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Optotune ELM-50-5.6-18-C

Test report

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Summary

- **Working distance (WD) range of 200mm-Inf**
- **Performance close to the Nyquist rate of 2.74µm pixel size**
  Resolution >150 lp/mm for WD range of >300 across the field
  Resolution >180 lp/mm under certain conditions
- **For short WDs (<300mm) a 5mm spacer is recommended**
- **Very negligible field curvature and distortion**
  Magnification and resolutions stays constant across the field
- **Very negligible vignetting (<2%)**
- **Resolution degrades (~10%) due to the gravity-coma for horizontal optical axis**
- **Very good polychromatic performance**
  Performance very similar between white and blue backlights

ELM-35-5.6-18-C Datasheet

Lens module specifications

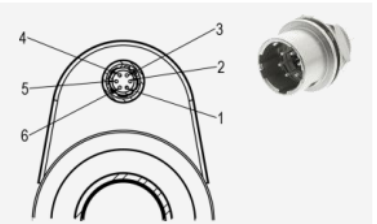
		EL-12-30-TC-VIS-16D	EL-7-20-TC-VIS-14D	
Effective focal length		46.4		mm
F/# (fixed)		3.5	5.6	
Maximum sensor format		1.1		inch
Maximum image circle (Φ)		18		mm
Lifecycles (10-90% sinusoidal)		>1'000'000'000		cycles
FOV for 1.1" sensor	Diagonal	20.3		°
	Horizontal	14.5		°
	Vertical	14.5		°
Back focal length (BFL)		10.08		mm (in air)
Optical distortion		<2.0		%
Pixel size (recommended)		2.74		µm
Wavelength range		420-900		nm
Relative illumination		>94	>94	%
Max chief ray angle		8.0		°
Working distance (WD) range[1]		200 to inf		mm
Optimal WD		600		mm
WD at 0 dpt		1000		mm
Mount		C-mount		
Filter thread		M55x0.5		
Connector type		Hirose (6 pins)		
Total track length (TTL)		91.1		mm
Dimension (Φ x L)		47.0 x 81.0		mm
Weight		289		g
Operating temperature		-20 to +65		°C
Storage temperature		-40 to +85		°C

Focus tunable lens specifications

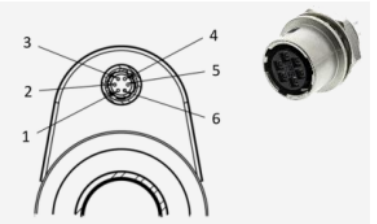
	EL-12-30-TC-VIS-16D	EL-7-20-TC-VIS-14D	
Focal power range (@25°C)	-6 to +10	-6 to +8	dpt
Focal power range for module WD range	-2.0 to 4.2		dpt
Temperature sensor and EEPROM	Yes		
Control current (typical)	-250 to +250		mA
Max. control current	-300 to +300		mA
Motor coil resistance @ 30°C	15	12	Ω
Absolute maximum voltage (coil)	6	6	V

Electrical layout

Hirose connector (HR10G-7R-6PB)	Function	Sensor pins
Pin 1	Control current +	-
Pin 2	Control current -	-
Pin 3	Ground	1-4
Pin 4	Vcc (3.0-3.7V)	8
Pin 5	I²C SCL	6
Pin 6	I²C SDA	5



Hirose connector (HR10G-7R-6SB)	Function	Value
Pin 1	GPIO Trigger	-
Pin 2	Analog In	0-10V
Pin 3	UART Tx / I²C SCL	TTL
Pin 4	UART Rx / I²C SDA	TTL
Pin 5	GND	-
Pin 6	Vcc	5-24V



