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Sill Optics Correctal T30/2.0 and Optotune EL-16-40 for fast focusing

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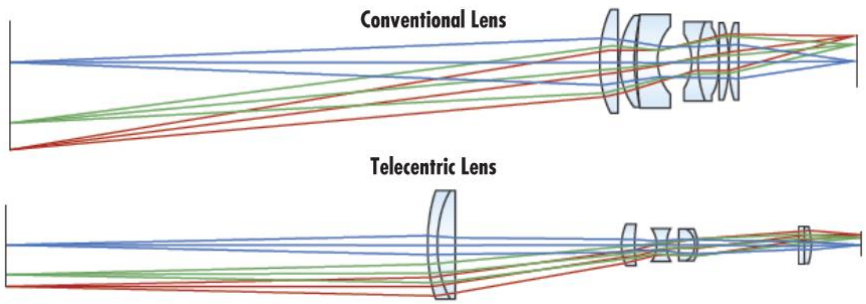
About telecentric lenses

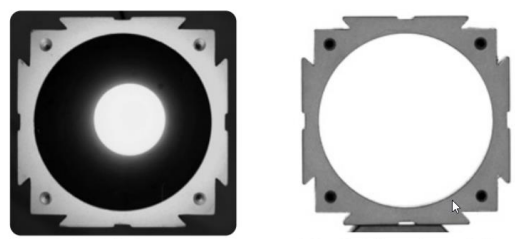
Telecentric lenses only accept incoming ray bundles that are parallel to the optical axis



Main benefits:

Constant magnification

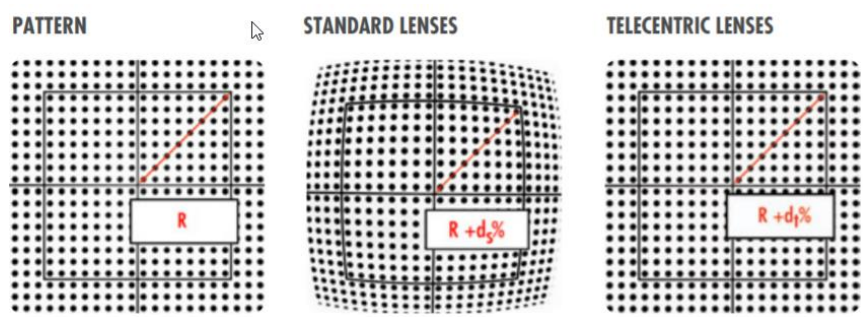
No perspective error



Common optics showing significant image perspective error.

A telecentric lens is able to cancel any perspective effect.

Nearly zero image distortion



Images courtesy of Edmund Optics

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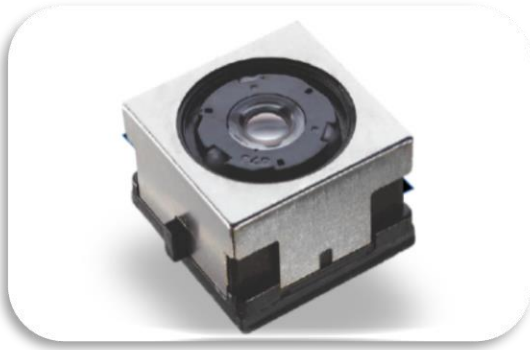
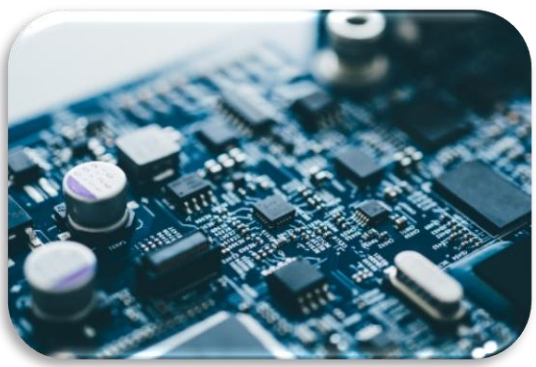
Application examples of telecentric lens + liquid lens

Contact lens inspection

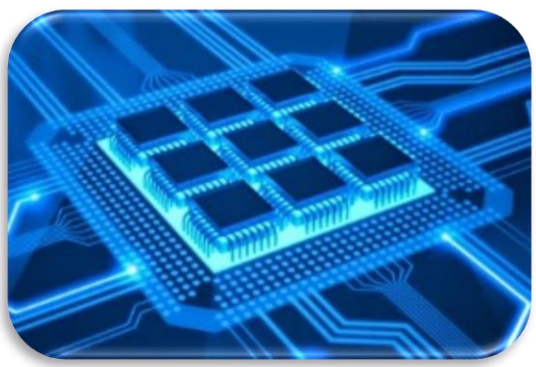


Camera phone lens inspection

And many more applications where the depth of field (DoF) of a telecentric lens is not large enough



