Berkeley MET5 reticle preliminary information

Designed by CXRO

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4. Minimum feature size as “nice to have”
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Extra: field descriptions

1. Name of mask

BMET5-R1

2. Purpose of mask

Imaging on Berkeley MET5

3. Target features / primary features

TBD

4. Minimum feature size ("nice to have")

40 nm CD dense

All fields have features >= 40 nm @ reticle with one exception: the contact bias field; it has features down to 22.5 nm @ reticle.

Field	@wafer (nm)	@mask (nm)	Notes
SE Contact bias split 1:1	12	60	12@0 bias (12/12); 14@-2 bias (12/16); 16@-4bias (12/20); 18@-6bias (12/24)
F2X / F2X Cleave / Contacts	12	60	6 nm lines @ 2X
Contact Bias	4.5	22.5	6 nm contact @ -25% bias
SE H/V Bias Split	8	40	8@0bias (8/8); 10@-2bias (8/12); 12@-4bias (8/16); 14@-6bias (8/20) 16@-8bias (8/24)
SE Cleave L/S	8	40	8/8
SE Line End And Distortion	8	40	8/8

5. Estimated pattern density

0.001 or 0.1% === (2.5e-5 + 5.18e-6)/0.0232

Calculation

Field area

- 19 x 19 fields
- Field size: 1e-3*150e-6.
- User over-estimate of 50% write cycle (it will be less)
- Total area:19*19*1e-3*150e-6*0.5 = 2.7e-5 m^2 written

Fiducials

- 8 elbows per line, 12 lines per fiducial, 2 fiducials on mask
- Each elbow is roughly 100e-6 x 270e-6
- They are 50% write cycle
- Total: 8*12*2*100e-6*270e-6 = 5.18e-6 m^2 written

Mask area = 0.0232 m^2 (6” x 6”)

6. Layout

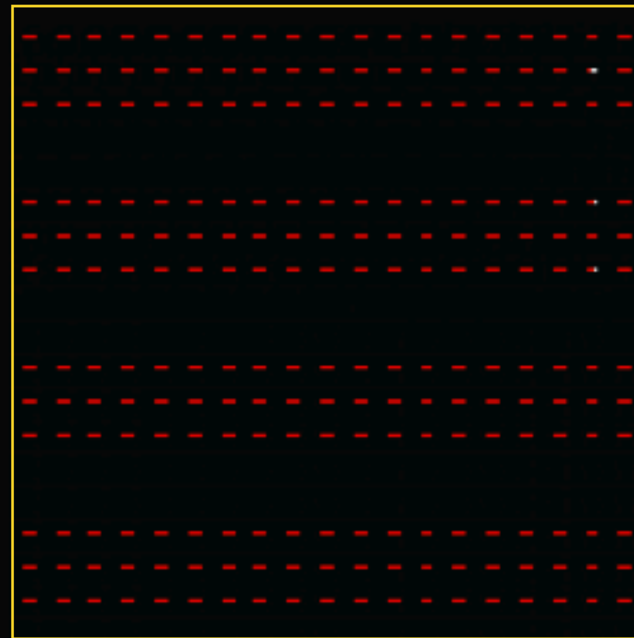
See next few slides

6” mask

Black is absorber. Mask is > 99.9% absorber

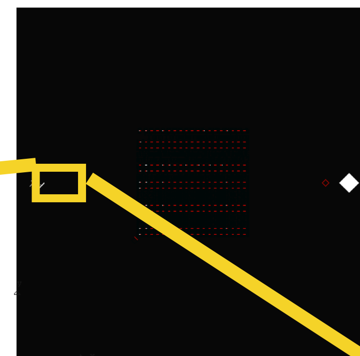
19 x 19 field grid

Fiducial



Fiducial

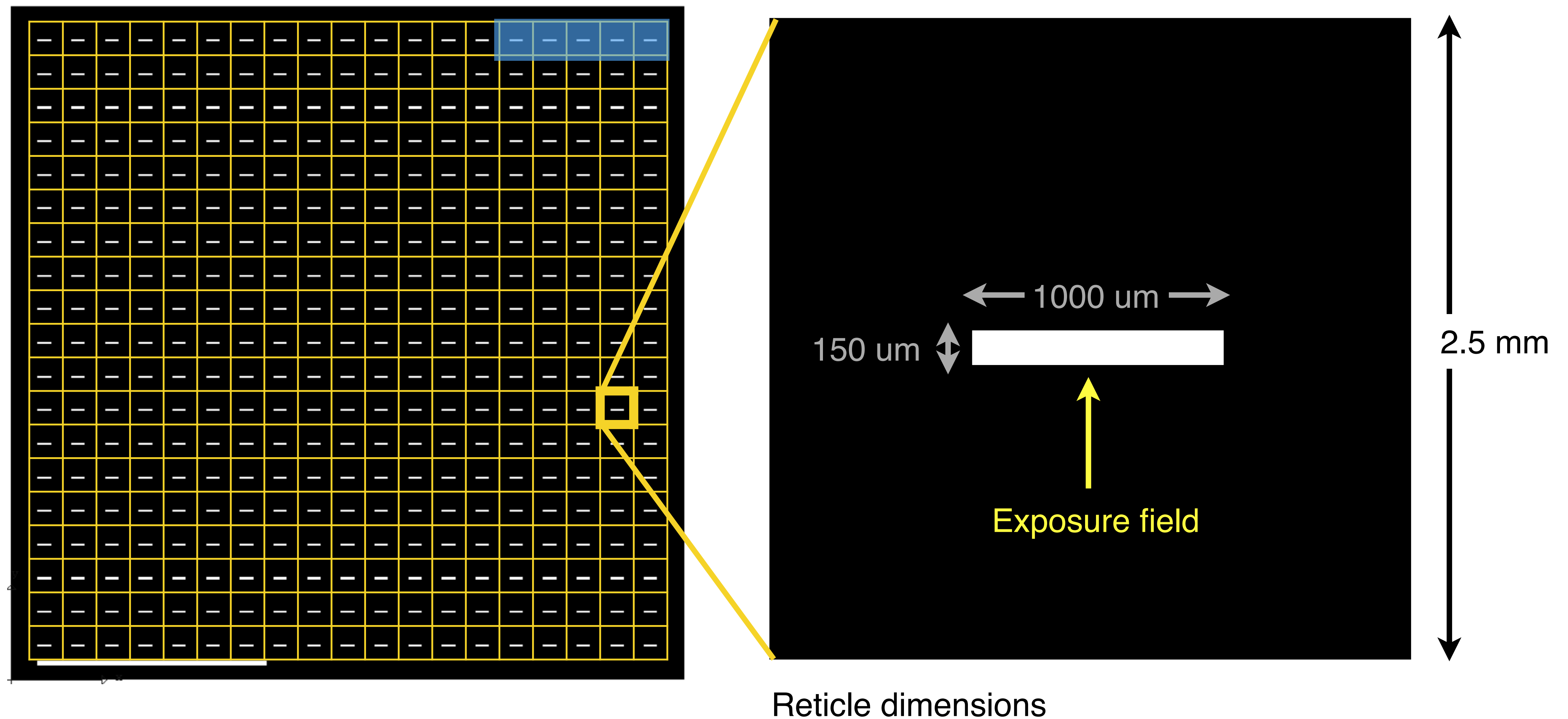
Zoom-in on fiducial



Chevron patterns on a grating carrier

Field grid: 19 x 19. Reticle dimensions shown

Mask supplier is allocated five 1000 um x 150 um (@reticle) fields, located at row 1, col 15 - col 19 of our field grid for internal use. CXRO agrees to print these fields with MET5, if requested.



Reticle dimensions

Field assignment

Bright field | Dark field

Column

Row

<table>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th></tr>
<tr><td>1</td><td colspan="10">Pupil Fill Monitor</td><td colspan="4">Clear</td><td colspan="5">Clear (mask supplier can use these)</td></tr>
<tr><td>2</td><td colspan="5">Illumination Monitor</td><td colspan="5">Illumination Monitor On Grating</td><td colspan="5">SE Line Space Bias BF</td><td colspan="4">SE Line Space Bias DF</td></tr>
<tr><td>3</td><td colspan="5">SE Line Space Cleave BF</td><td colspan="5">SE Line Space Cleave DF</td><td colspan="5">SE Line End And Distortion BF</td><td colspan="4">SE Line End And Distortion DF</td></tr>
<tr><td>4</td><td colspan="5">SE Contact Bias Split BF</td><td colspan="5">SE Contact Bias Split DF</td><td colspan="5">Contact Bias BF</td><td colspan="4">Contact Bias DF</td></tr>
<tr><td>5</td><td colspan="10">SE Contact Cleave 1:6 BF</td><td colspan="9">SE Contact Cleave 1:6 DF</td></tr>
<tr><td>6</td><td colspan="6">F2X</td><td colspan="6">F2X Cleave</td><td colspan="7">F2X Contact</td></tr>
<tr><td>7</td><td colspan="4">Aberration Monitor BF</td><td colspan="4">Aberration Monitor DF</td><td colspan="4">Aberration Monitor LBF</td><td colspan="4">F2X Aberration Monitor</td><td colspan="3">Zoneplate DF</td></tr>
<tr><td>8</td><td colspan="10">SE Contact Cleave 1:1 BF</td><td colspan="9">SE Contact Cleave 1:1 D</td></tr>
<tr><td>9</td><td colspan="19" rowspan="11">Interferometry Fields</td></tr>
<tr><td>10</td></tr>
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<tr><td>18</td></tr>
<tr><td>19</td></tr>
</table>

Layout continued …

See slides at the end for overview of some of the fields

7. Magnification

The GDS is in reticle coordinates. Print as-is. The litho tool has a magnification of 1/5, so features that are 100 nm in the GDS (reticle), for example, print at 20 nm at the wafer.

8. Absorber thickness preference

EUV process of record

9. GDS

Location
http://cxro.lbl.gov/wshare/cnanderson/BMET5-R1.gds

Size
873 Mb

What is absorber?
Layer 0
Layer 2 - Layer 1

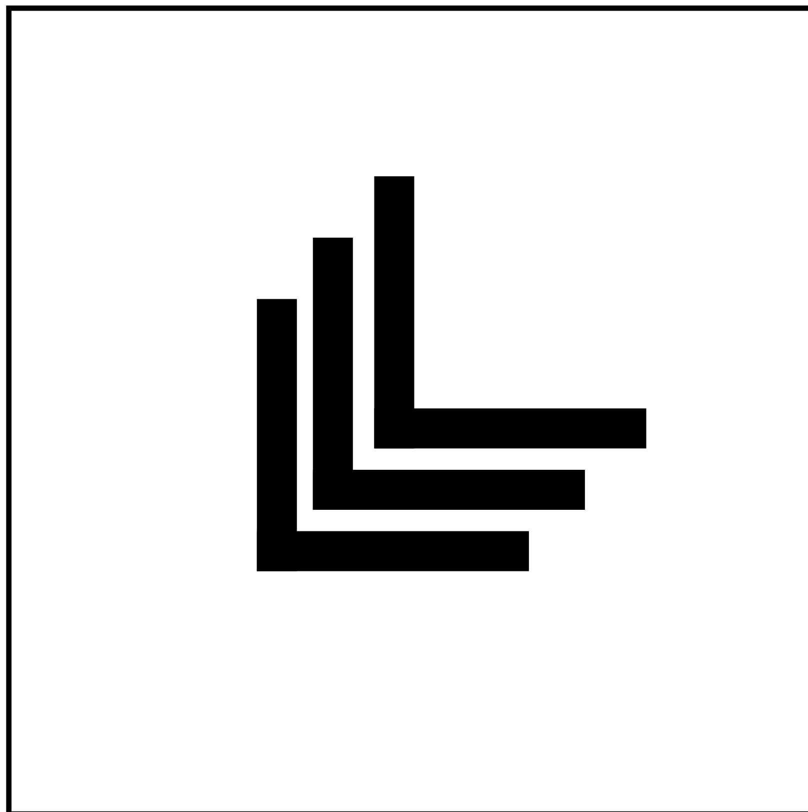
Library criteria
Units: um
Resolution: 10000

