parasitic pixels

21/02/2024 | 3D-ARCH

Geert Verhoeven

universität wien

PLEASE NOTE

This PDF does **not** display the GIFs used to explain the concept of camera shutter (slides 56–72).

For the **original *.pptx file** with all GIFs working, visit https://zenodo.org/records/10705140.

3D DATAFICATION

3D DATAFICATION



raw

3D DATAFICATION

raw | surface



3D DATAFICATION

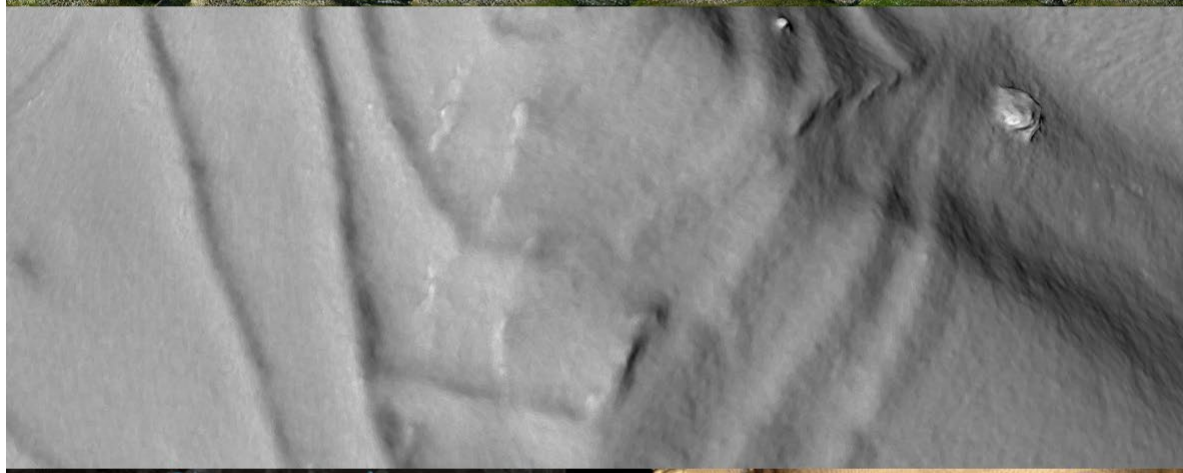
raw | surface | volume

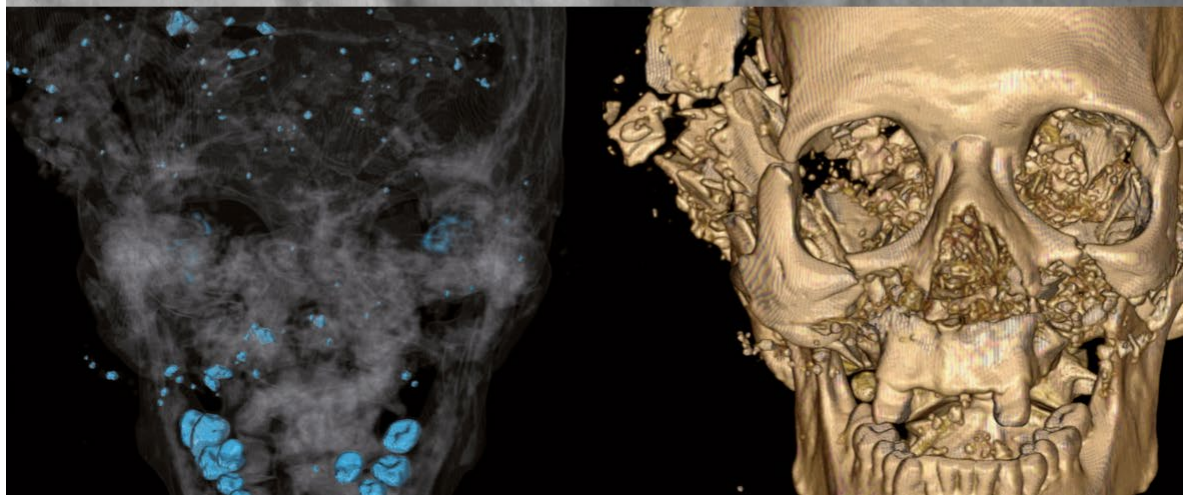


3D DATAFICATION

raw | surface | volume







3D DATAFICATION



raw | surface | volume

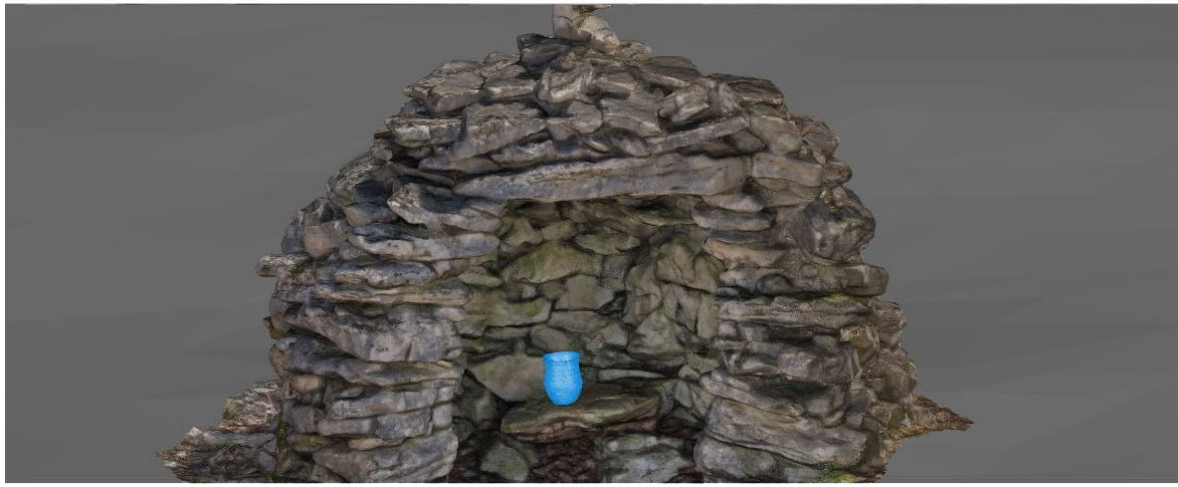
artefact

3D DATAFICATION

raw | surface | volume

artefact | site



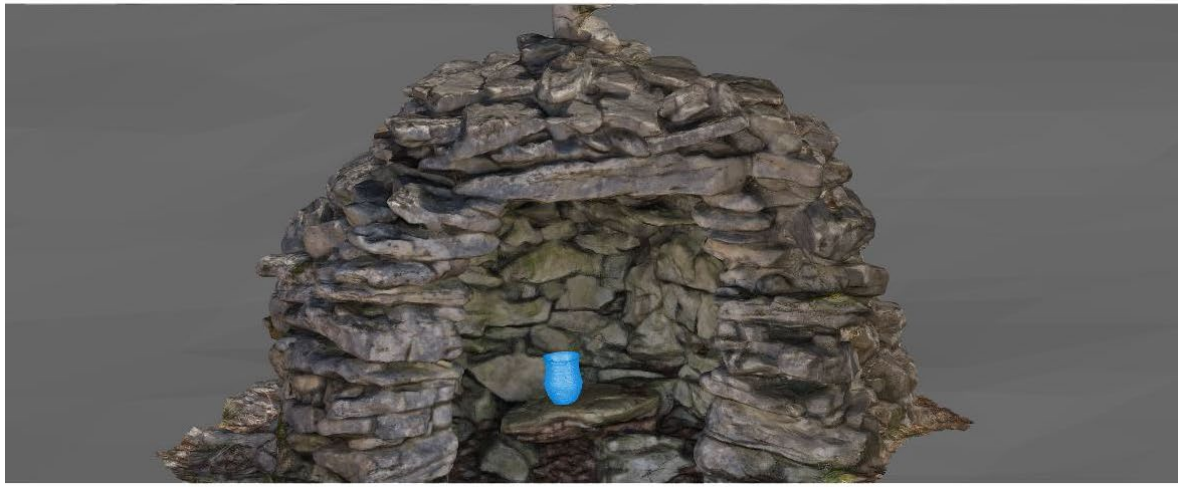


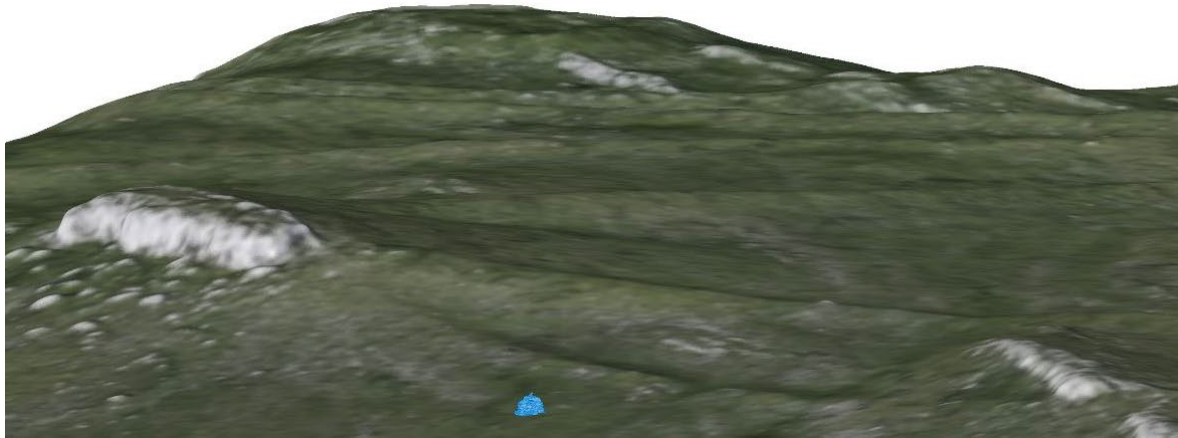
3D DATAFICATION

raw | surface | volume

artefact | site | landscape





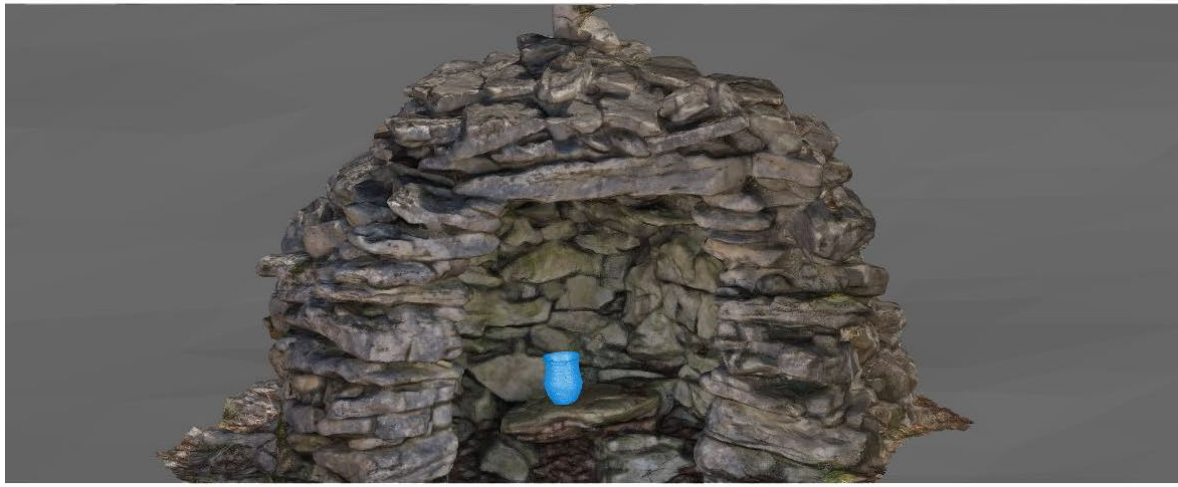


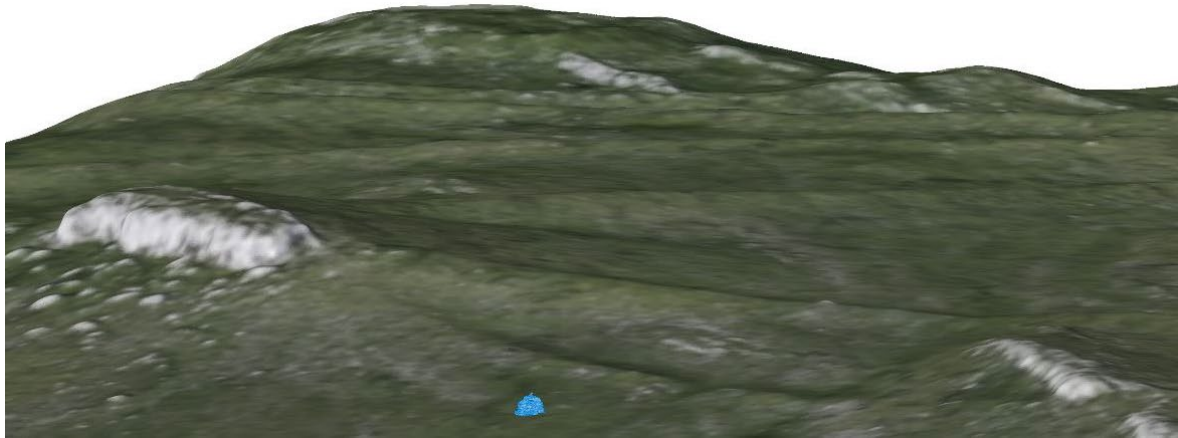
3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape







3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

≠ techniques



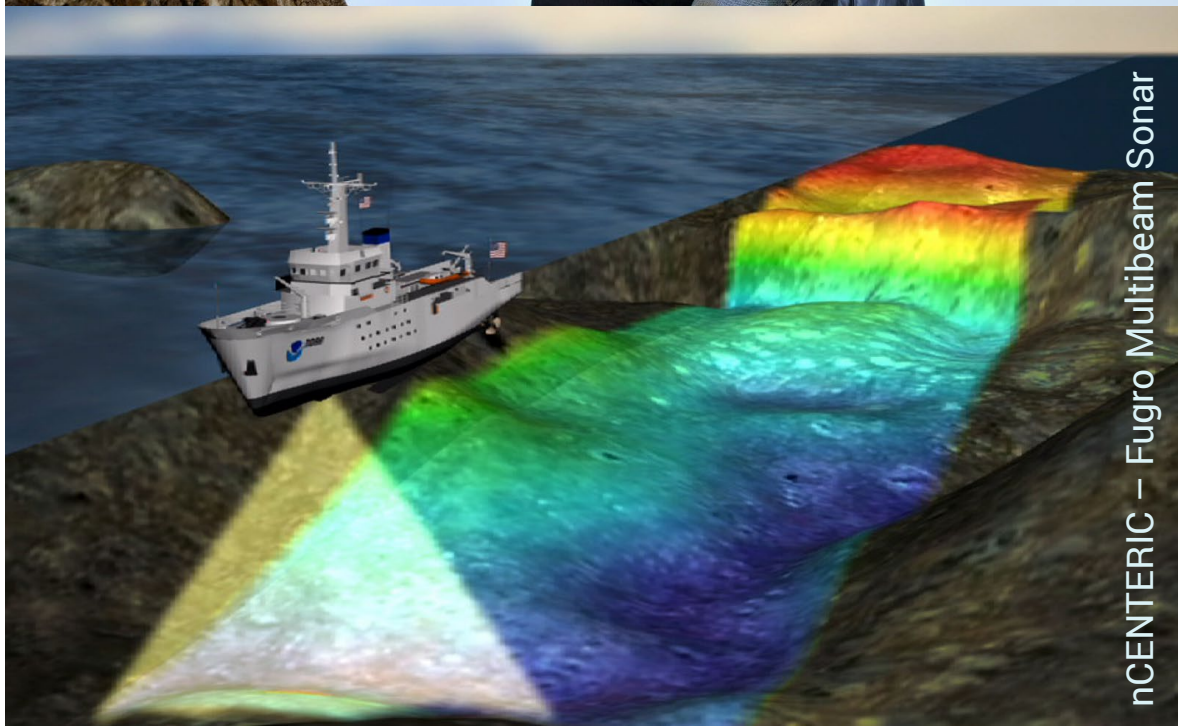
3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

≠ techniques





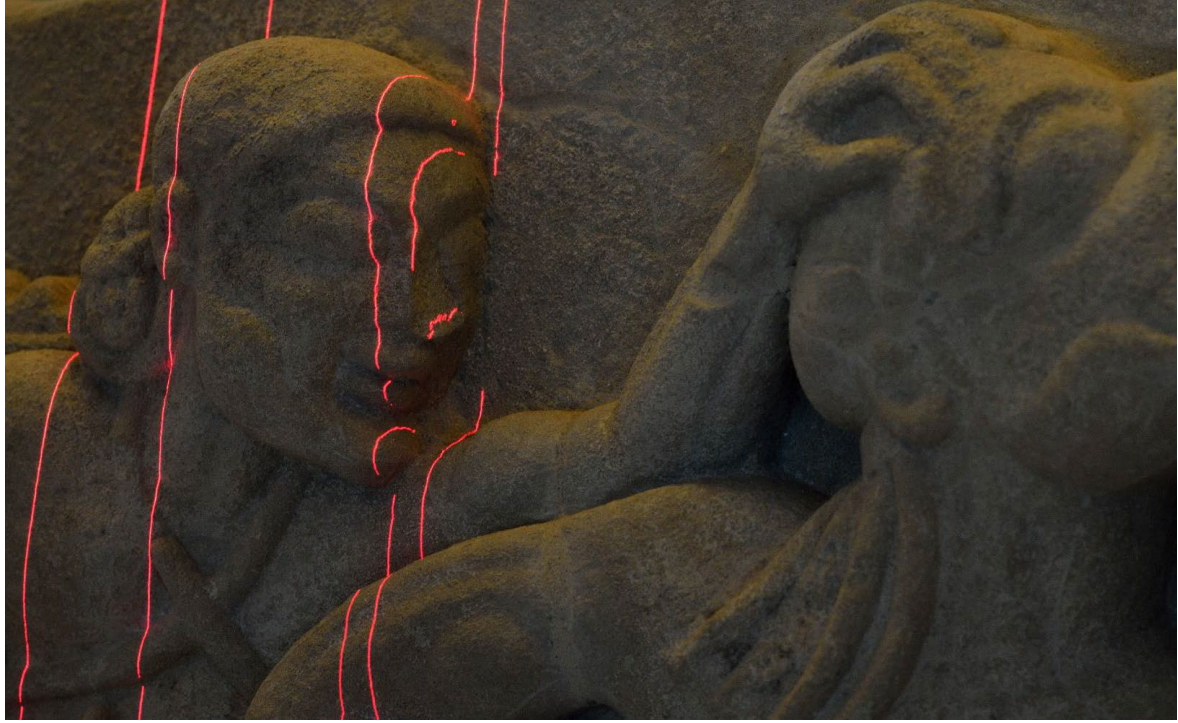
nCENTERIC – Fugro Multibeam Sonar

3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

≠ techniques



3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

≠ techniques





3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

≠ techniques



3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

≠ techniques





3D DATAFICATION

raw | **surface** | volume

artefact | **site** | landscape

image-based modelling





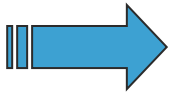
IMAGE-BASED (3D) (SURFACE) MODELLING

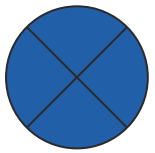
?

geometry

IMAGE-BASED (3D) (SURFACE) MODELLING







geometry

IMAGE-BASED (3D) (SURFACE) MODELLING

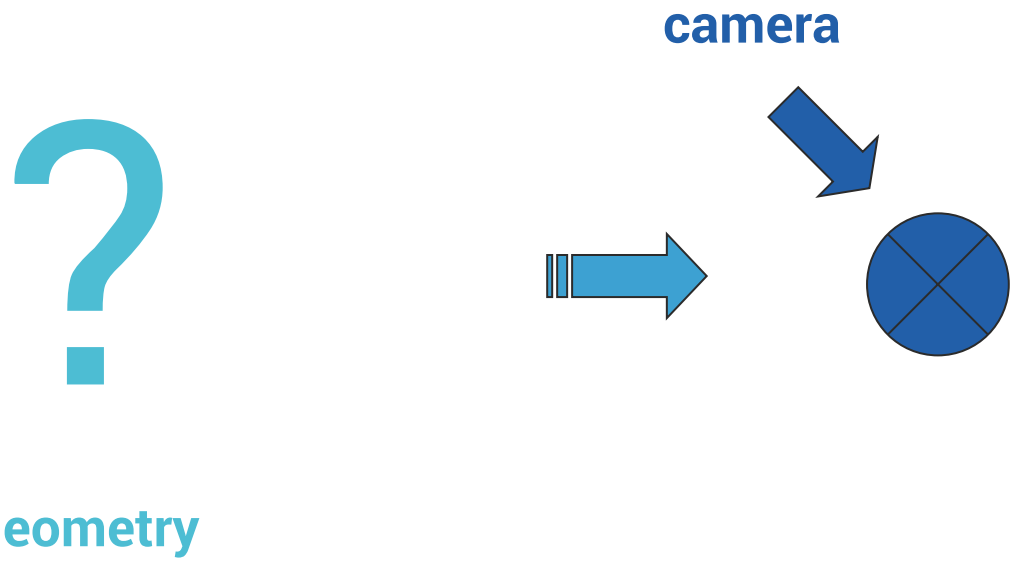


IMAGE-BASED (3D) (SURFACE) MODELLING

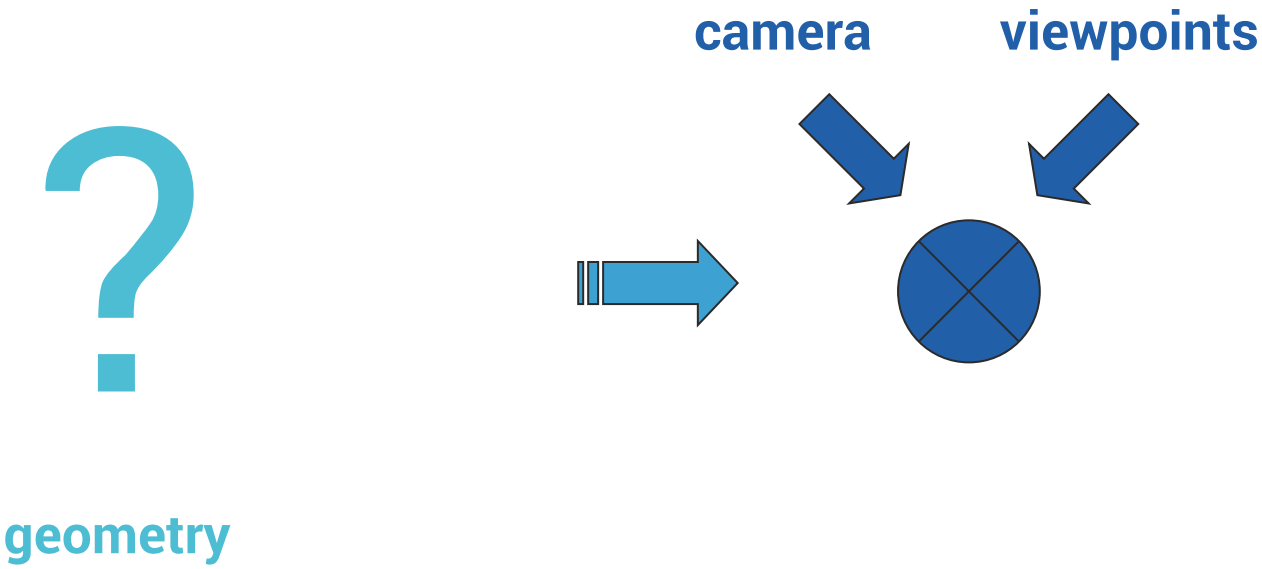


IMAGE-BASED (3D) (SURFACE) MODELLING

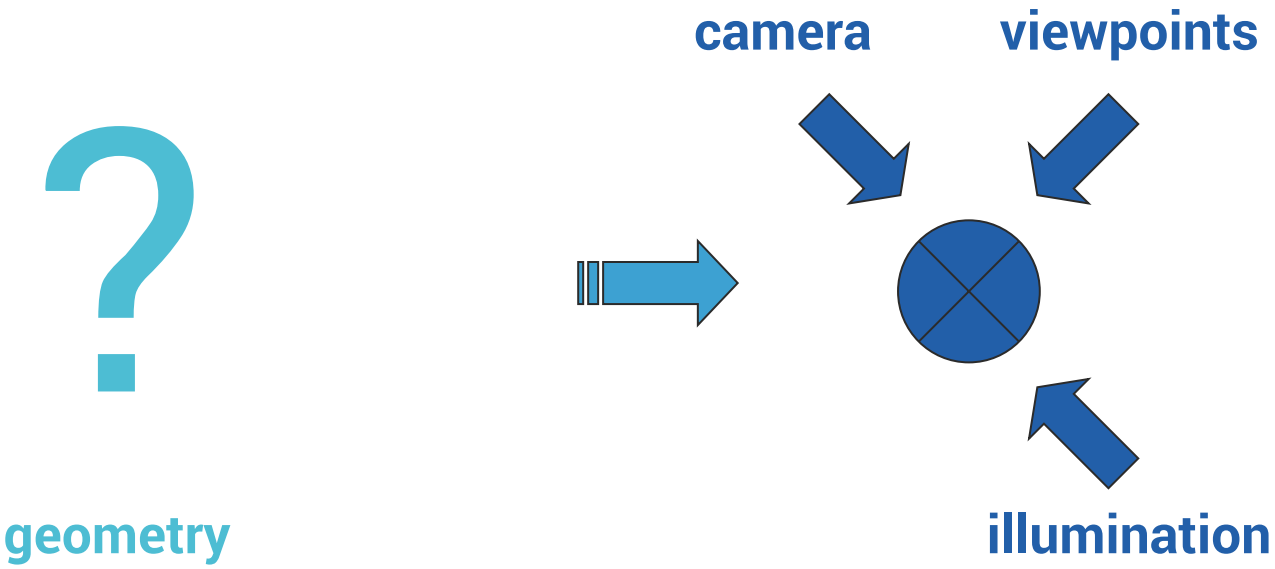


IMAGE-BASED (3D) (SURFACE) MODELLING

?

geometry

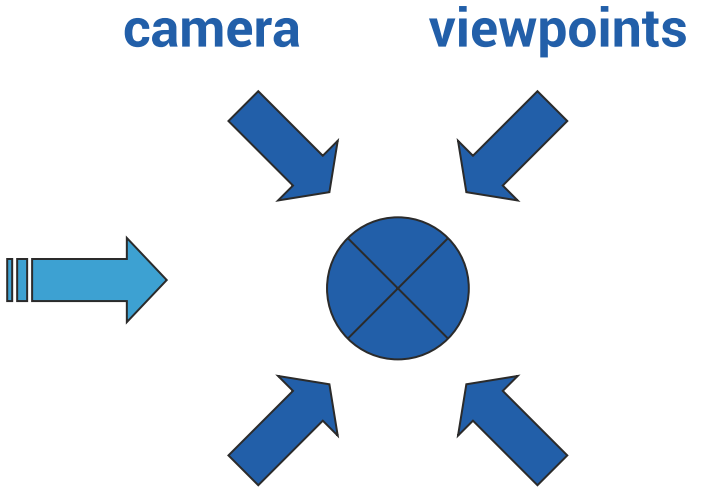


IMAGE-BASED (3D) (SURFACE) MODELLING

?

geometry

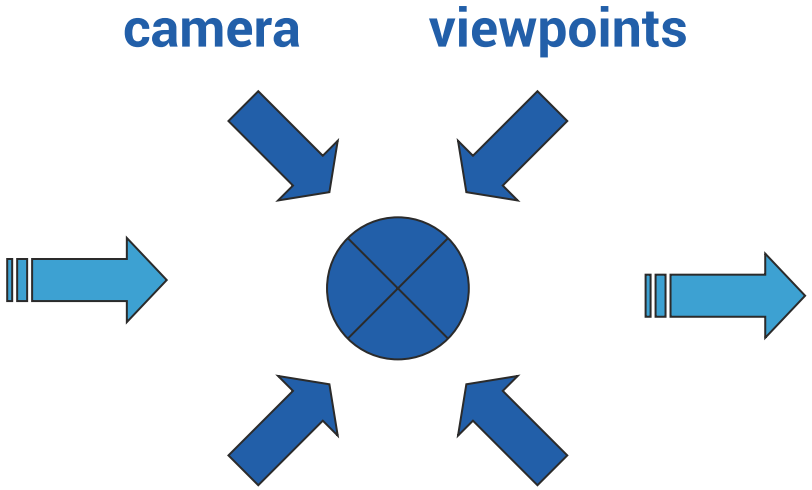
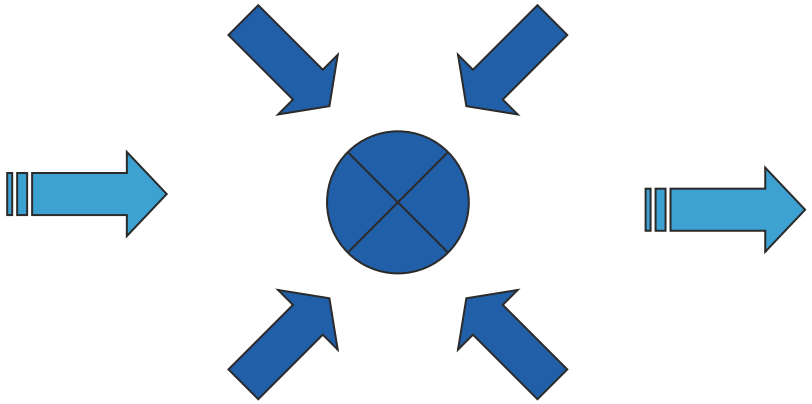


IMAGE-BASED (3D) (SURFACE) MODELLING

?

geometry





images

IMAGE-BASED (3D) (SURFACE) MODELLING

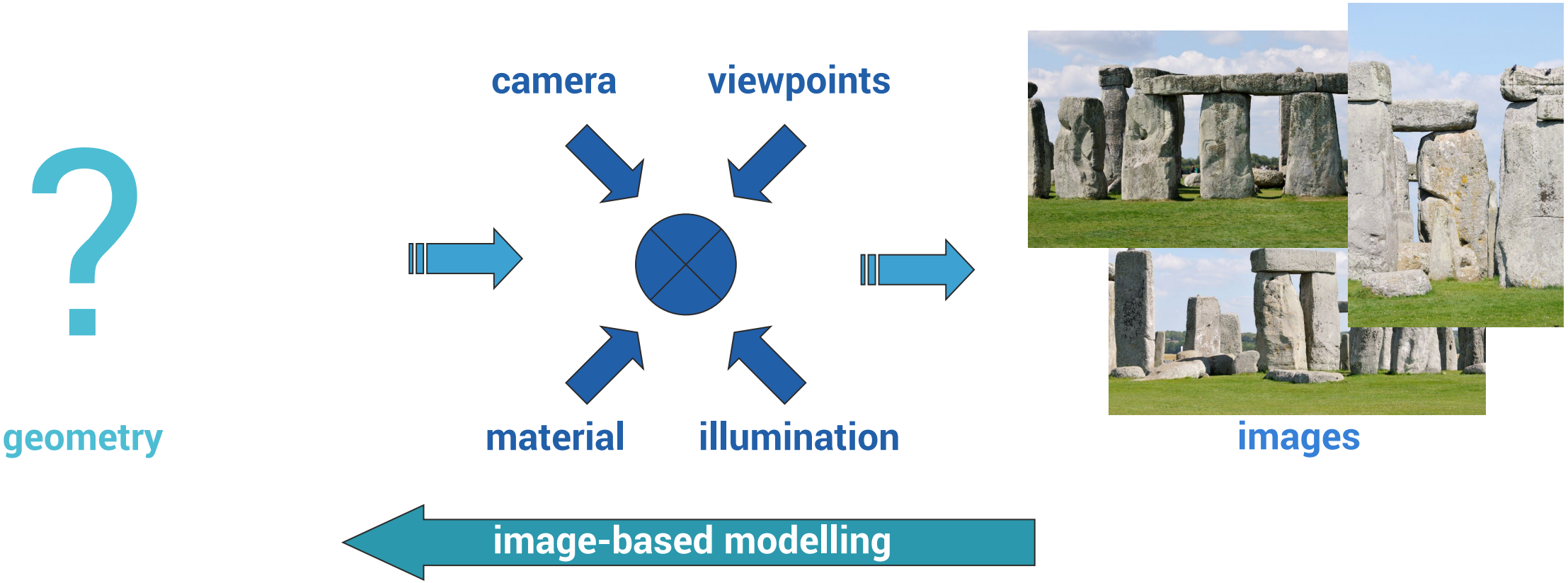
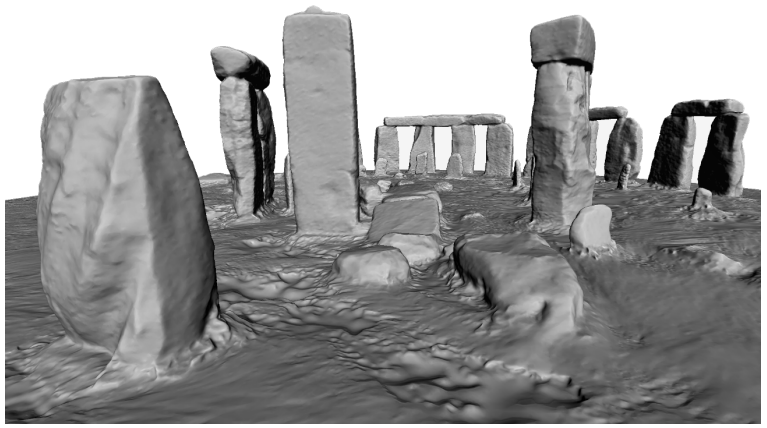
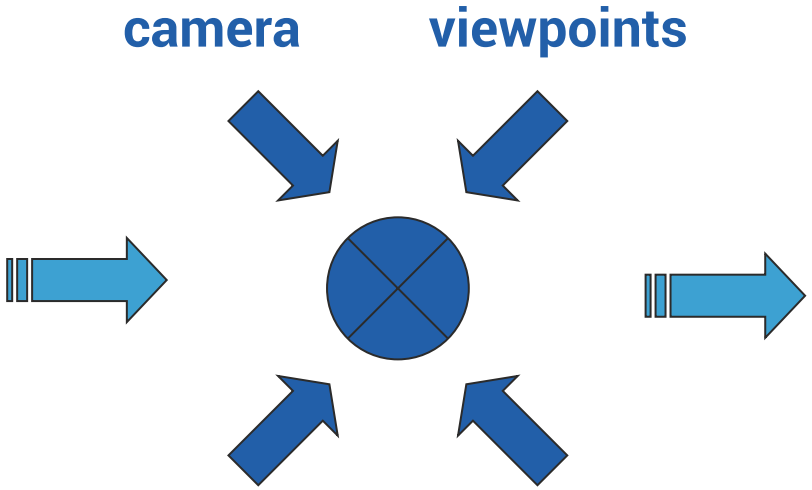


IMAGE-BASED (3D) (SURFACE) MODELLING



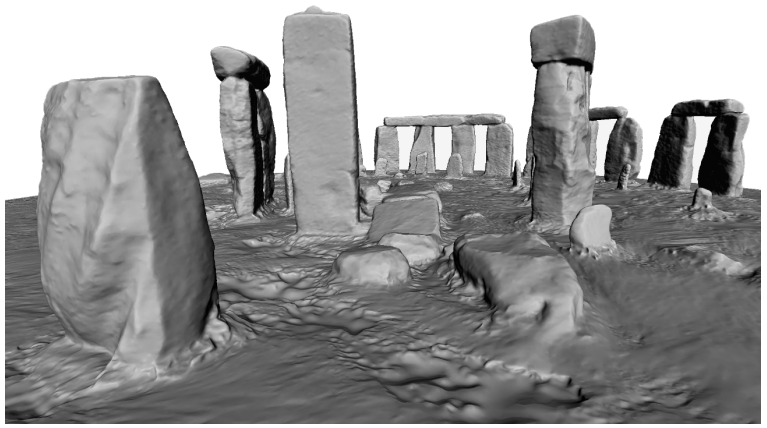


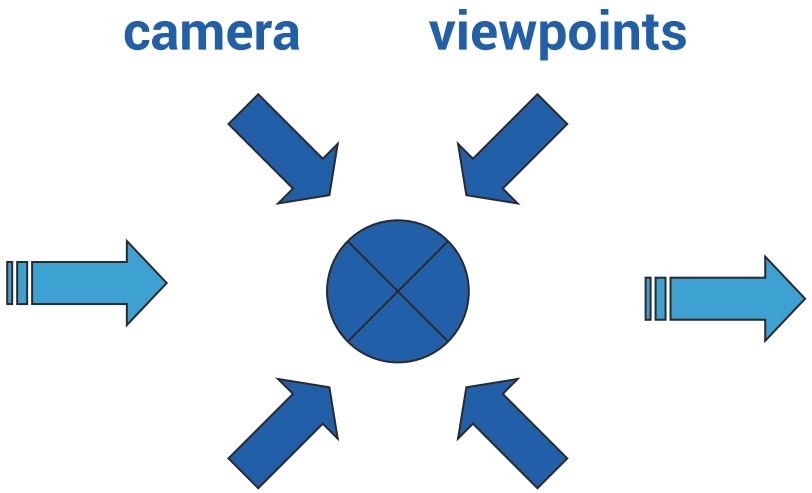


images

image-based modelling

IMAGE-BASED (3D) (SURFACE) MODELLING







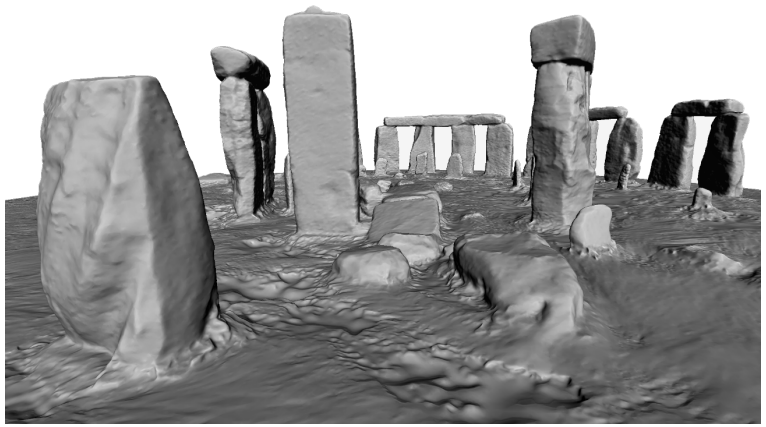
images

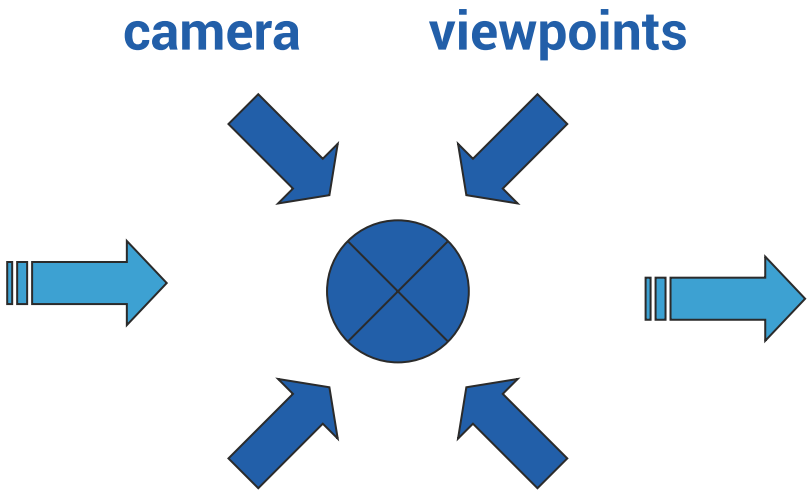
image-based modelling

structure from motion

multi-view stereo

IMAGE-BASED (3D) (SURFACE) MODELLING







images

image-based modelling

structure from motion

multi-view stereo

bundle adjustment

IMAGE-BASED (3D) (SURFACE) MODELLING

camera viewpoints

material illumination



images

image-based modelling

structure from motion

multi-view stereo

bundle adjustment

2 PARTS



BODY
parameter



LENS
parameter

2 PARTS

Negatively affect IBM



BODY
parameter



LENS
parameter

2 PARTS

Negatively affect IBM

Need more research



BODY
parameter



LENS
parameter

3 ASSUMPTIONS

3 ASSUMPTIONS

PERSONAL view

3 ASSUMPTIONS

PERSONAL view

ACCURACY needed

3 ASSUMPTIONS

PERSONAL view

ACCURACY needed

TERRESTRIAL ~~MACRO~~ photos

3 ASSUMPTIONS & 3 GOALS

PERSONAL view

ACCURACY needed

TERRESTRIAL ~~MACRO~~ photos

3 ASSUMPTIONS & 3 GOALS

PERSONAL view

ACCURACY needed

TERRESTRIAL ~~MACRO~~ photos

create AWARENESS

3 ASSUMPTIONS & 3 GOALS

PERSONAL view

ACCURACY needed

TERRESTRIAL ~~MACRO~~ photos

create AWARENESS

incentivise RESEARCH

3 ASSUMPTIONS & 3 GOALS

PERSONAL view

ACCURACY needed

TERRESTRIAL ~~MACRO~~ photos

create AWARENESS

incentivise RESEARCH

~~CRITICISM~~



PART 1

CAMERA SHUTTER

CAMERA SHUTTER



prevents | allows light to pass

CAMERA SHUTTER



prevents | allows light to pass



variable: 2 s, 1/50 s, 1/1000 s

CAMERA SHUTTER



prevents | allows light to pass



variable: 2 s, 1/50 s, 1/1000 s



freeze movement → short shutter speed

SHUTTER SPEED



CAMERA SHUTTER

electronic



mechanical

CAMERA SHUTTER

electronic



mechanical

global | progressive



leaf | rotary disc | rolling-blind

CAMERA SHUTTER

electronic



mechanical

global | progressive



leaf | rotary disc | rolling-blind

focal plane



central | behind-the-lens | focal plane

CAMERA SHUTTER

electronic  **mechanical**

global | progressive  leaf | rotary disc | **rolling-blind**

focal plane  central | behind-the-lens | **focal plane**

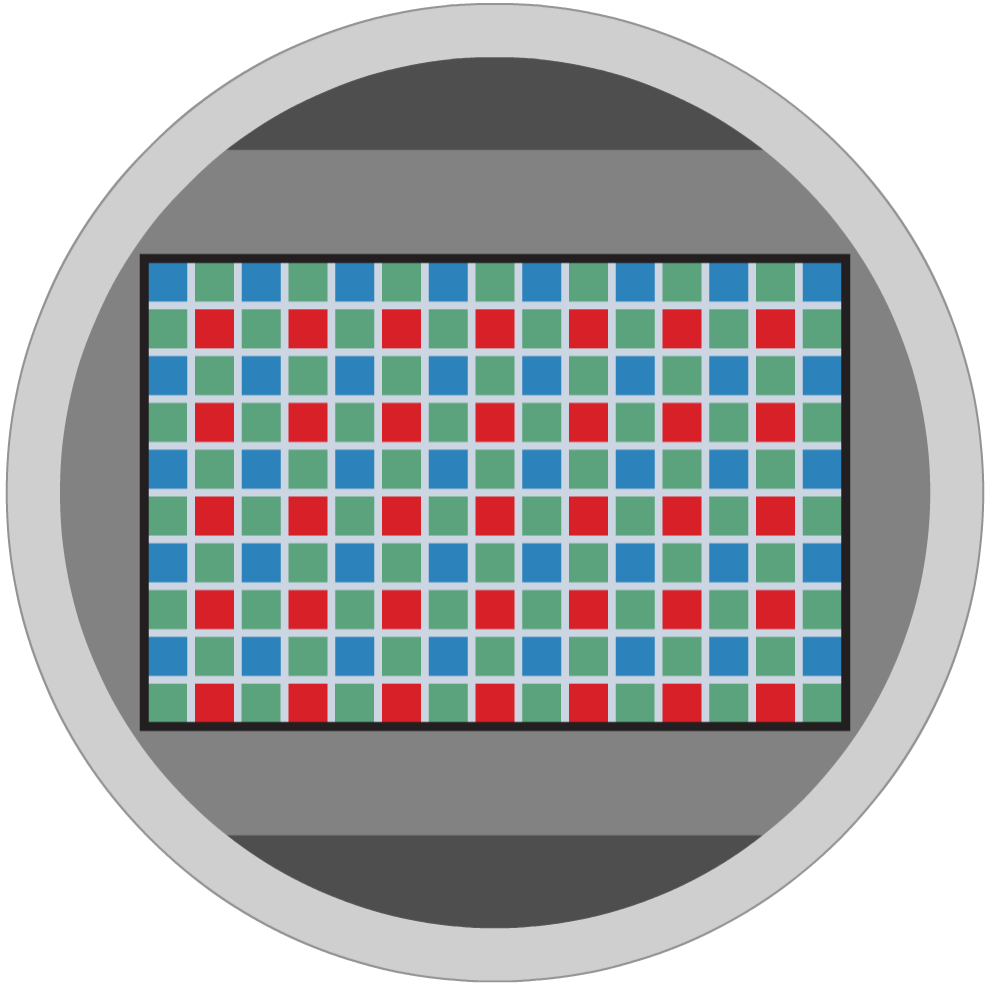
CAMERA SHUTTER

electronic  mechanical

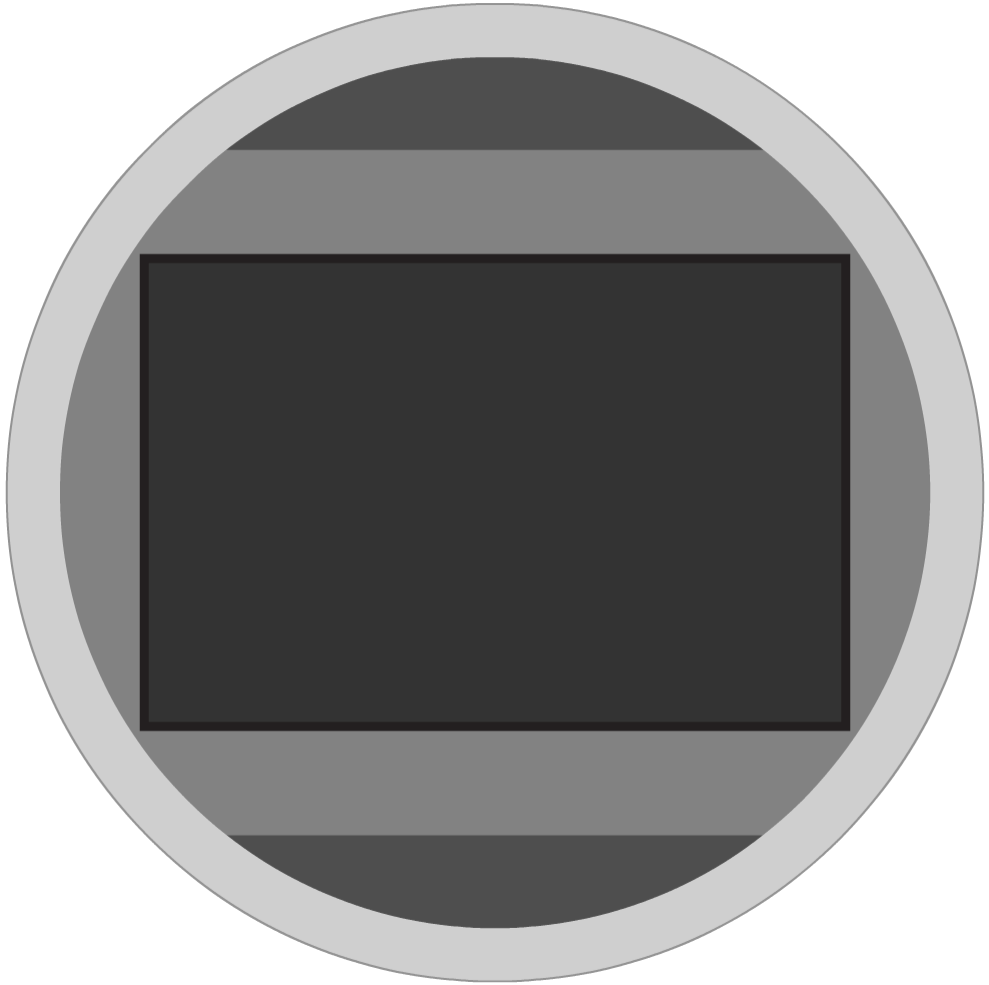
global | progressive  leaf | rotary disc | rolling-blind

