The SEMATECH Berkeley MET: early access to a 12-nm aerial image, a first look at 6-nm lithography, and OOB effects on EUV resist

CXRO THE CENTER FOR X-RAY OPTICS

JSR Micro JSR MATERIALS INNOVATION

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Chris Anderson, Lorie Mae Baclea-an , Paul Denham, Ken Goldberg, Gideon Jones, Brittany McClinton, Ryan Miyakawa, Patrick Naulleau, Senajith Rekawa, and Nathan Smith.

JSR Micro
MATERIALS INNOVATION
JSR

Ken Murayama and Hiroki Nakagawa

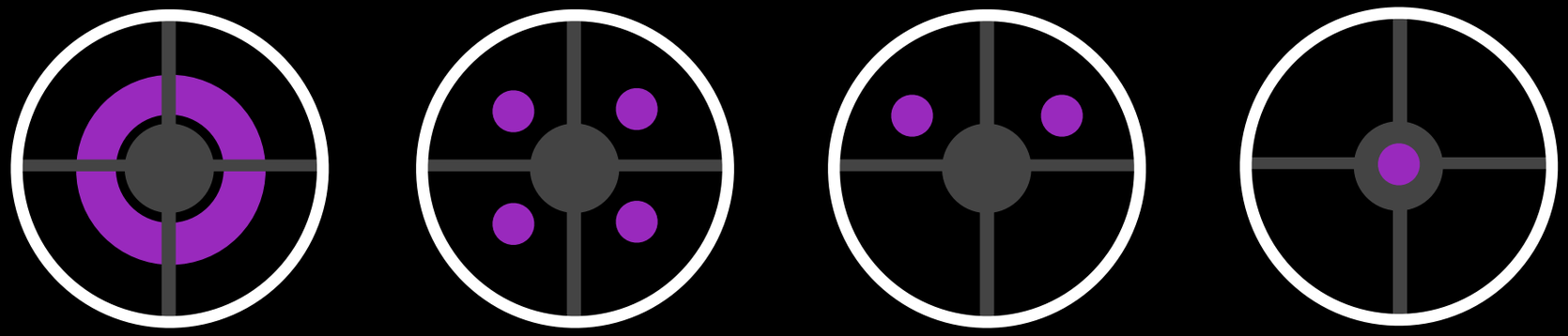
SEMATECH

Dominic Ashworth

inpria

Jason Stowers and Andrew Greenville

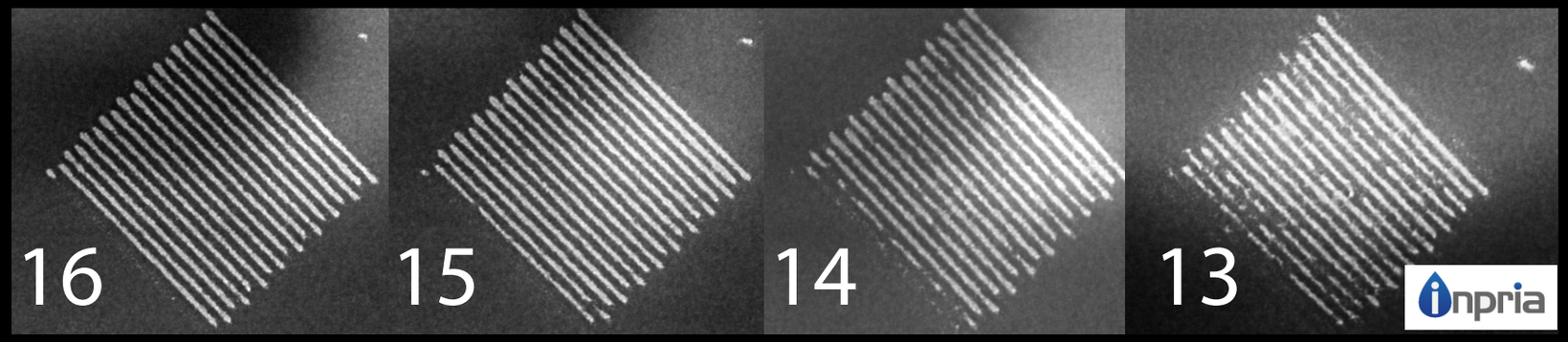
Berkeley toolset update



Engineered coherence

Demonstration of 15-nm half-pitch

Naulleau, et. al. EUVLS 2010



Q1-Q3 2011: 1500 wafers, 900 new resist + UL + dev

EUV resist and mask research

0.3-NA SEMATECH Berkeley MET

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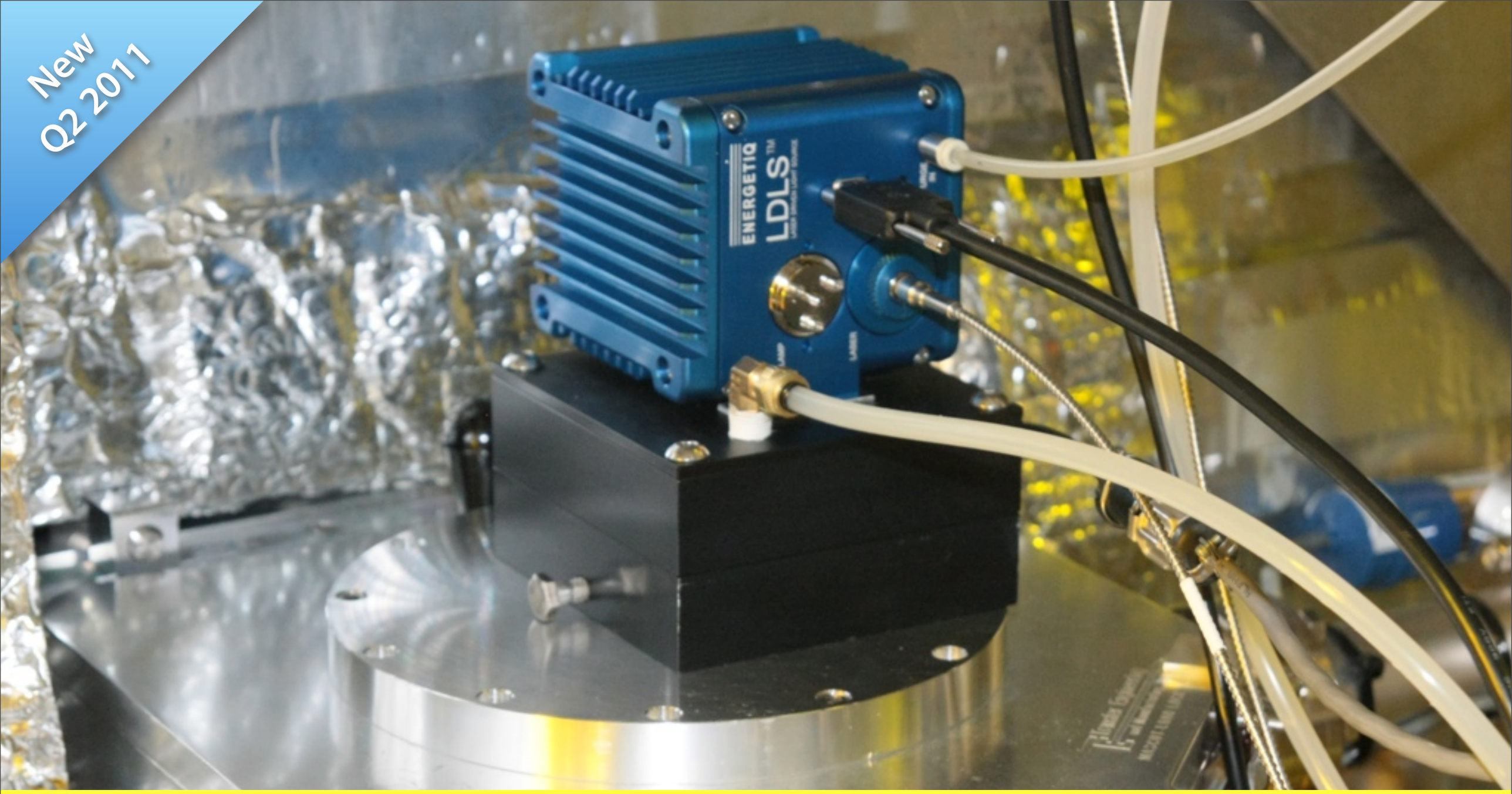

Q2-Q3 2011: 22 resists tested

In-vacuum OOB exposure

Selectable wavelength (193-nm, 248-nm)

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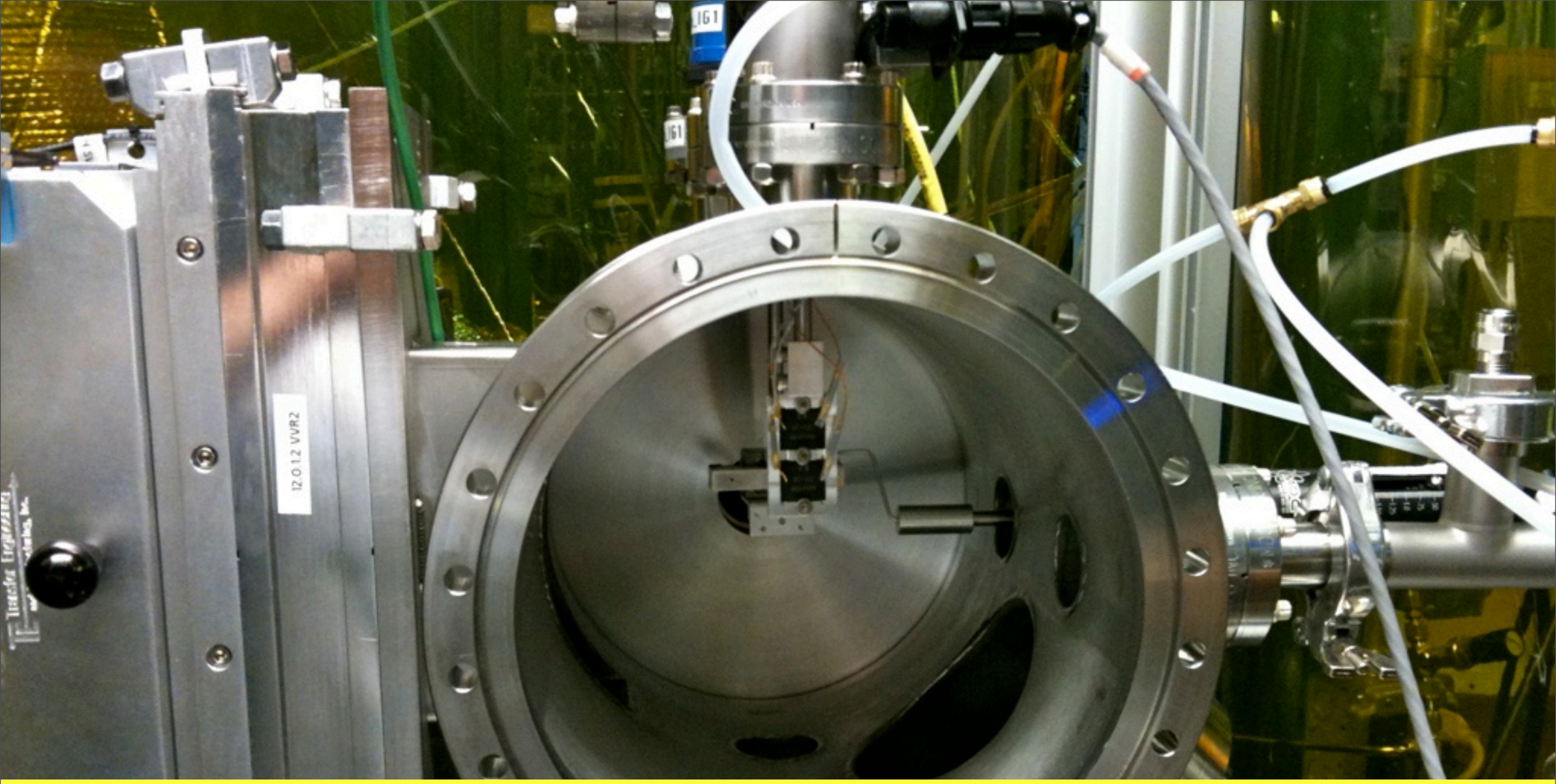

Q1-Q3 2011: 800 wafers, 460 new

Measure absolute sensitivity & contrast of EUV materials

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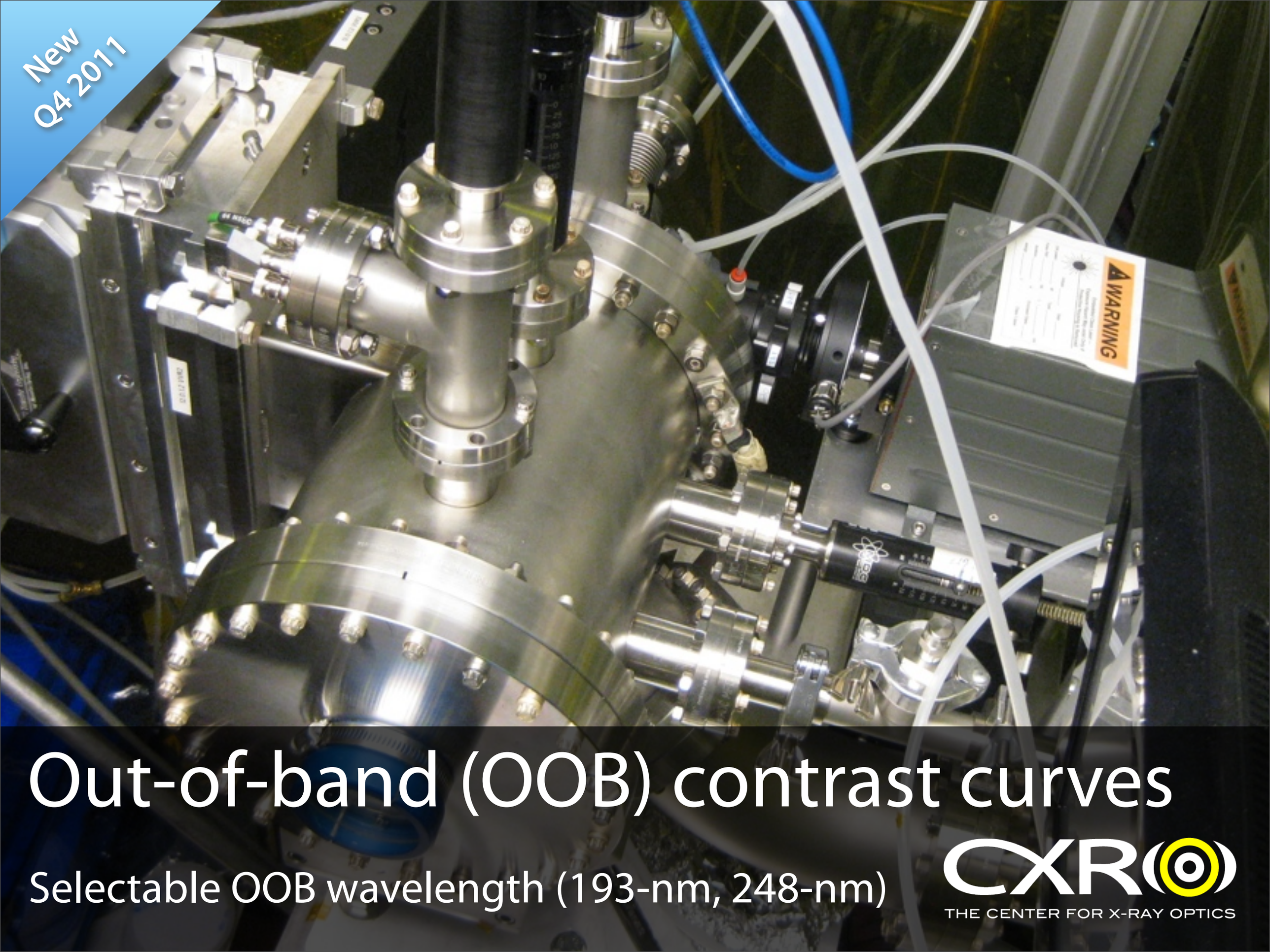

New
Q4 2011

Out-of-band (OOB) contrast curves

Selectable OOB wavelength (193-nm, 248-nm)