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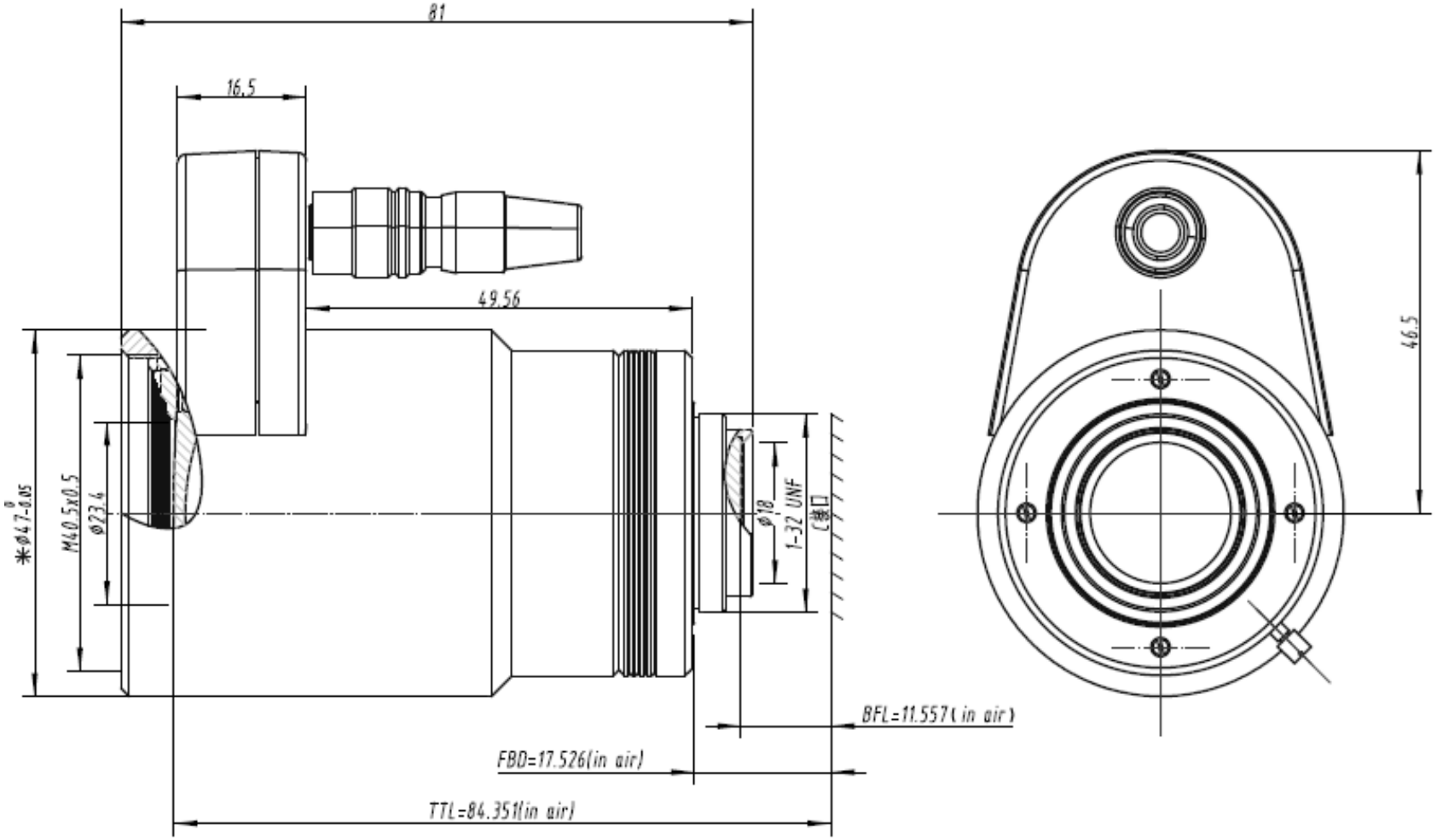
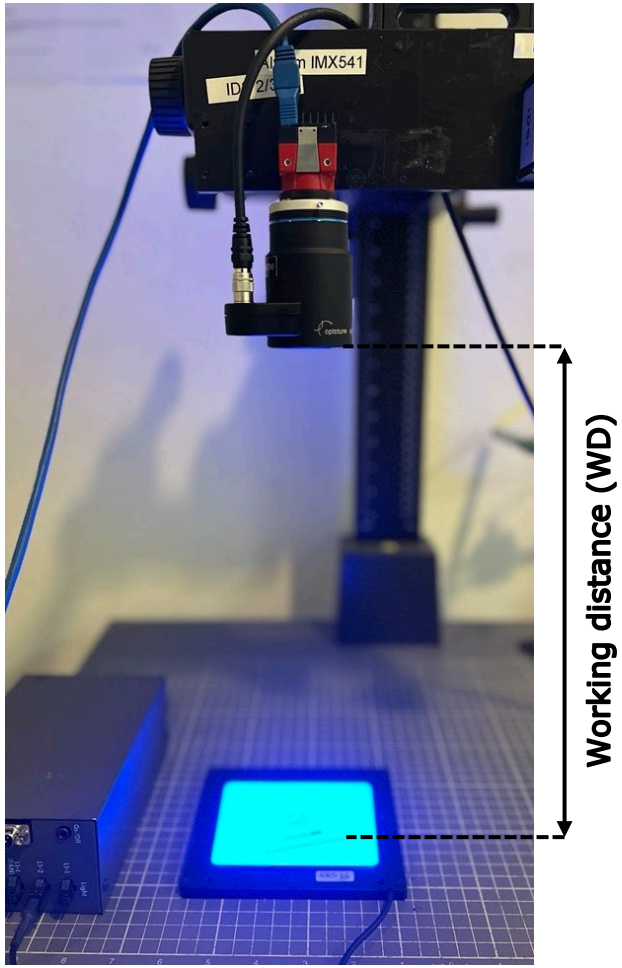
Mechanical drawing



Test Setup

Camera:	Alvium 1800 C-2040 1.1" 4512 x 4512 px Pixel size = 2.74 µm Nyquist rate = 182 lp/mm C-mount
Lens:	ELM-50-5.6-18-C
Tunable lens:	EL-7-20-TC-VIS SN: DHAA0142
Orientation:	Vertical Optical Axis
Driver:	ECC-1C SN:CXAB0235, FW: 2.0.741433
Target:	USAF chrome target, positive
Light:	White backlight (LED1-FLS-110x110W) Blue backlight