focal plane  central | behind-the-lens | focal plane

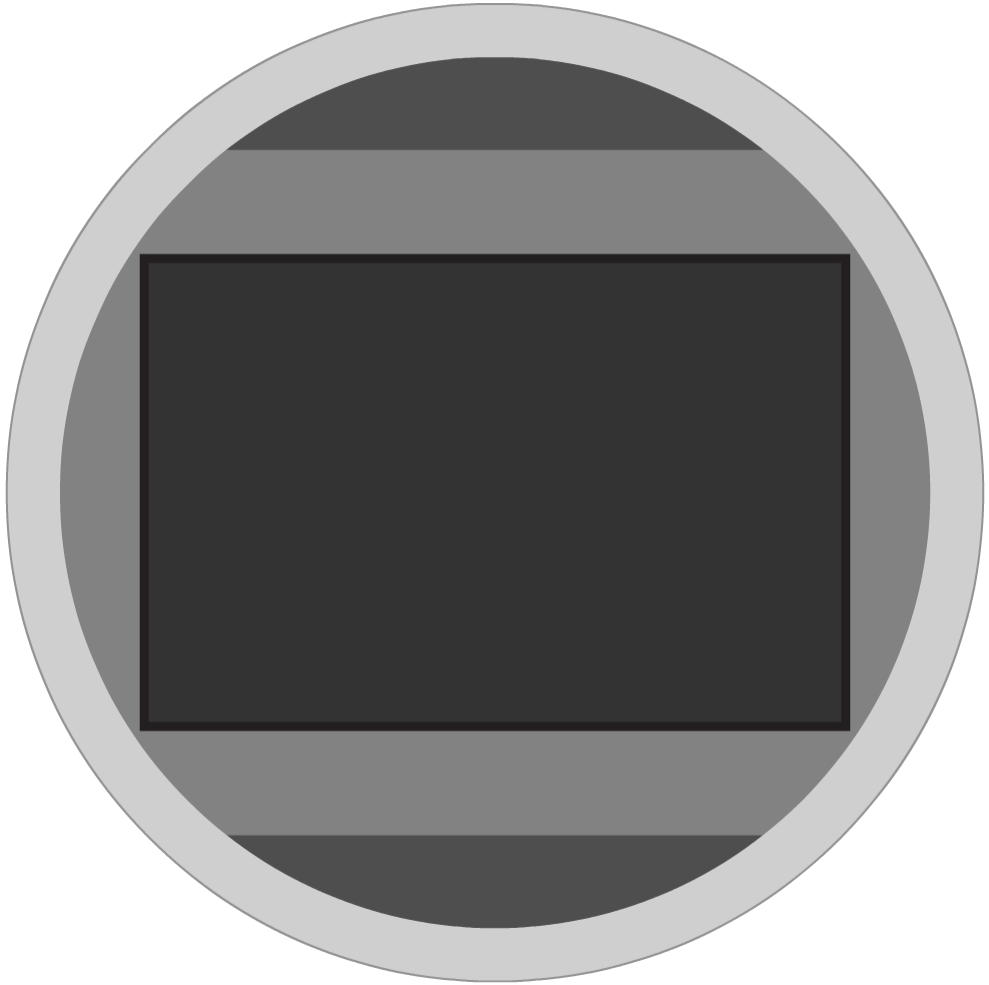
ROLLING-BLIND FOCAL PLANE SHUTTER



ROLLING-BLIND FOCAL PLANE SHUTTER

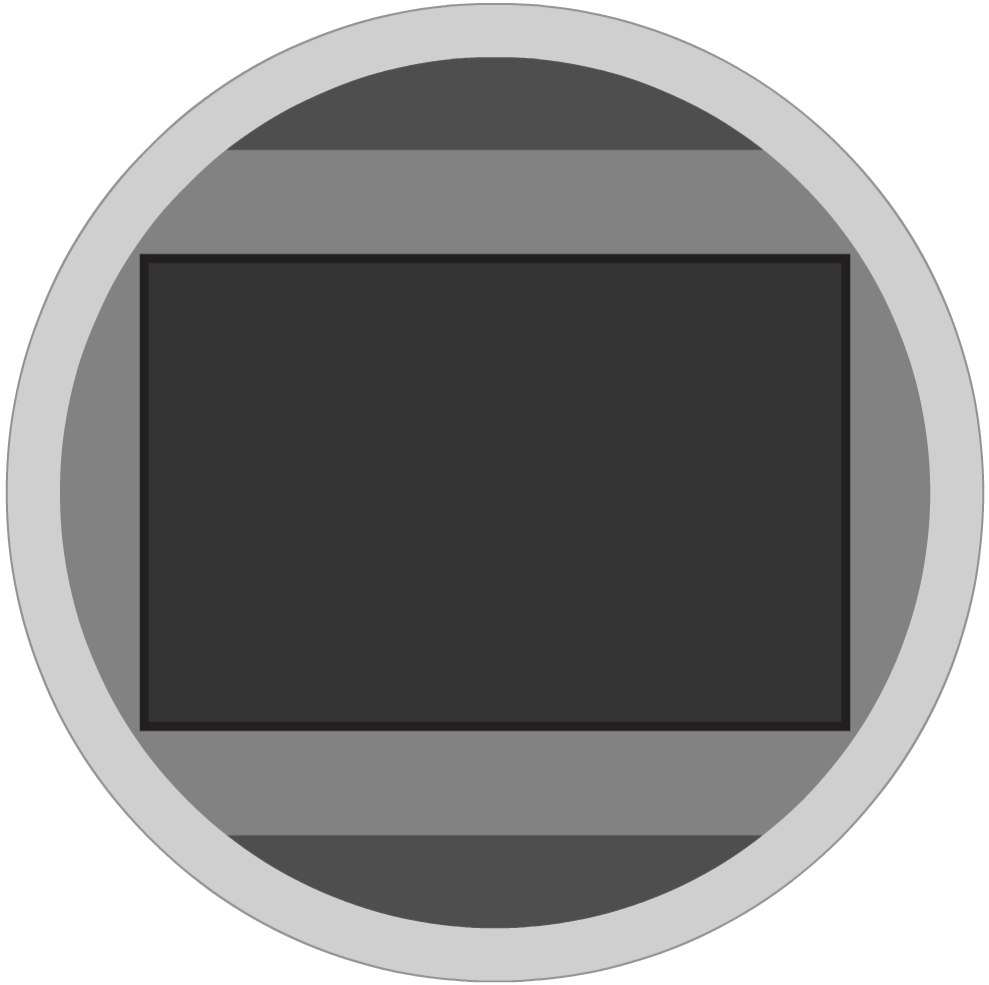


ROLLING-BLIND FOCAL PLANE SHUTTER



1s

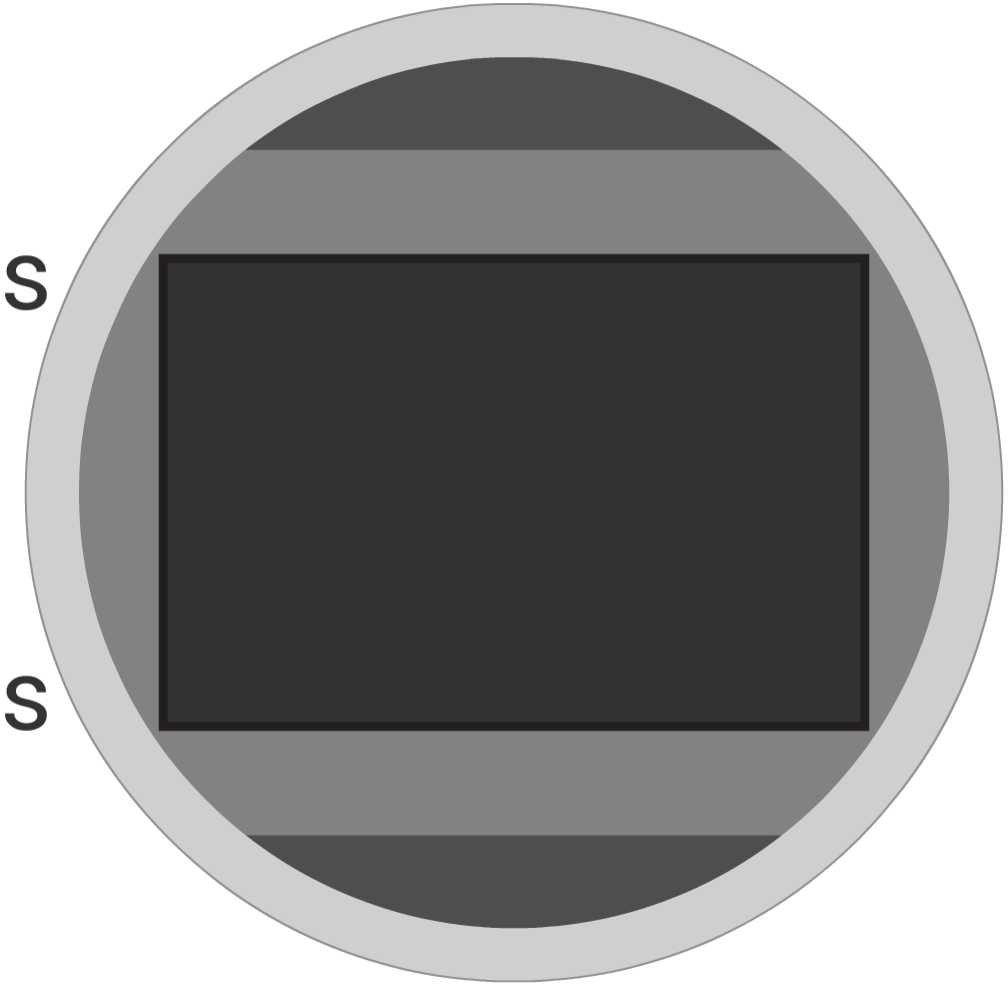
ROLLING-BLIND FOCAL PLANE SHUTTER



0.0000 s

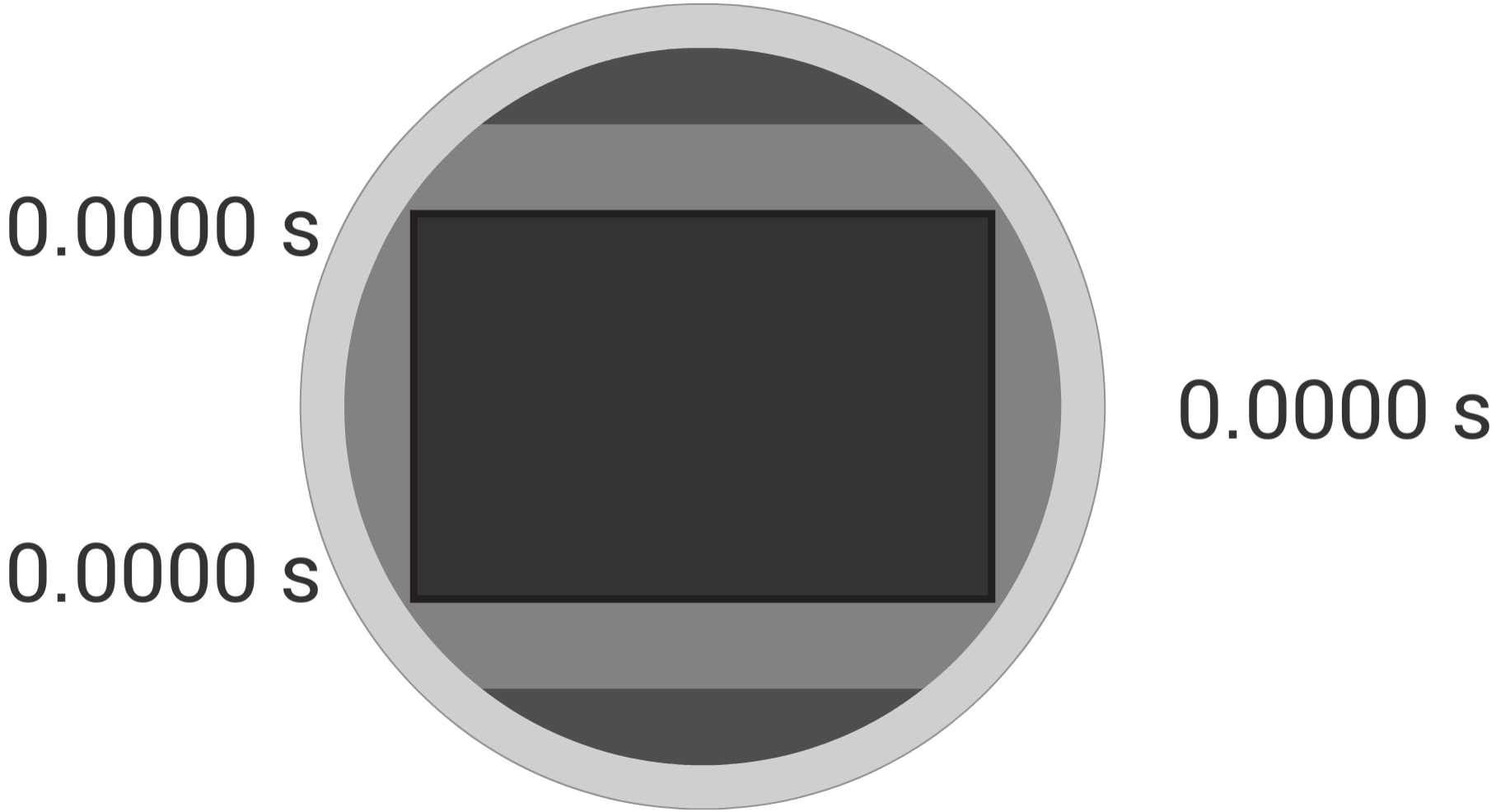
1 s

ROLLING-BLIND FOCAL PLANE SHUTTER



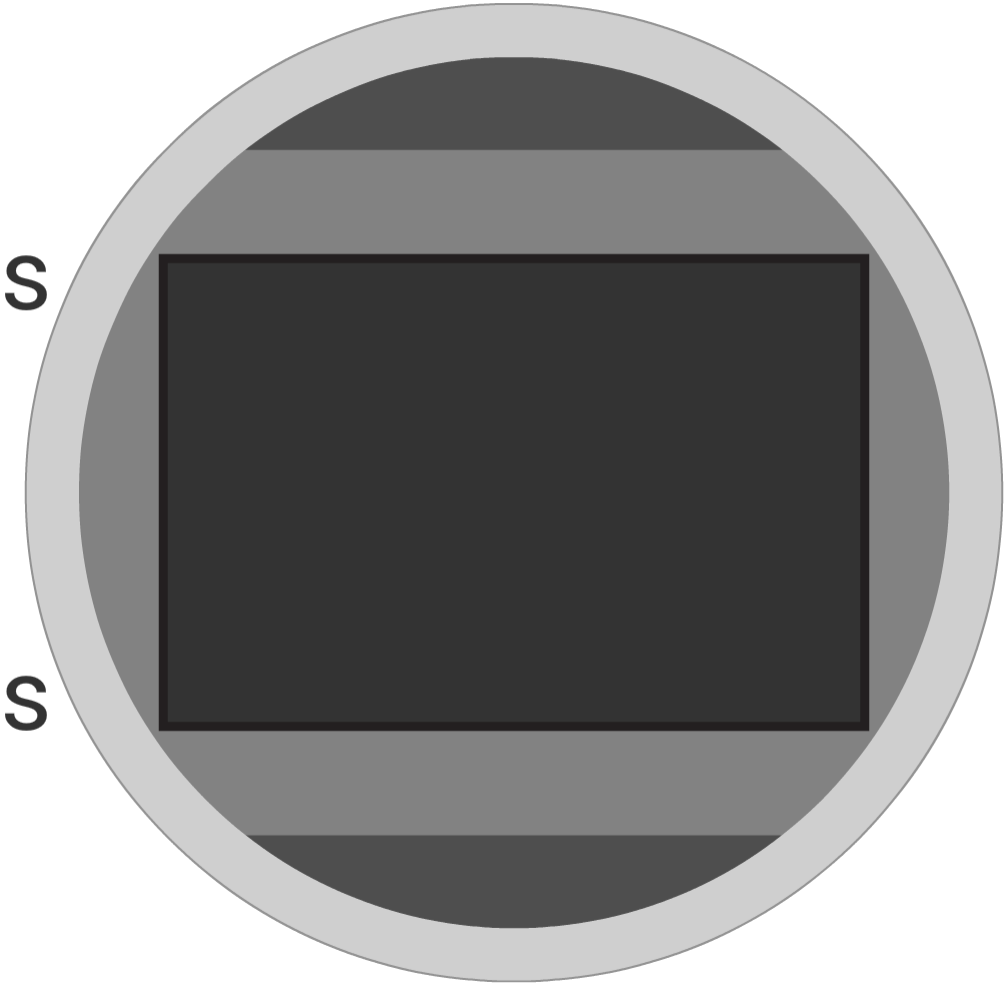
1 s

ROLLING-BLIND FOCAL PLANE SHUTTER



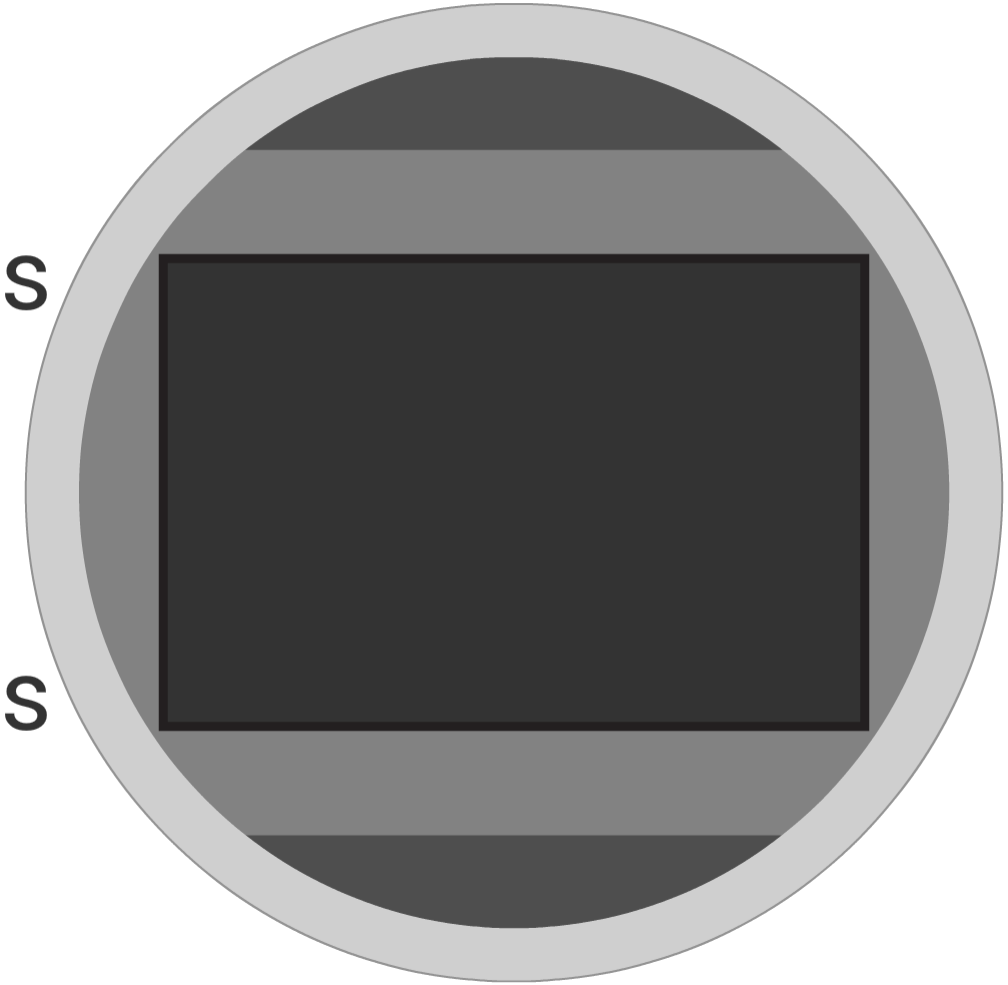
1 s

ROLLING-BLIND FOCAL PLANE SHUTTER



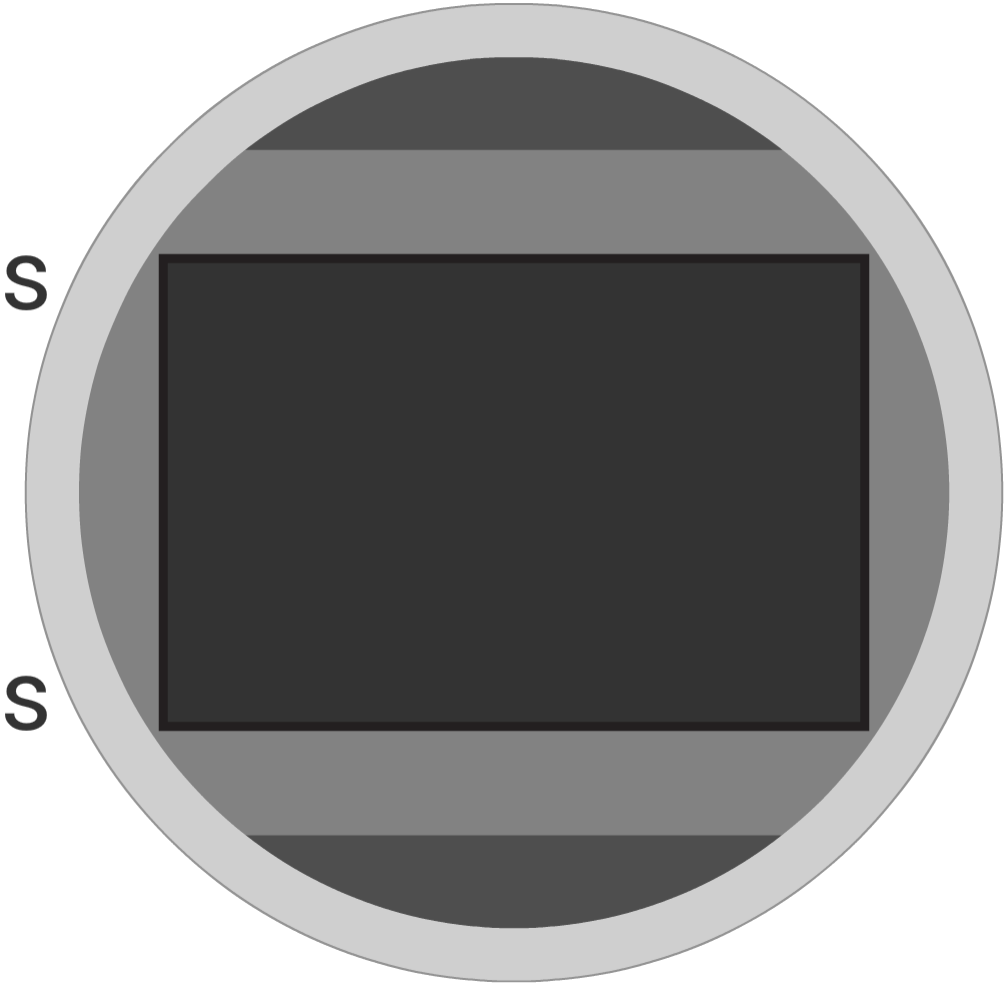
1 s
300

ROLLING-BLIND FOCAL PLANE SHUTTER



1 s / 1000

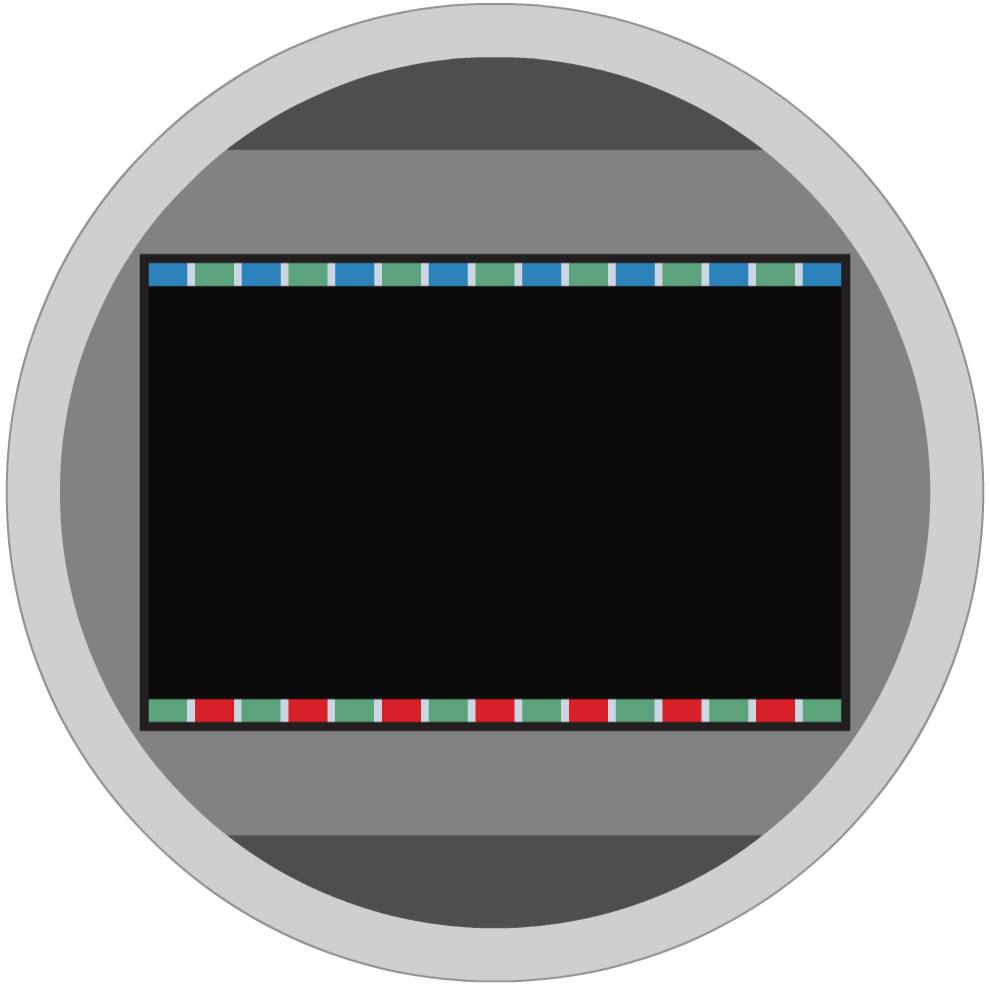
ROLLING-BLIND FOCAL PLANE SHUTTER



1 s
5000

ROLLING-BLIND FOCAL PLANE SHUTTER

0.0002 s

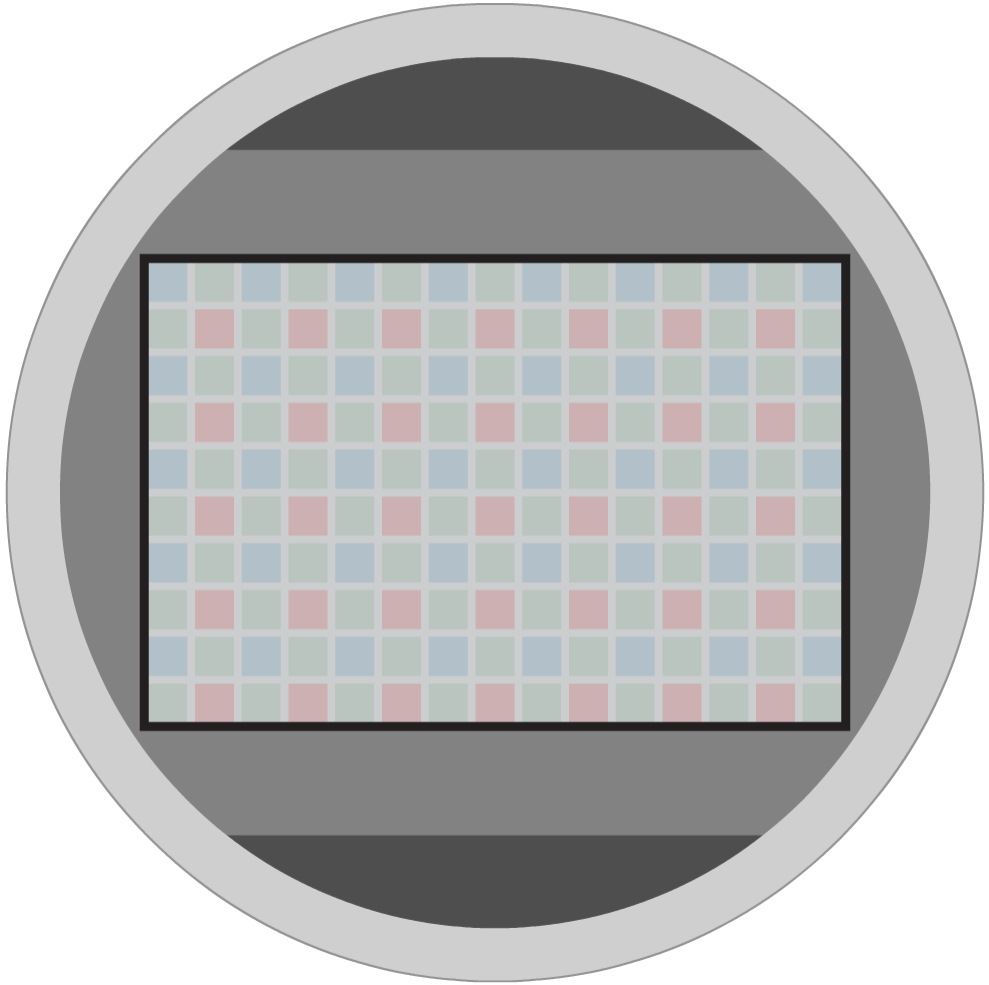


0.0035 s

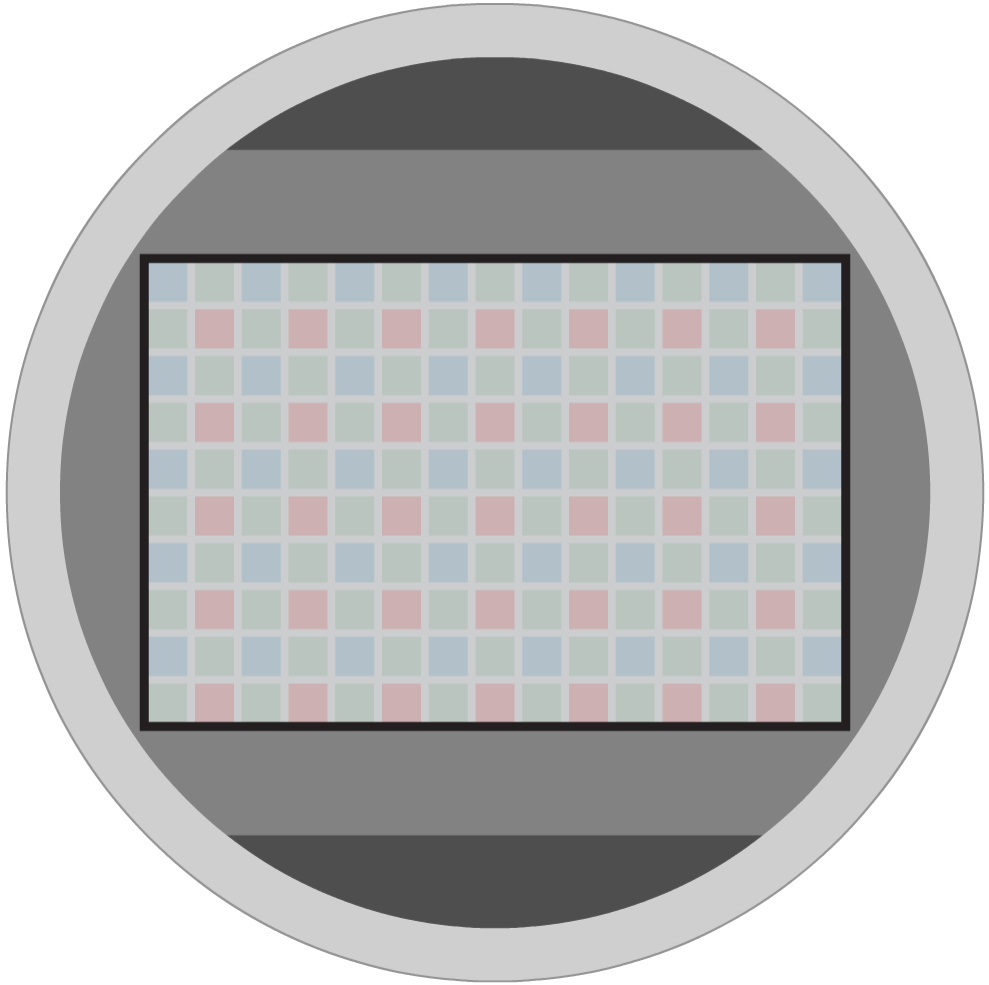
0.0002 s

1 s / 5000

ELECTRONIC SHUTTER



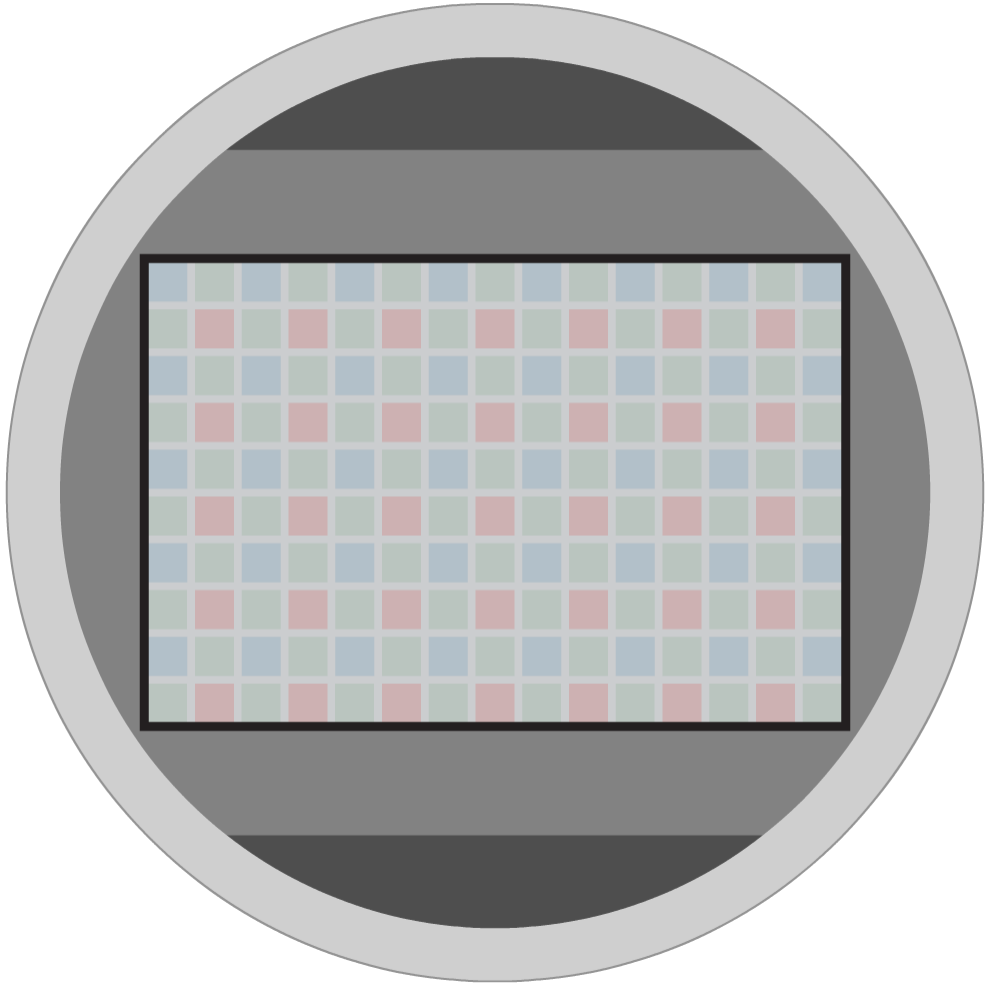
GLOBAL ELECTRONIC SHUTTER



0.00 s

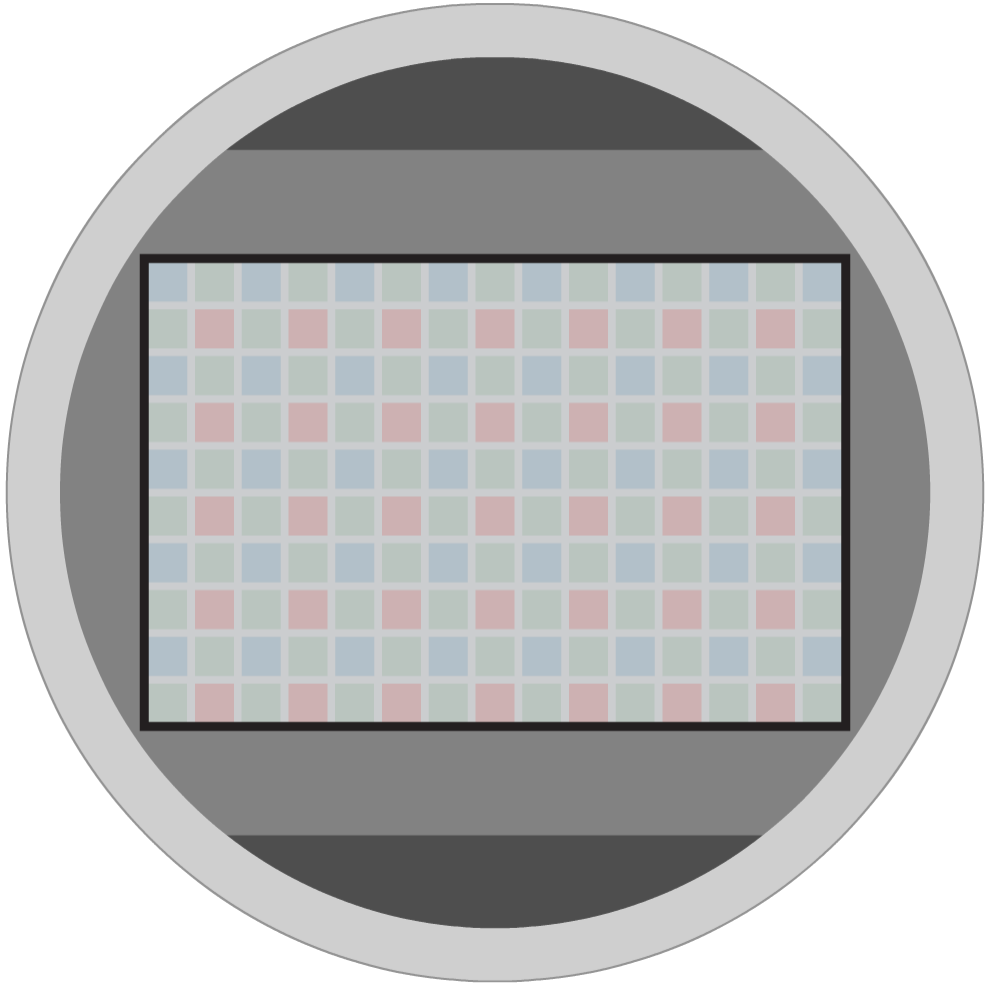
1 s

PROGRESSIVE ELECTRONIC SHUTTER



1s

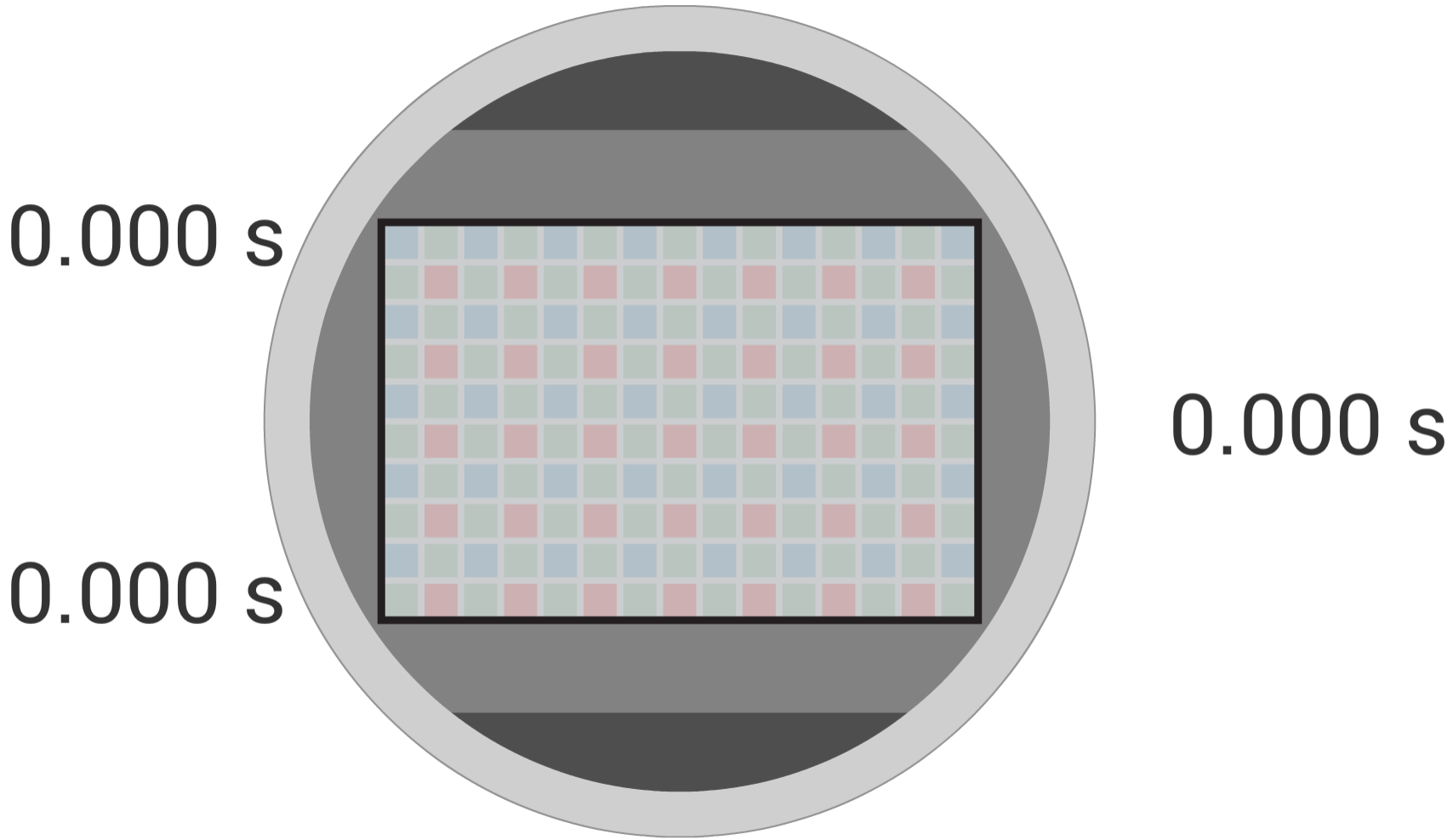
PROGRESSIVE ELECTRONIC SHUTTER



0.000 s

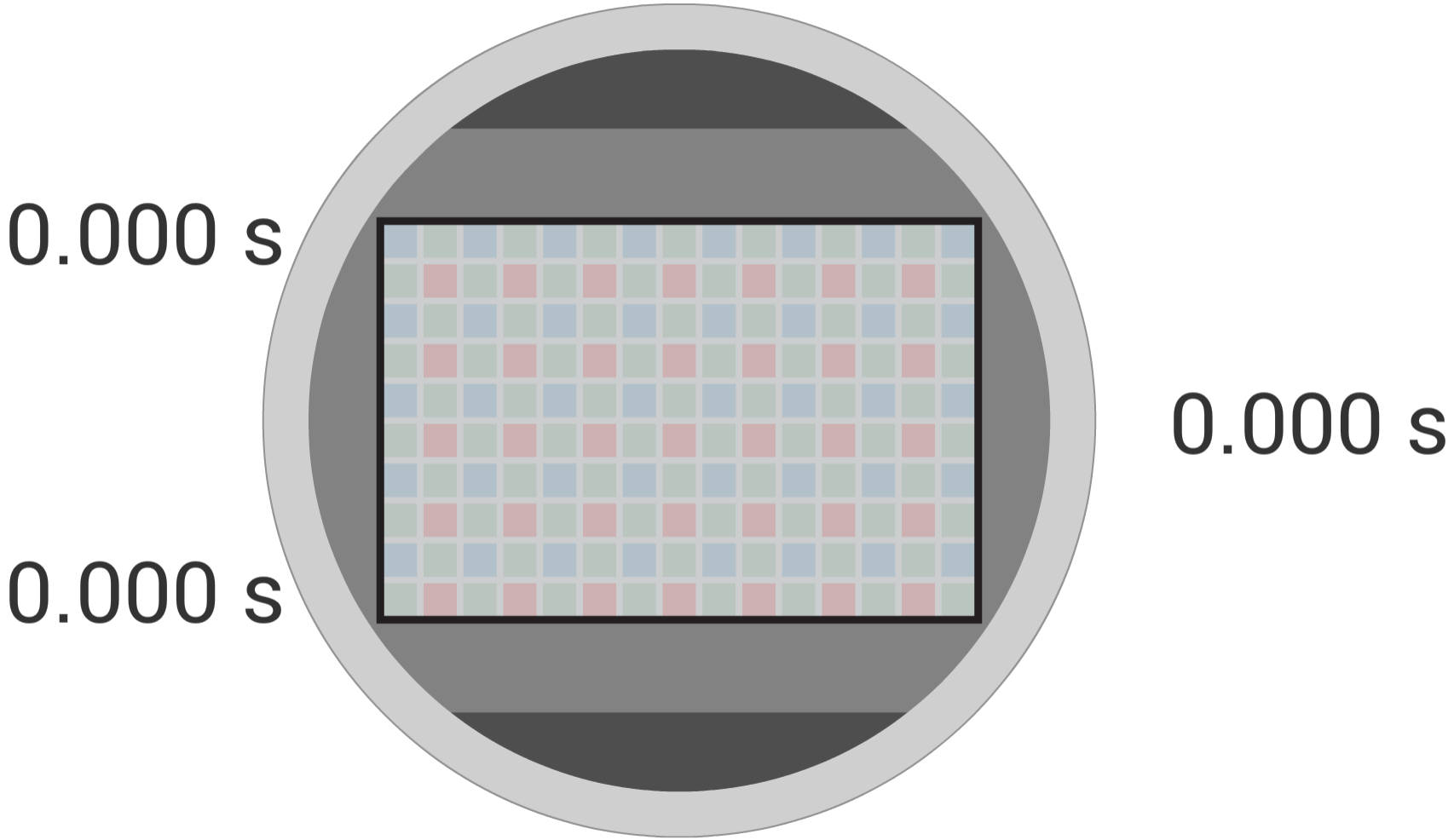
1 s

PROGRESSIVE ELECTRONIC SHUTTER



1 s

PROGRESSIVE ELECTRONIC SHUTTER



1 s
250

PROGRESSIVE ELECTRONIC SHUTTER



Zuzana Zizkova 2022

CAMERA TESTS



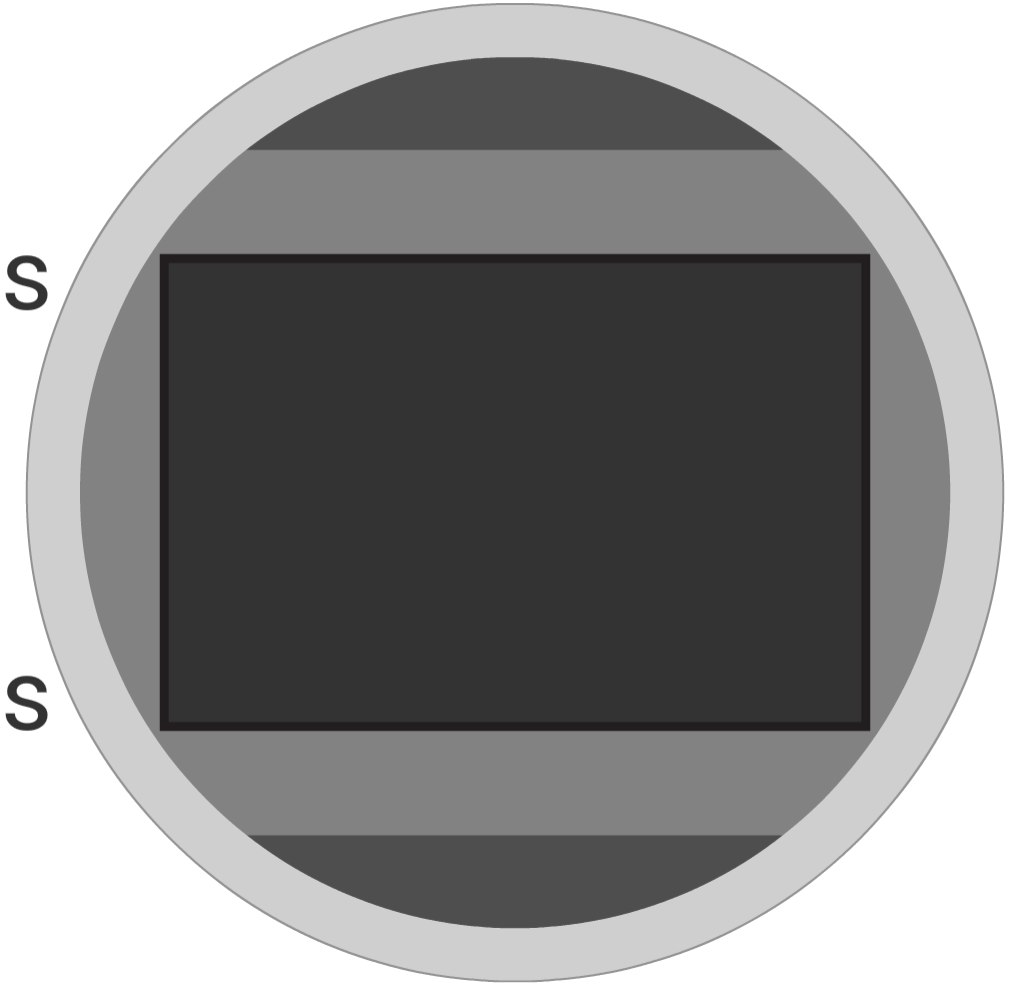
Nikon Z 7II



GoPro HERO11 Black

SHUTTER (READ-OUT) SPEED

0.00000 s



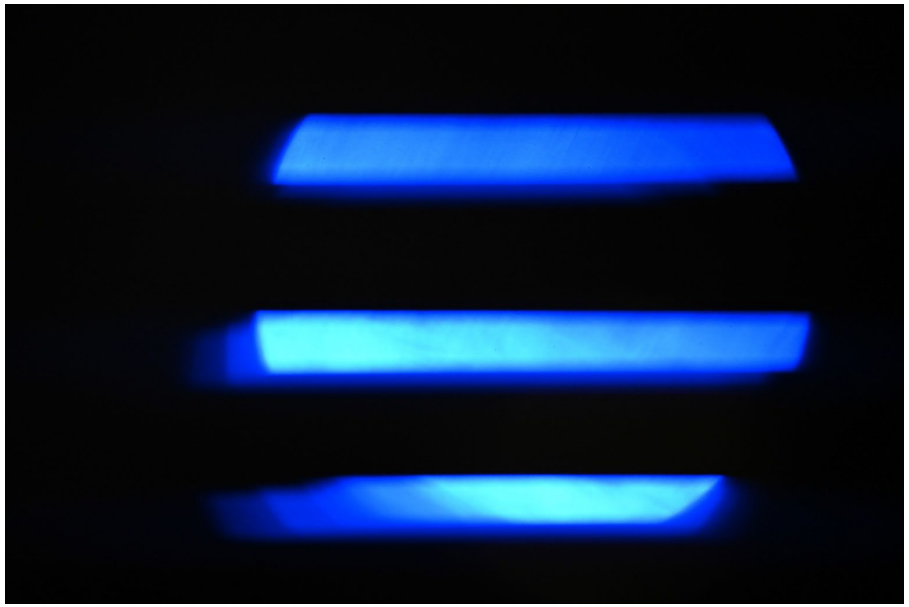
0.0000 s

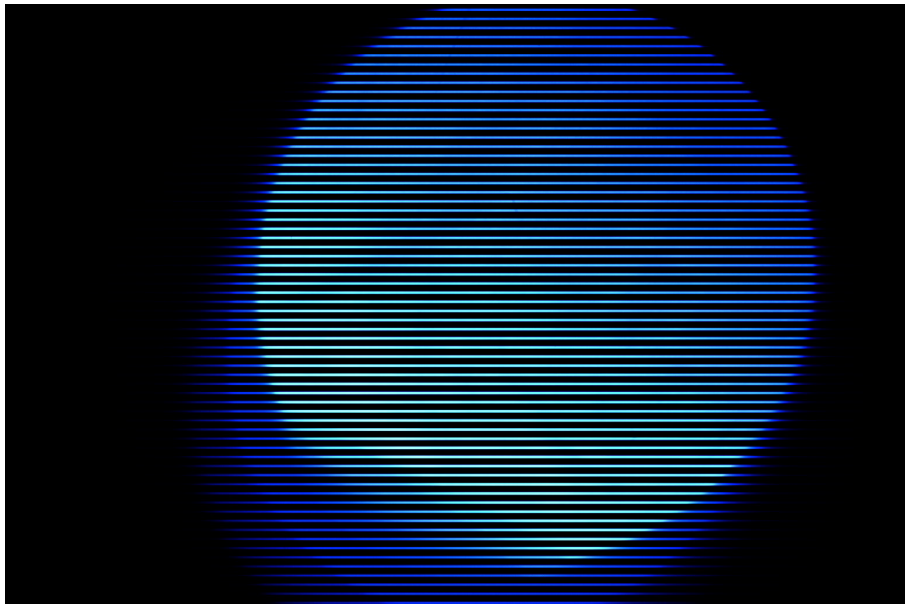
0.00000 s

SHUTTER (READ-OUT) SPEED



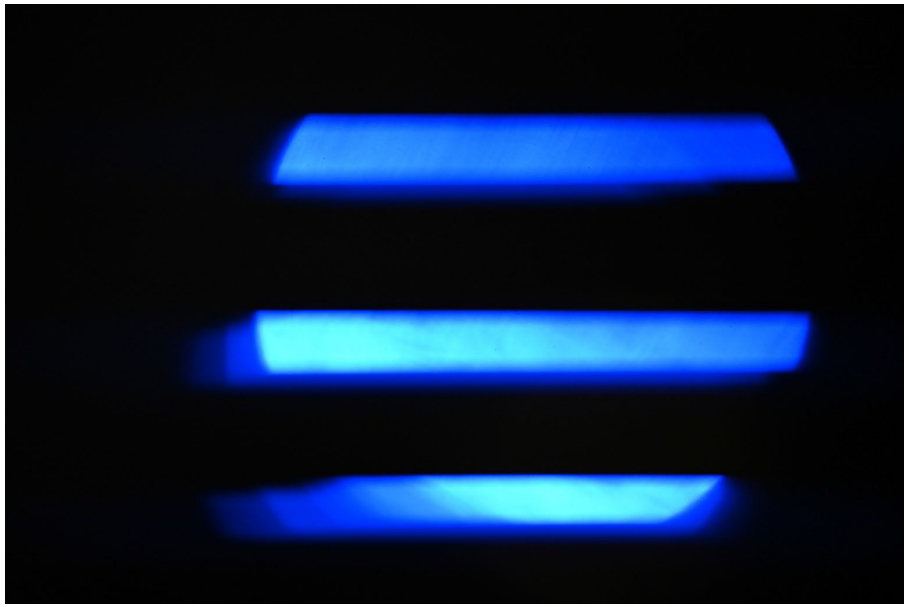
SHUTTER (READ-OUT) SPEED

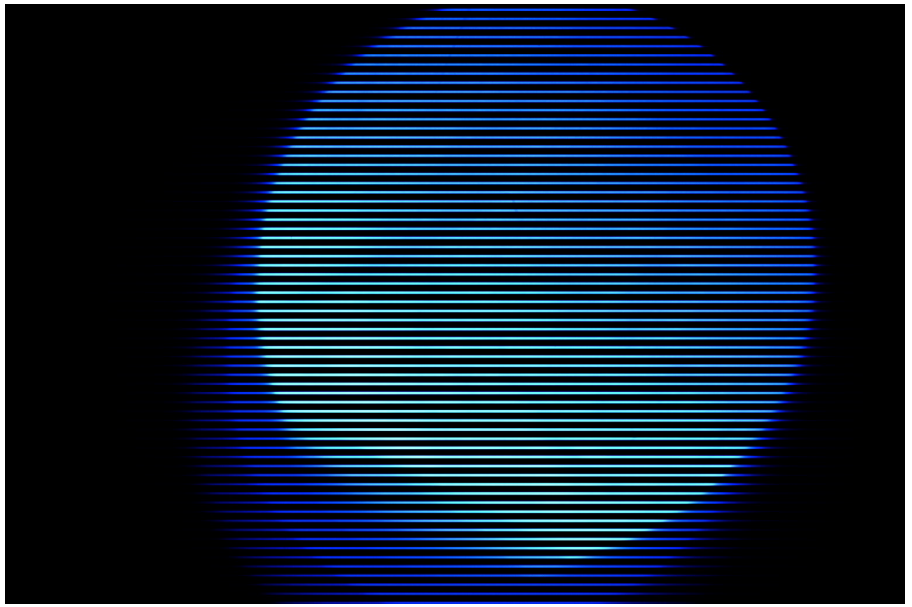


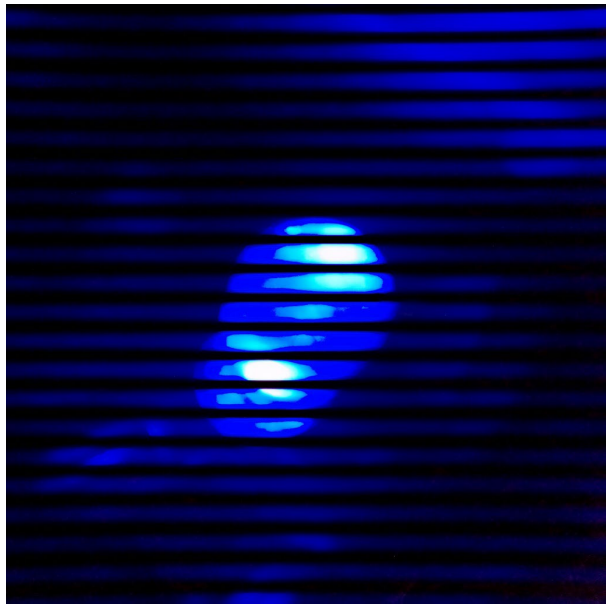


Nikon Z 7II

SHUTTER (READ-OUT) SPEED



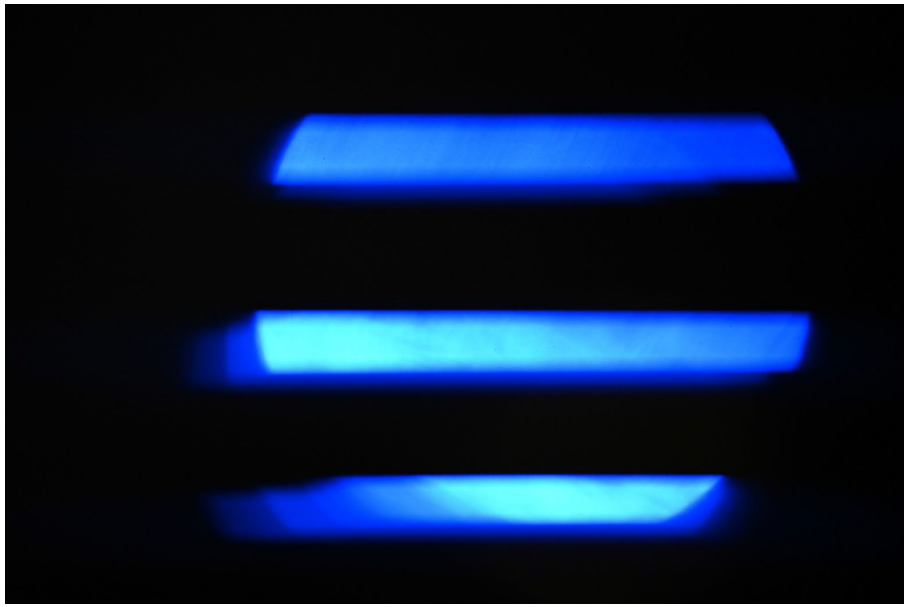


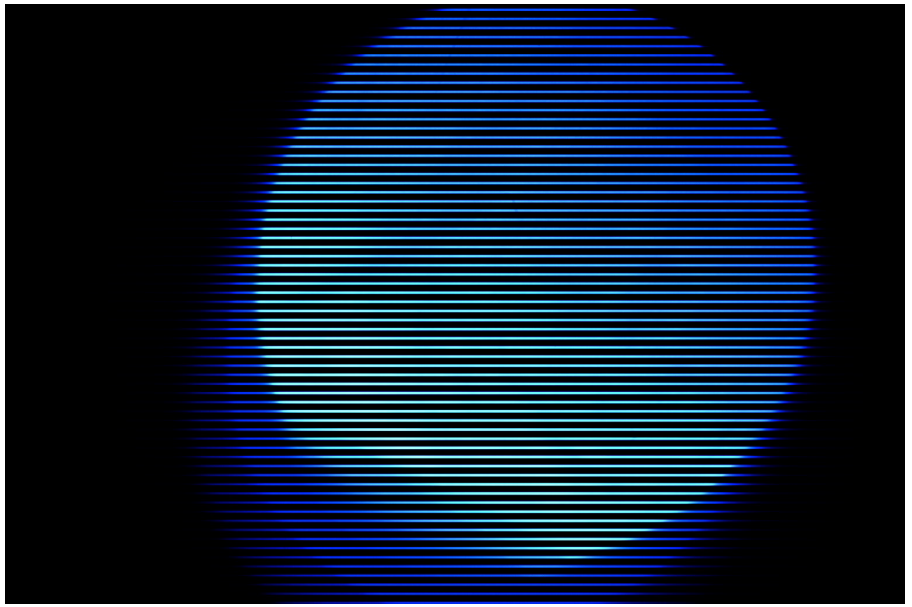


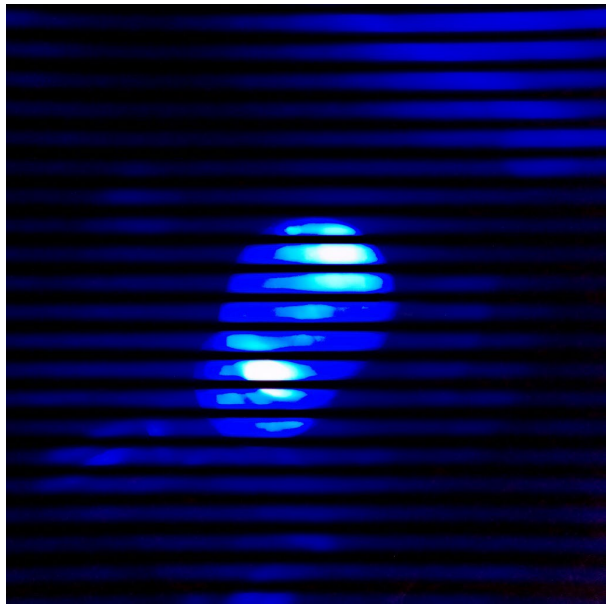
Nikon Z 7II

GoPro HERO11 Black

SHUTTER (READ-OUT) SPEED







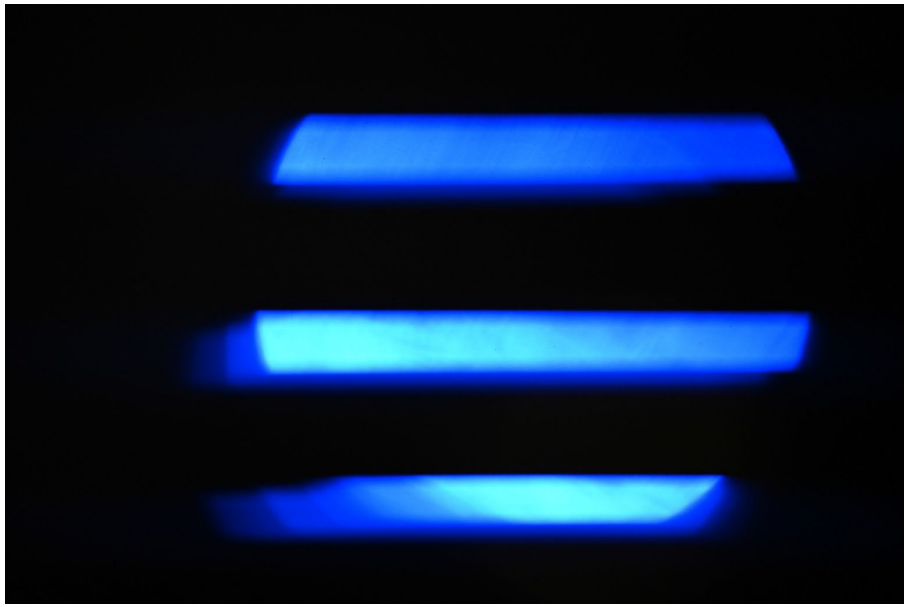
Nikon Z 7II

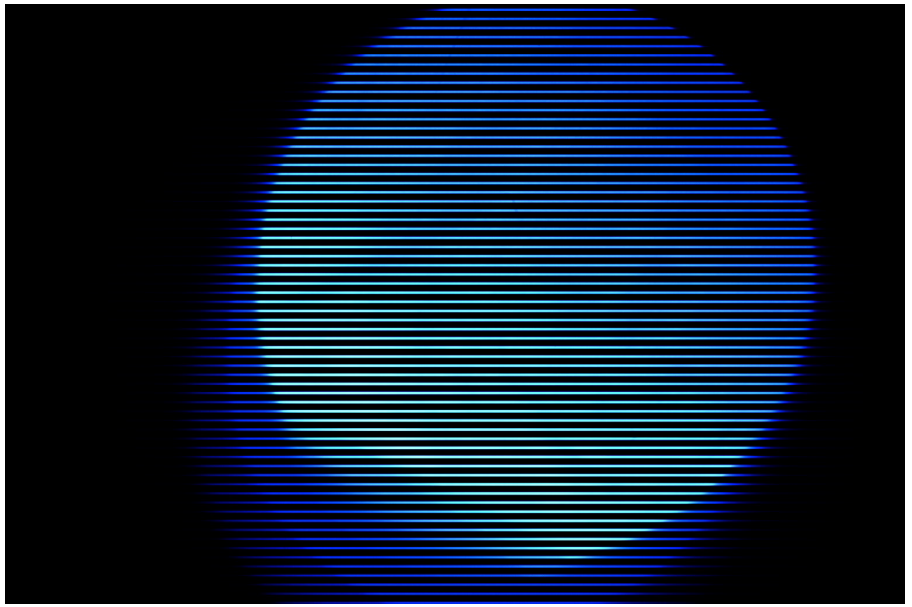
GoPro HERO11 Black

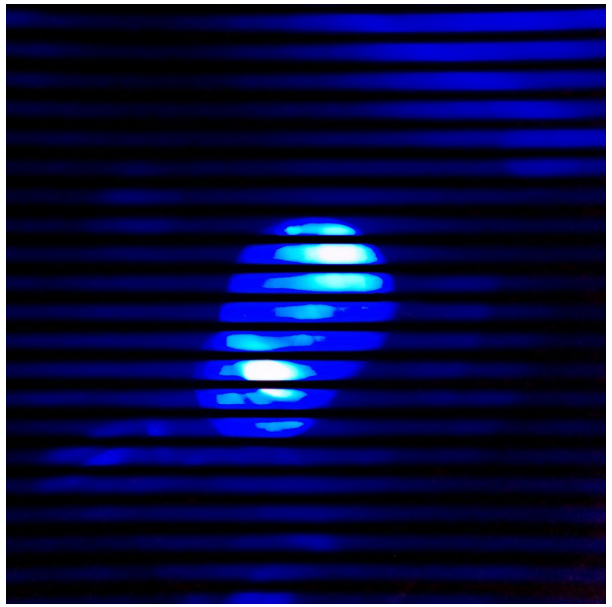
Mechanical shutter

Progressive electronic shutter

SHUTTER (READ-OUT) SPEED







Nikon Z 7II

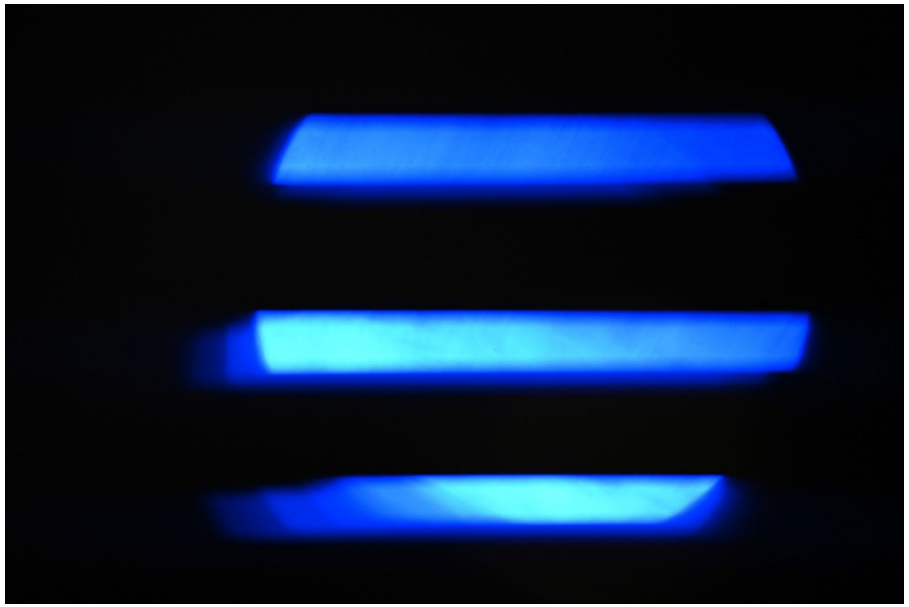
GoPro HERO11 Black

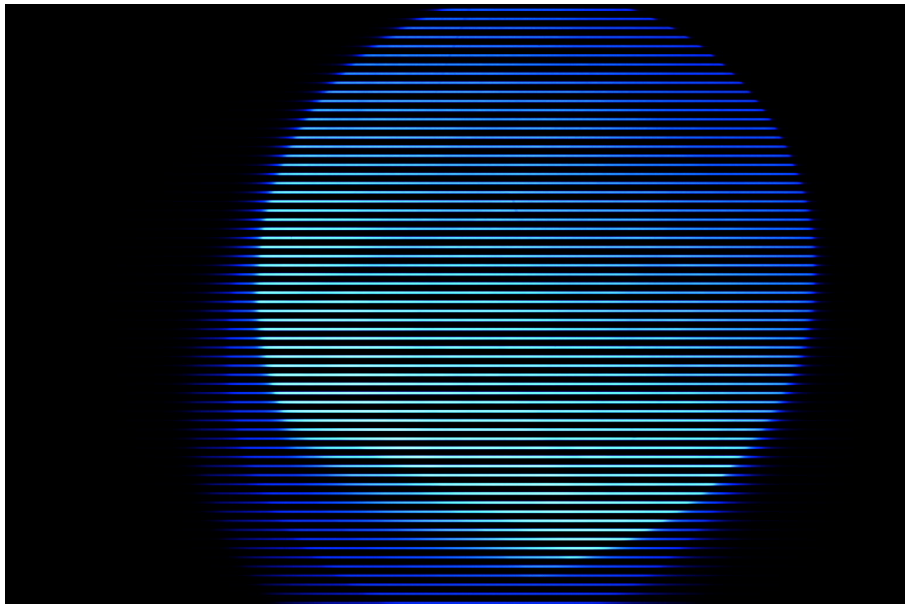
Mechanical shutter

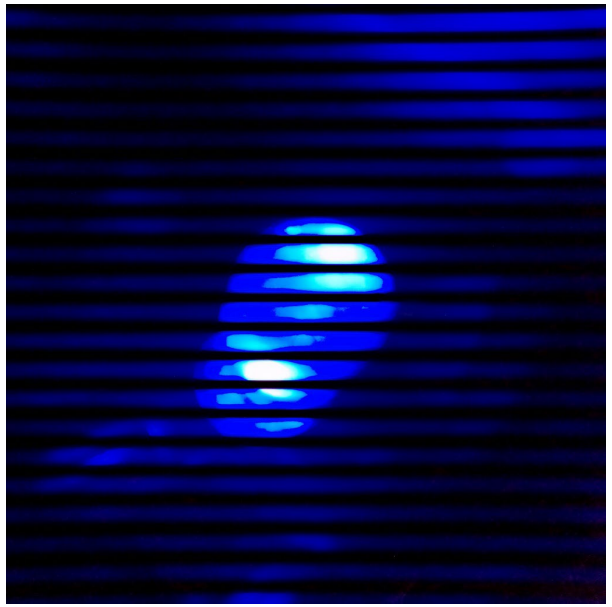
Progressive electronic shutter

1 / 300 s

SHUTTER (READ-OUT) SPEED

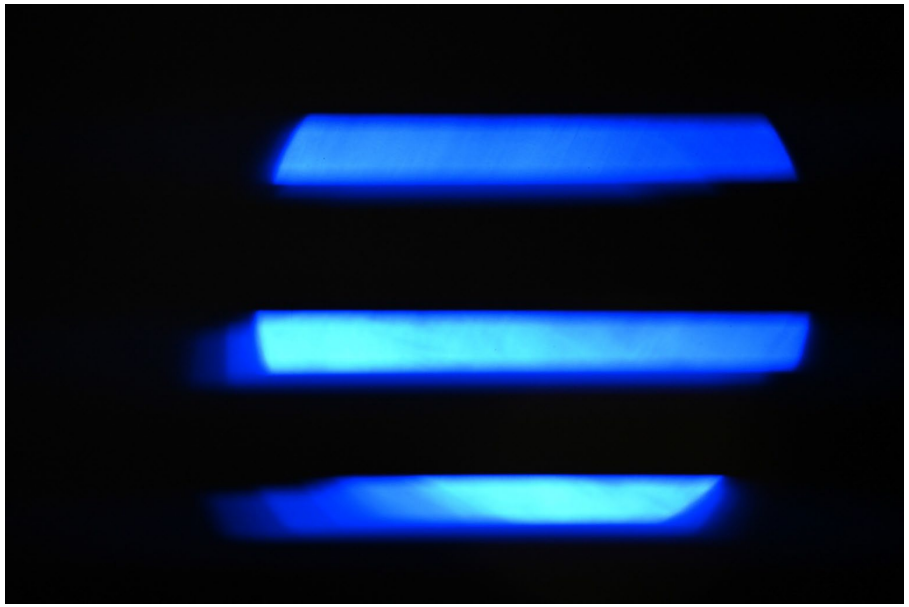


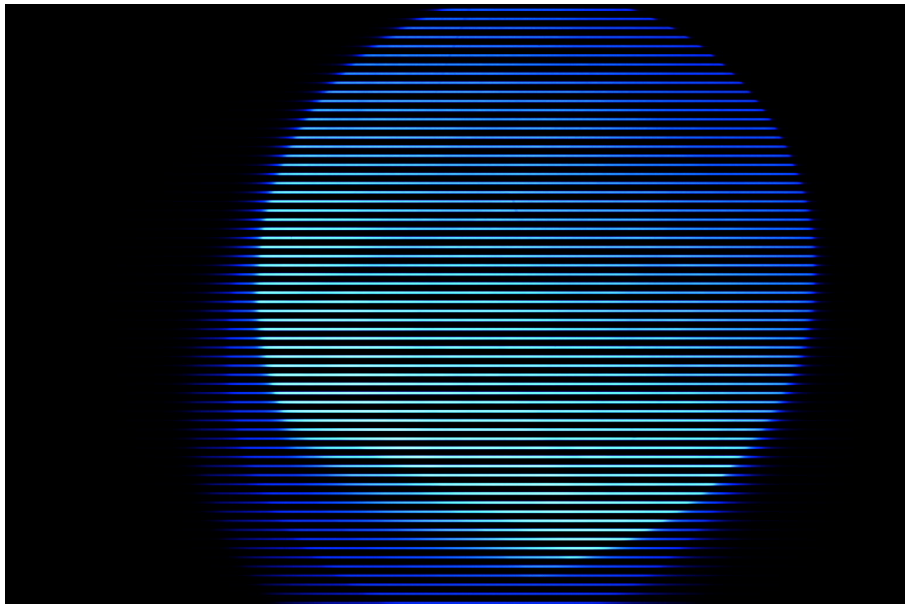


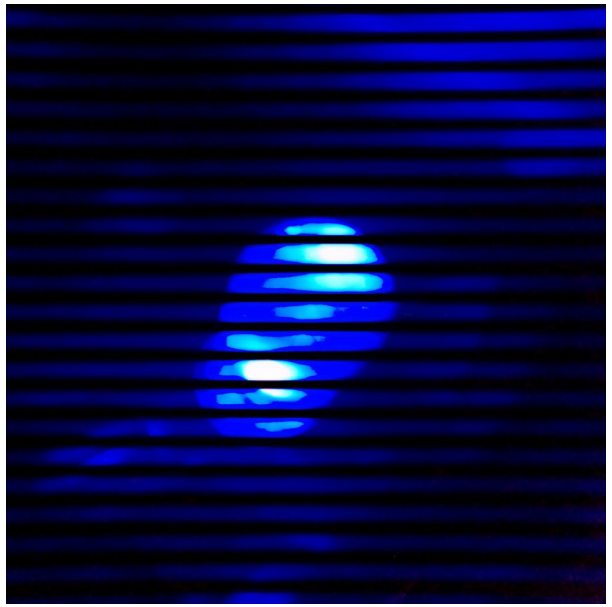


Nikon Z 7II	GoPro HERO11 Black
Mechanical shutter	Progressive electronic shutter
1 / 300 s	~ 1 / 50 s

SHUTTER (READ-OUT) SPEED

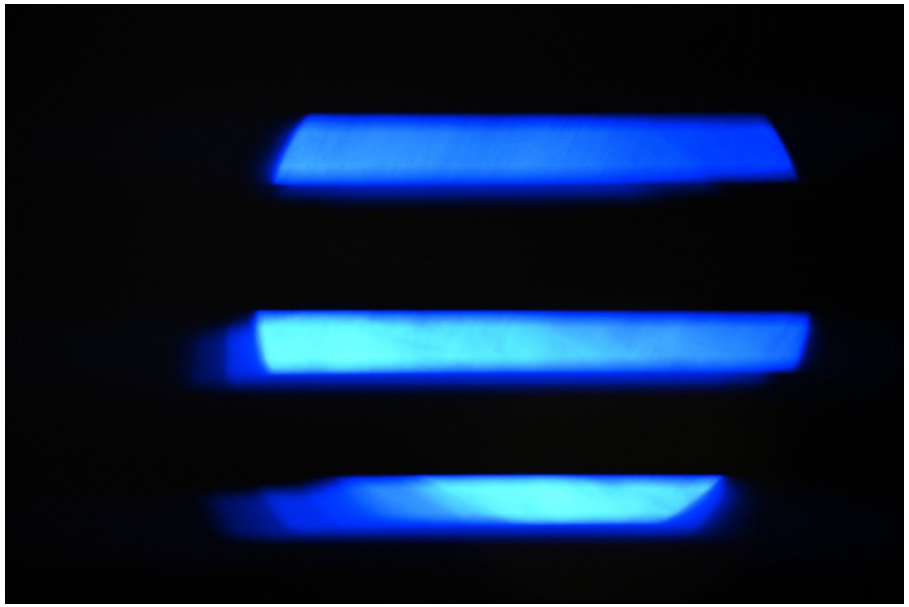


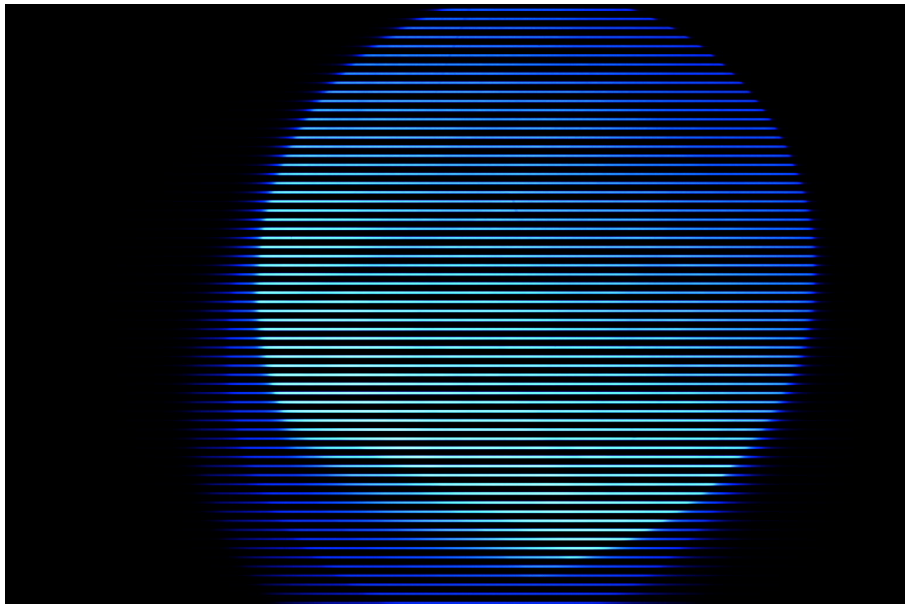


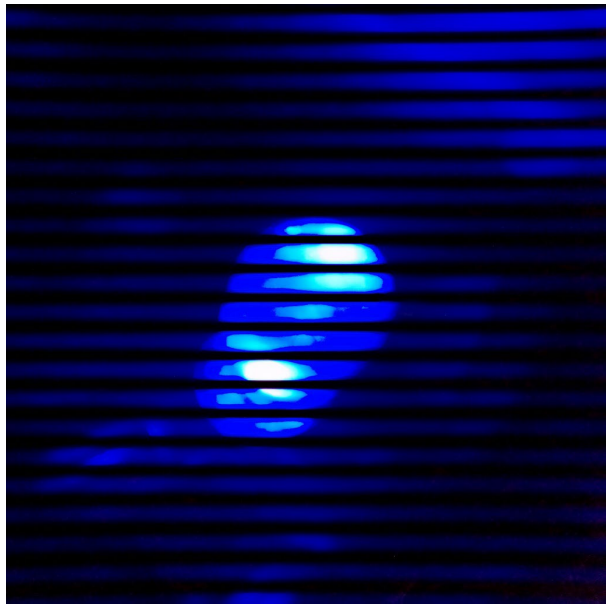


Nikon Z 7II		GoPro HERO11 Black
Mechanical shutter	Progressive electronic shutter	
1 / 300 s	~ 1 / 15 s	~ 1 / 50 s

SHUTTER (READ-OUT) SPEED







Nikon Z 7II		GoPro HERO11 Black
Mechanical shutter	Progressive electronic shutter	
1 / 300 s (25.9 km/h)	~ 1 / 15 s (1.3 km/h)	~ 1 / 50 s (1.0 km/h)

CASE STUDY 1

Graffitied wall (Vienna, 2024)



CASE STUDY 1



2x Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S

CASE STUDY 1





Mechanical shutter





Progressive electronic shutter

2x Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S