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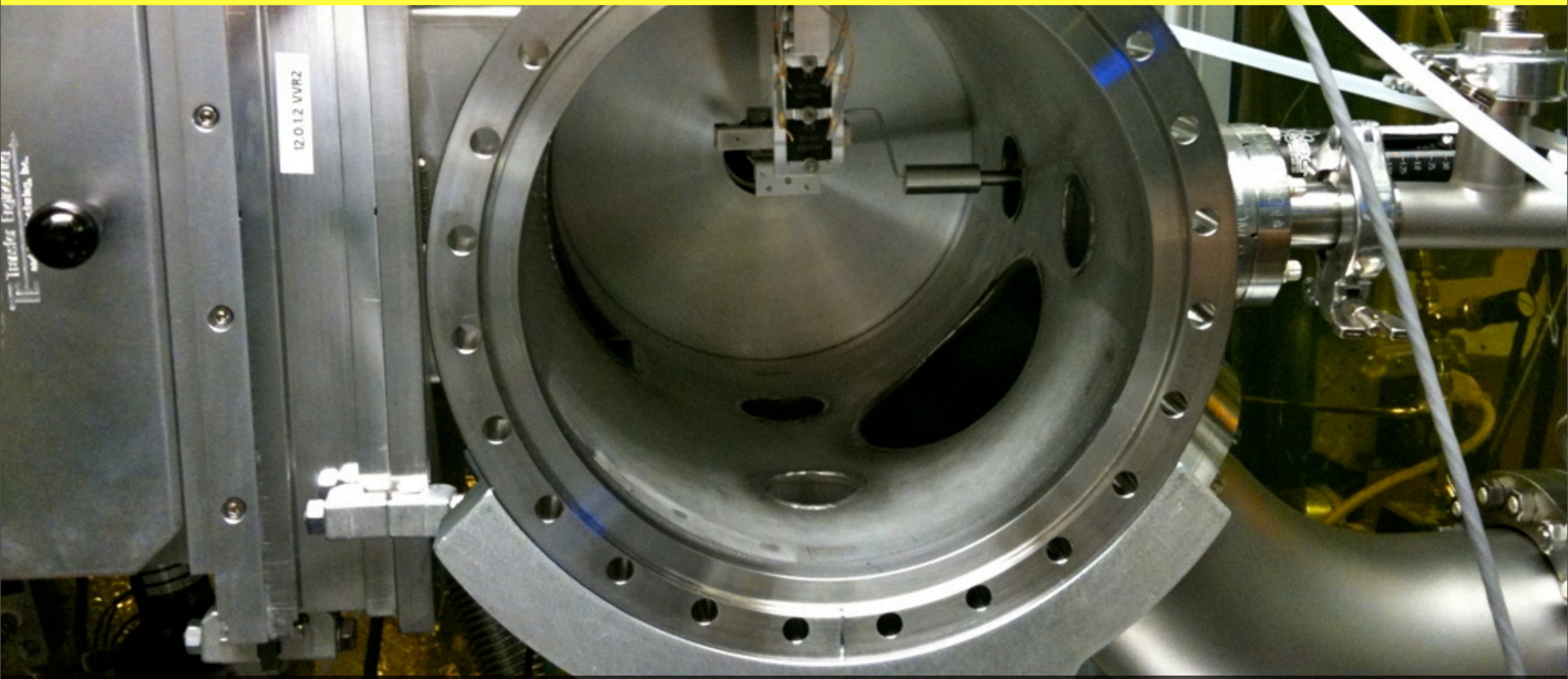
6.x-nm lithography

We have tested three materials:

1. BBR-2008A (organic, CA, 19-nm HP)
2. BBR-2008B (organic, CA, 24-nm HP)
3. Inpria XE15IB (inorganic, 15-nm HP)



6.7-nm contrast curves

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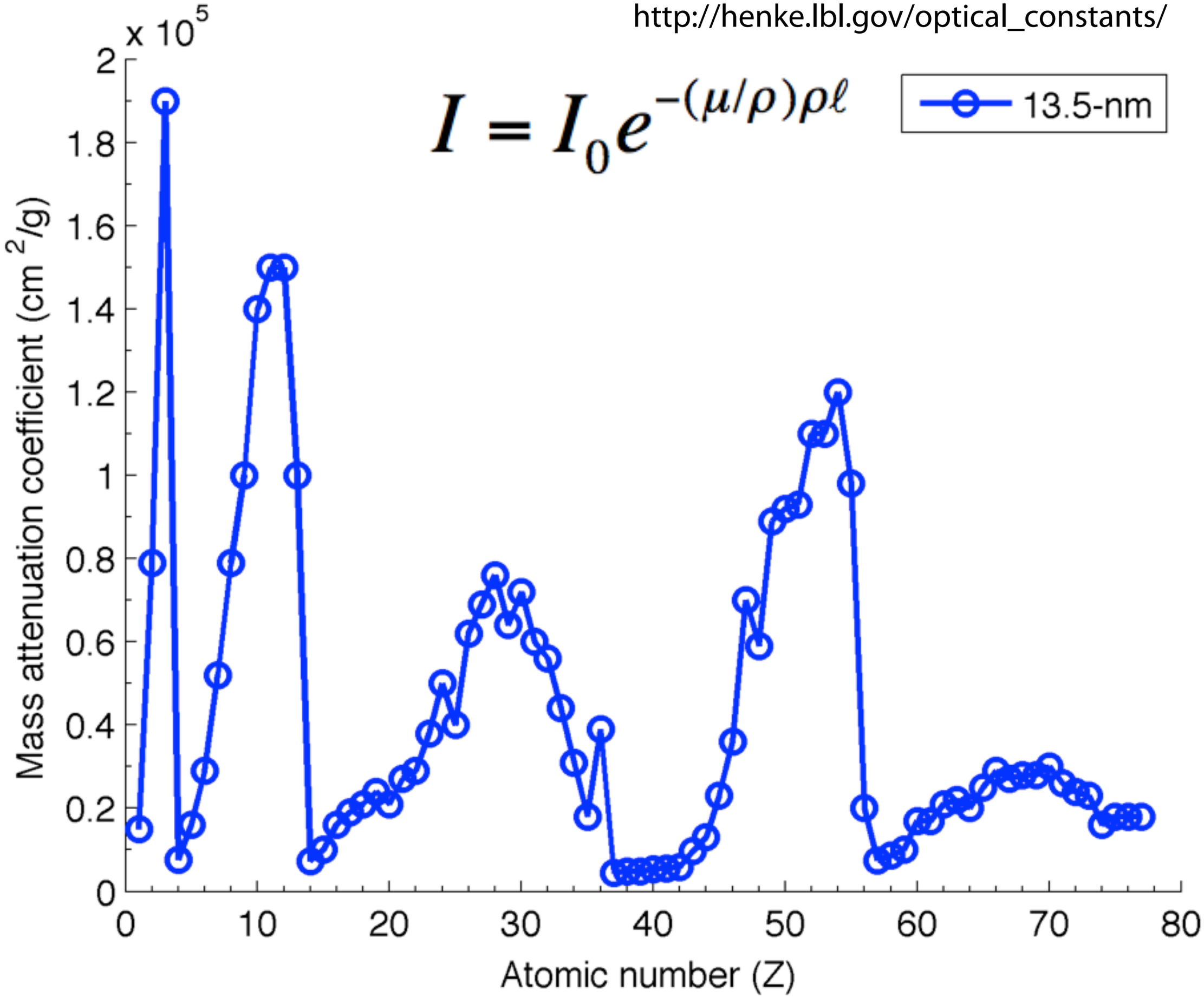
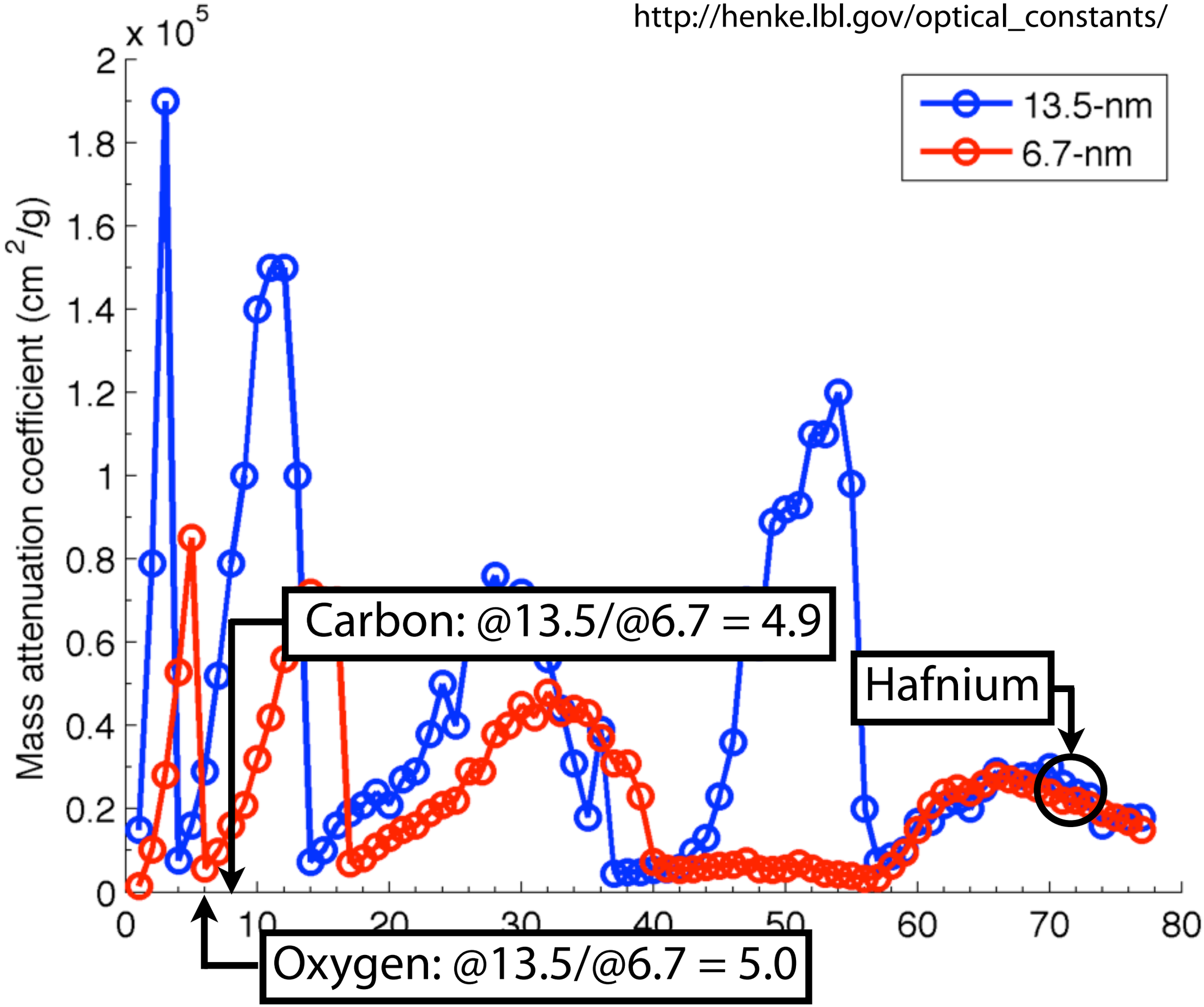
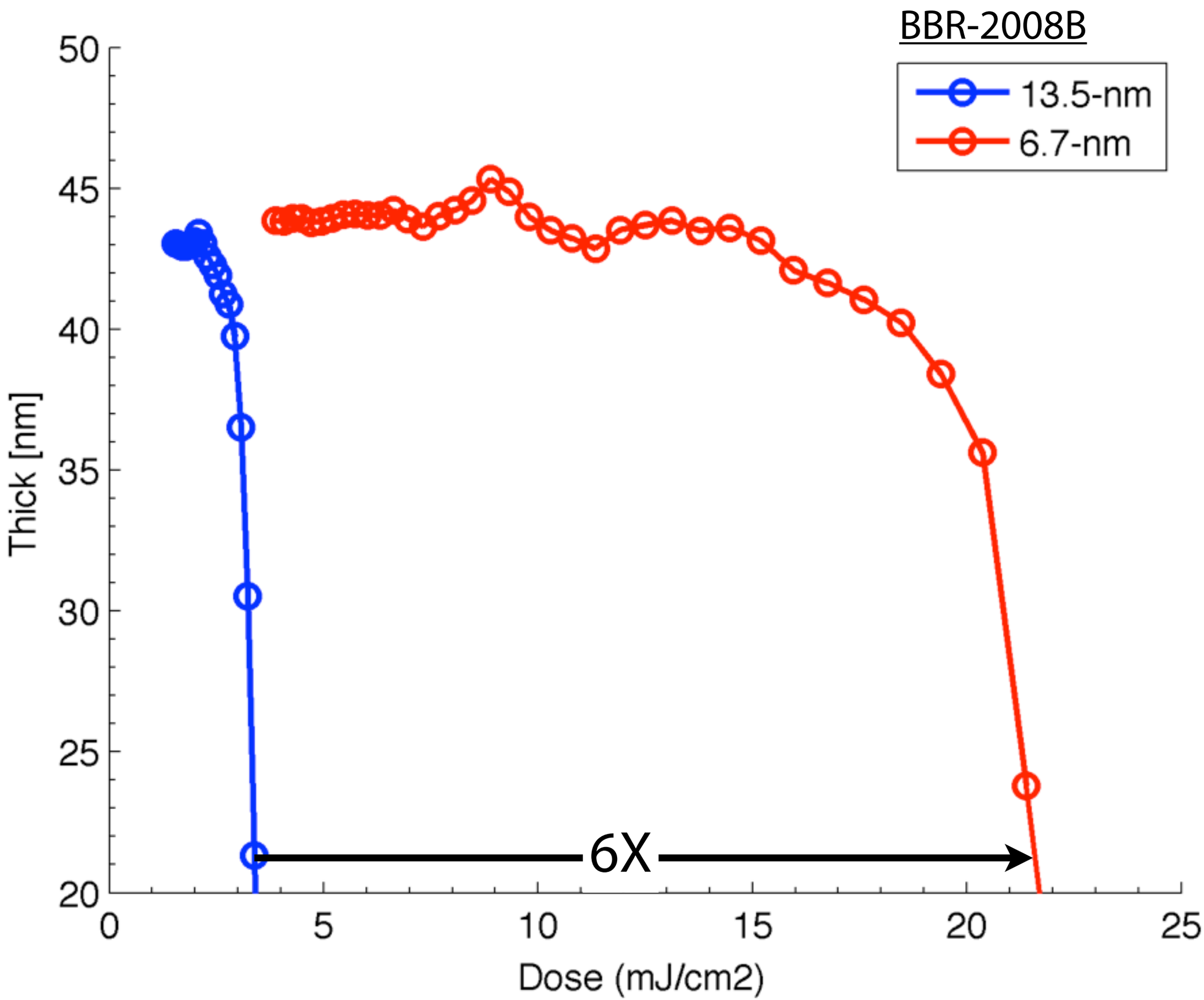
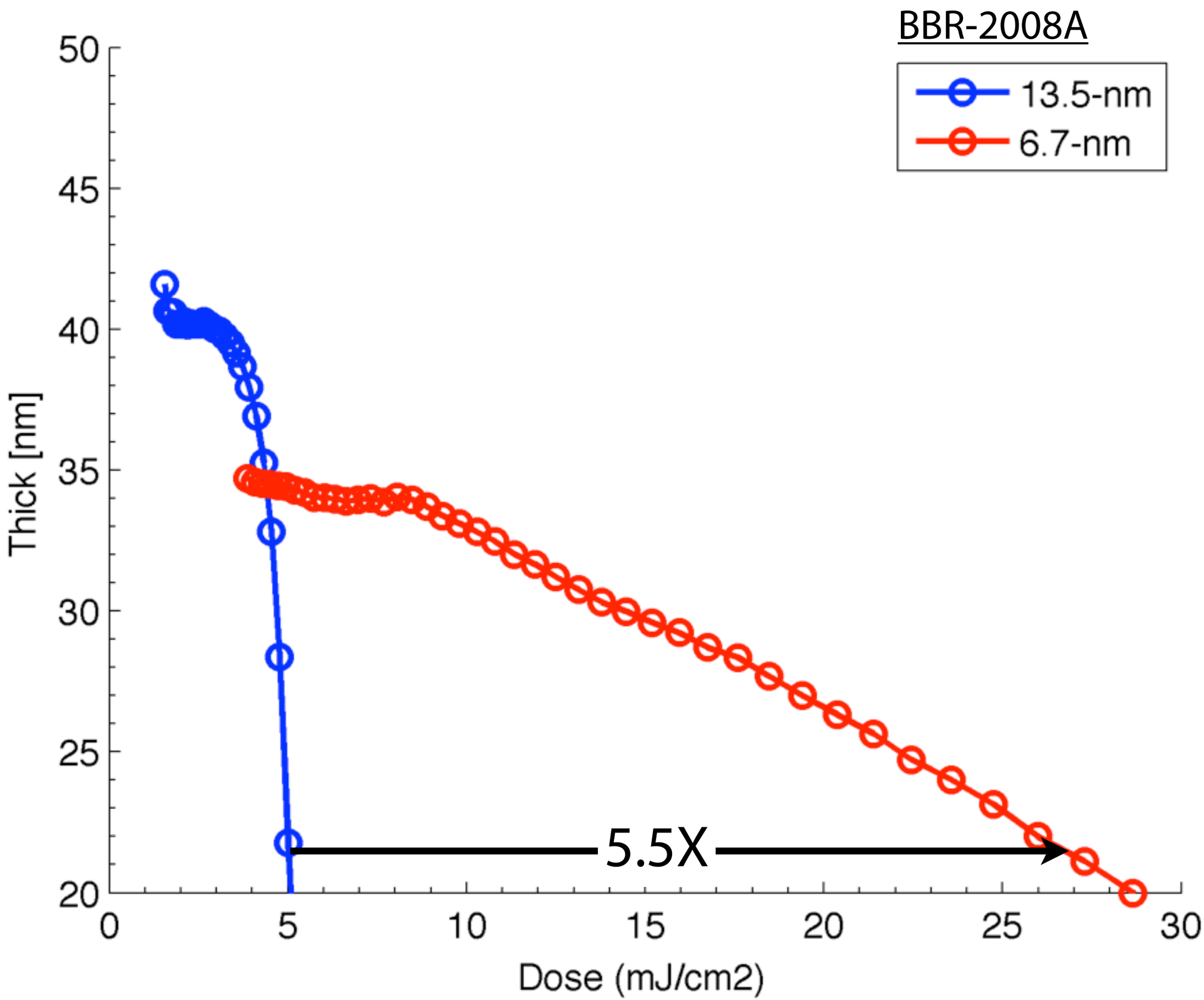
http://henke.lbl.gov/optical_constants/