Field of view with 1.1” sensor

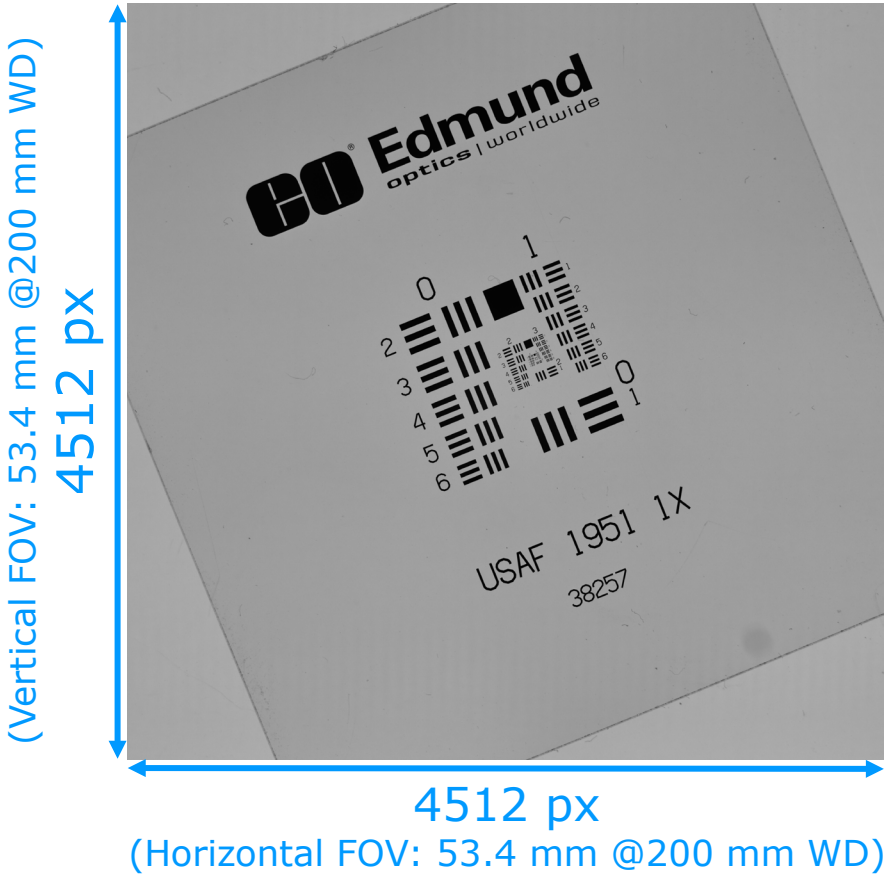
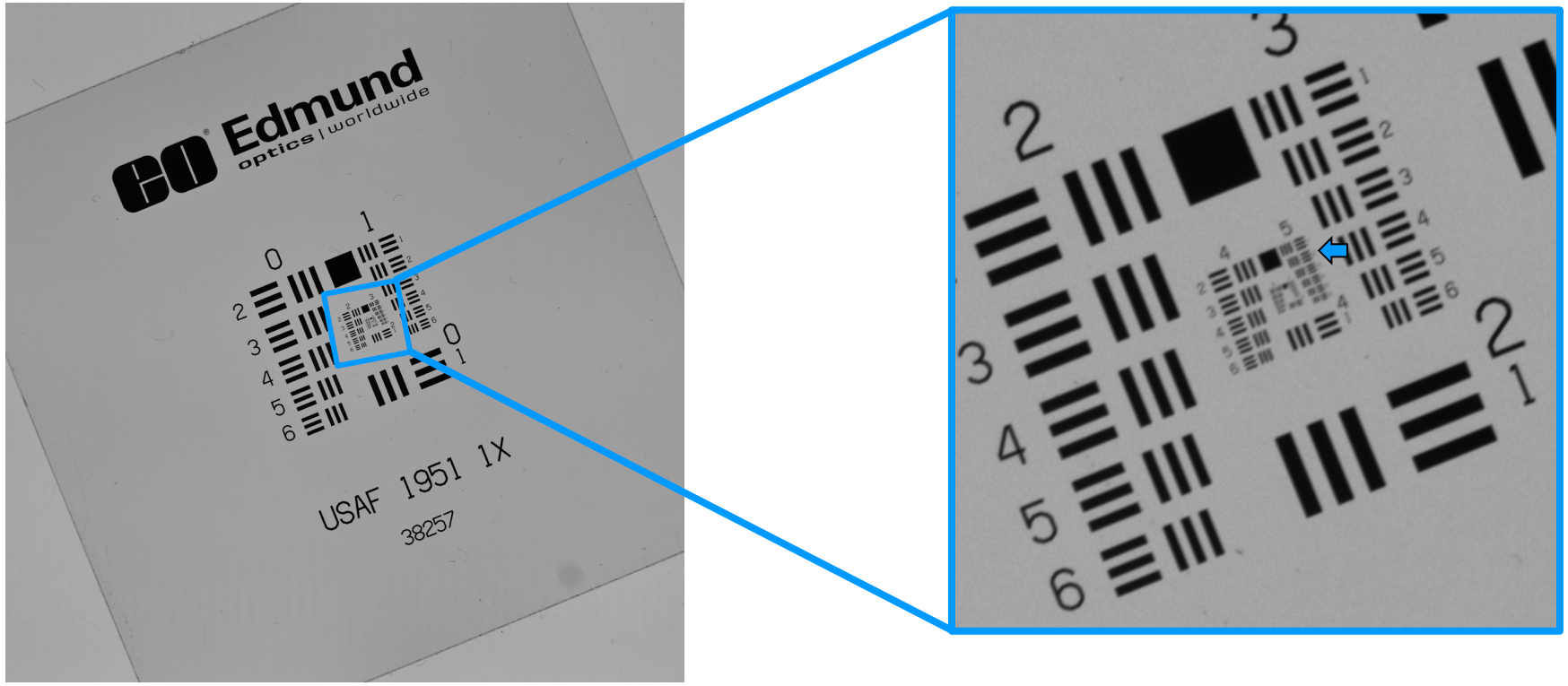


Image size (2.74 µm pixel size):

- Width = 12.4 mm
- Height = 12.4 mm
- Diagonal = 17.5 mm

Image evaluation

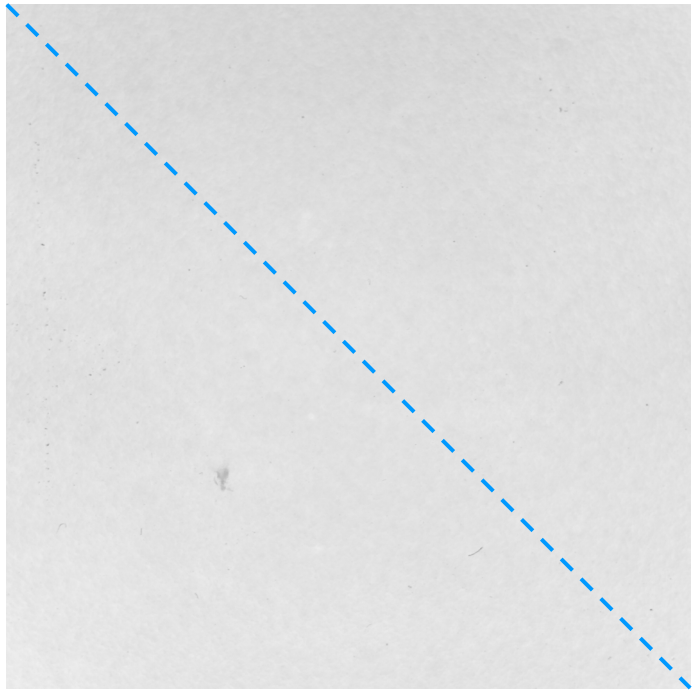
- All the images are taken at Gain 0, and without gamma correction
- The intensity of illumination is controlled to adjust the histogram of the images
- After acquisition, images are zoomed in to show the resolution-limited element



Relative illumination

- Vignetting of this ELM is 0.03EV (2%) for 1.1” sensor
- A 5mm spacer is used for the test at 200mm
- There is a negligible dependence to the focal power/WD for the vignetting