CASE STUDY 1





Mechanical shutter

exposure mode	*manual*
shutter speed	*1/400 s*
aperture	*f/4*
ISO	*400*
white balance	*cloudy*





Progressive electronic shutter

focusing	*off*
vibration reduct.	*off*
GSD	*? mm*
network	*51 photos*
image format	*JPG*

2x Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S

CASE STUDY 1





Mechanical shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*





Progressive electronic shutter

CASE STUDY 1





Mechanical shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*





Progressive electronic shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
	~~*rolling shutter compens.*~~
	regularised RS compens.
	full RS compensation
	full RS com. + adaptive IO
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*

CASE STUDY 1





Mechanical shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*





Progressive electronic shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
	~~*rolling shutter compens.*~~
	regularised RS compens.
	full RS compensation
	full RS com. + adaptive IO
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points					
RMS reproj. error					
max reproj. error					

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	22.2 k				
RMS reproj. error	0.21 (0.8 pix)				
max reproj. error	0.65 (59.6 pix)				

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	22.2 k	24.6 k			
RMS reproj. error	0.21 (0.8 pix)	0.42 (1.6 pix)			
max reproj. error	0.65 (59.6 pix)	1.29 (84.3 pix)			

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	22.2 k	24.6 k	24.1 k		
RMS reproj. error	0.21 (0.8 pix)	0.42 (1.6 pix)	0.25 (1.0 pix)		
max reproj. error	0.65 (59.6 pix)	1.29 (84.3 pix)	0.77 (64.3 pix)		

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	22.2 k	24.6 k	24.1 k	24.6 k	
RMS reproj. error	0.21 (0.8 pix)	0.42 (1.6 pix)	0.25 (1.0 pix)	0.18 (0.7 pix)	
max reproj. error	0.65 (59.6 pix)	1.29 (84.3 pix)	0.77 (64.3 pix)	0.56 (33.1 pix)	

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	22.2 k	24.6 k	24.1 k	24.6 k	24.6 k
RMS reproj. error	0.21 (0.8 pix)	0.42 (1.6 pix)	0.25 (1.0 pix)	0.18 (0.7 pix)	0.18 (0.7 pix)
max reproj. error	0.65 (59.6 pix)	1.29 (84.3 pix)	0.77 (64.3 pix)	0.56 (33.1 pix)	0.56 (33.1 pix)

CASE STUDY 1

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	22.2 k	24.6 k	24.1 k	24.6 k	24.6 k
RMS reproj. error	0.21 (0.8 pix)	0.42 (1.6 pix)	0.25 (1.0 pix)	0.18 (0.7 pix)	0.18 (0.7 pix)
max reproj. error	0.65 (59.6 pix)	1.29 (84.3 pix)	0.77 (64.3 pix)	0.56 (33.1 pix)	0.56 (33.1 pix)

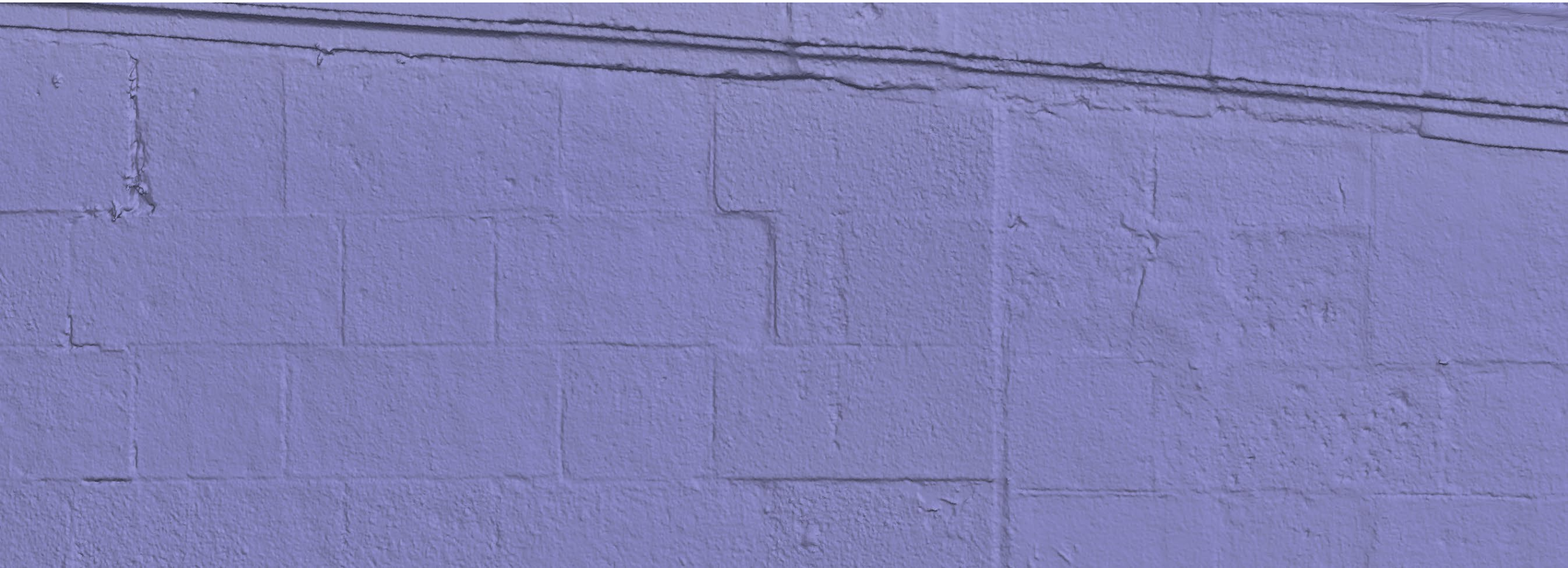
CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



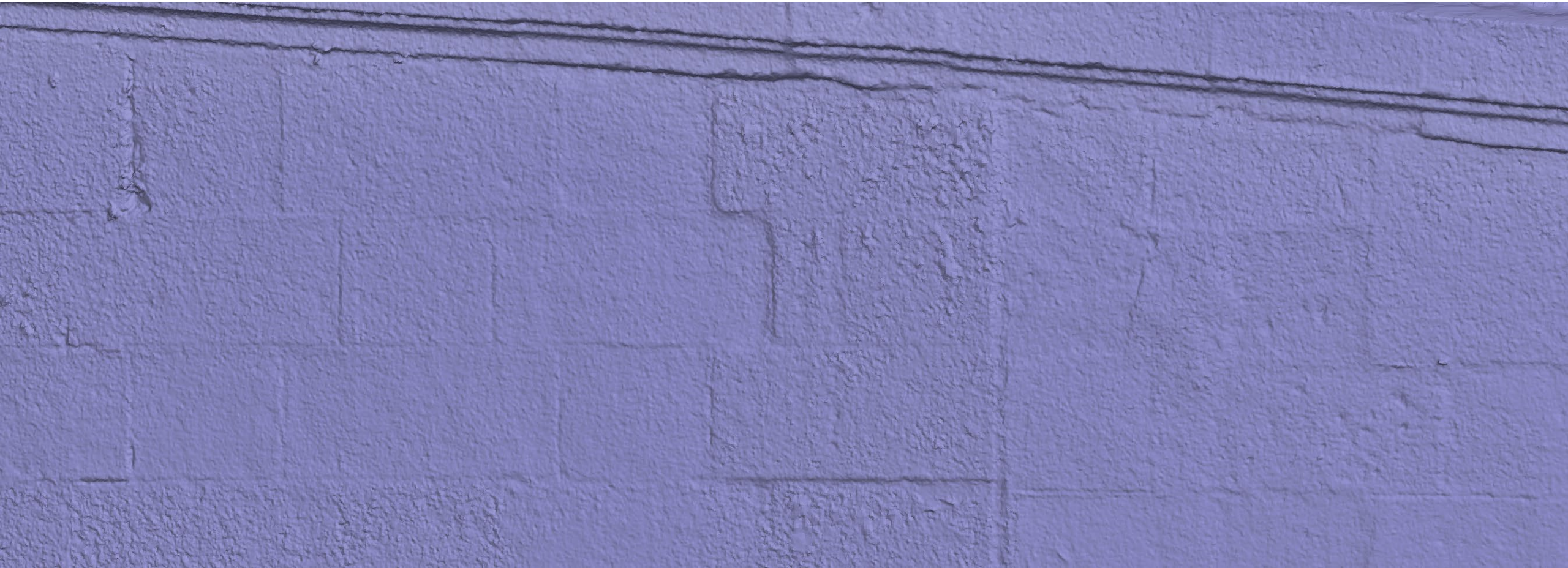
CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



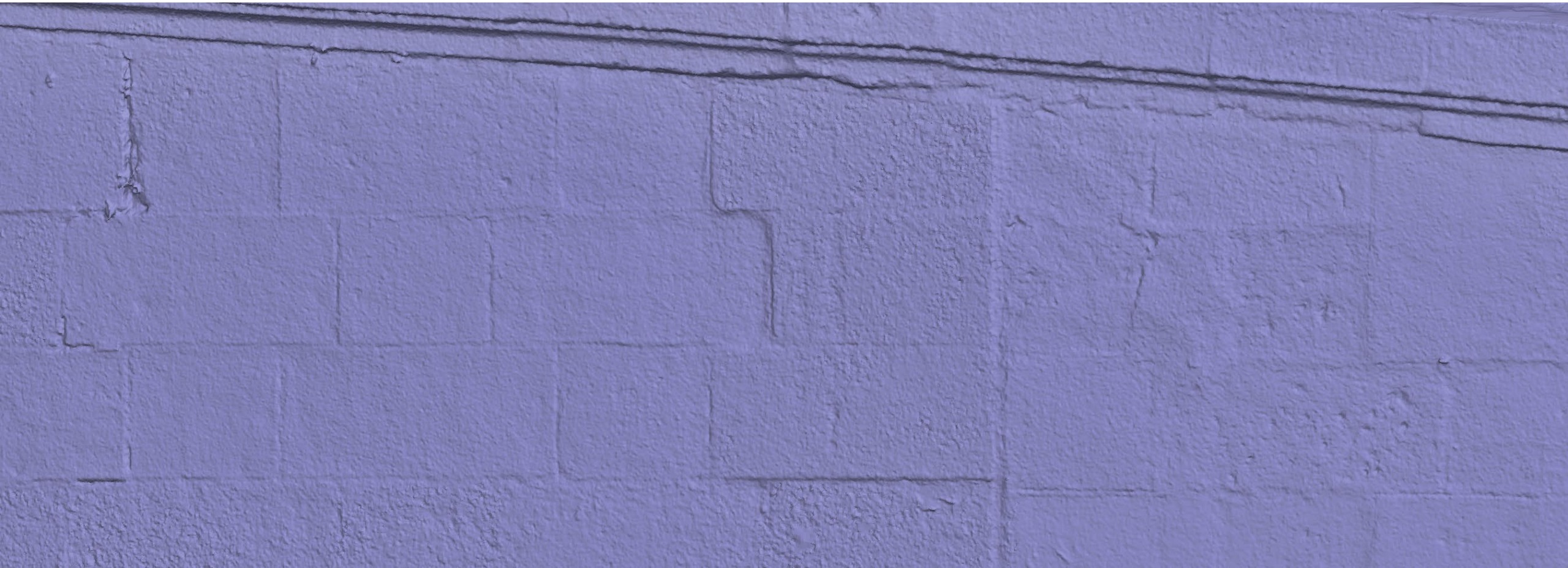
CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



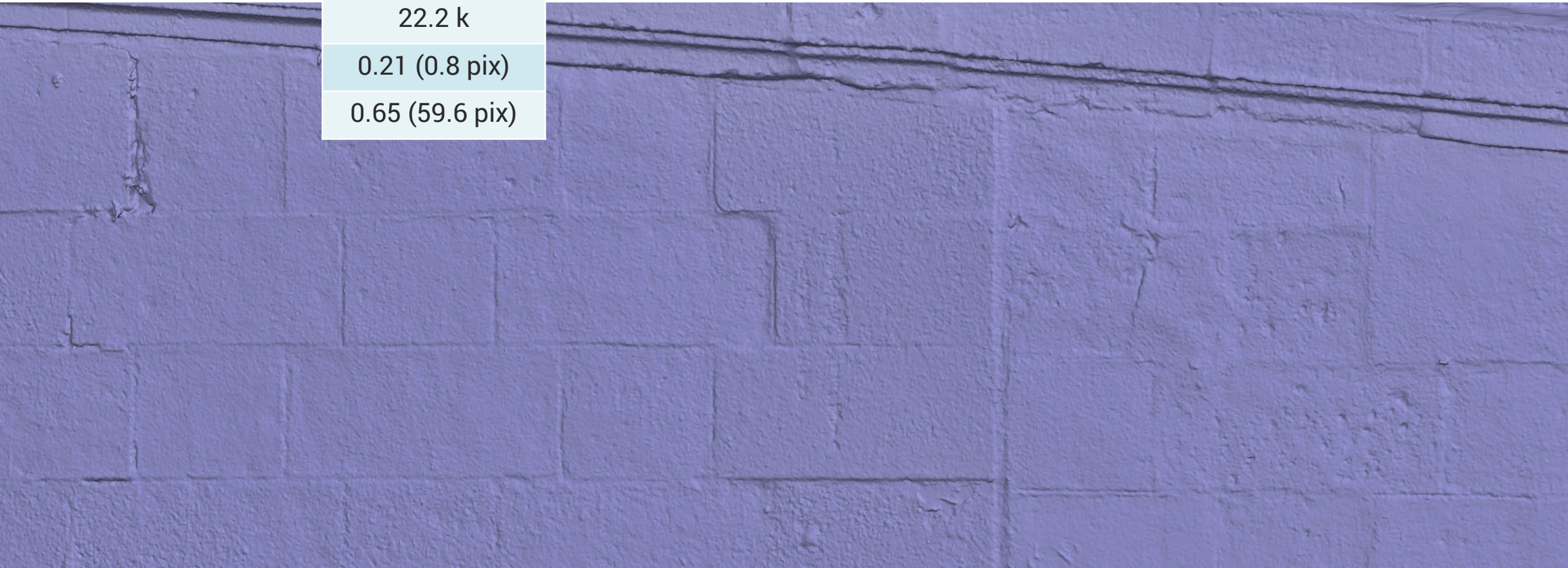
CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO
			24.6 k	
			0.18 (0.7 pix)	
			0.56 (33.1 pix)	



CASE STUDY 1

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO
22.2 k				
0.21 (0.8 pix)				
0.65 (59.6 pix)				



CASE STUDY 2

Otto Wagner Pavilion (Vienna, 1899)



CASE STUDY 2



2x Nikon Z7 II + Nikon NIKKOR Z 50 mm f/1.8 S

CASE STUDY 2



Mechanical shutter



Progressive electronic shutter

2x Nikon Z7 II + Nikon NIKKOR Z 50 mm f/1.8 S

CASE STUDY 2





Mechanical shutter

exposure mode	*manual*
shutter speed	*1/800 s*
aperture	*f/4*
ISO	*250*
white balance	*cloudy*