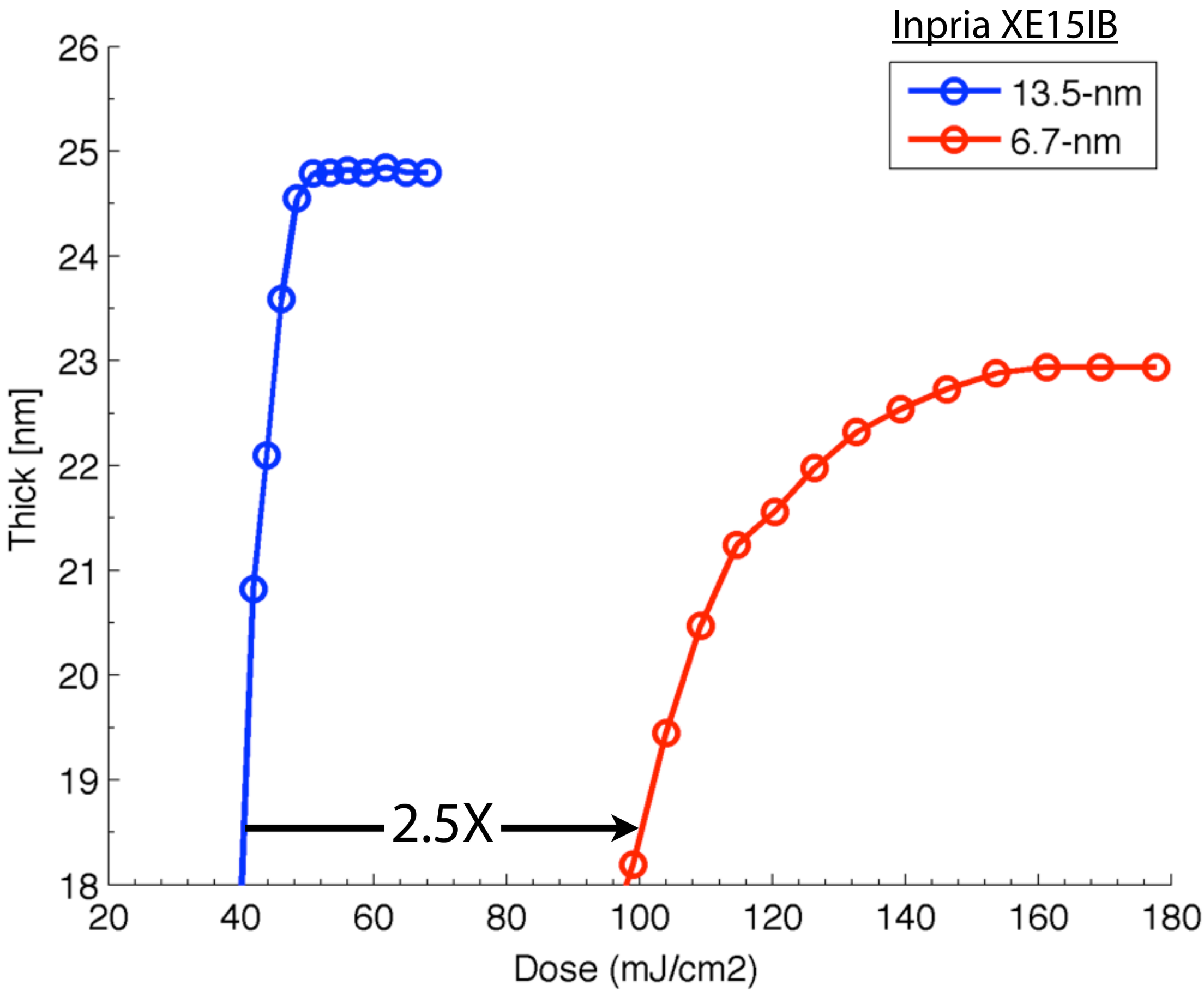


http://henke.lbl.gov/optical_constants/




BBR-2008B
13.5-nm
6.7-nm
Thick [nm]
50
45
40
35
30
25
20
0
5
10
15
20
25
Dose (mJ/cm2)
6X


BBR-2008A
13.5-nm
6.7-nm
Thick [nm]
50
45
40
35
30
25
20
0
5
10
15
20
25
30
Dose (mJ/cm2)
5.5X


Inpria XE15IB
13.5-nm
6.7-nm
Thick [nm]
26
25
24
23
22
21
20
19
18
20
40
60
80
100
120
140
160
180
Dose (mJ/cm2)
2.5X

5-6X loss in sensitivity @ 6.7

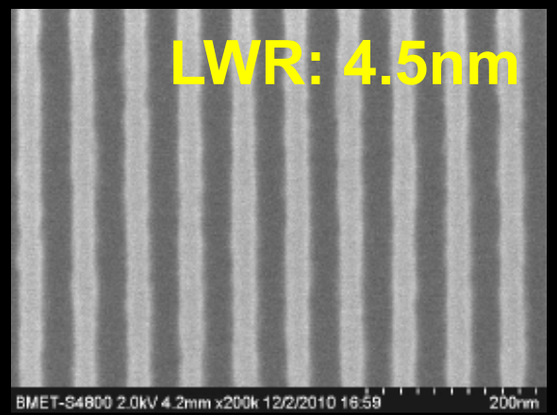
OOB update

32-nm half pitch

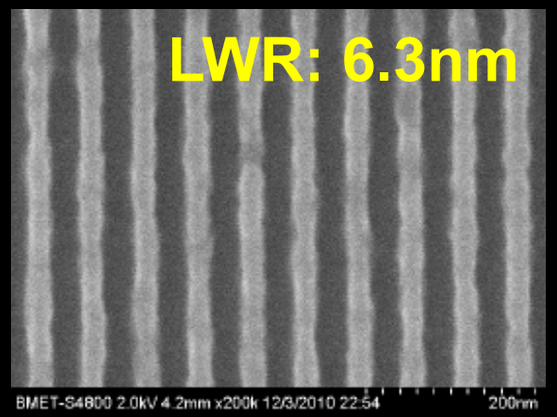
Resist A

PHS Polymer

EUV



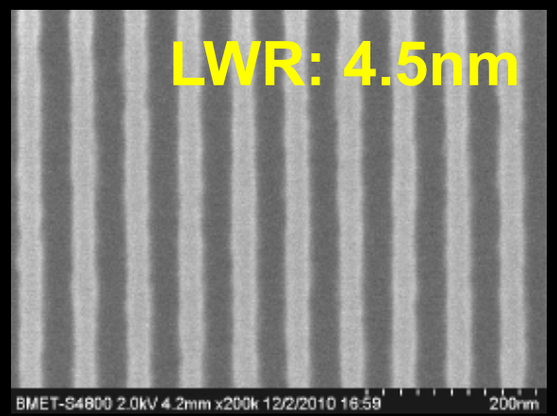
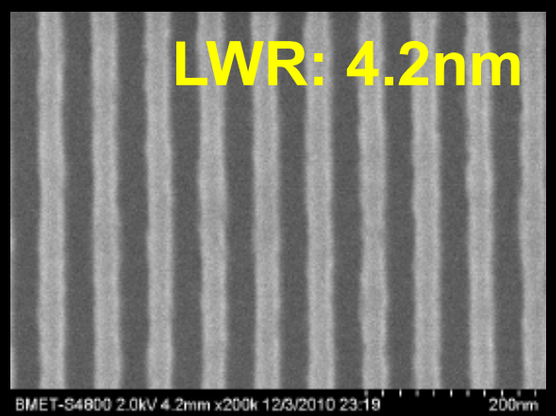
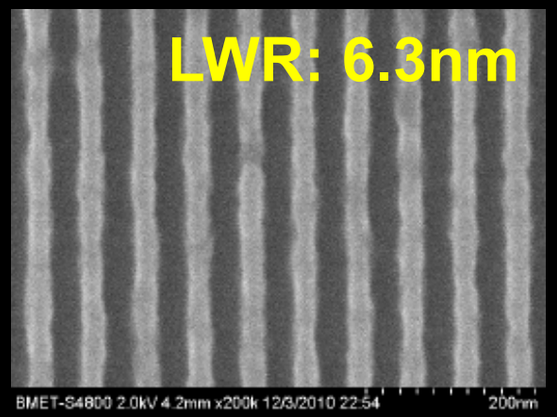
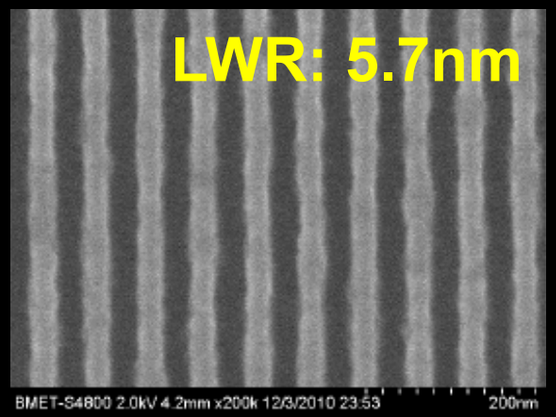
EUV + 10% 193 nm



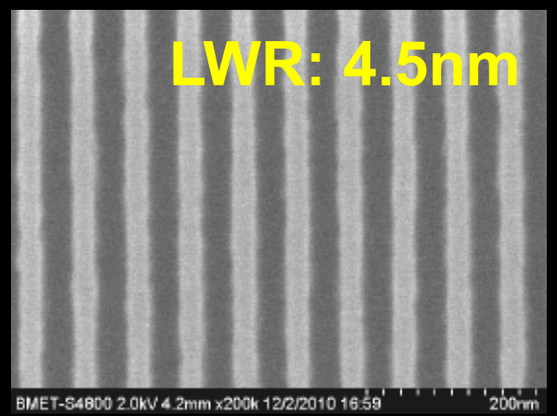
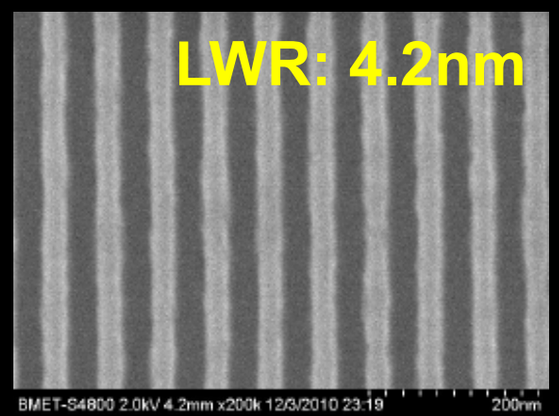
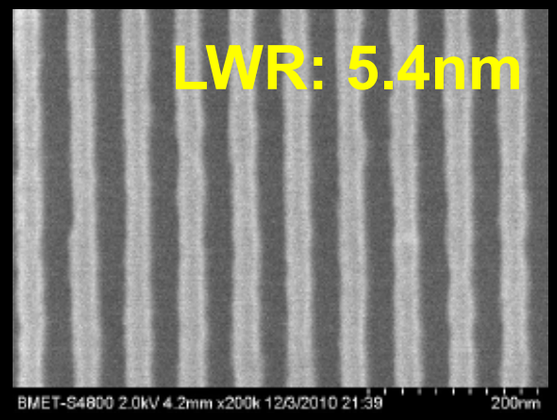
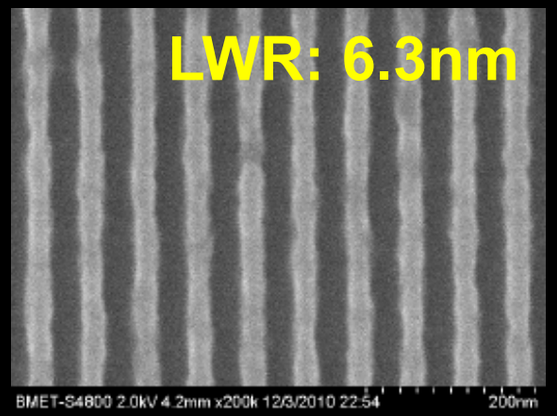
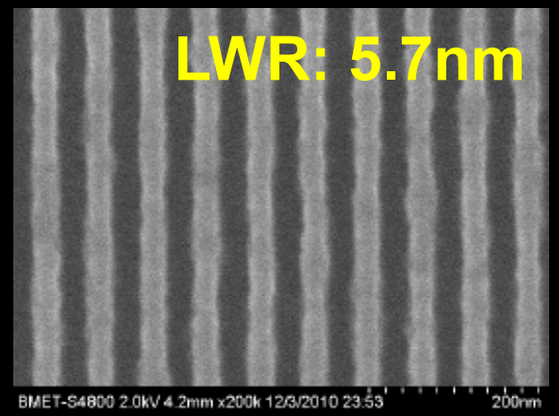
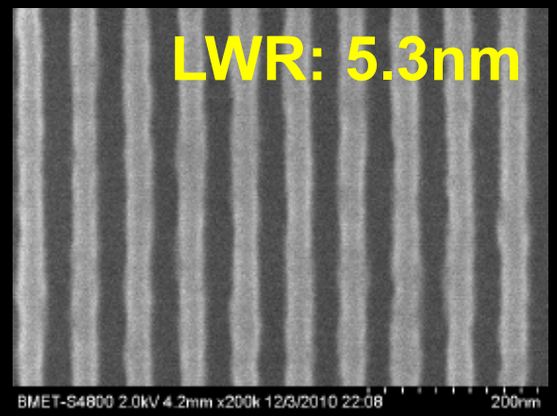
Δ Esize: 18.8%

Δ LWR: 40%

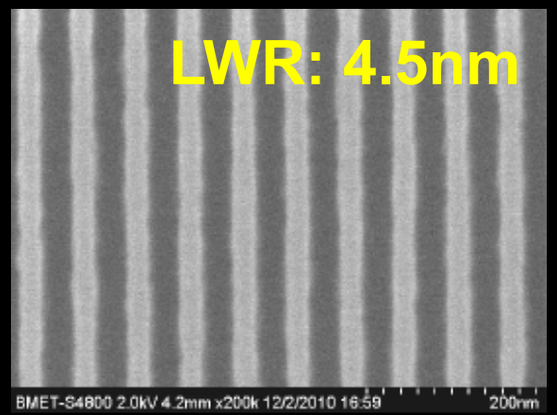
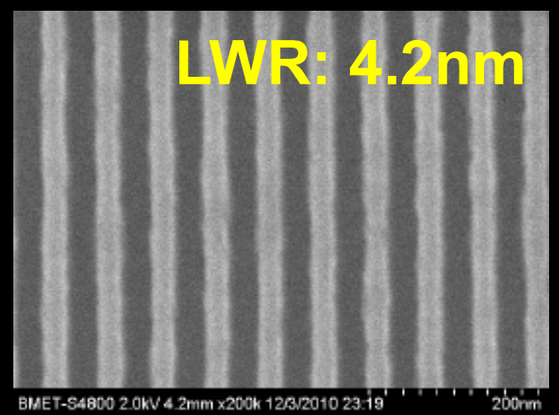
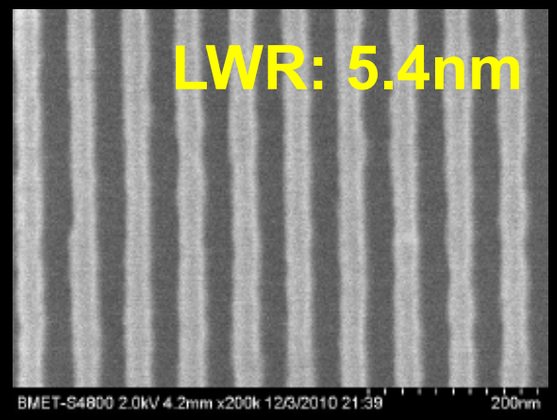
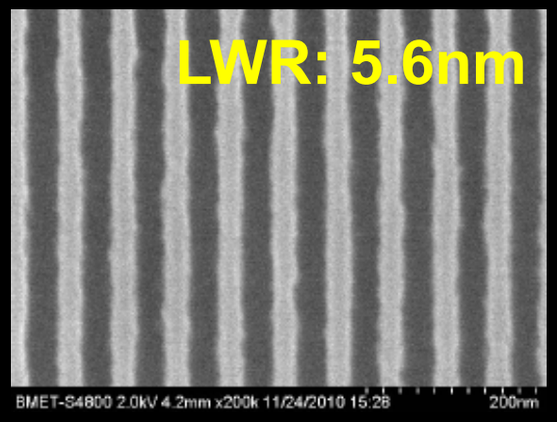
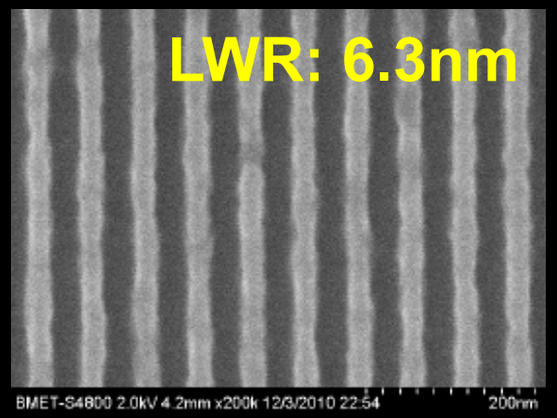
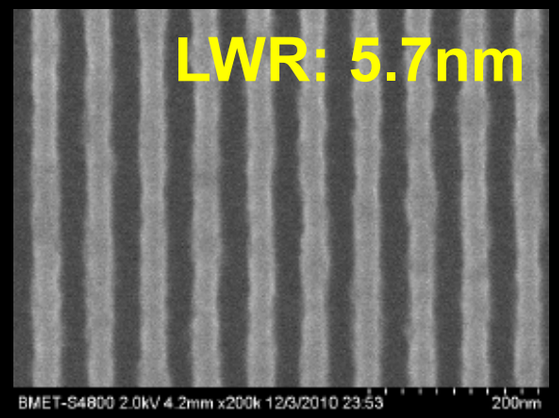
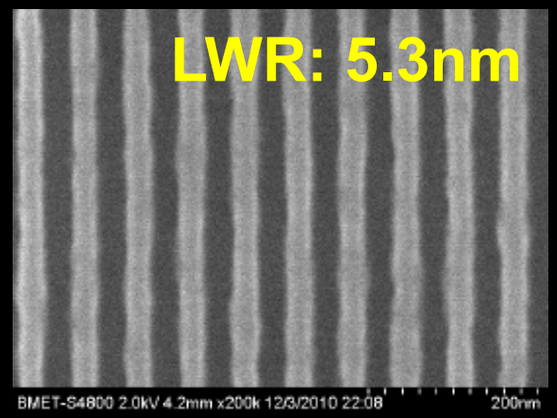
32-nm half pitch