10. Delivery target

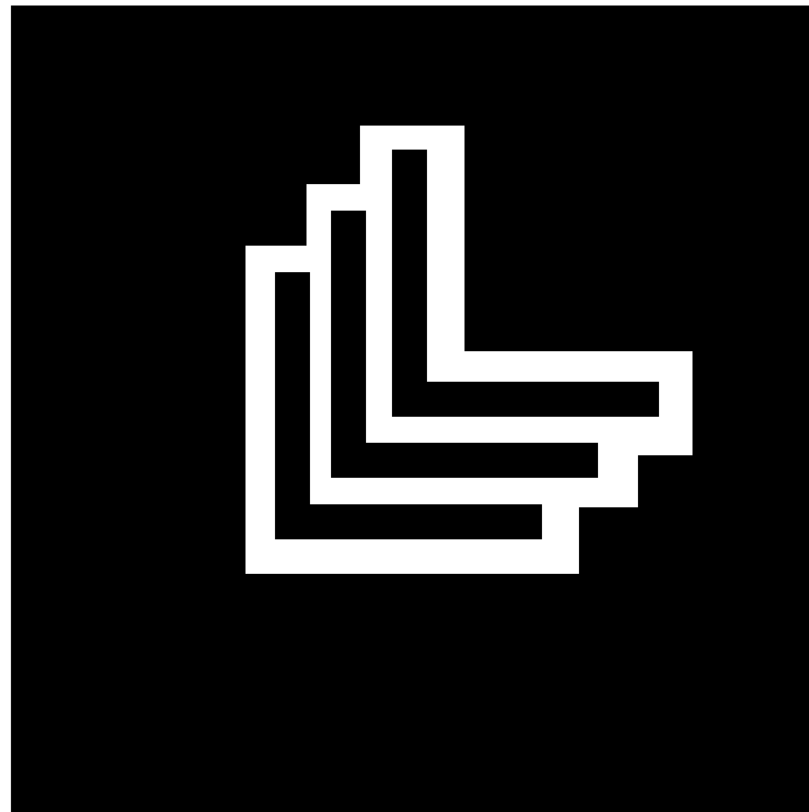
Dec 15, 2014

Field types

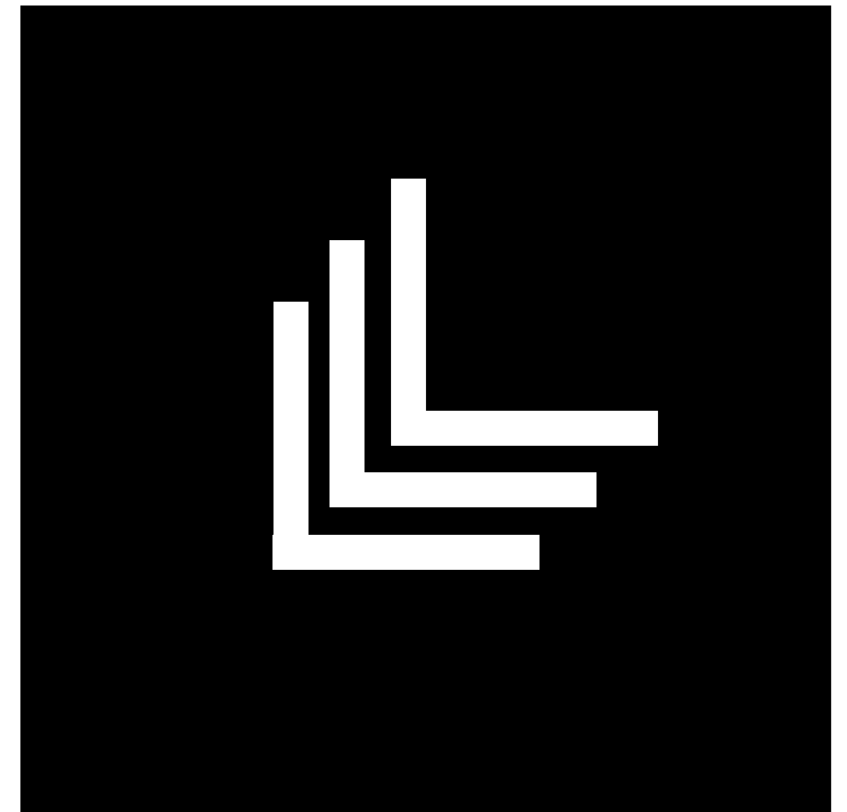
white = reflective
black = absorber



bright field
(BF)



local bright field
(LBF)



dark field
(DF)

Field of view: 200 um x 30 um (@ wafer)

MET5 field (red, 200 um x 30 um) compared to the MET3 field (yellow, 600 um x 200 um). It is 5% of the area.

Field descriptions

- All dimensions shown are at the wafer
- Use 5X larger for mask
- These are high-level summaries/ overviews of each field. Detailed PDFs of each field can be downloaded just below the link you clicked to open this document.

Pupil fill monitor

15 um x 15 um clear field

Clear

200 um x 30 um bright field

Illumination monitor

3 x 20 grid of 10 um x 10 um cells with

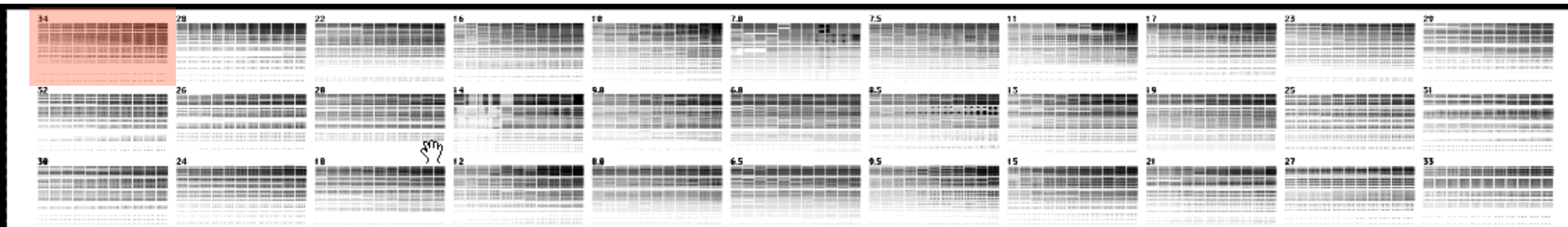
-100 -10	-90 -10	-80 -10	-70 -10	-60 -10	-50 -10	-40 -10	-30 -10	-20 -10	-10 -10	0 -10	10 -10	20 -10	30 -10	40 -10	50 -10	60 -10	70 -10	80 -10	90 -10
-100 0	-90 0	-80 0	-70 0	-60 0	-50 0	-40 0	-30 0	-20 0	-10 0	0 0	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0
-100 10	-90 10	-80 10	-70 10	-60 10	-50 10	-40 10	-30 10	-20 10	-10 10	0 10	10 10	20 10	30 10	40 10	50 10	60 10	70 10	80 10	90 10

