

NPL Optical Dimensional Standard For Vision Machines & Microscopy Range 1 μm - 60 mm

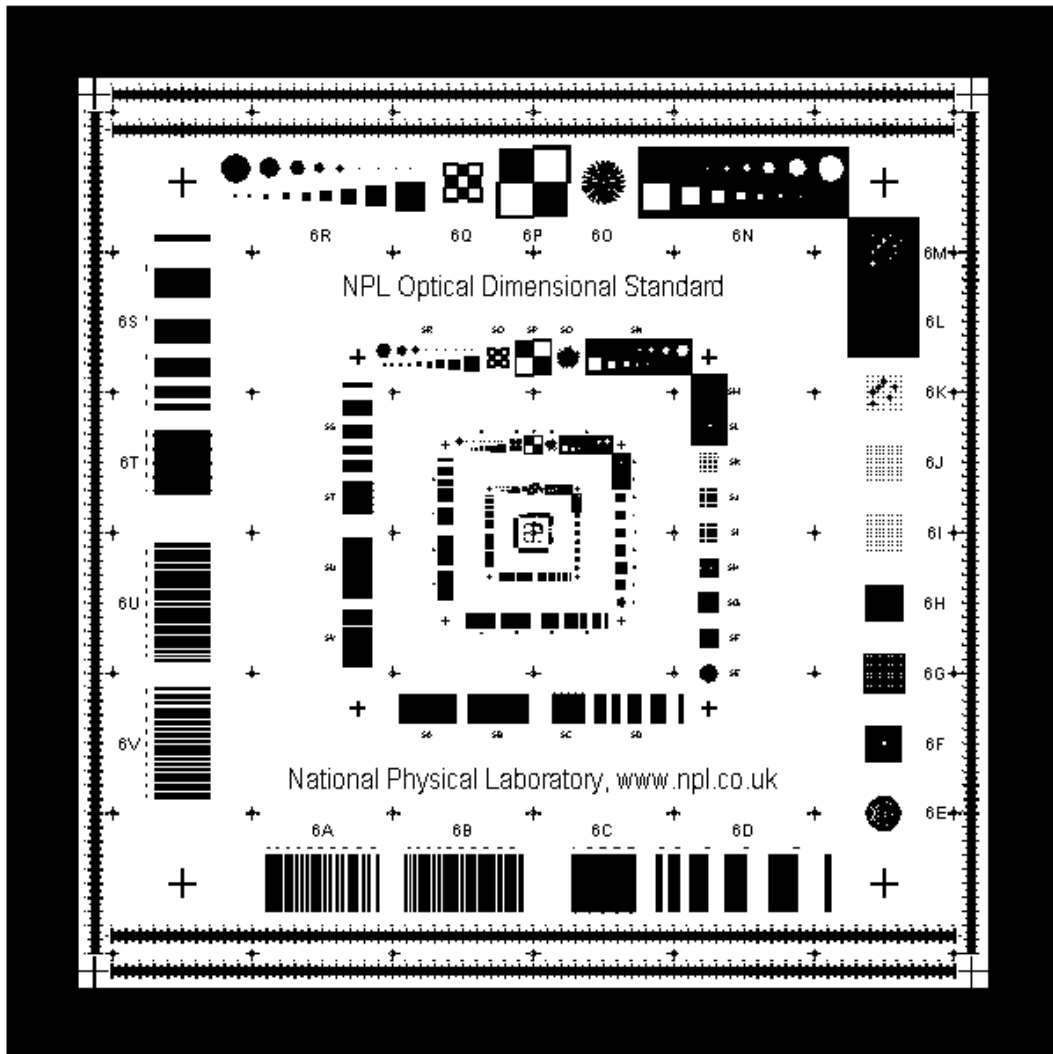


Figure 1: New Optical Dimensional Standard.

The NPL Optical Dimensional Standard is a correct reading, bright chrome on a 100 mm square quartz photomask. The dark areas on the figures indicate the opaque chrome layer. All the quoted dimensions are in micrometres unless otherwise stated. The standard appears as in Figure 1. There are twenty two patterns, scaled and repeated on the substrate six times to enable its use at different magnifications, with an additional six linear scales and an x-y stage position calibration grid. The patterns found on the mask are listed below.