	Resist A ***PHS Polymer***	***Resist B*** ***PHS Polymer***
EUV		
EUV + 10% 193 nm	 **Δ Esize: 18.8%** **Δ LWR: 40%**	 **Δ Esize: 6.7%** **Δ LWR: 36%**

32-nm half pitch

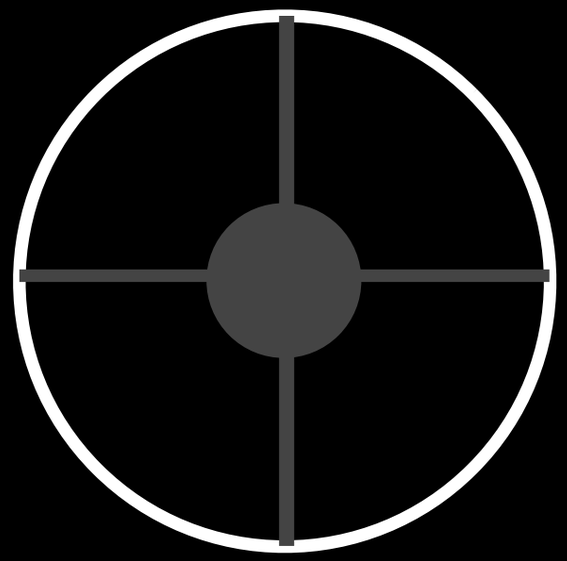
	Resist A	***Resist B***	***Resist C***
	PHS Polymer	***PHS Polymer***	***PHS Polymer***
EUV			
EUV + 10% 193 nm			
	Δ Esize: 18.8% **Δ LWR: 40%**	**Δ Esize: 6.7%** **Δ LWR: 36%**	**Δ Esize: 13.1%** **Δ LWR: 0%**

32-nm half pitch

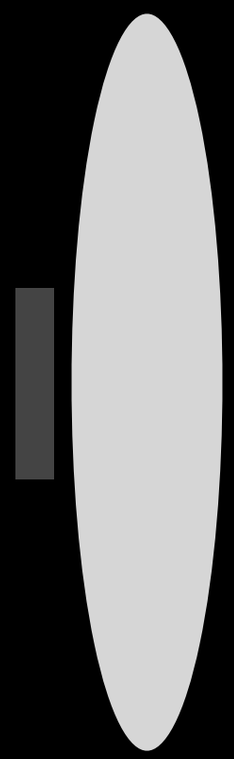
	Resist A PHS Polymer	Resist B PHS Polymer	Resist C PHS Polymer	Resist D ArF Polymer
EUV	 LWR: 4.5nm	 LWR: 4.2nm	 LWR: 5.4nm	 LWR: 5.6nm
EUV + 10% 193 nm	 LWR: 6.3nm Δ Esize: 18.8% Δ LWR: 40%	 LWR: 5.7nm Δ Esize: 6.7% Δ LWR: 36%	 LWR: 5.3nm Δ Esize: 13.1% Δ LWR: 0%	No printing Δ Esize: N/A

