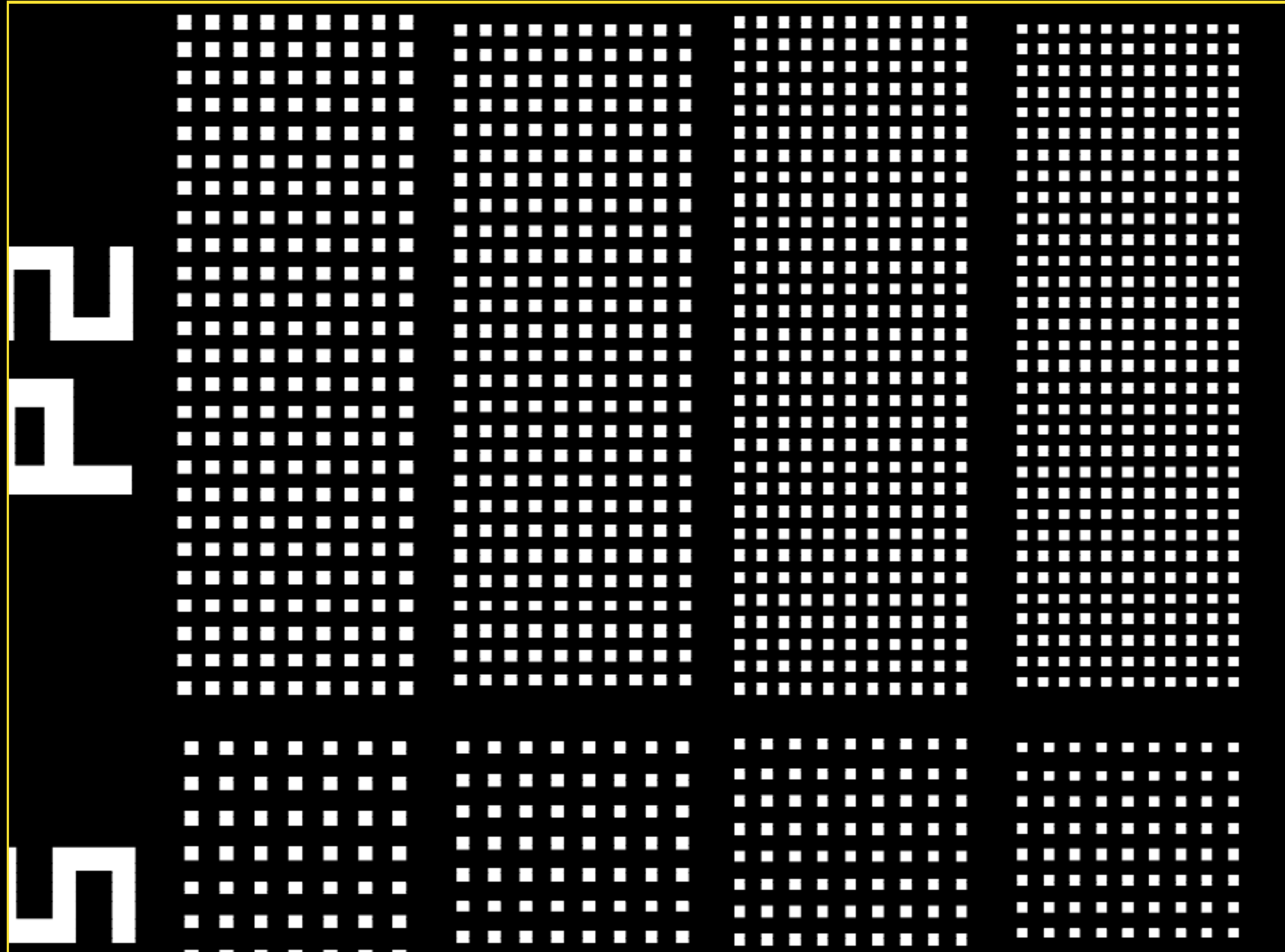
GENERAL PURPOSE



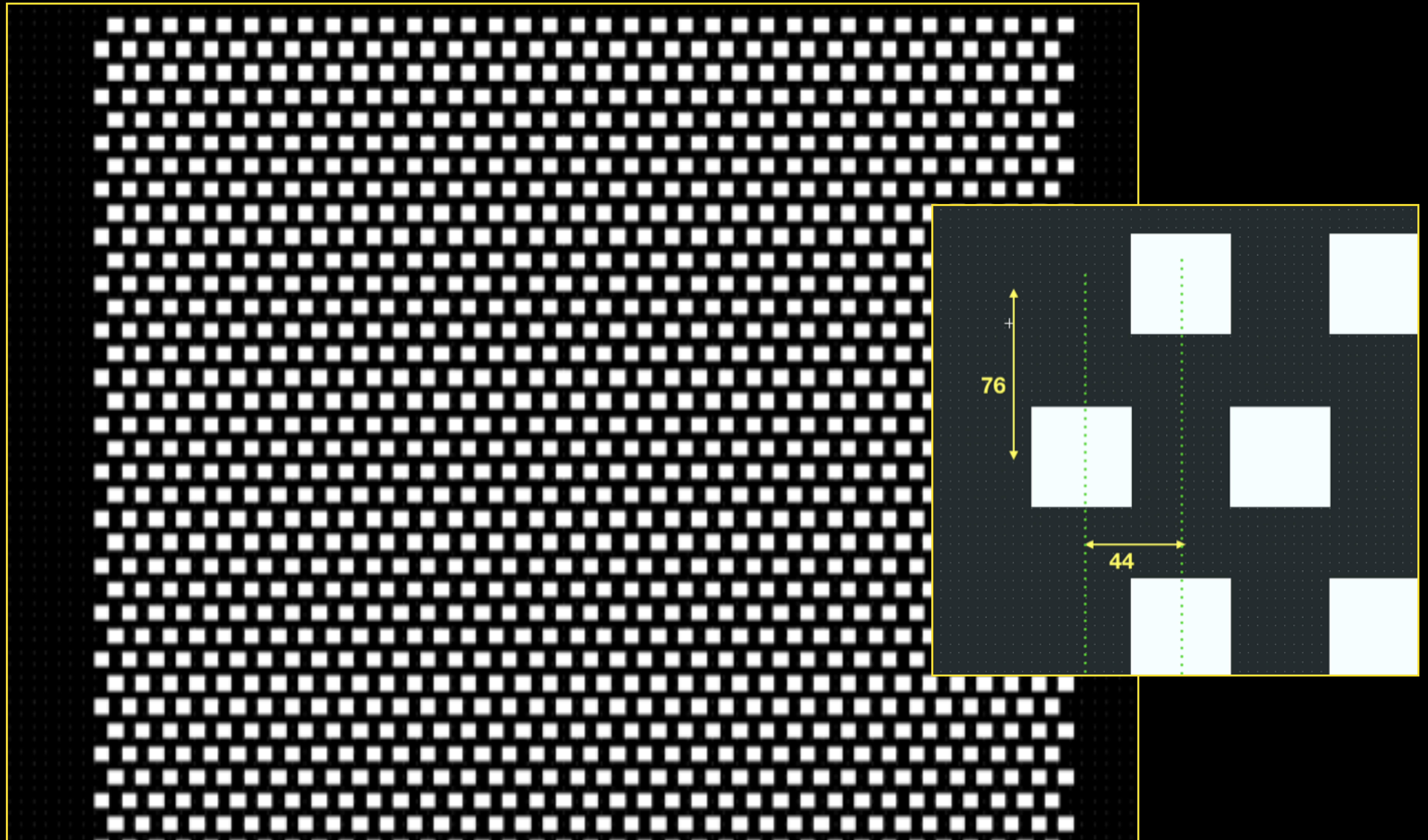
LINES



CONTACTS



HEX CONTACTS



REQUESTS?