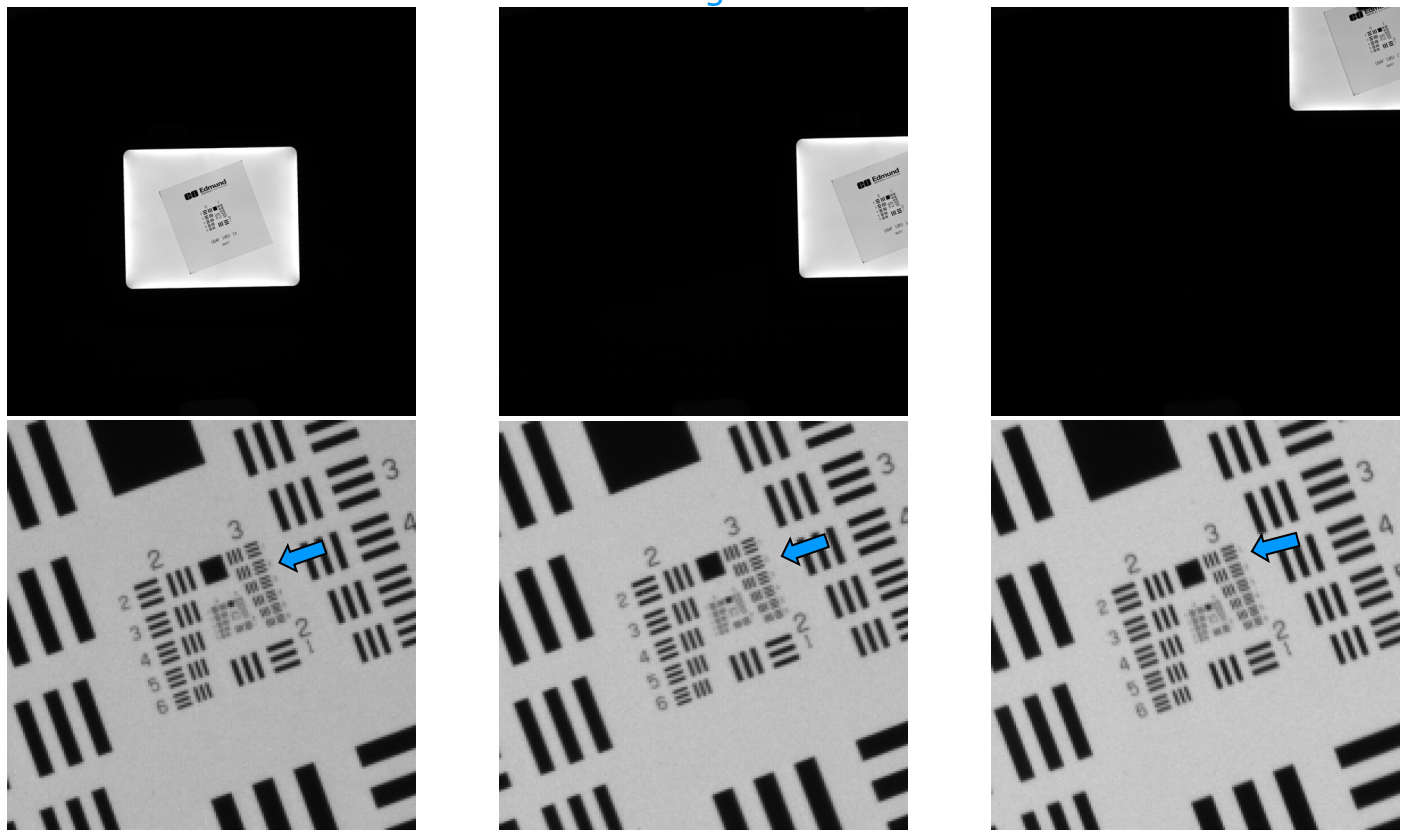
Image taken at WD 200mm, +3.15dpt



WD 920 mm: +0.11dpt, Blue light
Performance is close to Nyquist limit

Camera
Sensor size = 4512 x 4512 px
Pixel size = 2.74 um
Nyquist limit = 182 lp/mm

Light
Blue background illumination



	Center	Edge	Corner
USAF element:	3/2	3/2	3/1
Line width (um):	55.68	55.68	62.5
Lp/mm (object):	9	9	8
Magnification:	0.053	0.054	0.054
Lp/mm (image):	**169**	**166**	**148**

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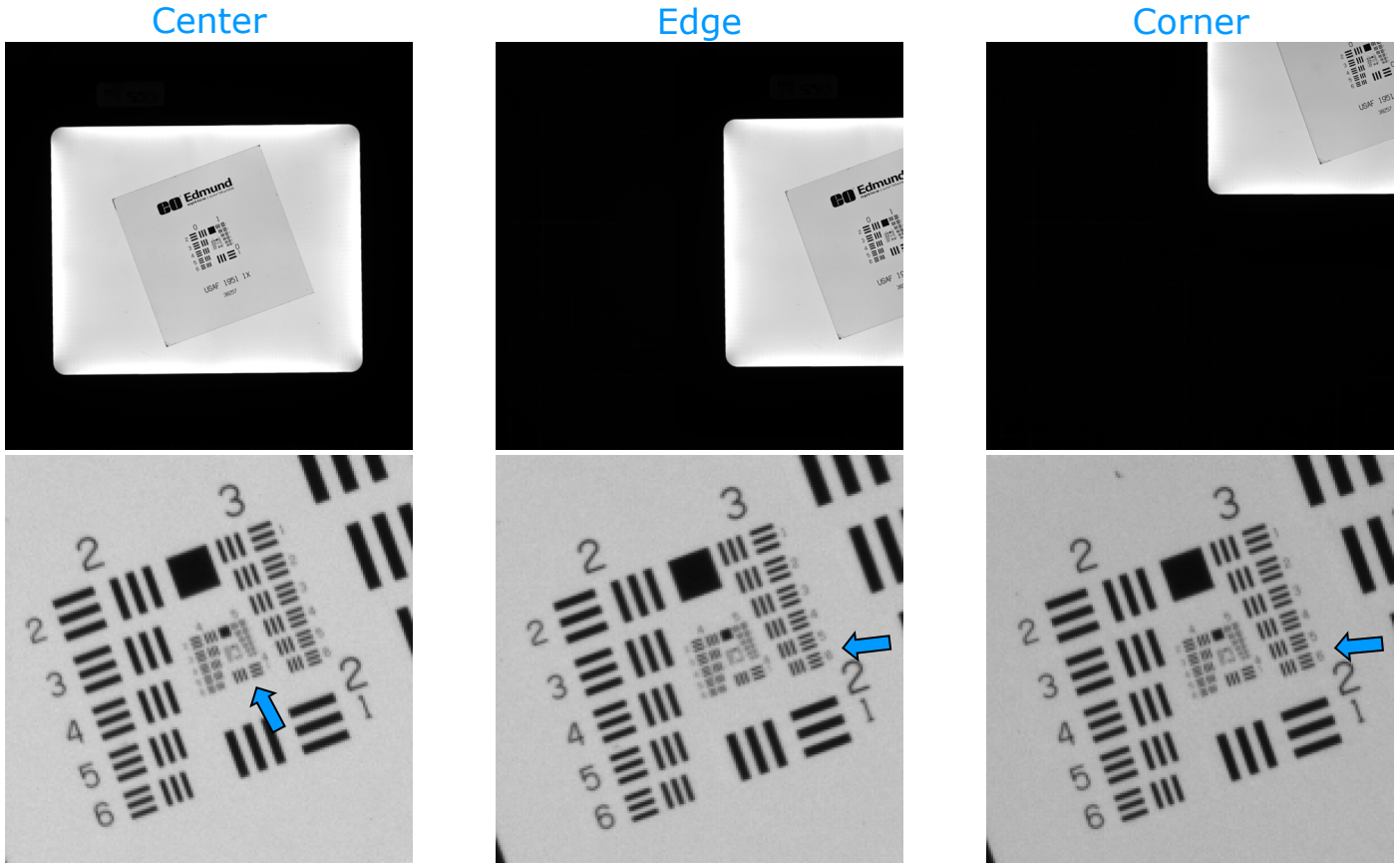
WD 500 mm: +1.75dpt, Blue light
Performance is close to Nyquist limit