Early access to a 12-nm aerial image

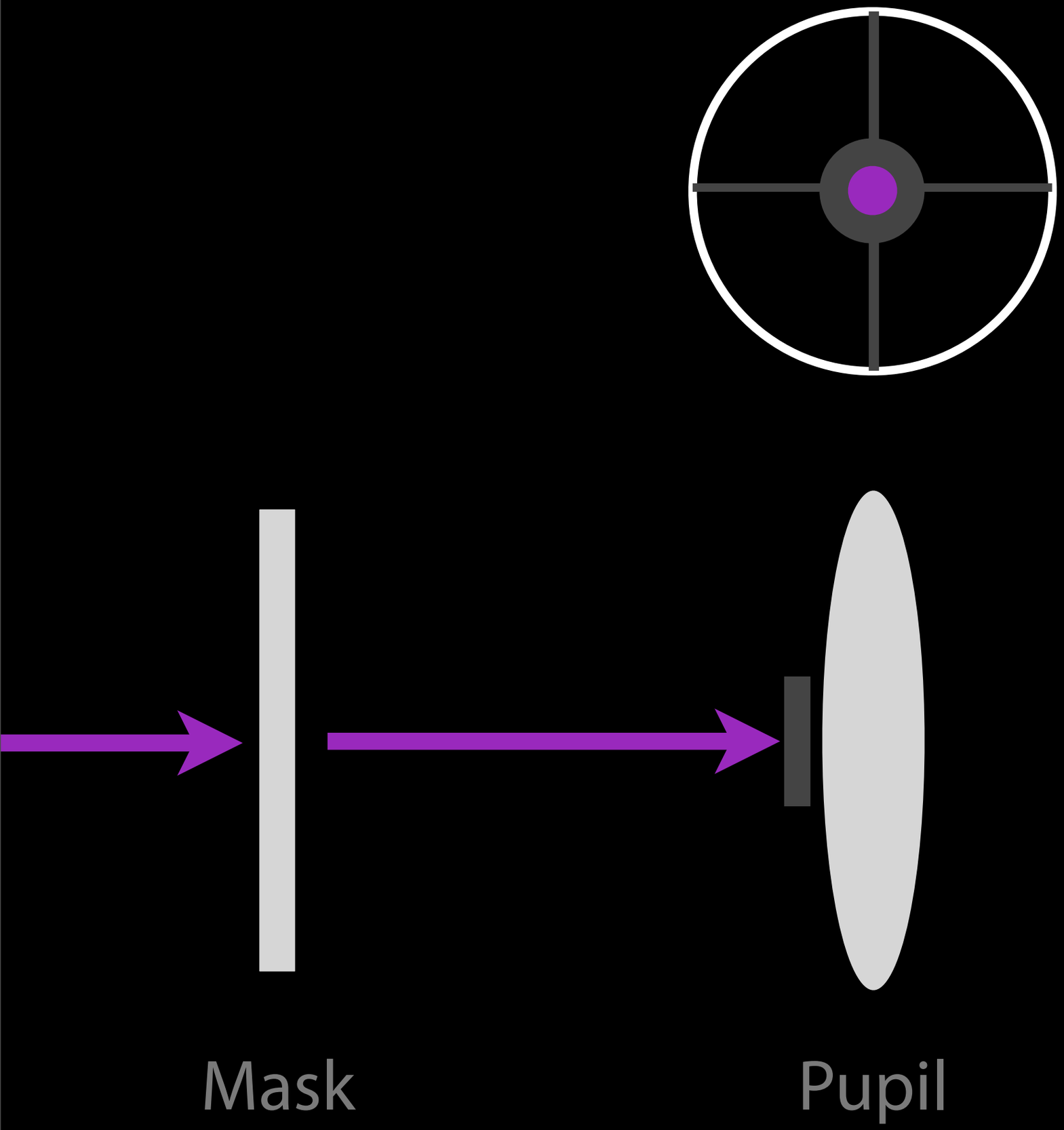
Pseudo phase-shift-mask

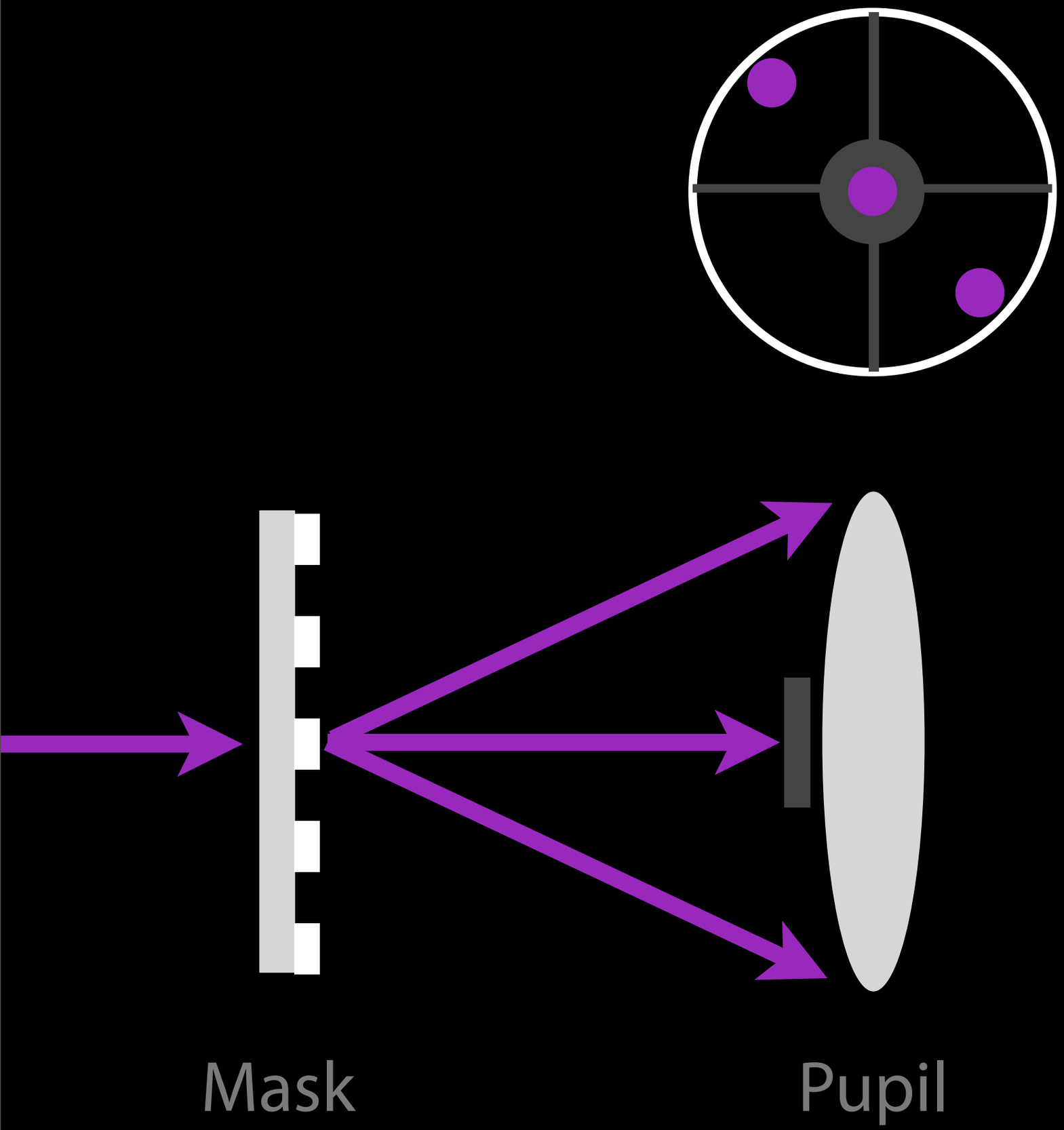


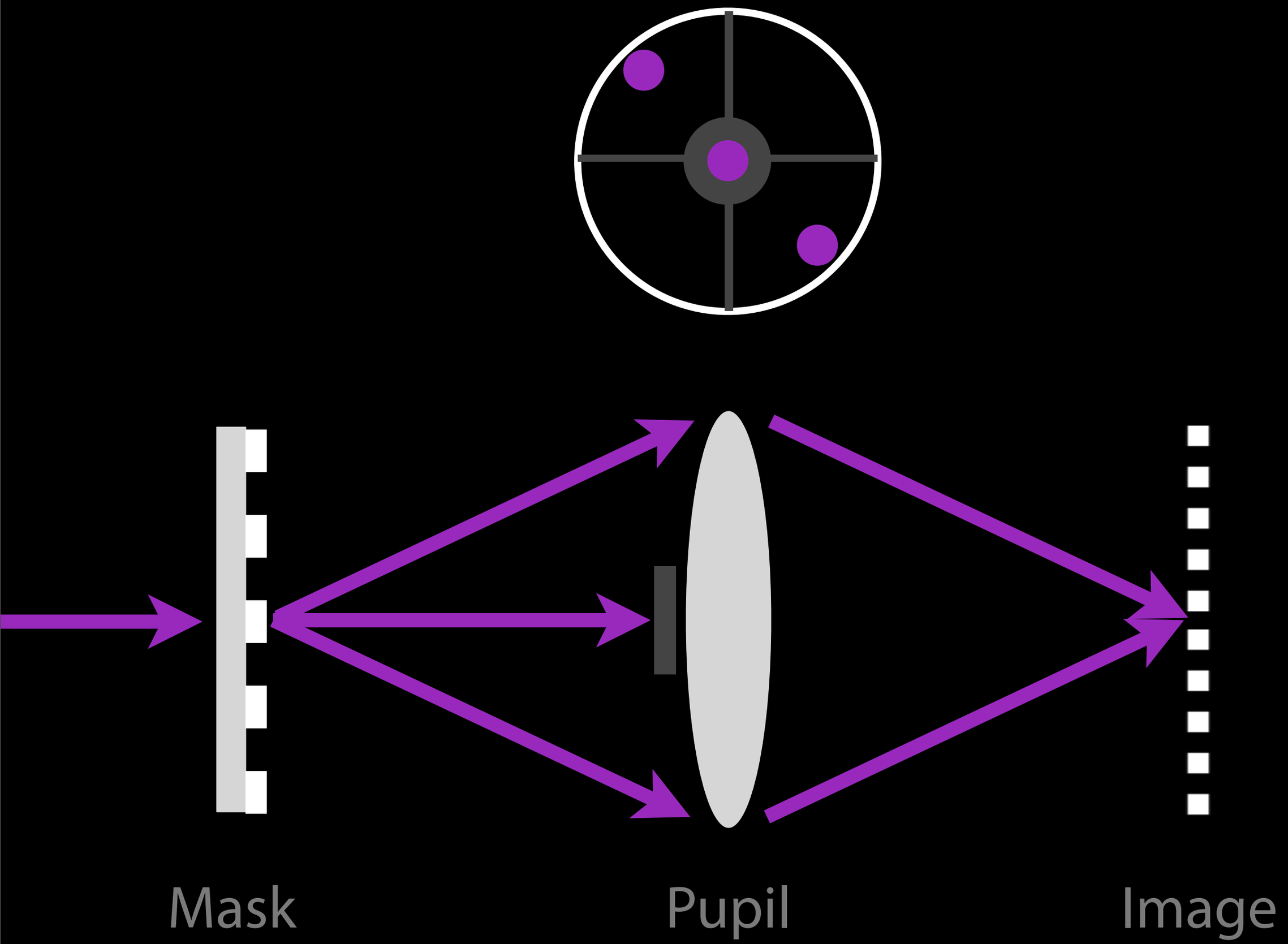
Mask

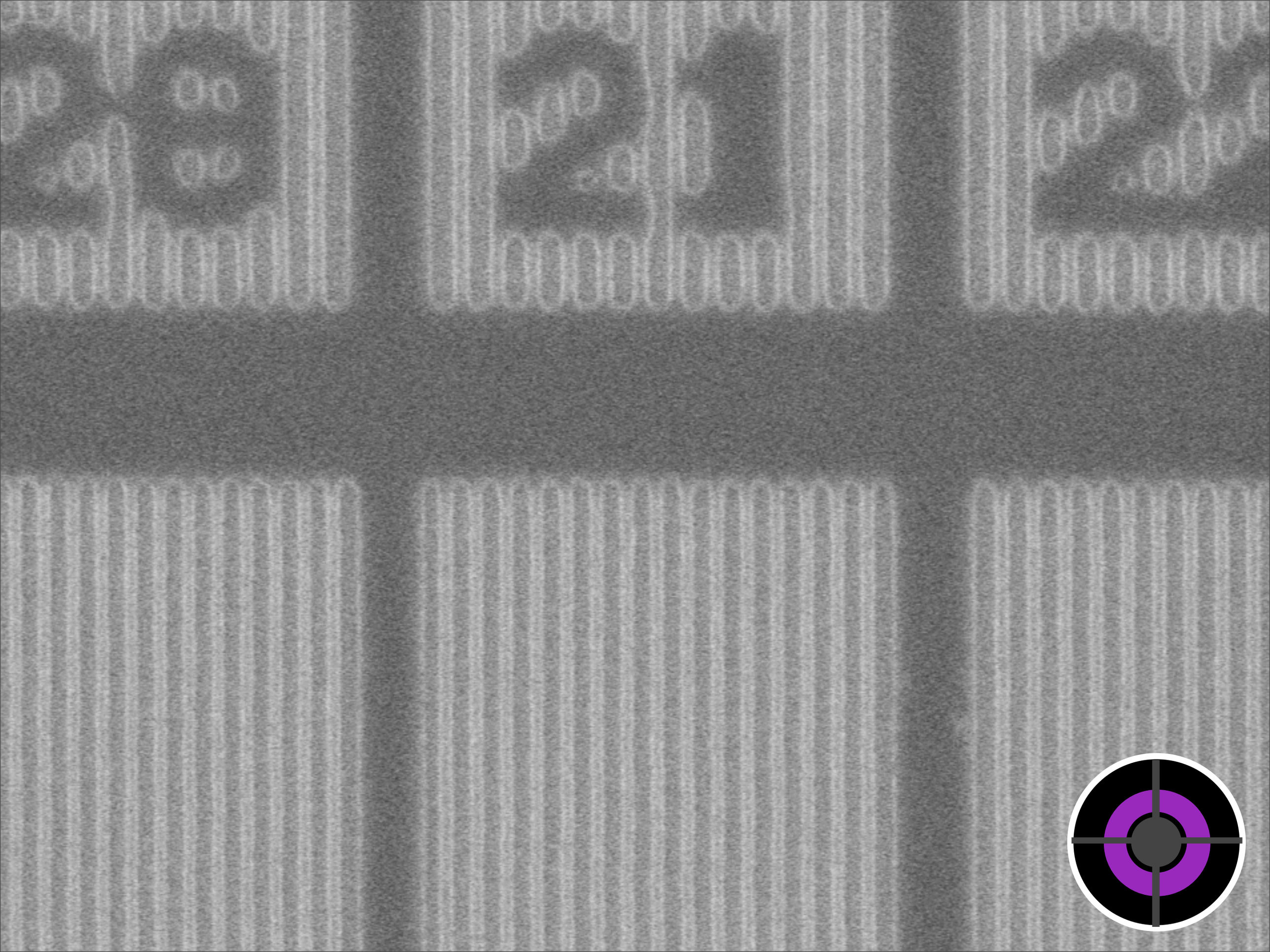


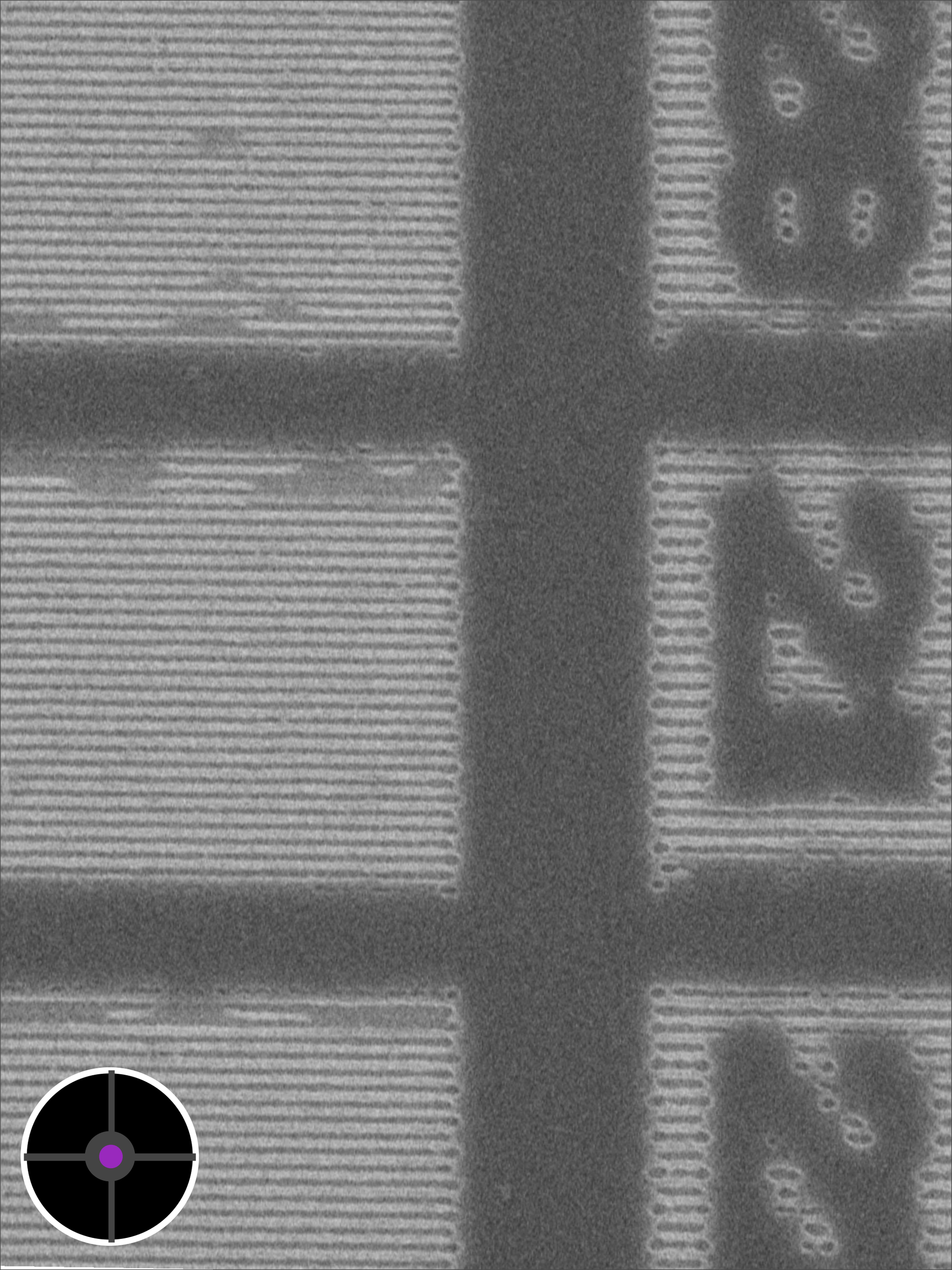
Pupil


Mask
Pupil


Mask
Pupil

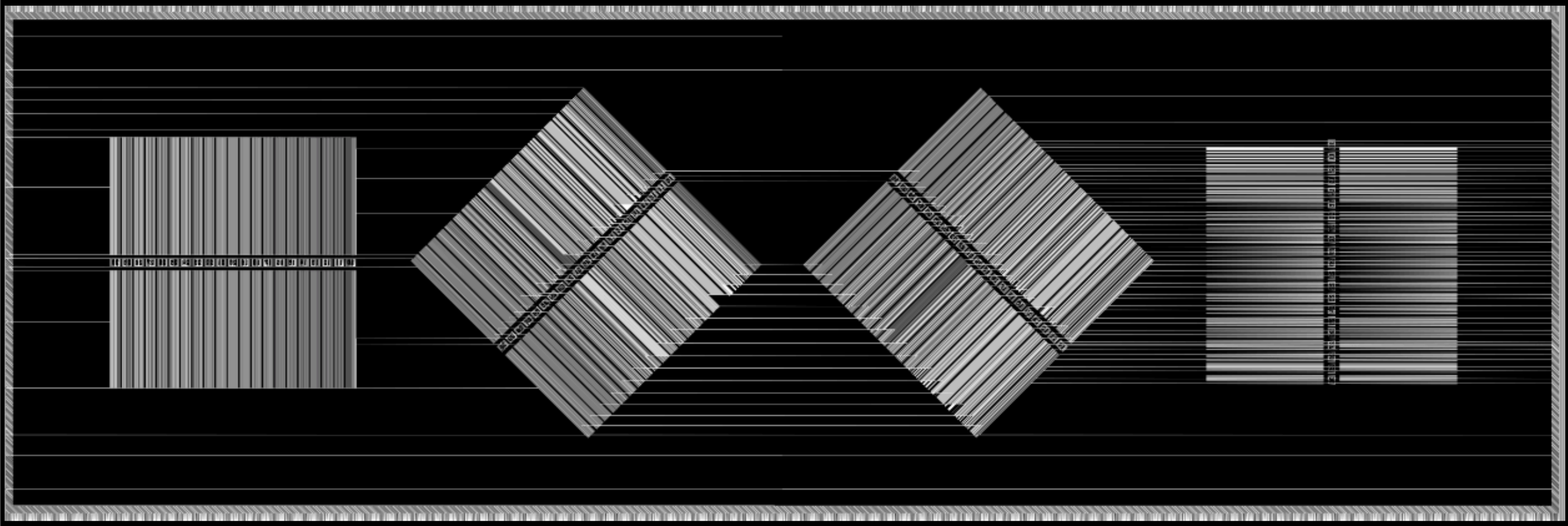

Mask
Pupil
Image





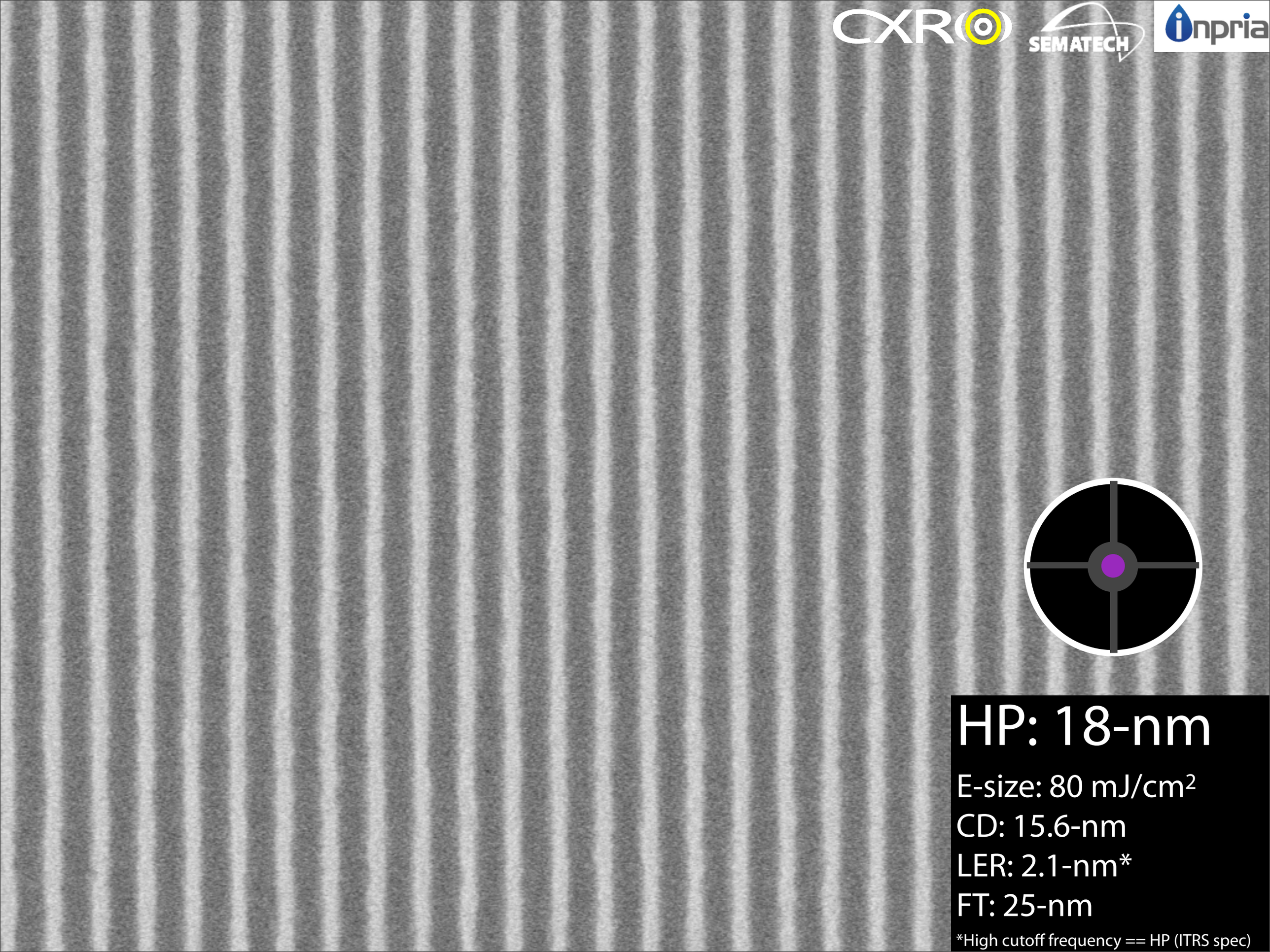
Pseudo PSM subfield

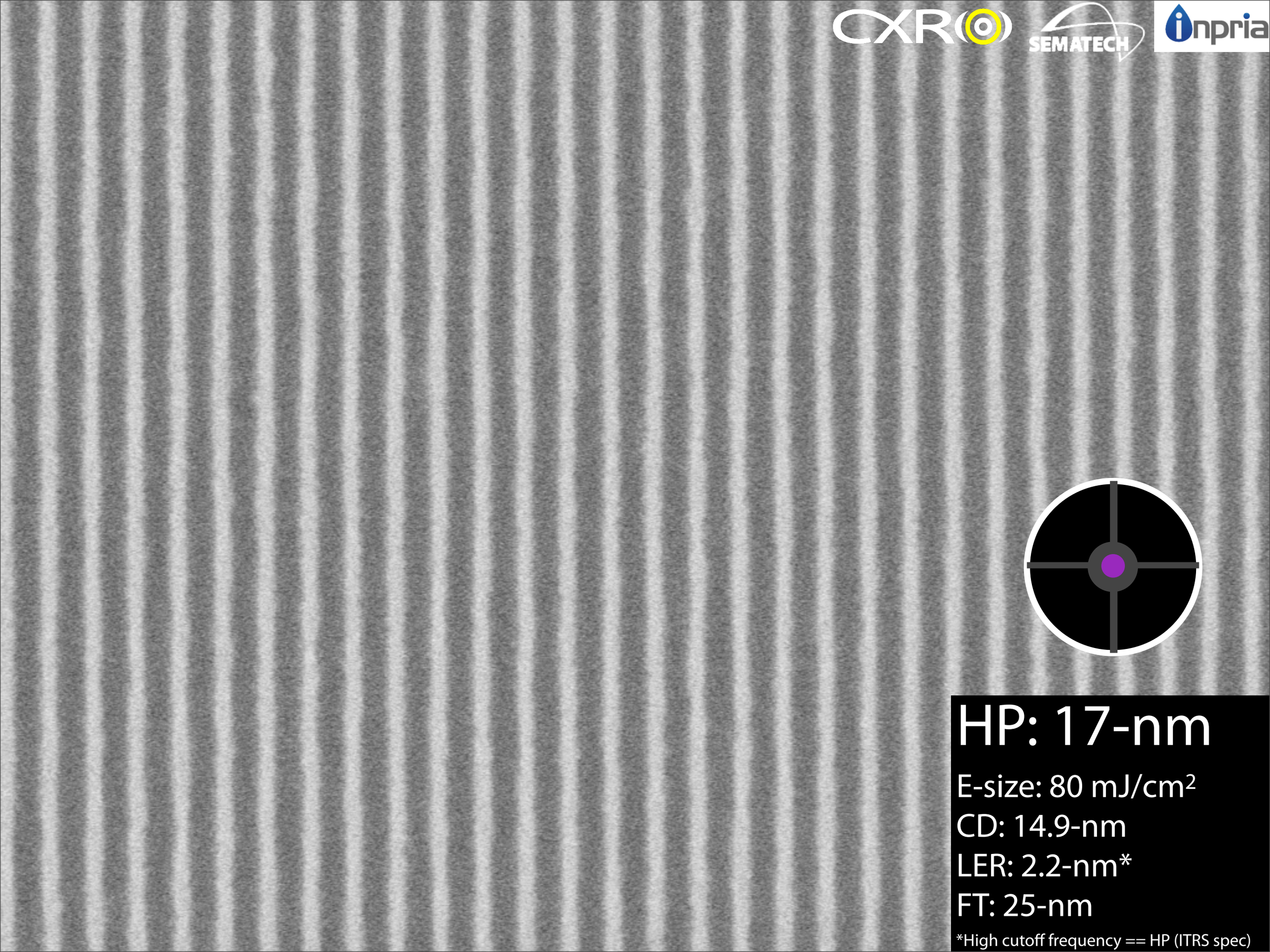
0, 90, +45, -45 orientations. 30-nm HP to 10-nm HP