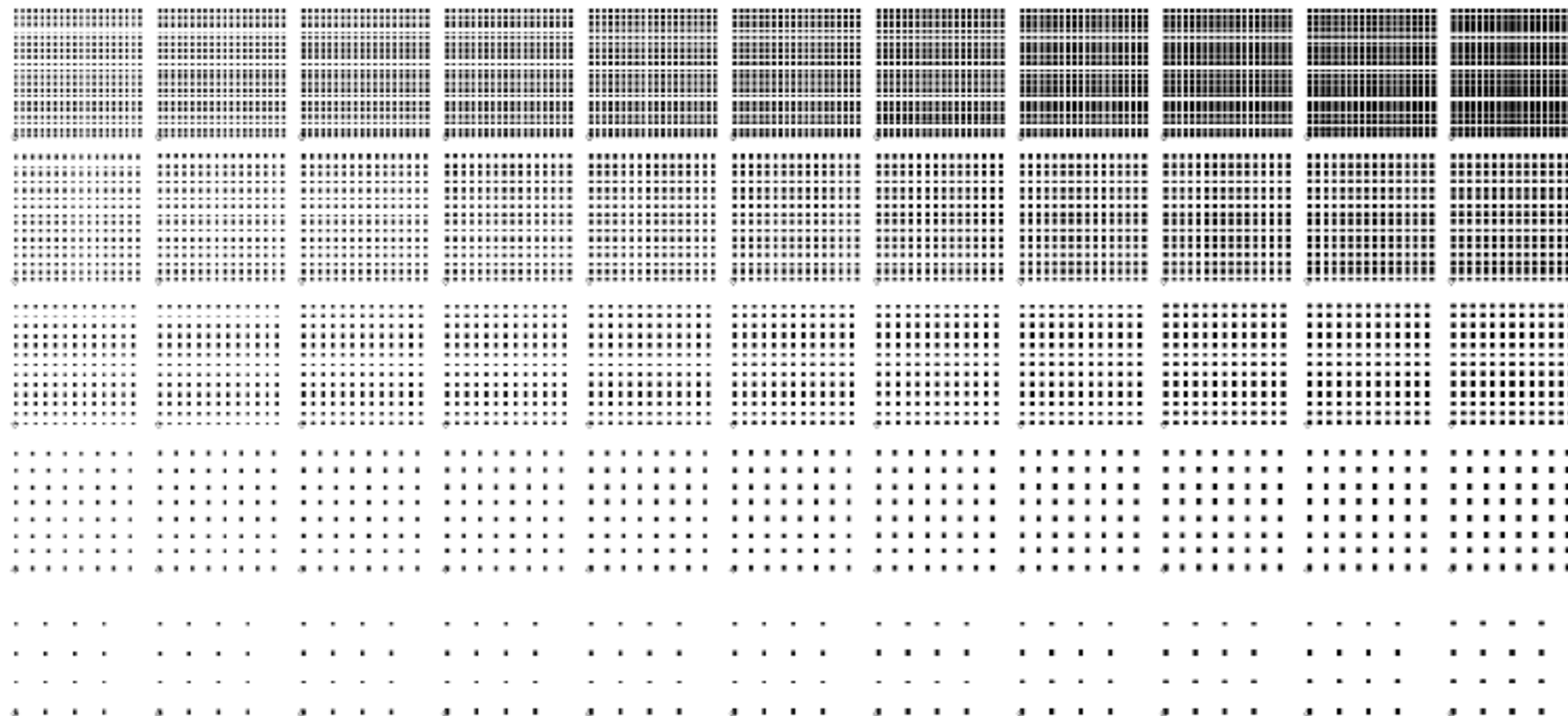
Illumination monitor on grating

Illumination monitor on 40 nm 1:1 grating

Contact bias

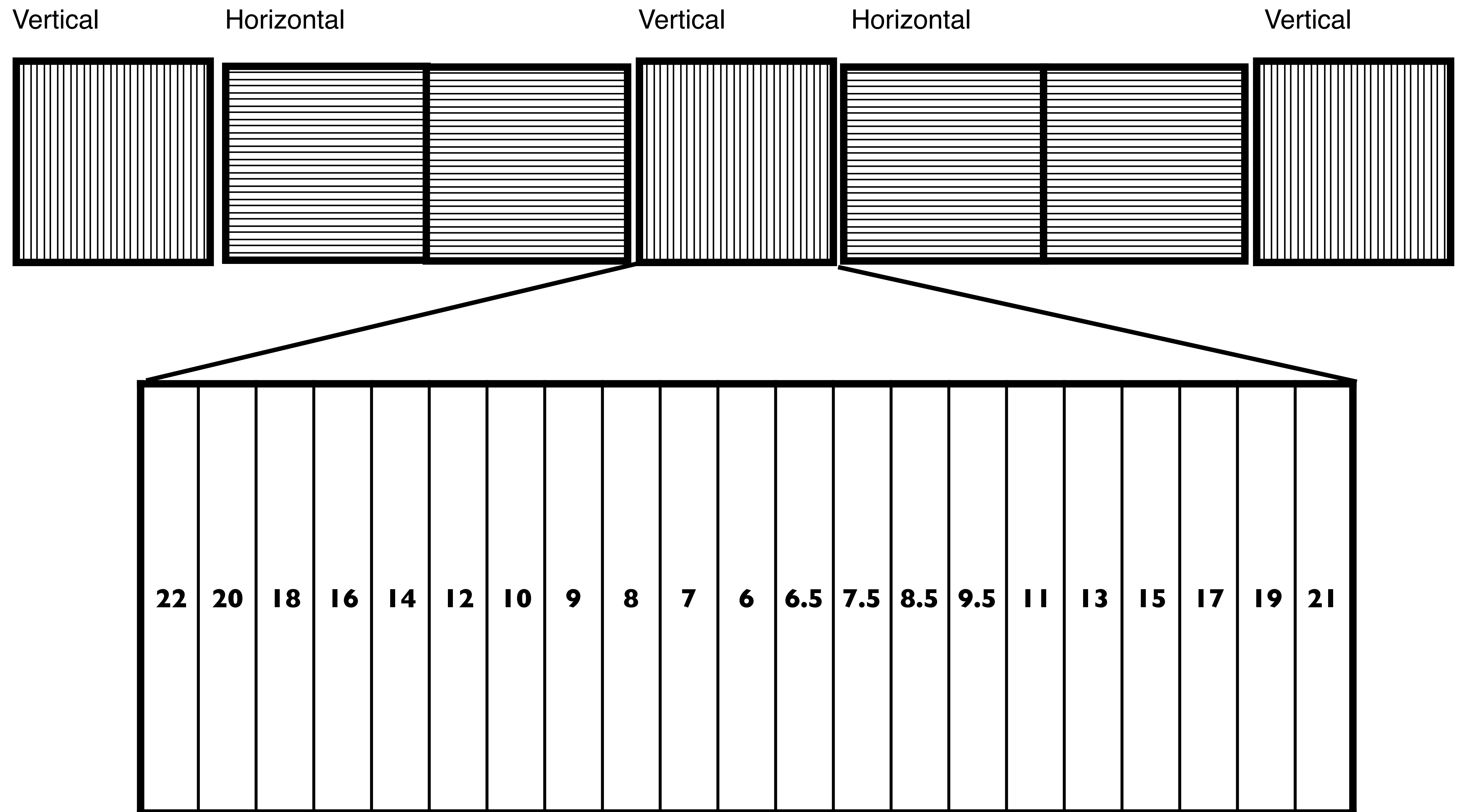
CD = [34 nm : -1 nm : 10 nm] & [9.5 nm :-0.5 nm : 6 nm]
Bias = -25% : 5% : 25%
Duty = 1:1, 1:1.5: 1:2, 1:4, 1:8





F2X

HV [22 nm : -1 nm : 10 nm] & [9.5 nm : -0.5



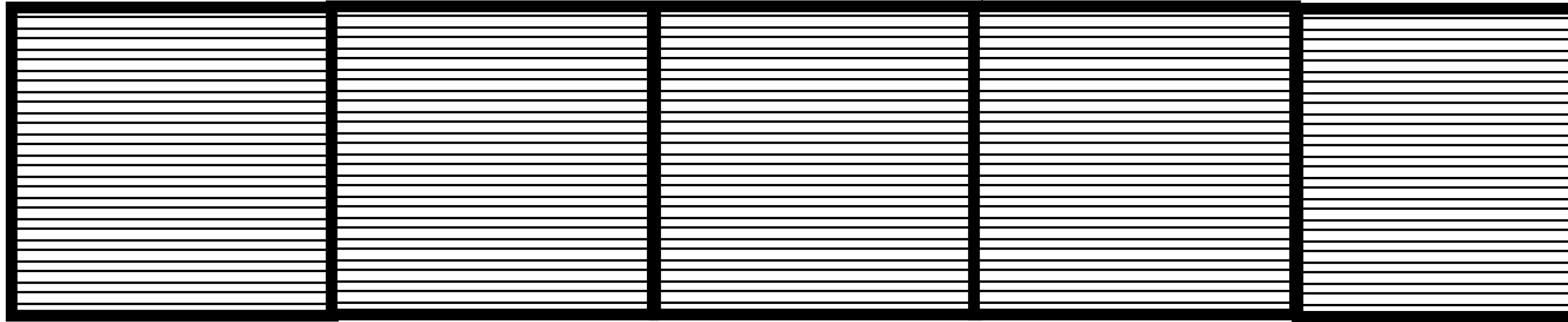
F2X (screenshot)

labels on matching carriers in order to print

22 20 18 16 14 12 10 9.0 8.0 7.0 6.0 6.5 7.5 8.5 9.5 11 13 15 17

F2X cleave

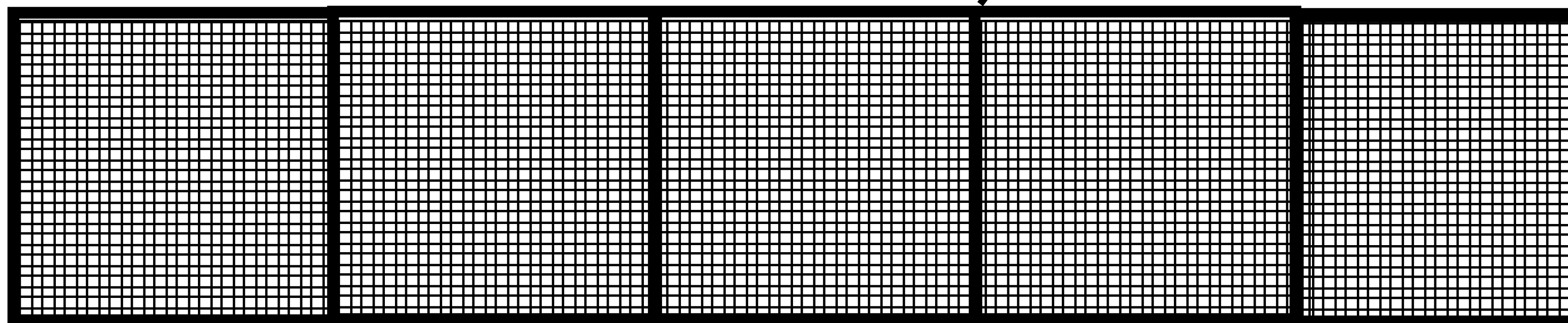
[22 nm : -1 nm : 10 nm]
&



F2X cleave (screenshot)