Progressive electronic shutter

focusing	*off*
vibration reduct.	*off*
GSD	*1.3 mm*
network	*43 photos*
image format	*JPG*

2x Nikon Z7 II + Nikon NIKKOR Z 50 mm f/1.8 S

CASE STUDY 2



Mechanical shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*



Progressive electronic shutter

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
	~~*rolling shutter compens.*~~
	regularised RS compens.
	full RS compensation
	full RS com. + adaptive IO
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points					
RMS reproj. error					
max reproj. error					

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	9.5 k				
RMS reproj. error	0.14 (0.8 pix)				
max reproj. error	0.43 (30.4 pix)				

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	9.5 k	10.0 k			
RMS reproj. error	0.14 (0.8 pix)	0.85 (3.5 pix)			
max reproj. error	0.43 (30.4 pix)	2.67 (96.6 pix)			

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	9.5 k	10.0 k	10.4 k		
RMS reproj. error	0.14 (0.8 pix)	0.85 (3.5 pix)	0.37 (1.7 pix)		
max reproj. error	0.43 (30.4 pix)	2.67 (96.6 pix)	1.14 (77.2 pix)		

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	9.5 k	10.0 k	10.4 k	10.6 k	
RMS reproj. error	0.14 (0.8 pix)	0.85 (3.5 pix)	0.37 (1.7 pix)	0.28 (1.3 pix)	
max reproj. error	0.43 (30.4 pix)	2.67 (96.6 pix)	1.14 (77.2 pix)	0.87 (55.7 pix)	

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	9.5 k	10.0 k	10.4 k	10.6 k	10.6 k
RMS reproj. error	0.14 (0.8 pix)	0.85 (3.5 pix)	0.37 (1.7 pix)	0.28 (1.3 pix)	0.28 (1.3 pix)
max reproj. error	0.43 (30.4 pix)	2.67 (96.6 pix)	1.14 (77.2 pix)	0.87 (55.7 pix)	0.88 (55.7 pix)

CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
tie points	9.5 k	10.0 k	10.4 k	10.6 k	10.6 k
RMS reproj. error	0.14 (0.8 pix)	0.85 (3.5 pix)	0.37 (1.7 pix)	0.28 (1.3 pix)	0.28 (1.3 pix)
max reproj. error	0.43 (30.4 pix)	2.67 (96.6 pix)	1.14 (77.2 pix)	0.87 (55.7 pix)	0.88 (55.7 pix)

CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



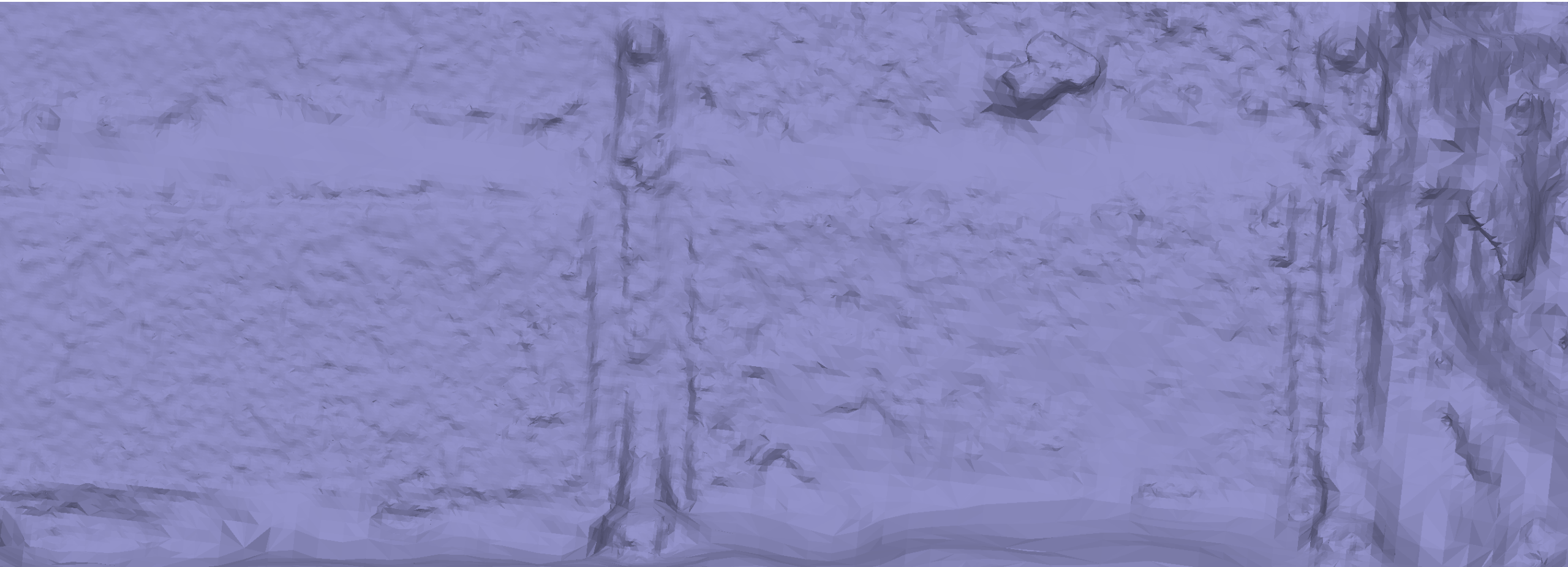
CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO



CASE STUDY 2

mechanical	electronic shutter			
	no RSC	regularis. RSC	full RSC	full RSC + adap. IO
			10.6 k	
			0.28 (1.3 pix)	
			0.87 (55.7 pix)	



CASE STUDY 2

	mechanical	electronic shutter			
		no RSC	regularis. RSC	full RSC	full RSC + adap. IO
9.5 k					
0.14 (0.8 pix)					
0.43 (30.4 pix)					



CASE STUDY 3

Wotruba Church (Vienna, 1976)



C.Stadler/Bwag 2020

CASE STUDY 3







Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S	GoPro HERO11 Black

CASE STUDY 3



Mechanical shutter





Progressive electronic shutter

Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S	GoPro HERO11 Black

CASE STUDY 3

exposure mode	*A-priority*
shutter speed	*≥ 1/200 s*
aperture	*f/5.6*
ISO	*≤ 200*
white balance	*auto*



Mechanical shutter





Progressive electronic shutter

focusing	*off*
vibration reduct.	*off*
GSD	*~1.5 mm*
network	*148 photos*
image format	*JPG*

Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S

GoPro HERO11 Black

CASE STUDY 3

exposure mode	*A-priority*
shutter speed	*≥ 1/200 s*
aperture	*f/5.6*
ISO	*≤ 200*
white balance	*auto*



Mechanical shutter



focusing	*off*
vibration reduct.	*off*
GSD	*~1.5 mm*
network	*148 photos*
image format	*JPG*

Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S

exposure mode	*auto*
shutter speed	*≥ 1/1000 s*
aperture	*f/2.5*
ISO	*≤ 400*
white balance	*auto*



Progressive electronic shutter

focusing	*off*
vibration reduct.	*off*
GSD	*~1.4 mm*
network	*132 photos*
image format	*JPG*

GoPro HERO11 Black

CASE STUDY 3

exposure mode	*A-priority*
shutter speed	*≥ 1/200 s*
aperture	*f/5.6*
ISO	*≤ 200*
white balance	*auto*



Standing still



focusing	*off*
vibration reduct.	*off*
GSD	*~1.5 mm*
network	*148 photos*
image format	*JPG*

Nikon Z7 II + Nikon NIKKOR Z 20 mm f/1.8 S

exposure mode	*auto*
shutter speed	*≥ 1/1000 s*
aperture	*f/2.5*
ISO	*≤ 400*
white balance	*auto*



Walking

focusing	*off*
vibration reduct.	*off*
GSD	*~1.4 mm*
network	*132 photos*
image format	*JPG*

GoPro HERO11 Black

CASE STUDY 3







Standing still

Walking

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*

CASE STUDY 3







Standing still

Agisoft Metashape 2.1.0

SfM	*40k IPs / 4k tie points*
control	*3 GCPs Helmert transform*
MVS	*polymesh (depth maps)*

Walking

Agisoft Metashape 2.1.0

SfM	*incremental*
	25k IPs / 3k tie points
	~~compens.~~ / regularised / full

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points			
RMS reproj. error			
max reproj. error			

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k		
RMS reproj. error	0.53 (5.0 pix)		
max reproj. error	1.26 (114.2 pix)		

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	**regularis. RSC**	**full RSC**
tie points	24.4 k	28.0 k	
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	**regularis. RSC**	**full RSC**
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	**regularis. RSC**	**full RSC**
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

1 m / s (3.6 km/h)

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

1 m / s (3.6 km/h)

@ 5 m

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

1 m / s (3.6 km/h)

1 / 200 s

@ 5 m

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

1 m / s (3.6 km/h)

1 / 800 s

@ 5 m

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

1 m / s (3.6 km/h)

1 / 2000 s

@ 5 m

CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)

1 m / s (3.6 km/h)

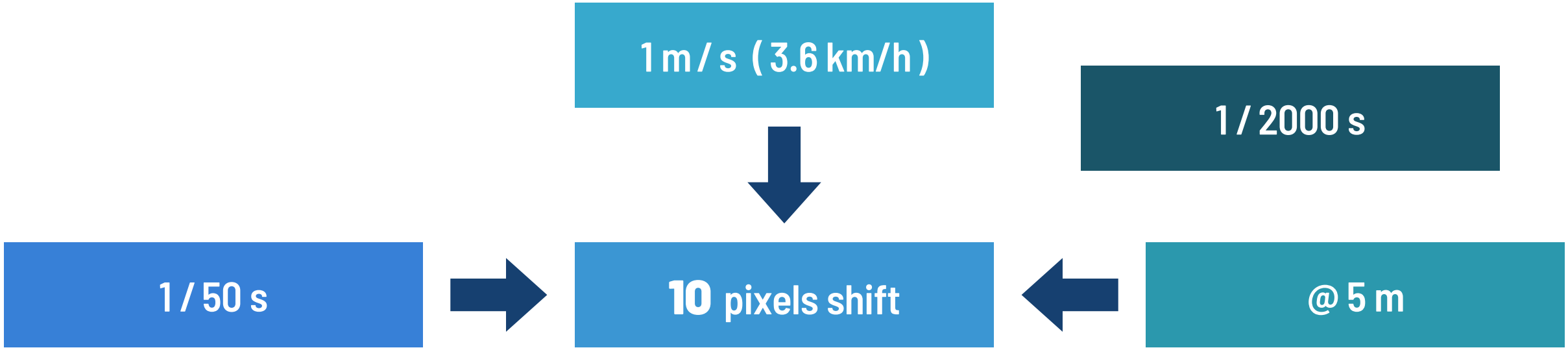
1 / 2000 s

1 / 50 s

@ 5 m

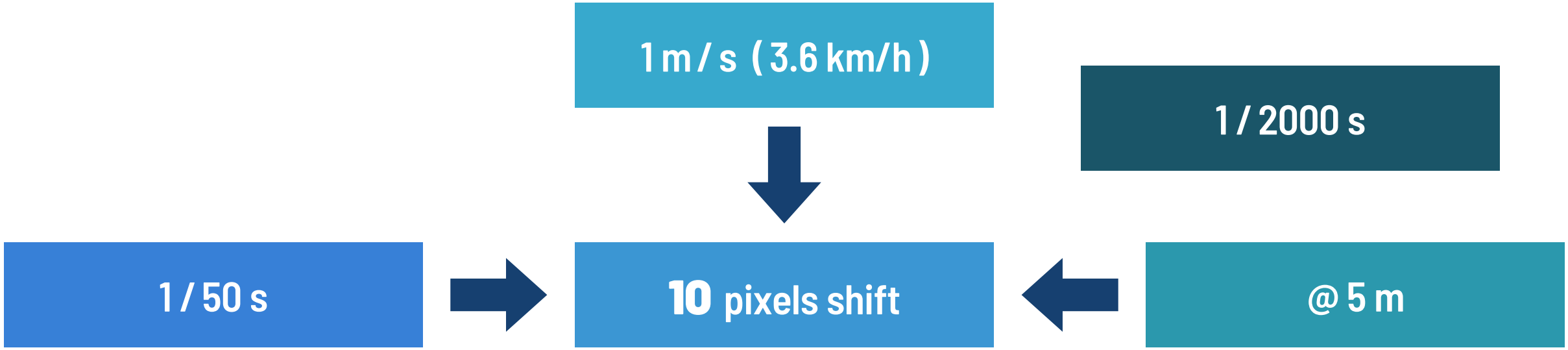
CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)



CASE STUDY 3

	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC
tie points	24.4 k	28.0 k	41.7 k
RMS reproj. error	0.53 (5.0 pix)	0.48 (4.3 pix)	0.30 (2.5 pix)
max reproj. error	1.26 (114.2 pix)	1.19 (113.3 pix)	0.98 (84.4 pix)



