



shaping the future of optics



ELM-35-5.6-16-C test report Optotune/Kowa 35mm lens

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Compact, off-the-shelf fixed focal length lens with autofocus

➤ In combination with up to 1" camera, a **full imaging system** with:

- ✓ **Compact form factor**
- ✓ **Fast focusing and Autofocus**
- ✓ **High resolution accross all FOV**
- ✓ **Great mono- and polychromatic performance**
- ✓ **Orientation independent resolution**



➤ Ideal for applications with medium field of view:

- ✓ **Robot Vision**
- ✓ **Bottle inspection**
- ✓ **Electronics inspection**



Summary

➤ **Large working distance (WD) range**

- From 250 mm to infinity
- Optical leverage 150 mm/dpt in the 250-750 mm range
- Angular Field of View with 1" sensor (horizontal): 24°

➤ **Resolution** suitable for 3.45 um pixel size:

- **Nyquist limit** (up to 144 lp/mm) almost everywhere in the FOV at F/5.6
- Resolution at F/11 limited by diffraction

➤ **Image quality**

- No distortion
- **Great polychromatic and monochromatic** performance
- **Same vertical and horizontal optical axis** performance

Test setup



Camera: 1.1" cropped to 1", 3768 x 2782 px,
Pixel size = 3.45 um

Model: IDS UI-3200SE-M-GL

Lens: ELM-35 with EL-16-40-VIS-5D-C