Electronics inspection



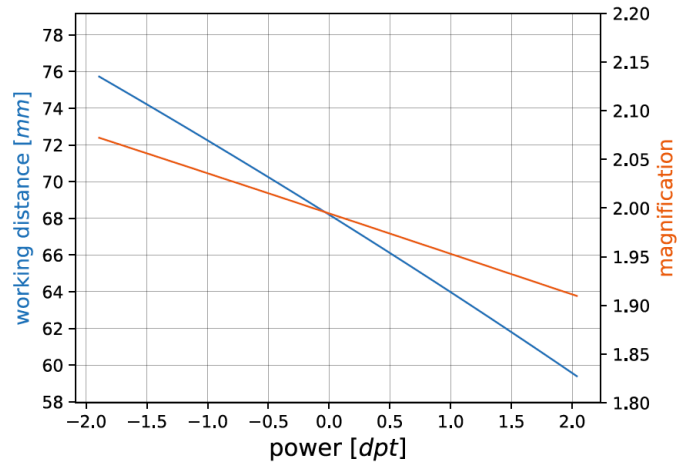
IC inspection

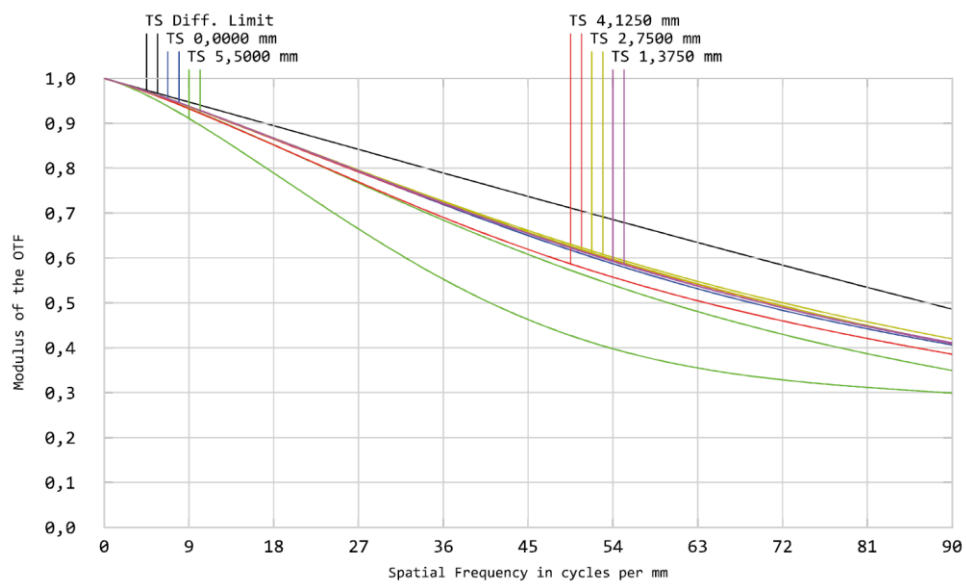
Test report summary

- Up to 20mm working distance range
  - Recommended range is 8mm
- High resolution of up to 127 lp/mm
  - Same as without any liquid lens
  - Best performance at 66% iris setting
- Resolution stays constant across the field
- Very good polychromatic performance
  - Performance very similar between white and red backlights