MATERIAL PROCESSING

SCREEN SK80EX

SCREEN SK80EX

- 200 mm wafers

SCREEN SK80EX

- 200 mm wafers
- H20-based processing

SCREEN SK80EX

- 200 mm wafers
- H20-based processing
- Non-H20-based processing

SCREEN SK80EX

- 200 mm wafers
- H20-based processing
- Non-H20-based processing
- 4 hot plates (250C)

SCREEN SK80EX

- 200 mm wafers
- H20-based processing
- Non-H20-based processing
- 4 hot plates (250C)
- 2 chill plates

SCREEN SK80EX

- 200 mm wafers
- H20-based processing
- Non-H20-based processing
- 4 hot plates (250C)
- 2 chill plates
- 1 HMDS (vapor)

SCREEN SK80EX

- 200 mm wafers
- H20-based processing
- Non-H20-based processing
- 4 hot plates (250C)
- 2 chill plates
- 1 HMDS (vapor)
- Ellipsometry / Thickness

H20-BASED PROCESSING

- Plumbed TMAH (2.3 wt. % in H20)
- Plumbed DI H20
- Plumbed Surfactant Rinse (TBD)
- Spare Plumbed Aqueous Developer (TBD)
- Manual Syringe Dispense for everything else

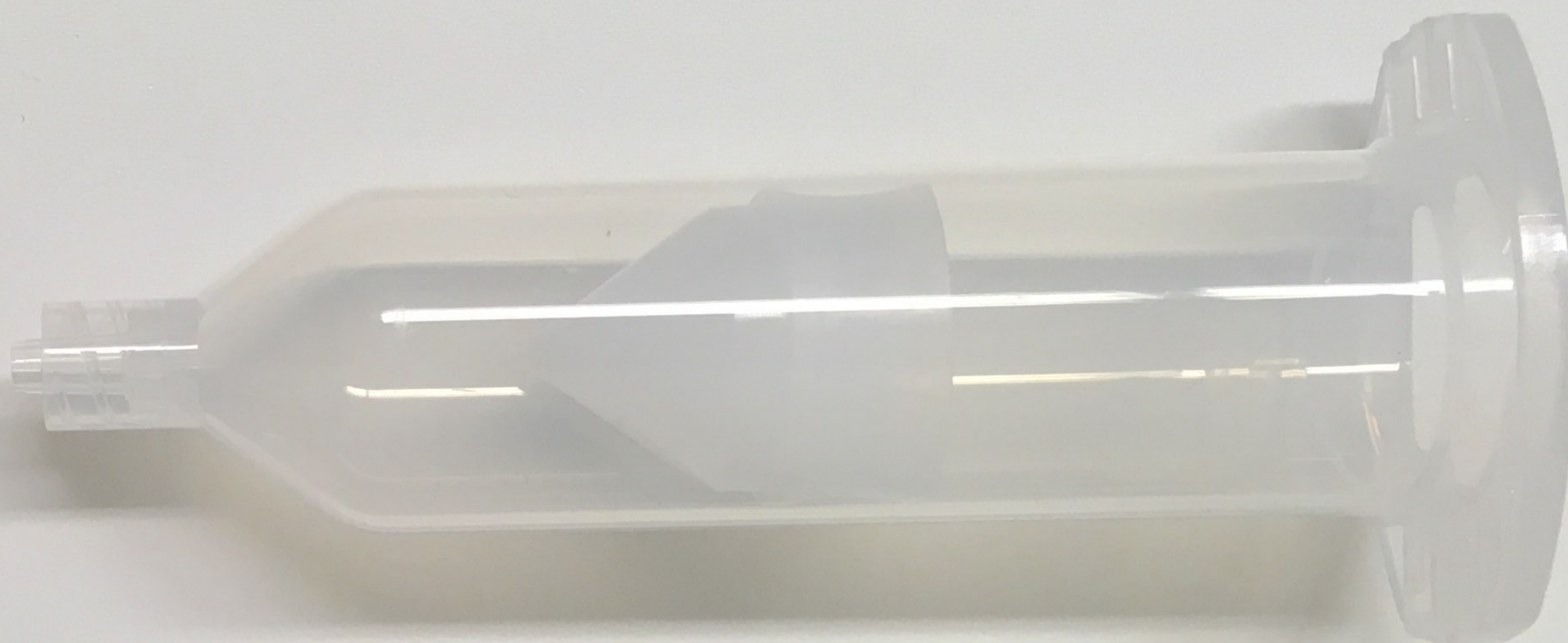
NON-H20-BASED PROCESSING

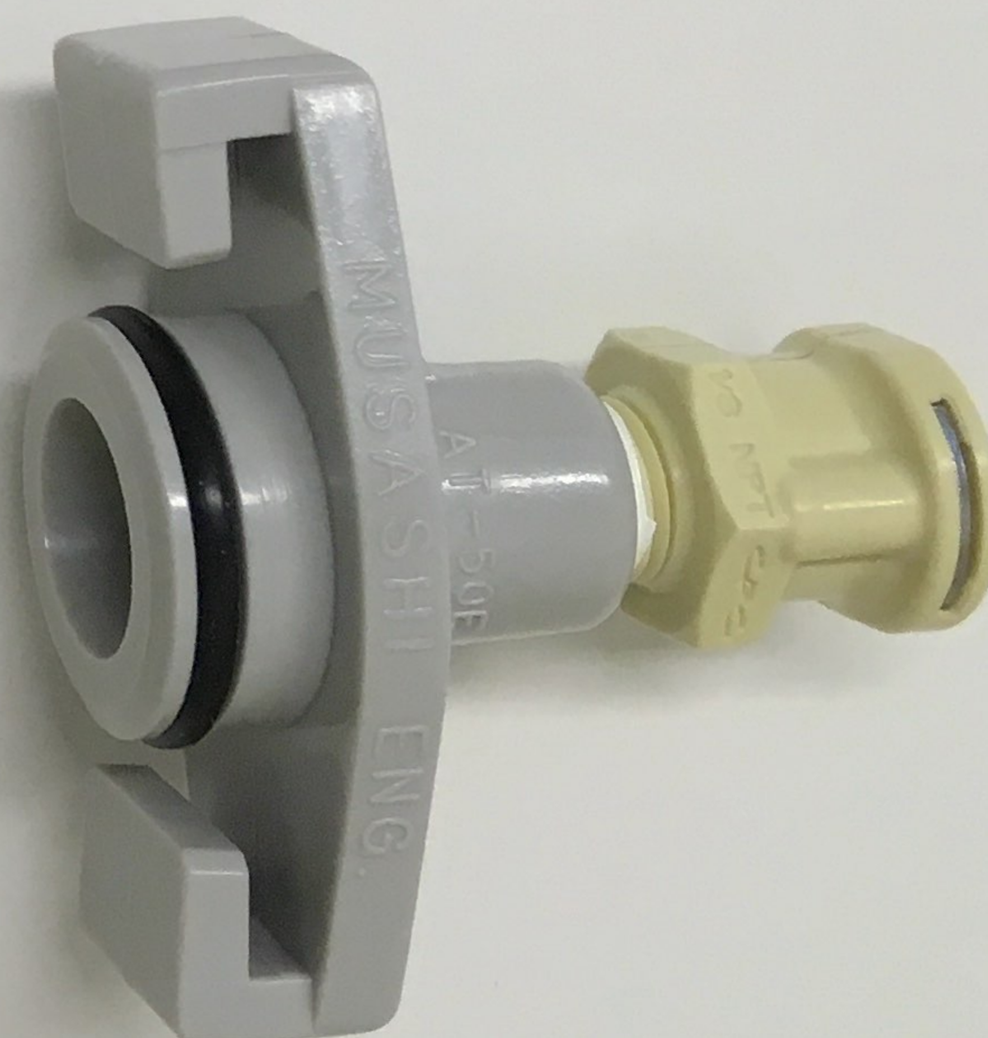
- Plumbed 2-Heptanone (Develop or Pre-Wet)
- Plumbed 70/30 PGME/PGMEA (Bowl Rinse, EBR, BSR, Pot Rinse)
- Automated syringe dispense for everything else (resists, ULs)
- Split drain for material compatibility

20 ML

70 ML

13




MUSASHI ENG.