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Small Clear Linewidths

Patterns (1-6)A

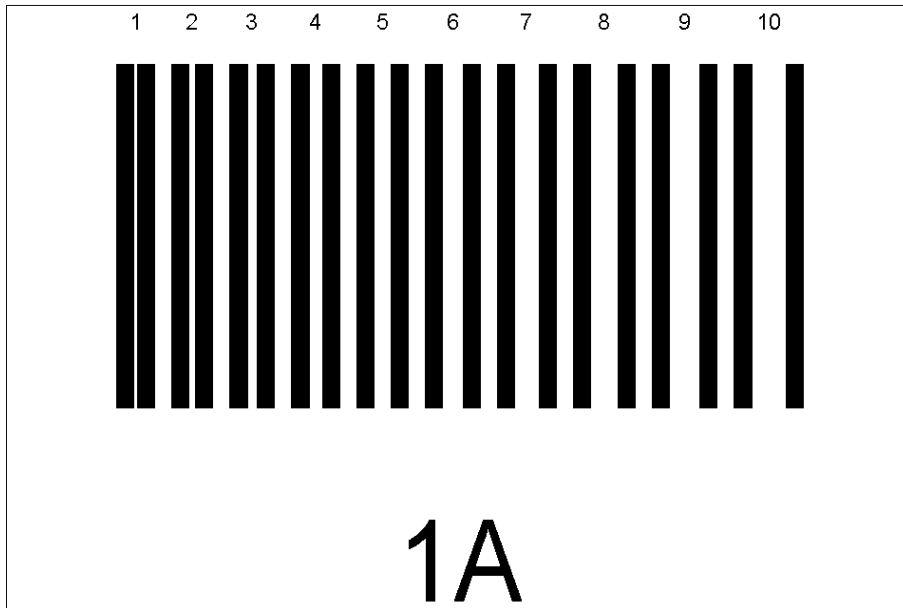


Figure 2: Pattern A

Pattern (1-6)A, shown in Figure 2, comprises ten clear optical linewidths. Opaque lines bound each clear line, with each set of linewidth and bounding lines being edge to edge separated by the width of the bounding lines. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1A	Pattern 2A	Pattern 3A	Pattern 4A	Pattern 5A	Pattern 6A
Clear Linewidth 1	1	2	5	10	20	40
Clear Linewidth 2	2	4	10	20	40	80
Clear Linewidth 3	3	6	15	30	60	120
Clear Linewidth 4	4	8	20	40	80	160
Clear Linewidth 5	5	10	25	50	100	200
Clear Linewidth 6	6	12	30	60	120	240
Clear Linewidth 7	7	14	35	70	140	280
Clear Linewidth 8	8	16	40	80	160	320
Clear Linewidth 9	9	18	45	90	180	360
Clear Linewidth 10	10	20	50	100	200	400
Opaque Linewidth	5	10	25	50	100	200
Edge to Edge Separation	5	10	25	50	100	200
Pattern Height	100	200	500	1000	2000	4000

Pattern (1-6)V is identical to pattern (1-6)A, rotated by 90°.

Small Opaque Linewidths

Patterns (1-6)B

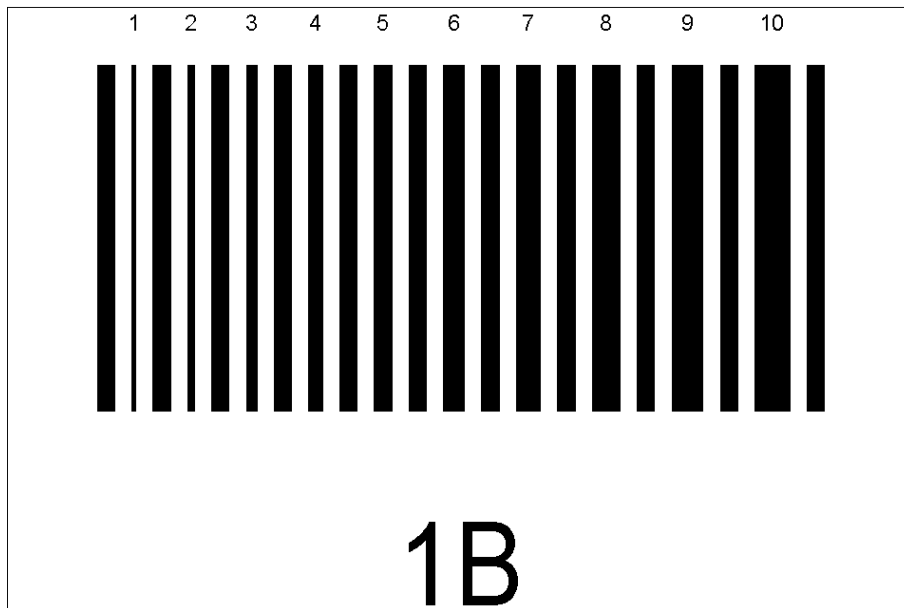


Figure 3: Pattern (1-6)B

Pattern (1-6)B, shown in Figure 3, comprises ten opaque optical linewidths. Opaque lines bound each dark line, with each set of linewidth and bounding lines being edge to edge separated by the width the bounding lines. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1B	Pattern 2B	Pattern 3B	Pattern 4B	Pattern 5B	Pattern 6B
Opaque Linewidth 1	1	2	5	10	20	40
Opaque Linewidth 2	2	4	10	20	40	80
Opaque Linewidth 3	3	6	15	30	60	120
Opaque Linewidth 4	4	8	20	40	80	160
Opaque Linewidth 5	5	10	25	50	100	200
Opaque Linewidth 6	6	12	30	60	120	240
Opaque Linewidth 7	7	14	35	70	140	280
Opaque Linewidth 8	8	16	40	80	160	320
Opaque Linewidth 9	9	18	45	90	180	360
Opaque Linewidth 10	10	20	50	100	200	400
Opaque Linewidth	5	10	25	50	100	200
Edge to Edge Separation	5	10	25	50	100	200
Pattern Height	100	200	500	1000	2000	4000

Pattern (1-6)U is identical to pattern (1-6)B, rotated by 90°.