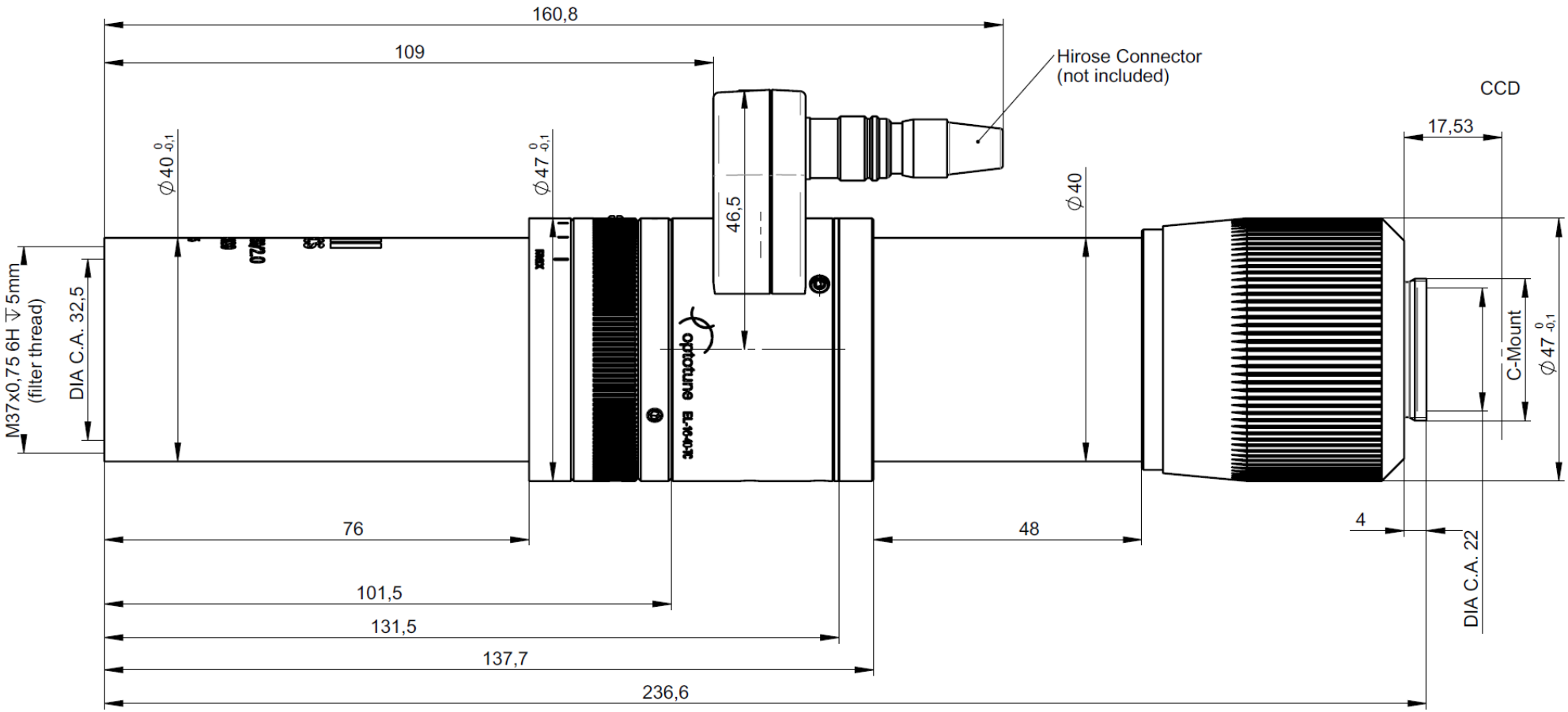
Main specifications

specifications	
article number	S5VPJ6420
wavelength range [nm]	450-700
design wavelength [nm]	450 - 700
nominal magnification (+/-5%	2.000
nominal working dist. [mm] (+/-2%)	68.2
object size [mm] at a chip size of [mm]	4.4 x 3.3 8.8 x 6.6 (2/3“)
object size [mm] at a chip size of [mm]	6.4 x 4.8 12.8 x 9.6 (1“)
object size [mm] at a chip size of [mm]	7.1 x 5.3 14.1 x 10.6 (1.1“)
max. distortion [%]	0.16
max. telecentricity error [°]	0.03
recommended numerical aperture	0.120
WD at +3.0 dpt	55.4
magn. at +3.0 dpt	1.87
WD at -2.0 dpt	76.3
magn. at -2.0 dpt	2.08
weight [kg]	not yet weighed
flange back distance [mm]	17.53

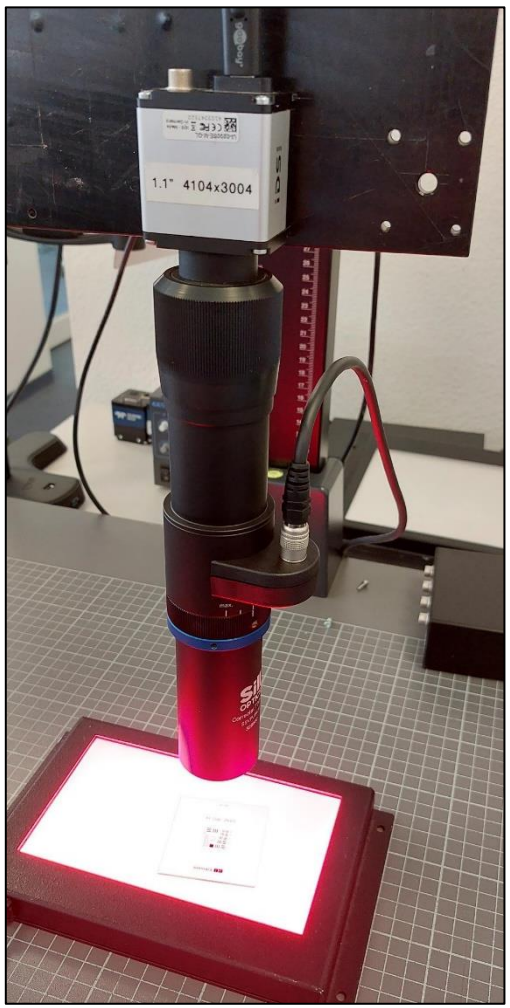




Mechanical drawing

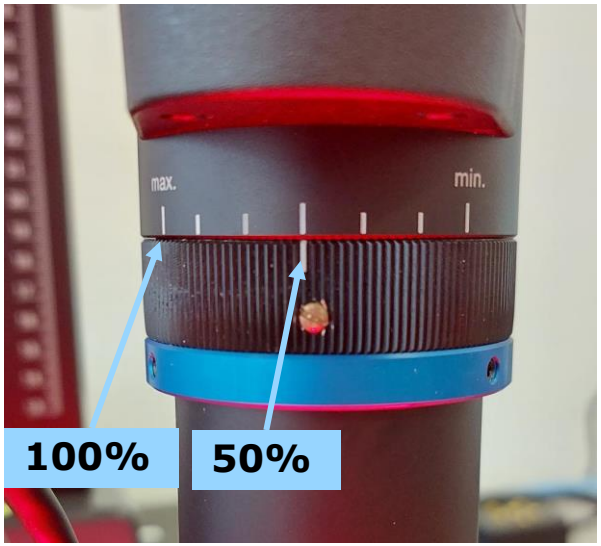


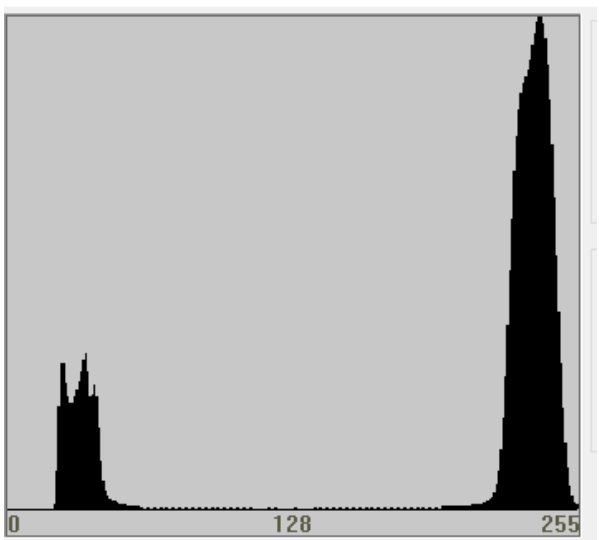
Test setup



Camera:	1" IDS 4104 x 3004 pixels 3.45 um pixel size
Lens:	Sill Optics Correctal T30/2.0
Tunable lens:	EL-16-40-TC-VIS-5D-1-C (class 1) S/N: ANAA4004 WFE @ 0 mA = 0.05 λ RMS @532 nm
Controller:	ICC-4C
Target:	Transparent USAF target
Light:	Red/white backlight
Optical axis:	Vertical