Camera
Sensor size = 4512 x 4512 px
Pixel size = 2.74 um
Nyquist limit = 182 lp/mm

Light
Blue background illumination



	Center	Edge	Corner
USAF element:	4/1	3/6	3/6
Line width (um):	31.25	35.08	35.08
Lp/mm (object):	16	14	14
Magnification:	0.093	0.095	0.095
Lp/mm (image):	**172**	**150**	**150**

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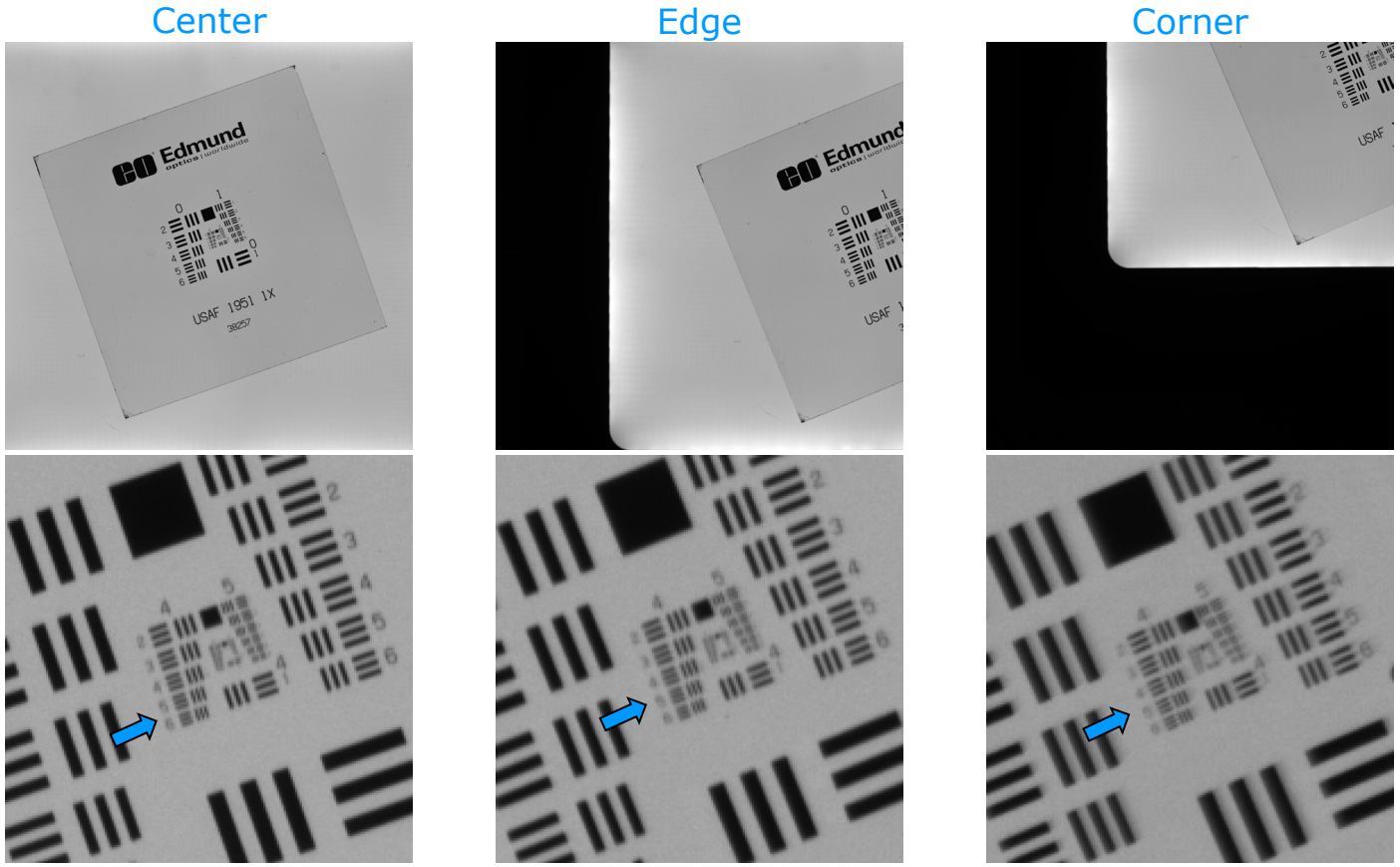
WD 300 mm: +0.38dpt, 5mm Spacer, Blue light
Performance is close to Nyquist limit

Camera
Sensor size = 4512 x 4512 px
Pixel size = 2.74 um
Nyquist limit = 182 lp/mm

Light
Blue background illumination



	Center	Edge	Corner
USAF element:	4/6	4/5	4/5
Line width (um):	17.54	19.69	19.69
Lp/mm (object):	29	25	25
Magnification:	0.157	0.158	0.160
Lp/mm (image):	**182**	**161**	**159**