USER COMMISSIONING

40

COMMISSIONING SHIFTS

08:00 - 16:00

ENGINEERING

16:00 - 24:00

USER OPS

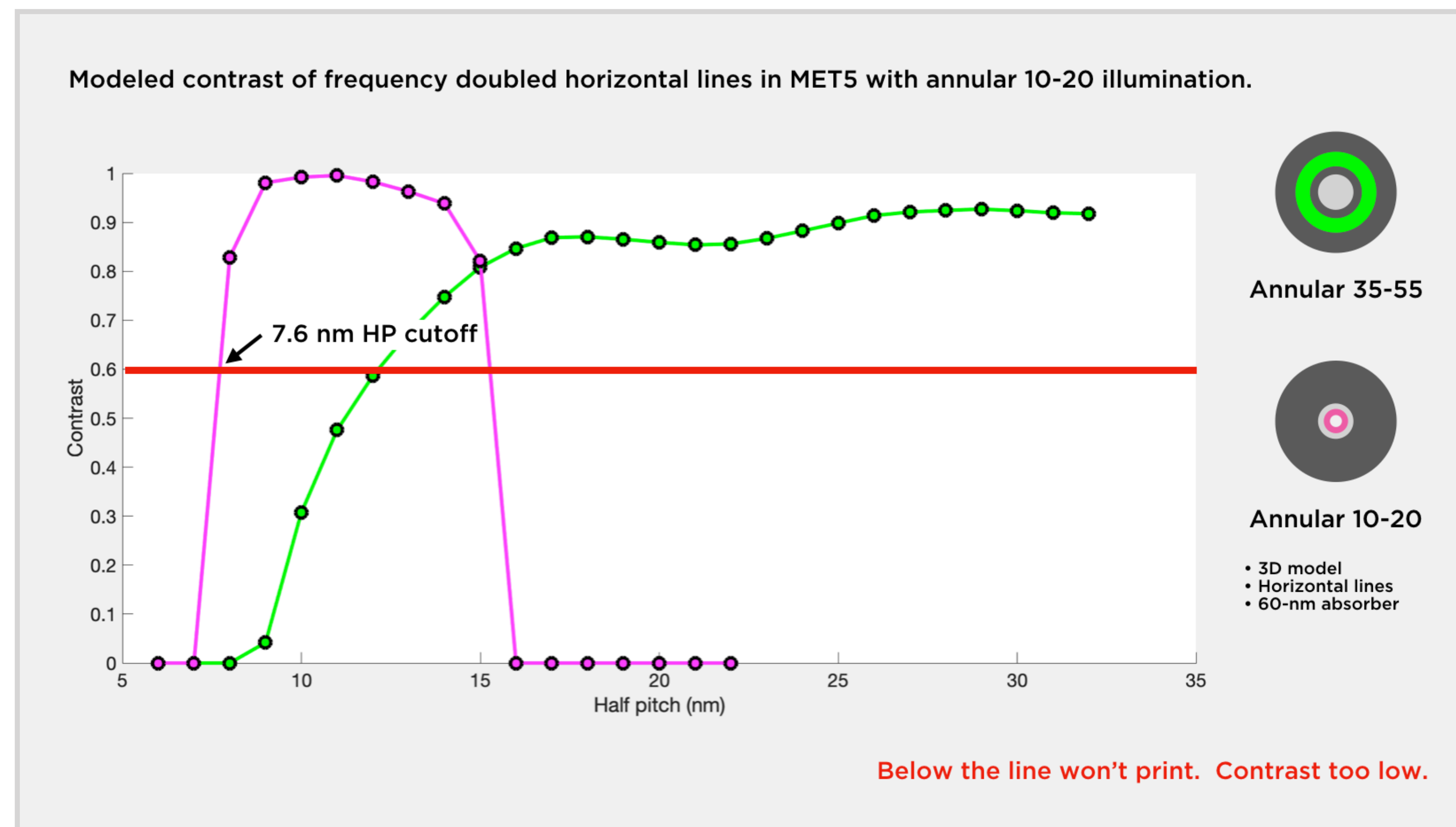
6

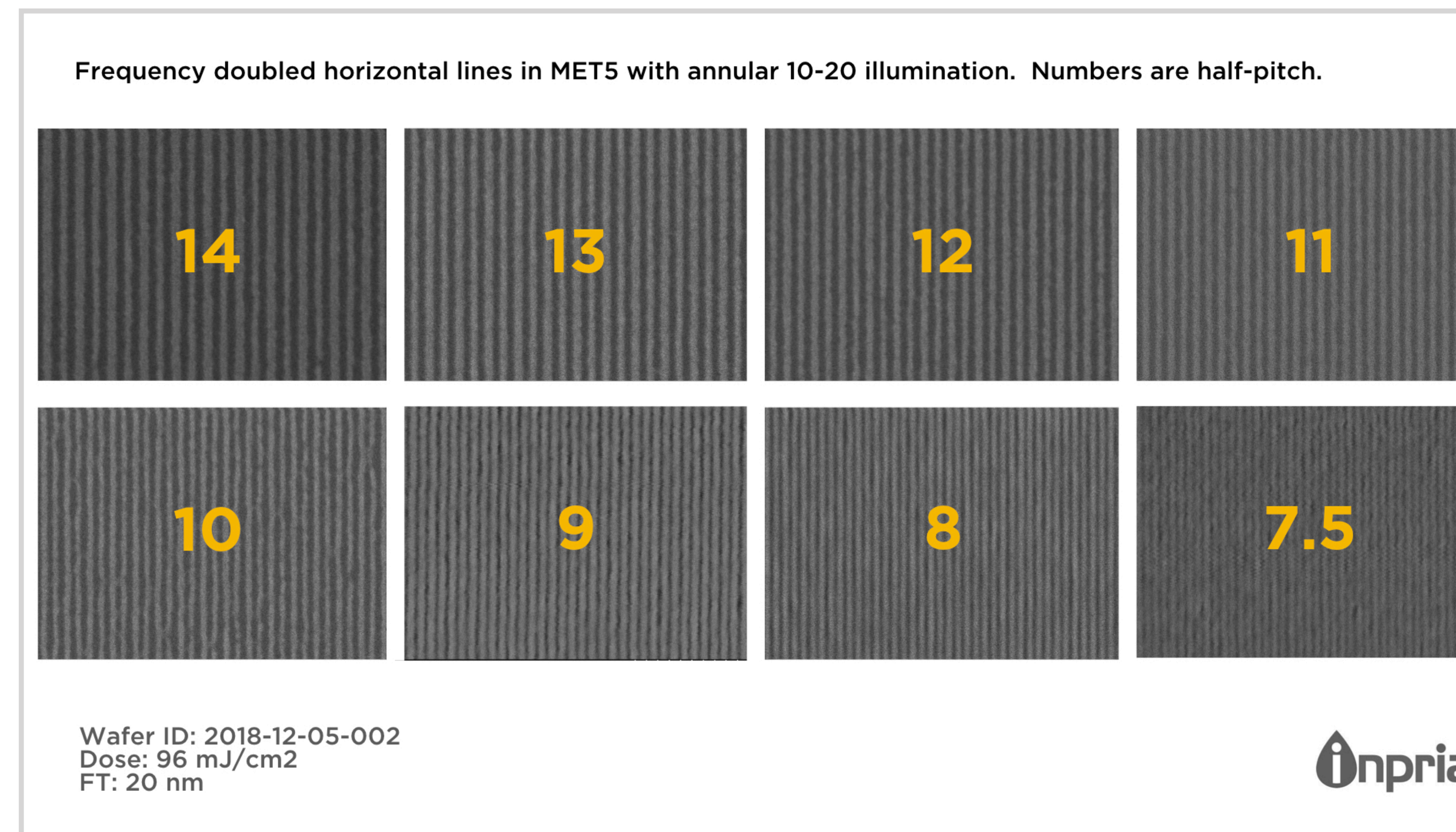
WAFERS PER SHIFT

2 - 3 FOR SETUP
2 - 3 FOR CUSTOMER