Test setup



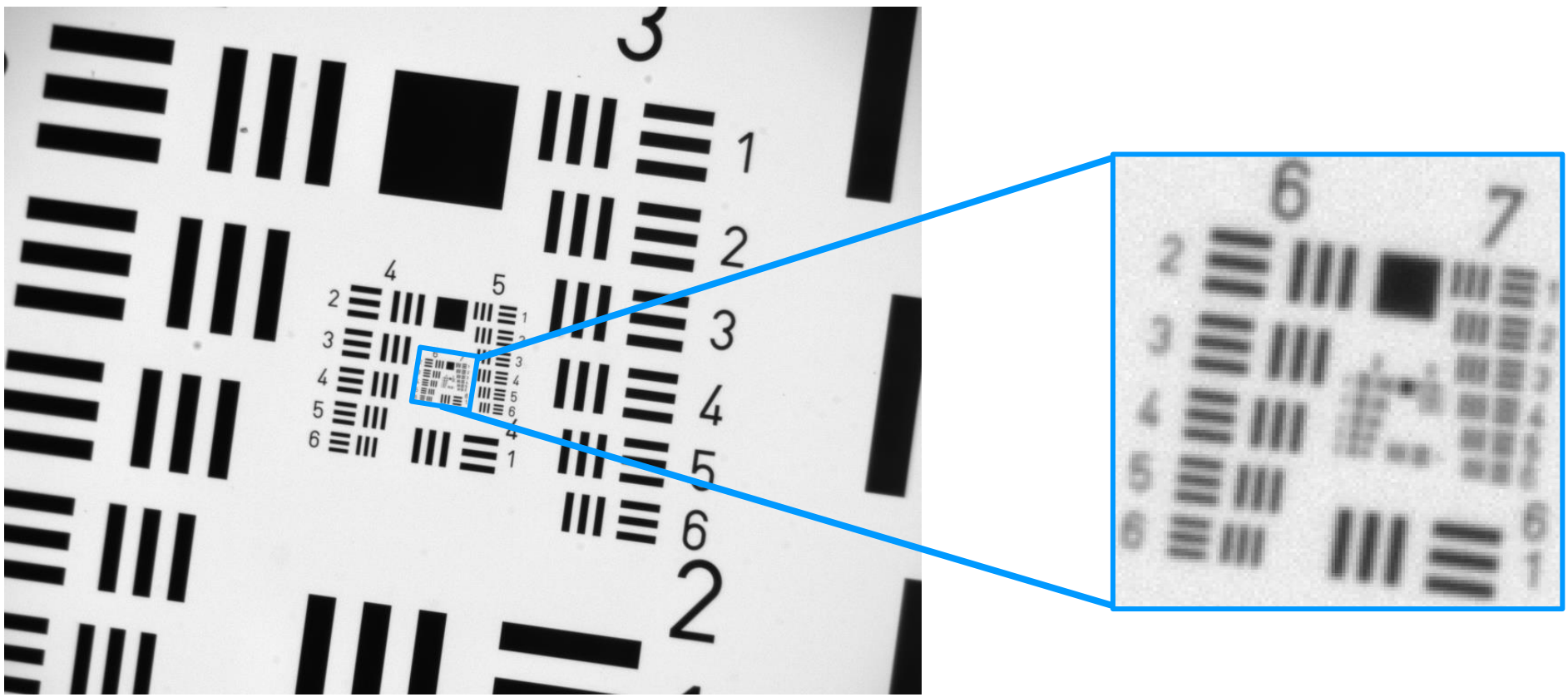


➢The variable iris was adjusted at different aperture levels

➢The exposure time was then adjusted accordingly in order to maximize dynamic range