Pitch Patterns

Patterns (1-6)C

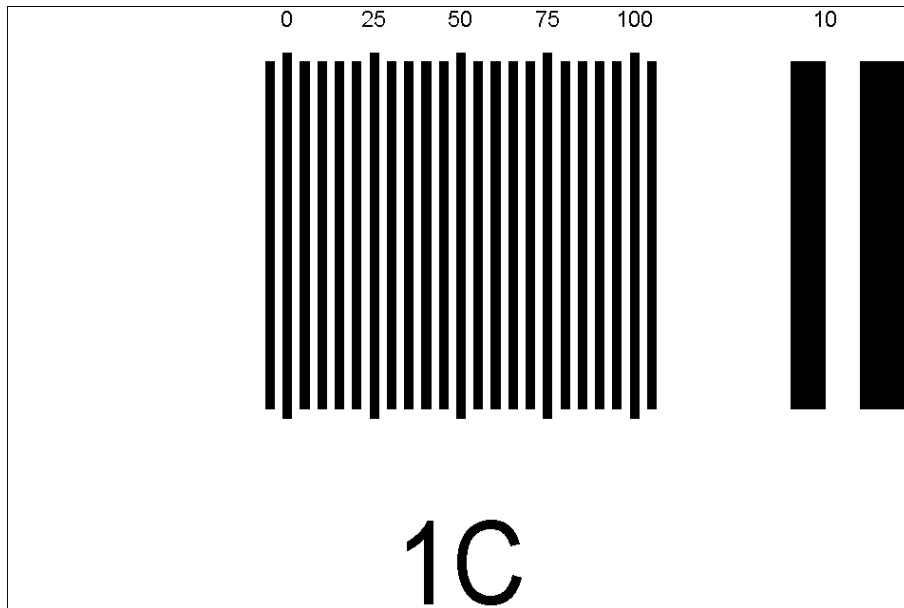


Figure 4: Pattern (1-6)C

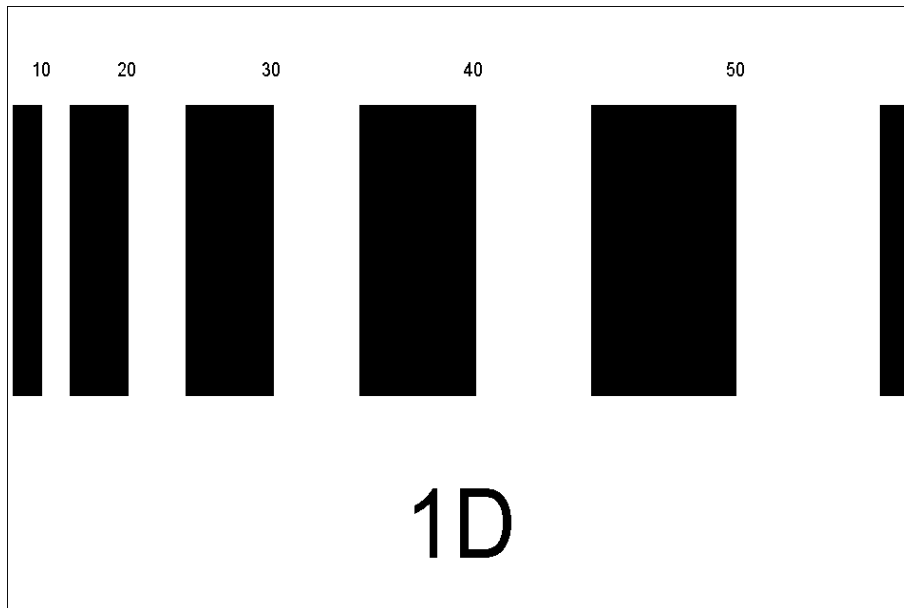
Pattern (1-6)C is shown in Figure 4 and is an optical scale with a mark to space ratio of 1. The numbered lines are elongated by 10% to aid identification. The first and last lines of the scale are sacrificial, to preserve the characteristics of the first and last elongated lines. Each pattern, 1-6, has the following nominal dimensions:

Features	Pattern 1C	Pattern 2C	Pattern 3C	Pattern 4C	Pattern 5C	Pattern 6C
Linewidth	2.5	5	12.5	25	50	100
Scale Pitch	5	10	25	50	100	200
Scale Length	100	200	500	1000	2000	4000
Pattern Height	100	200	500	1000	2000	4000
Numbered Line Height	110	220	550	1100	2200	4400

Pattern (1-6)T is identical to pattern (1-6)C, rotated by 90°.

Large Linewidths

Patterns (1-6)D



Pattern (1-6)D comprises five opaque and five clear optical linewidths. The last clear linewidth is bounded by an opaque linewidth with the same width as the first dark line. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1D	Pattern 2D	Pattern 3D	Pattern 4D	Pattern 5D	Pattern 6D
Opaque Linewidth 1	10	20	50	100	200	400
Clear Linewidth 1	10	20	50	100	200	400
Opaque Linewidth 2	20	40	100	200	400	800
Clear Linewidth 2	20	40	100	200	400	800
Opaque Linewidth 3	30	60	150	300	600	1200
Clear Linewidth 3	30	60	150	300	600	1200
Opaque Linewidth 4	40	80	200	400	800	1600
Clear Linewidth 4	40	80	200	400	800	1600
Opaque Linewidth 5	50	100	250	500	1000	2000
Clear Linewidth 5	50	100	250	500	1000	2000
Final Opaque Linewidth	10	20	50	100	200	400
Pattern Height	100	200	500	1000	2000	4000

Pattern (1-6)S is identical to pattern (1-6)D, rotated by 90°.

Concentric Circles

Patterns (1-6)E

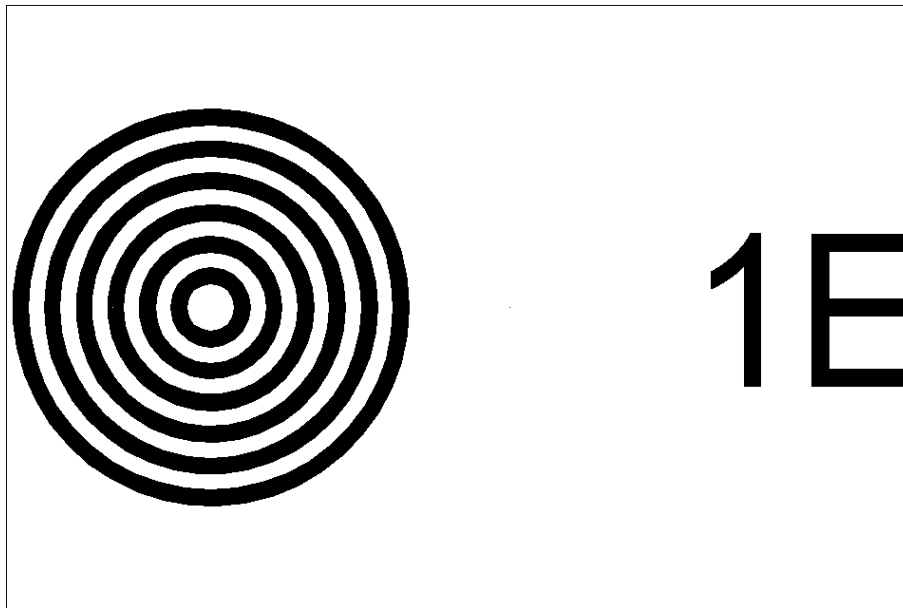


Figure 5: Pattern (1-6)E

Pattern (1-6)E, as shown in Figure 5, comprises 6 opaque concentric donuts. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1E	Pattern 2E	Pattern 3E	Pattern 4E	Pattern 5E	Pattern 6E
Internal Diameter, Donut 1	7.5	15	37.5	75	150	300
External Diameter, Donut 1	12.5	25	62.5	125	250	500
Internal Diameter, Donut 2	17.5	35	87.5	175	350	700
External Diameter, Donut 2	22.5	45	112.5	225	450	900
Internal Diameter, Donut 3	27.5	55	137.5	275	550	1100
External Diameter, Donut 3	32.5	65	162.5	325	650	1300
Internal Diameter, Donut 4	37.5	75	187.5	375	750	1500
External Diameter, Donut 4	42.5	85	212.5	425	850	1700
Internal Diameter, Donut 5	47.5	95	237.5	475	950	1900
External Diameter, Donut 5	52.5	105	262.5	525	1050	2100
Internal Diameter, Donut 6	57.5	115	287.5	575	1150	2300
External Diameter, Donut 6	62.5	125	312.5	625	1250	2500
Opaque Linewidth	5	10	25	50	100	200