CASE STUDY 3

Nikon Z7ii	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC



CASE STUDY 3

Nikon Z7ii	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC



CASE STUDY 3

Nikon Z7ii	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC



CASE STUDY 3

Nikon Z7ii	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC



CASE STUDY 3

Nikon Z7ii	GoPro HERO11 Black		
	no RSC	regularis. RSC	full RSC



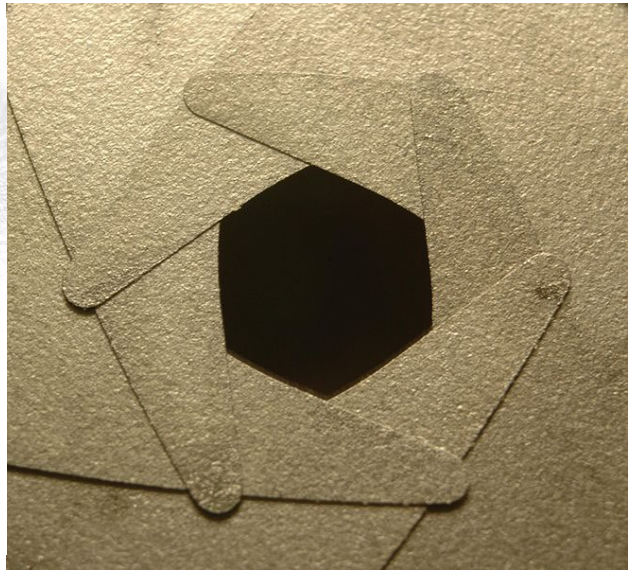


PART 2

APERTURE

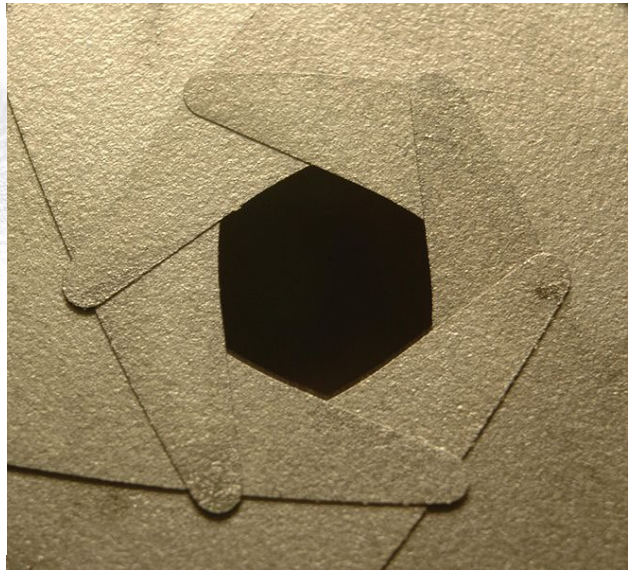
APERTURE





APERTURE

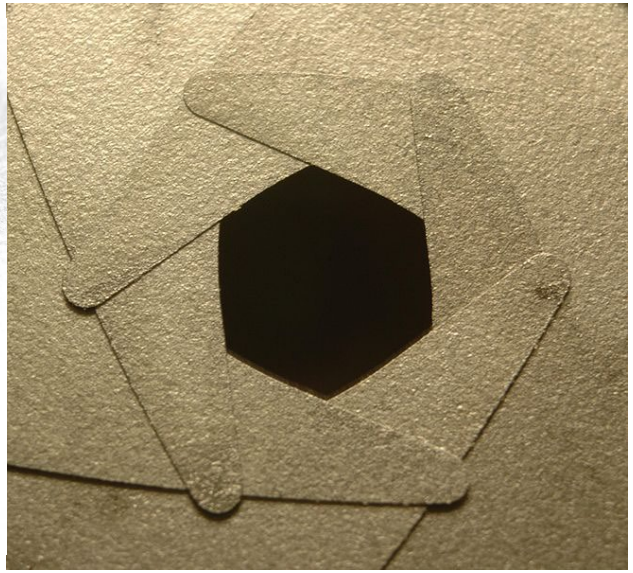






APERTURE







f/ 8	(relative) aperture
8	*f*-number | *f*-stop

APERTURE



f-number x √2

f/1.4	*f*/2	*f*/2.8	*f*/4	*f*/5.6	*f*/8	*f*/11	*f*-stop

APERTURE



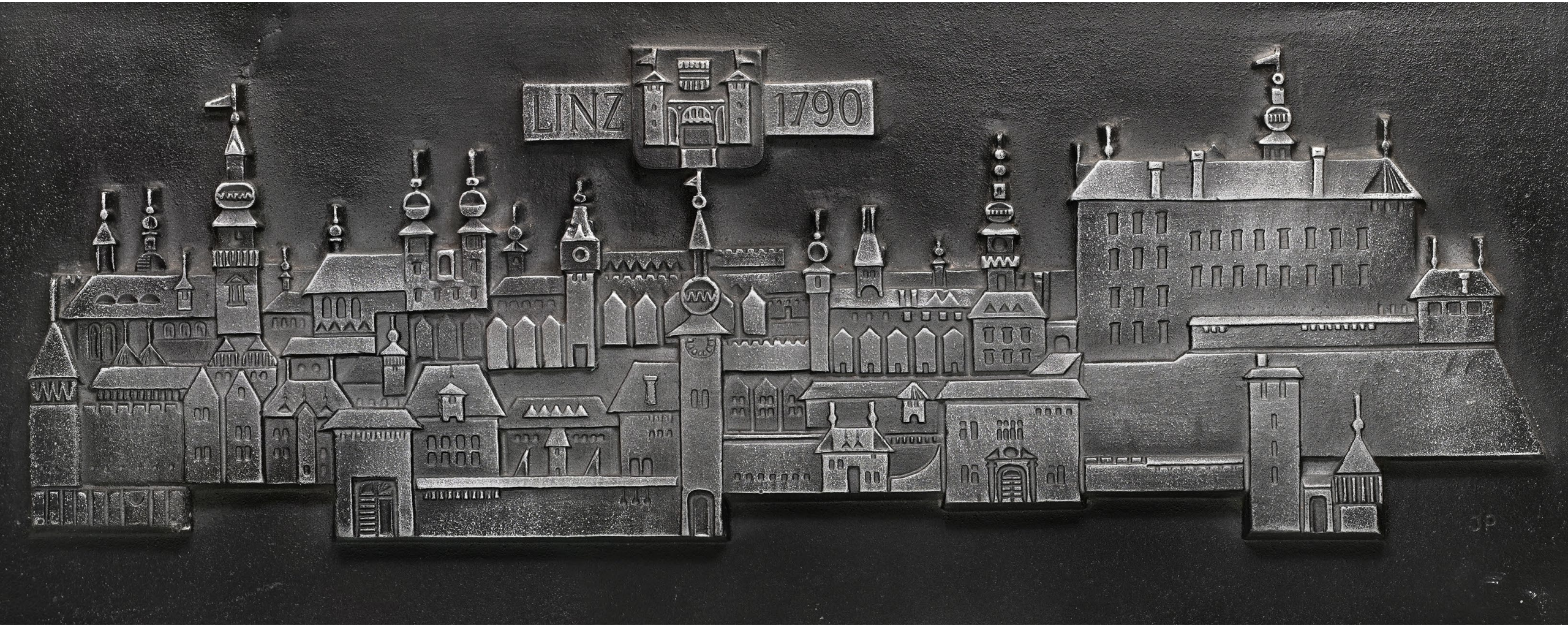
f-number x √2

f/1.4	*f*/2	*f*/2.8	*f*/4	*f*/5.6	*f*/8	*f*/11	*f*-stop

DEPTH OF FIELD

DIFFRACTION

DEPTH OF FIELD



DEPTH OF FIELD



f/4

DEPTH OF FIELD



f / 5.6

DEPTH OF FIELD



f/8

DEPTH OF FIELD



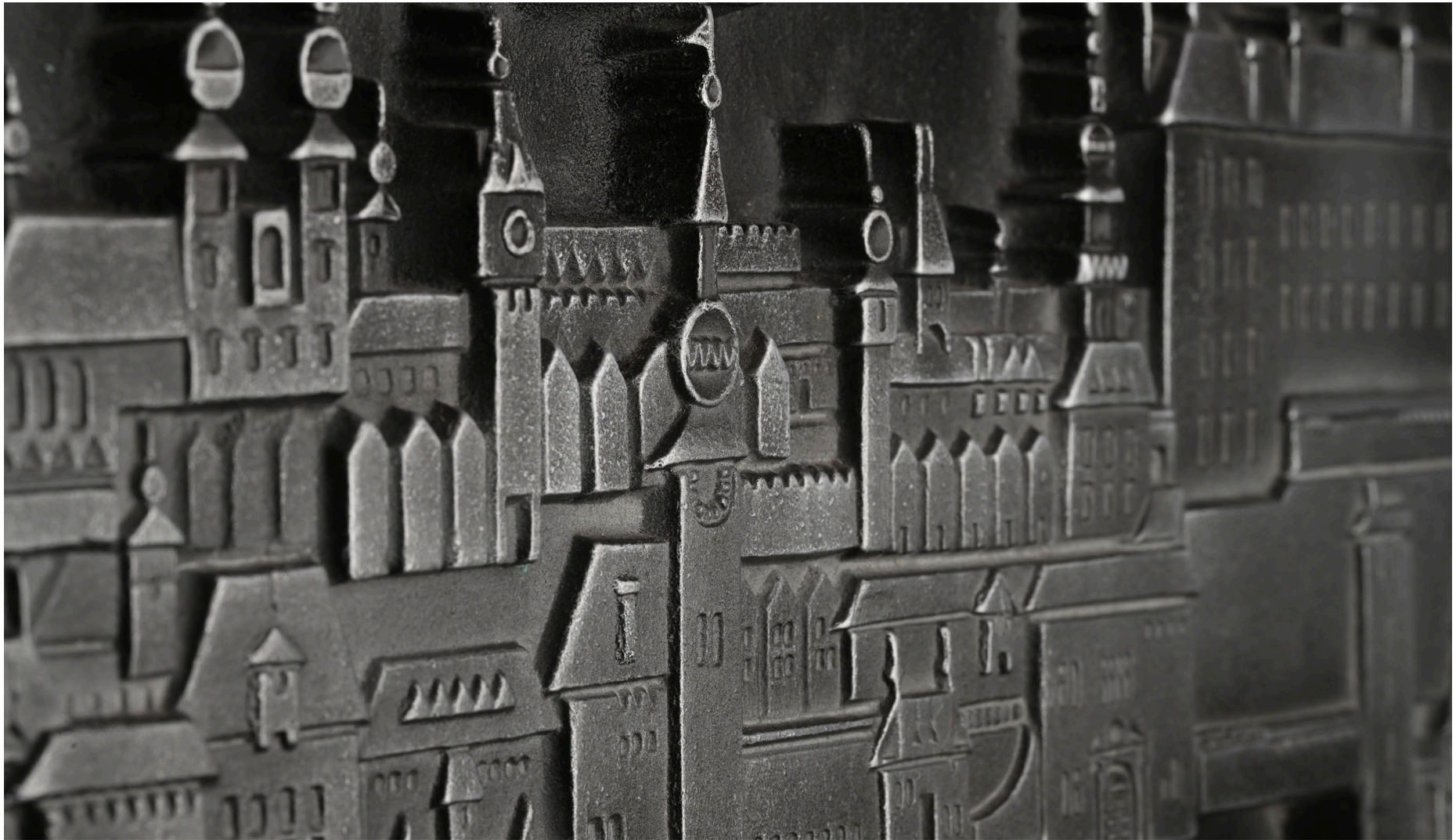
f / 11

DEPTH OF FIELD



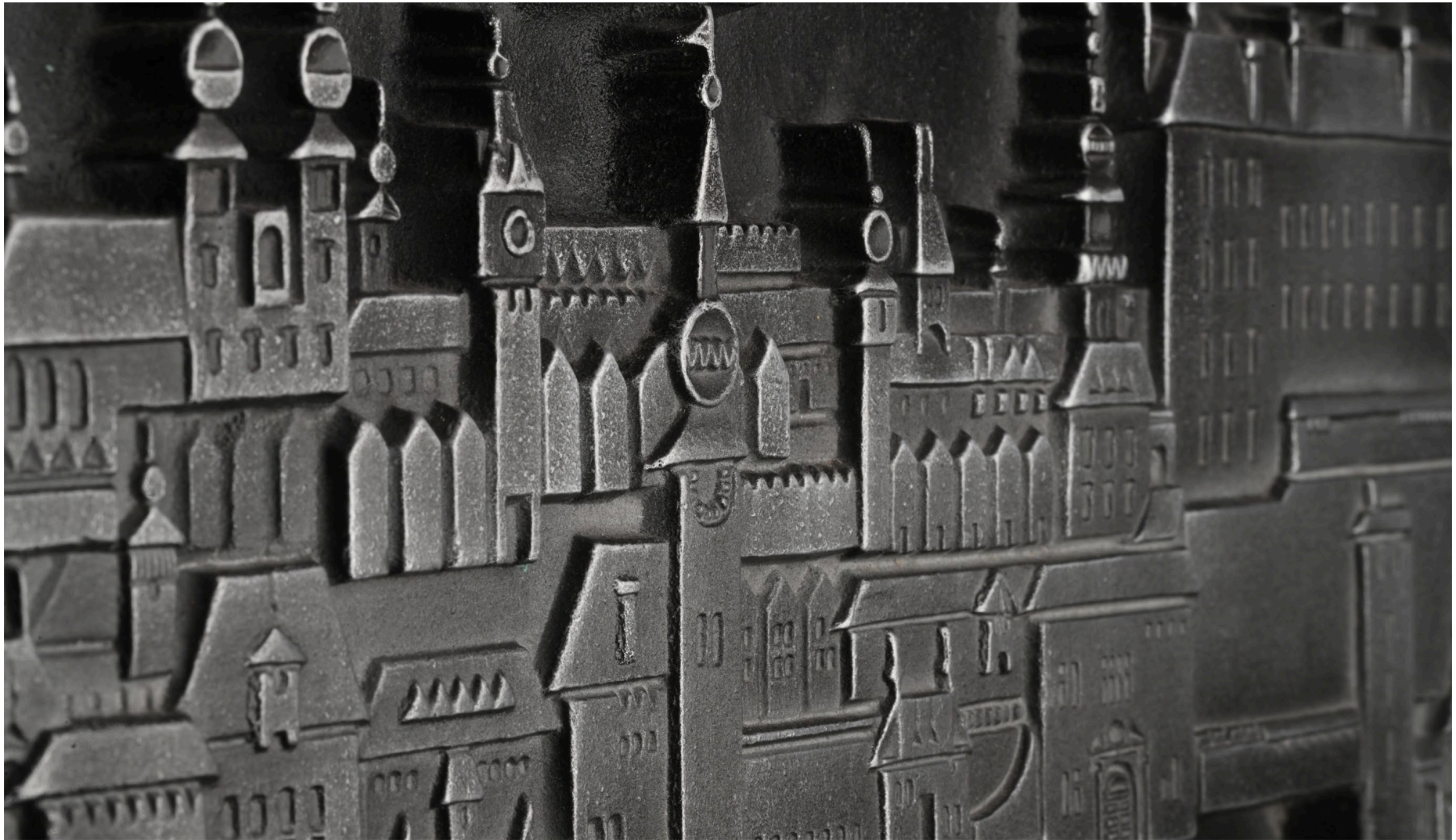
f / 16

DEPTH OF FIELD



f / 22

DEPTH OF FIELD



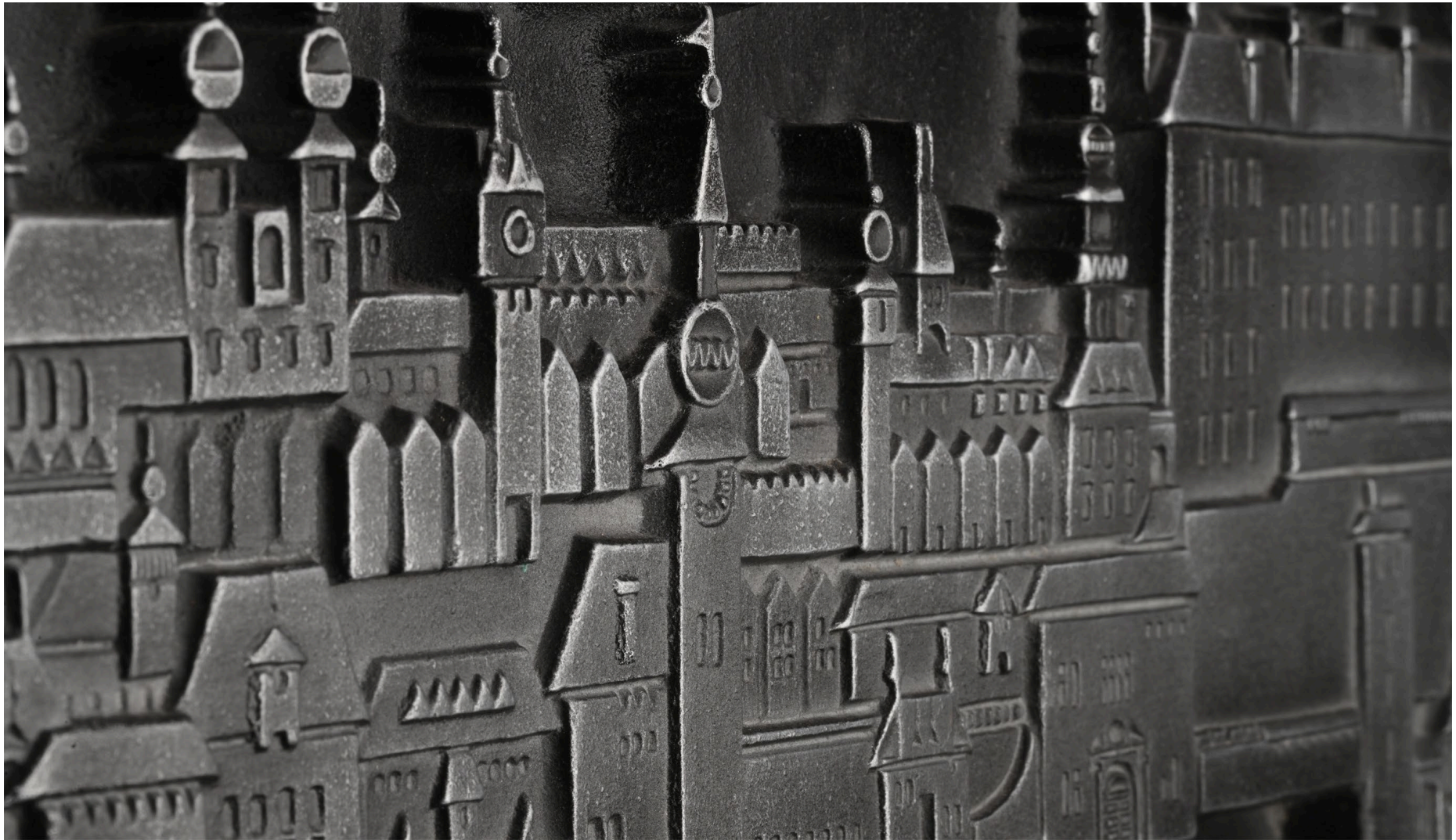
f / 32

DEPTH OF FIELD



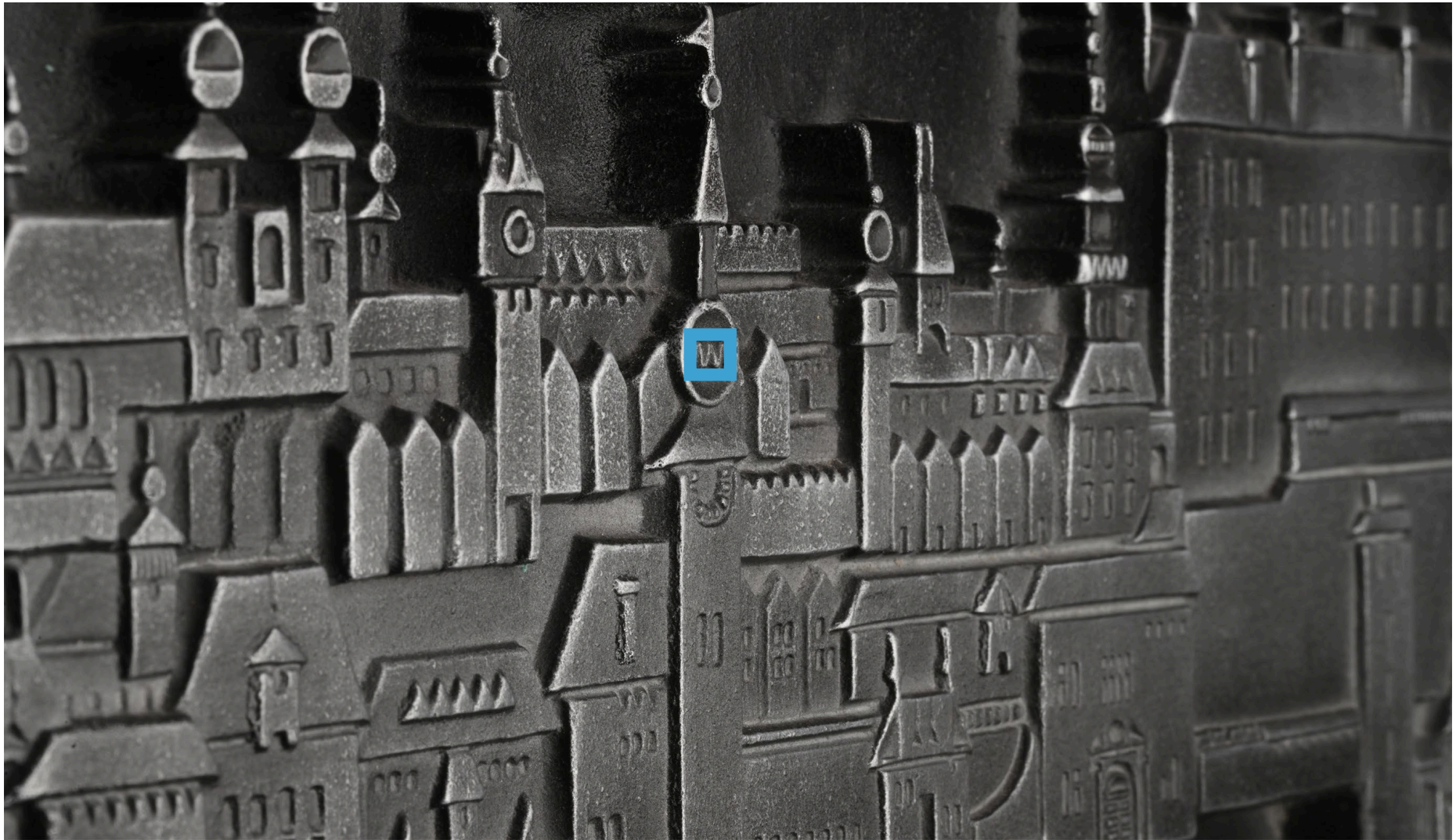
f/4

DEPTH OF FIELD

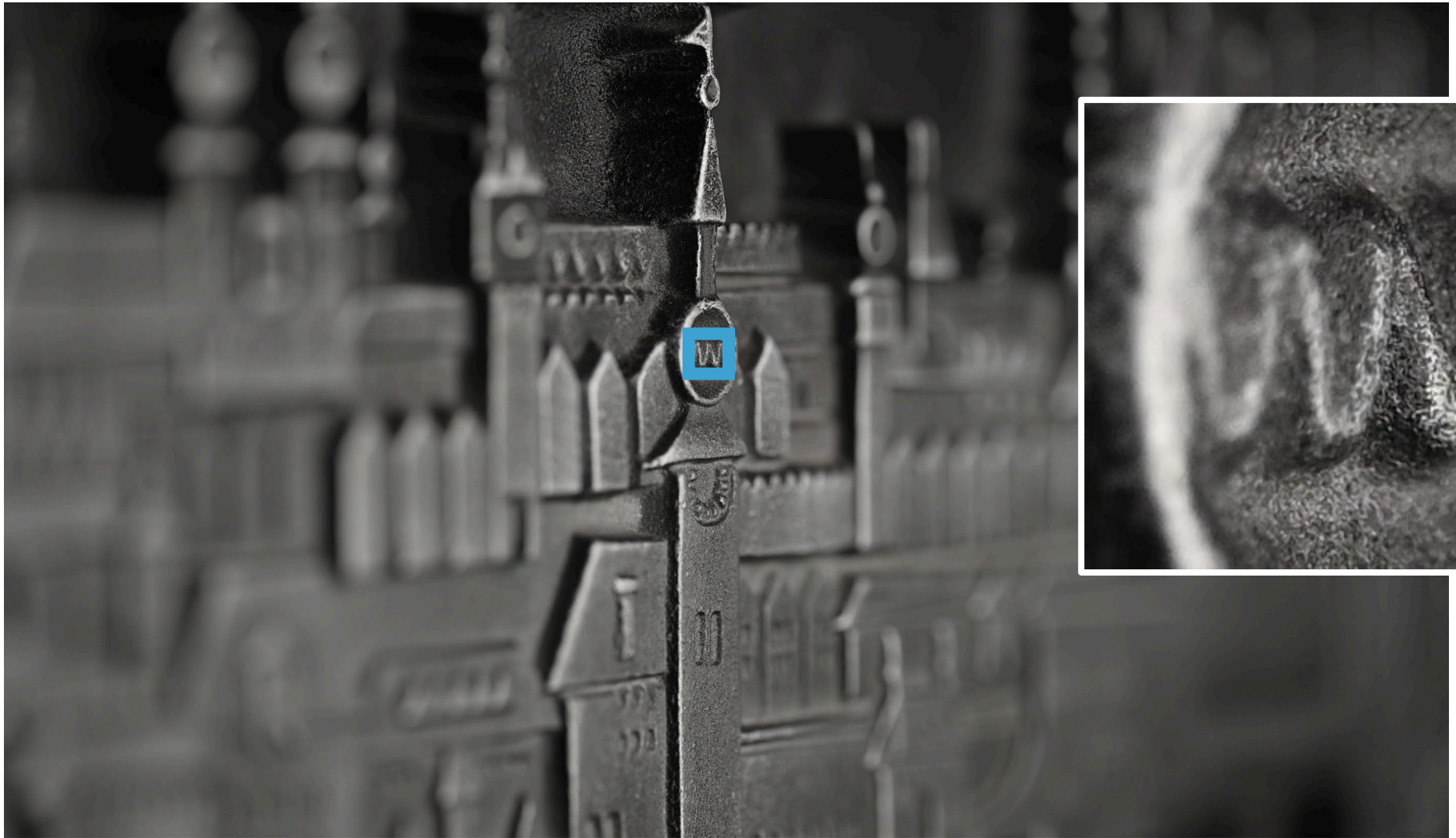


f / 32

DEPTH OF FIELD

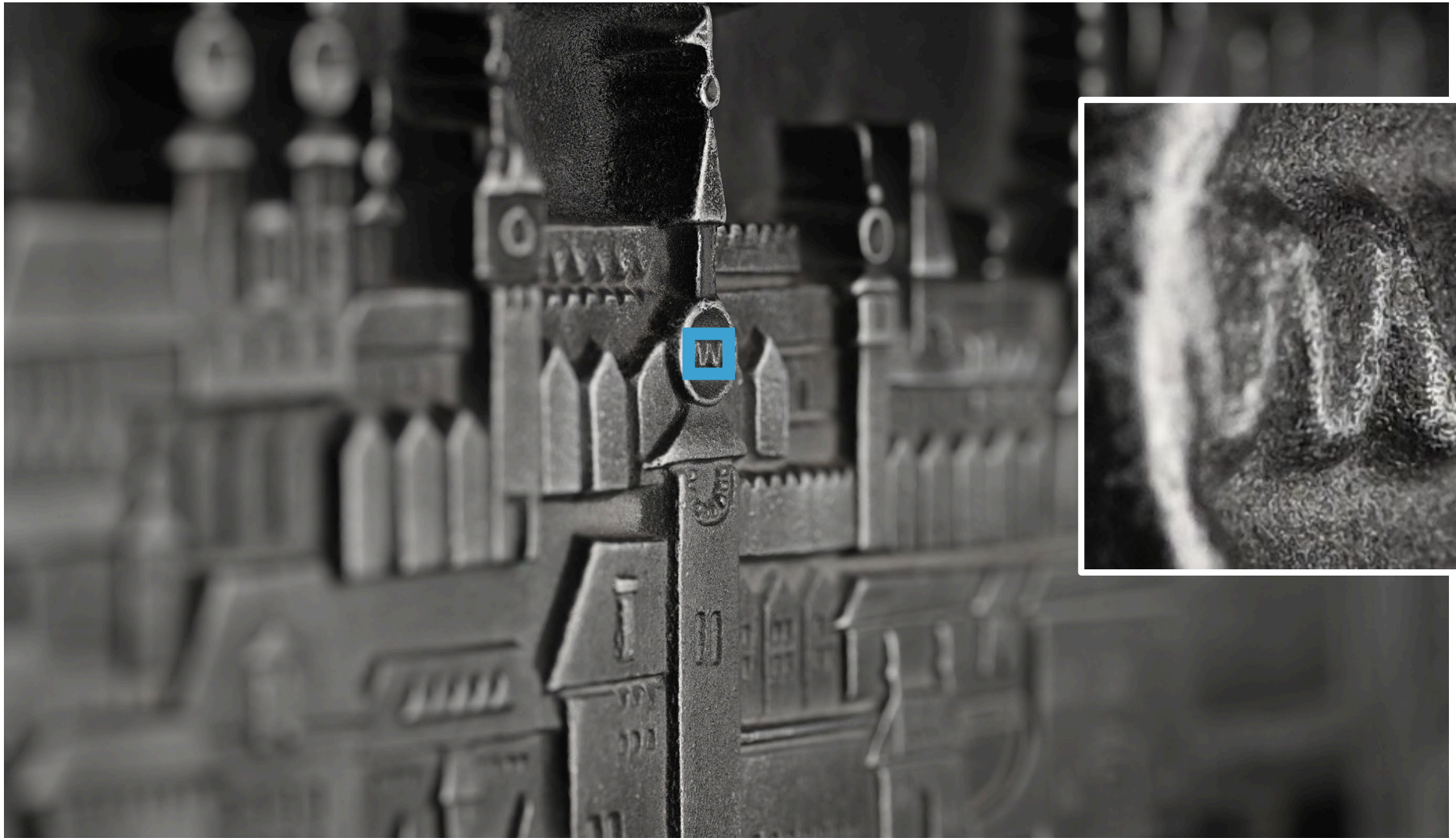


DIFFRACTION



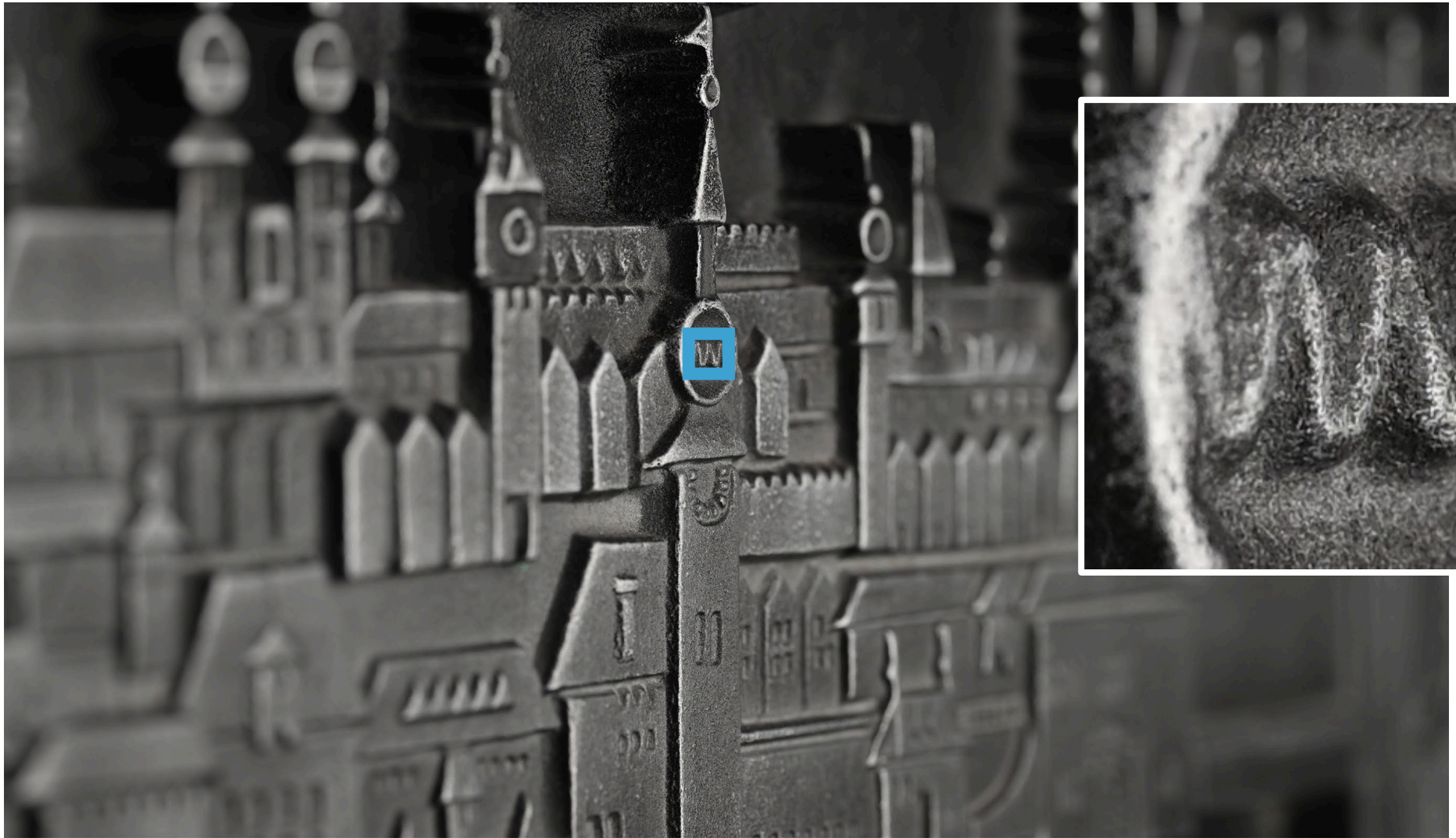
f/4

DIFFRACTION

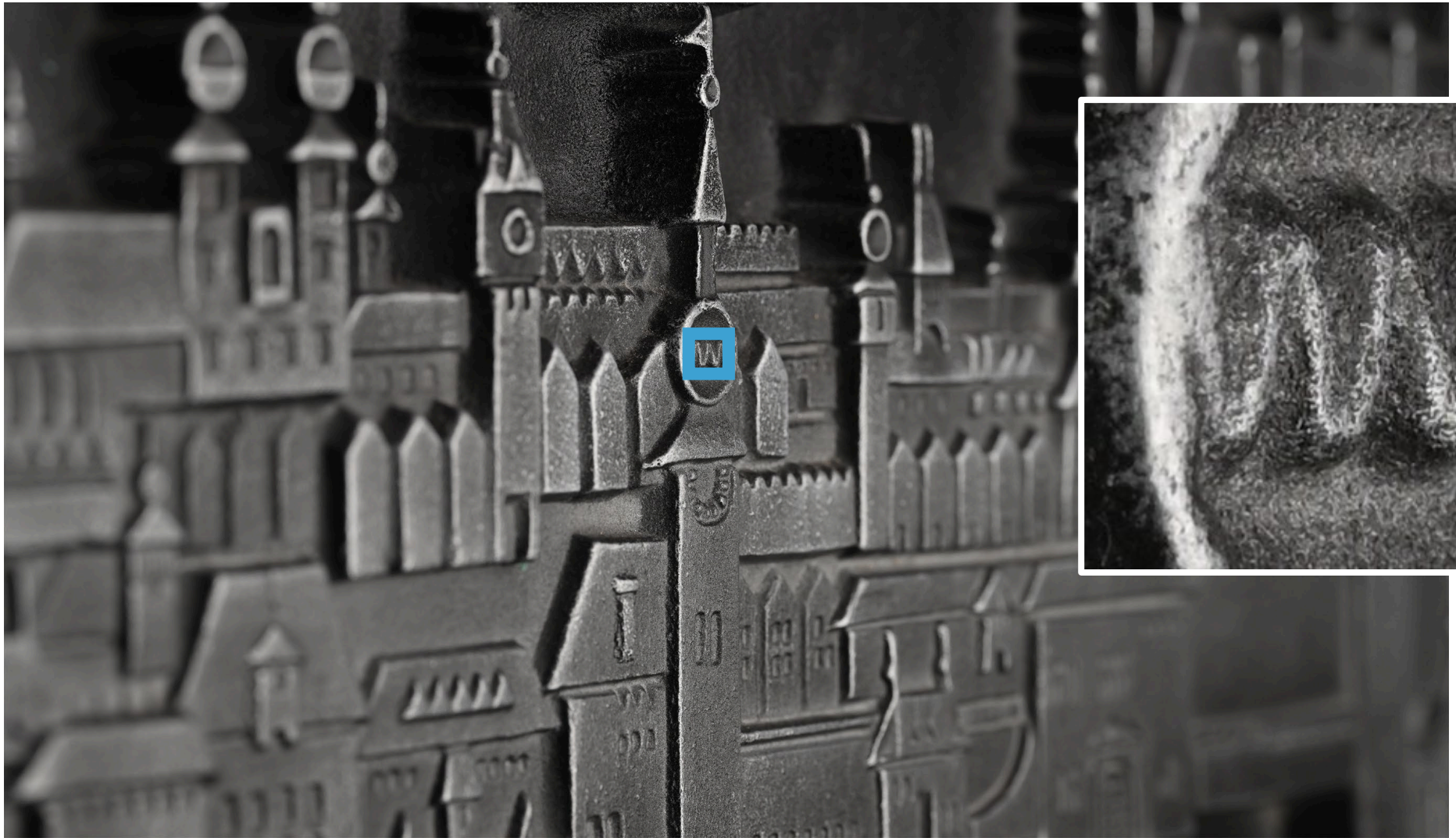


f / 5.6

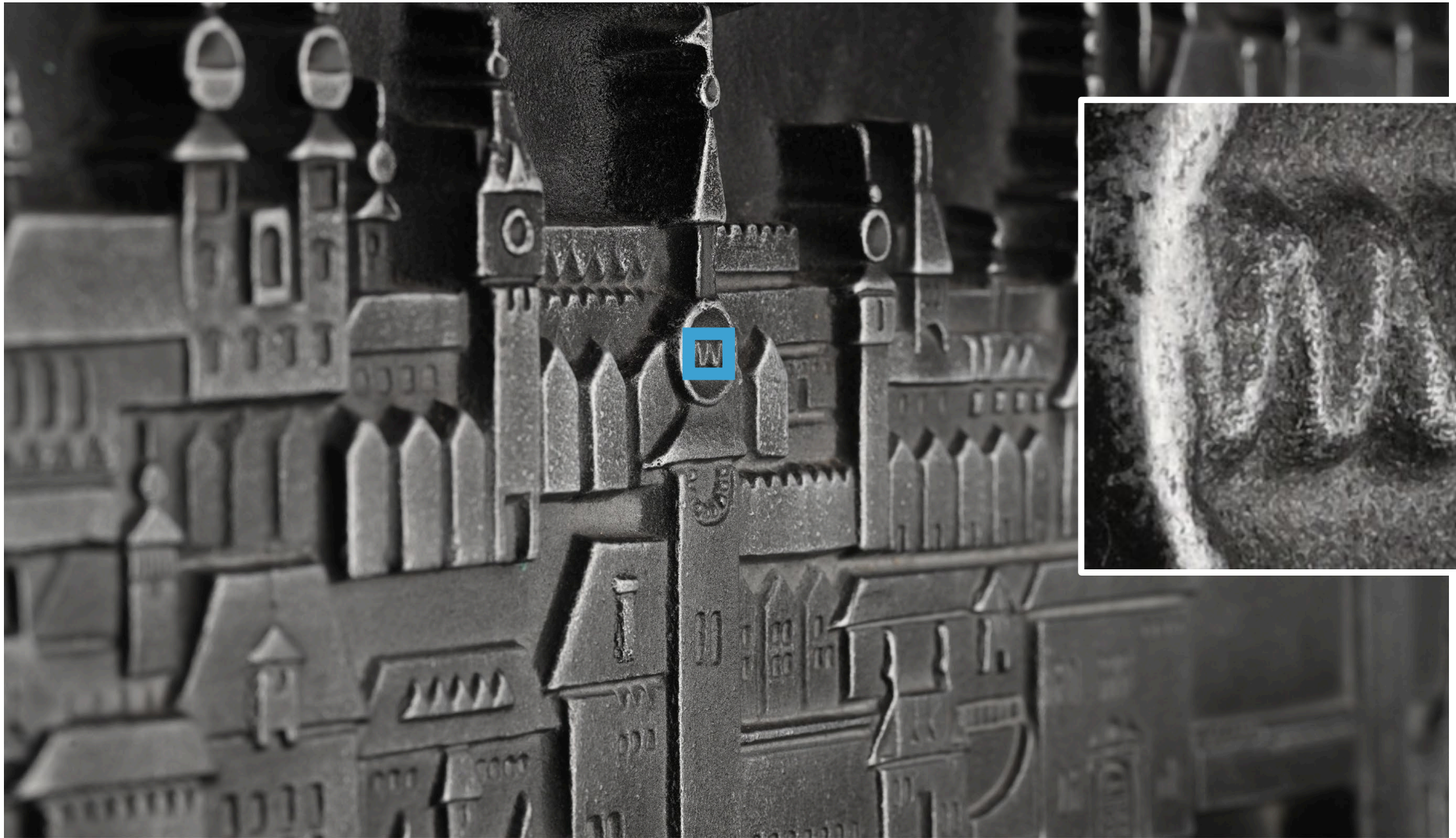
DIFFRACTION



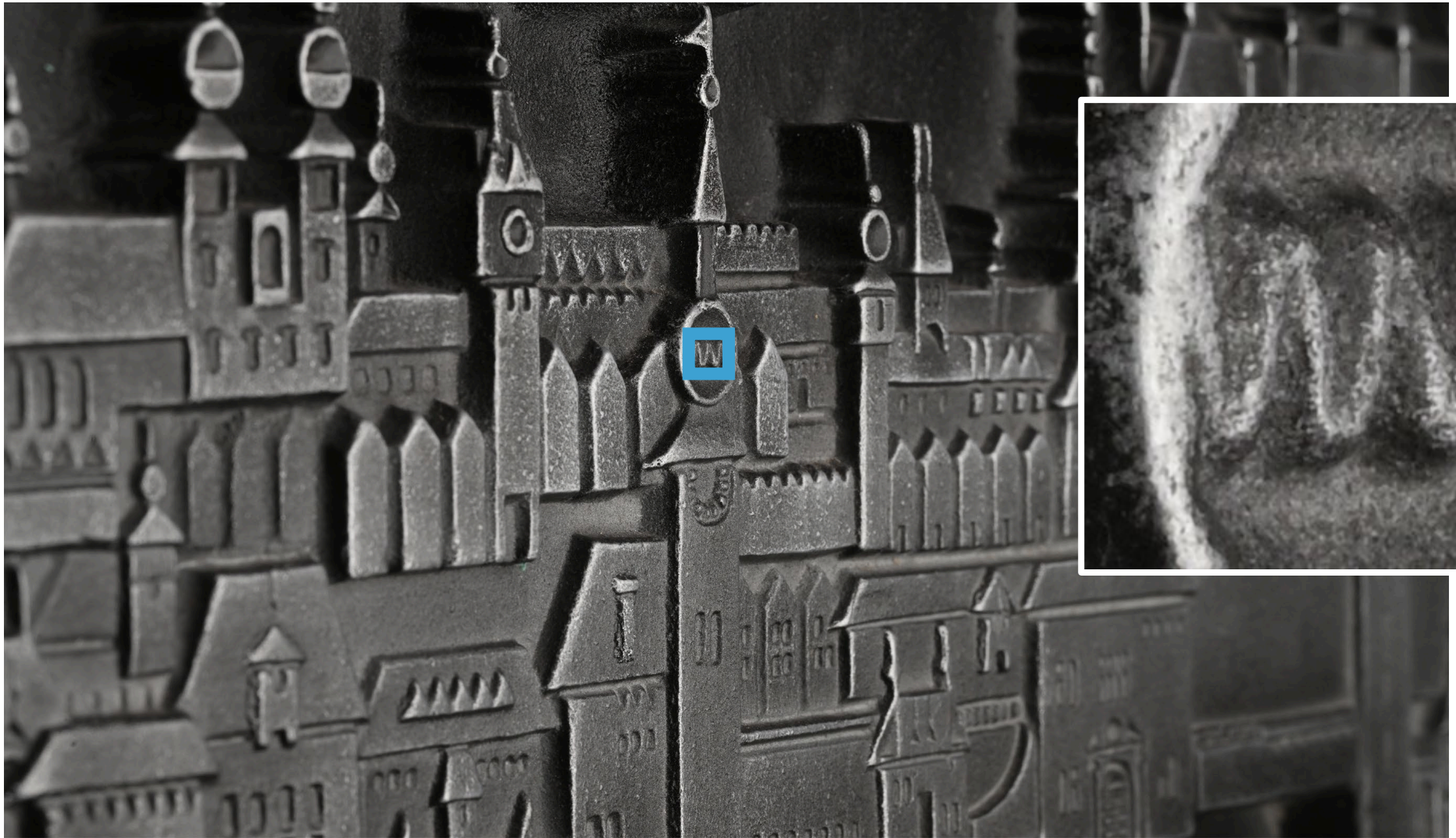
DIFFRACTION



DIFFRACTION

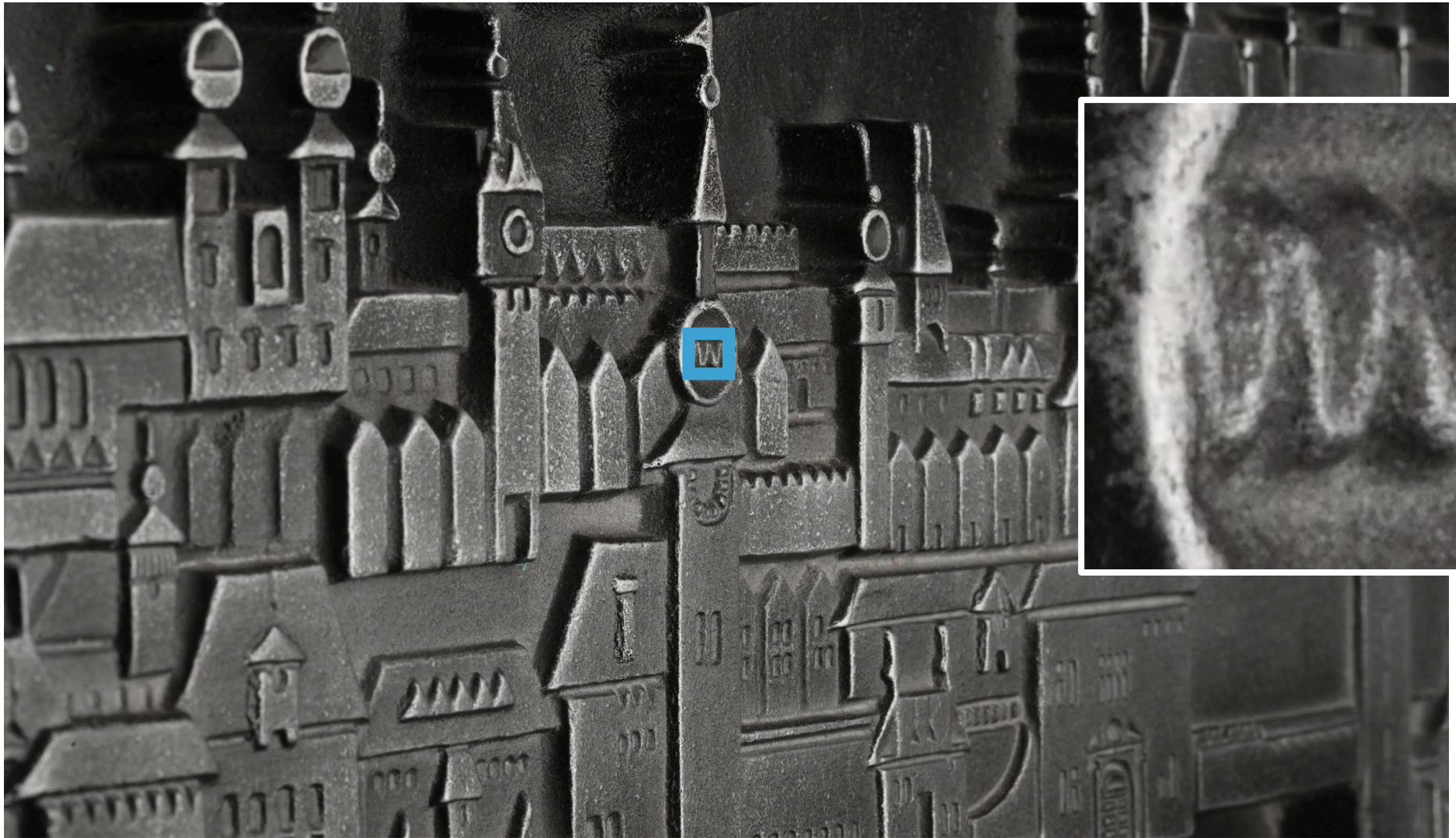


DIFFRACTION



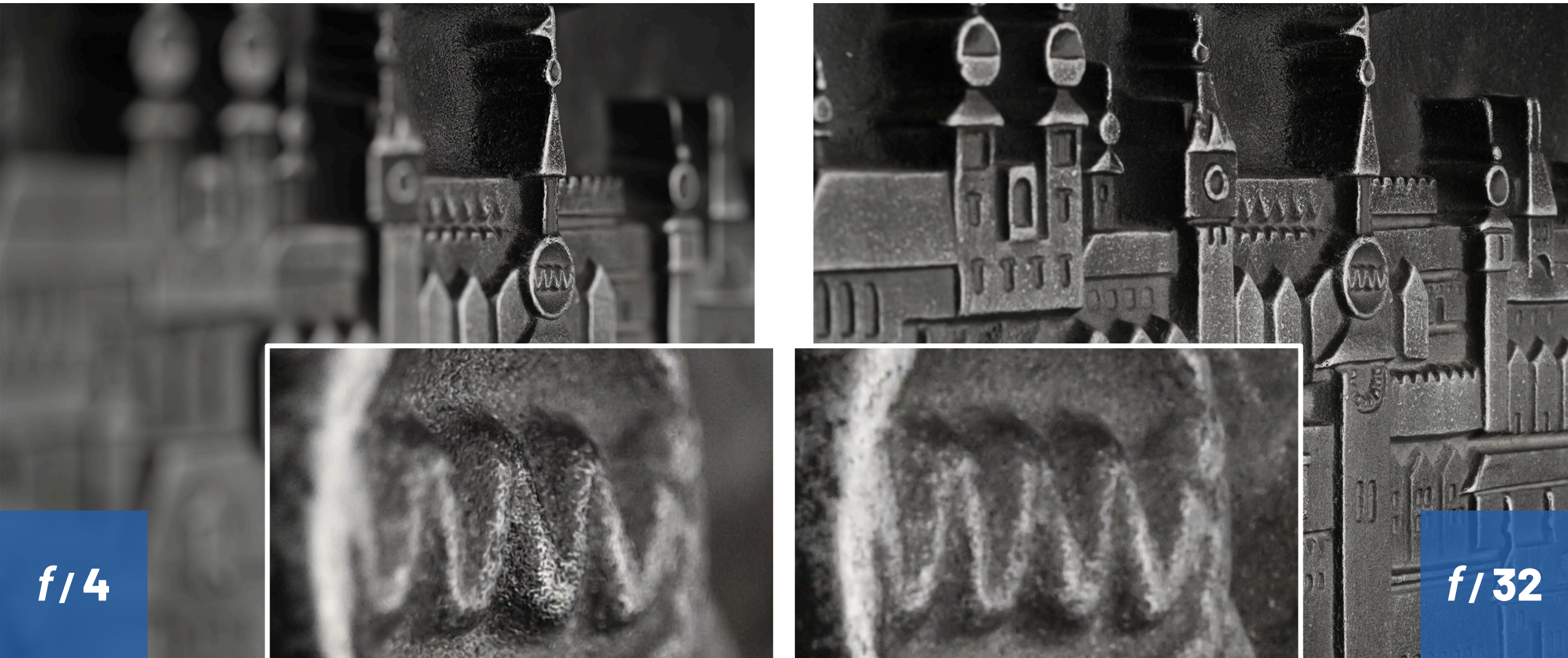
f / 22

DIFFRACTION



f/32

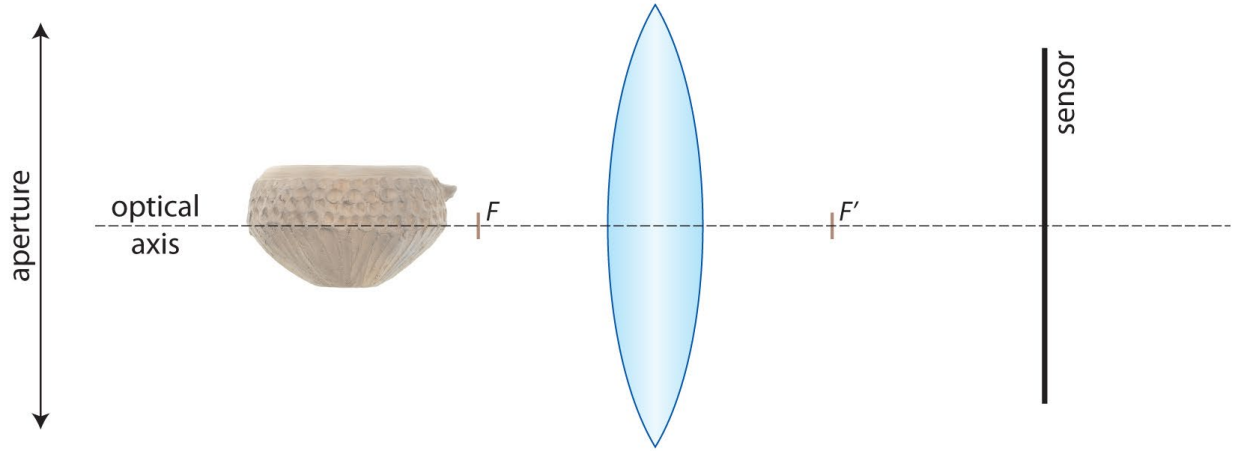
DEPTH OF FIELD vs DIFFRACTION



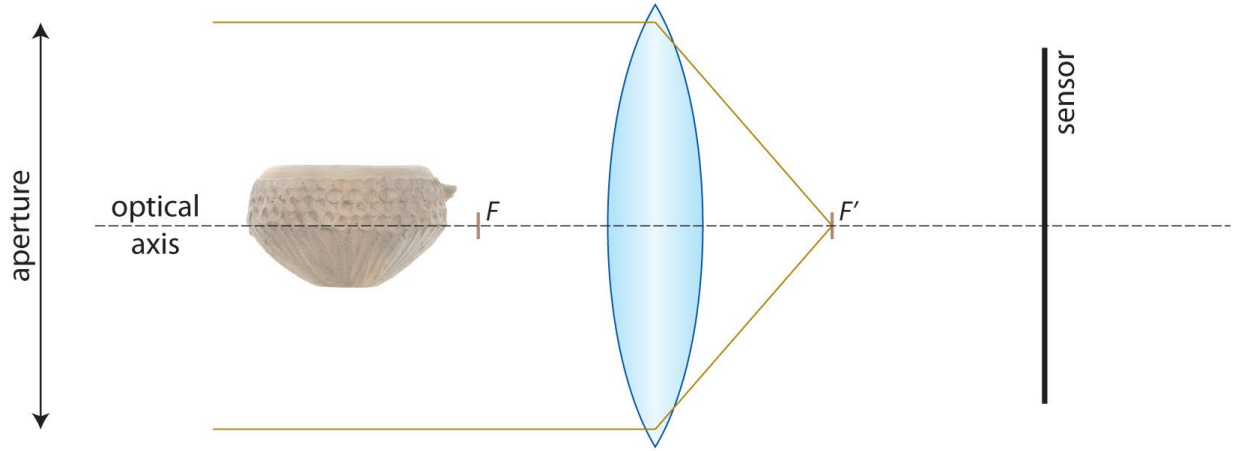
f/4

f/32

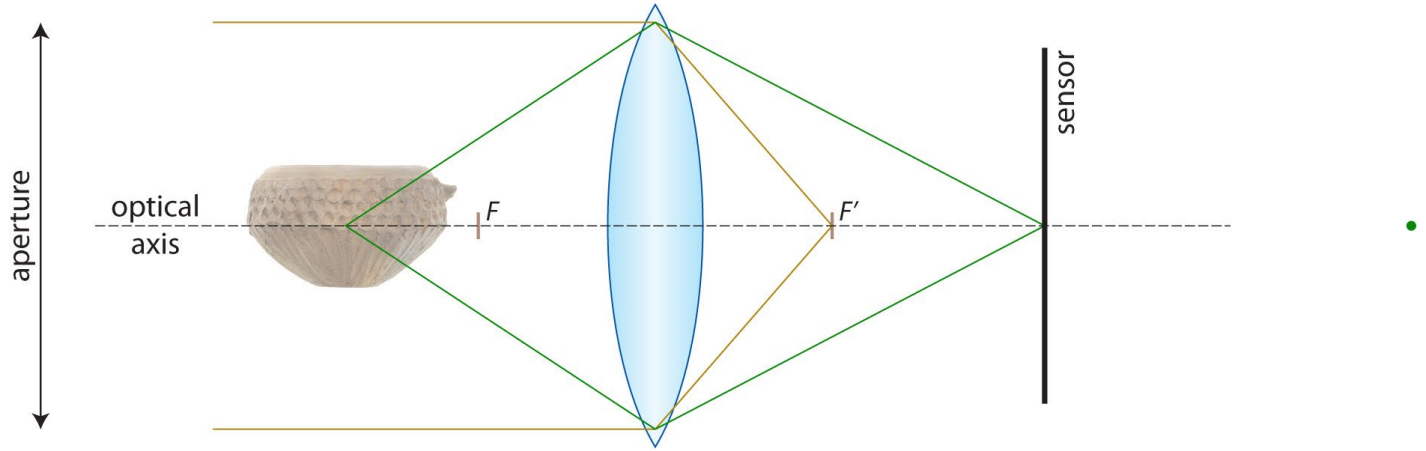
CIRCLE OF CONFUSION



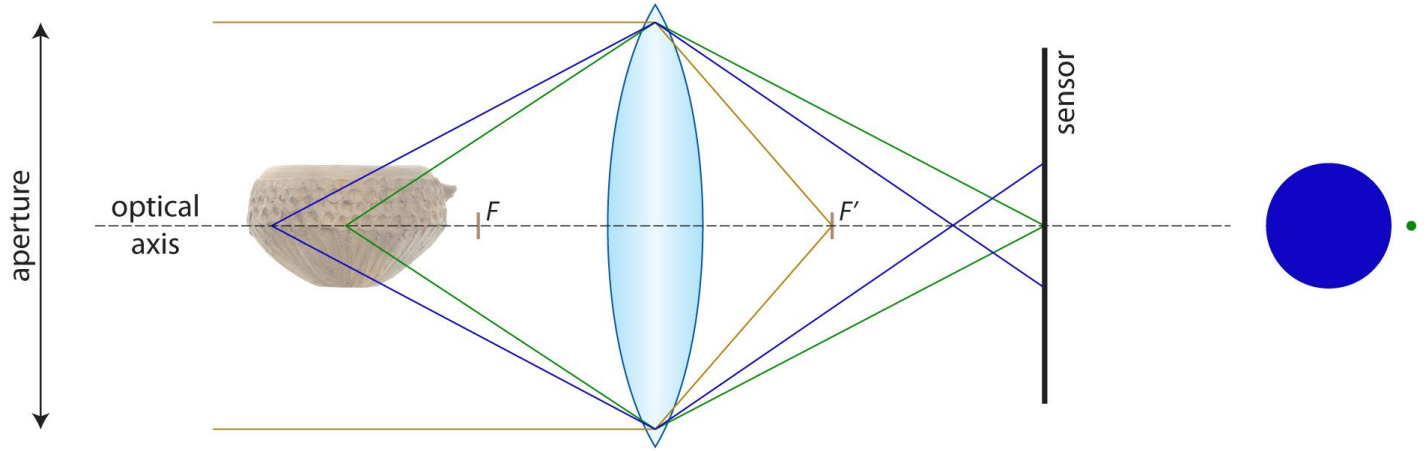
CIRCLE OF CONFUSION



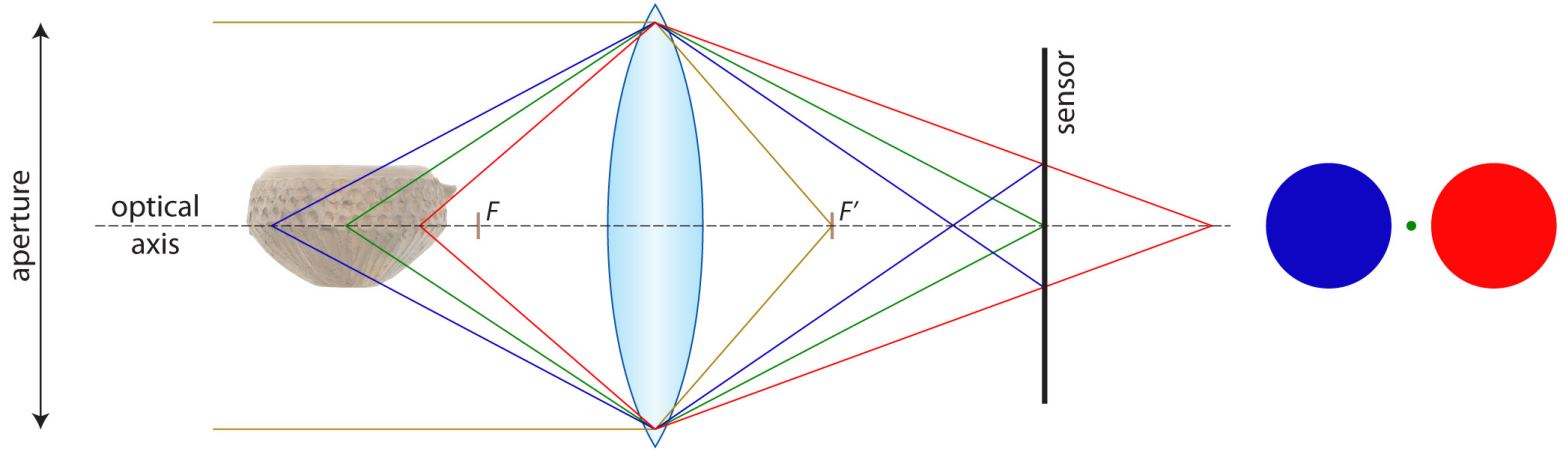
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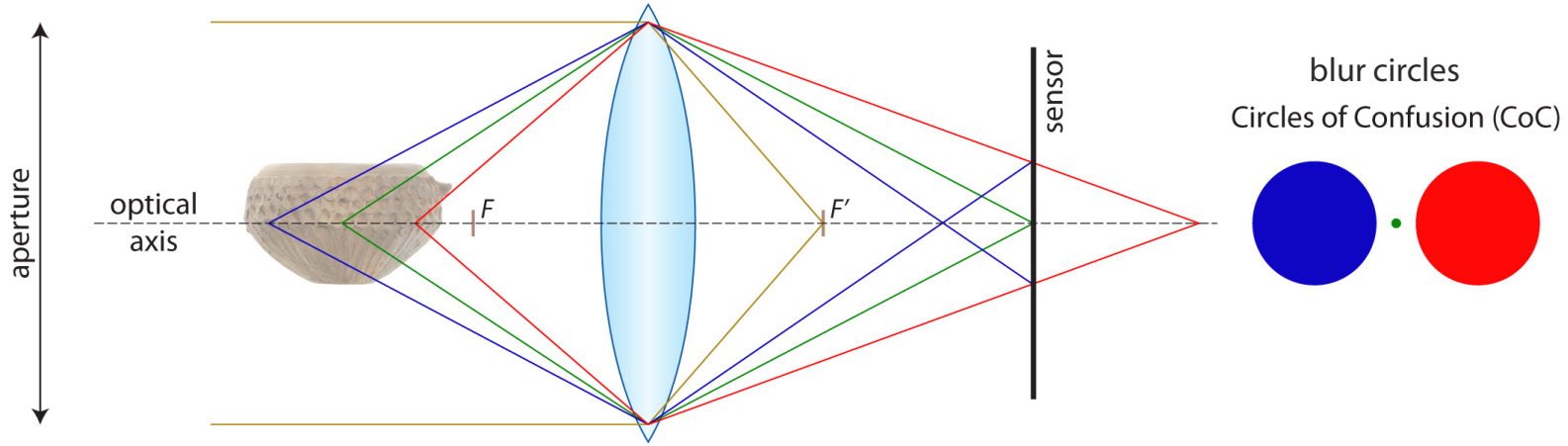
CIRCLE OF CONFUSION



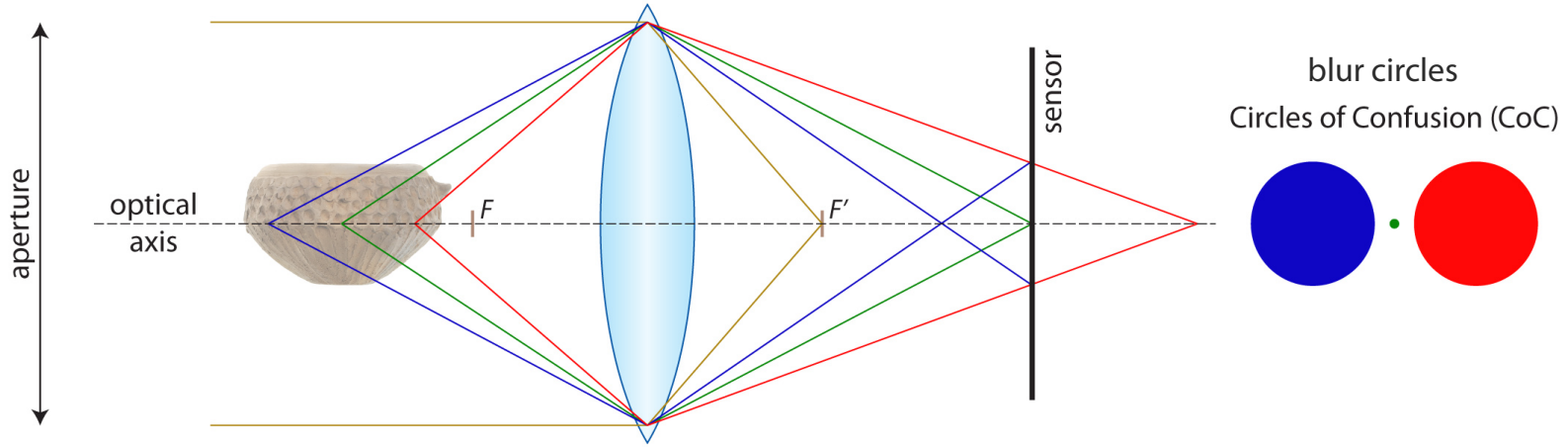
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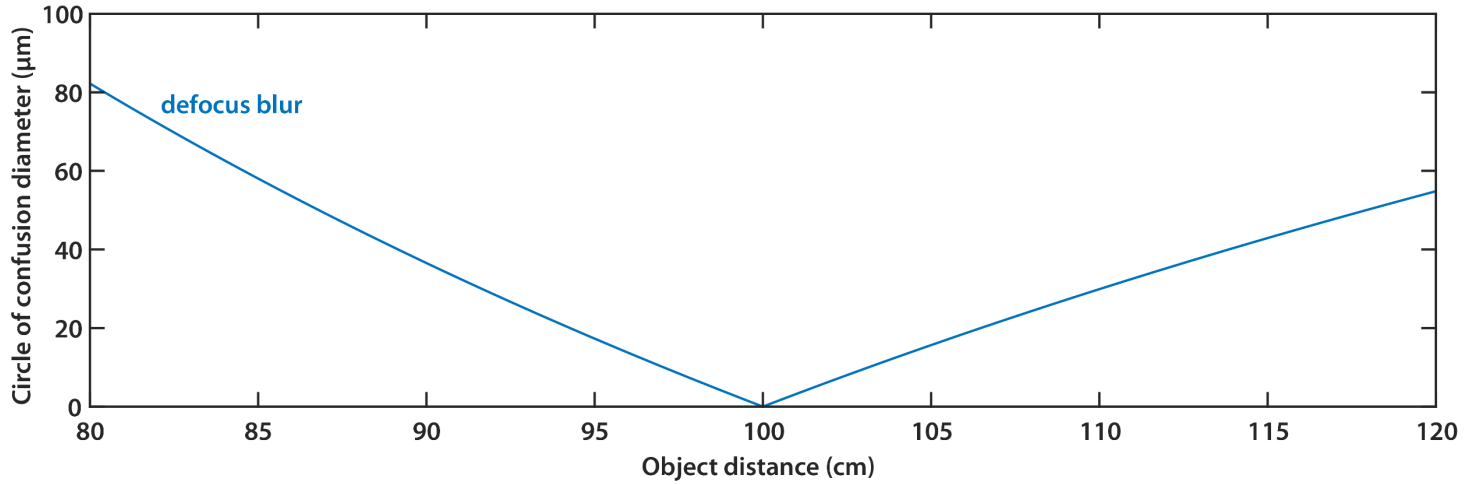


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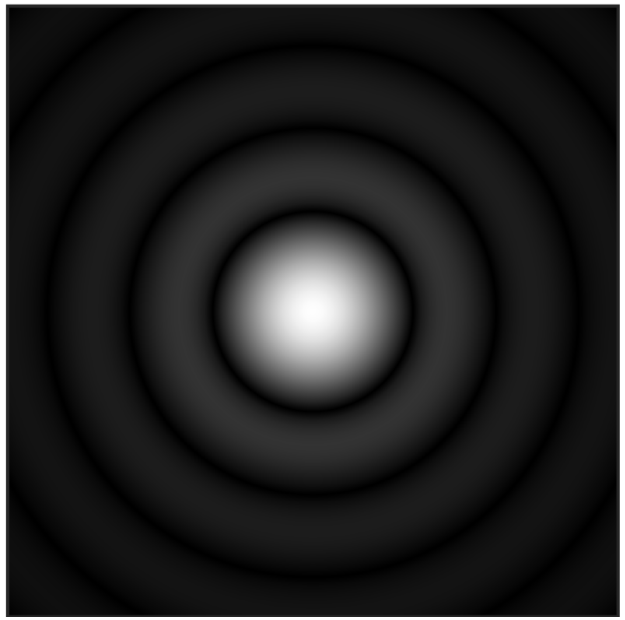


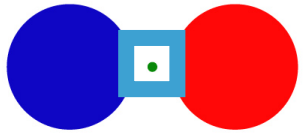
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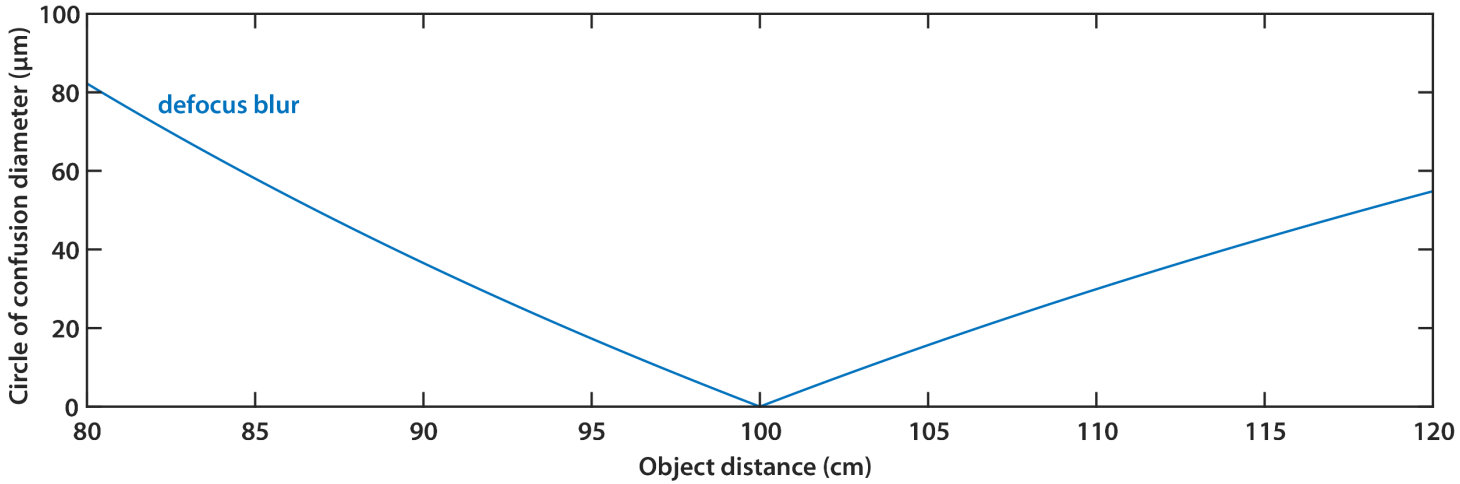




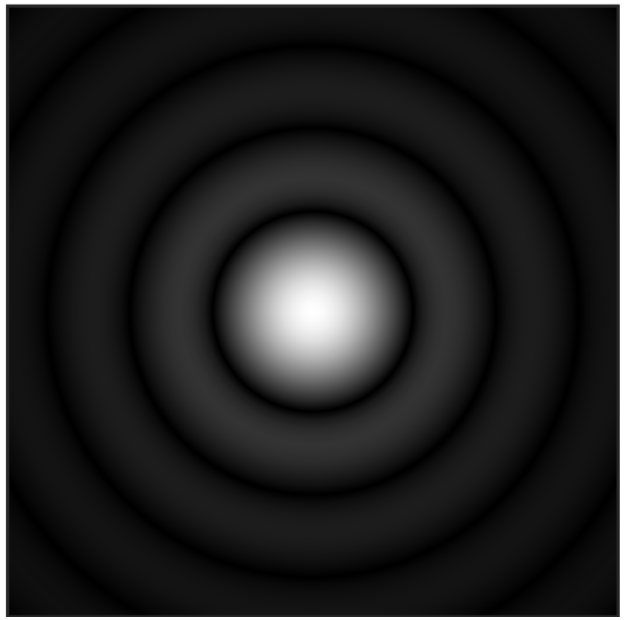
CIRCLE OF LEAST CONFUSION

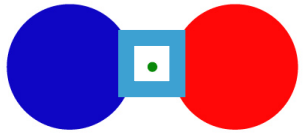


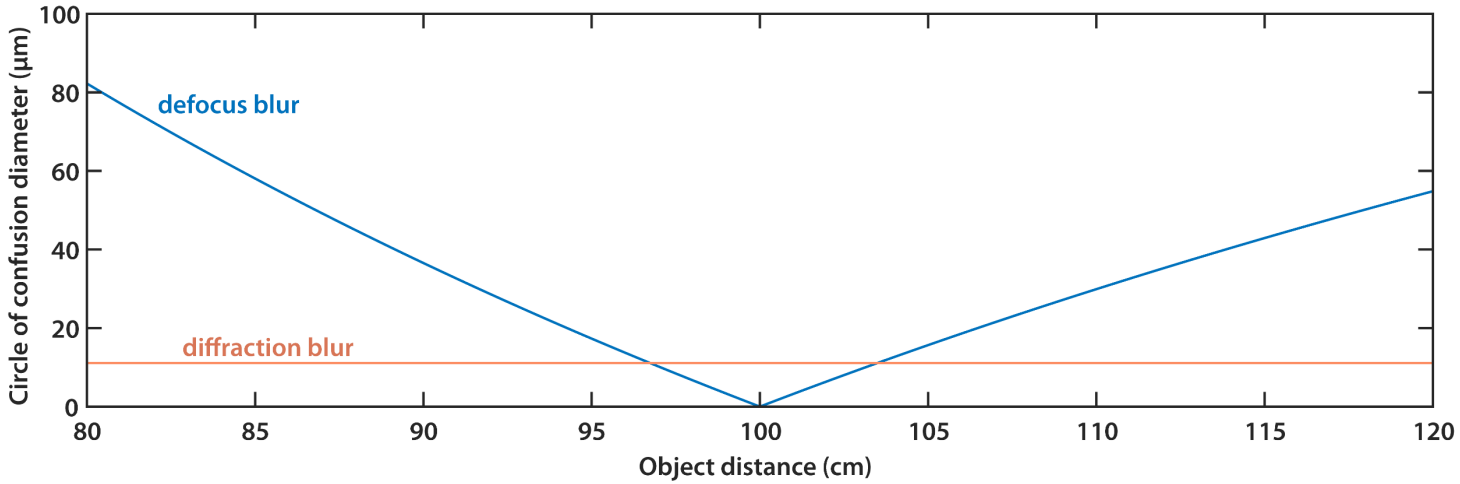




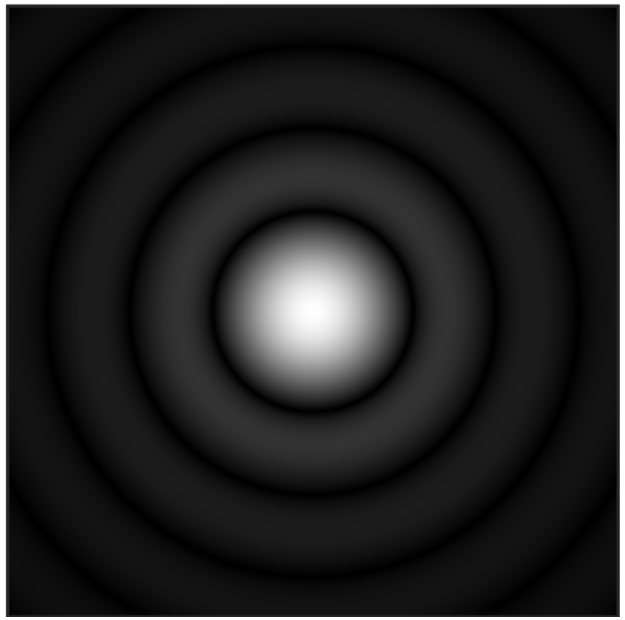
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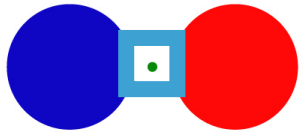


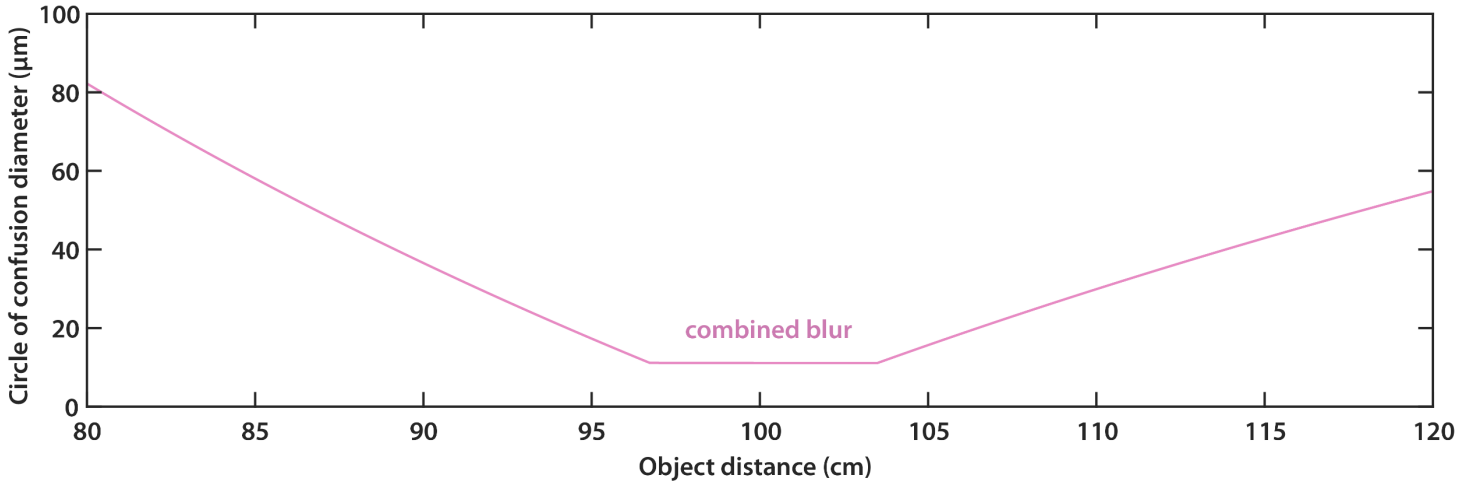




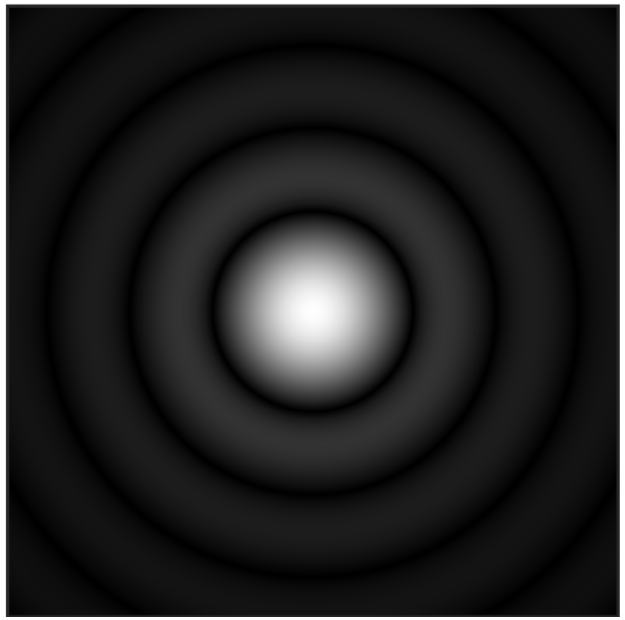
CIRCLE OF LEAST CONFUSION

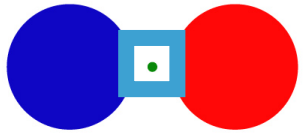


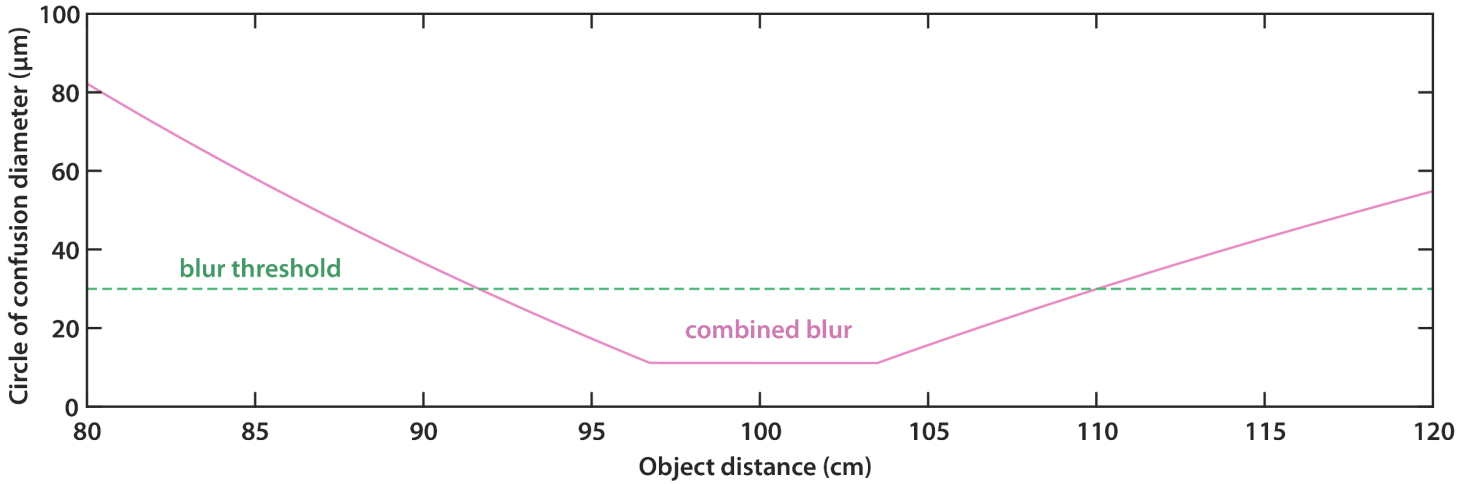




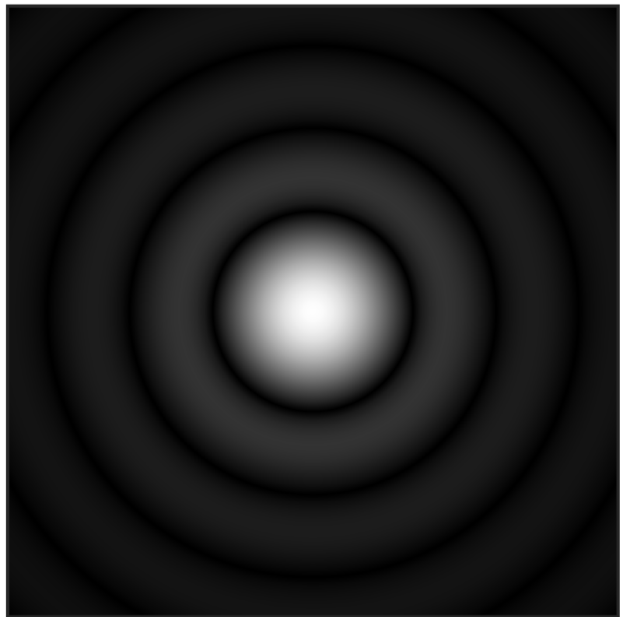
CIRCLE OF LEAST CONFUSION





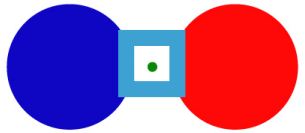


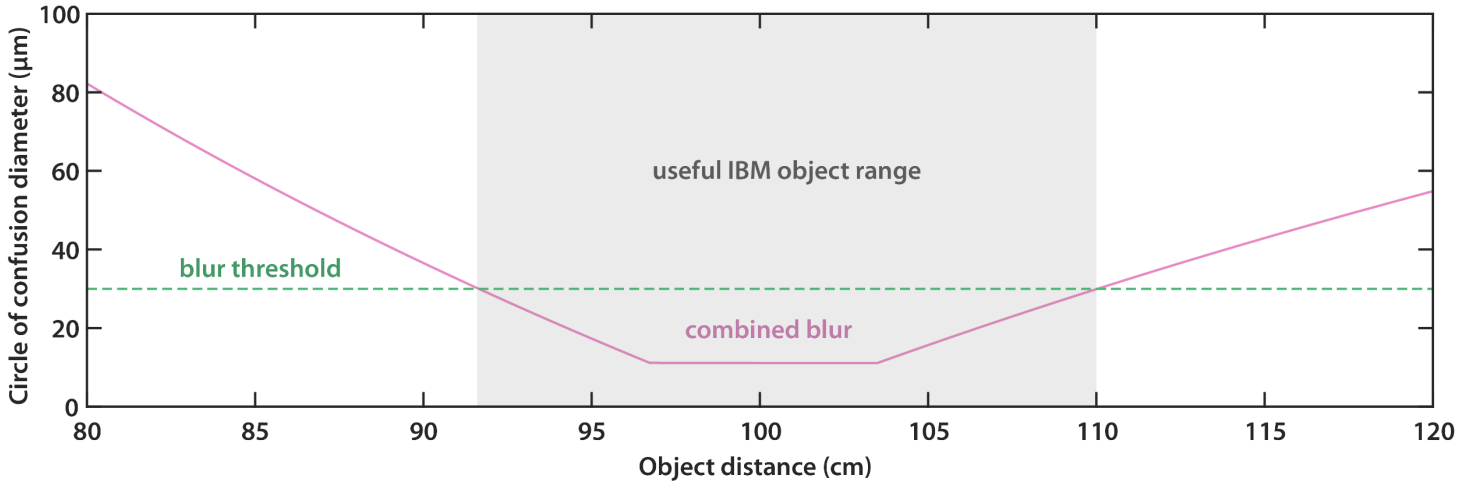
CIRCLE OF LEAST CONFUSION



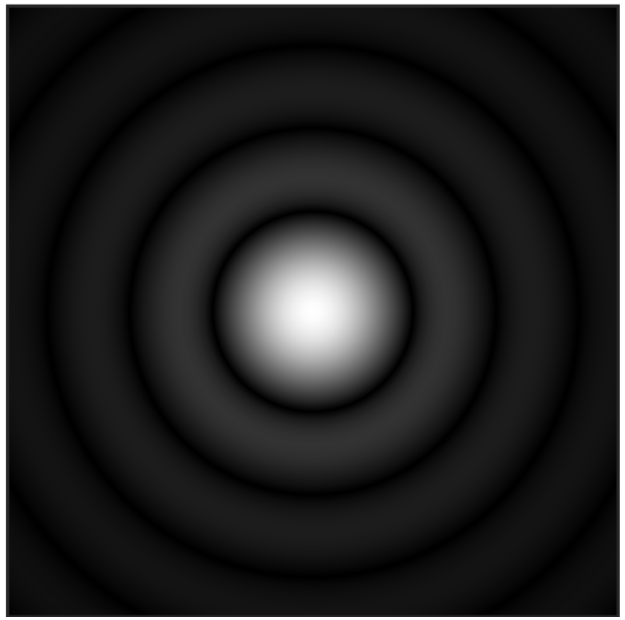
blur circles

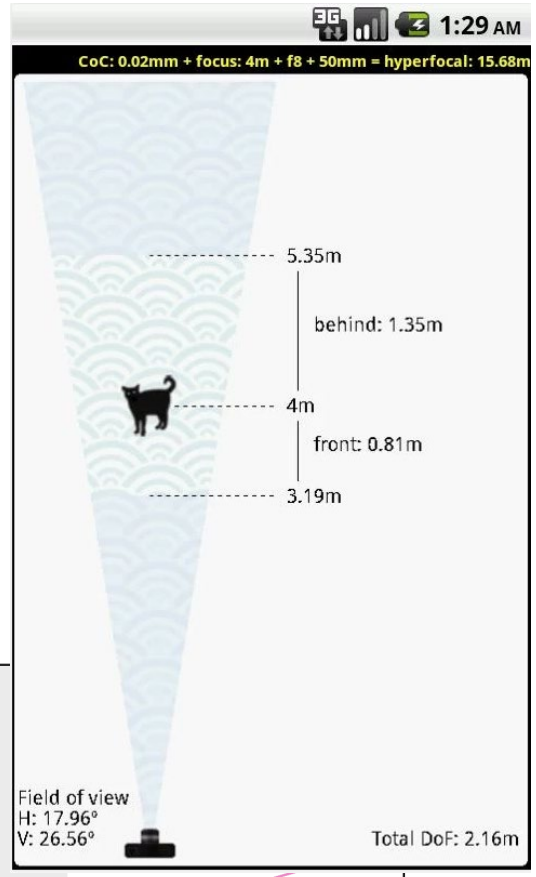
Circles of Confusion (CoC)