RESOLUTION

General agreement between modeling and printing





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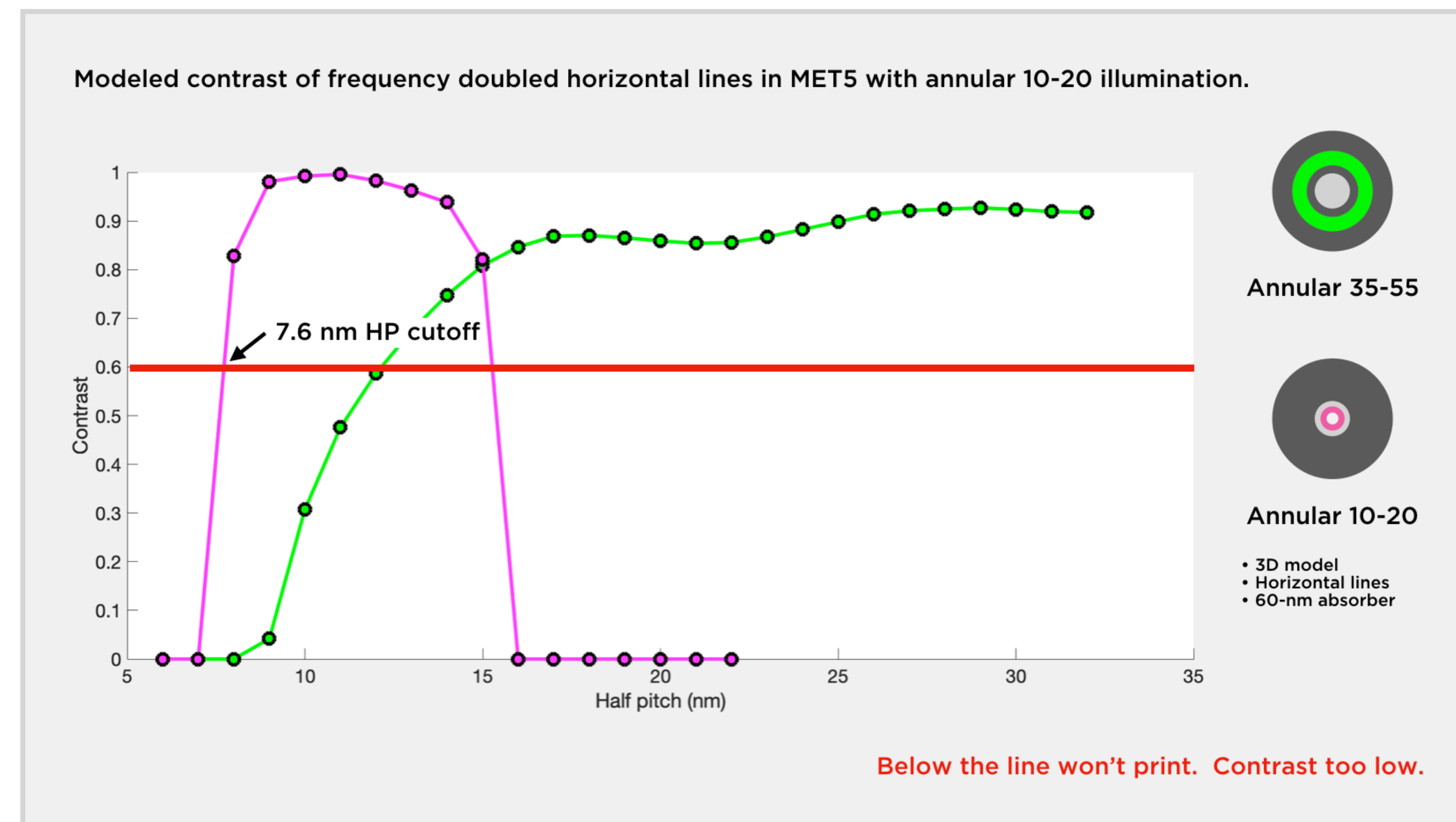
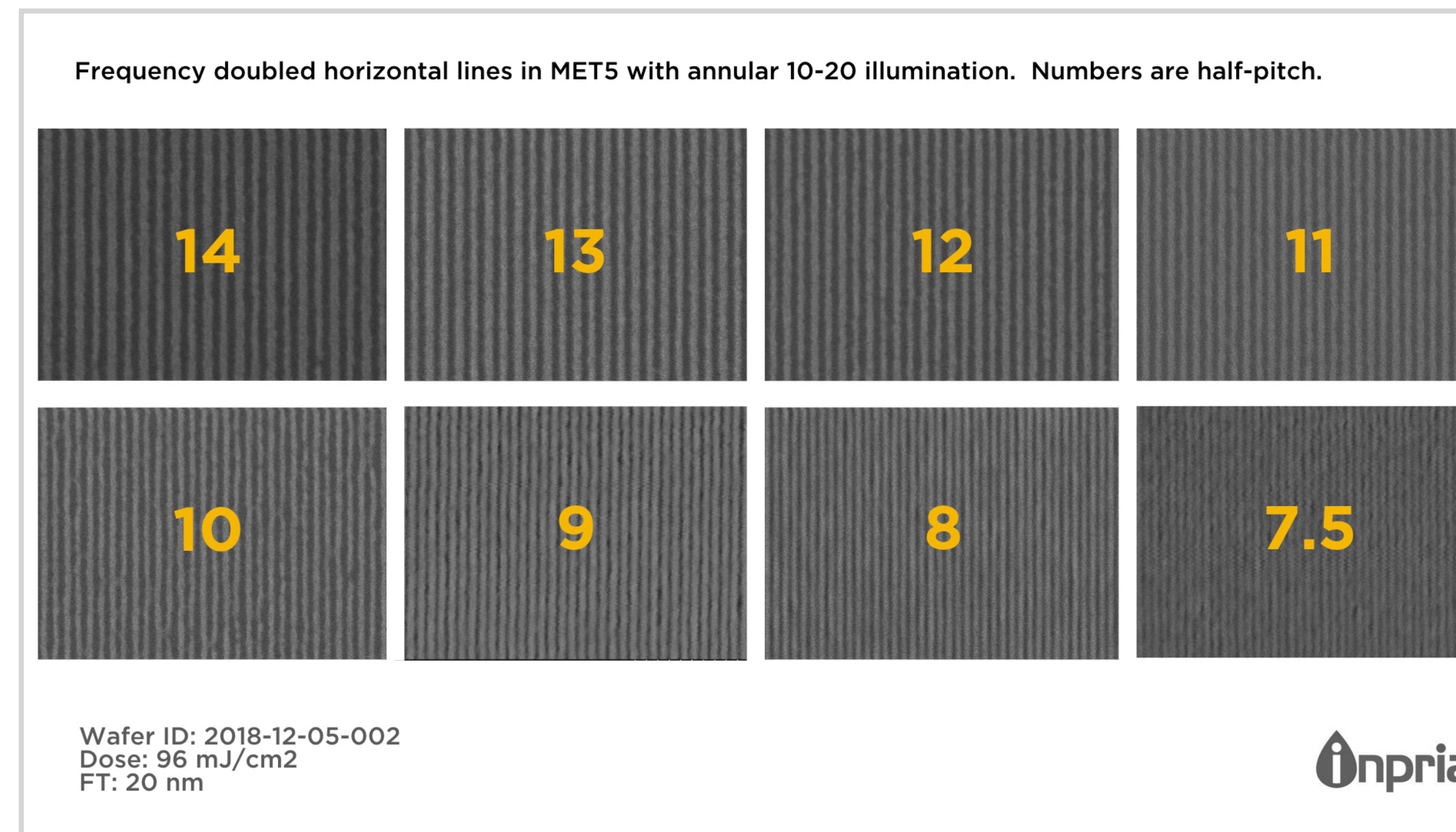
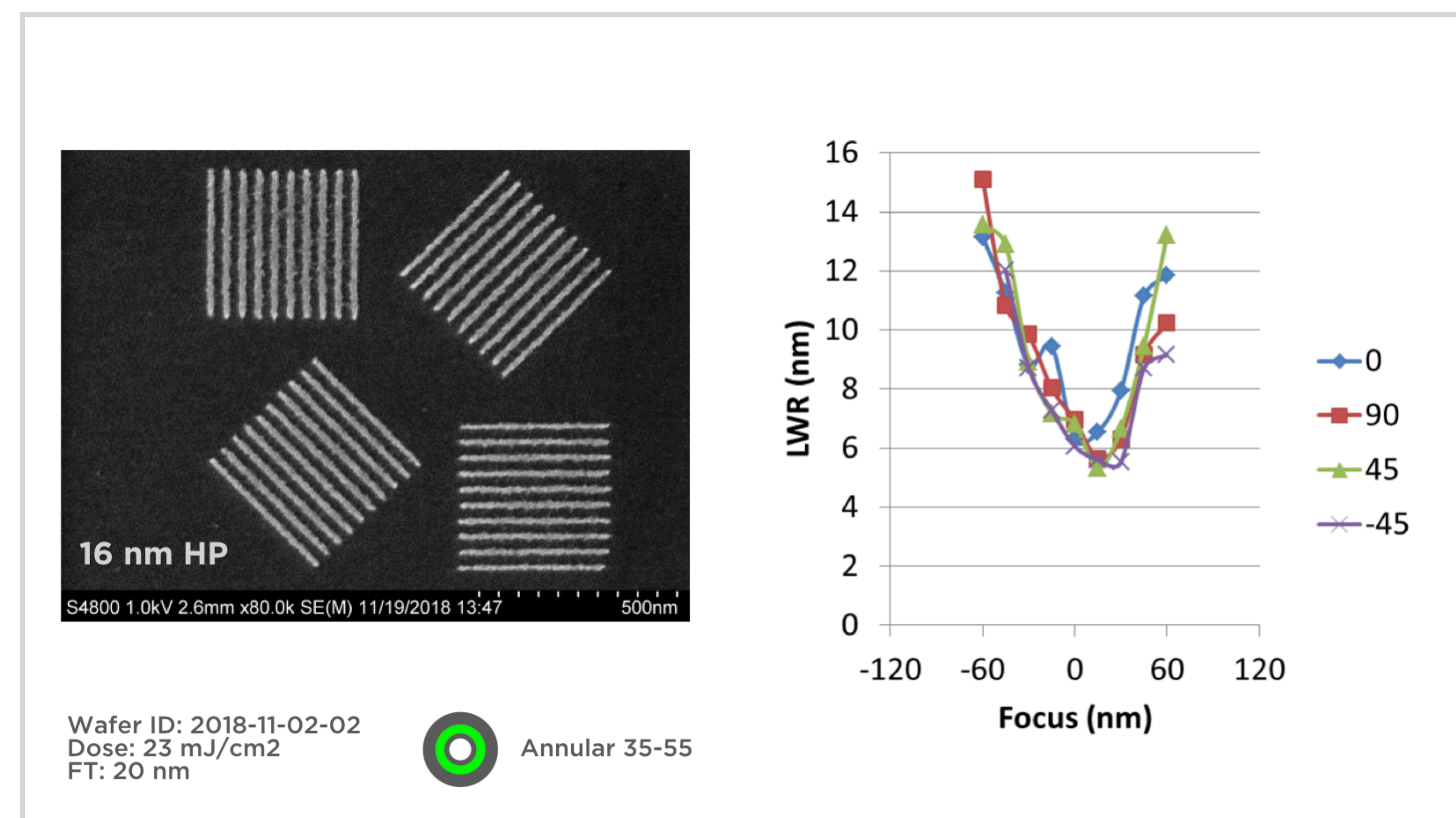