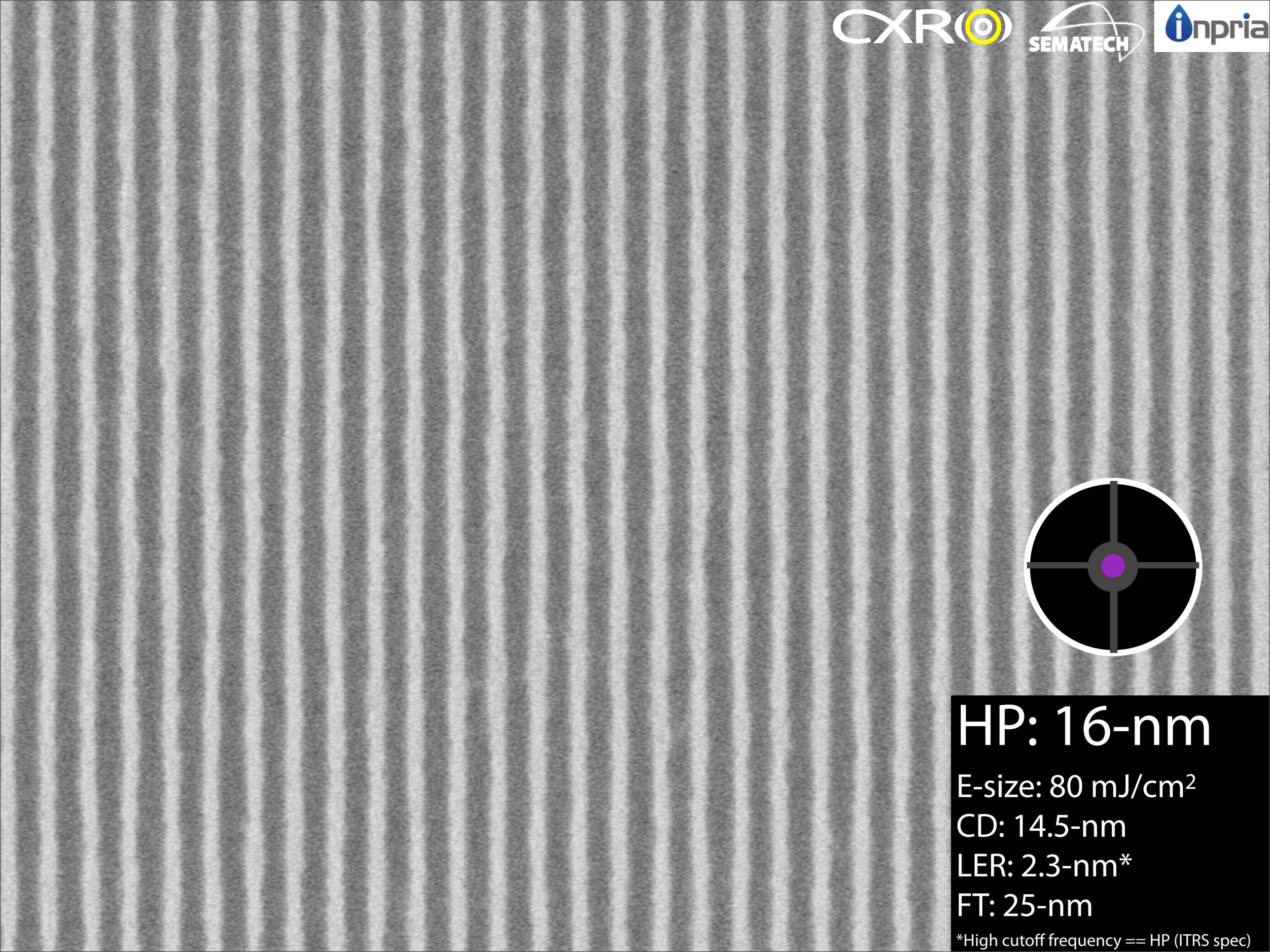


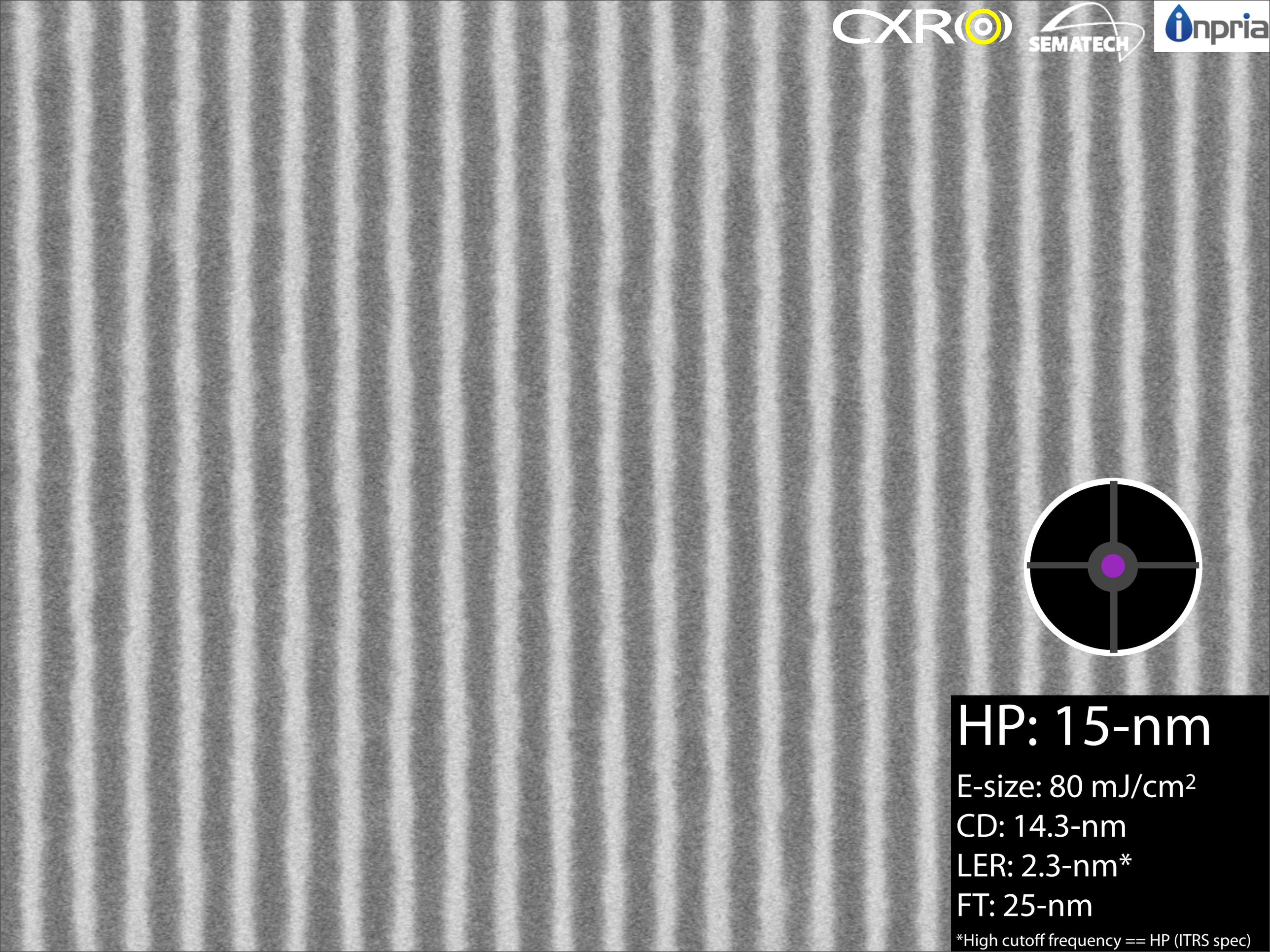
Sept. + Oct. 2011: 19 resists

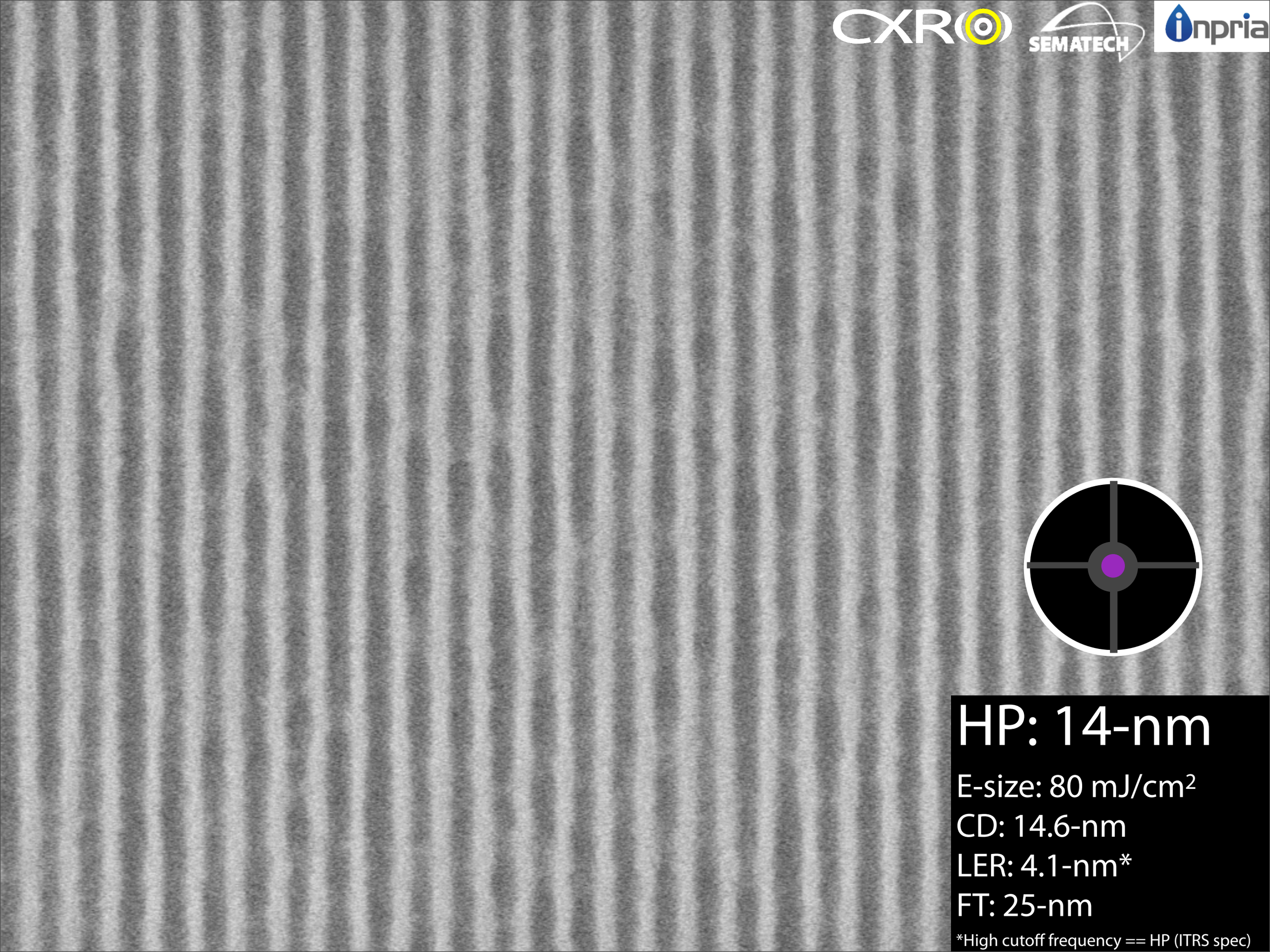
Demonstration of aerial image down to 13-nm HP

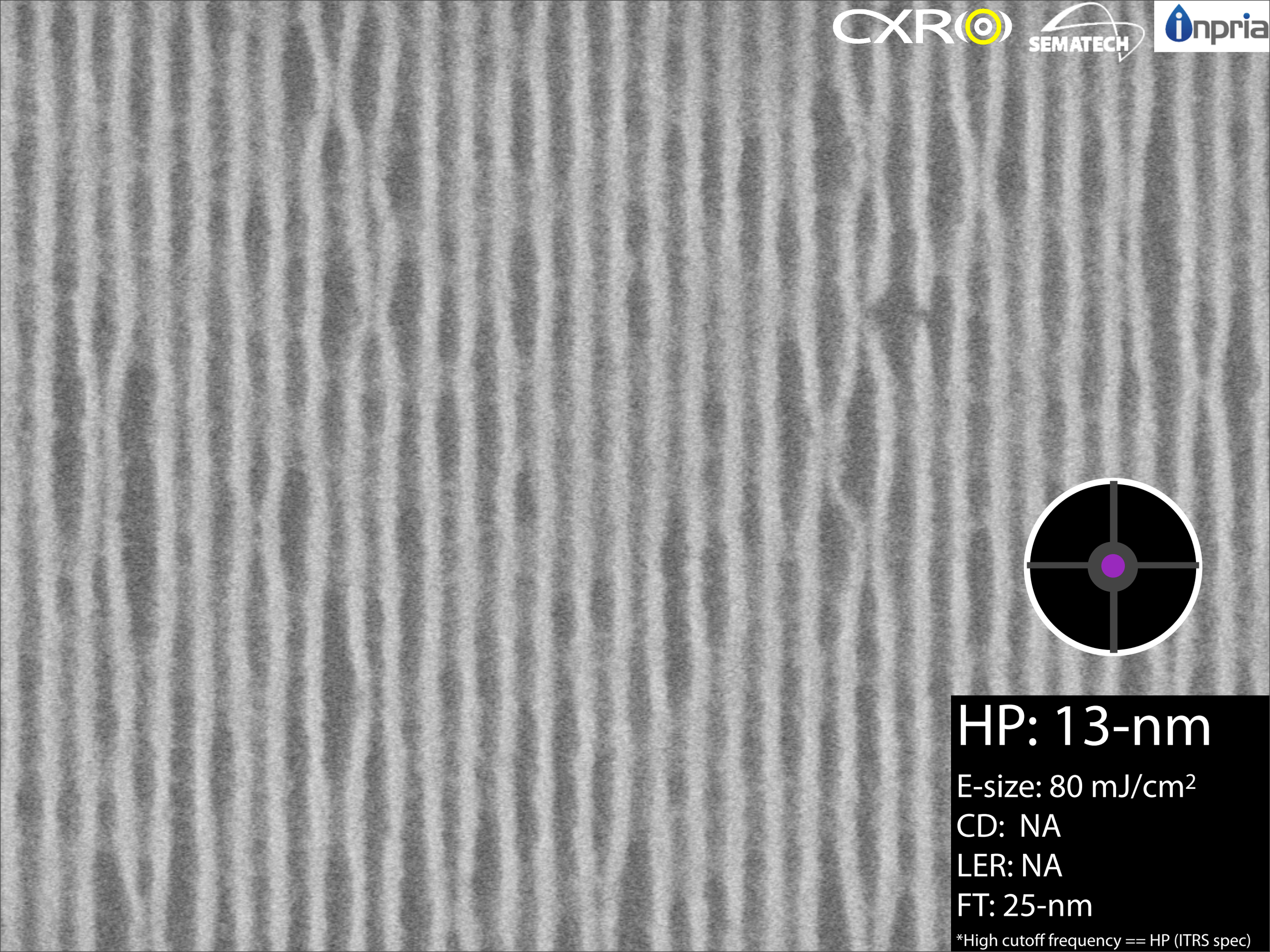

HP: 18-nm
E-size: 80 mJ/cm2
CD: 15.6-nm
LER: 2.1-nm*
FT: 25-nm
*High cutoff frequency == HP (ITRS spec)

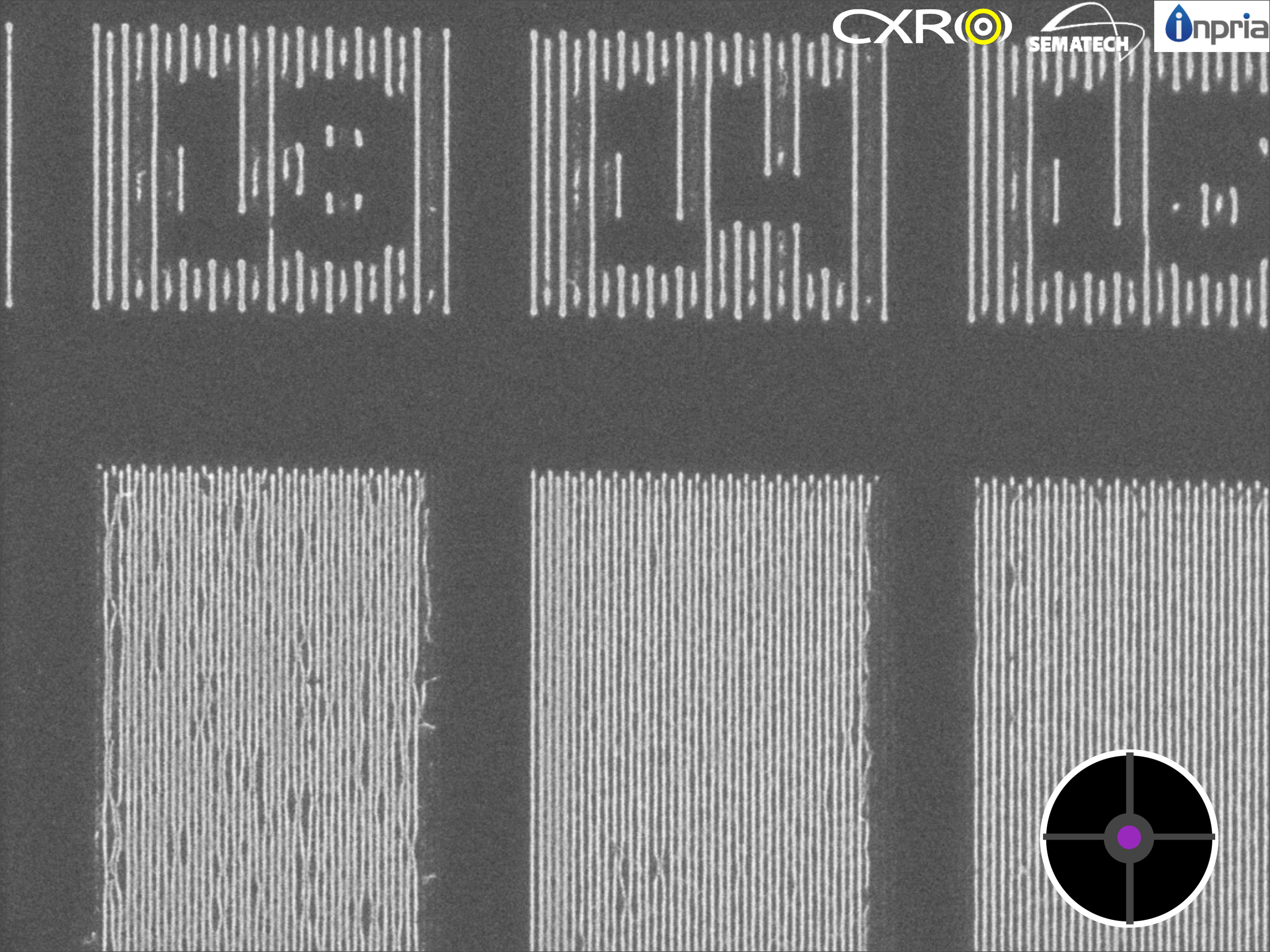

HP: 17-nm
E-size: 80 mJ/cm²
CD: 14.9-nm
LER: 2.2-nm*
FT: 25-nm
*High cutoff frequency == HP (ITRS spec)


HP: 16-nm
E-size: 80 mJ/cm2
CD: 14.5-nm
LER: 2.3-nm*
FT: 25-nm
*High cutoff frequency == HP (ITRS spec)


HP: 15-nm
E-size: 80 mJ/cm2
CD: 14.3-nm
LER: 2.3-nm*
FT: 25-nm
*High cutoff frequency == HP (ITRS spec)


HP: 14-nm
E-size: 80 mJ/cm²
CD: 14.6-nm
LER: 4.1-nm*
FT: 25-nm
*High cutoff frequency == HP (ITRS spec)