Method for image evaluation

- After acquisition, images are zoomed in to show resolution limited element



Adding the liquid lens does not change performance

Camera

Sensor size = 4104x3004 pixels

Nyquist limit = 145 lp/mm

Pixel size = 3.45 um

Exposure time = 10ms

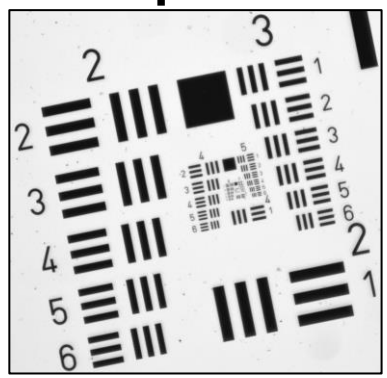
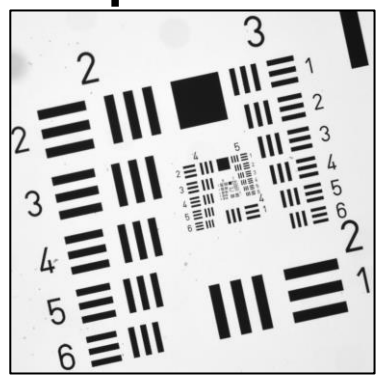
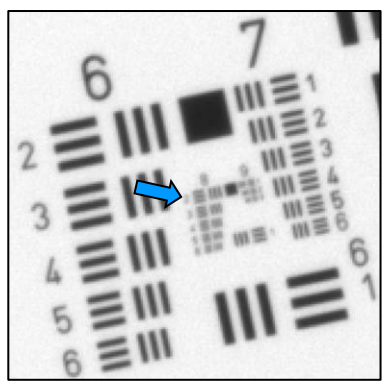
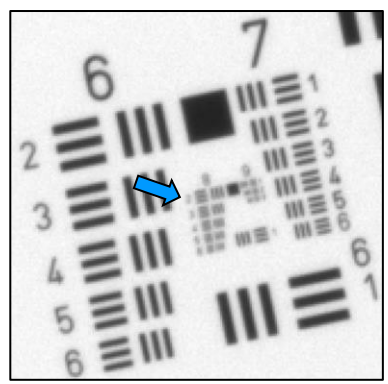
Lens

0 dpt (68mm WD)

Iris fully open

Light

Red background illumination

	No Liquid Lens	Liquid Lens
		
		
USAF element:	8/1	8/1
Line width (um):	1.95	1.95
Lp/mm (object):	256	256
Magnification:	2.026	2.026
Lp/mm (image):	**127**	**127**

optotune

Center only @ 0 dpt, white light, 68 mm WD

Camera

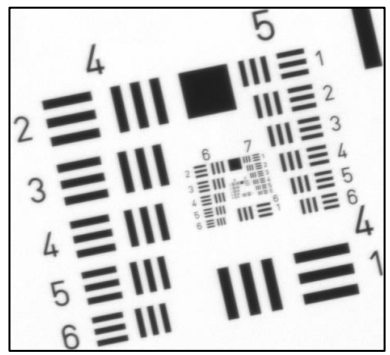
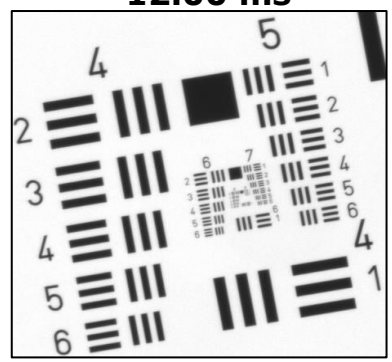
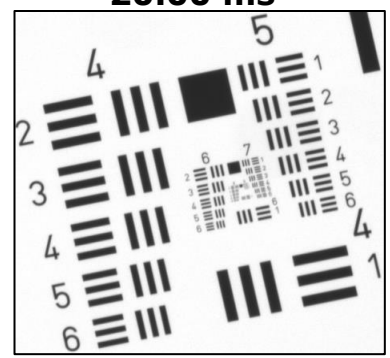
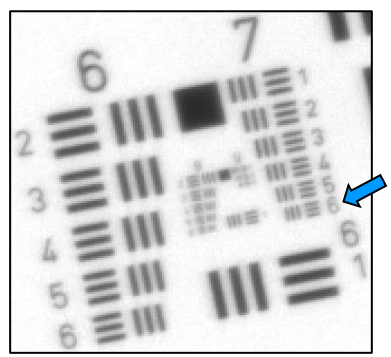
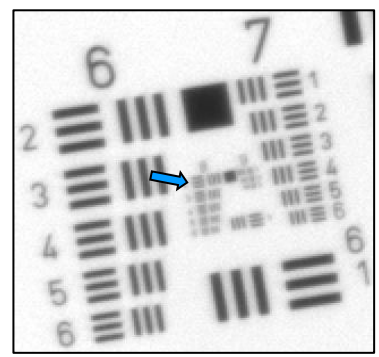
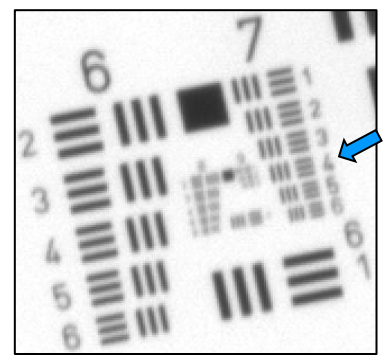
Sensor size = 4104x3004 pixels

Nyquist limit = 145 lp/mm

Pixel size = 3.45 um

Light

White background illumination

	Max aperture 11.00 ms	66% Iris 12.00 ms	50% Iris 20.00 ms
			
			
USAF element:	7/6	8/1	7/4
Line width (um):	2.19	1.95	2.76
Lp/mm (object):	228	256	181
Magnification:	2.026	2.026	2.026
Lp/mm (image):	**113**	**127**	**89**