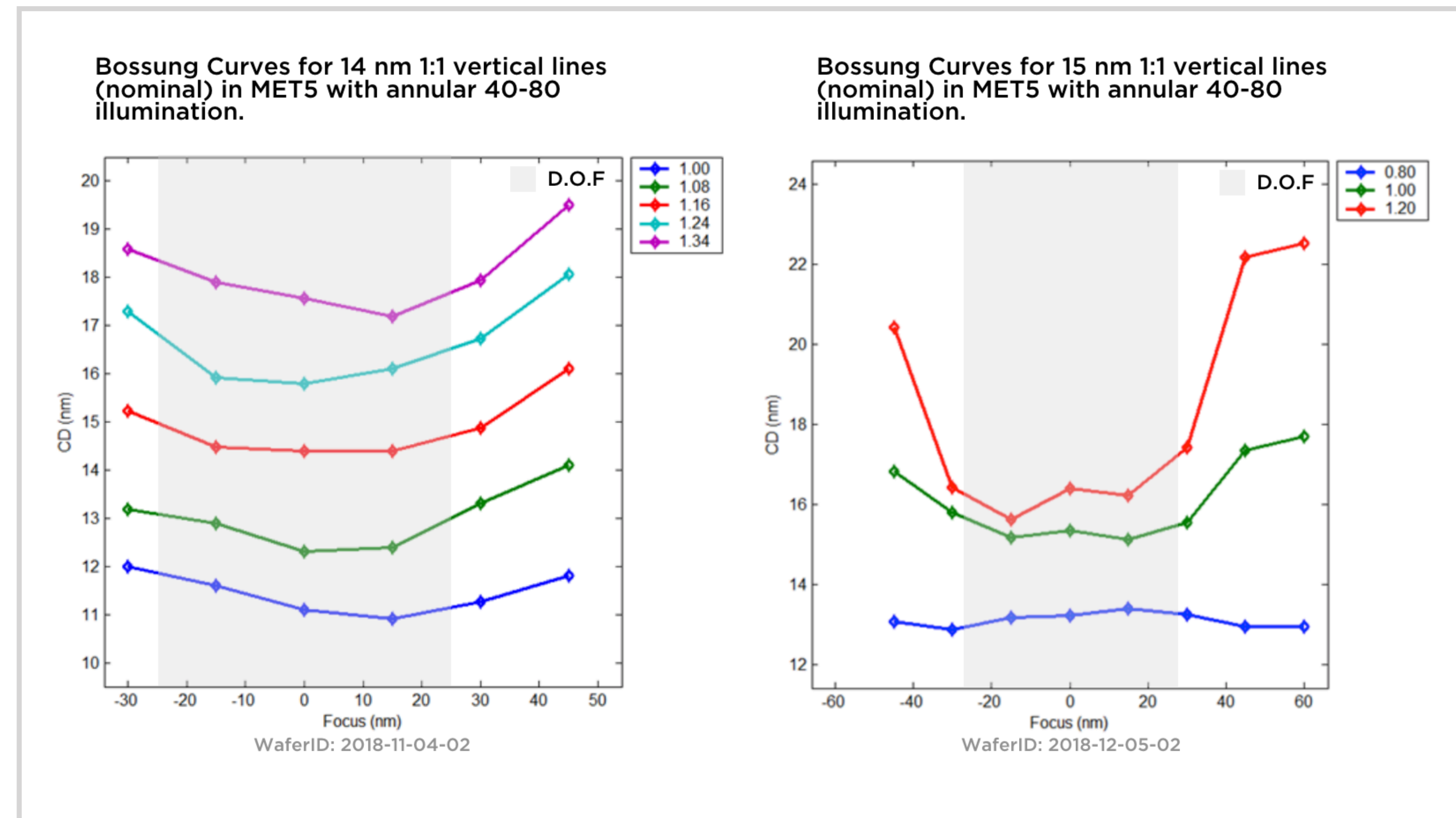


ASTIGMATISM Print-based demonstration meets specification



FOCUS CONTROL

Well-behaved Bossung curves