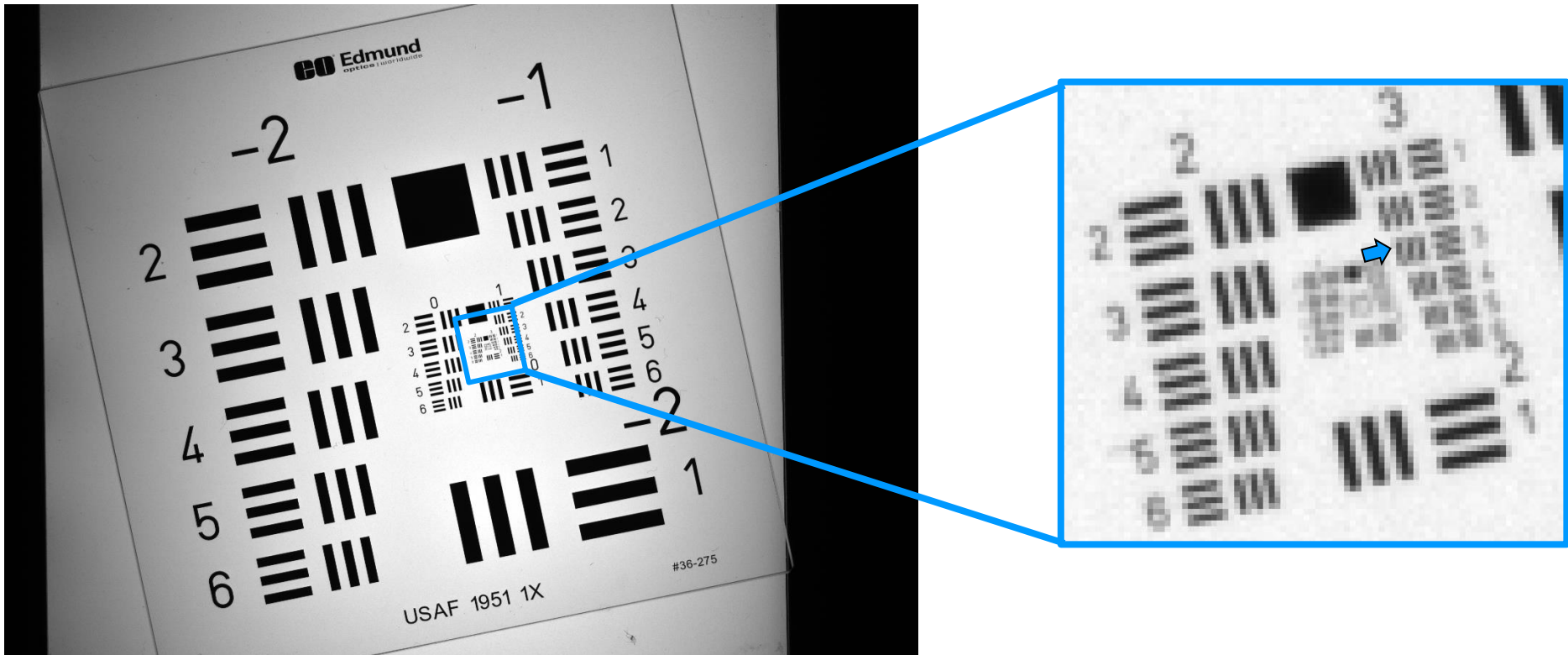
Driver: Optotune Lens Driver 4i

Target: USAF chrome target, transparent

Light: Red/White backlight

Methods for image evaluation

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



WD = 250 mm, @ 3 dpt, F/5.6, HFOV = 113 mm

Camera

Sensor size = 3678x2782 pixels

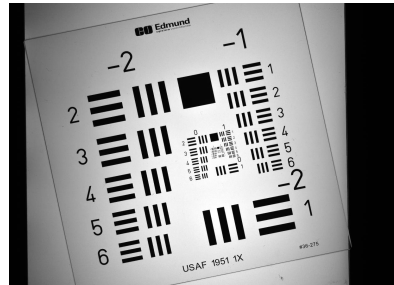
Nyquist limit = 144 lp/mm

Pixel size = 3.45 μ m

Light

Red background illumination

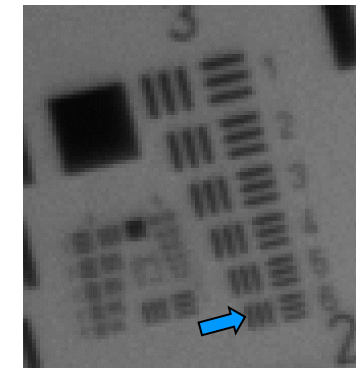
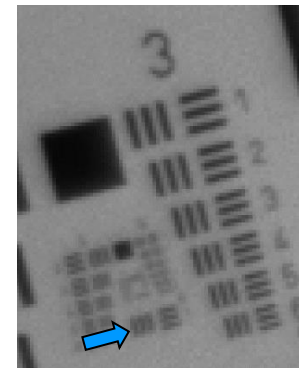
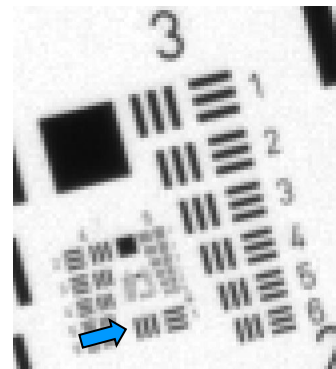
Center



Edge



Corner



USAF element: 4/1
Line width (μ m): 31.25
Lp/mm (object): 16
Magnification: 0.115
Lp/mm (image): 139

USAF element: 4/1
Line width (μ m): 31.25
Lp/mm (object): 16
Magnification: 0.115
Lp/mm (image): 139

USAF element: 3/6
Line width (μ m): 35.08
Lp/mm (object): 14
Magnification: 0.115
Lp/mm (image): 124

WD = 250 mm, @ 3 dpt, F/11 loss of resolution due to diffraction

Camera

Sensor size = 3678x2782 pixels

Nyquist limit = 144 lp/mm

Pixel size = 3.45 μm

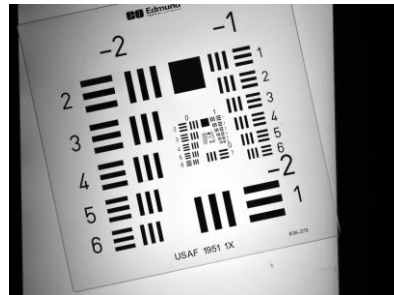
Light

Red background illumination

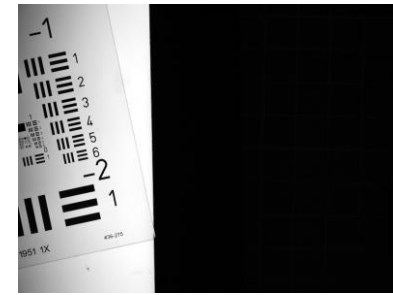
$$\xi_{\text{Diffraction Limit}} = \frac{1}{(f/\#) \times \lambda} \times \left(\frac{1000\mu\text{m}}{1\text{mm}} \right)$$