optotune

Center only @ 0 dpt, Red light, 68 mm WD
Vertical Optical Axis

Camera

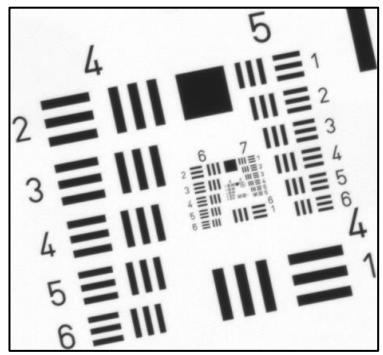
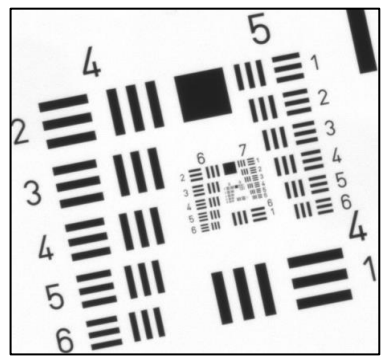
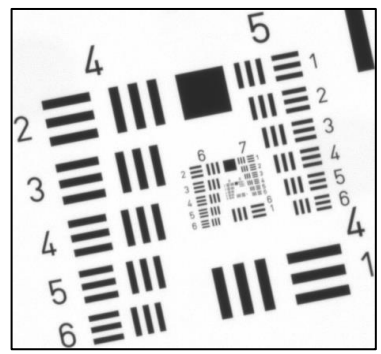
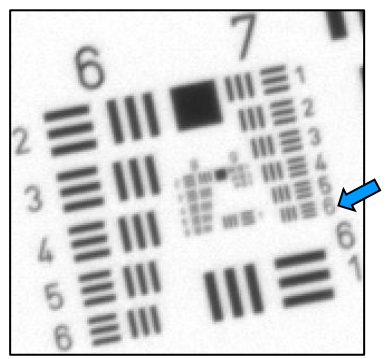
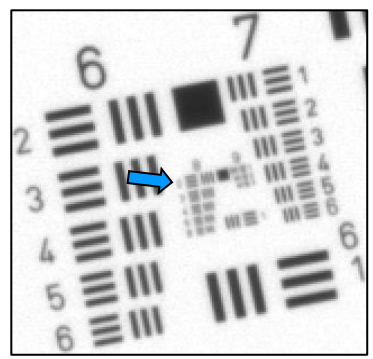
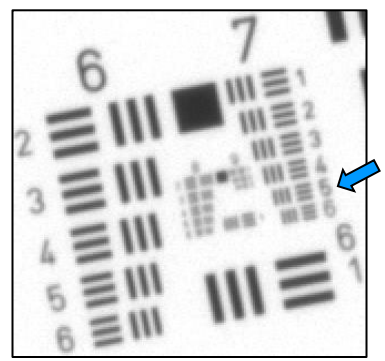
Sensor size = 4104x3004 pixels

Nyquist limit = 145 lp/mm

Pixel size = 3.45 um

Light

Red background illumination

	Max aperture 8.90 ms	66% aperture 10.00 ms	50% Iris 16.00 ms
			
			
USAF element:	7/6	8/1	7/5
Line width (um):	2.19	1.95	2.46
Lp/mm (object):	228	256	203
Magnification:	2.026	2.026	2.026
Lp/mm (image):	**113**	**127**	**100**

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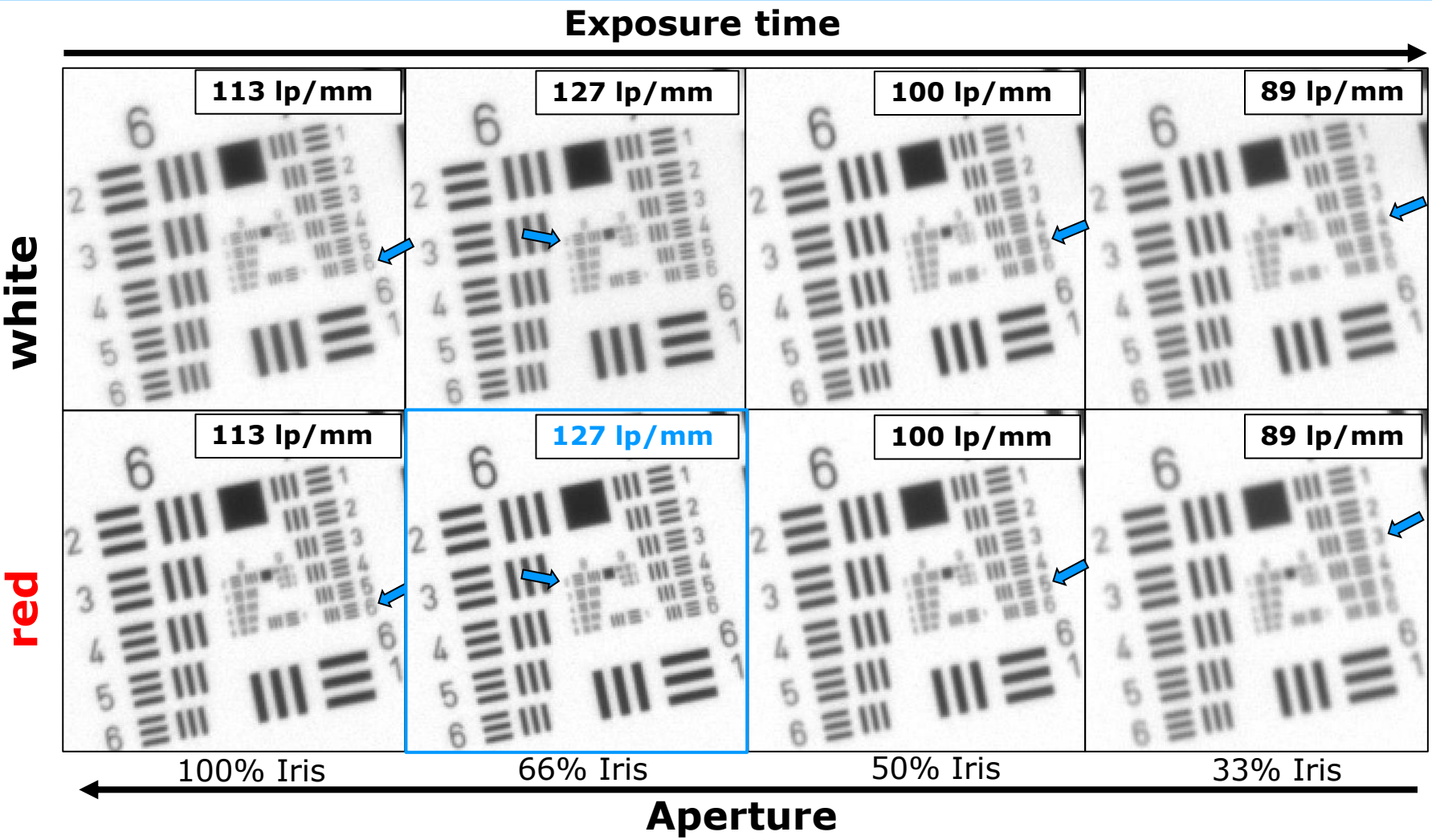
Best performance with red backlight and 66% open iris