Concentric Squares

Patterns (1-6)F

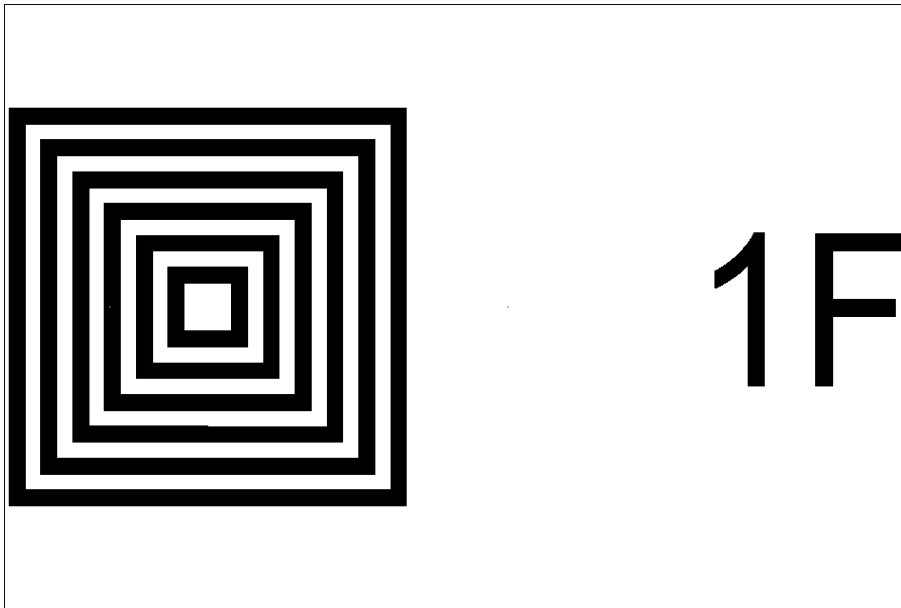


Figure 6: Pattern (1-6)F

Pattern (1-6)F, as shown in Figure 8, comprises 6 concentric squares. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1F	Pattern 2F	Pattern 3F	Pattern 4F	Pattern 5F	Pattern 6F
Internal Width, Square 1	7.5	15	37.5	75	150	300
External Width, Square 1	12.5	25	62.5	125	250	500
Internal Width, Square 2	17.5	35	87.5	175	350	700
External Width, Square 2	22.5	45	112.5	225	450	900
Internal Width, Square 3	27.5	55	137.5	275	550	1100
External Width, Square 3	32.5	65	162.5	325	650	1300
Internal Width, Square 4	37.5	75	187.5	375	750	1500
External Width, Square 4	42.5	85	212.5	425	850	1700
Internal Width, Square 5	47.5	95	237.5	475	950	1900
External Width, Square 5	52.5	105	262.5	525	1050	2100
Internal Width, Square 6	57.5	115	287.5	575	1150	2300
External Width, Square 6	62.5	125	312.5	625	1250	2500
Opaque Linewidth	5	10	25	50	100	200

Clear Square Arrays

Pattern (1-6)G

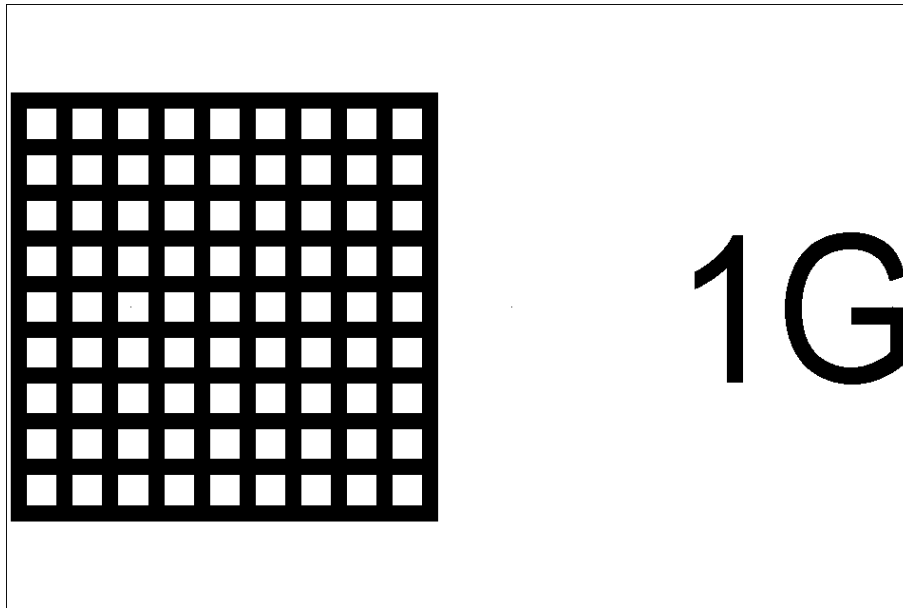


Figure 7: Pattern (1-6)G

Pattern (1-6)G is a mono-sized array of 81 clear squares, separated by an opaque grid. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1G	Pattern 2G	Pattern 3G	Pattern 4G	Pattern 5G	Pattern 6G
Opaque Linewidth	2.5	5	12.5	25	50	100
Opaque Pitch (C-C)	7.5	15	37.5	75	150	300
Clear Square Width	5	10	25	50	100	200
Opaque Pattern Width	70	140	350	700	1400	2800