= 140 lp/mm @ 650nm

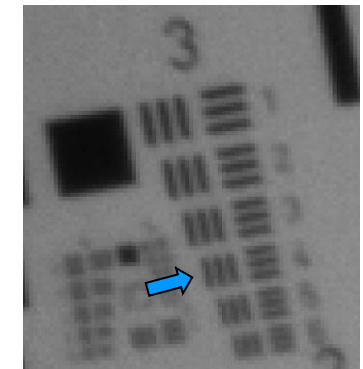
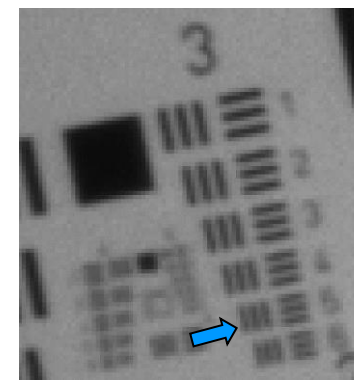
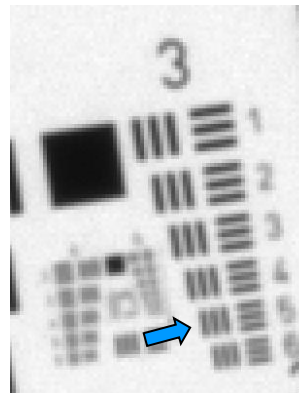
Center



Edge



Corner



USAF element:	3/6	3/5	3/4
Line width (μm):	35.08	39.37	44.19
Lp/mm (object):	14	13	11
Magnification:	0.115	0.115	0.115
Lp/mm (image):	124	110	98

WD = 500 mm, @ 0.56 dpt, F/5.6, HFOV = 203 mm

Camera

Sensor size = 3678x2782 pixels

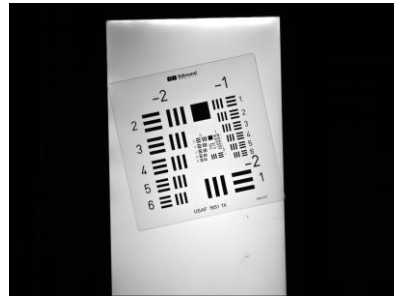
Nyquist limit = 144 lp/mm

Pixel size = 3.45 μ m

Light

Red background illumination

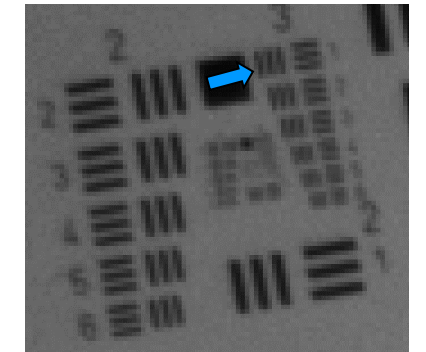
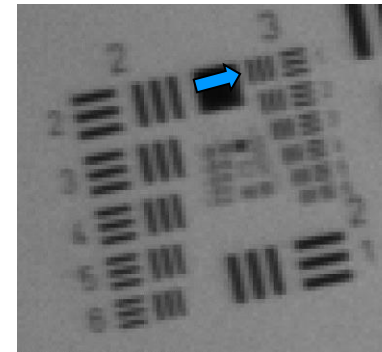
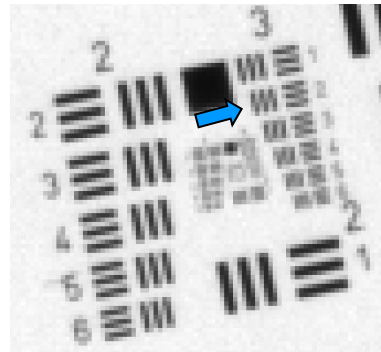
Center