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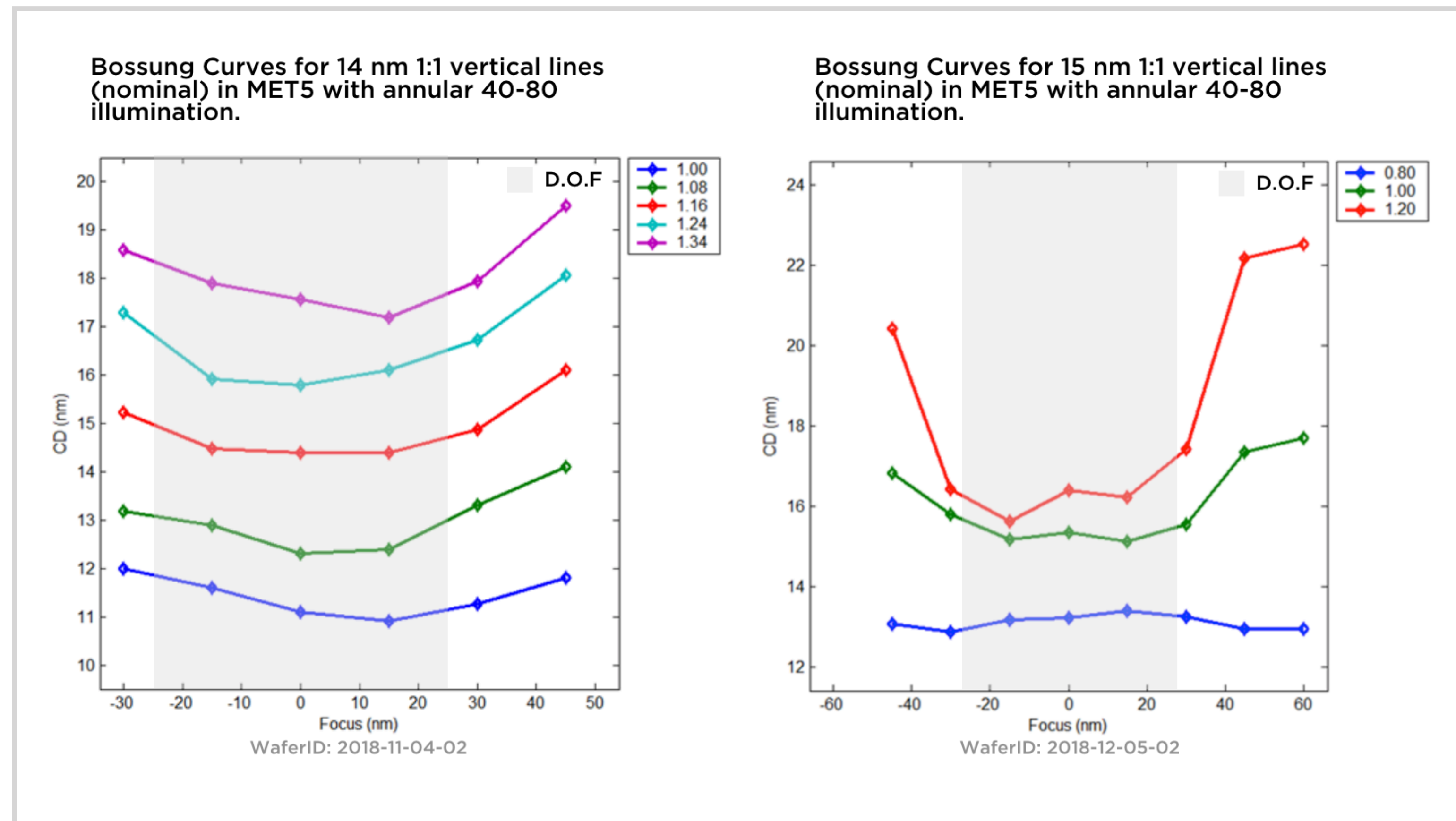
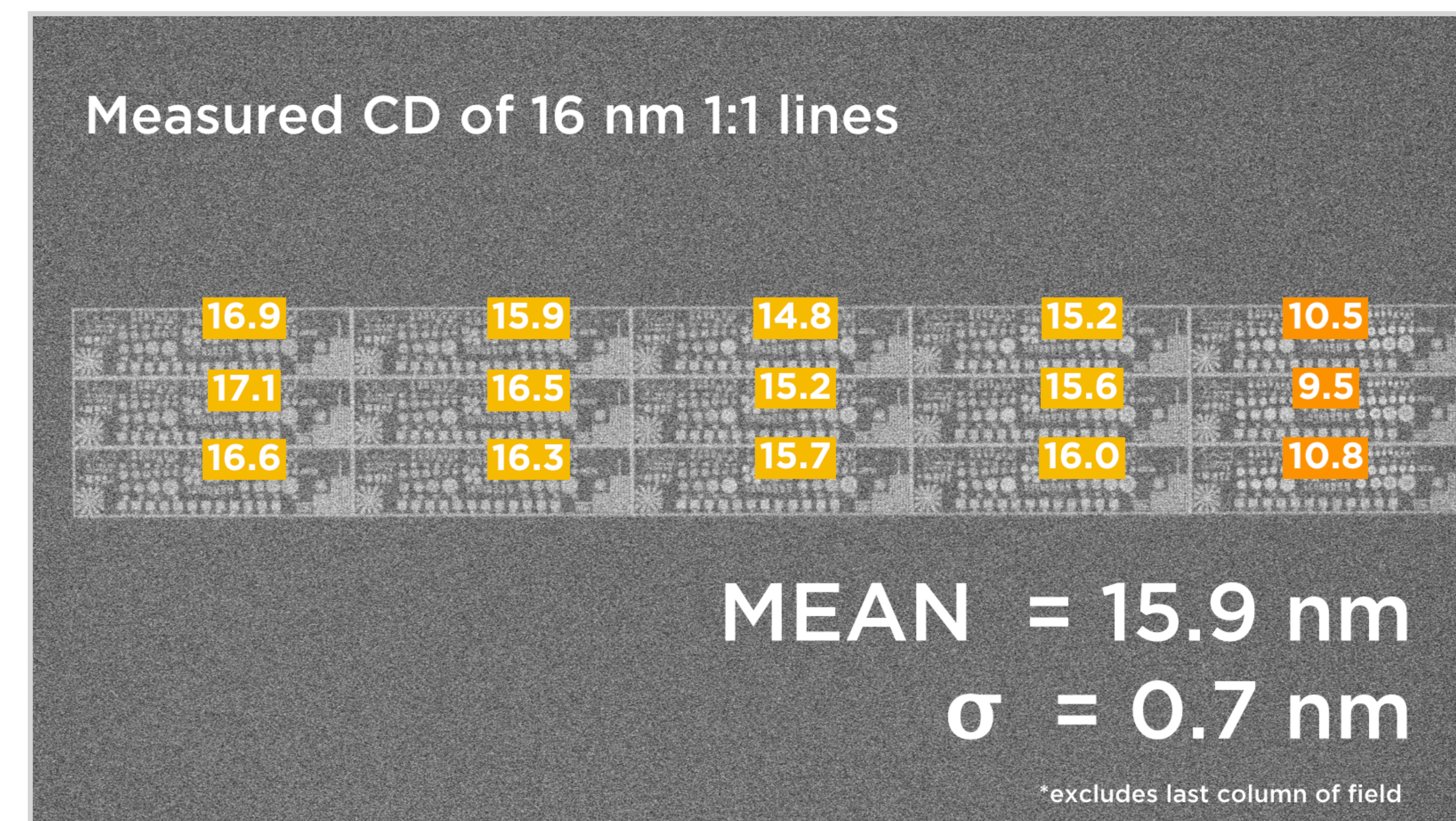