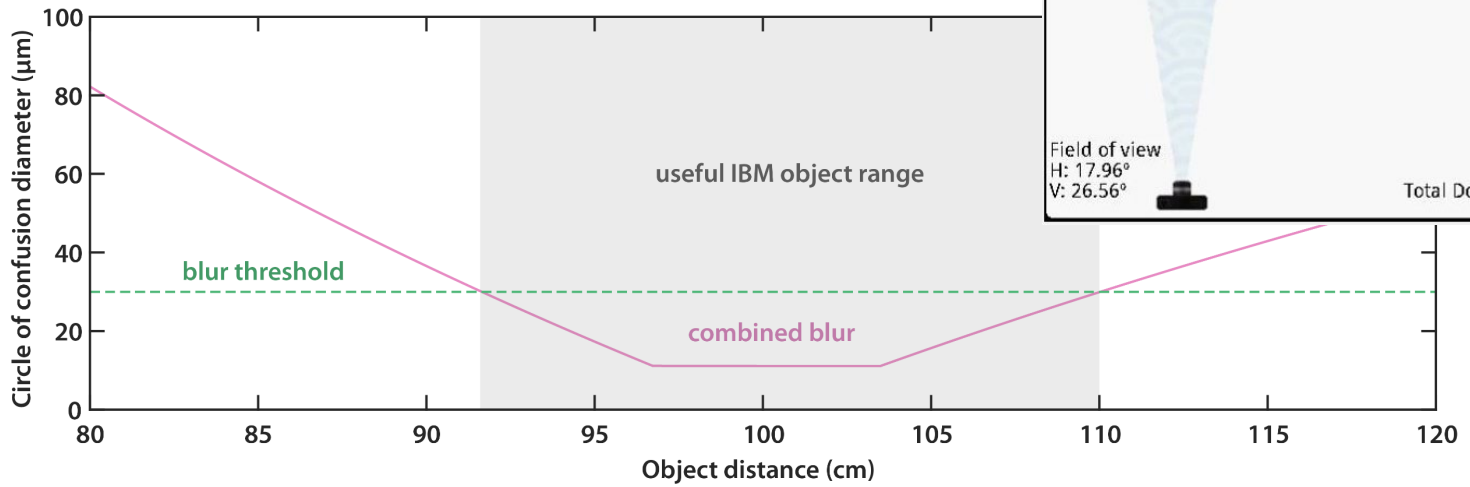




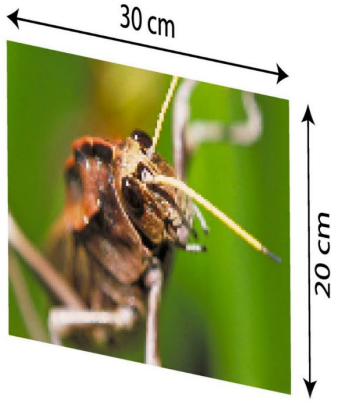
CIRCLE OF LEAST CONFUSION



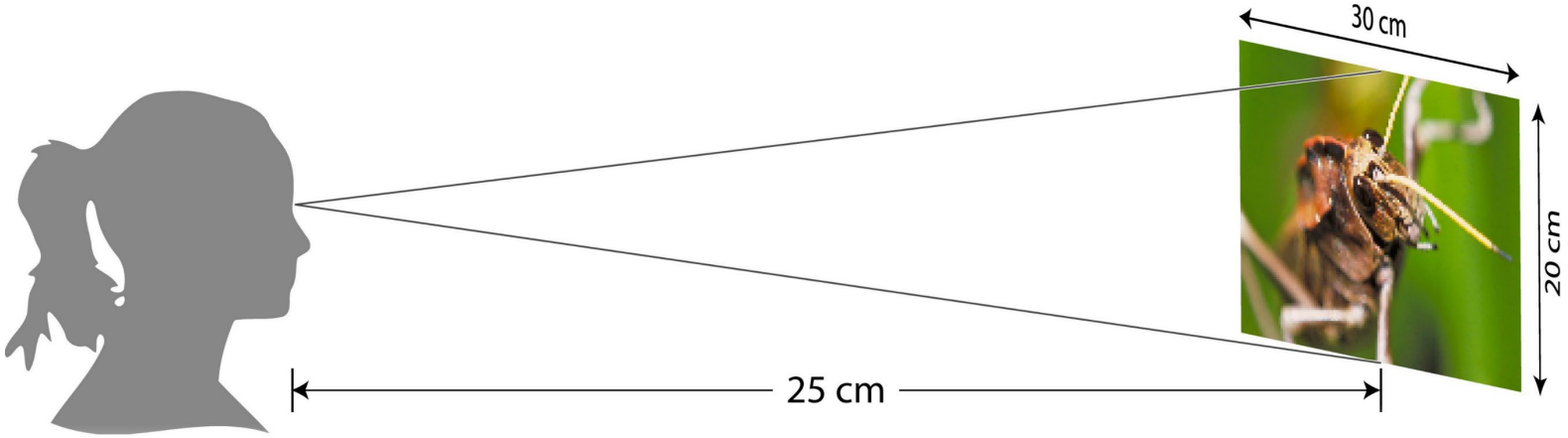




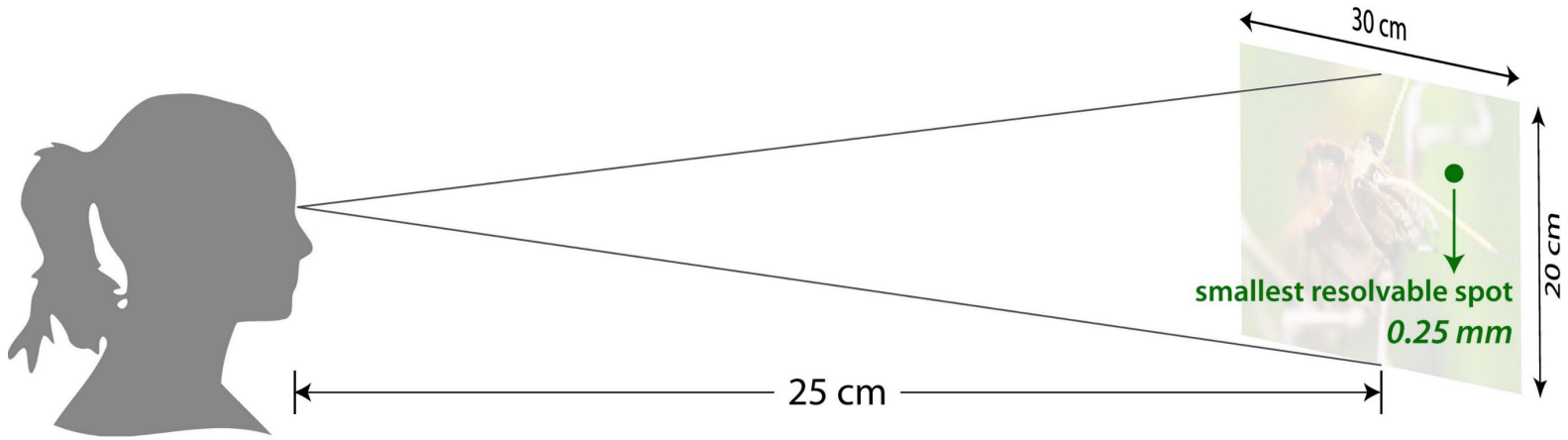
CIRCLE OF CONFUSION THRESHOLD



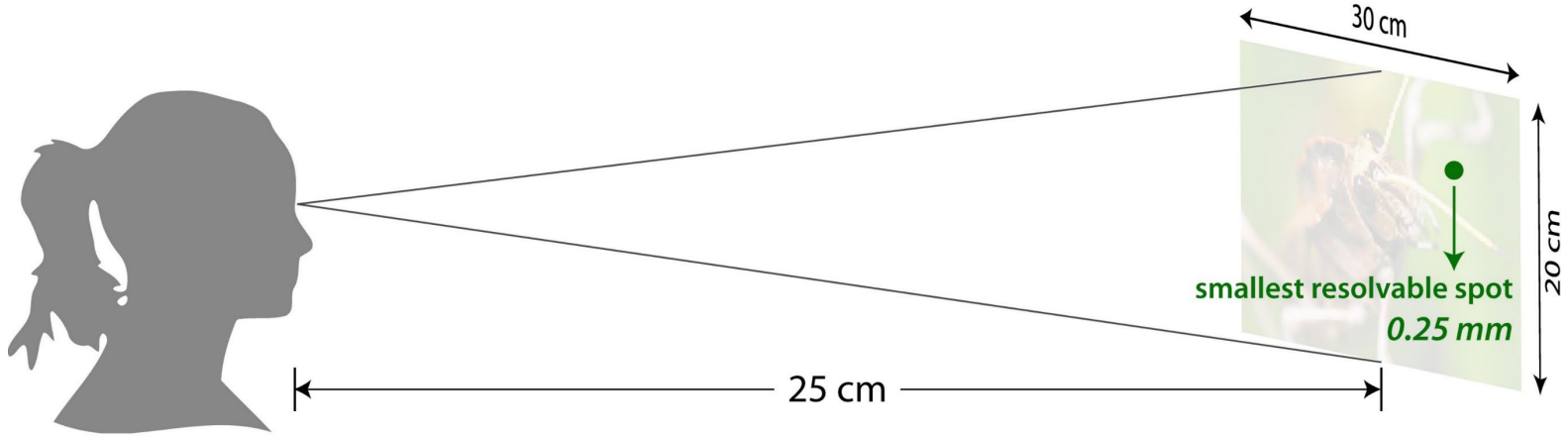
CIRCLE OF CONFUSION THRESHOLD

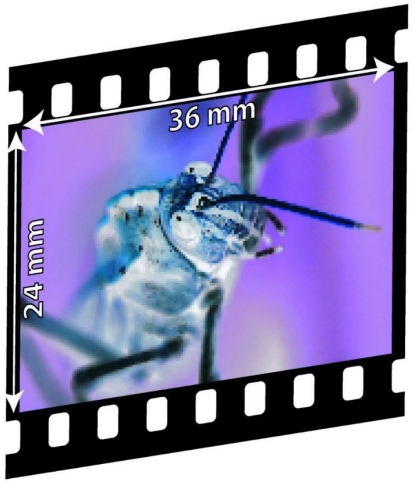


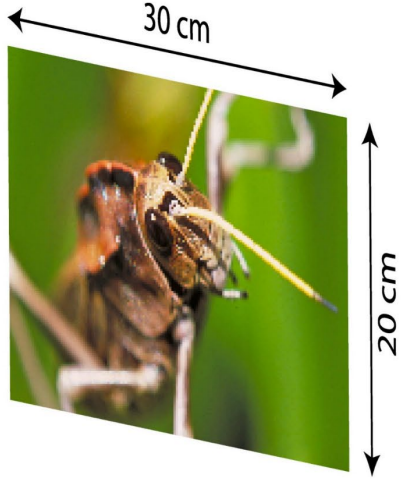
CIRCLE OF CONFUSION THRESHOLD



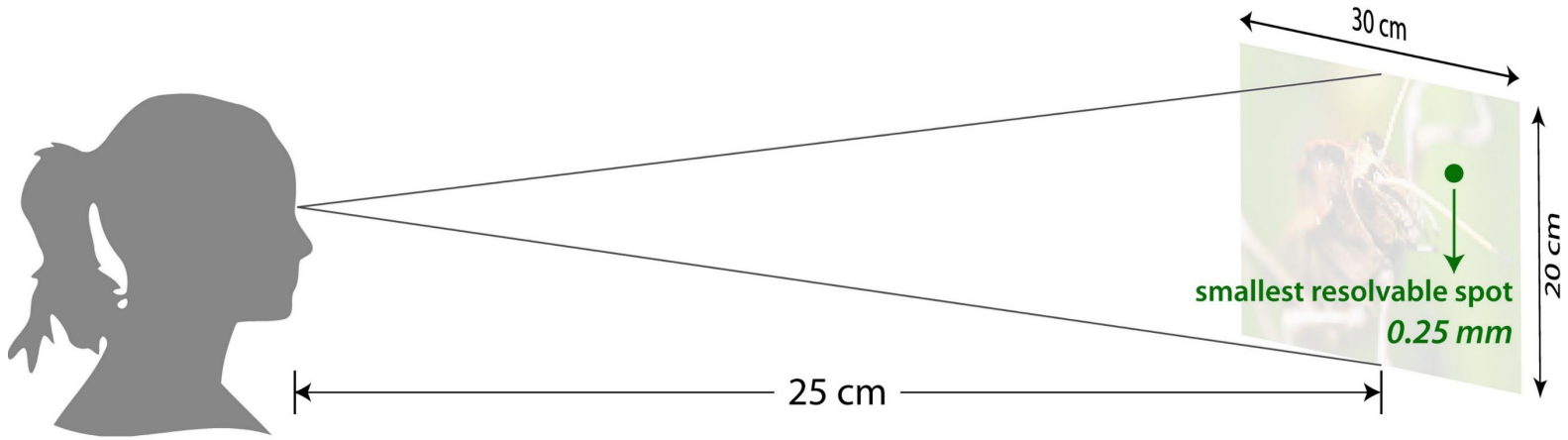
CIRCLE OF CONFUSION THRESHOLD

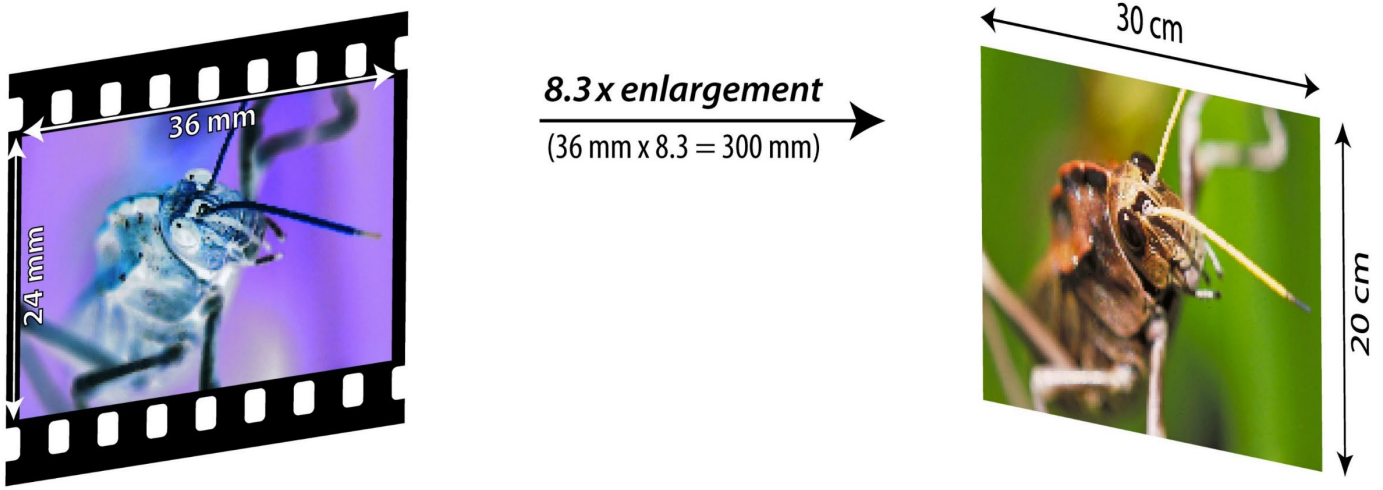




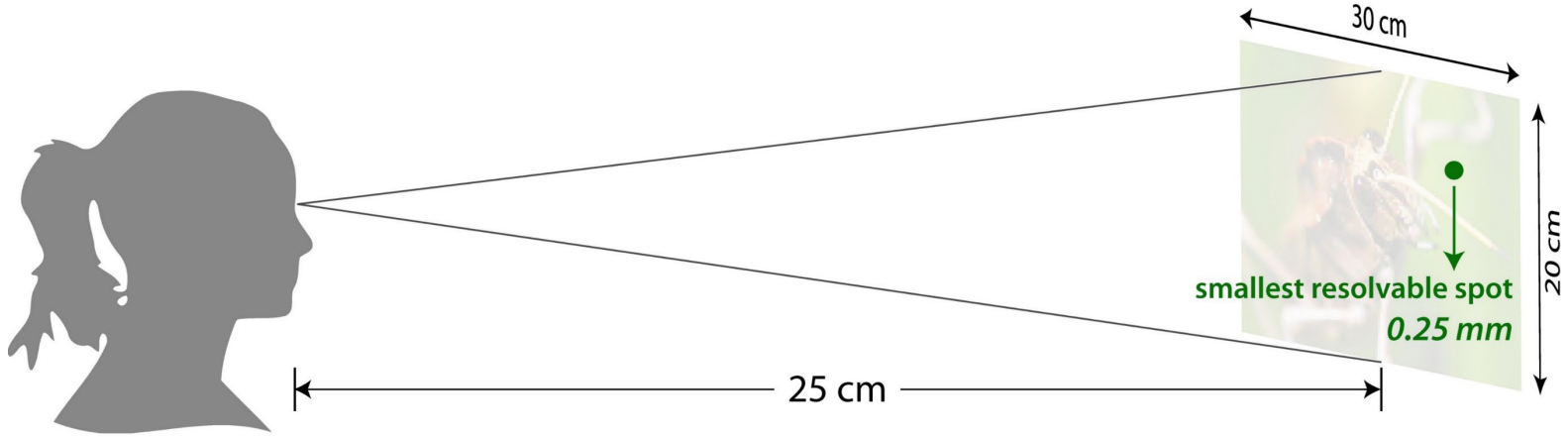


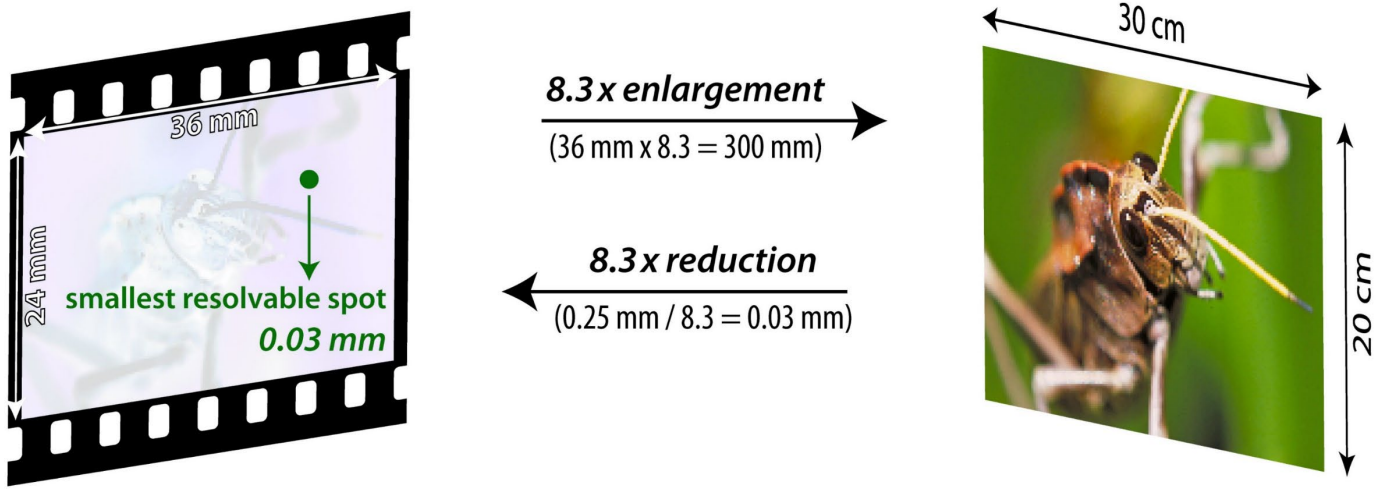
CIRCLE OF CONFUSION THRESHOLD



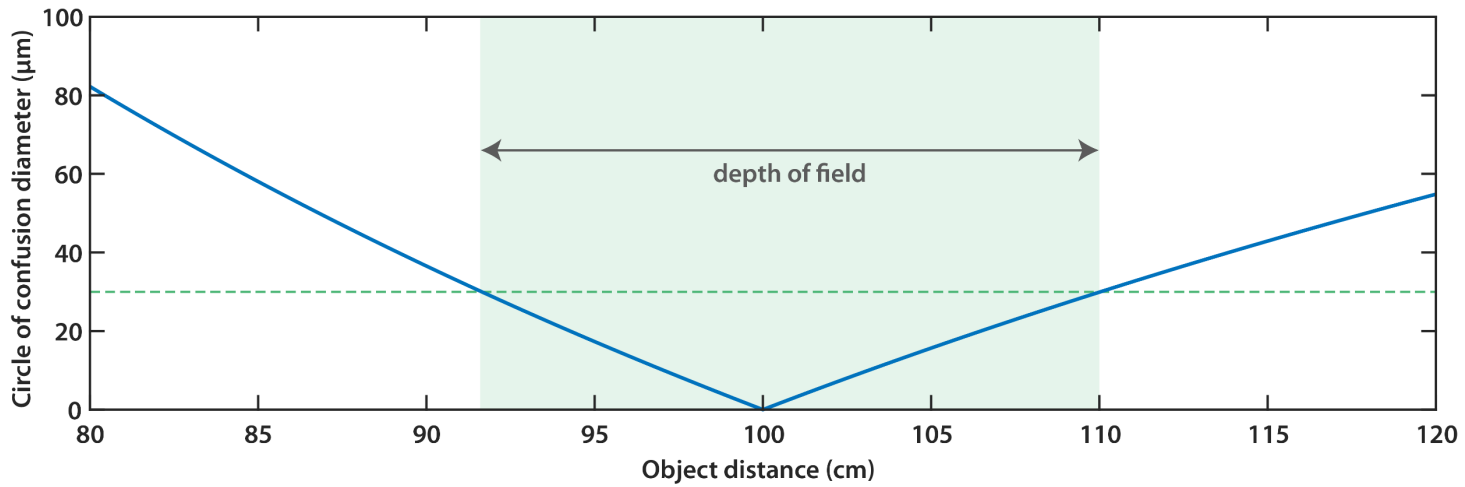


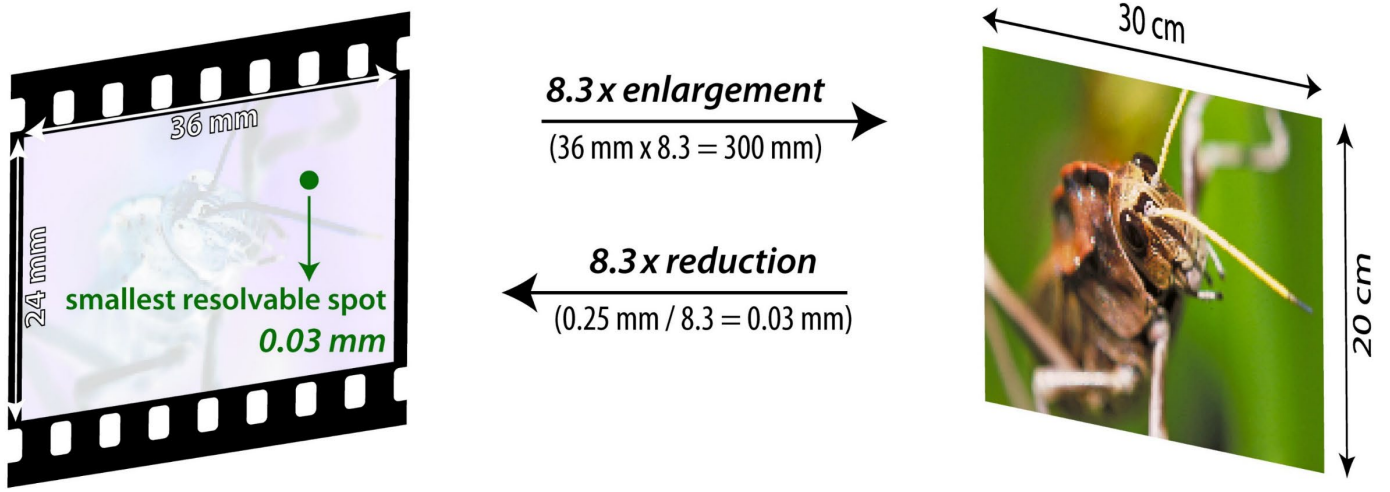
CIRCLE OF CONFUSION THRESHOLD



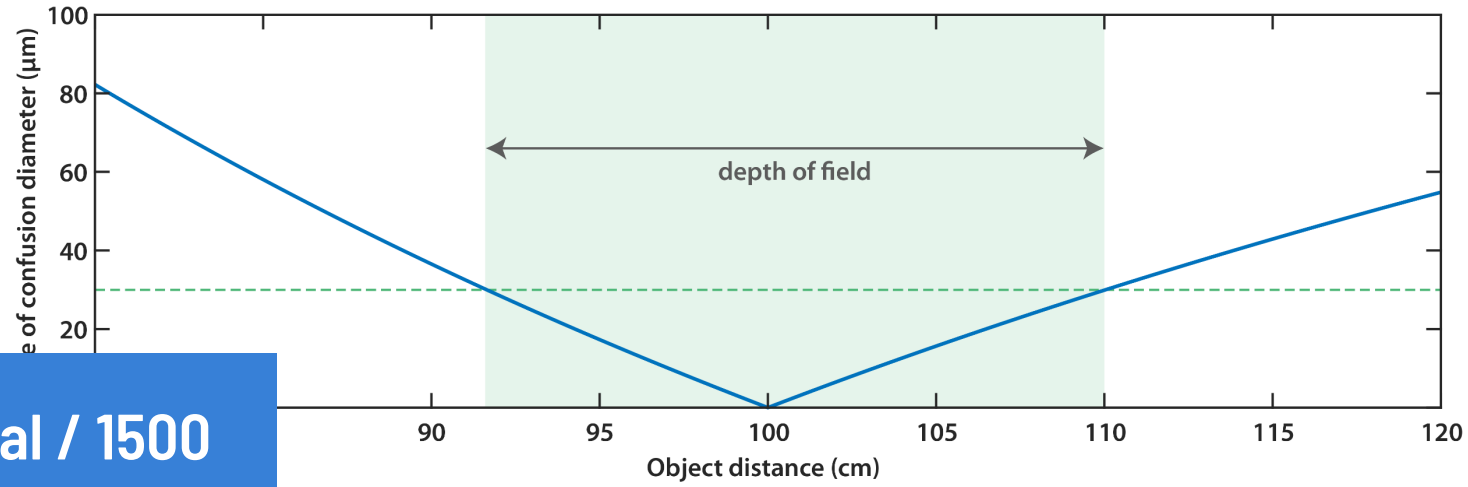


CIRCLE OF CONFUSION THRESHOLD

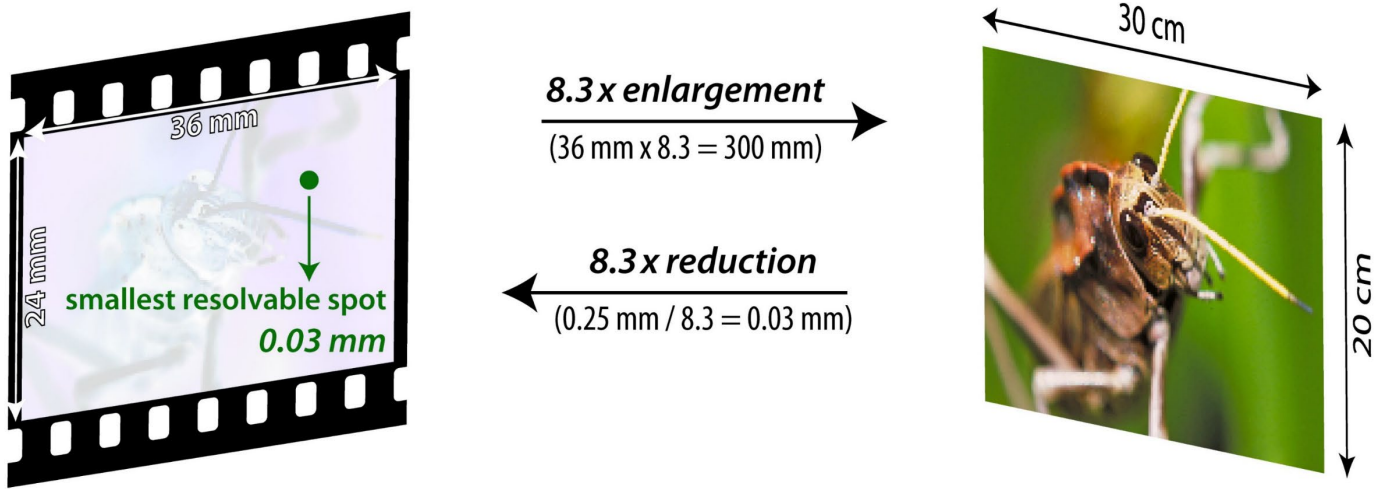




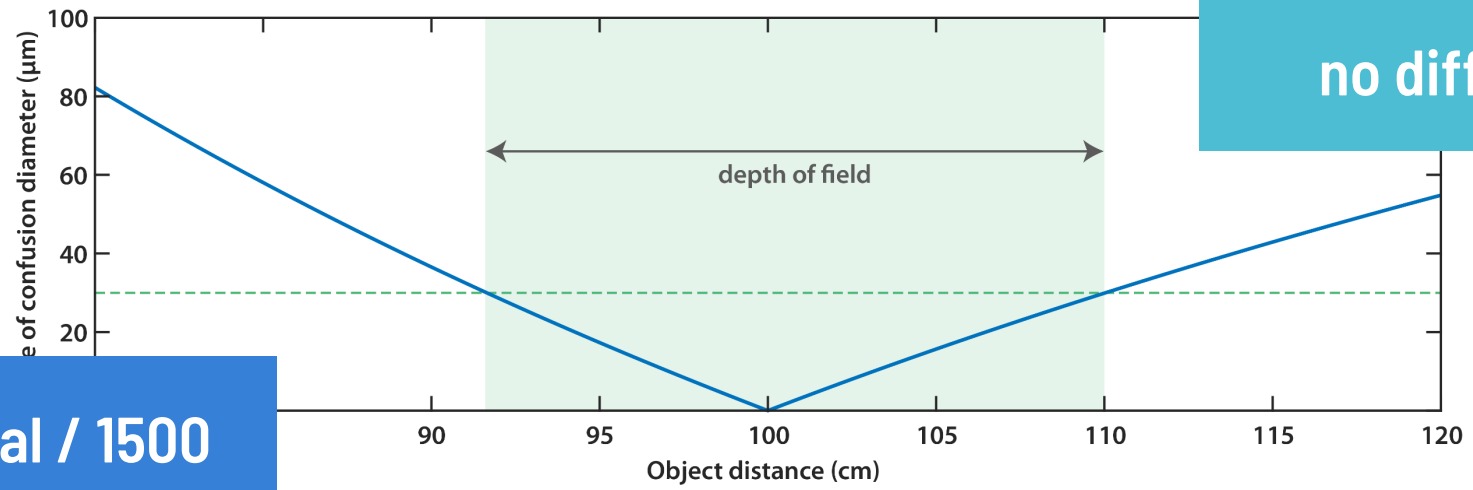
CIRCLE OF CONFUSION THRESHOLD



sensor diagonal / 1500

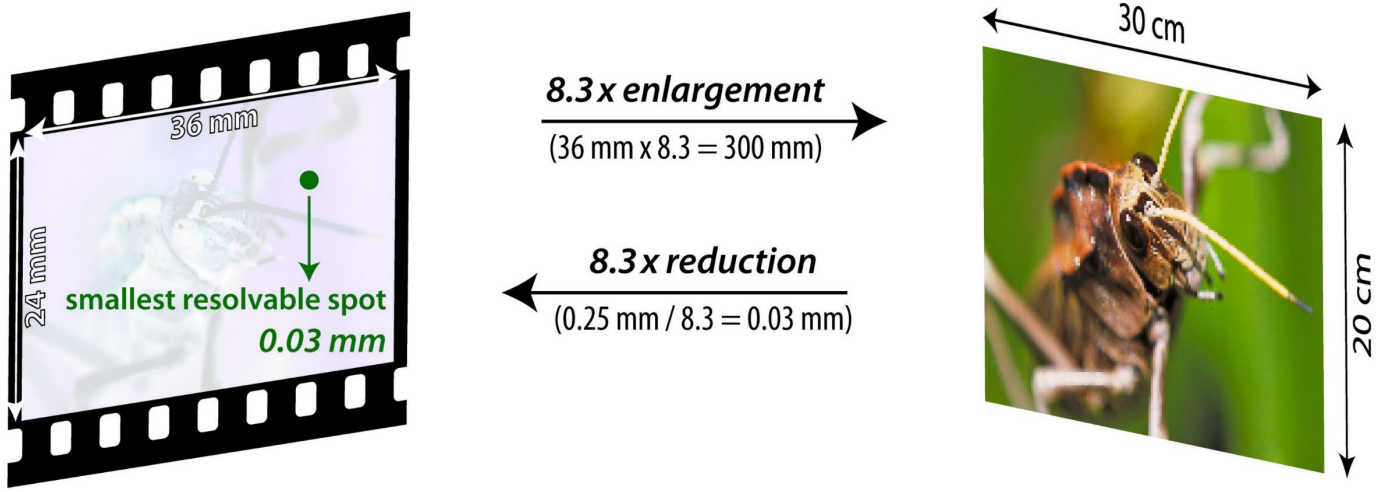


CIRCLE OF CONFUSION THRESHOLD

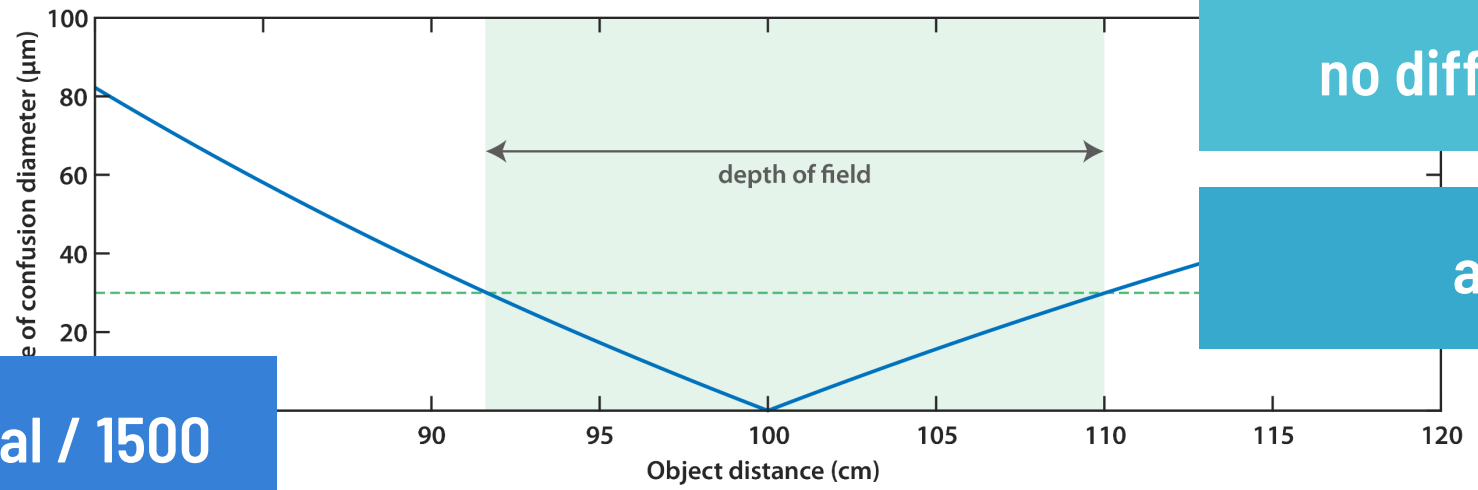


no diffraction blur

sensor diagonal / 1500



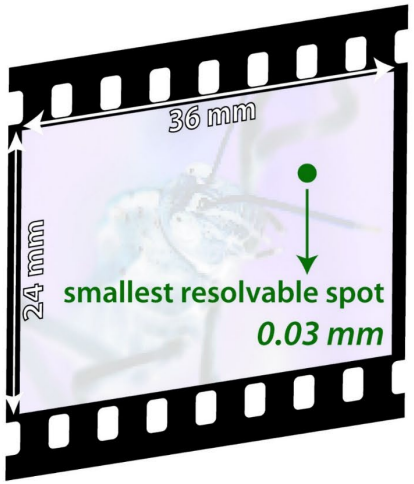
CIRCLE OF CONFUSION THRESHOLD



no diffraction blur

ancient

sensor diagonal / 1500

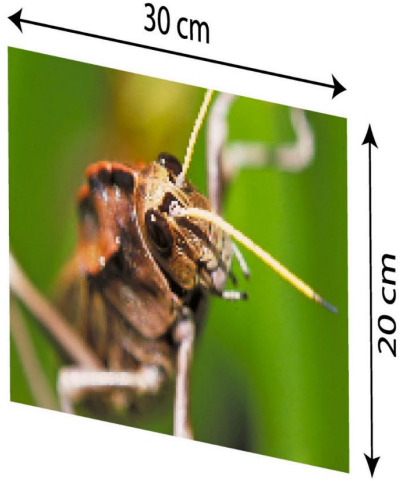


8.3 x enlargement

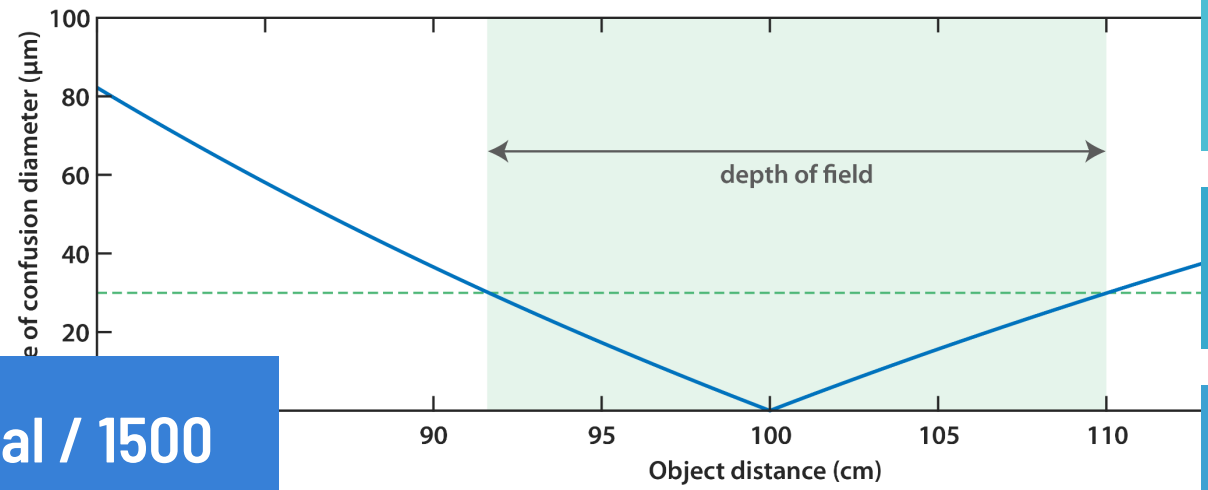
(36 mm x 8.3 = 300 mm)

8.3 x reduction

(0.25 mm / 8.3 = 0.03 mm)



CIRCLE OF CONFUSION THRESHOLD

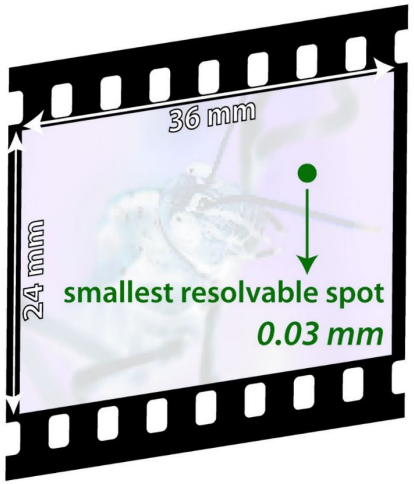


sensor diagonal / 1500

no diffraction blur

ancient

IBM ?