Opaque Square Arrays

Pattern (1-6)H

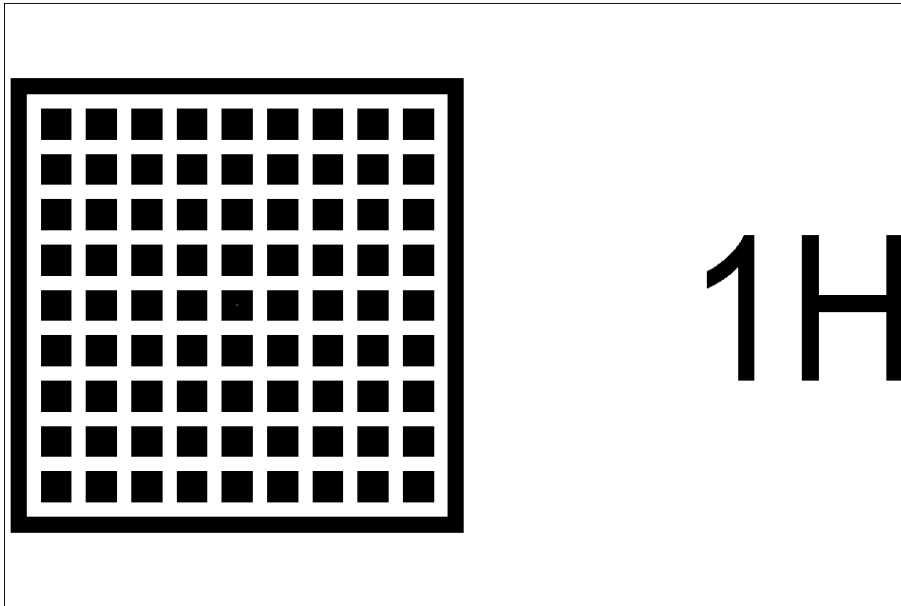


Figure 8: Pattern (1-6)H

Pattern (1-6)H is a mono-sized array of 81 opaque squares, separated by a clear grid. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1H	Pattern 2H	Pattern 3H	Pattern 4H	Pattern 5H	Pattern 6H
Clear Linewidth	2.5	5	12.5	25	50	100
Clear Pitch (C-C)	7.5	15	37.5	75	150	300
Opaque Square Width	5	10	25	50	100	200
Clear Pattern Width	70	140	350	700	1400	2800

Opaque Elliptical Arrays

Pattern (1-6)I

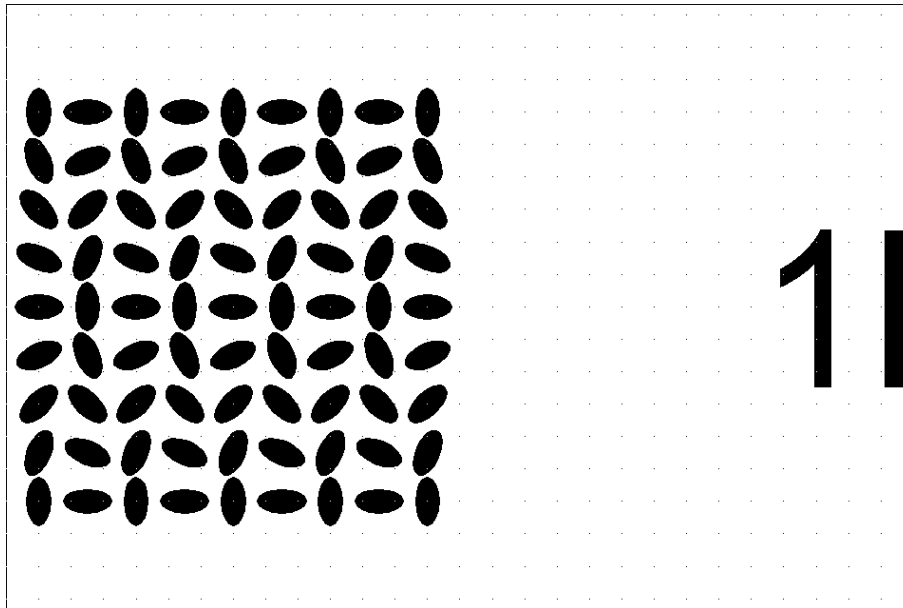


Figure 9: Pattern (1-6)I

Figure 5 shows Pattern (1-6)I, which consists of 81 ellipses. The ellipses have an aspect ratio of 2. Starting from the first row, each ellipse is rotated by 22.5° along the horizontal axis, through a total of 180° . The second row is rotated by 90° and the subsequent rows are repeats of the first two. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1I	Pattern 2I	Pattern 3I	Pattern 4I	Pattern 5I	Pattern 6I
Major Axis	7.5	15	37.5	75	150	300
Minor Axis	3.75	7.5	18.75	37.5	75	150
C-C Pitch	7.5	15	37.5	75	150	300