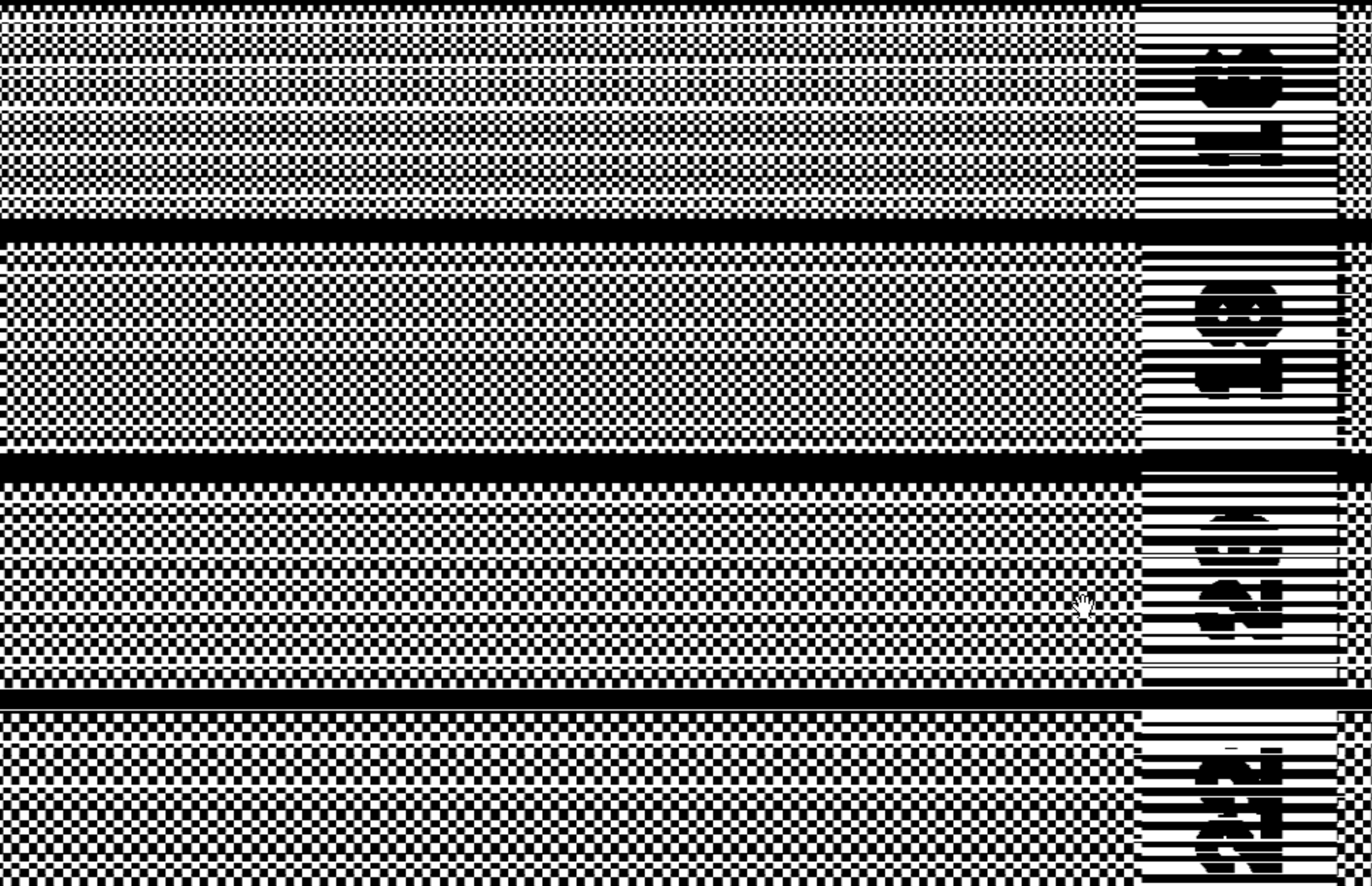
F2X contacts

[22 nm : -1 nm : 10 nm]
&

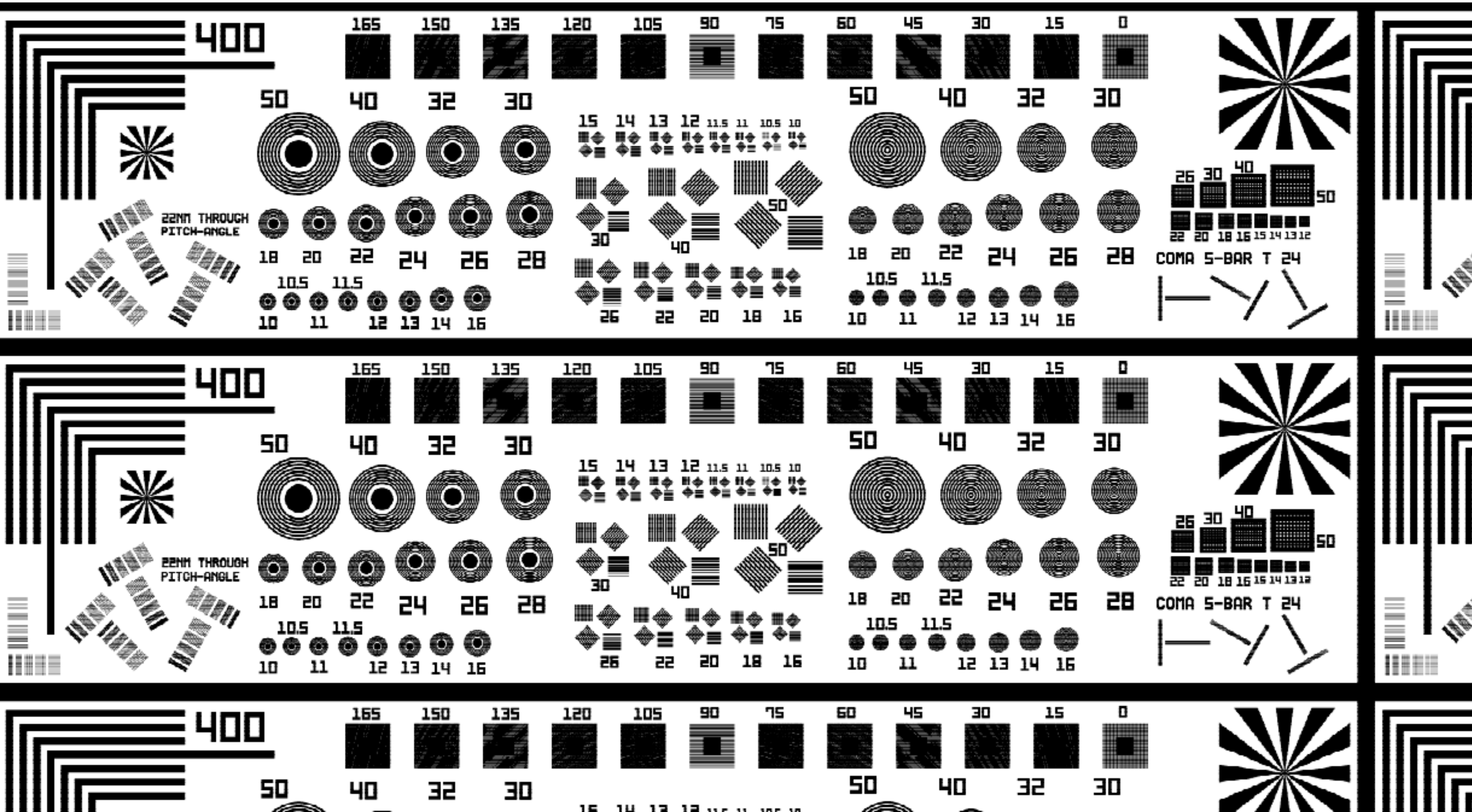


21
19
17
15
13
11
9.5
8.5
7.5
6.5
6
7
8
9
10
12
14
16
18
20
22

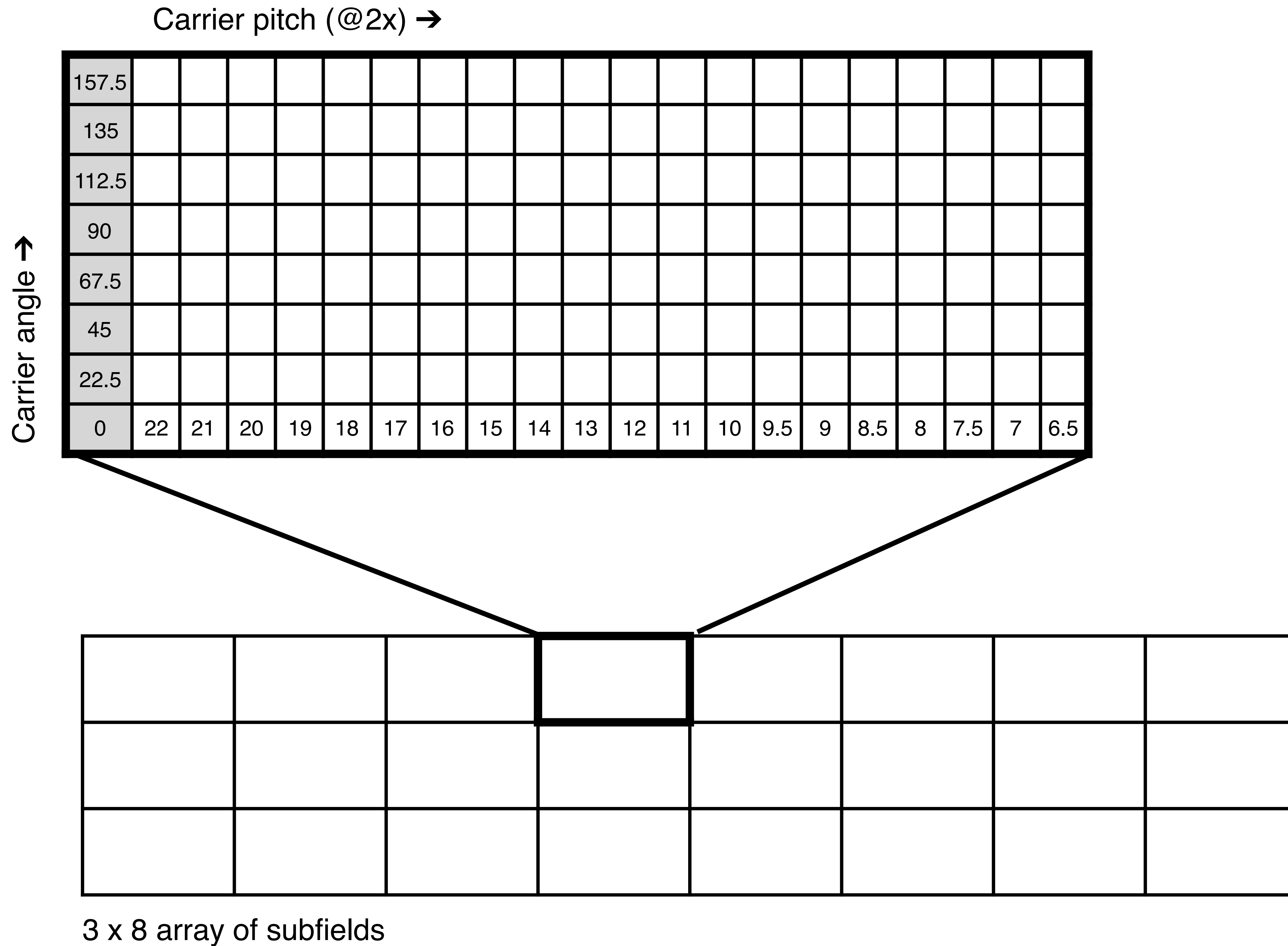
F2X contacts (screenshot)