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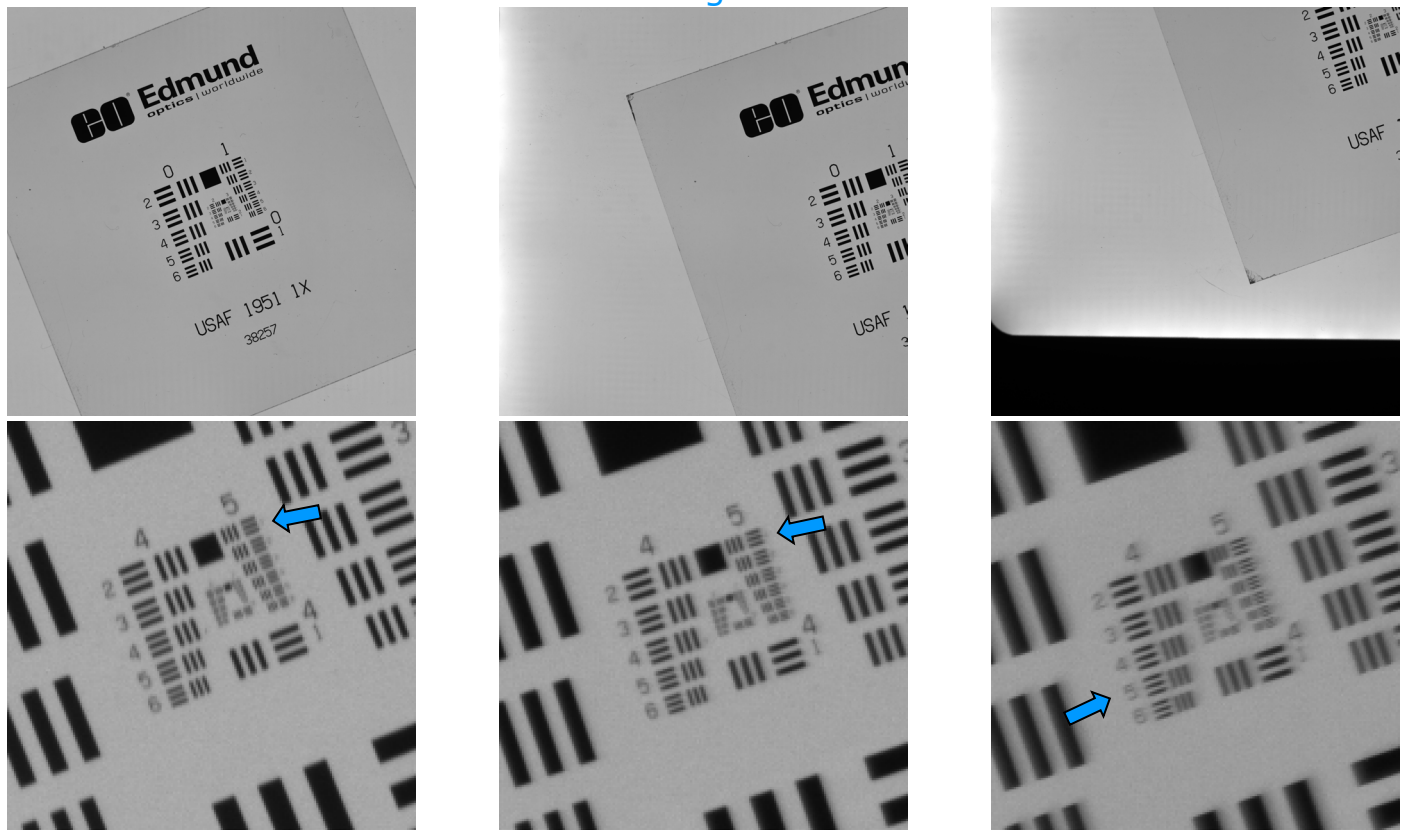
WD 200 mm: +3.00dpt, 5mm Spacer, Blue light
Performance is close to Nyquist limit

Camera
Sensor size = 4512 x 4512 px
Pixel size = 2.74 um
Nyquist limit = 182 lp/mm

Light
Blue background illumination



	Center	Edge	Corner
USAF element:	5/1	5/1	4/5
Line width (um):	15.63	15.63	19.69
Lp/mm (object):	32	32	25
Magnification:	0.232	0.235	0.235
Lp/mm (image):	**138**	**136**	**108**

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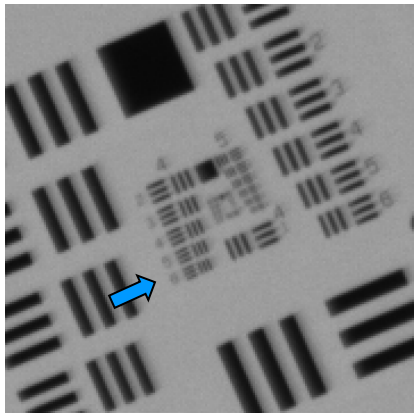
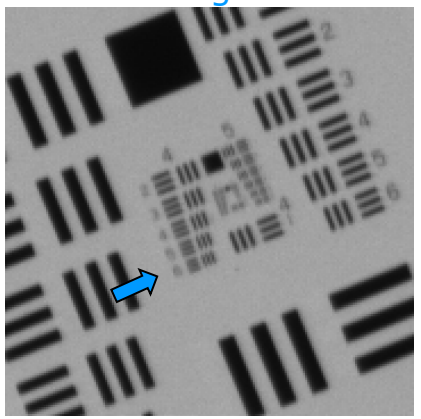
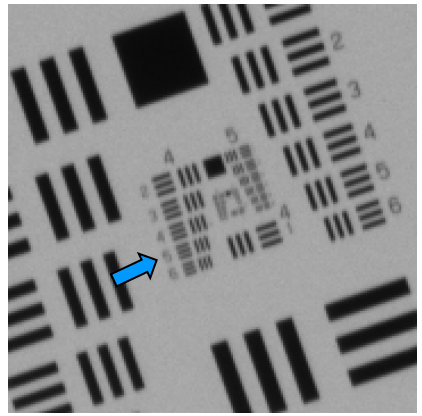
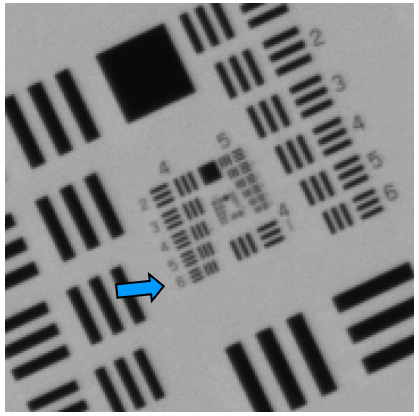
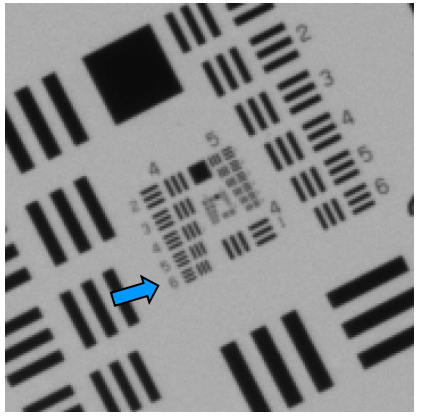
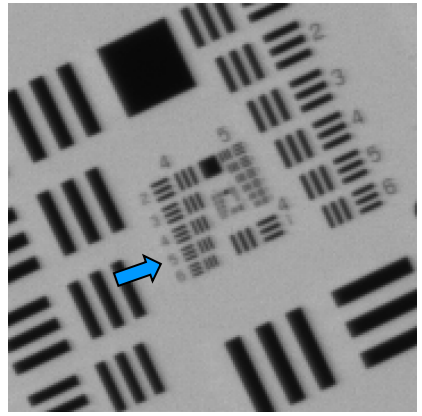
Polychromatic performance: White LED vs. Blue LED
WD 300mm, +0.38dpt, 5mm Spacer