Opaque Spot Arrays

Pattern (1-6)J

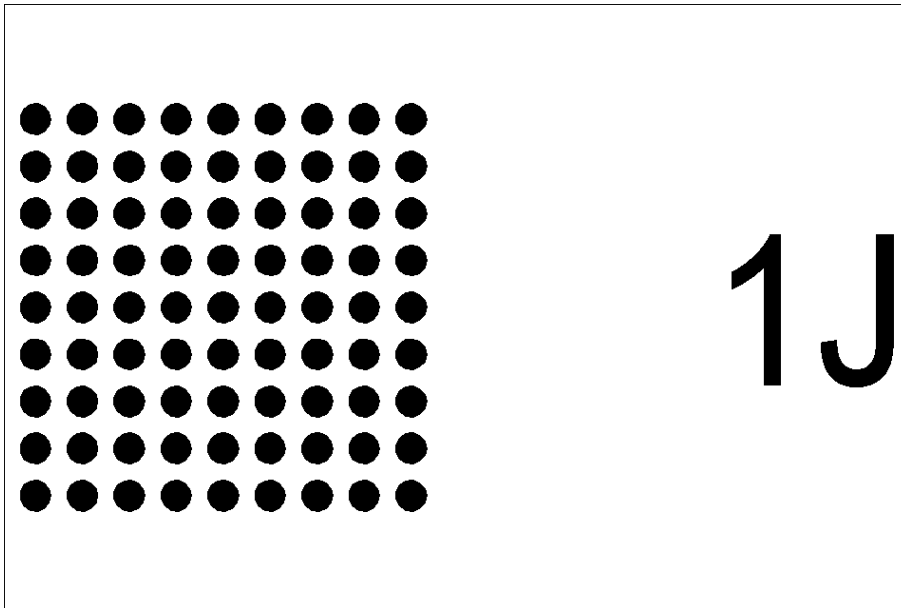


Figure 10: Pattern (1-6)J

Figure 10 shows Pattern (1-6)J, consisting of a 9x9 array of monosize spots. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1J	Pattern 2J	Pattern 3J	Pattern 4J	Pattern 5J	Pattern 6J
Diameter	5	10	25	50	100	200
C-C Pitch	7.5	15	37.5	75	150	300

Opaque Log-Normal Arrays

Pattern (1-6)K

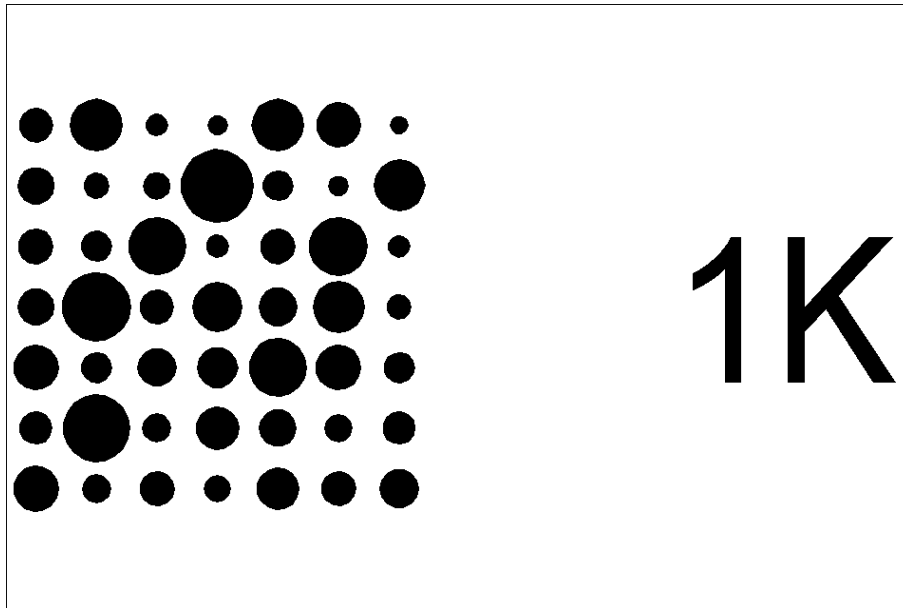


Figure 11: Pattern (1-6)K

Figure 11 shows Pattern (1-6)K, which consists of 49 spots forming a log normally distributed array. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1K	Pattern 2K	Pattern 3K	Pattern 4K	Pattern 5K	Pattern 6K
Minimum Diameter	3	6	15	30	60	120
Maximum Diameter	12	24	60	120	240	480
C-C Pitch	10	20	50	100	200	400

Clear Spot Arrays

Pattern (1-6)L

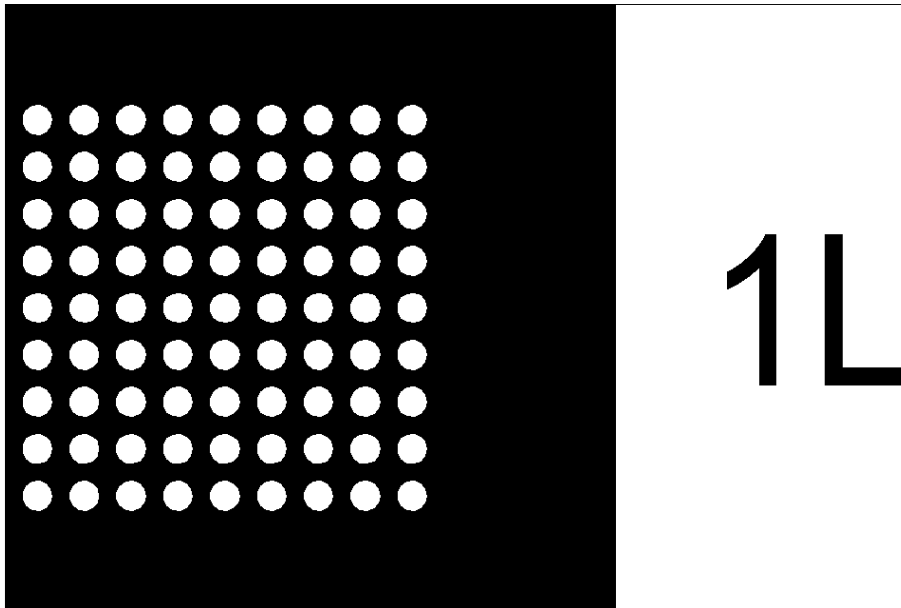


Figure 12: Pattern (1-6)L

Figure 12 shows Pattern (1-6)L, consisting of a 9x9 array of clear monosize spots. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1J	Pattern 2J	Pattern 3J	Pattern 4J	Pattern 5J	Pattern 6J
Diameter	5	10	25	50	100	200
C-C Pitch	7.5	15	37.5	75	150	300