Edge



Corner



USAF element:	3/2
Line width (μ m):	55.68
Lp/mm (object):	9
Magnification:	0.064
Lp/mm (image):	140

USAF element:	3/1
Line width (μ m):	62.5
Lp/mm (object):	8
Magnification:	0.064
Lp/mm (image):	124

USAF element:	3/1
Line width (μ m):	62.5
Lp/mm (object):	8
Magnification:	0.064
Lp/mm (image):	124

WD = 750 mm, @ -0.3 dpt, F/5.6, FOV = 317 mm

Camera

Sensor size = 3678x2782 pixels

Nyquist limit = 144 lp/mm

Pixel size = 3.45 μm

Light

Red background illumination

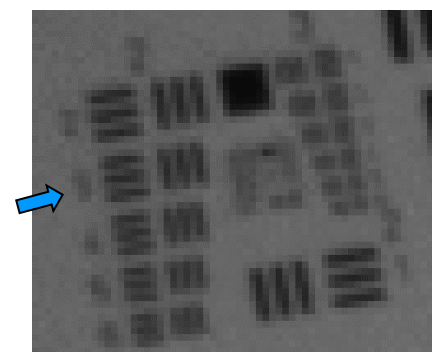
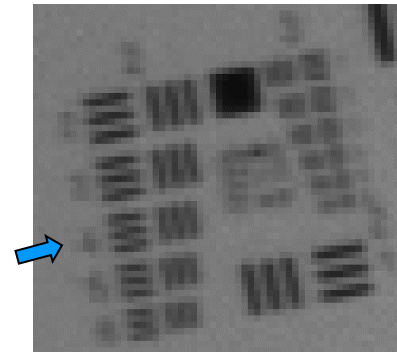
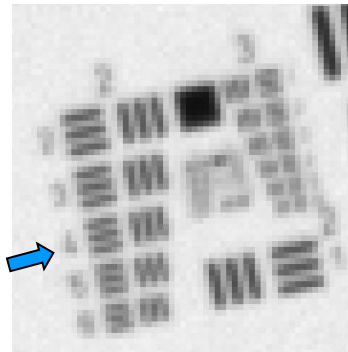
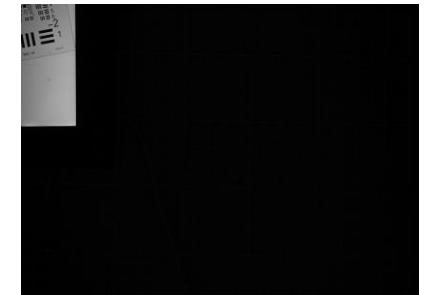
Center



Edge



Corner



USAF element: 2/4
Line width (μm): 88.39
Lp/mm (object): 6
Magnification: 0.041
Lp/mm (image): 138

2/4
88.39
6
0.041
138

2/3
99.21
5
0.041
123

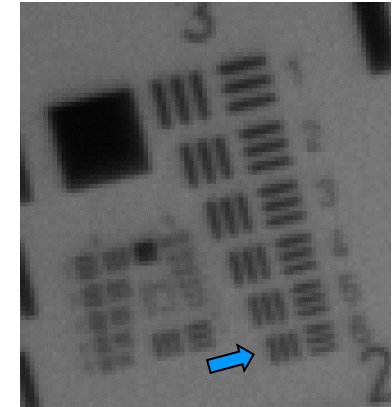
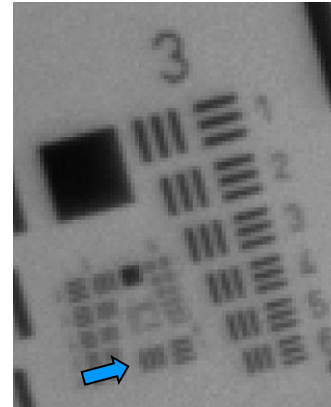
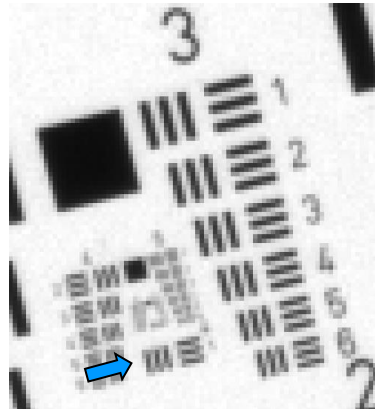
Monochromatic vs white light