Camera
Sensor size = 4512 x 4512 px
Pixel size = 2.74 um
Nyquist limit = 182 lp/mm

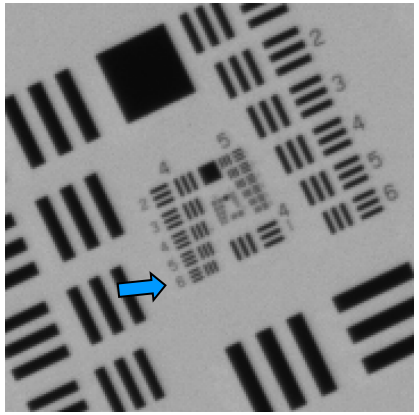
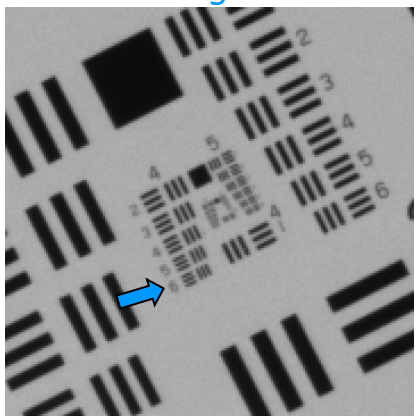
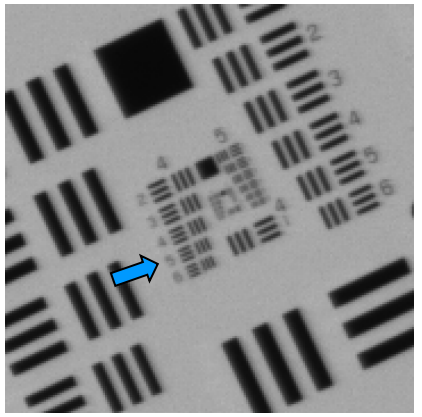
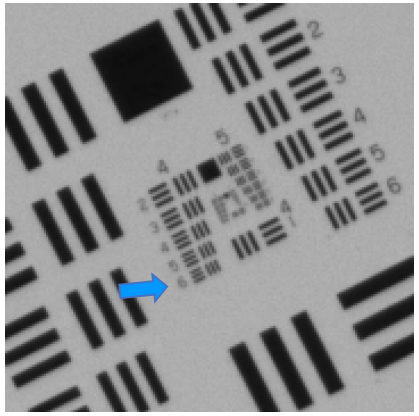
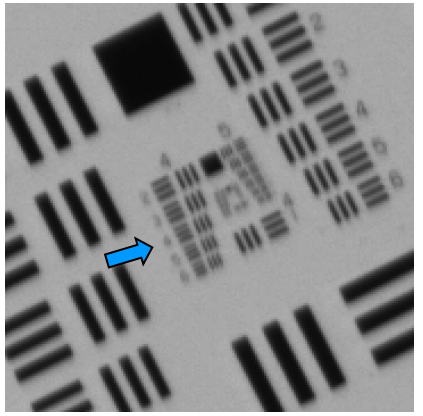
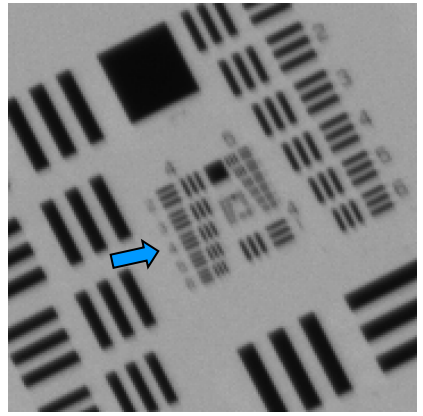
	Center	Edge	Corner
Blue	 182 LP/mm	 161 LP/mm	 159 LP/mm
White	 182 LP/mm	 181 LP/mm	 159 LP/mm

Vertical vs. Horizontal optical axis
WD 300mm, +0.54dpt, 5mm Spacer, White LED

Camera
Sensor size = 4512 x 4512 px
Pixel size = 2.74 um
Nyquist limit = 182 lp/mm