HP: 13-nm
E-size: 80 mJ/cm2
CD: NA
LER: NA
FT: 25-nm
*High cutoff frequency == HP (ITRS spec)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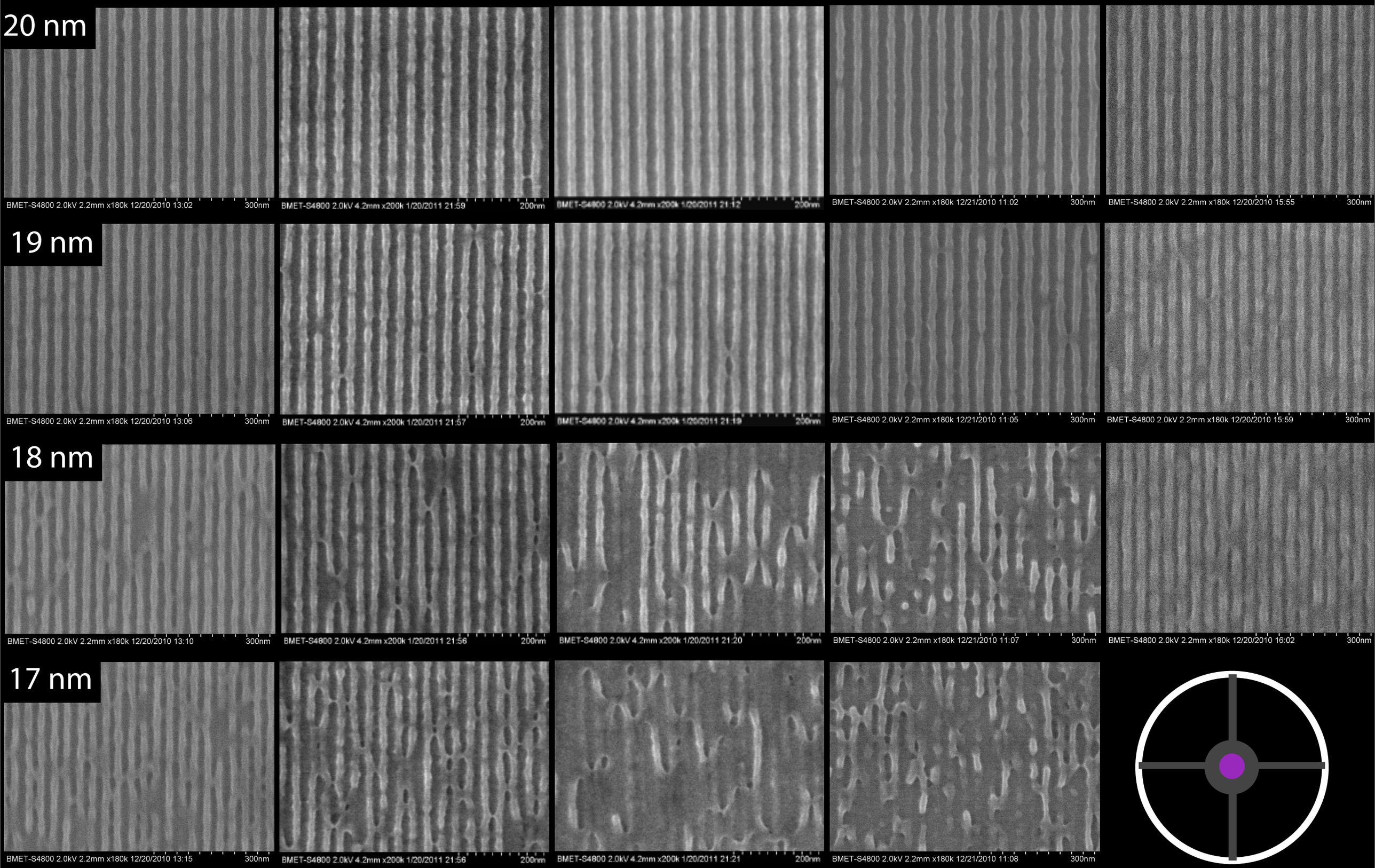
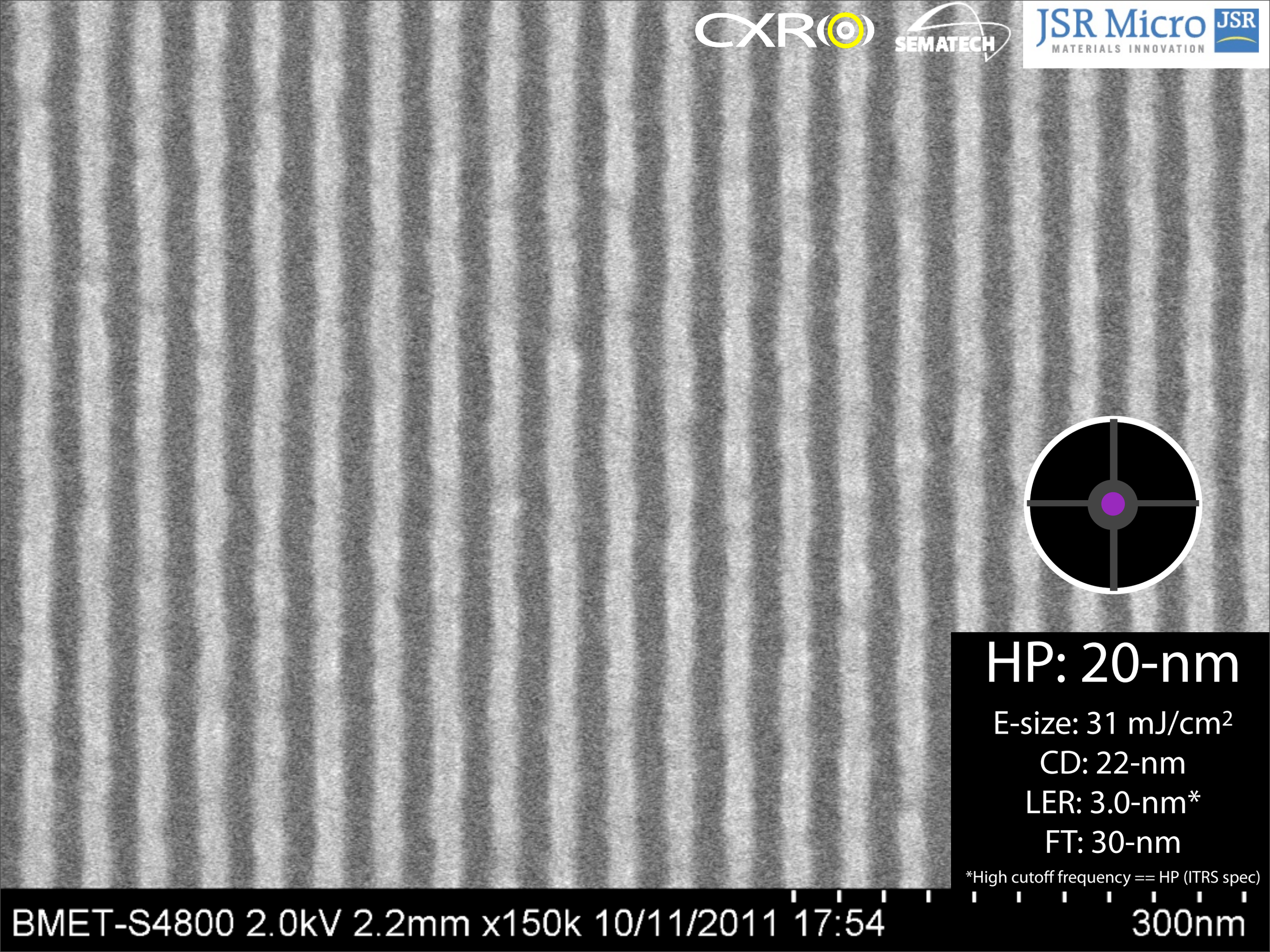
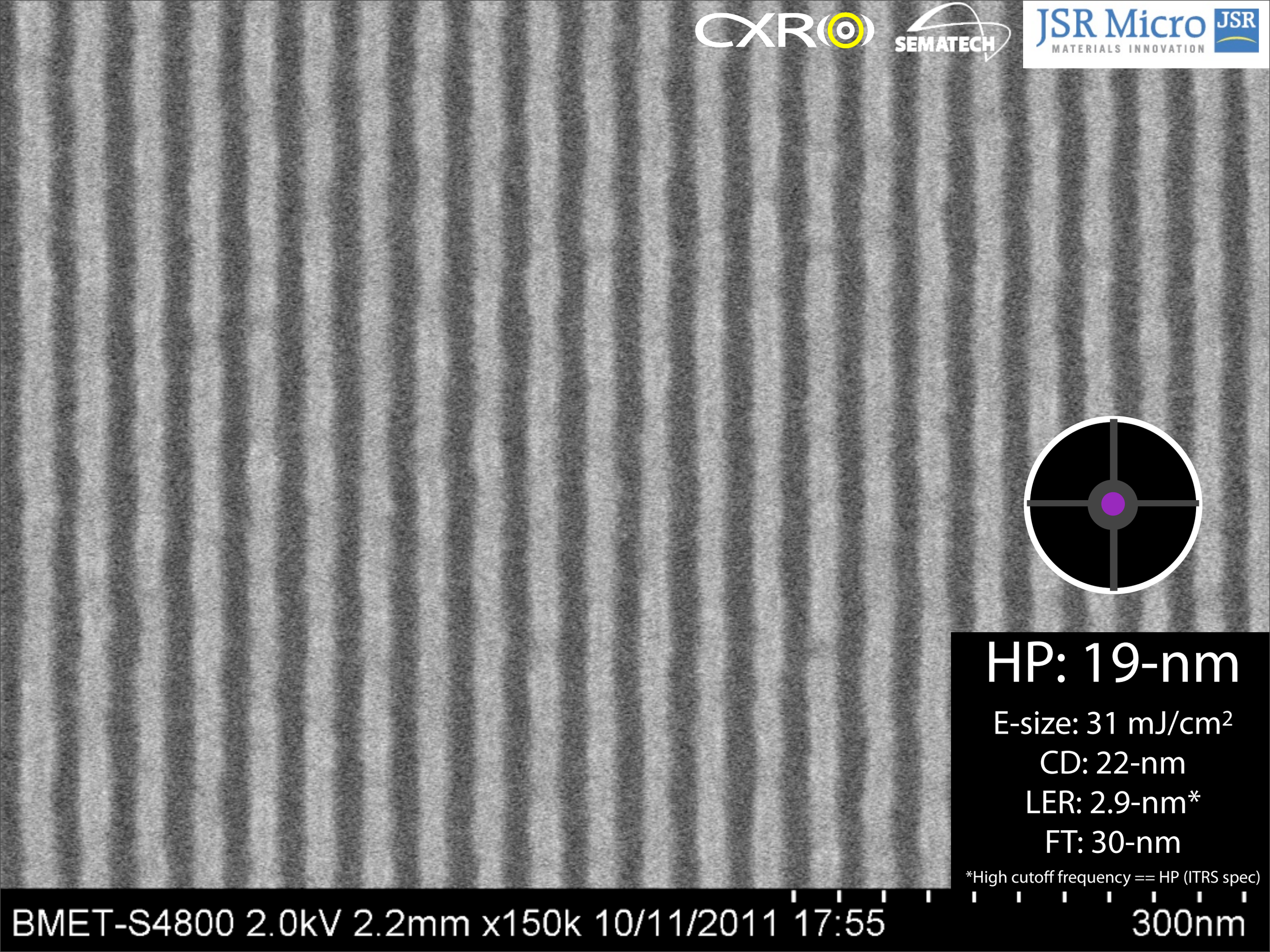
Screening previous champions

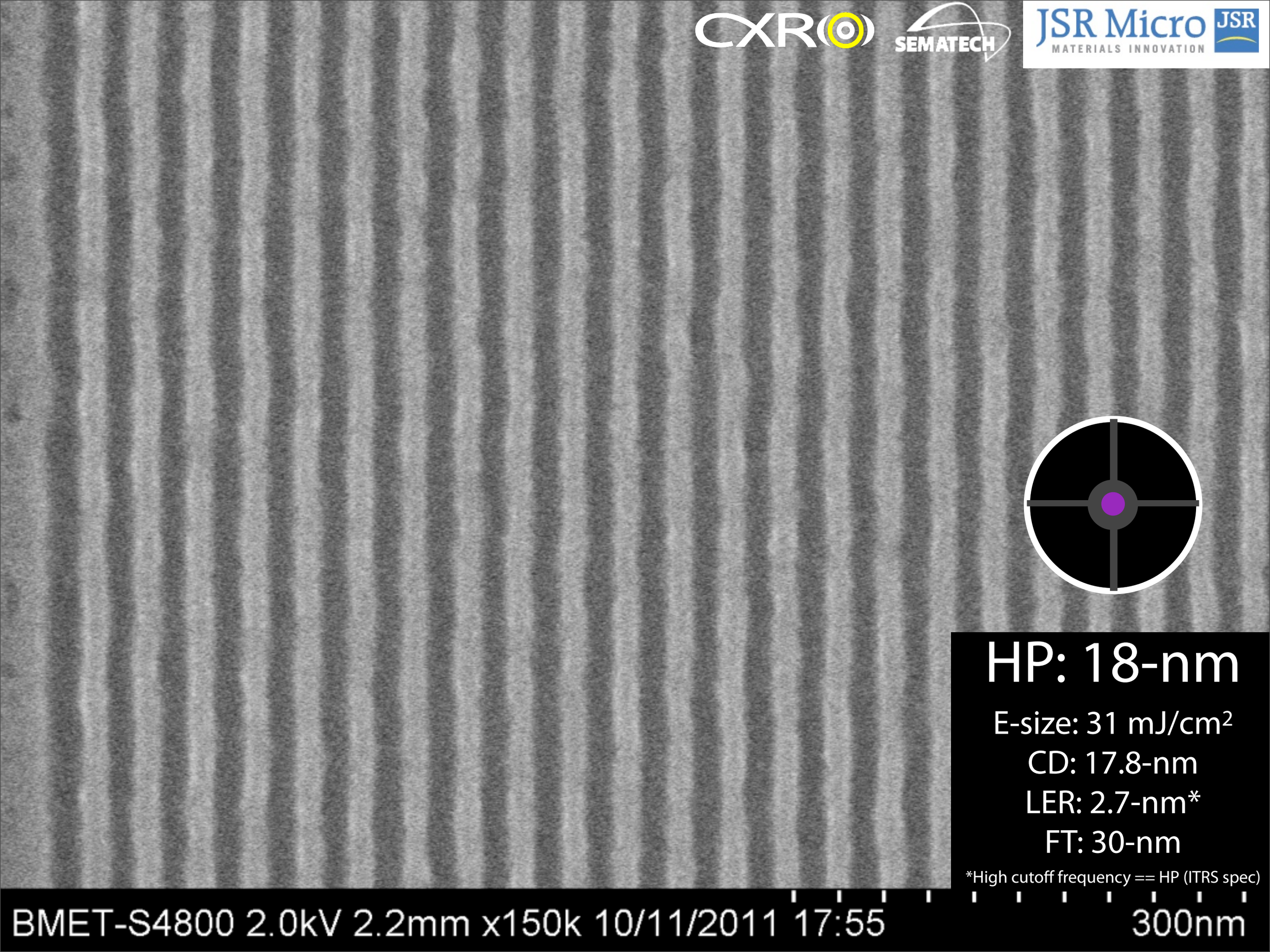
BBR-2008A 16 mJ, 45FT	JSR EUVJ-684 13 mJ, 40FT	Resist 2010A 20 mJ, 40FT	Resist 2010B 13 mJ, 45FT	Resist 2010C 12 mJ, 45FT
20 nm				
19 nm				
18 nm				
17 nm				