0 dpt, Red light, 68 mm WD

Camera

Sensor size = 4104x3004 pixels

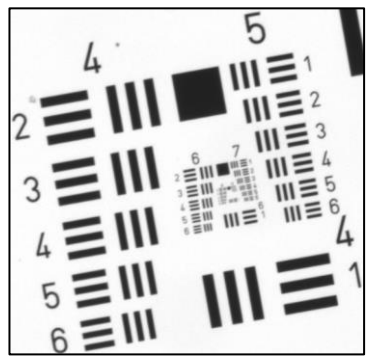
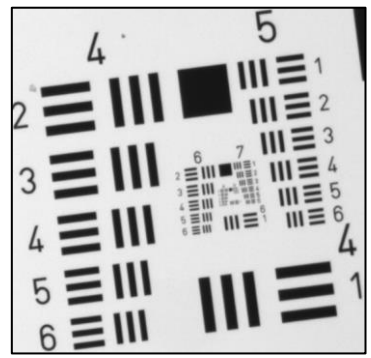
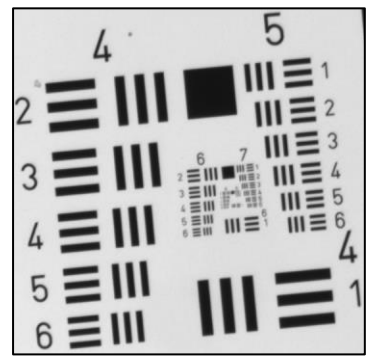
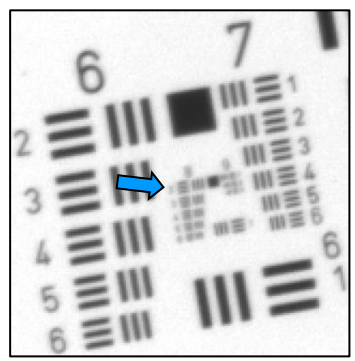
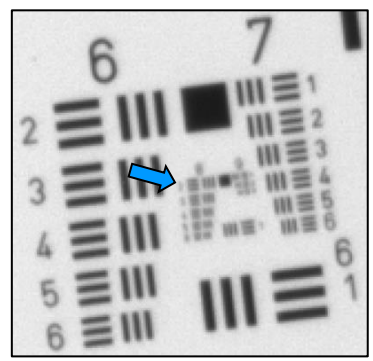
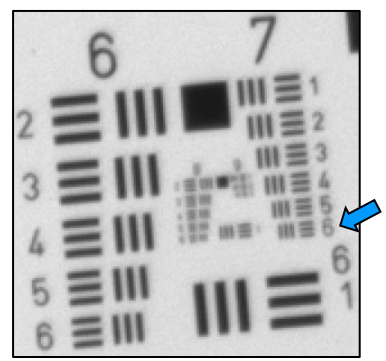
Nyquist limit = 145 lp/mm

Pixel size = 3.45 um

Exposure time = 10ms

Light

Red background illumination

	Center	Edge	Corner
			
			
USAF element:	8/1	8/1	7/6
Line width (um):	1.95	1.95	2.19
Lp/mm (object):	256	256	228
Magnification:	2.026	2.026	2.026
Lp/mm (image):	**127**	**127**	**113**