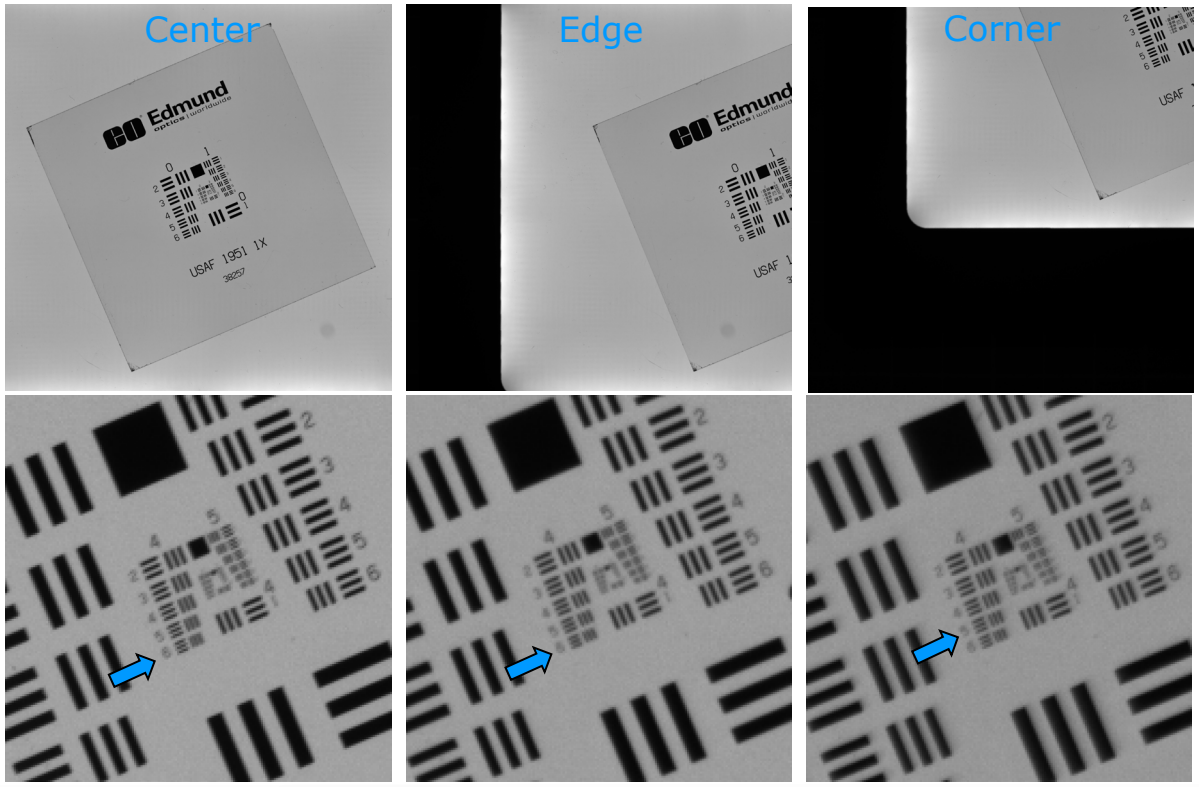
Light
White background illumination

EL-7-20 Gravity coma: 0.05λ

	Center	Edge	Corner
Vertical OA	 182 LP/mm	 181 LP/mm	 159 LP/mm
Horizontal OA	 182 LP/mm	 143 LP/mm	 141 LP/mm

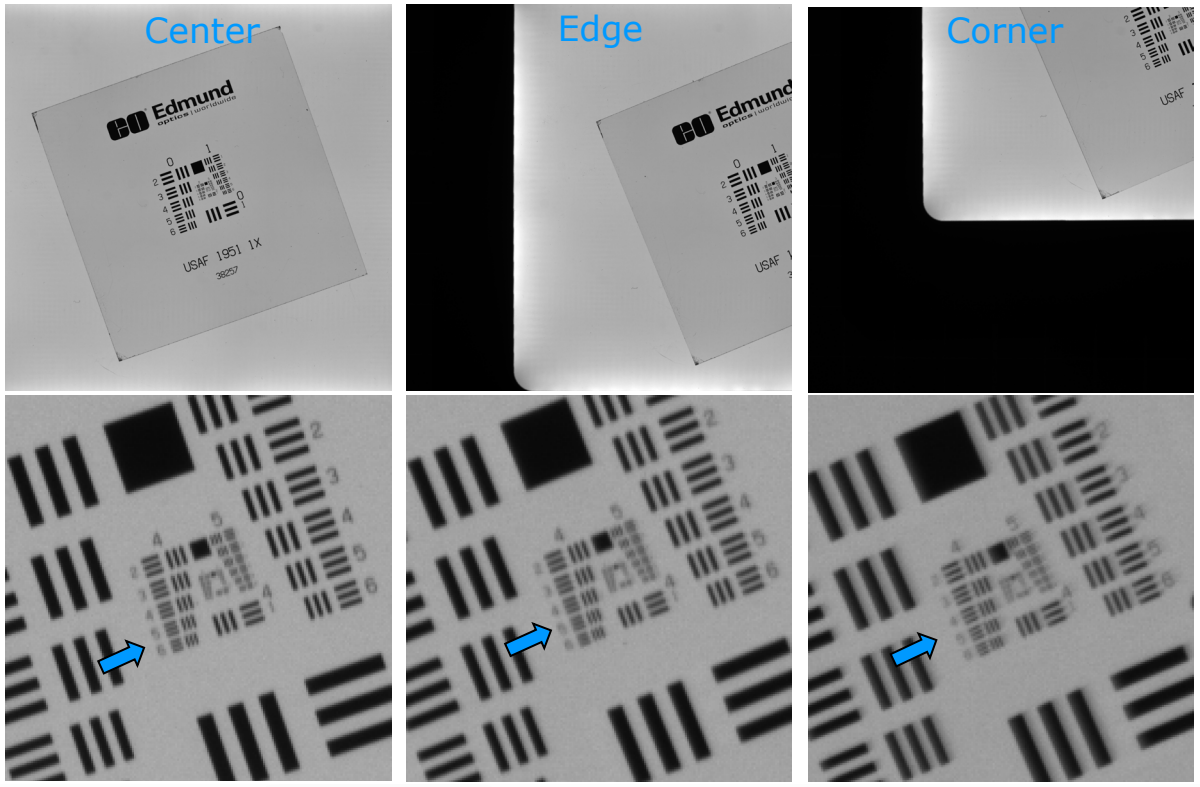
ELM-50-3.5 and ELM-50-5.6 comparison
WD 300 mm, 5mm Spacer, Blue light

ELM-50-3.5 with EL-12-30



	Center	Edge	Corner
USAF element:	4/6	4/5	4/5
Line width (um):	17.54	19.69	19.69
Lp/mm (obj):	29	25	25
Magnification:	0.157	0.158	0.160
Lp/mm (img):	**182**	**161**	**159**

ELM-50-5.6 with EL-7-20



	Center	Edge	Corner
USAF element:	4/6	4/5	4/5
Line width (um):	17.54	19.69	19.69
Lp/mm (obj):	29	25	25
Magnification:	0.157	0.158	0.160
Lp/mm (img):	**182**	**161**	**159**

ELM-50-3.5 and ELM-50-5.6 comparison
Depth of field analysis

Theoretical value of depth of field (DoF): $DoF = 2Nc(WD/f)^2$

- Linear relation with F-number (*N*) and quadratic relation to WD/f, with *WD* is the distance and *f* is the focal length
- DoF is measured in *dpt* based on the FWHM of a Sobel-filter based contrast metric
- A 2nd-order polynomial is fitted to the data. The relationship with *WD* is not perfectly quadratic because effective *f* and object-side principal plane position also change