Clear Log-Normal Arrays

Pattern (1-6)M

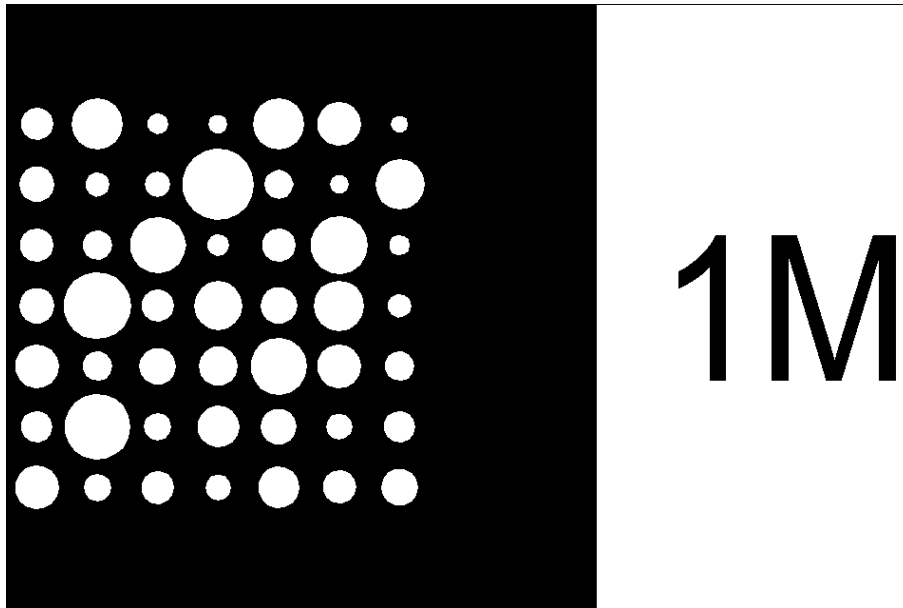


Figure 13: Pattern (1-6)M

Figure 11 shows Pattern (1-6)M, which consists of 49 clear spots forming a log normally distributed array. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1K	Pattern 2K	Pattern 3K	Pattern 4K	Pattern 5K	Pattern 6K
Minimum Diameter	3	6	15	30	60	120
Maximum Diameter	12	24	60	120	240	480
C-C Pitch	10	20	50	100	200	400

Root-2 Progressions

Pattern (1-6)N

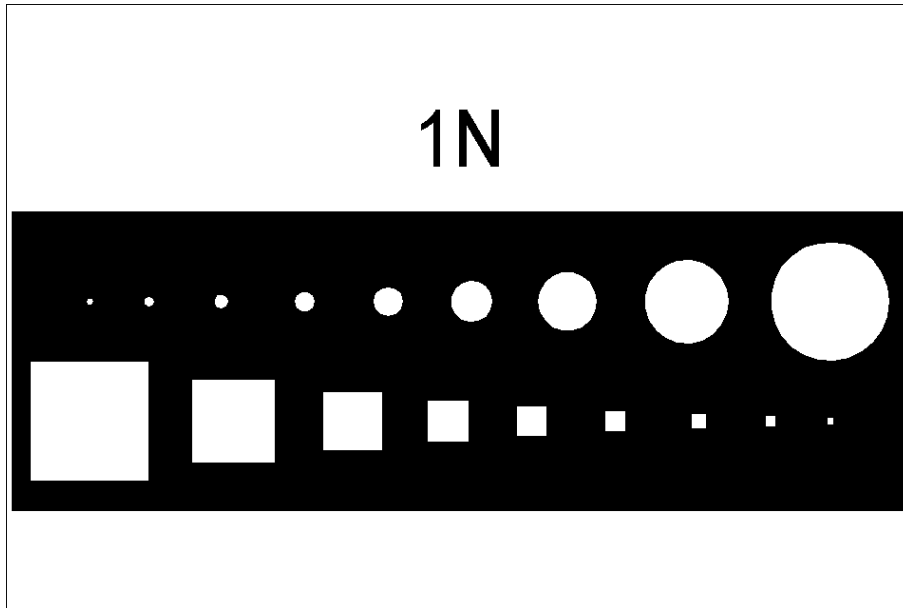


Figure 14: Pattern (1-6)N

Pattern (1-6)N, as shown in Figure 14, consists of a Root-2 progression of clear spots and a progression of clear squares with nominally the same dimensions as the spot diameters. Each pattern, 1-6, has the following nominal dimensions:

Feature	Pattern 1N	Pattern 2N	Pattern 3N	Pattern 4N	Pattern 5N	Pattern 6N
Spot 1 Diameter/ Square 1 Width	50.000	100.000	250.000	500.000	1000.000	2000.000
Spot 2 Diameter/ Square 2 Width	35.355	70.711	176.777	353.553	707.107	1414.214
Spot 3 Diameter/ Square 3 Width	25.000	50.000	125.000	250.000	500.000	1000.000
Spot 4 Diameter/ Square 4 Width	17.678	35.355	88.388	176.777	353.553	707.107
Spot 5 Diameter/ Square 5 Width	12.500	25.000	62.500	125.000	250.000	500.000
Spot 6 Diameter/ Square 6 Width	8.839	17.678	44.194	88.388	176.777	353.553
Spot 7 Diameter/ Square 7 Width	6.250	12.500	31.250	62.500	125.000	250.000
Spot 8 Diameter/ Square 8 Width	4.419	8.839	22.097	44.194	88.388	176.777
Spot 9 Diameter/ Square 9 Width	3.125	6.250	15.625	31.250	62.500	125.000

Pattern (1-6)R is the positive copy of pattern (1-6)N, with the same nominal dimensions.