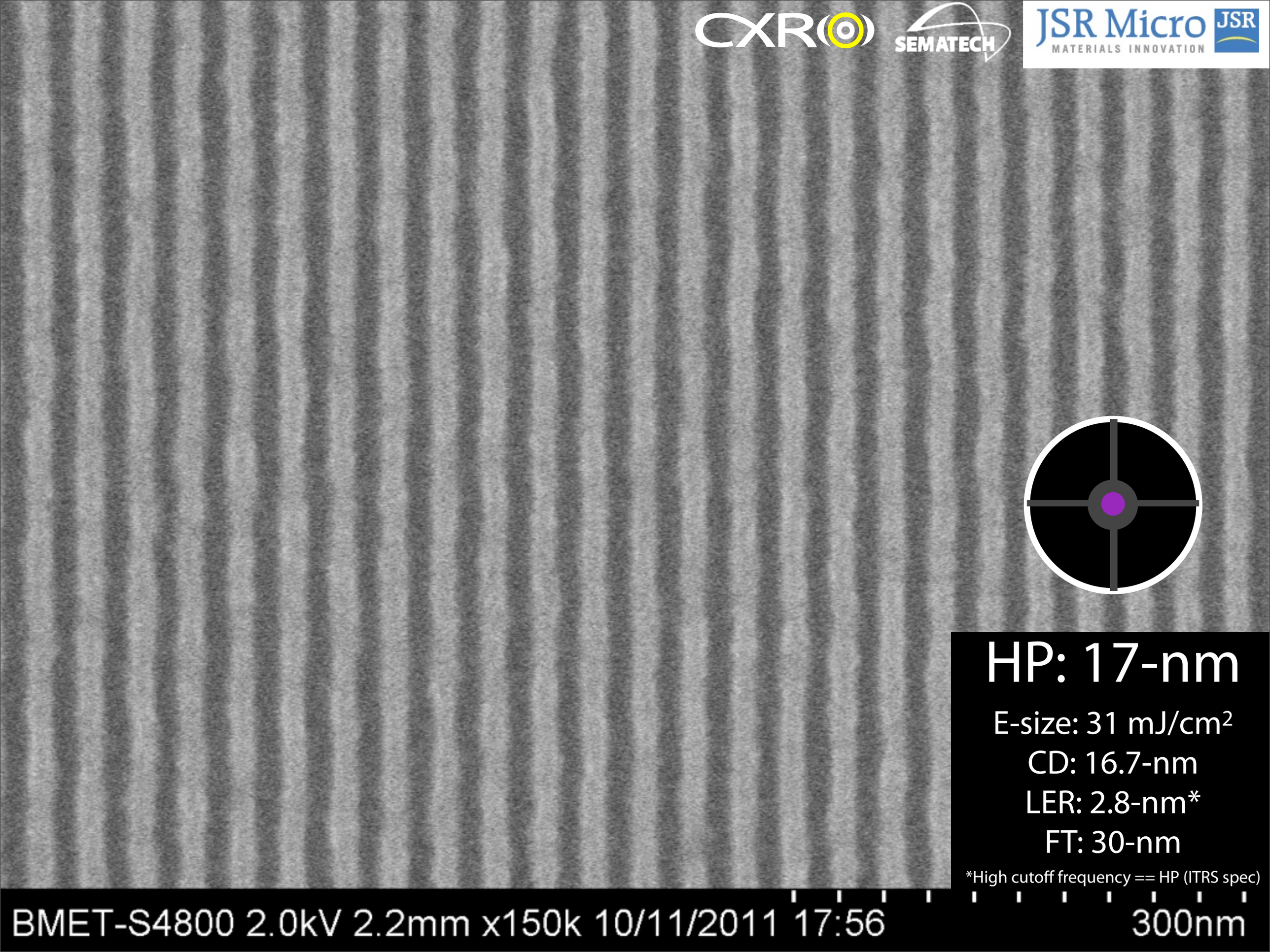


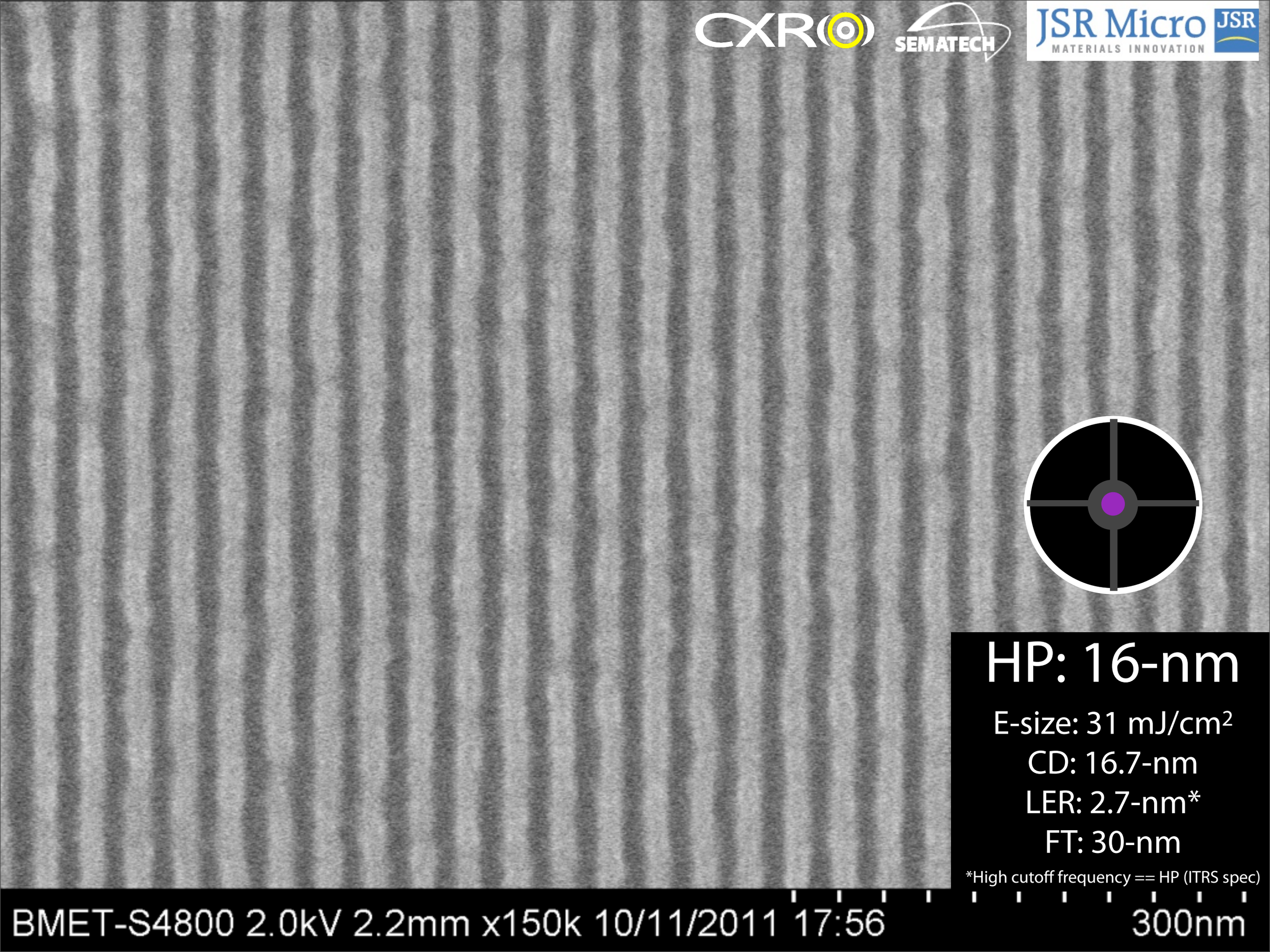
All resists on HMDS-Si. FT = film thickness in nm.

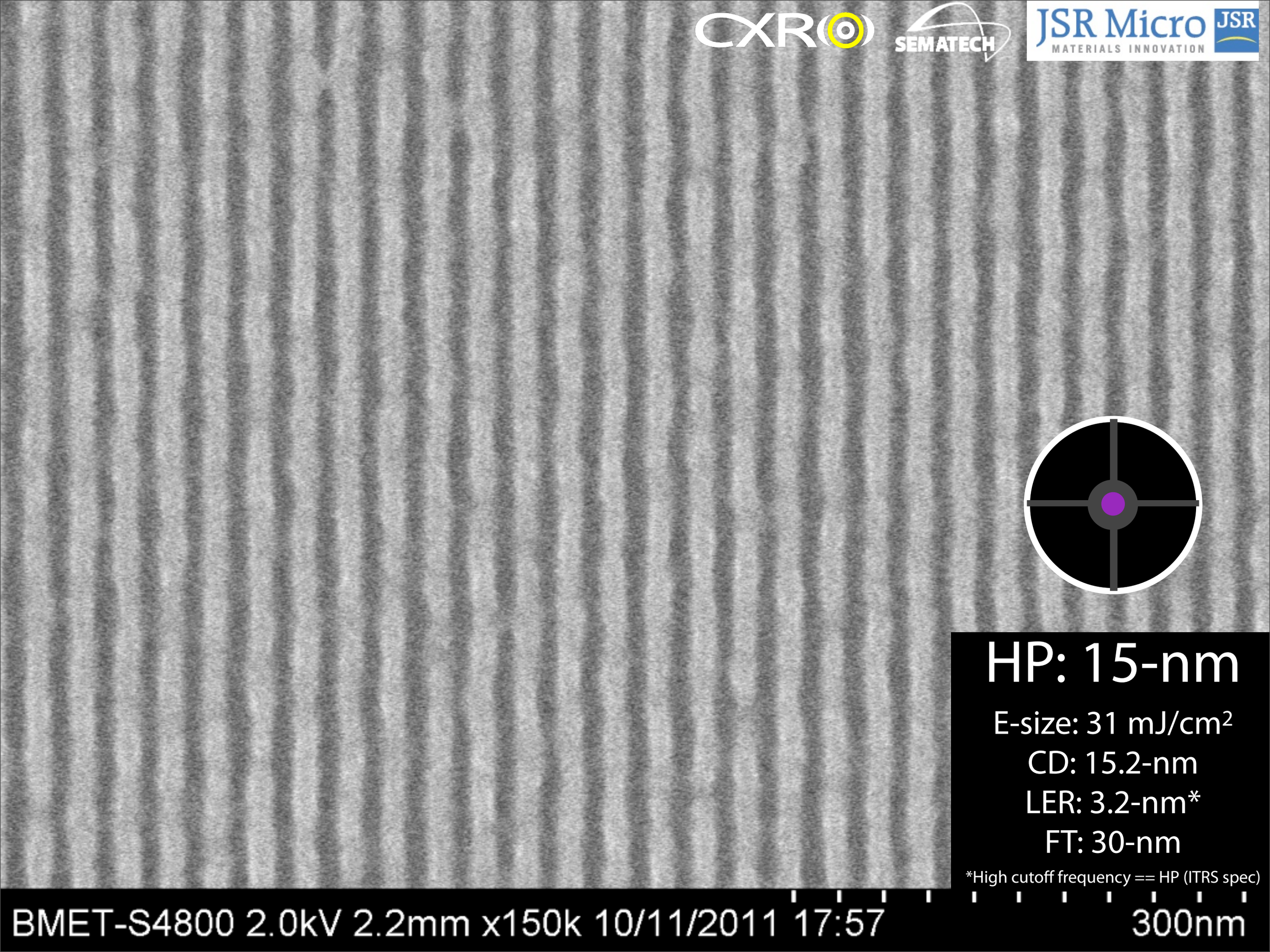

CXRO
SEMATECH
JSR Micro
MATERIALS INNOVATION
JSR
HP: 20-nm
E-size: 31 mJ/cm2
CD: 22-nm
LER: 3.0-nm*
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:54
300nm


CXRO
SEMATECH
JSR Micro
MATERIALS INNOVATION
JSR
HP: 19-nm
E-size: 31 mJ/cm2
CD: 22-nm
LER: 2.9-nm*
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:55
300nm


CXRO
SEMATECH
JSR Micro
MATERIALS INNOVATION
JSR
HP: 18-nm
E-size: 31 mJ/cm2
CD: 17.8-nm
LER: 2.7-nm*
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:55
300nm


CXRO
SEMATECH
JSR Micro
MATERIALS INNOVATION
JSR
HP: 17-nm
E-size: 31 mJ/cm2
CD: 16.7-nm
LER: 2.8-nm*
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:56
300nm


CXRO
SEMATECH
JSR Micro
MATERIALS INNOVATION
JSR
HP: 16-nm
E-size: 31 mJ/cm2
CD: 16.7-nm
LER: 2.7-nm*
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:56
300nm


CXRO
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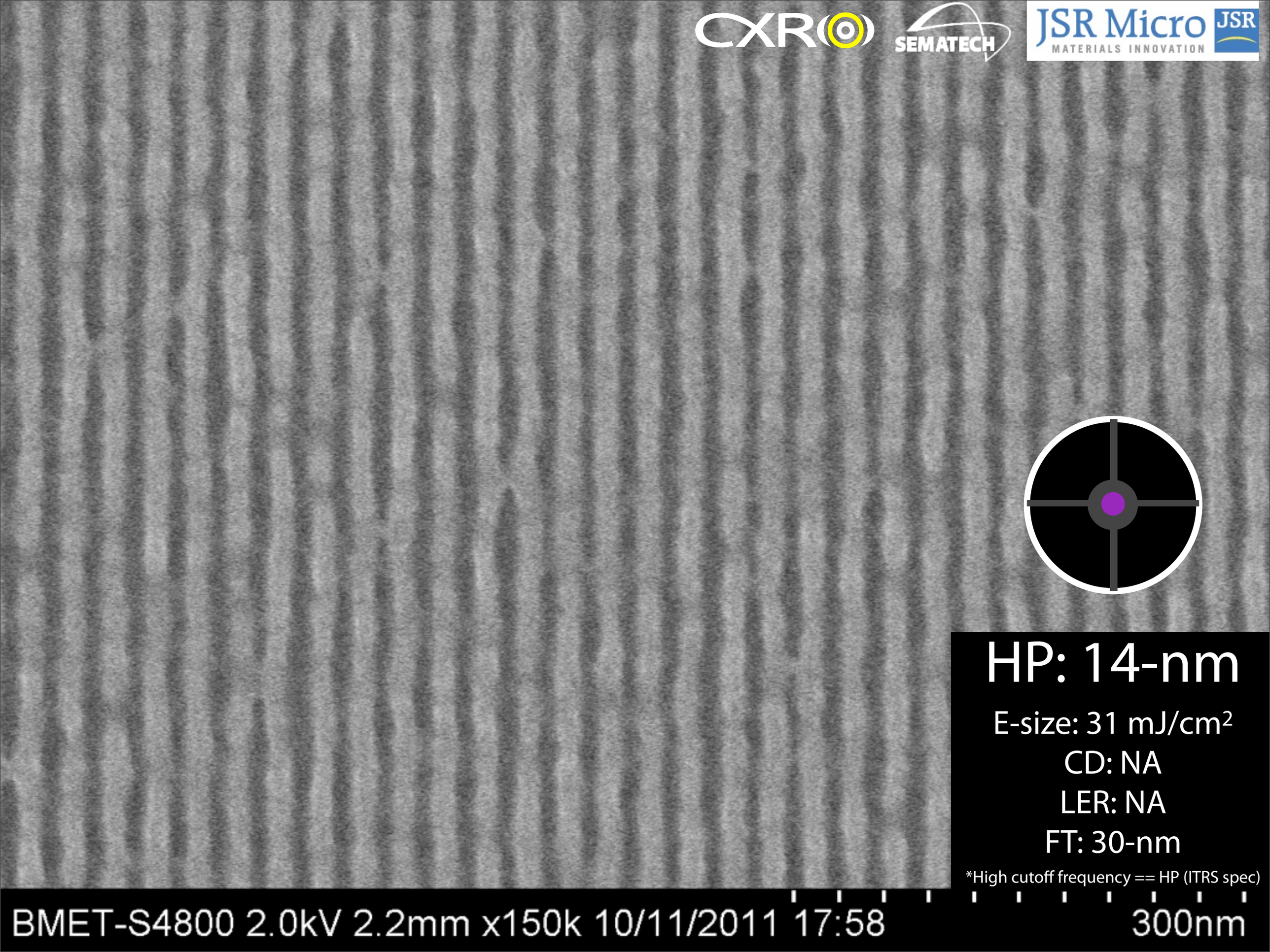
JSR Micro
MATERIALS INNOVATION
JSR
HP: 15-nm
E-size: 31 mJ/cm²
CD: 15.2-nm
LER: 3.2-nm*
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:57
300nm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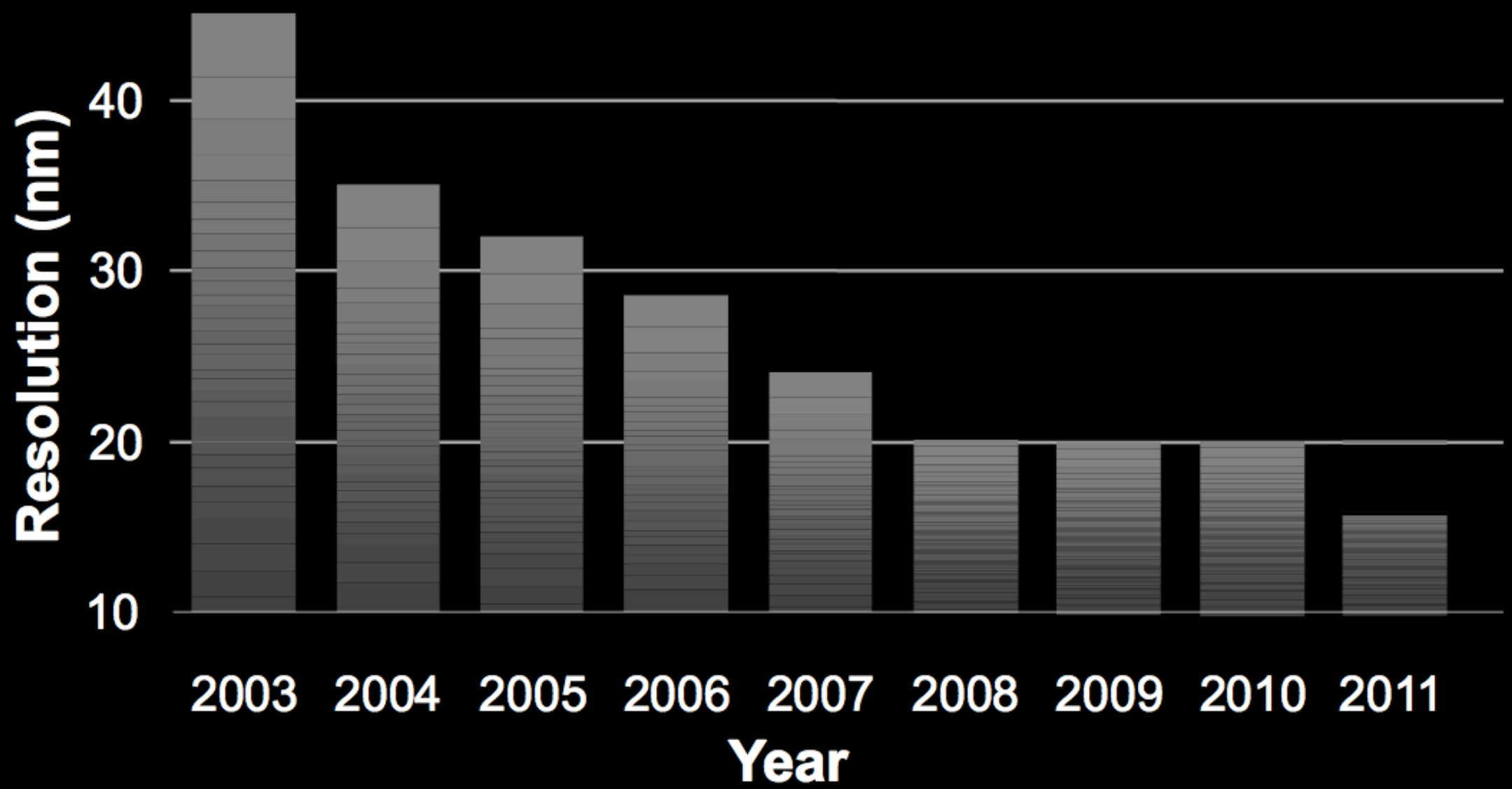
MATERIALS INNOVATION
JSR
HP: 14-nm
E-size: 31 mJ/cm²
CD: NA
LER: NA
FT: 30-nm
*High cutoff frequency == HP (ITRS spec)
BMET-S4800 2.0kV 2.2mm x150k 10/11/2011 17:58
300nm

Naulleau, et. al. SPIE 2010

Progress stalled in CA resist resolution



Summary

6.x-nm lighography

EUV resists 5X-6X slower @6-nm

OOB

In-vacuum OOB exposure added to MET Q3 2011

New contrast curve capability Q4 2011

Pseudo PSM technique delivering 12-nm aerial image now available to all BMET users

19-nm HP @ 16 mJ

15-nm HP @ 31 mJ

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