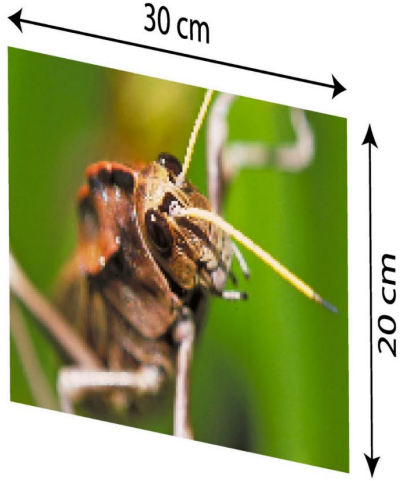


8.3 x enlargement

(36 mm x 8.3 = 300 mm)

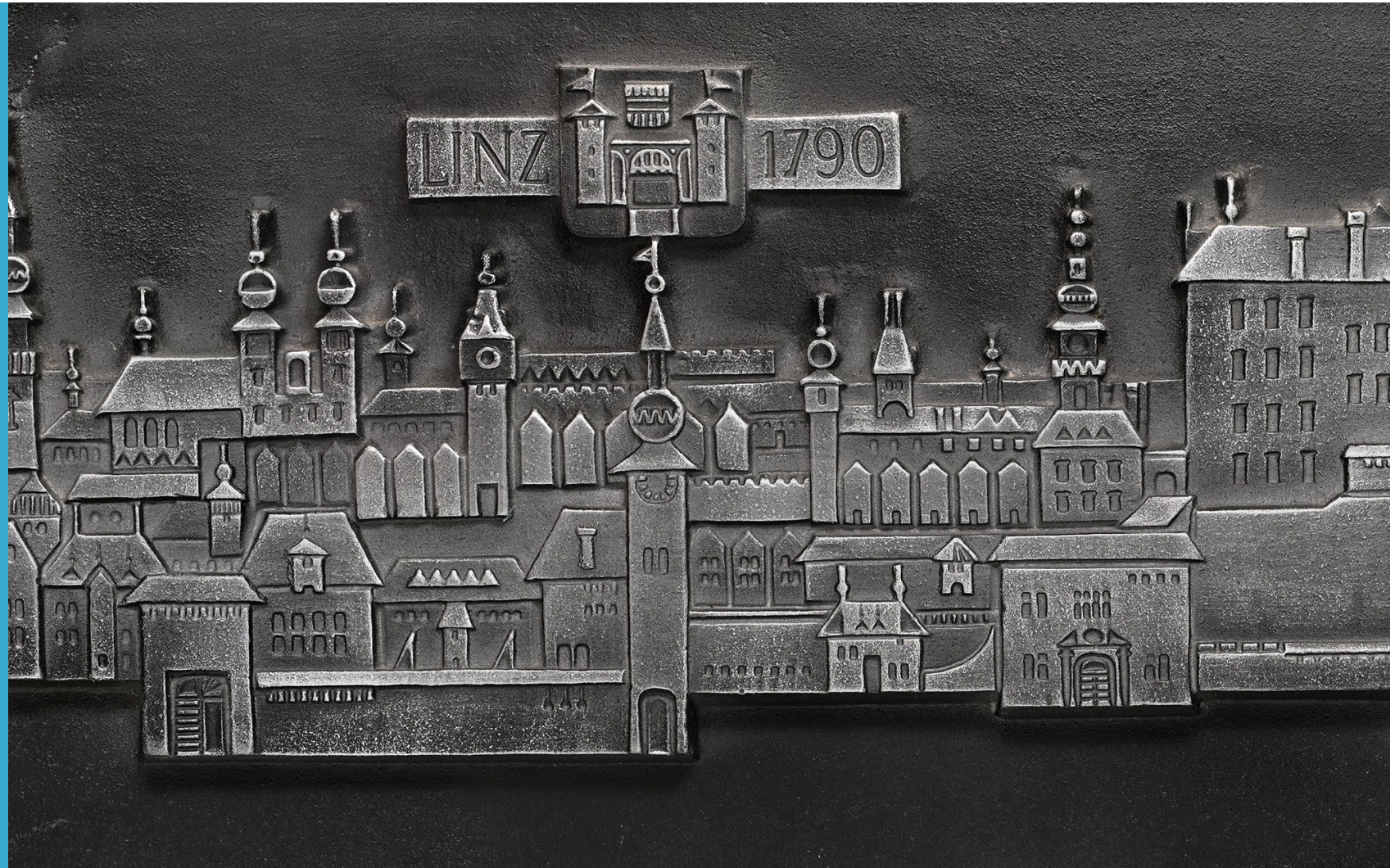
8.3 x reduction

(0.25 mm / 8.3 = 0.03 mm)



CASE STUDY 4

Relief sculpture (Linz)



CASE STUDY 4


LINZ 1790
WILDERNESS
REAL NATURE
ADULT
DEEP FOREST
95% 5% 0%
3er Pack
SALZ
LANNERFALKE
MEERJUNKER
BRILLENPUTZTÜCHER
Meßmer

CASE STUDY 4



CASE STUDY 4







Nikon Z7 II + Nikon NIKKOR Z 50 mm f/1.8 S

CASE STUDY 4







Nikon Z7 II + Nikon NIKKOR Z 50 mm f/1.8 S

CASE STUDY 4



120 cm



120 cm NEEWER slider

CASE STUDY 4



120 cm





Nikon NX tether

CASE STUDY 4



120 cm



exposure mode	*manual*
shutter speed	*1/4 s – 4 s*
aperture	*f/4 – f/16*
ISO	*250*
white balance	*3500 K*
image format	*RAW*

focusing	*off*
vibration reduct.	*off*
GSD	*~0.1 mm*
network	*714 photos*
lateral overlap	*90 %*

Nikon NX tether

CASE STUDY 4



120 cm

f / 4

f / 5.6

f / 8

f / 11

f / 16

CASE STUDY 4



118 cm

f / 4

CASE STUDY 4



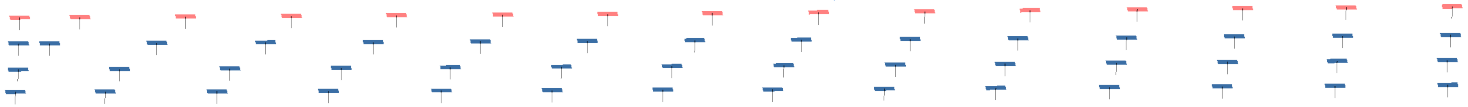
116 cm

f / 4

CASE STUDY 4



114 cm



f / 4

f / 5.6

f / 8

f / 11

f / 16

CASE STUDY 4



112 cm

f / 4

CASE STUDY 4



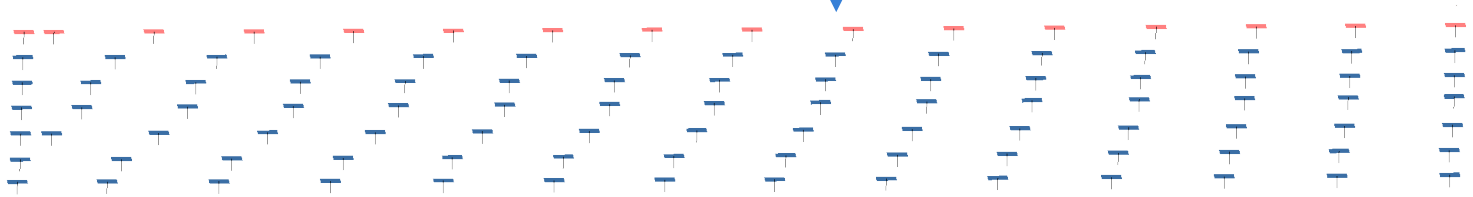
110 cm

f / 4

CASE STUDY 4



108 cm



f / 4

f / 5.6

f / 8

f / 11

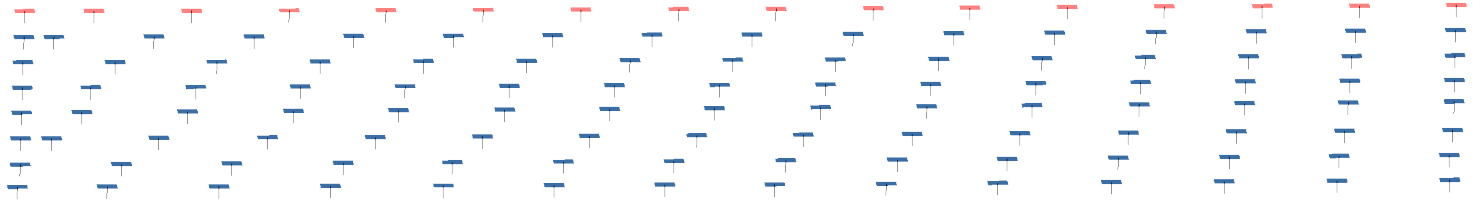
f / 16

CASE STUDY 4



106 cm

f / 4

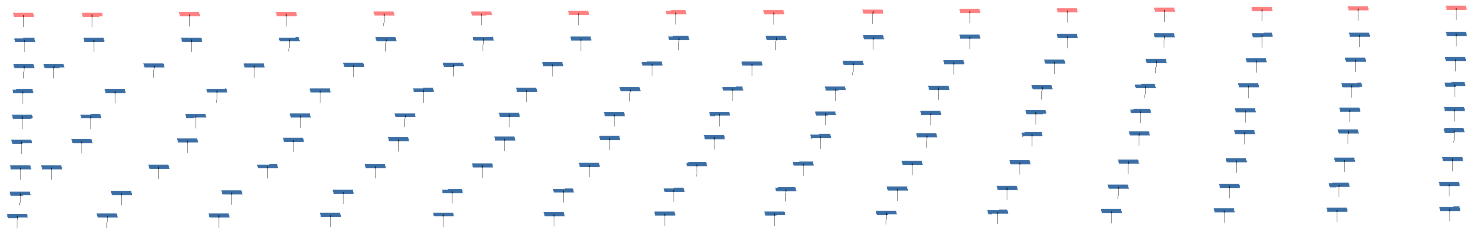


CASE STUDY 4



104 cm

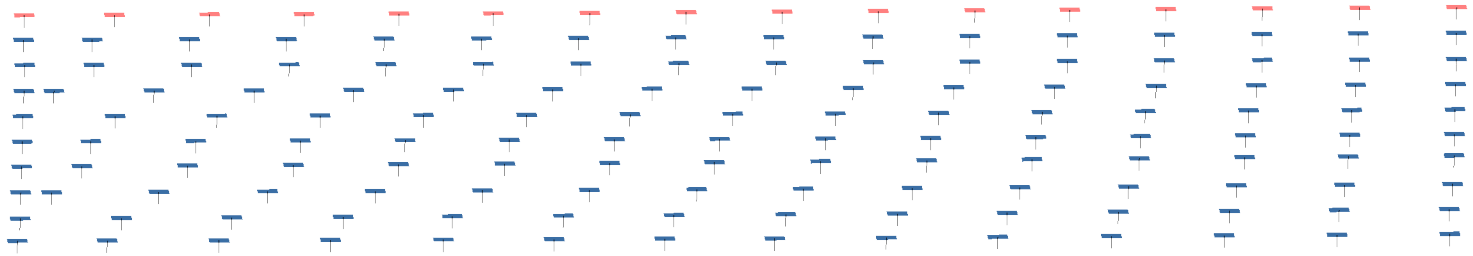
f / 4



CASE STUDY 4



102 cm



f / 4

f / 5.6

f / 8

f / 11

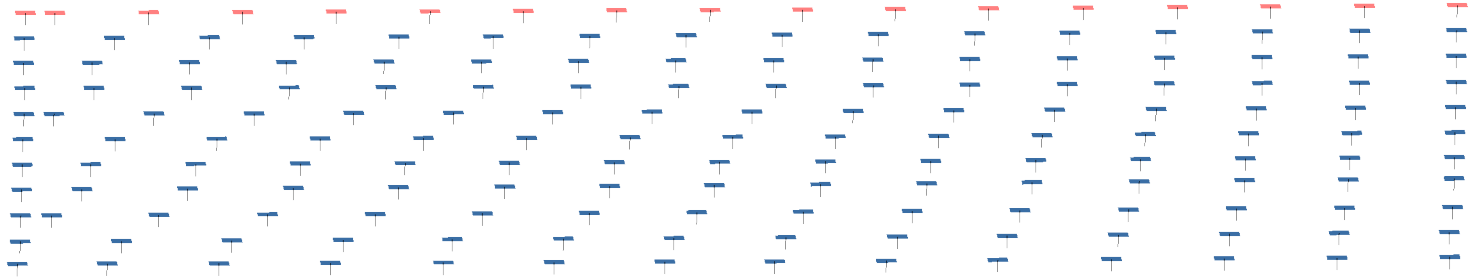
f / 16

CASE STUDY 4



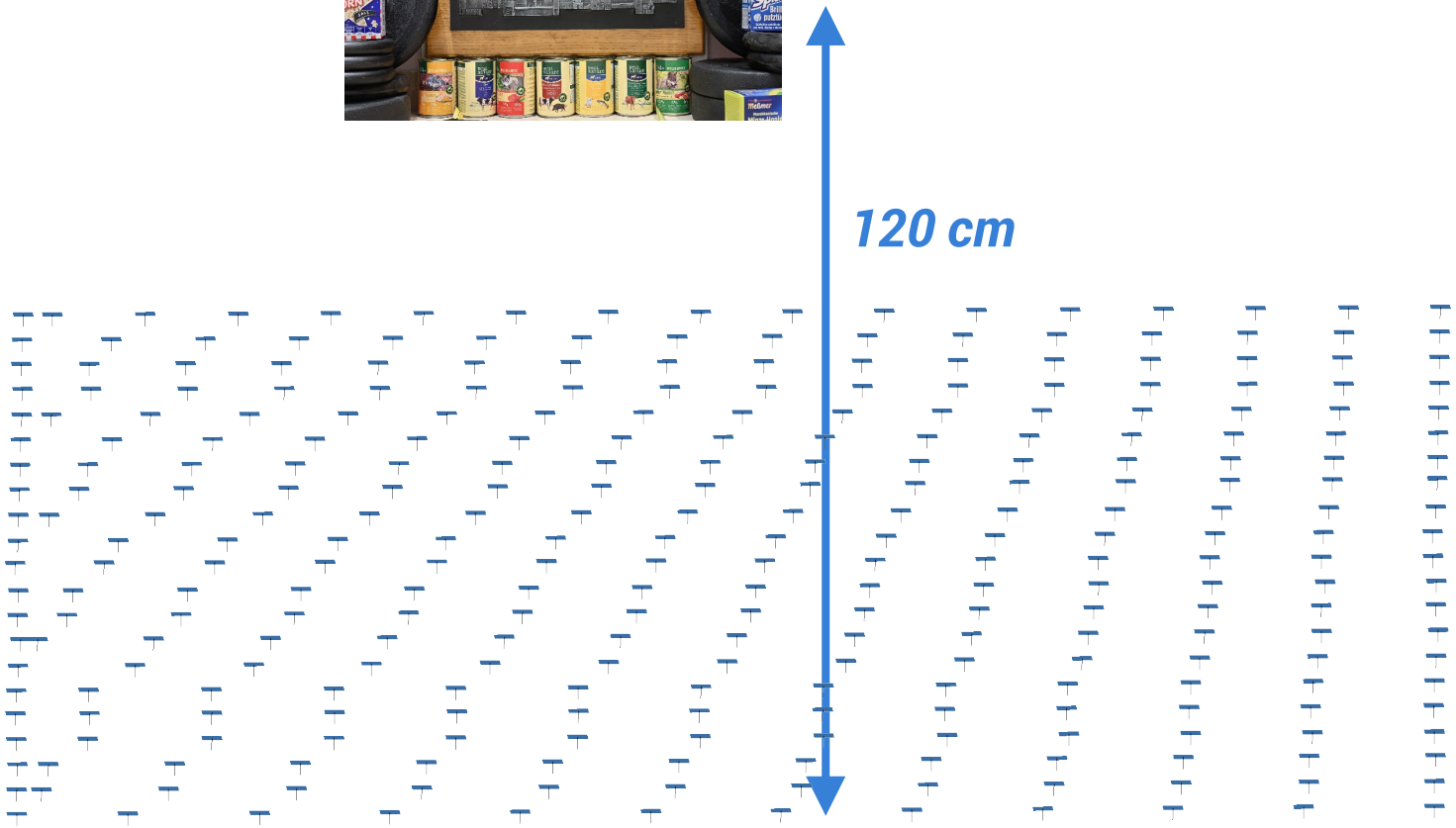
100 cm

f / 4



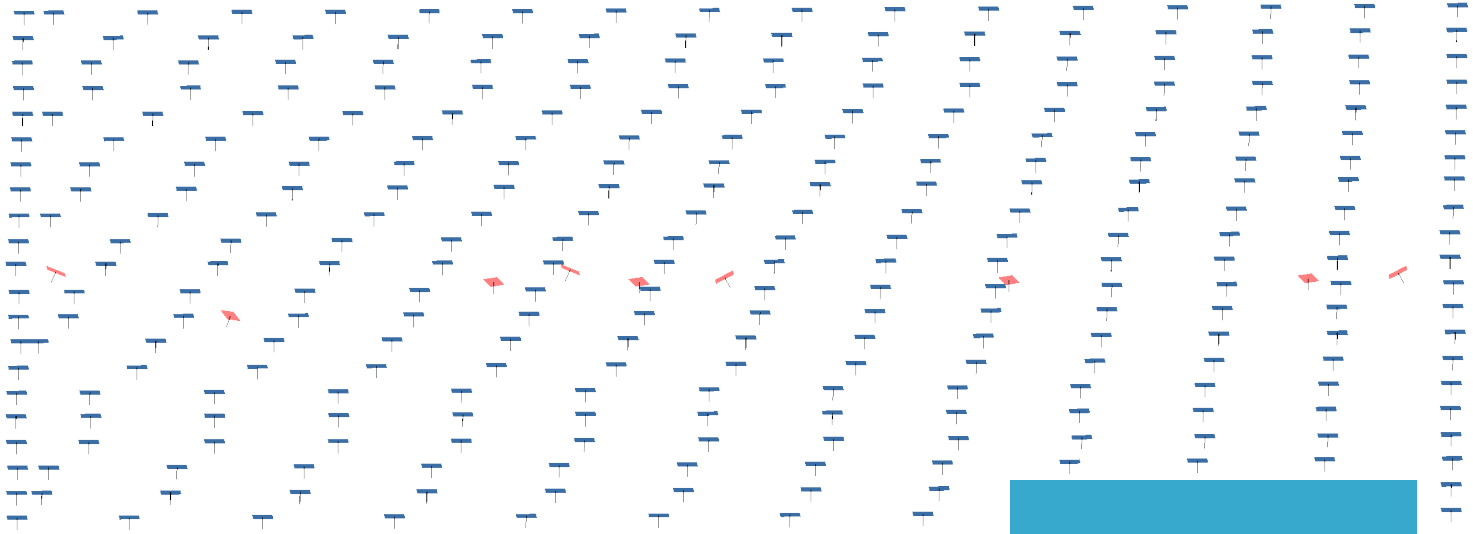
CASE STUDY 4





CASE STUDY 4

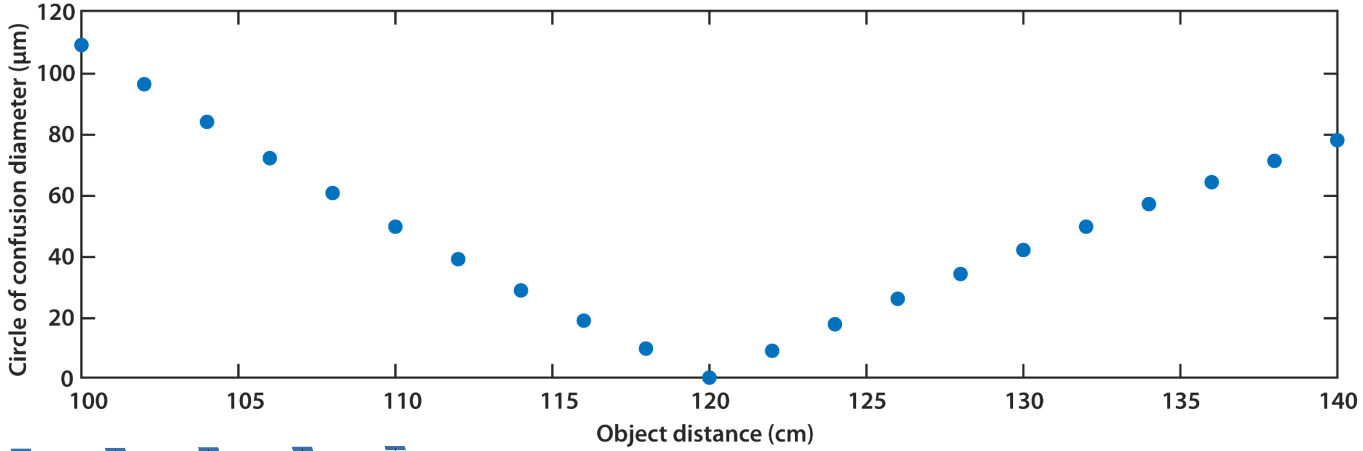


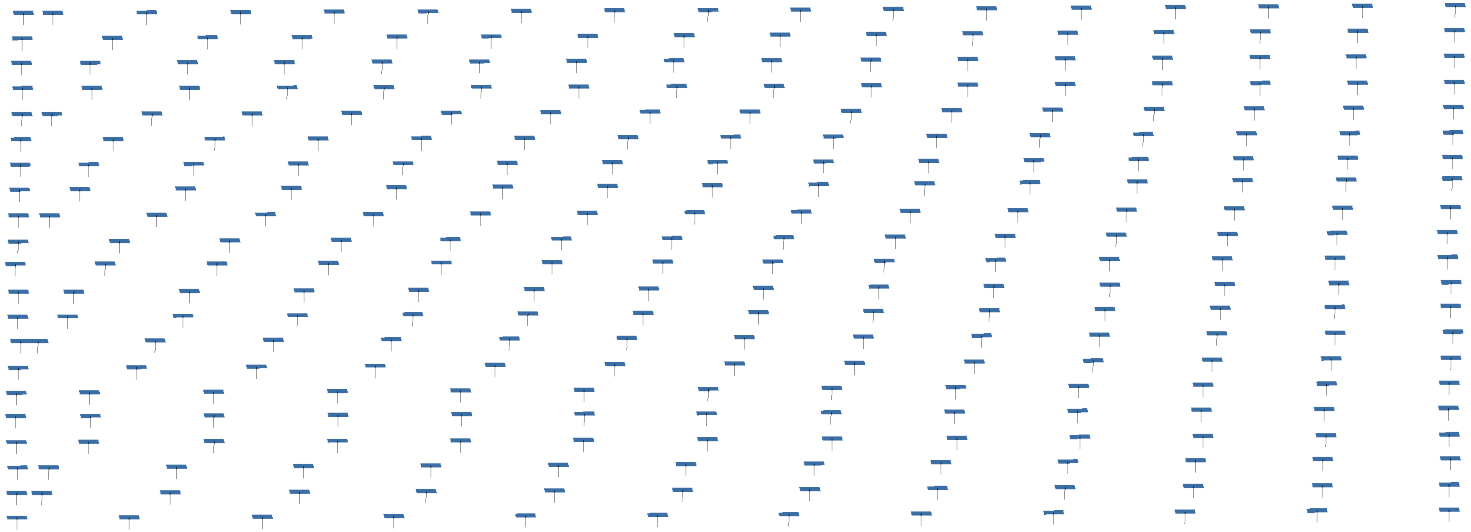


714 photos

CASE STUDY 4

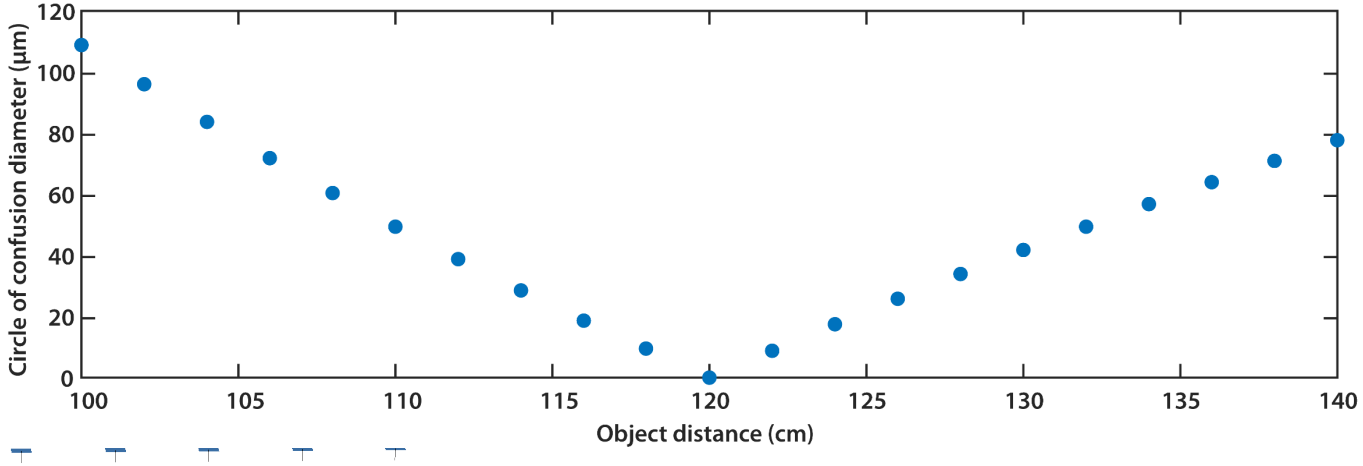


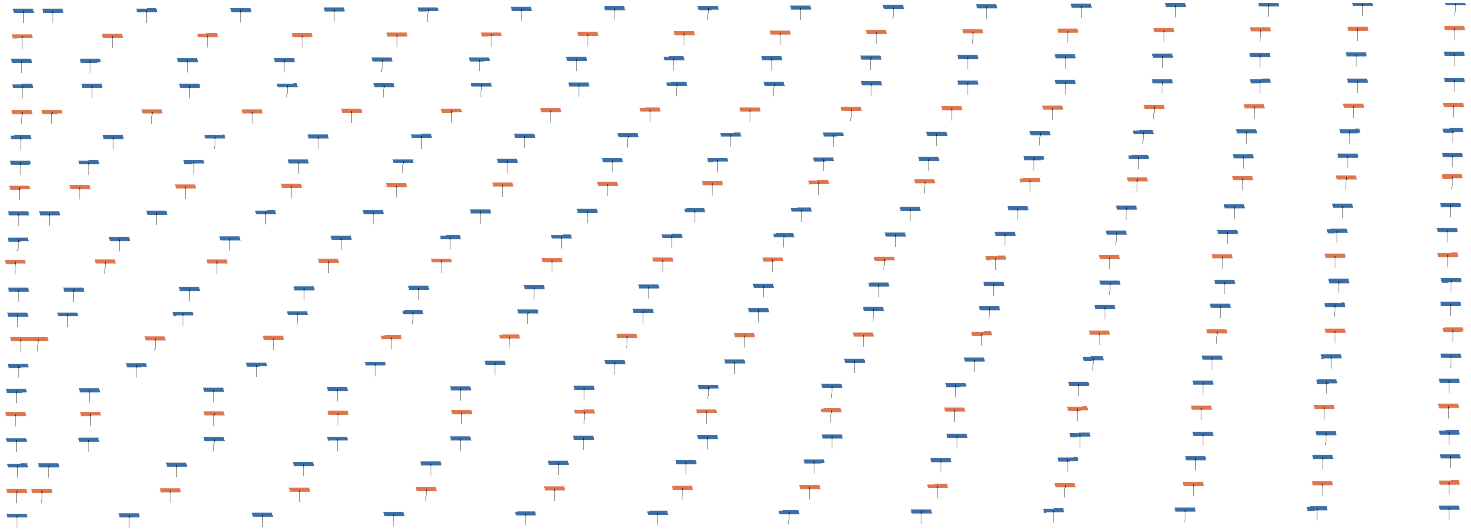

Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)



CASE STUDY 4

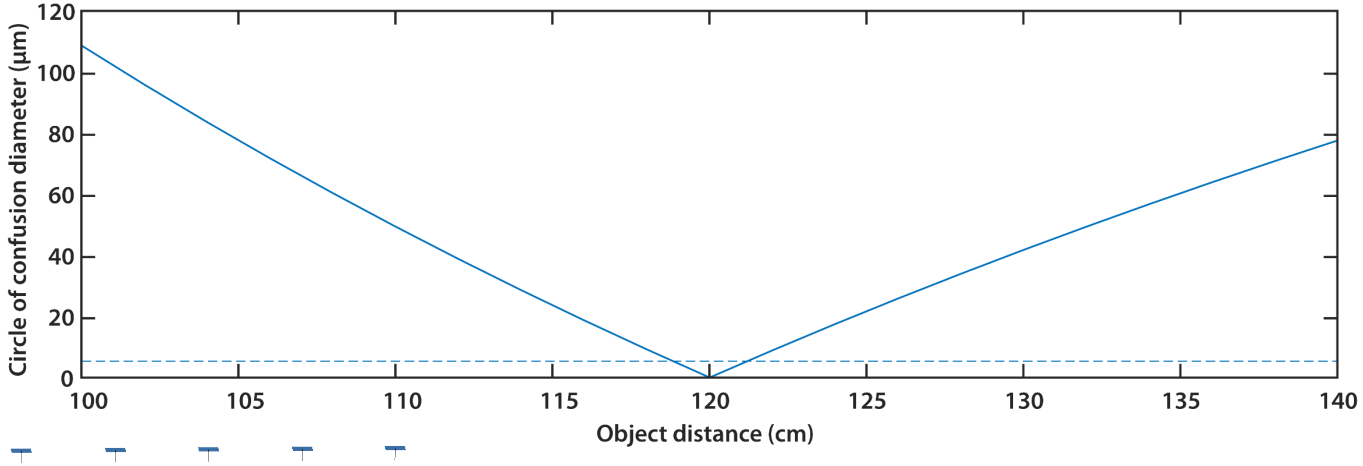


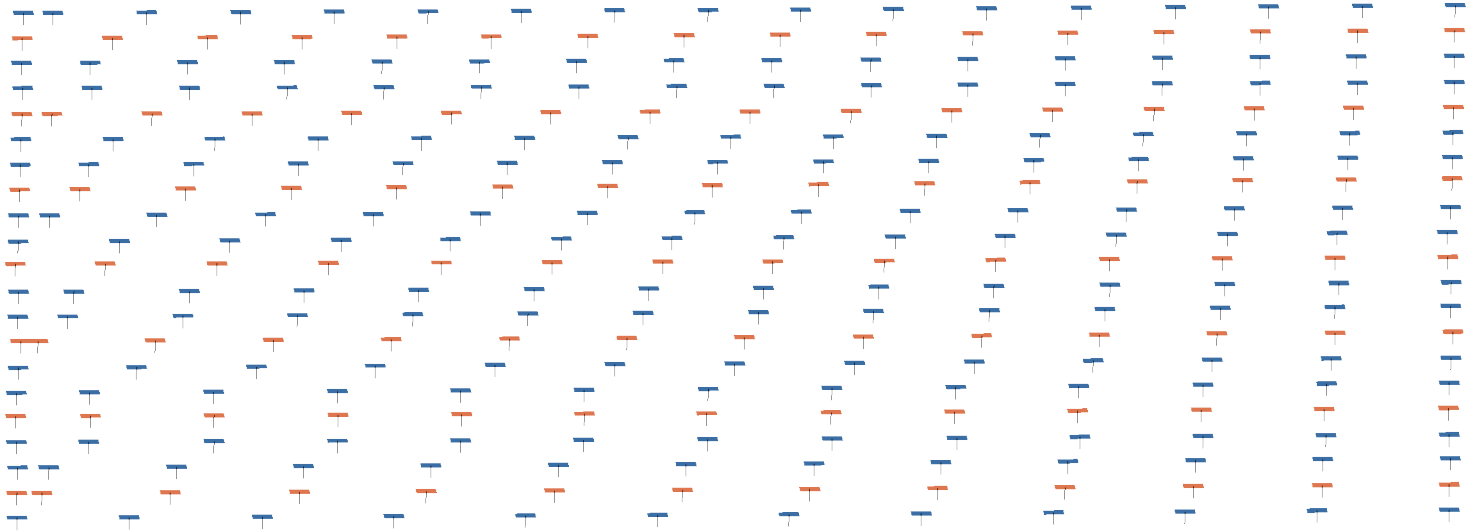

Circle of confusion diameter (µm)
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100
80
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100
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110
115
120
125
130
135
140
Object distance (cm)



CASE STUDY 4

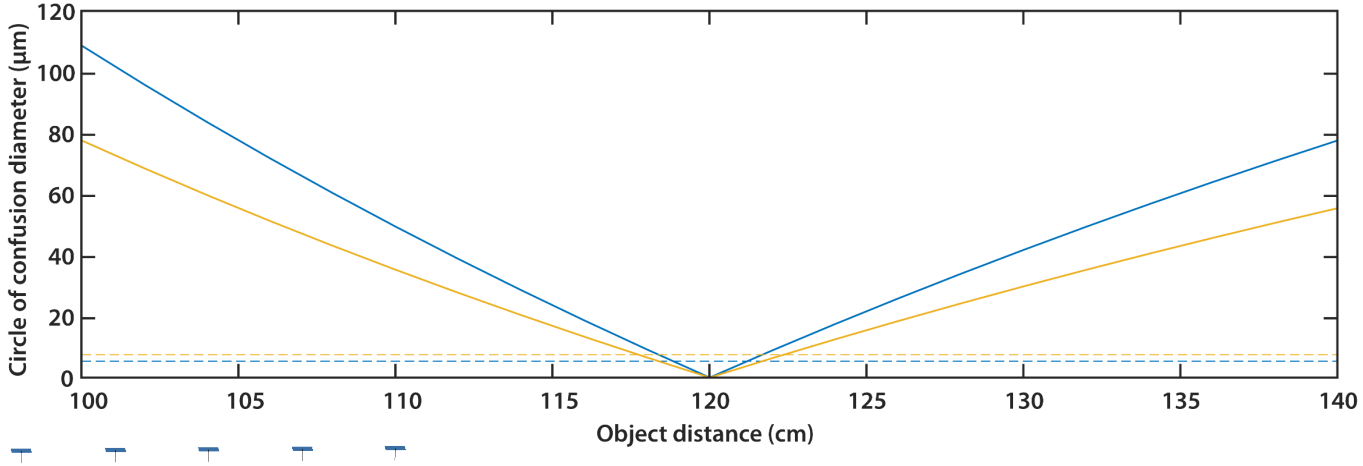


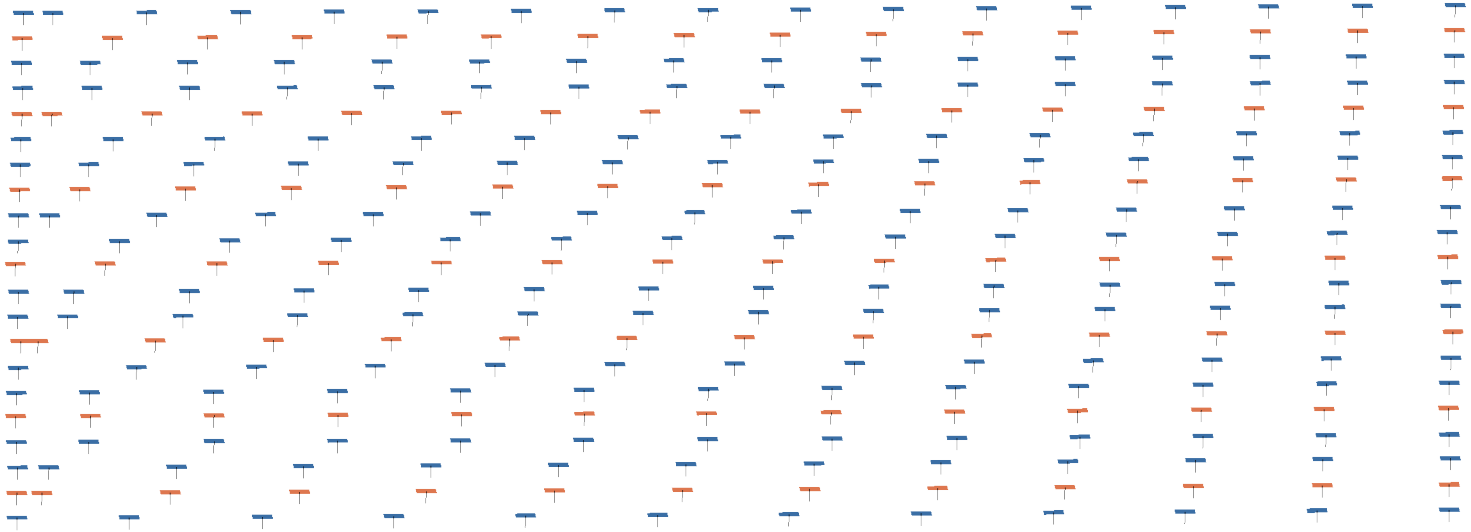

Circle of confusion diameter (µm)
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100
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110
115
120
125
130
135
140
Object distance (cm)



CASE STUDY 4

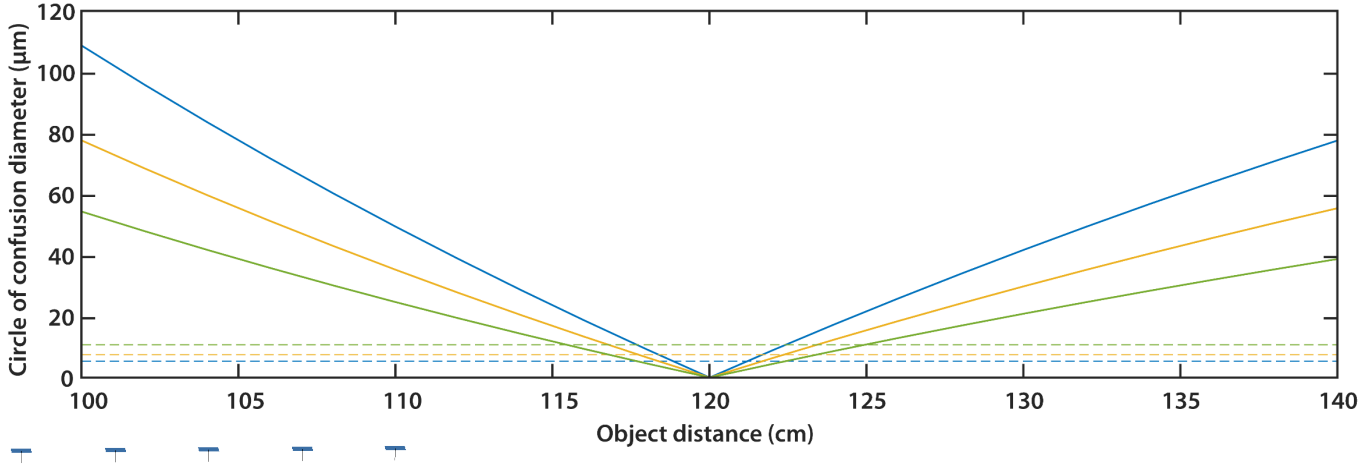


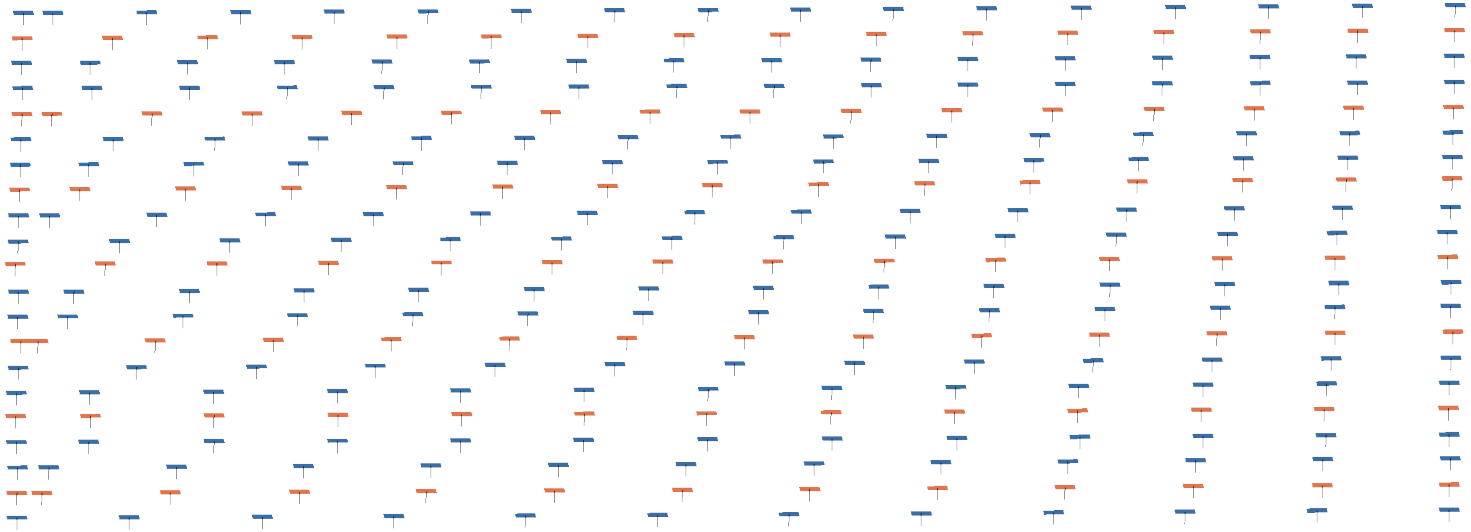

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120
125
130
135
140
Object distance (cm)



CASE STUDY 4

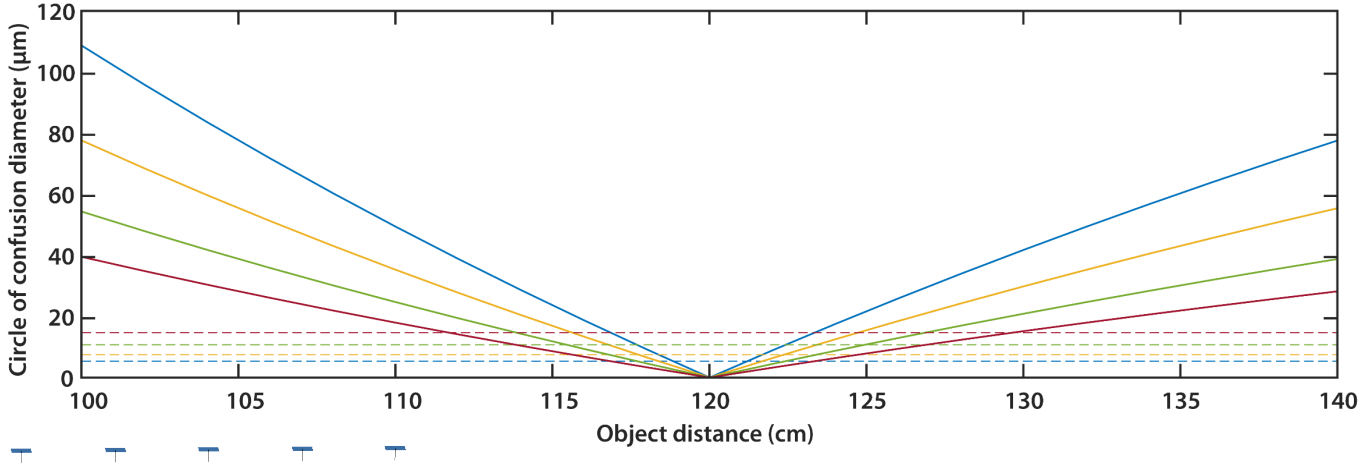


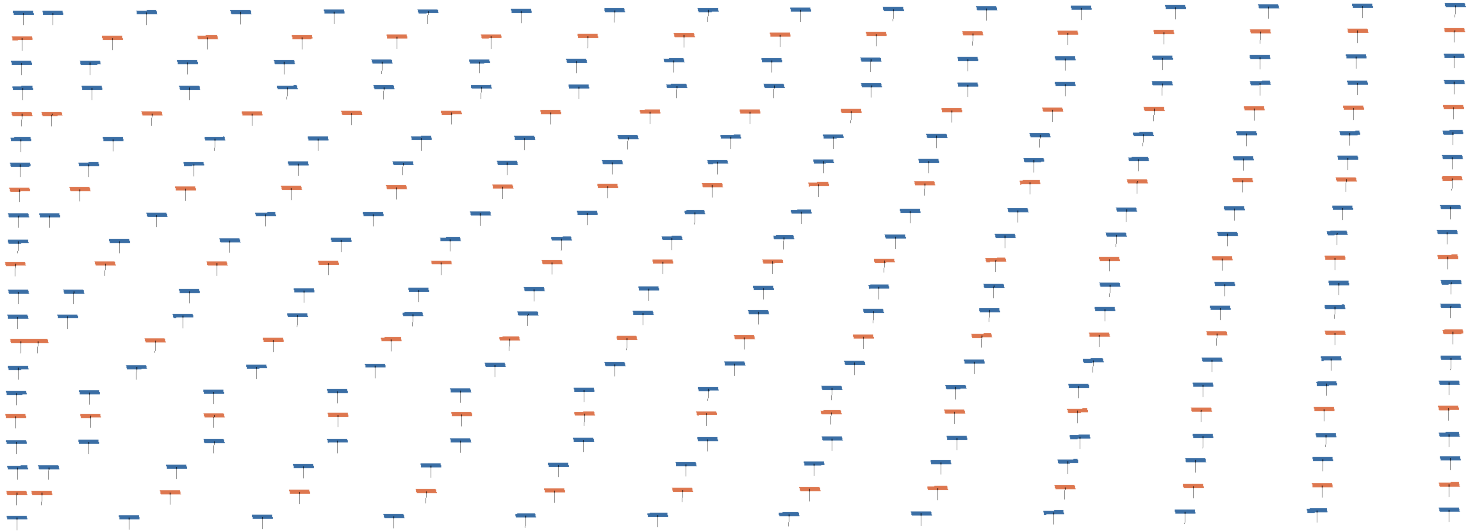

Circle of confusion diameter (µm)
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115
120
125
130
135
140
Object distance (cm)



CASE STUDY 4

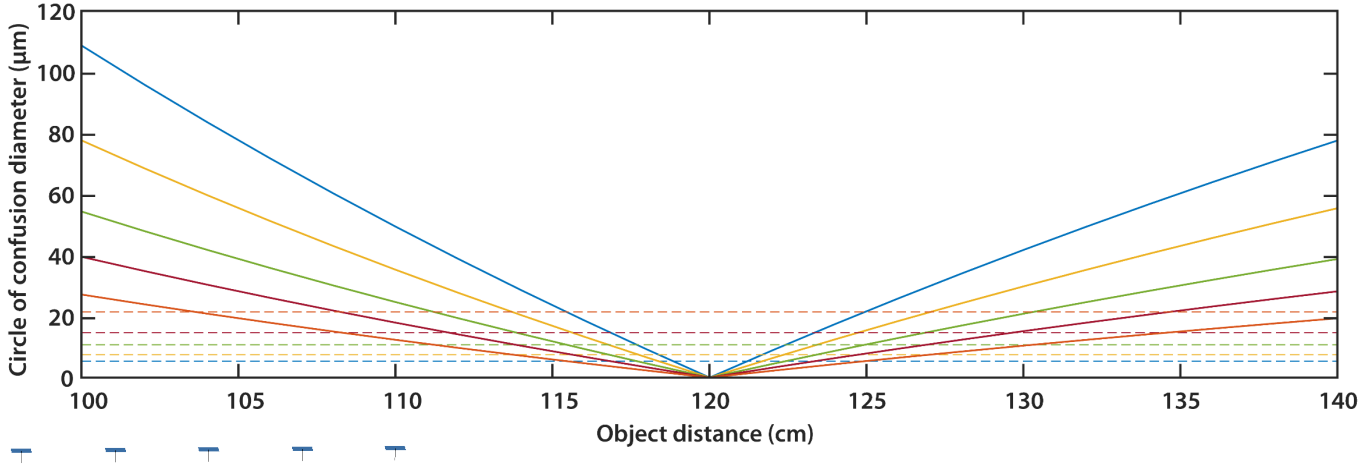


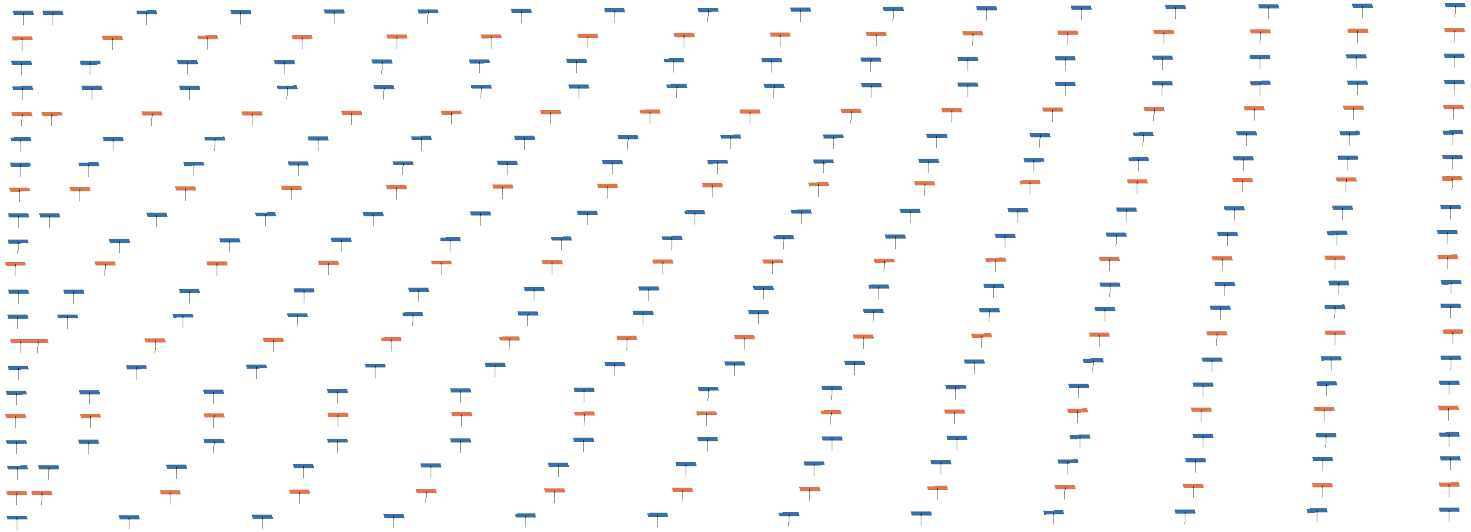

Circle of confusion diameter (µm)
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40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)