Center

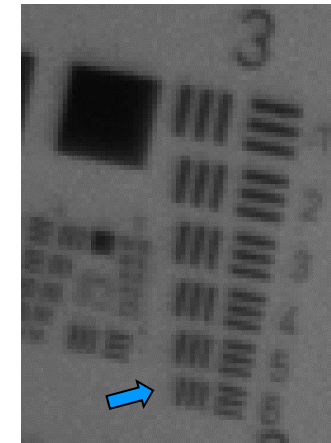
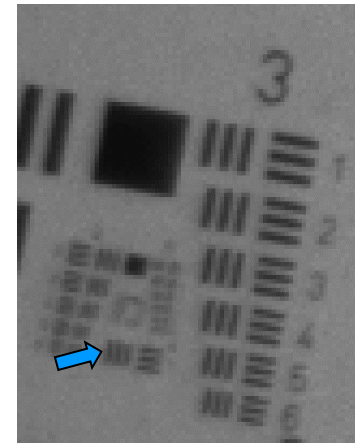
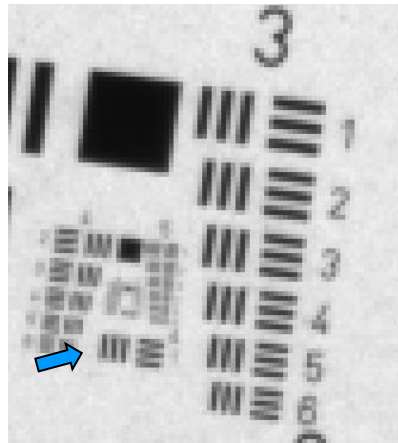
Edge

Corner

Red



White



No loss of image quality with white light!

Benchmark without liquid lens, WD 405 mm, F/5.6

17mm of spacer added to compensate for EL-16-40 thickness

Camera

Sensor size = 3678x2782 pixels

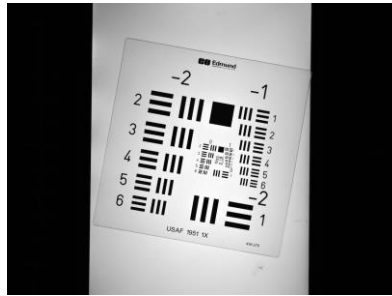
Nyquist limit = 144 lp/mm

Pixel size = 3.45 μm

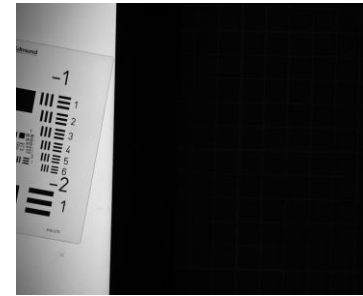
Light

Red background illumination

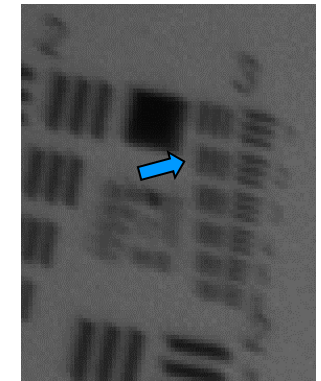
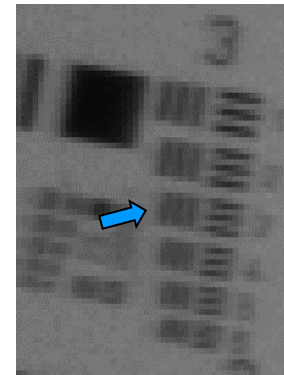
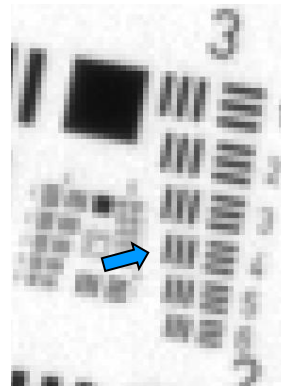
Center