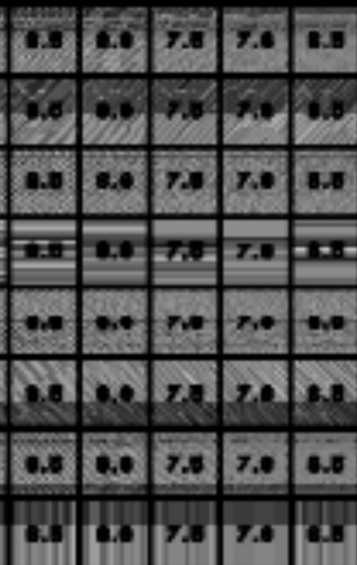
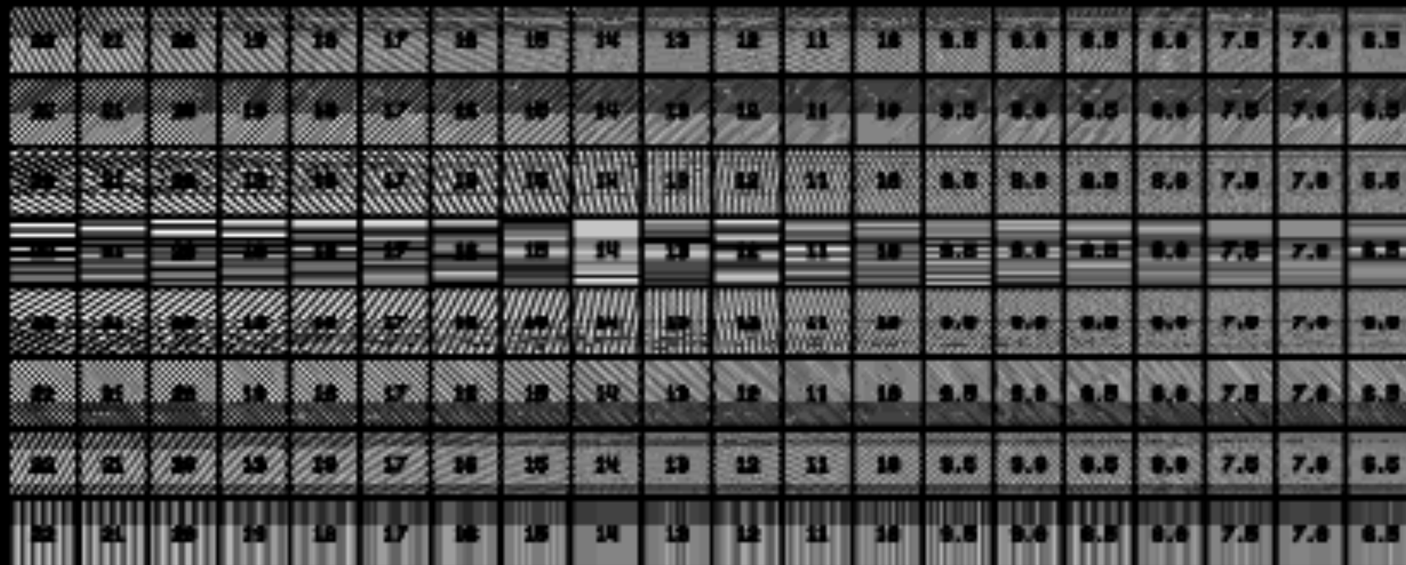
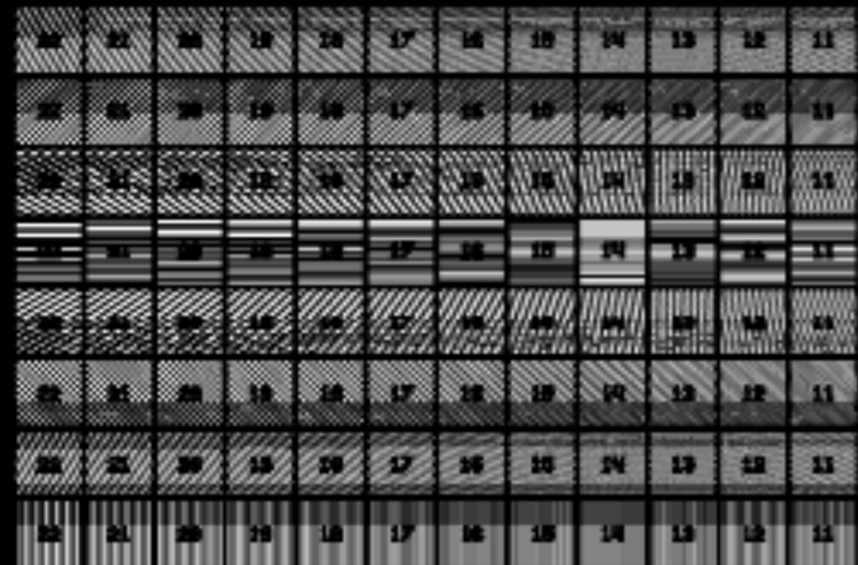
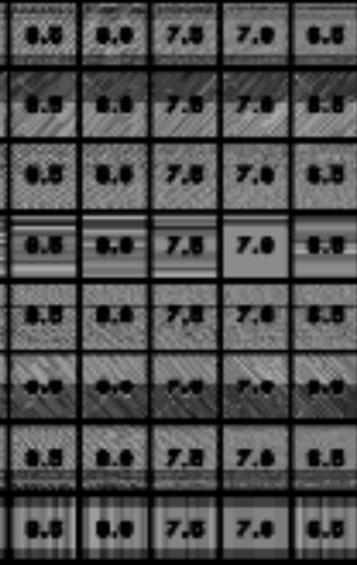
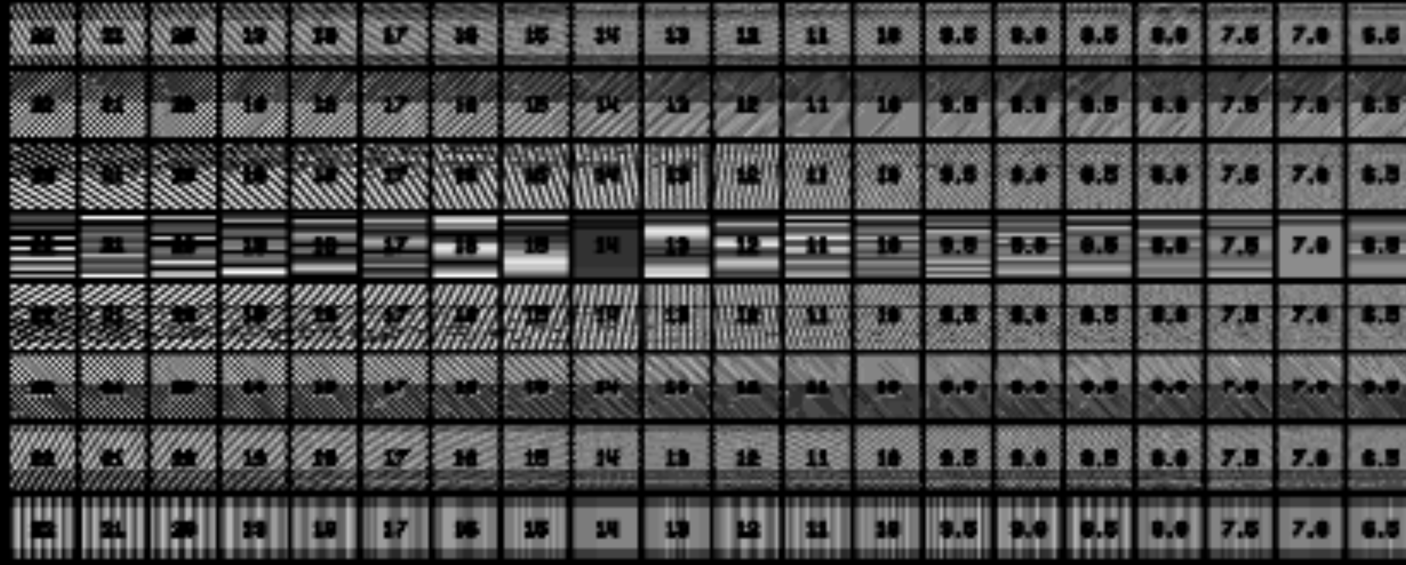
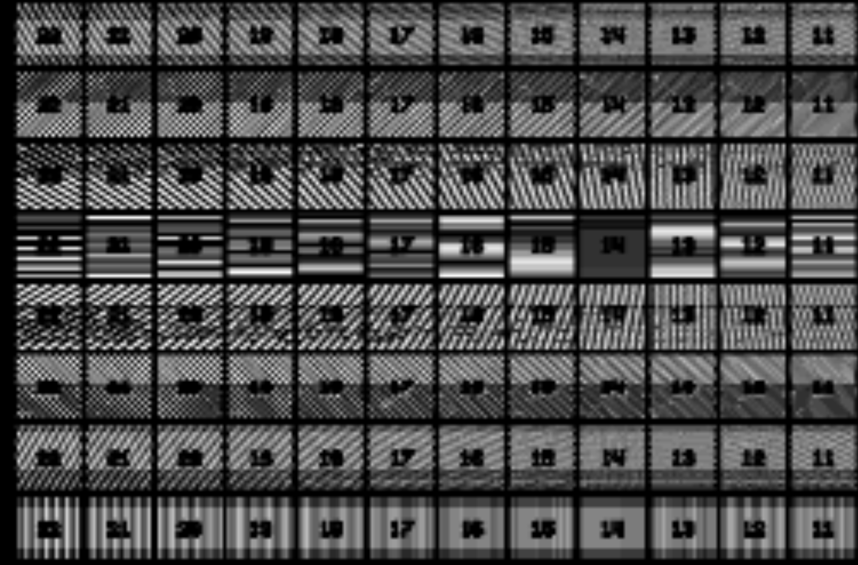
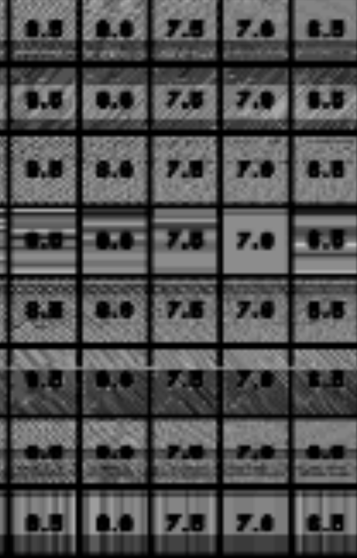
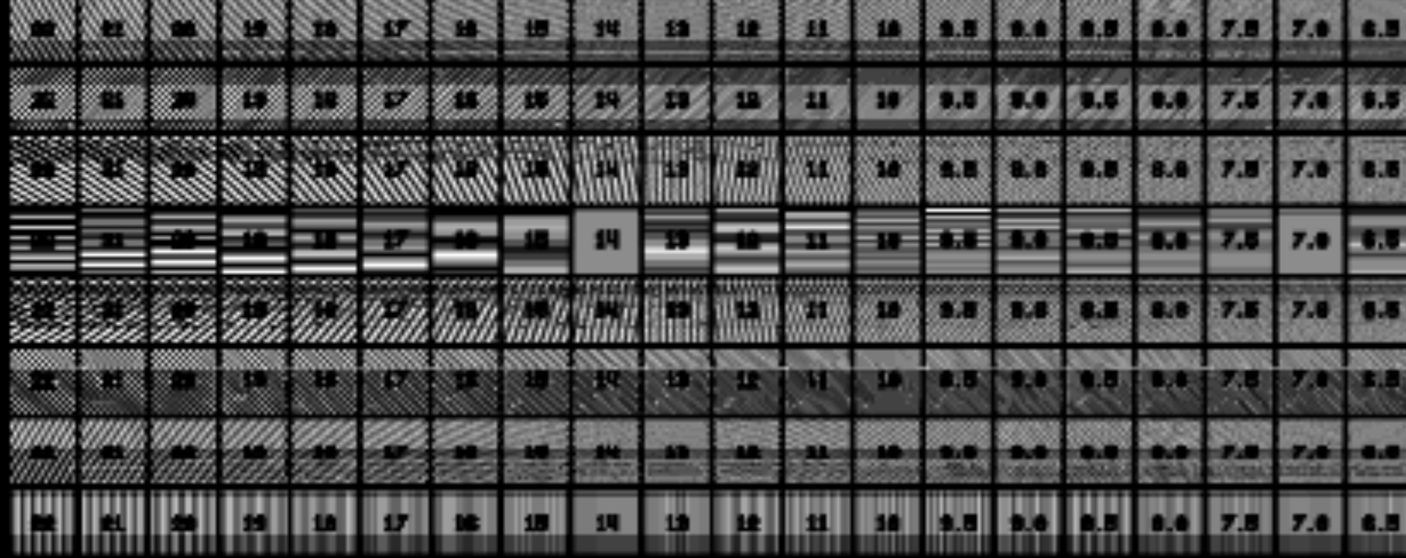
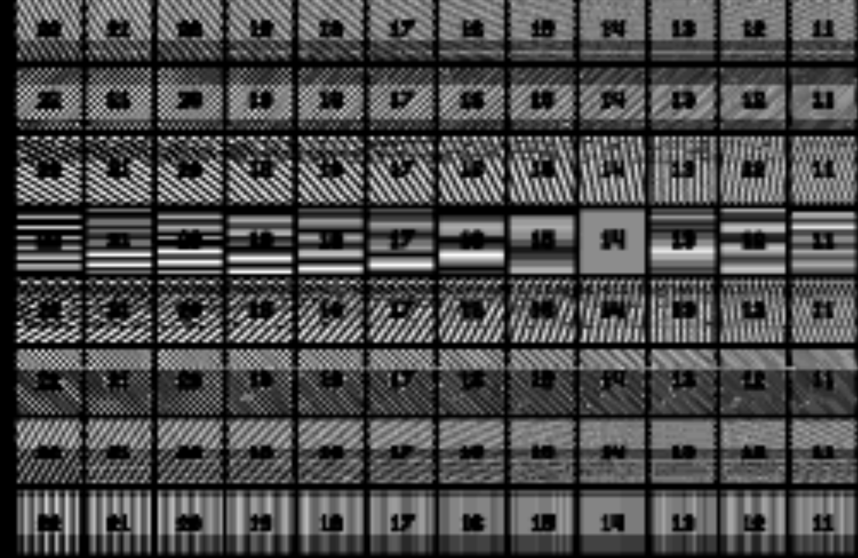
LBL aberration monitor



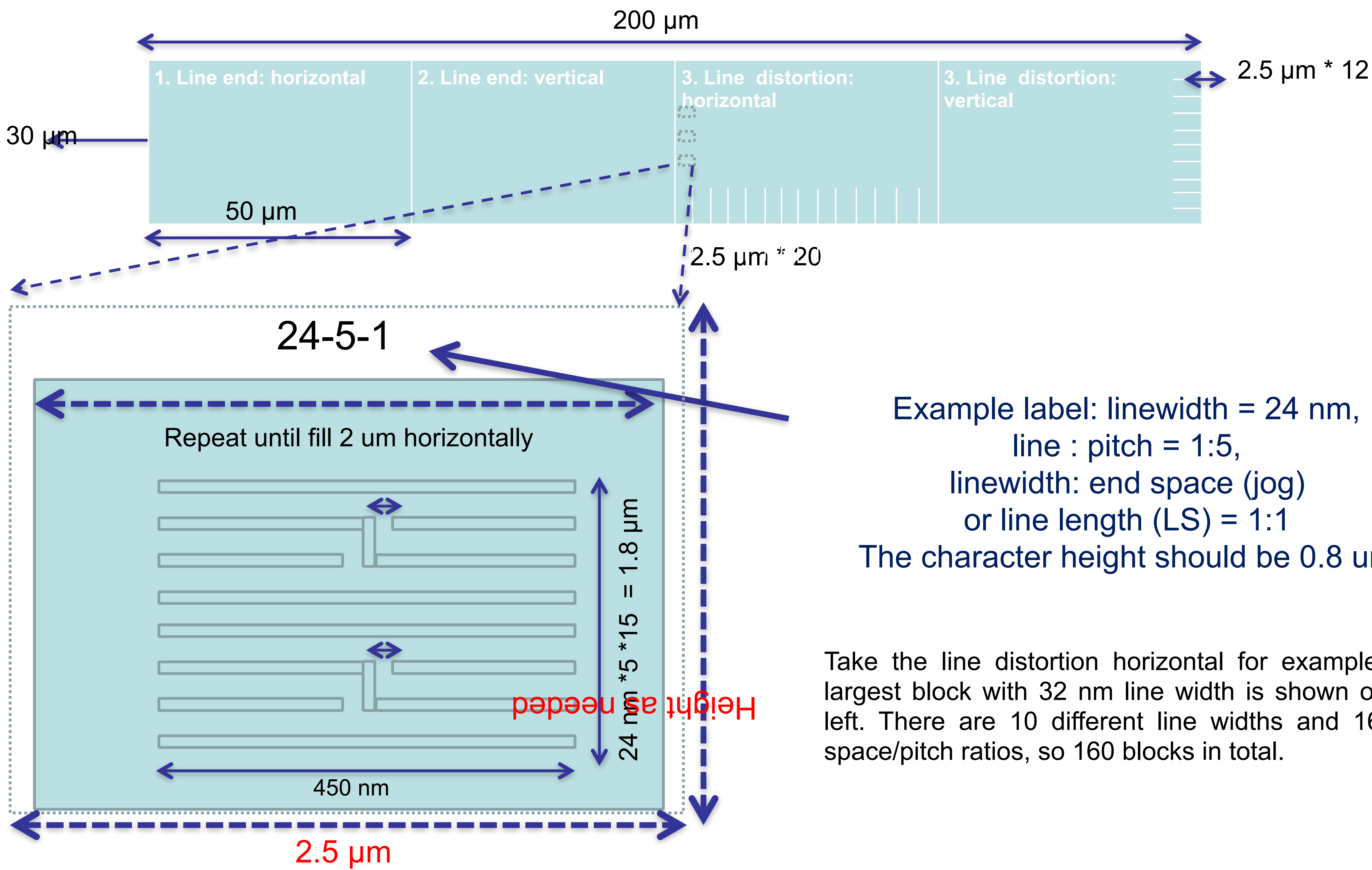
F2X aberration monitor



F2X aberration monitor detail

SE line end and distortion



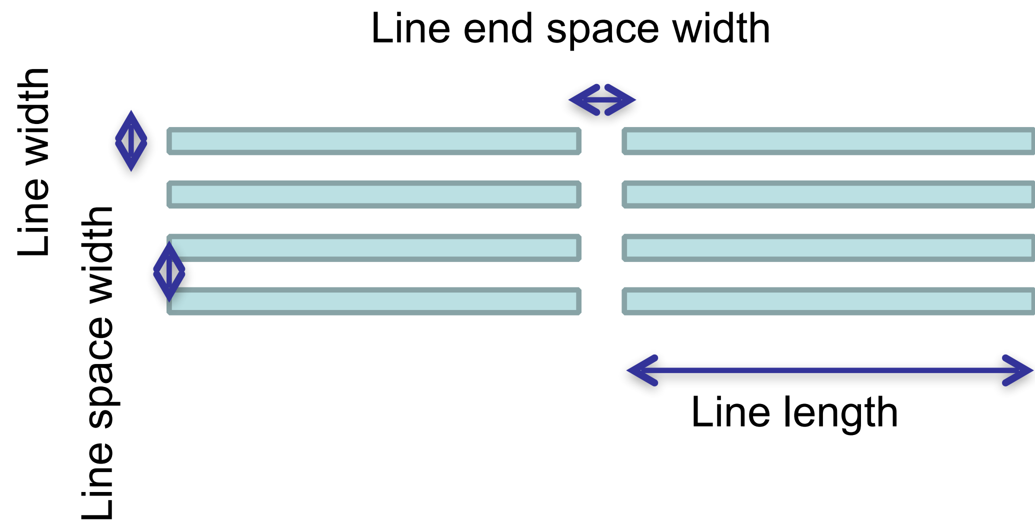
Take the line distortion horizontal for example, the largest block with 32 nm line width is shown on the left. There are 10 different line widths and 16 line space/pitch ratios, so 160 blocks in total.