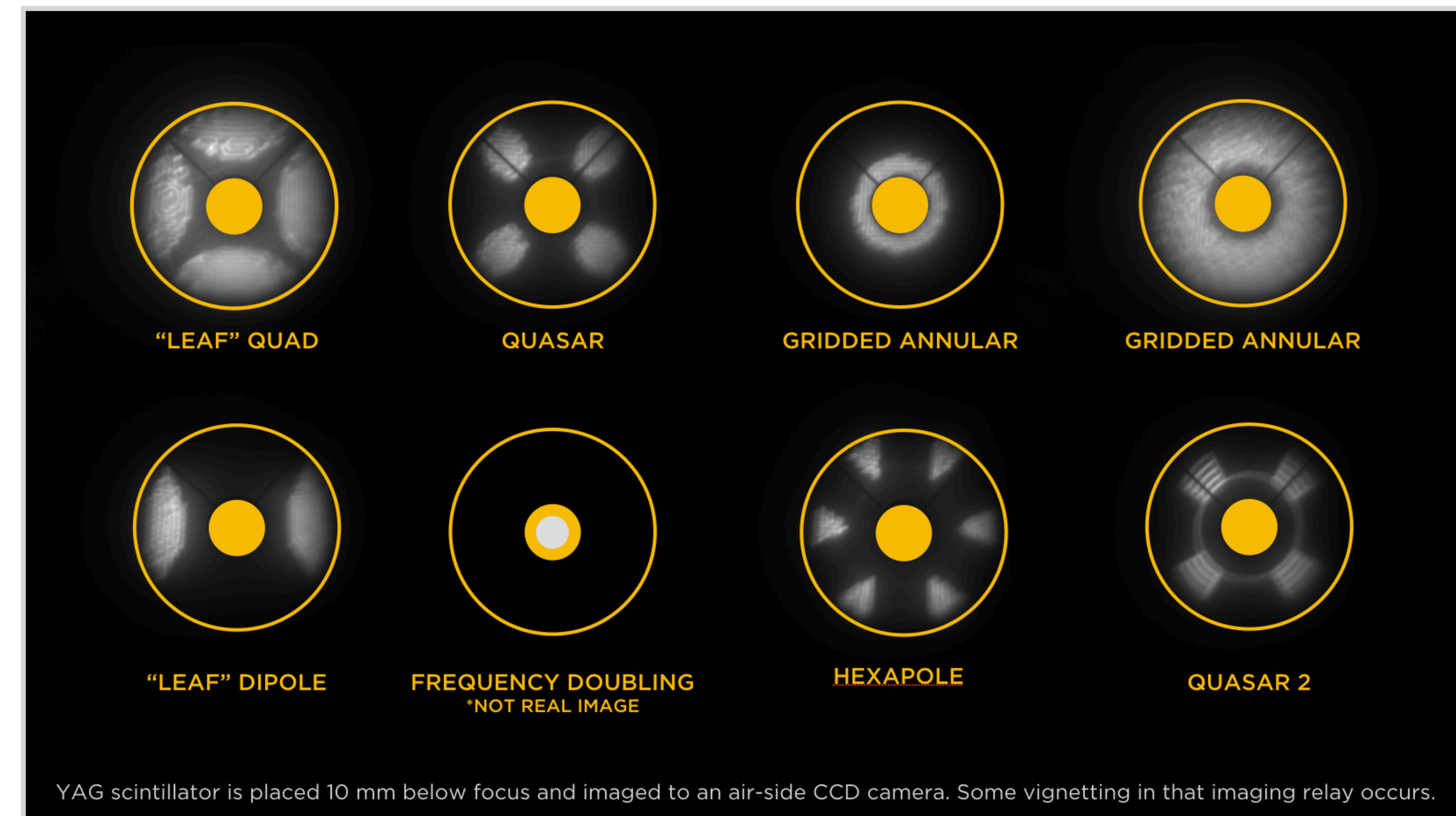
DOSE CONTROL

In-situ diode at wafer and established calibration procedure.
Uniformity in spec over 80%. Will be improved.



PUPIL CONTROL

Free form capable of all standard shapes and SMO



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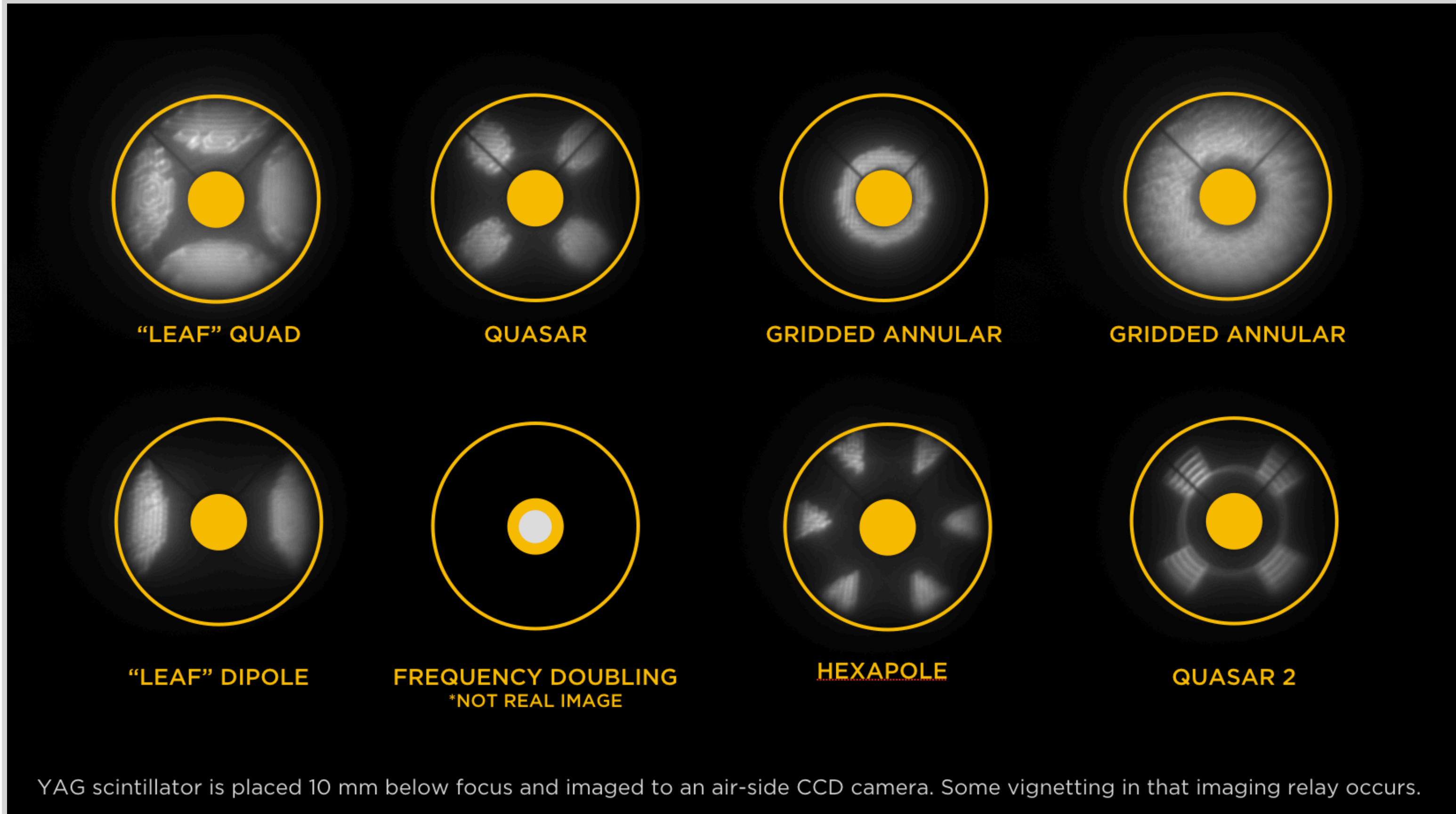