Edge



Corner



USAF element:	3/4
Line width (μm):	44.19
Lp/mm (object):	11
Magnification:	0.081
Lp/mm (image):	140

USAF element:	3/3
Line width (μm):	49.61
Lp/mm (object):	10
Magnification:	0.081
Lp/mm (image):	125

USAF element:	3/2
Line width (μm):	55.68
Lp/mm (object):	9
Magnification:	0.081
Lp/mm (image):	111

With liquid lens @ 1.12 dpt, WD 405 mm, F/5.6

Camera

Sensor size = 3678x2782 pixels

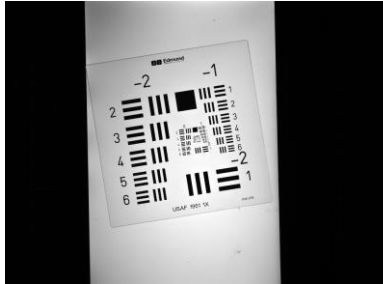
Nyquist limit = 144 lp/mm

Pixel size = 3.45 μm

Light

Red background illumination

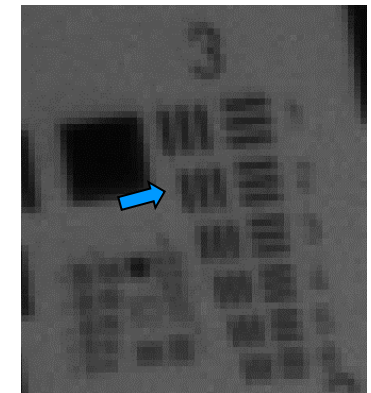
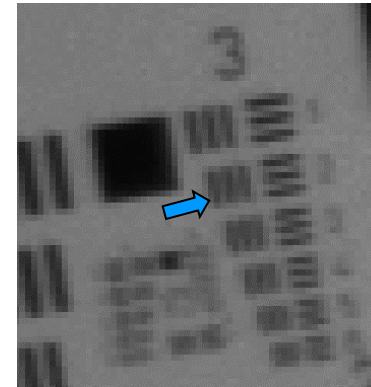
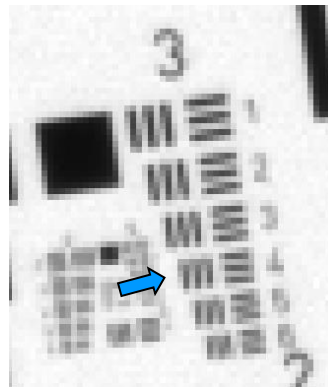
Center



Edge



Corner



USAF element:	3/4	3/3	3/2
Line width (μm):	44.19	49.61	55.68
Lp/mm (object):	11	10	9
Magnification:	0.081	0.081	0.081
Lp/mm (image):	140	125	111

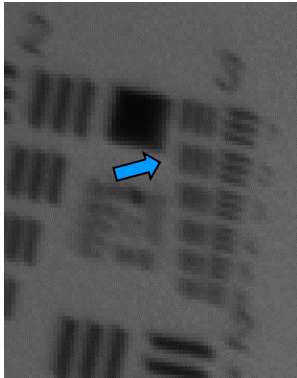
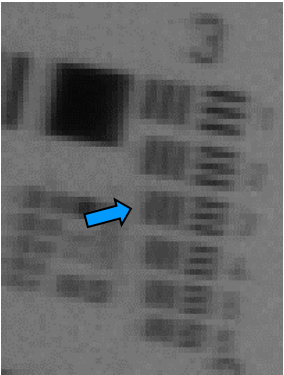
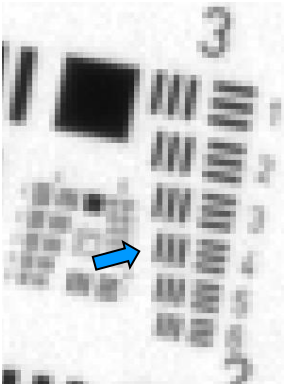
Comparison with/without liquid lens