SE line end and distortion

1. Line end

Line length 1, 1.5, 2, 5X line width

Line width	Line space: line width	# of lines
8nm, 10nm 12nm,14nm 16nm, 18nm, 20nm, 24nm 28nm, 32nm	1:1, 1:1.5, 1:2, 1:5	20 lines

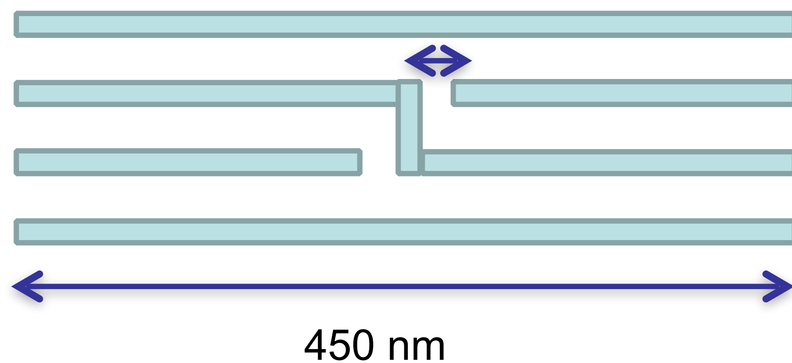


2. Distortion

Line end space width

1X, 1.5X, 2X, 5X line width

Line width	Line space: line width	# of lines
8nm, 10nm 12nm,14nm 16nm, 18nm, 20nm, 24nm, 28nm, 32nm	1:1, 1:1.5, 1:2, 1:5	16 lines



SE line end

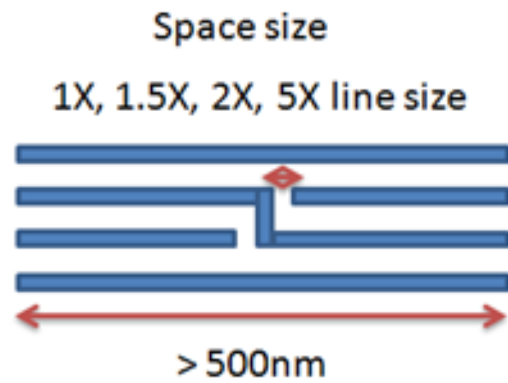
Example of line end for 8 , 12, 32 nm lines

Line widht	Line space width	End space size	Line length		Line width	Line space width	End space size	Line length		Line width	Line space width	End space size	Line length
8	8	12	8		12	12	18	12		32	32	48	32
8	8	12	12		12	12	18	18		32	32	48	48
8	8	12	16		12	12	18	24		32	32	48	64
8	8	12	40		12	12	18	60		32	32	48	160
8	12	12	8		12	18	18	12		32	48	48	32
8	12	12	12		12	18	18	18		32	48	48	48
8	12	12	16		12	18	18	24		32	48	48	64
8	12	12	40		12	18	18	60		32	48	48	160
8	16	12	8		12	24	18	12		32	64	48	32
8	16	12	12		12	24	18	18		32	64	48	48
8	16	12	16		12	24	18	24		32	64	48	64
8	16	12	40		12	24	18	60		32	64	48	160
8	40	12	8		12	60	18	12		32	160	48	32
8	40	12	12		12	60	18	18		32	160	48	48
8	40	12	16		12	60	18	24		32	160	48	64
8	40	12	40		12	60	18	60		32	160	48	160
												1.5X line width	
											1X, 1.5X,2X,5X		
													1X, 1.5X,2X,5X

SE line distortion

2. Distortion

Space size	Line size	Pitch	# of lines
1X, 1.5X, 2X, 5X line size	10nm,12nm 14nm, 16nm 18nm, 20nm 22nm, 24nm 28nm, 32nm	1:1, 1:1.5,1:2, 1:5	> 12 lines > 3 sets



\> 500nm

Line size	Pitch	Space size
10	1 : 1	10
10	1 : 1	15
10	1 : 1	20
10	1 : 1	50
10	1 : 1.5	10
10	1 : 1.5	15
10	1 : 1.5	20
10	1 : 1.5	50
10	1 : 2	10
10	1 : 2	15
10	1 : 2	20
10	1 : 2	50
10	1 : 5	10
10	1 : 5	15
10	1 : 5	20
10	1 : 5	50

Line size	Pitch	Space size
12	1 : 1	12
12	1 : 1	18
12	1 : 1	24
12	1 : 1	60
12	1 : 1.5	12
12	1 : 1.5	18
12	1 : 1.5	24
12	1 : 1.5	60
12	1 : 2	12
12	1 : 2	18
12	1 : 2	24
12	1 : 2	60
12	1 : 5	12
12	1 : 5	18
12	1 : 5	24
12	1 : 5	60

Line size	Pitch	Space size
14	1 : 1	14
14	1 : 1	21
14	1 : 1	28
14	1 : 1	70
14	1 : 1.5	14
14	1 : 1.5	21
14	1 : 1.5	28
14	1 : 1.5	70
14	1 : 2	14
14	1 : 2	21
14	1 : 2	28
14	1 : 2	70
14	1 : 5	14
14	1 : 5	21
14	1 : 5	28
14	1 : 5	70

Line size	Pitch	Space size
16	1 : 1	16
16	1 : 1	24
16	1 : 1	32
16	1 : 1	80
16	1 : 1.5	16
16	1 : 1.5	24
16	1 : 1.5	32
16	1 : 1.5	80
16	1 : 2	16
16	1 : 2	24
16	1 : 2	32
16	1 : 2	80
16	1 : 5	16
16	1 : 5	24
16	1 : 5	32
16	1 : 5	80

Line size	Pitch	Space size
18	1 : 1	18
18	1 : 1	27
18	1 : 1	36
18	1 : 1	90
18	1 : 1.5	18
18	1 : 1.5	27
18	1 : 1.5	36
18	1 : 1.5	90
18	1 : 2	18
18	1 : 2	27
18	1 : 2	36
18	1 : 2	90
18	1 : 5	18
18	1 : 5	27
18	1 : 5	36
18	1 : 5	90

Line size	Pitch	Space size
20	1 : 1	20
20	1 : 1	30
20	1 : 1	40
20	1 : 1	100
20	1 : 1.5	20
20	1 : 1.5	30
20	1 : 1.5	40
20	1 : 1.5	100
20	1 : 2	20
20	1 : 2	30
20	1 : 2	40
20	1 : 2	100
20	1 : 5	20
20	1 : 5	30
20	1 : 5	40
20	1 : 5	100

Line size	Pitch	Space size
22	1 : 1	22
22	1 : 1	33
22	1 : 1	44
22	1 : 1	110
22	1 : 1.5	22
22	1 : 1.5	33
22	1 : 1.5	44
22	1 : 1.5	110
22	1 : 2	22
22	1 : 2	33
22	1 : 2	44
22	1 : 2	110
22	1 : 5	22
22	1 : 5	33
22	1 : 5	44
22	1 : 5	110

Line size	Pitch	Space size
24	1 : 1	24
24	1 : 1	36
24	1 : 1	48
24	1 : 1	120
24	1 : 1.5	24
24	1 : 1.5	36
24	1 : 1.5	48
24	1 : 1.5	120
24	1 : 2	24
24	1 : 2	36
24	1 : 2	48
24	1 : 2	120
24	1 : 5	24
24	1 : 5	36
24	1 : 5	48
24	1 : 5	120

Line size	Pitch	Space size
28	1 : 1	28
28	1 : 1	42
28	1 : 1	56
28	1 : 1	140
28	1 : 1.5	28
28	1 : 1.5	42
28	1 : 1.5	56
28	1 : 1.5	140
28	1 : 2	28
28	1 : 2	42
28	1 : 2	56
28	1 : 2	140
28	1 : 5	28
28	1 : 5	42
28	1 : 5	56
28	1 : 5	140

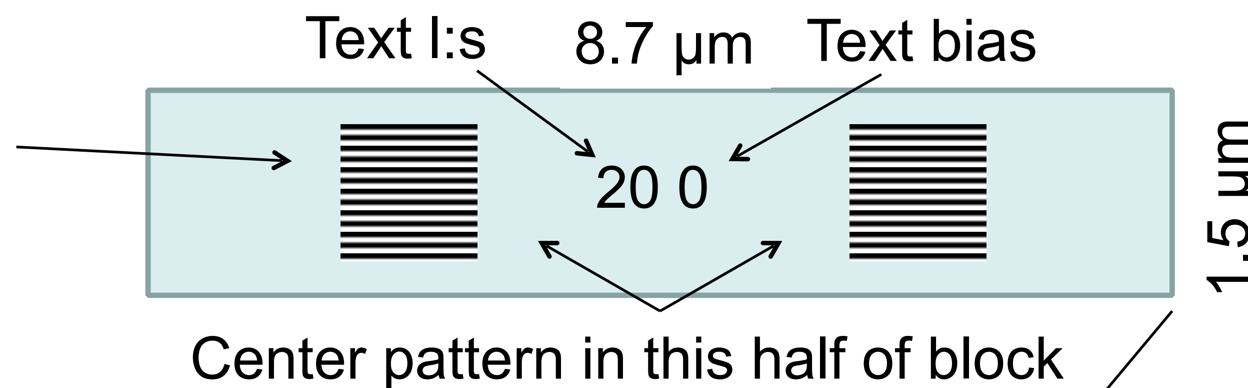
Line size	Pitch	Space size
32	1 : 1	32
32	1 : 1	48
32	1 : 1	64
32	1 : 1	160
32	1 : 1.5	32
32	1 : 1.5	48
32	1 : 1.5	64
32	1 : 1.5	160
32	1 : 2	32
32	1 : 2	48
32	1 : 2	64
32	1 : 2	160
32	1 : 5	32
32	1 : 5	48
32	1 : 5	64
32	1 : 5	160

SE line and space: Horizontal/Vertical with bias split

- LS 1:1, Pitch = 2x this number.
- Line & space size = 50, 40, 30, 28, 26, 24, 22, 20, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8 nm
- Bias size applied to line is from -10 to +10 nm by 2 nm increments
- Adjust space through bias to maintain constant pitch for each row

LW	50	45	40	35	30	28	26	24	22	20	18	16	15	14	13	12	11	10	9	8
Pairs	***13***	***15***	***15***	***19***	***23***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***

Make l:s pattern with # of pairs from table above. Make lines “as long as possible”.