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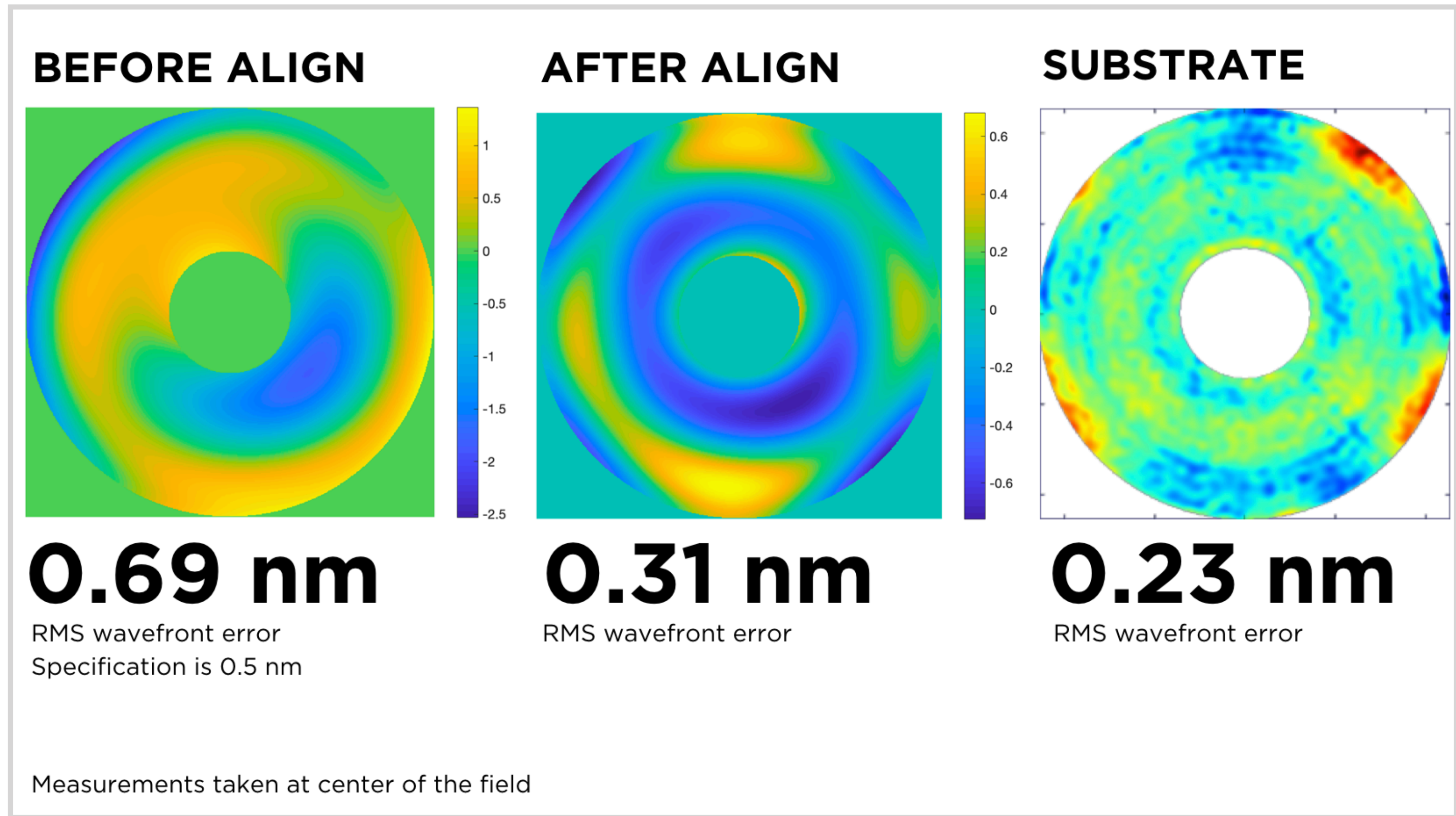
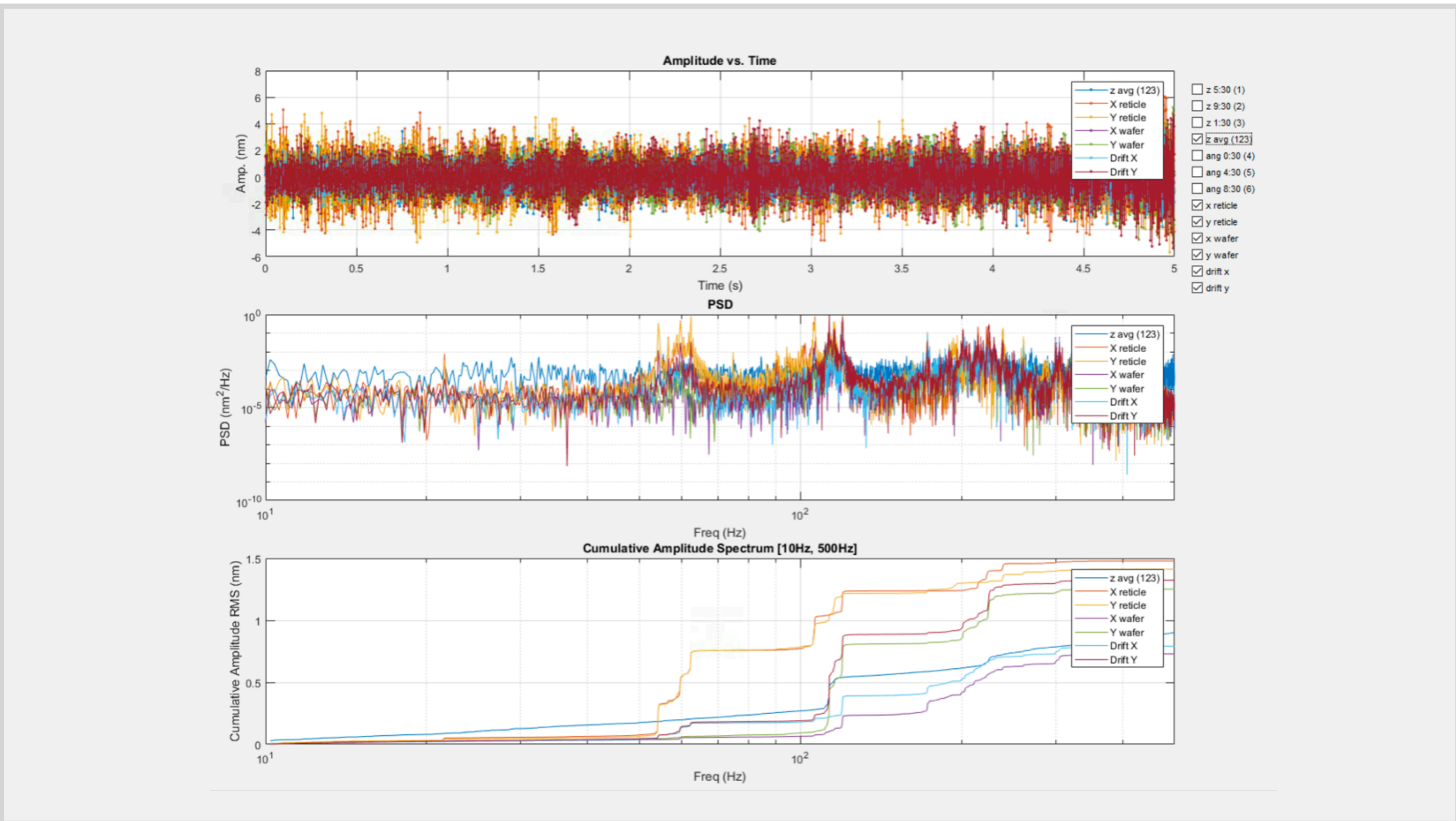
ON-BOARD LSI & VIBRATION MONITOR



Measurements taken at center of the field



TRACK TAILORED FOR RESEARCH

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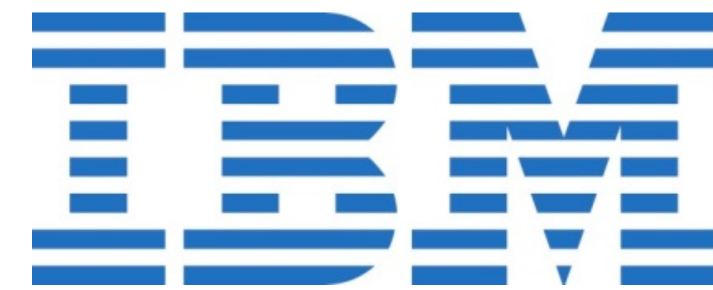
USER COMMISSIONING SHIFTS STARTED IN APRIL AND ARE ONGOING

EUREKA



ASTRILEUX
ACCELERATING THE FUTURE