Center

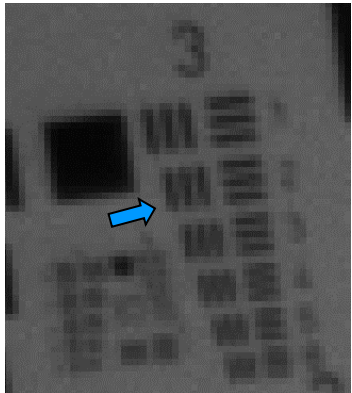
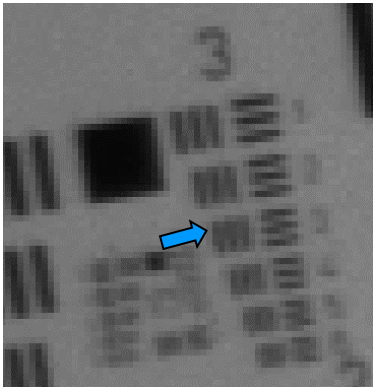
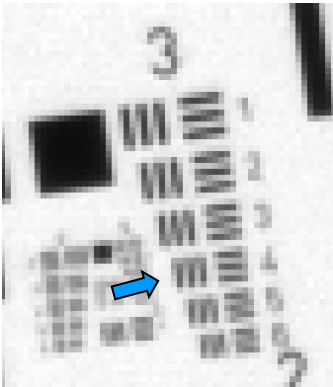
Edge

Corner

Without
EL-16-40



With
EL-16-40



No loss of image quality with liquid lens!

With liquid lens @ 1.12 dpt, WD 405 mm, F/#=5.6

Horizontal optical axis

Camera

Sensor size = 3678x2782 pixels

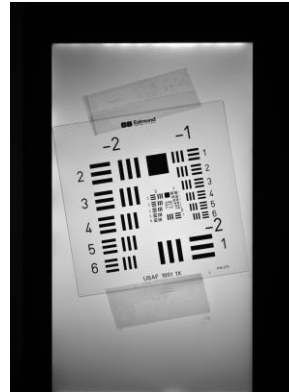
Nyquist limit = 144 lp/mm

Pixel size = 3.45 μm

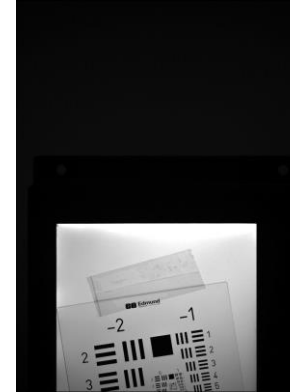
Light

Red background illumination

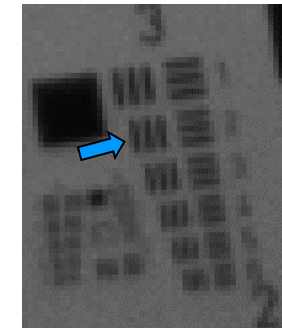
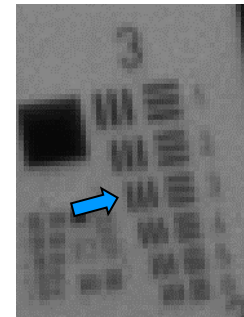
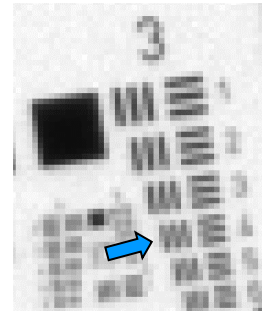
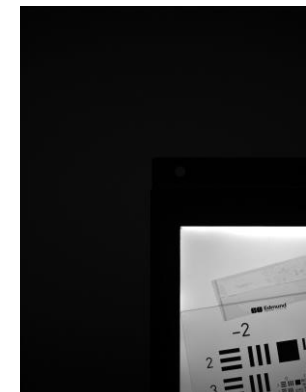
Center