optotune

-1 dpt, Red light, 72 mm WD

Camera

Sensor size = 4104x3004 pixels

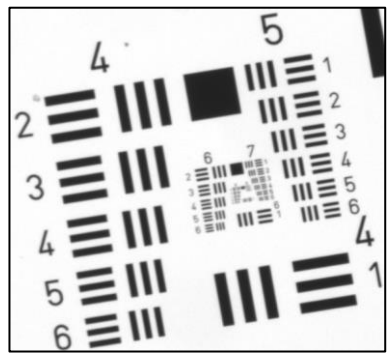
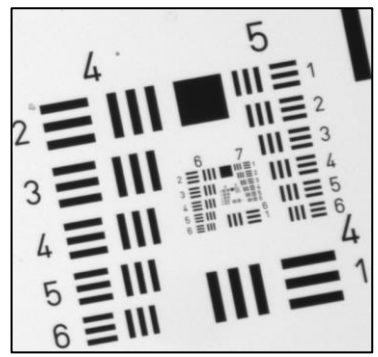
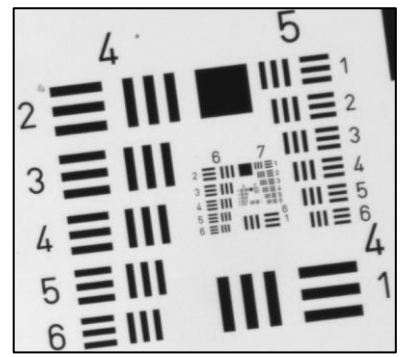
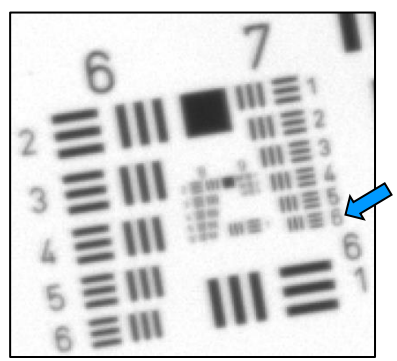
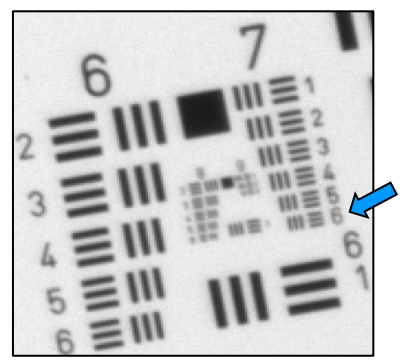
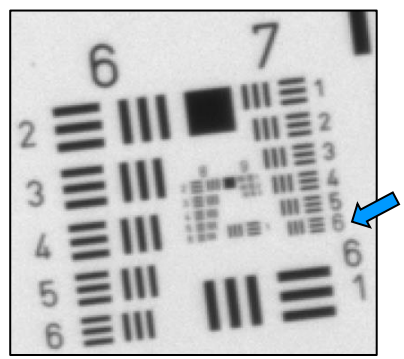
Nyquist limit = 145 lp/mm

Pixel size = 3.45 um

Exposure time = 10ms

Light

Red background illumination

	Center	Edge	Corner
			
			
USAF element:	7/6	7/6	7/6
Line width (um):	2.19	2.19	2.19
Lp/mm (object):	228	228	228
Magnification:	2.026	2.026	2.026
Lp/mm (image):	**113**	**113**	**113**

optotune

+1 dpt, Red light, 64 mm WD

Camera

Sensor size = 4104x3004 pixels

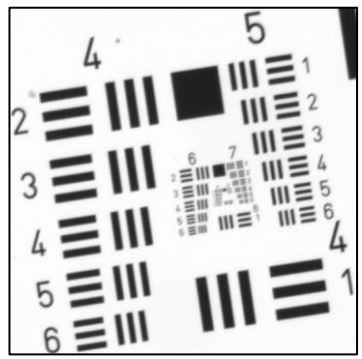
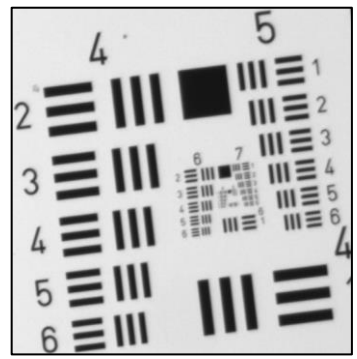
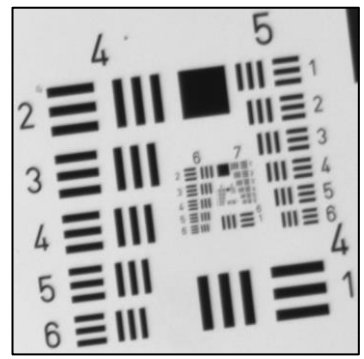
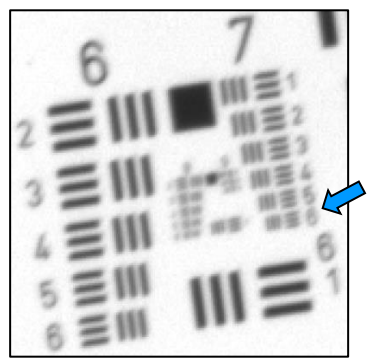
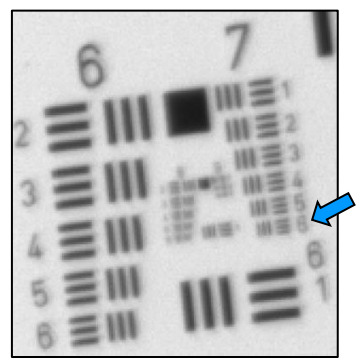
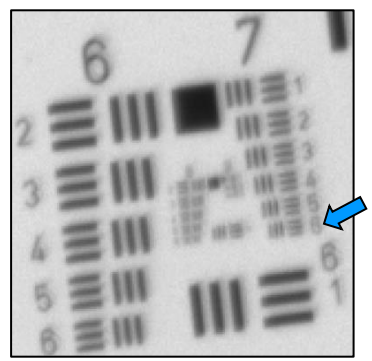
Nyquist limit = 145 lp/mm

Pixel size = 3.45 um

Exposure time = 10ms

Light

Red background illumination

	Center	Edge	Corner
			
			
USAF element:	7/6	7/6	7/6
Line width (um):	2.19	2.19	2.19
Lp/mm (object):	228	228	228
Magnification:	2.026	2.026	2.026
Lp/mm (image):	**113**	**113**	**113**

optotune

Performance remains good across the field and working distance range

Red backlight,
10 ms exposure time