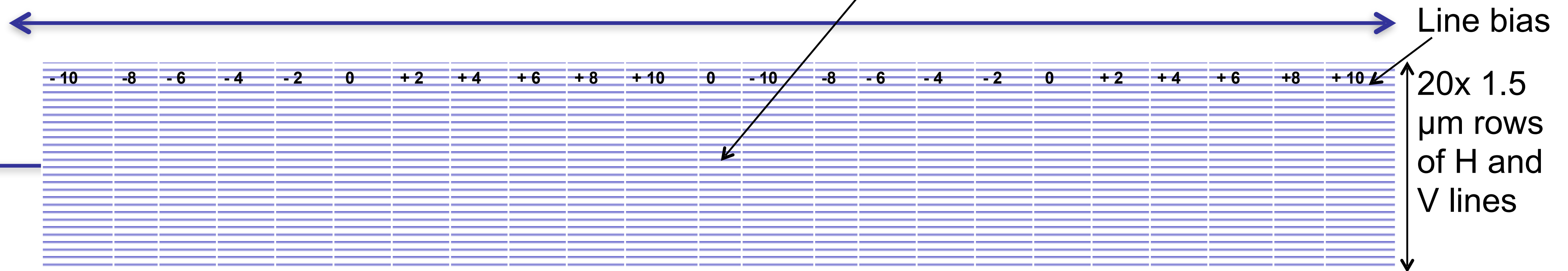


Center pattern in this half of block

Decrease line width
Increase space

200 µm

Decrease space width
Increase line



30 µm

8.7µm

Maintain pitch for each row

See next slide

SE line and space bias split array (bias applies to line [no absorber])

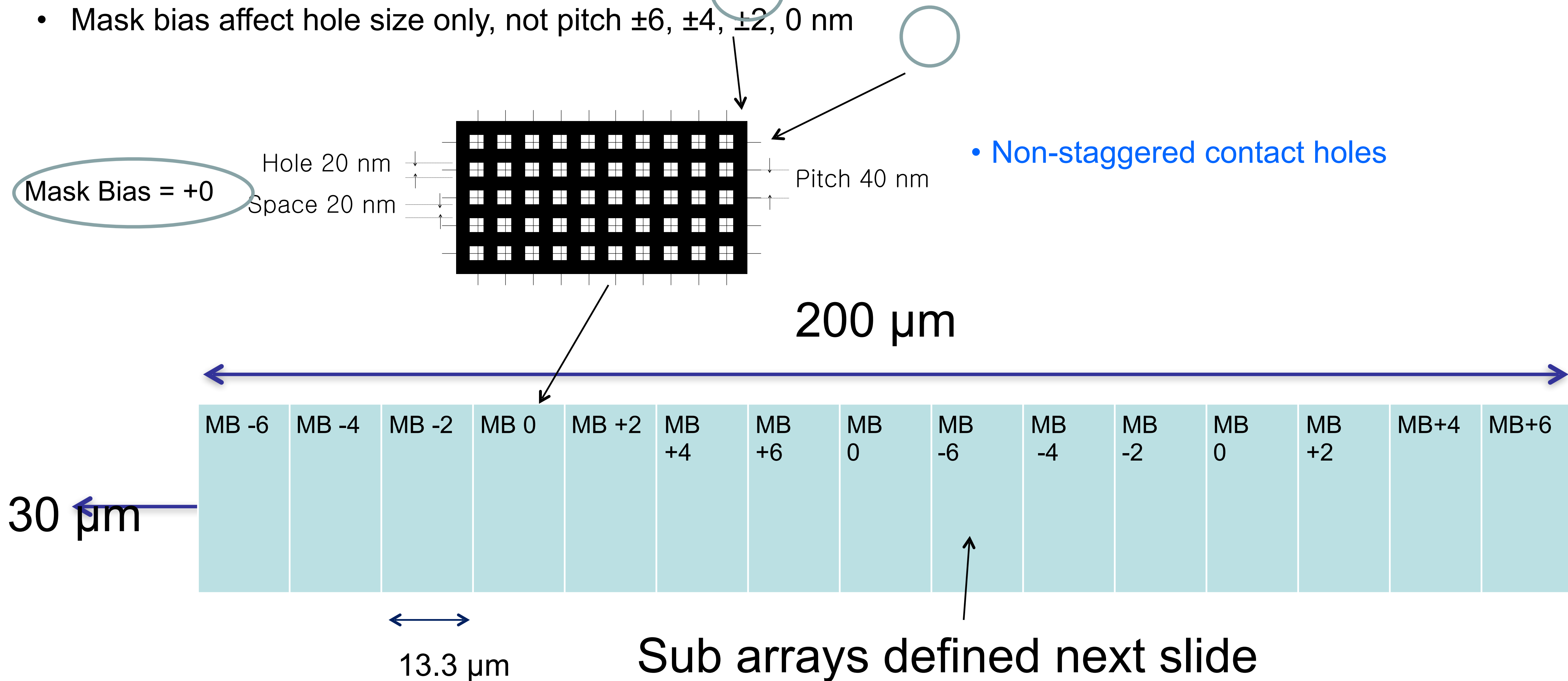
45-10	45 -8	45 -6	45 -4	45 -2	45	45 +2	45 +4	45 +6	45 +8	45+10
35-10	*35 -8*	*35 -6*	*35 -4*	*35 -2*	*35*	*35 +2*	*35 +4*	*35 +6*	*35 +8*	*35+10*
28-10	*28 -8*	*28 -6*	*28 -4*	*28 -2*	*28*	*28 +2*	*28 +4*	*28 +6*	*28 +8*	*28+10*
24-10	*24 -8*	*24 -6*	*24 -4*	*24 -2*	*24*	*24 +2*	*24 +4*	*24 +6*	*24 +8*	*24+10*
20-10	*20 -8*	*20 -6*	*20 -4*	*20 -2*	*20*	*20 +2*	*20 +4*	*20 +6*	*20 +8*	*20+10*
	16 -8	*16 -6*	*16 -4*	*16 -2*	*16*	*16 +2*	*16 +4*	*16 +6*	*16 +8*	
		14 -6	*14 -4*	*14 -2*	*14*	*14 +2*	*14 +4*	*14 +6*		
			12 -4	*12 -2*	*12*	*12 +2*	*12 +4*			
				10 -2	*10*	*10 +2*				
					8					
					9					
				11 -2	*11*	*11 +2*				
			13 -4	*13 -2*	*13*	*13 +2*	*13 +4*			
		15 -6	*15 -4*	*15 -2*	*15*	*15 +2*	*15 +4*	*15 +6*		
18-10	*18 -8*	*18 -6*	*18 -4*	*18 -2*	*18*	*18 +2*	*18 +4*	*18 +6*	*18 +8*	*18+10*
22-10	*22 -8*	*22 -6*	*22 -4*	*22 -2*	*22*	*22 +2*	*22 +4*	*22 +6*	*22 +8*	*22+10*
26-10	*26 -8*	*26 -6*	*26 -4*	*26 -2*	*26*	*26 +2*	*26 +4*	*26 +6*	*26 +8*	*26+10*
30-10	*30 -8*	*30 -6*	*30 -4*	*30 -2*	*30*	*30 +2*	*30 +4*	*30 +6*	*30 +8*	*30+10*
40-10	*40 -8*	*40 -6*	*40 -4*	*40 -2*	*40*	*40 +2*	*40 +4*	*40 +6*	*40 +8*	*40+10*
50-10	*50 -8*	*50 -6*	*50 -4*	*50 -2*	*50*	*50 +2*	*50 +4*	*50 +6*	*50 +8*	*50+10*

Line & space size (nm);
pitch in 2x this #

Bias applied to line (nm)
Maintain pitch for each row

SE contact hole bias split (hole:spacing = 1:1)

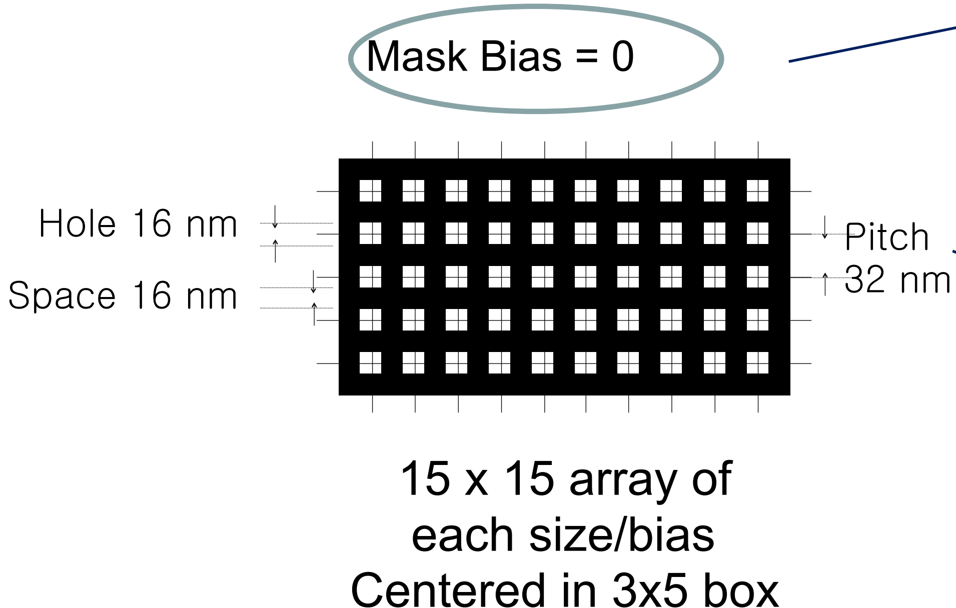
- Contact hole size: spacing = 1:1 (with ± bias added to hole size)
- Contact hole size 50, 30, 28, 26, 24, 22, 20, 18, 17, 16, 15, 14, 13, 12 nm
- Mask bias affect hole size only, not pitch ±6, ±4, ±2, 0 nm



Sub arrays defined next slide

Maintain pitch for each bias

SE contact hole bias split – sub array mask bias definition



Not all size & bias combinations will exist. Mask size & bias described on next slide.

SE contact hole bias split

Mask Bias Split Description

Split#	Design Rule	MB -6nm		MB -4nm		MB -2nm		No bias		MB +2nm		MB +4nm		MB +6nm	
		Hole Space	Bar	Hole Space	Bar	Hole Space	Bar	Hole Space	Bar	Hole Space	Bar	Hole Space	Bar	Hole Space	Bar
1	50nmHP	44	56	46	54	48	52	50	50	52	48	54	46	56	44
5	30nmHP	24	36	26	34	28	32	30	30	32	28	34	26	36	24
6	28nmHP	22	34	24	32	26	30	28	28	30	26	32	24	34	22
7	26nmHP	20	32	22	30	24	28	26	26	28	24	30	22	32	20
8	24nmHP	18	30	20	28	22	26	24	24	26	22	28	20	30	18
9	22nmHP	16	28	18	26	20	24	22	22	24	20	26	18	28	16
10	20nmHP	14	26	16	24	18	22	20	20	22	18	24	16	26	14
11	18nmHP	12	24	14	22	16	20	18	18	20	16	22	14	24	12
12	17nmHP			13	21	15	19	17	17	19	15	21	13		
13	16nmHP			12	20	14	18	16	16	18	14	20	12		
14	15nmHP					13	17	15	15	17	13				
15	14nmHP					12	16	14	14	16	12				
16	13nmHP							13	13						
17	12nmHP							12	12						