Edge



Corner

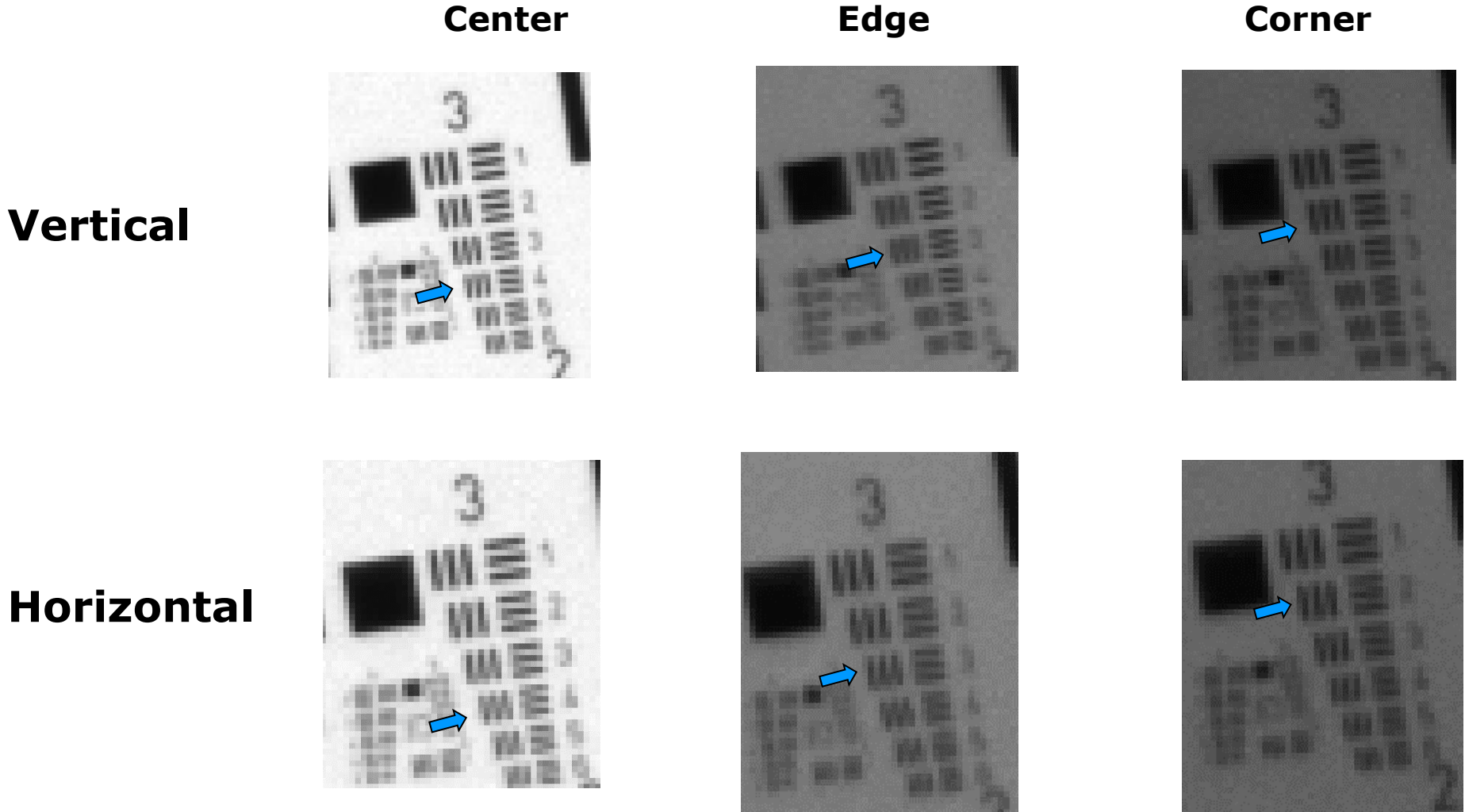


USAF element:	3/4
Line width (μm):	44.19
Lp/mm (object):	11
Magnification:	0.081
Lp/mm (image):	140

USAF element:	3/3
Line width (μm):	49.61
Lp/mm (object):	10
Magnification:	0.081
Lp/mm (image):	125

USAF element:	3/2
Line width (μm):	55.68
Lp/mm (object):	9
Magnification:	0.081
Lp/mm (image):	111

Comparison horizontal/vertical optical axis



No loss of image quality in horizontal optical axis!