Star Test Pattern

Patterns (1-6)O

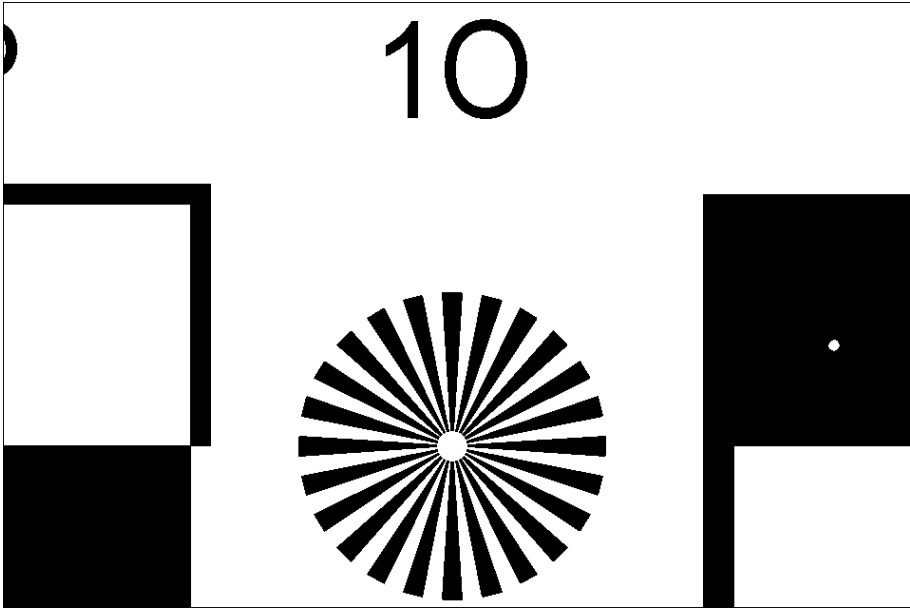


Figure 15: Pattern (1-6)O

Figure 15 shows Pattern (1-6)O, a star target. This consists of 24 7.5° opaque wedges designed as a test pattern for identifying focus error, astigmatism and resolution. There will be no calibration performed on this feature.

Feature	Pattern 1F	Pattern 2F	Pattern 3F	Pattern 4F	Pattern 5F	Pattern 6F
Minimum Wedge Separation	0.5	1	2.5	5	10	20
Maximum Wedge Separation	5	10	25	50	100	200
Pattern Diameter (Approx.)	76.55	153.1	382.75	765.5	1531	3062

Chequered Patterns

Patterns (1-6) P and Q

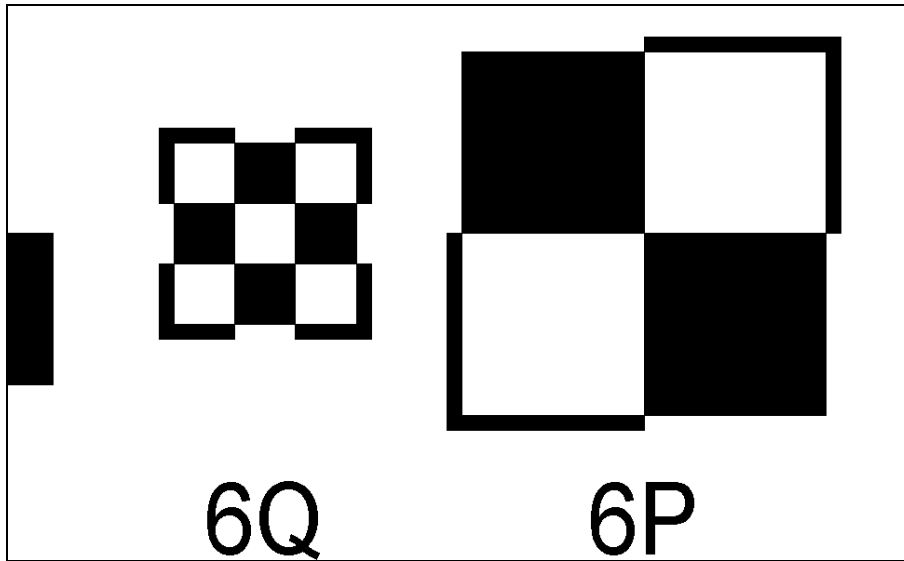


Figure 16: Patterns (1-6)P and (1-6)Q

Figure 16 shows the chequered patterns, (1-6)P and (1-6)Q, consisting of clear and opaque squares of nominally the same dimensions.

Feature	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6
Pattern P square dimensions	62.5	125	312.5	625	1250	2500
Pattern Q square dimensions	20	40	100	200	400	800

Linear Scales and X-Y Calibration Grid

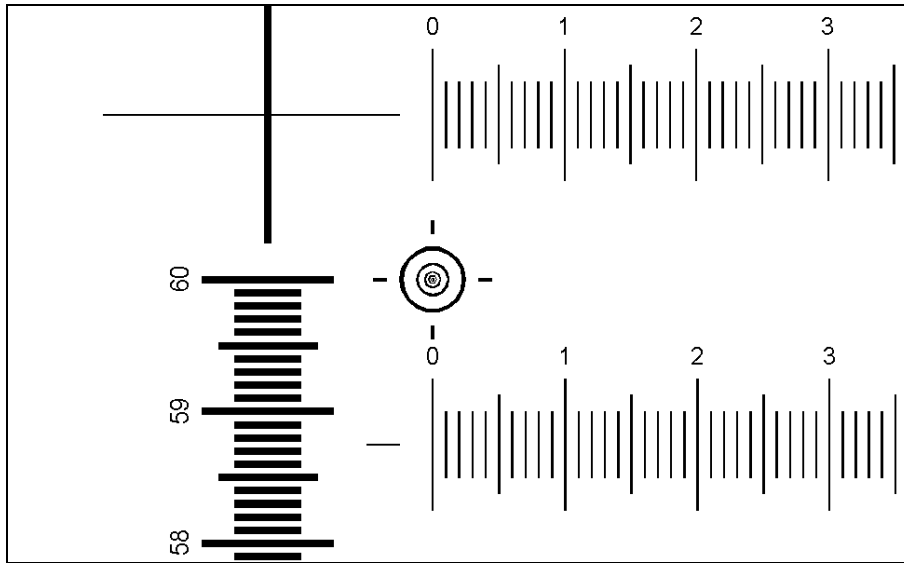


Figure 17: Optical Scales

The mask contains 6 linear optical scales, 4 horizontal and two vertical. The innermost horizontal scales have been designed with a sinusoidal error. All the scales are 60 mm in length. Three of the scales have a nominal line width of 50 μm and the others 10 μm . Every tenth line is 1 mm long and numbered from 1-60. The nominal pitch is 100 μm and the fifth line between each numbered line is 0.75 mm long.

Figure 17 also shows one of the 49 targets forming the 60 mm x 60 mm X-Y calibration pattern. Each target consists of concentric circles, designed so that the pattern may be used at different magnifications. The nominal pitch between targets is 10 mm, in both the X and Y axes.