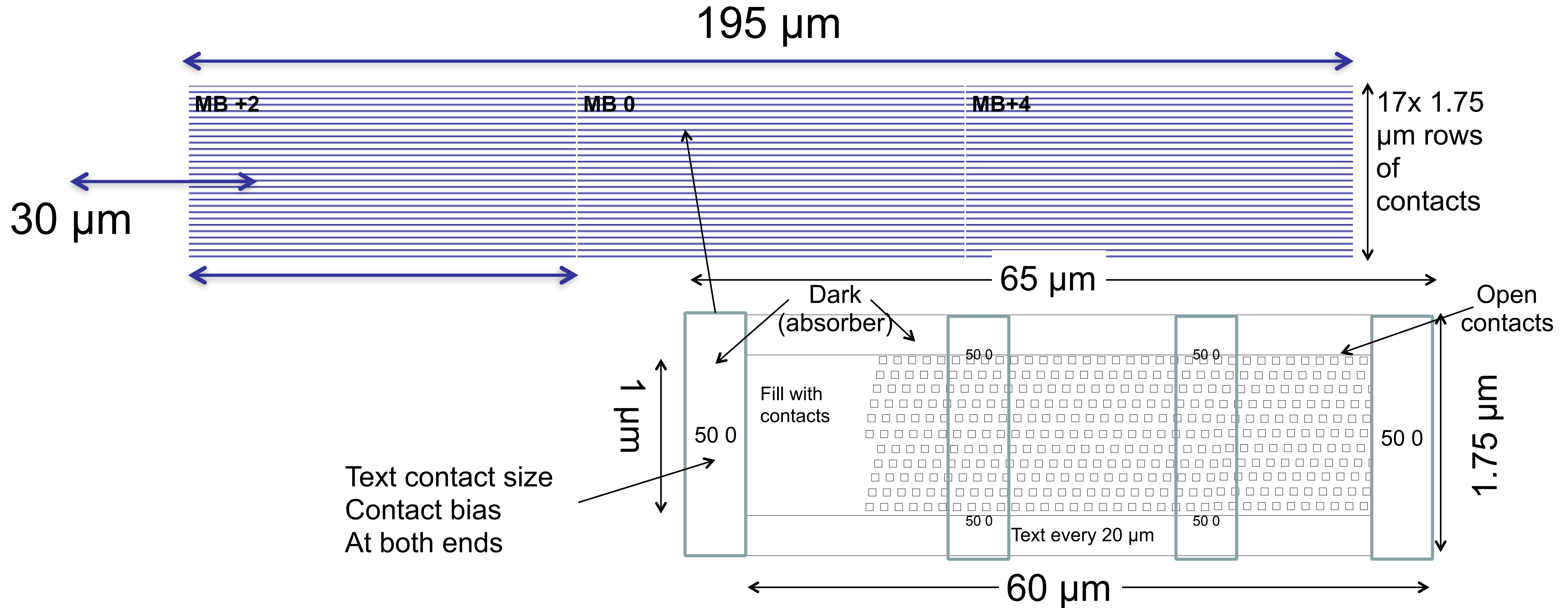
SE cleavable contact hole 1:1 and mask bias

Mask Bias 0nm, +2nm and +4nm

- CH : spacing = 1:1, bias affects contact only. Adjust space to maintain pitch.
- Contact hole size 50, 40, 30, 26, 22, 18, 16, 14, 12, 13, 15, 17, 20, 24, 28, 35, 45 nm

The contacts are staggered on a 5 row periodicity (edge start at 1, 1.2, 1.4, 1.6, 1.8, 1, … times period)

Center in 1 µm strip with # of rows in table



Contact size	50	45	40	35	30	28	26	24	22	20	18	17	16	15	14	13	12
Rows	***10***	***11***	***12***	***14***	***16***	***17***	***19***	***20***	***22***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***
2 nm bias	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***N***	***N***
4 nm bias	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***	***N***	***N***	***N***	***N***

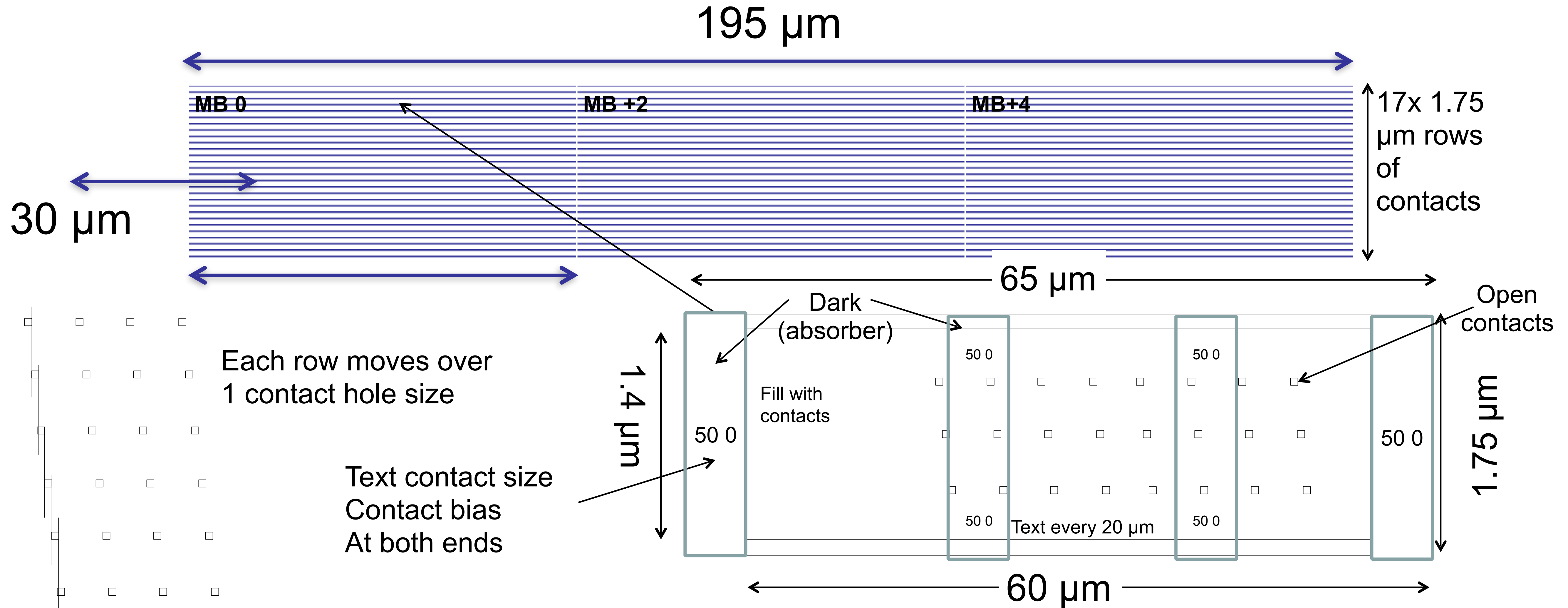
Do not include these features

SE cleavable contact hole 1:6 and mask bias

Mask Bias 0nm, +2nm and +4nm

- CH : spacing = 1:6, bias affects contact only. Adjust space to maintain pitch.
- Contact hole size 50, 40, 30, 26, 22, 18, 16, 14, 12, 13, 15, 17, 20, 24, 28, 35, 45 nm

The contact rows are staggered with each one moving over by 1 contact width.
Center in 1.4 µm strip with # of rows in table



Contact size	50	45	40	35	30	28	26	24	22	20	18	17	16	15	14	13	12
Rows	*4*	*4*	*5*	*5*	*6*	*7*	*7*	*8*	*9*	*10*	*11*	*11*	*12*	*13*	*14*	*15*	*16*

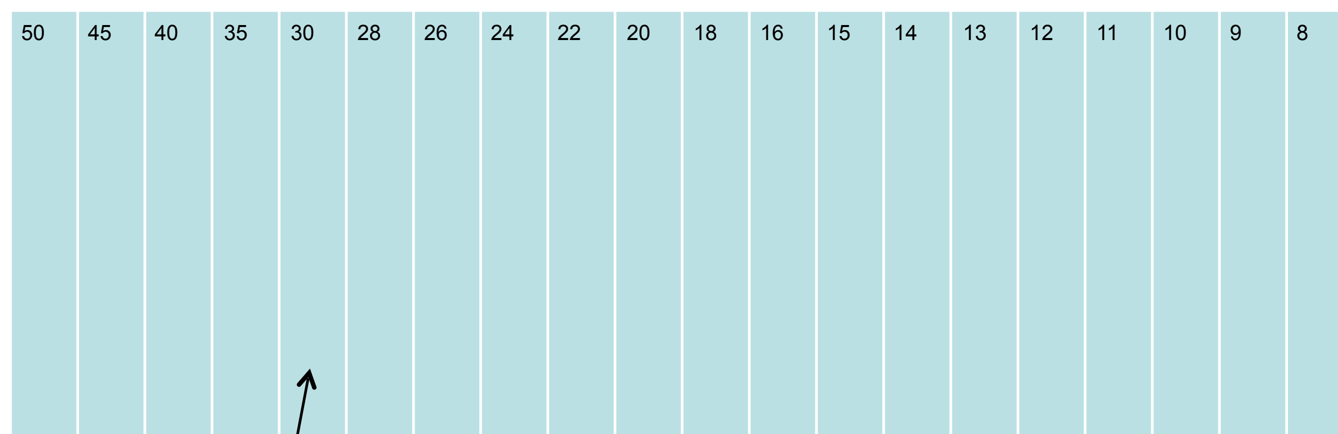
SE cleavable line and space

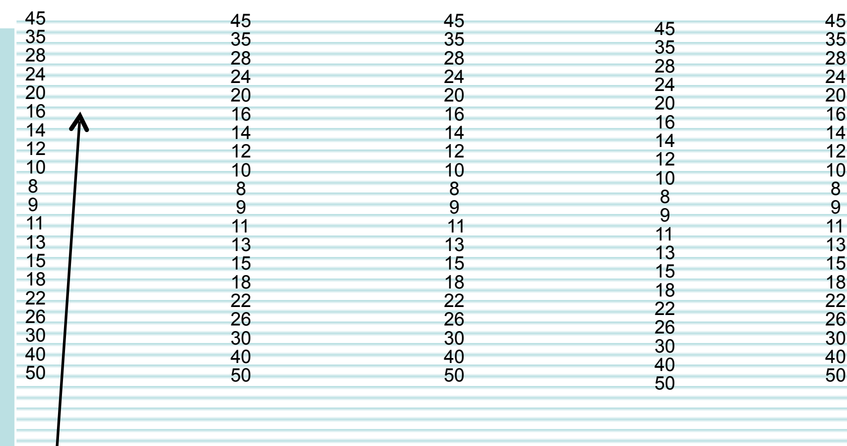
- Horizontal and vertical cleavable lines, No Mask Bias
- L:S = 1:1 (pitch = 2x line width)
- Line width 50, 45, 40, 35, 30, 28, 26, 24, 22, 20, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8 nm

LW	50	45	40	35	30	28	26	24	22	20	18	16	15	14	13	12	11	10	9	8
Horz Pairs	***13***	***15***	***15***	***19***	***23***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***	***25***

200 µm

Text/labels every 20 µm along lines





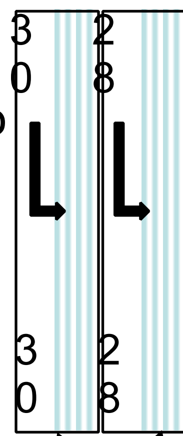
30 µm
Long L:S

l:s set = 1.5 µm

6 µm

120 µm

~80 µm
Long L:S



This text applies to these lines

Text at both ends of lines

50 l:s pairs

This text applies to these lines

l:s set = 1.5 µm

Table above for # of l:s pairs

Legacy slides

4. Minimum feature size (“nice to have”)

52.5 nm CD dense contacts (@reticle)

Notes

Calculated for most aggressive possible rotated 4-pole contact printing.

Offset = 0.9, Pole Sigma = 0.1; Rotation = 45-deg;

This is equivalent to a Horz/Vert NA of 0.9*0.5*2/sqrt(2) = 0.63 which supports 21.2 nm period or 10.6 nm CD

Field assignment

Bright field | Dark field

Column

Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Pupil Fill Monitor (1 x 10)										Clear (1 x 9)								
2	Illumination Monitor (1 x 10)										Illumination Monitor On Grating (1 x 9)								
3	SE Line Space Bias BF (1 x 10)										SE Line Space Bias DF (1 x 9)								
4	SE Line Space Cleave BF (1 x 10)										SE Line Space Cleave DF (1 x 9)								
5	SE Line End And Distortion BF (1 x 10)										SE Line End And Distortion DF (1 x 9)								
6	SE Contact Bias Split BF (1 x 5)					SE Contact Bias Split DF (1 x 5)					Contact Bias BF (1 x 5)					Contact Bias DF (1 x 4)			
7	SE Contact Cleave 1:6 BF (1 x 5)					SE Contact Cleave 1:6 DF (1 x 5)					SE Contact Cleave 1:1 BF (1 x 5)					SEContact Cleave 1:1 DF (1 x 4)			
8	F2X (1 x 6)						F2X Cleave (1 x 6)						F2X Contacts (1 x 7)						
9	Aberration Monitor BF (1 x 4)				Aberration Monitor DF (1 x 4)				Aberration Monitor LBF (1 x 4)				F2X Aberration Monitor (1 x 4)				Zoneplate DF (1 x 3)		
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			