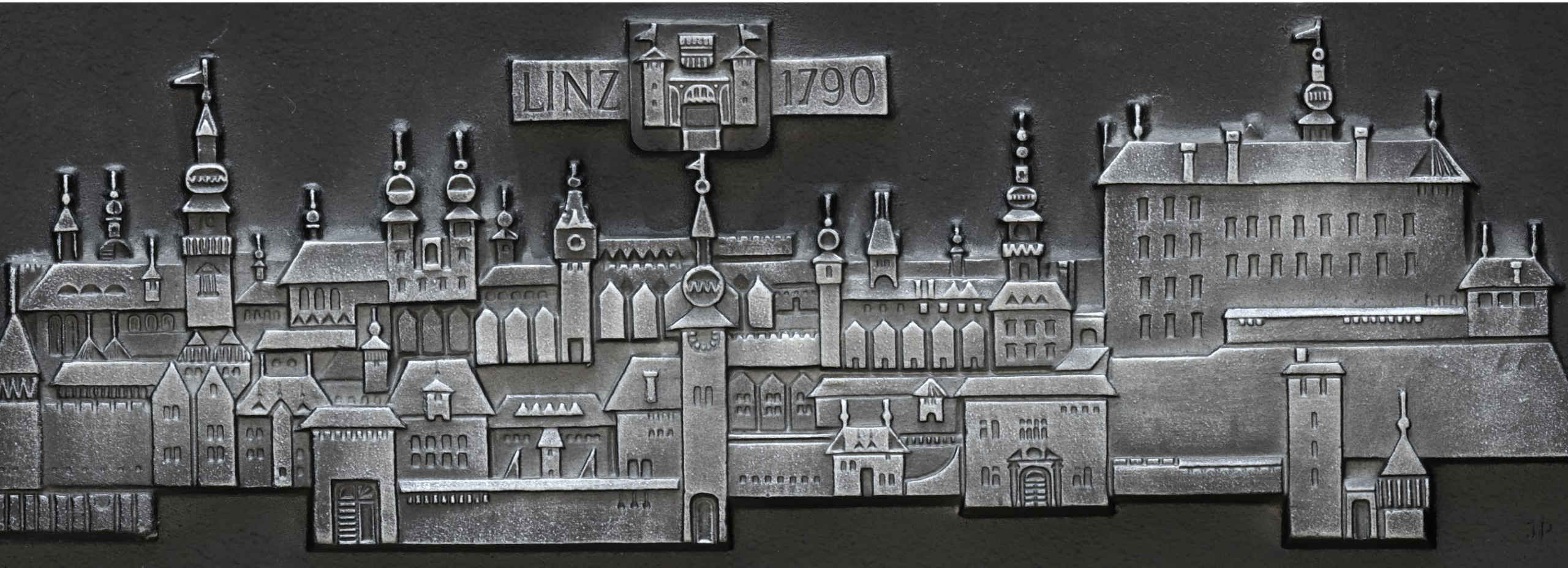
CASE STUDY 4



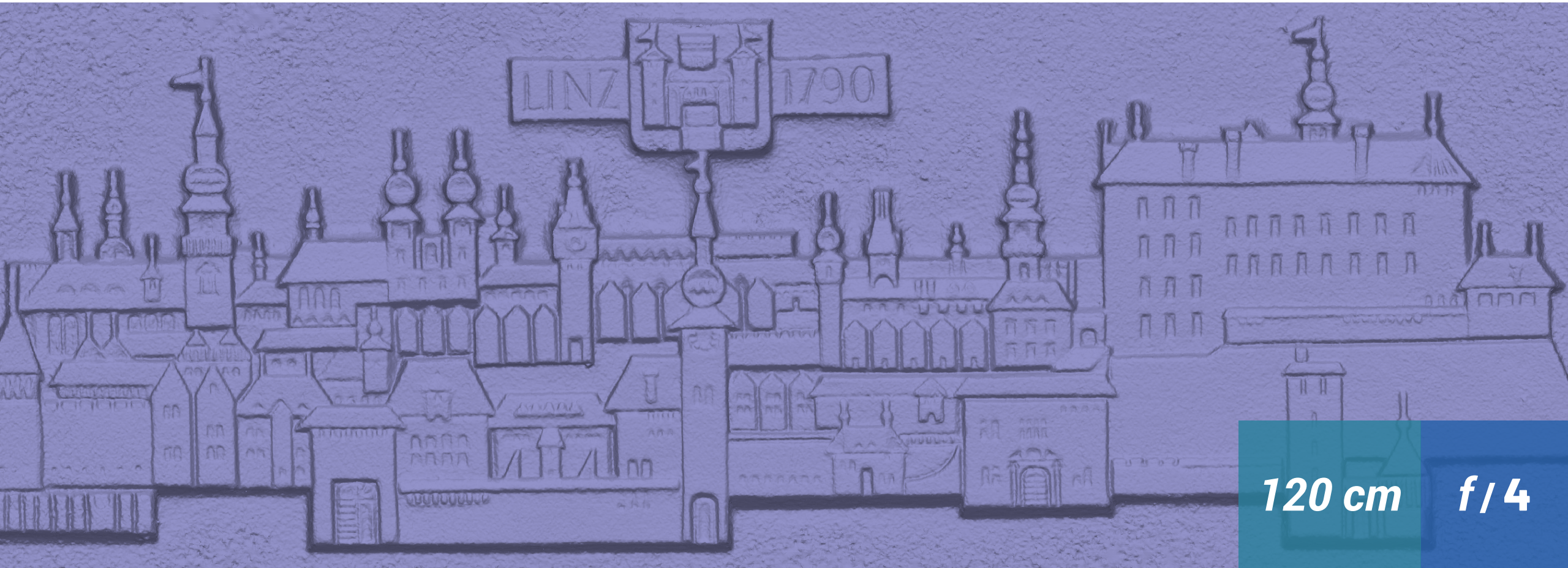

Circle of confusion diameter (µm)
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120
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Object distance (cm)



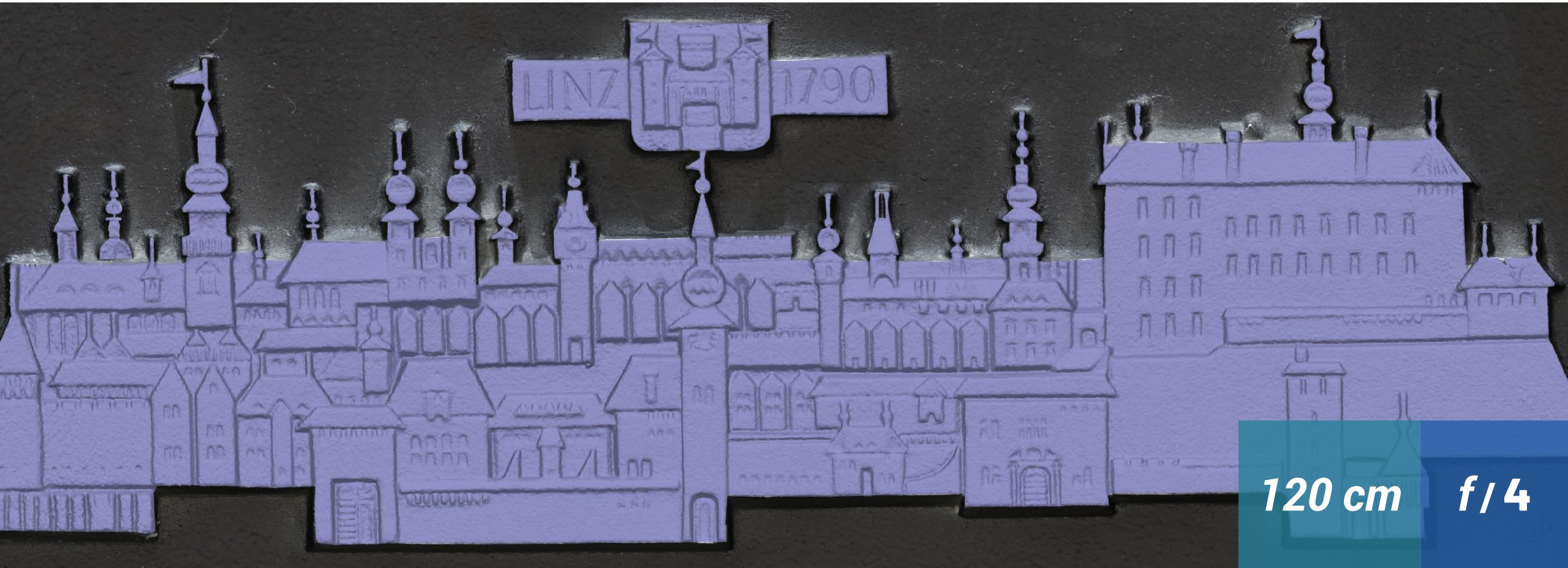
CASE STUDY 4



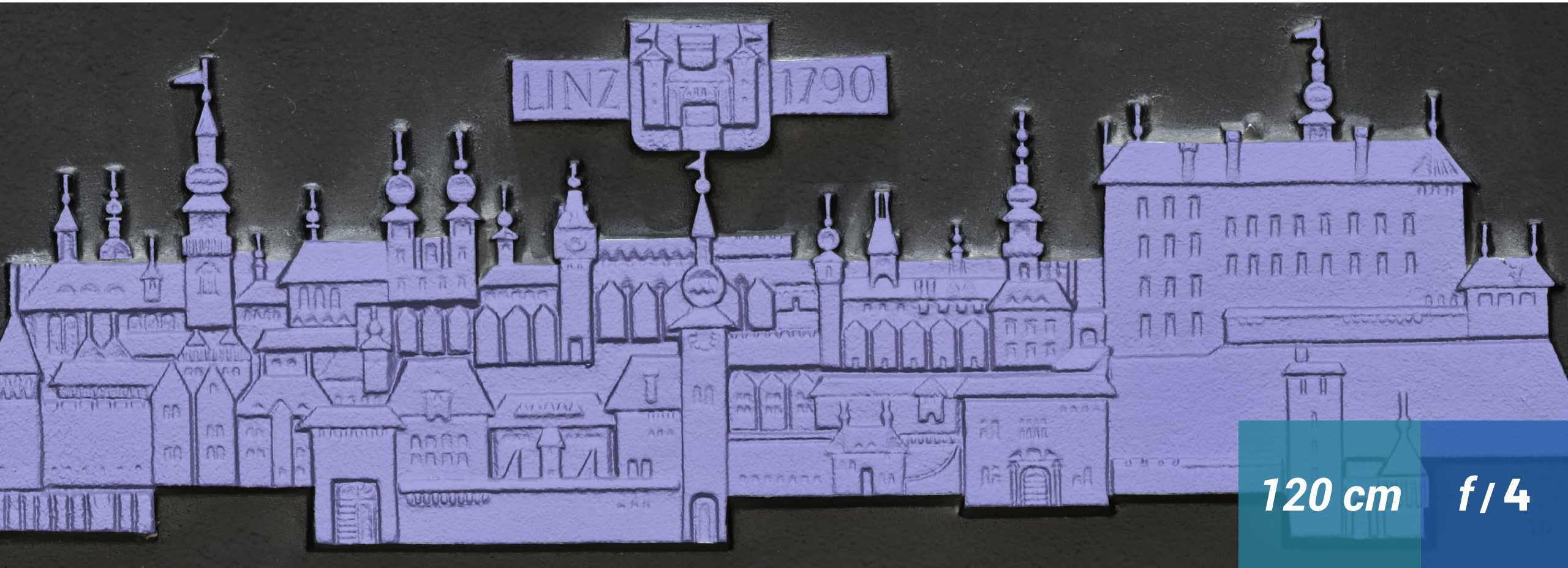
CASE STUDY 4



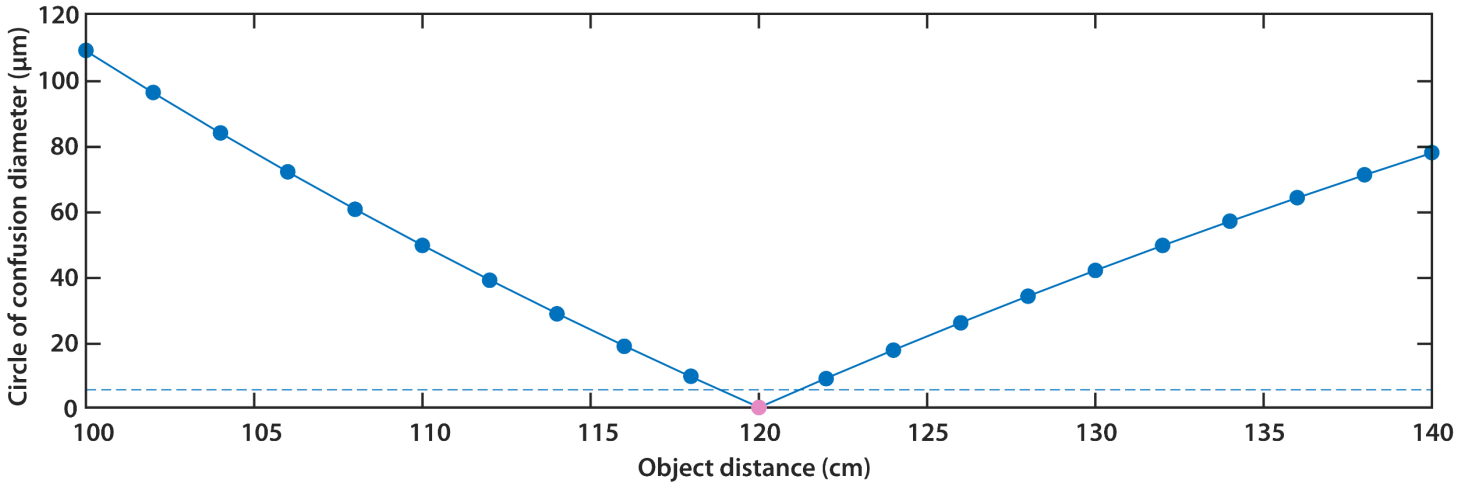
CASE STUDY 4

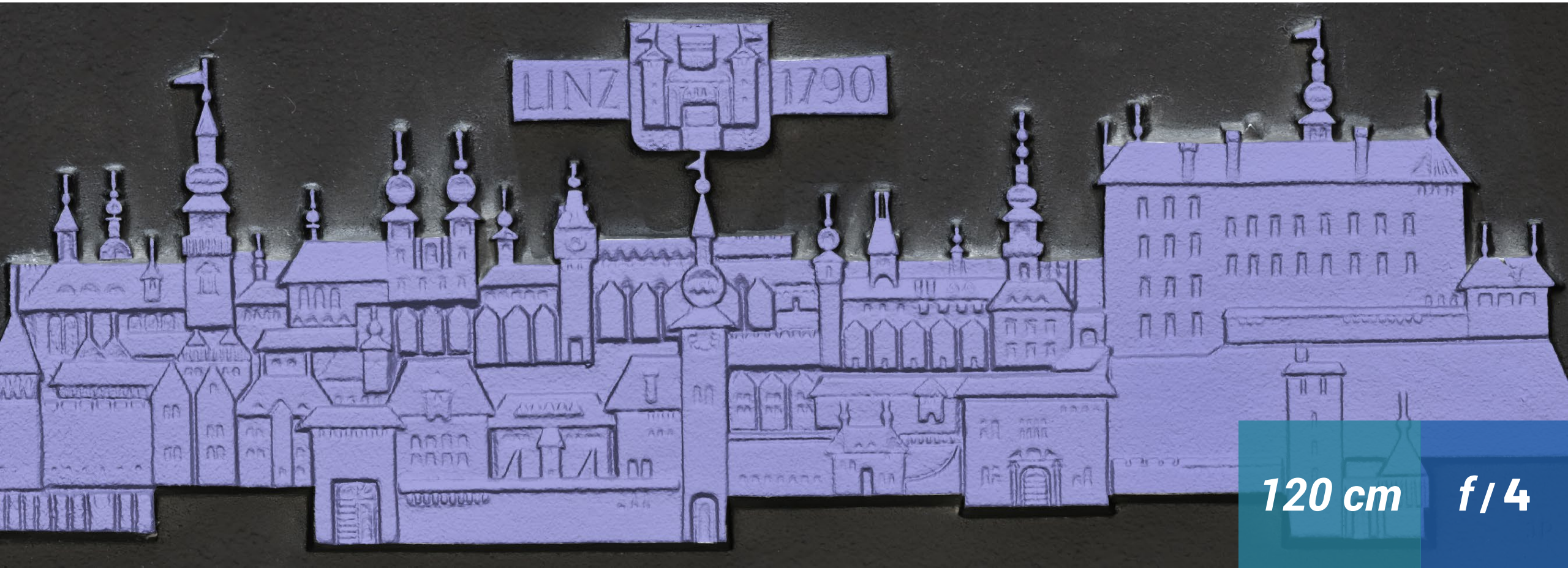


CASE STUDY 4

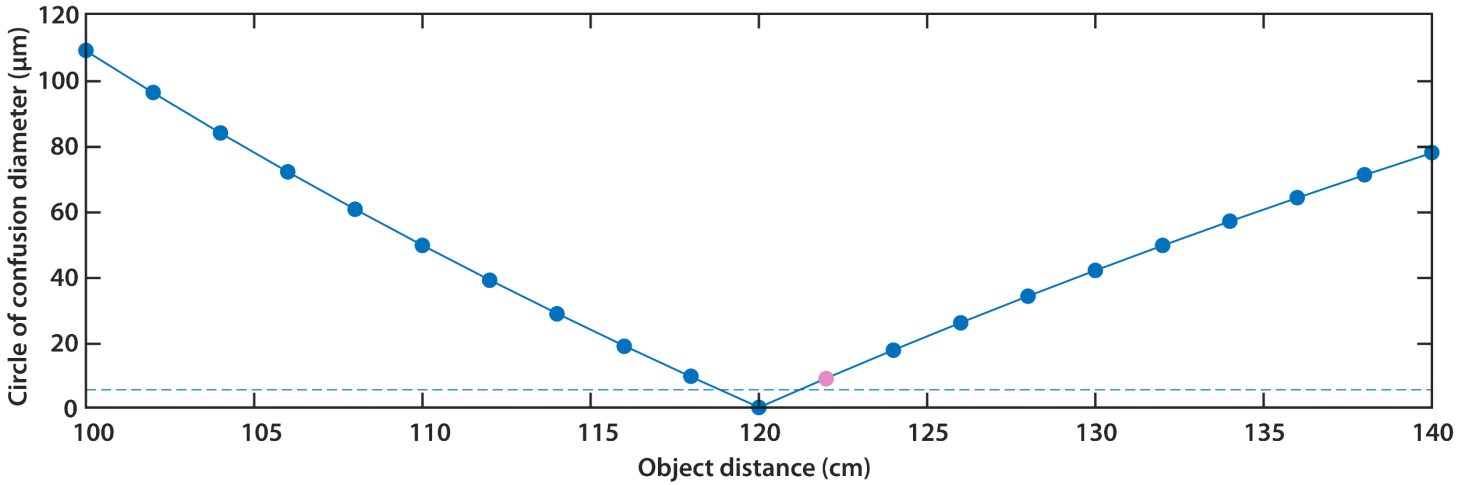


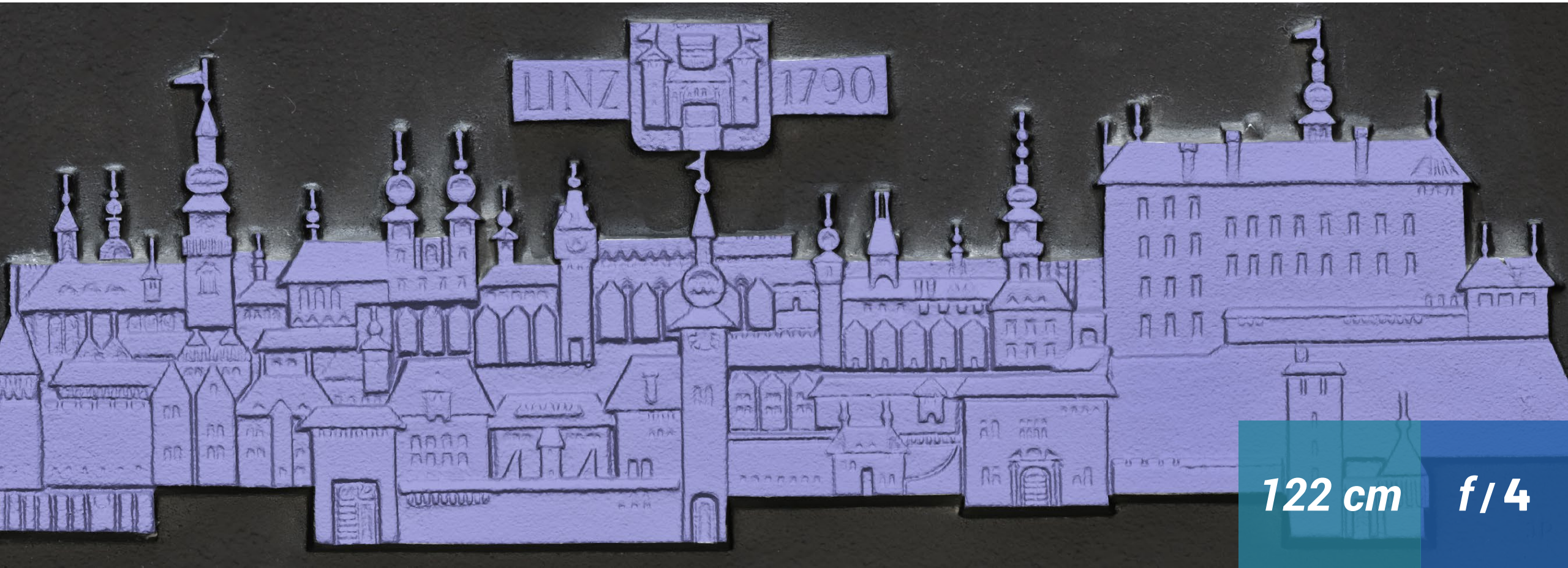
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

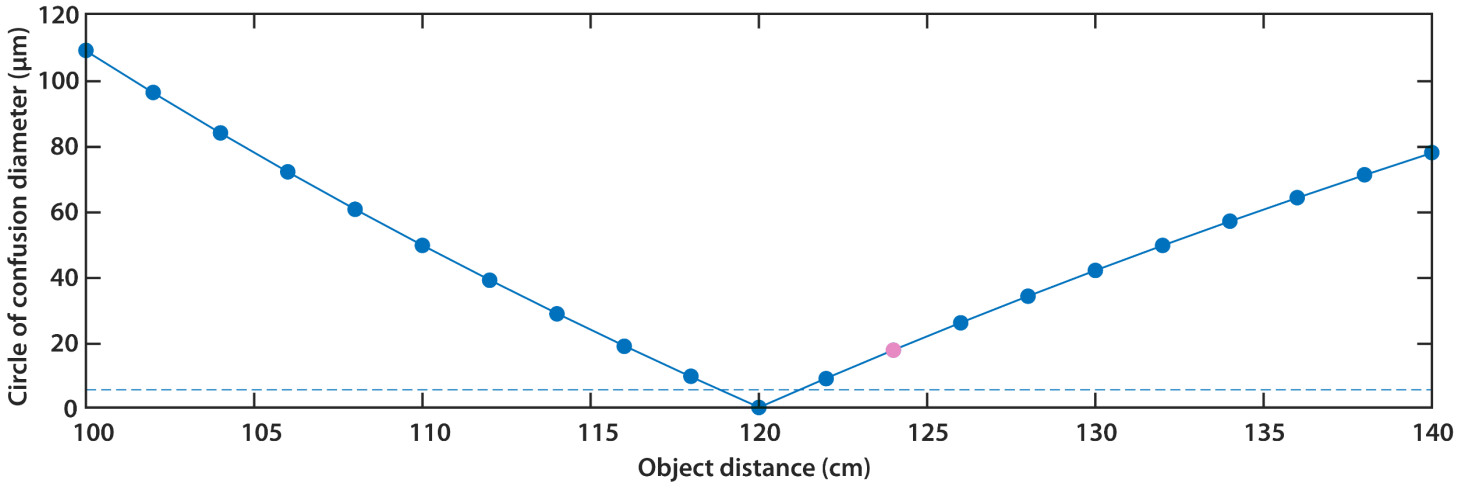

LINZ
1790
120 cm
f / 4

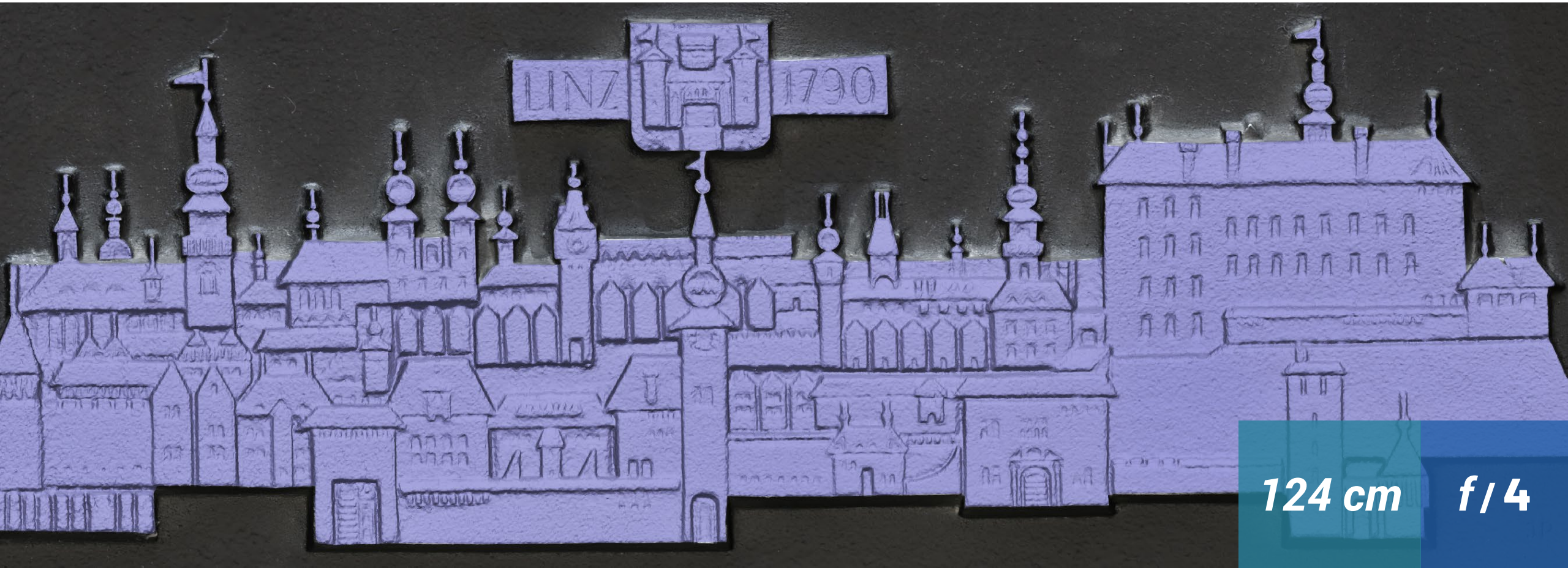
CASE STUDY 4


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140
Object distance (cm)

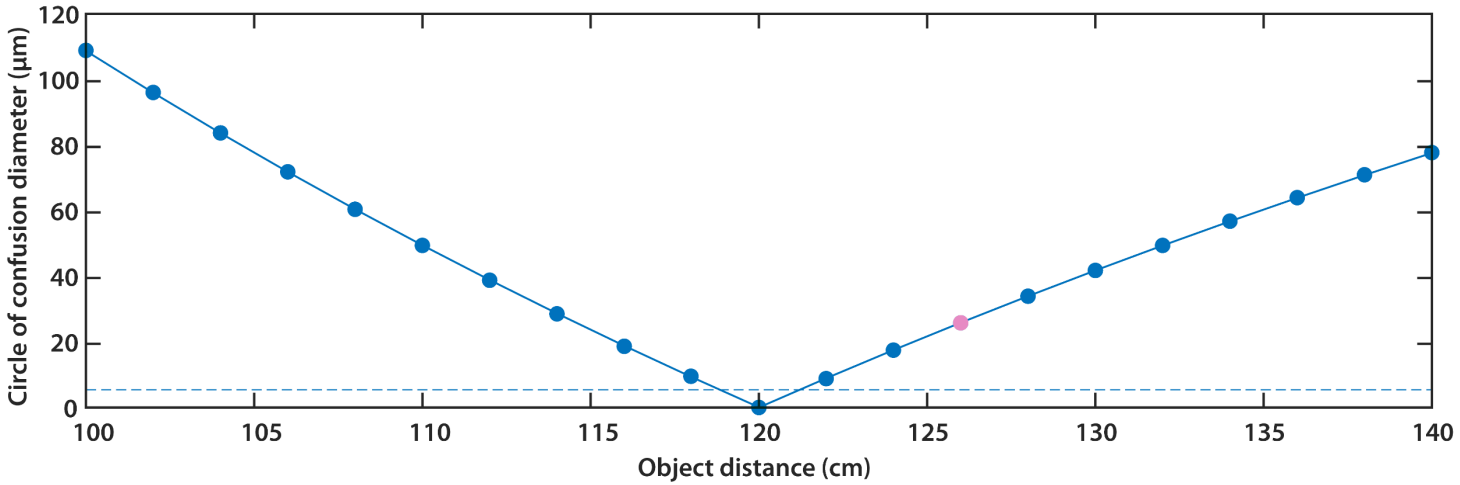

LINZ
1790
122 cm
f / 4

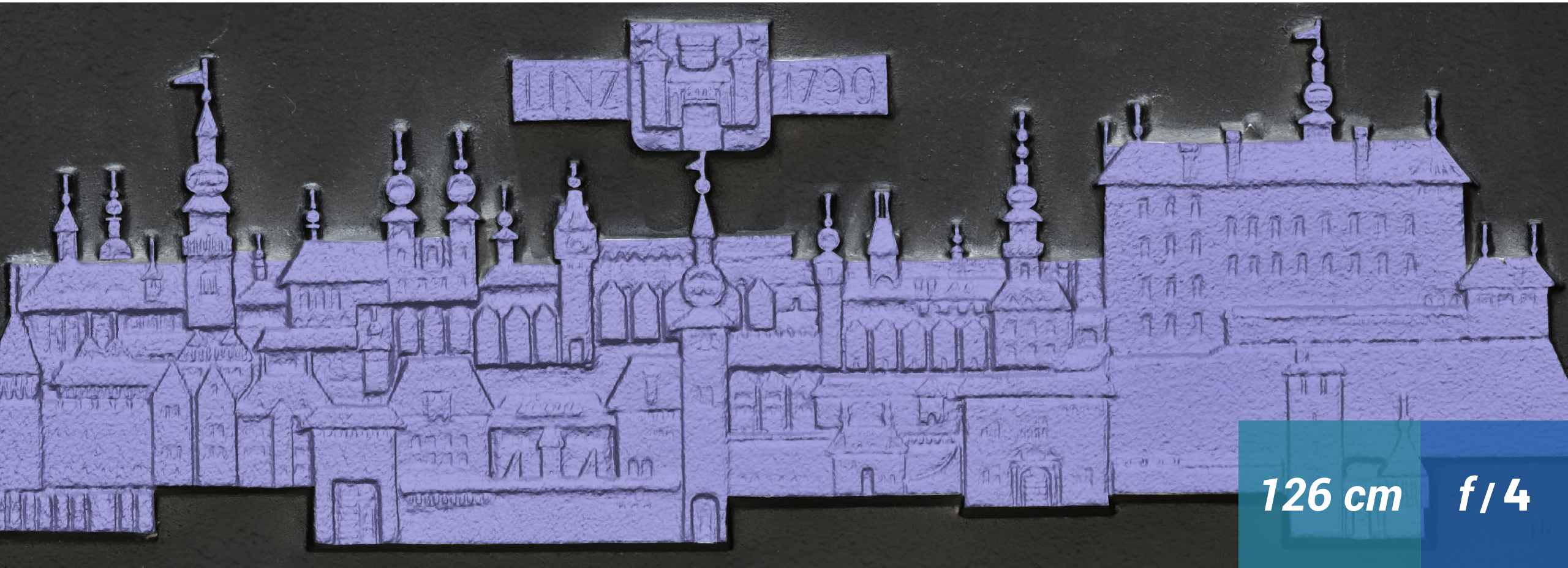
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

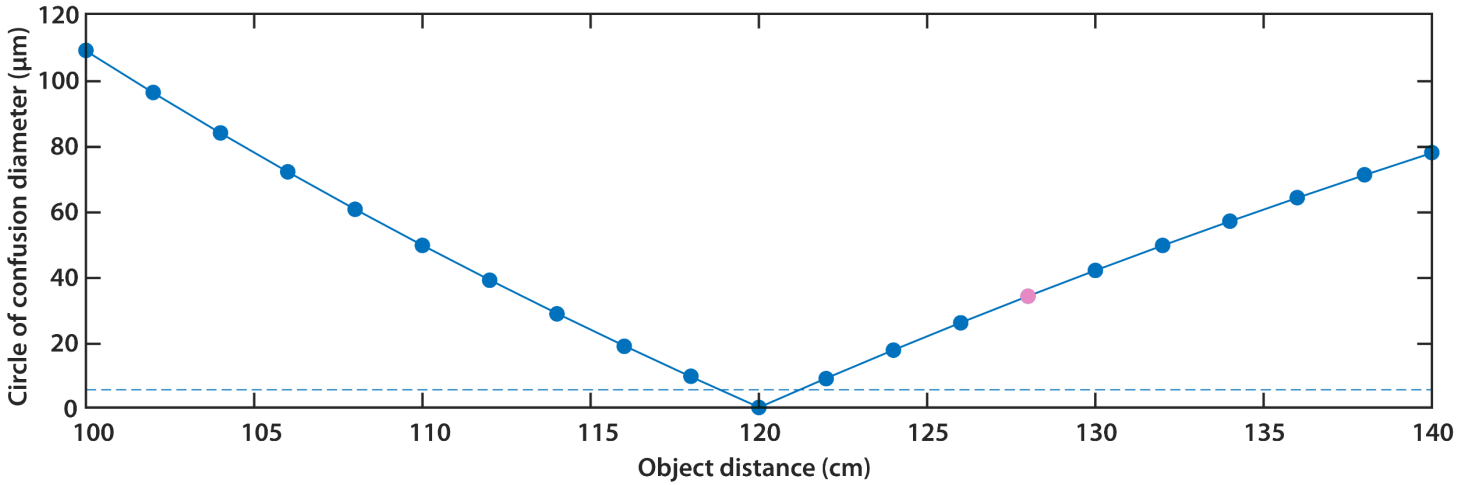

LINZ
1790
124 cm
f / 4

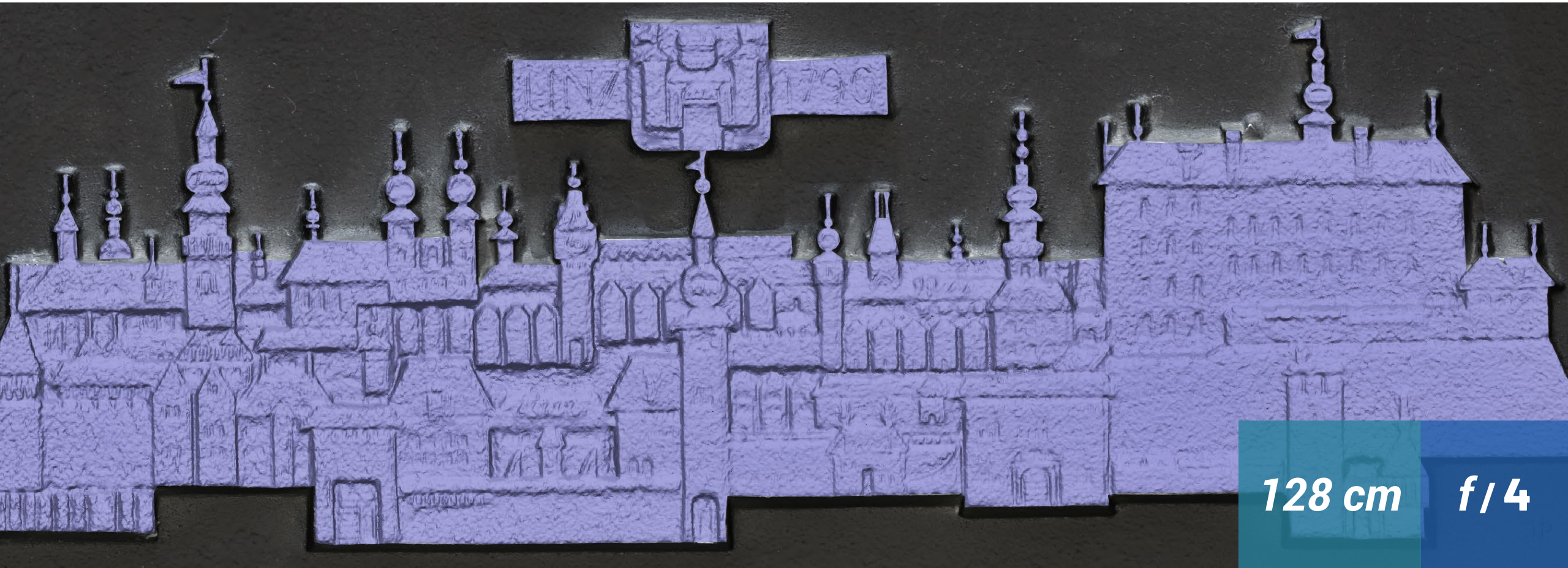
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

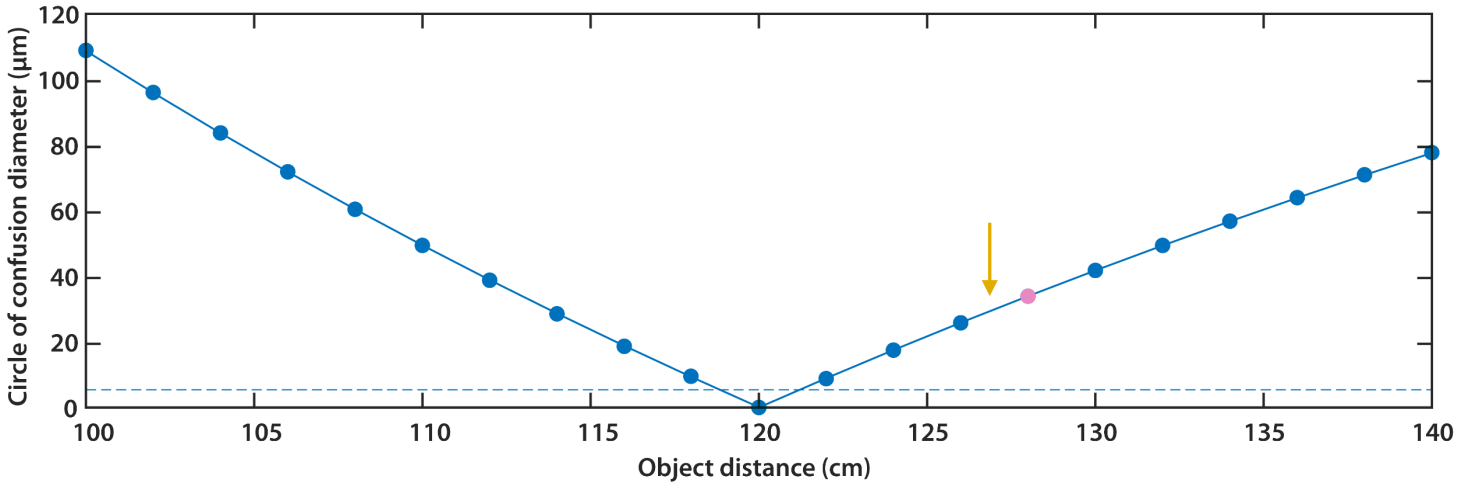

126 cm
f / 4

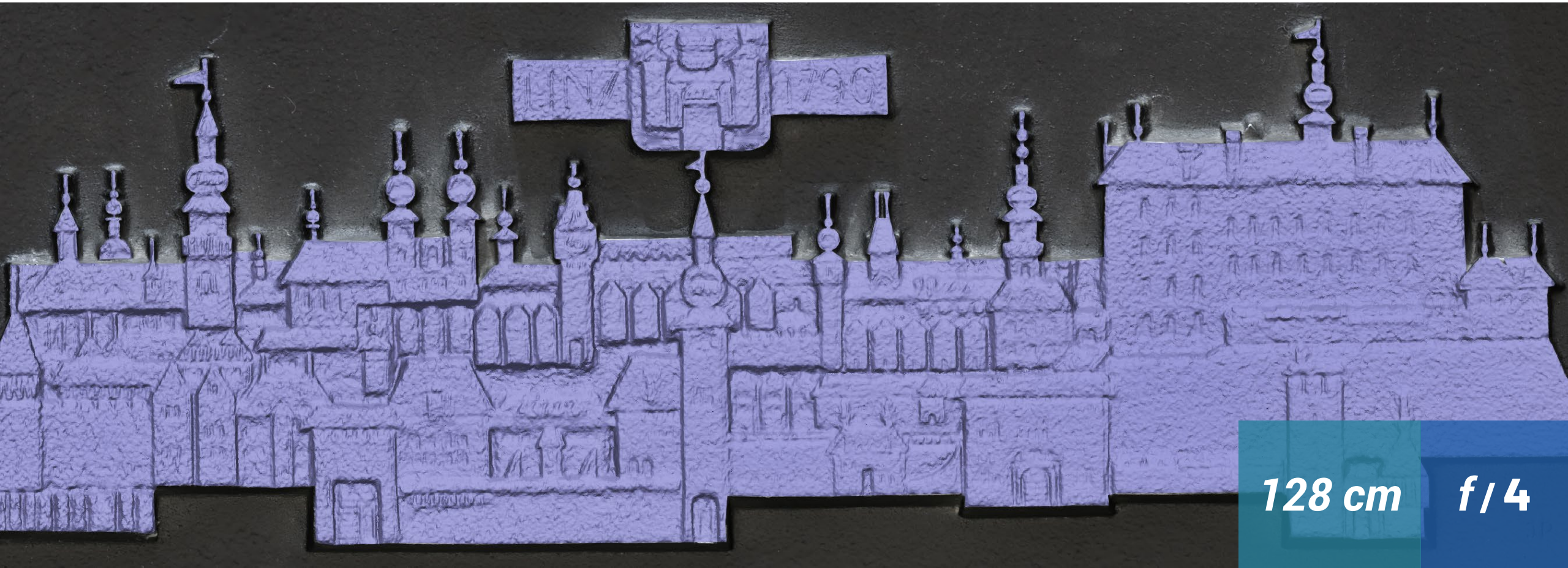
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

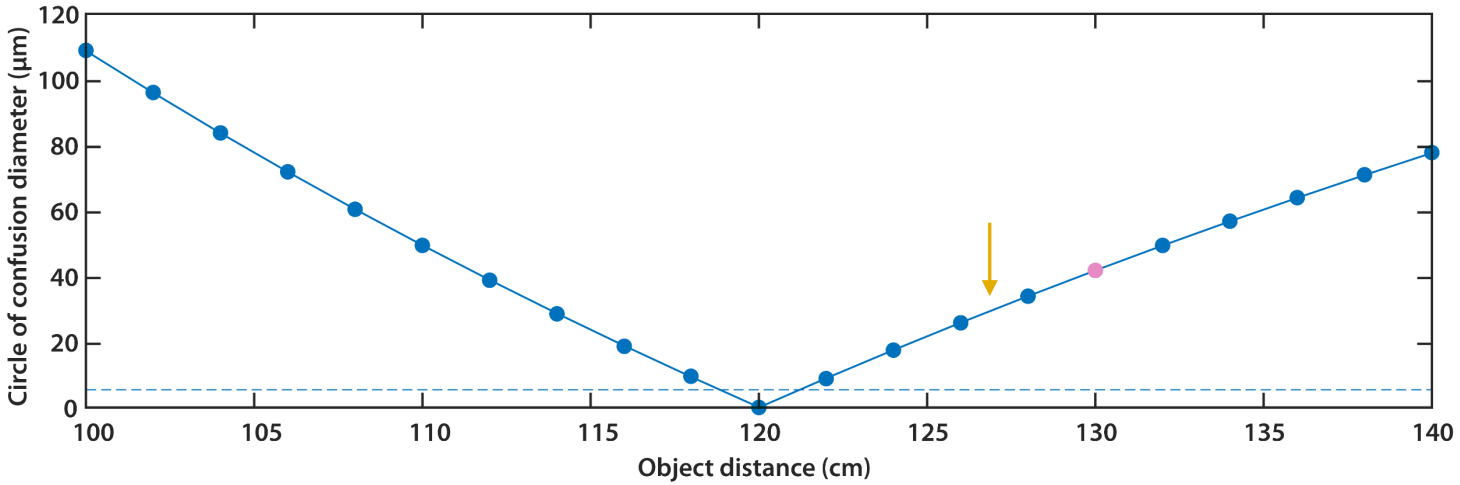

128 cm
f / 4

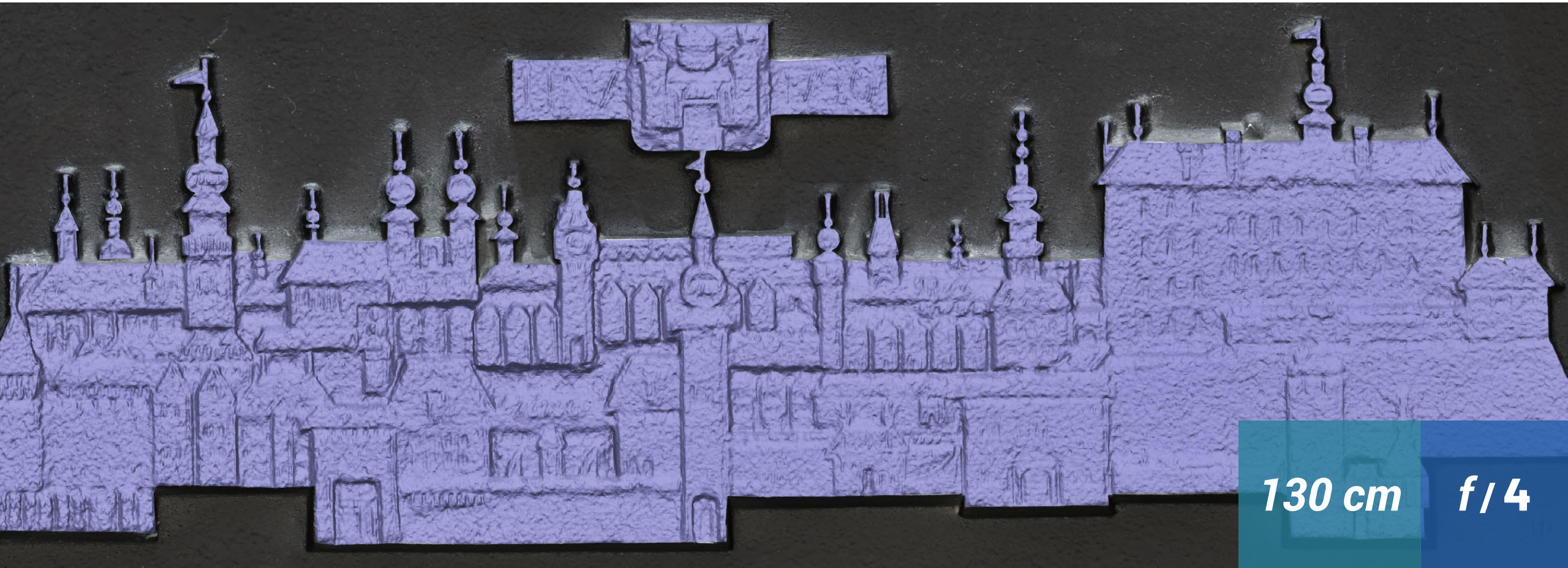
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

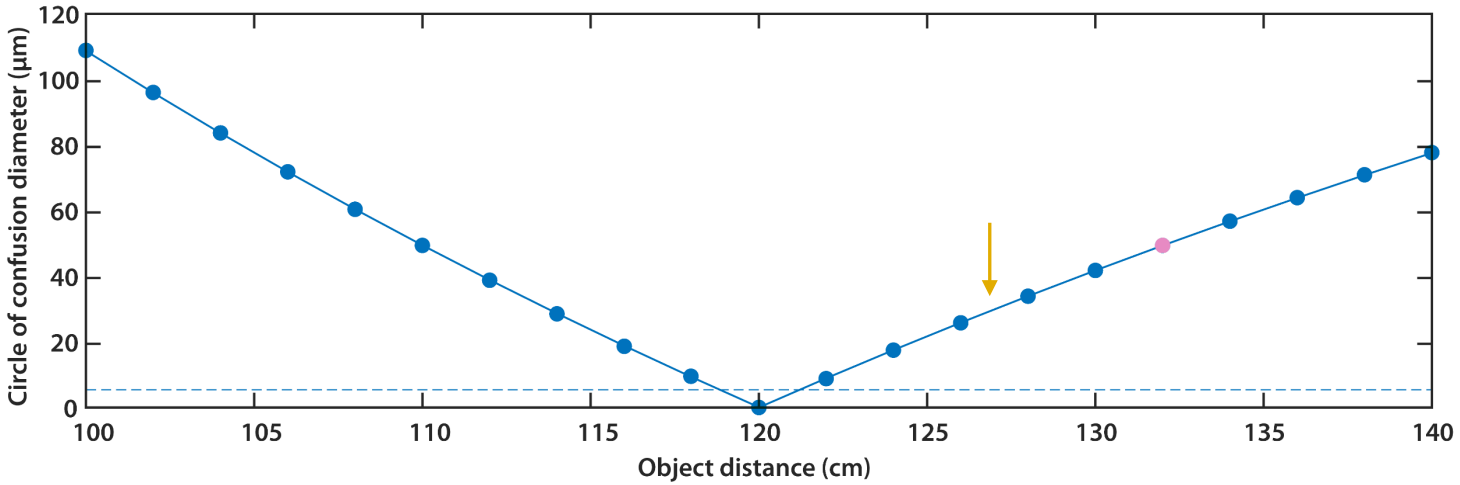

128 cm
f / 4

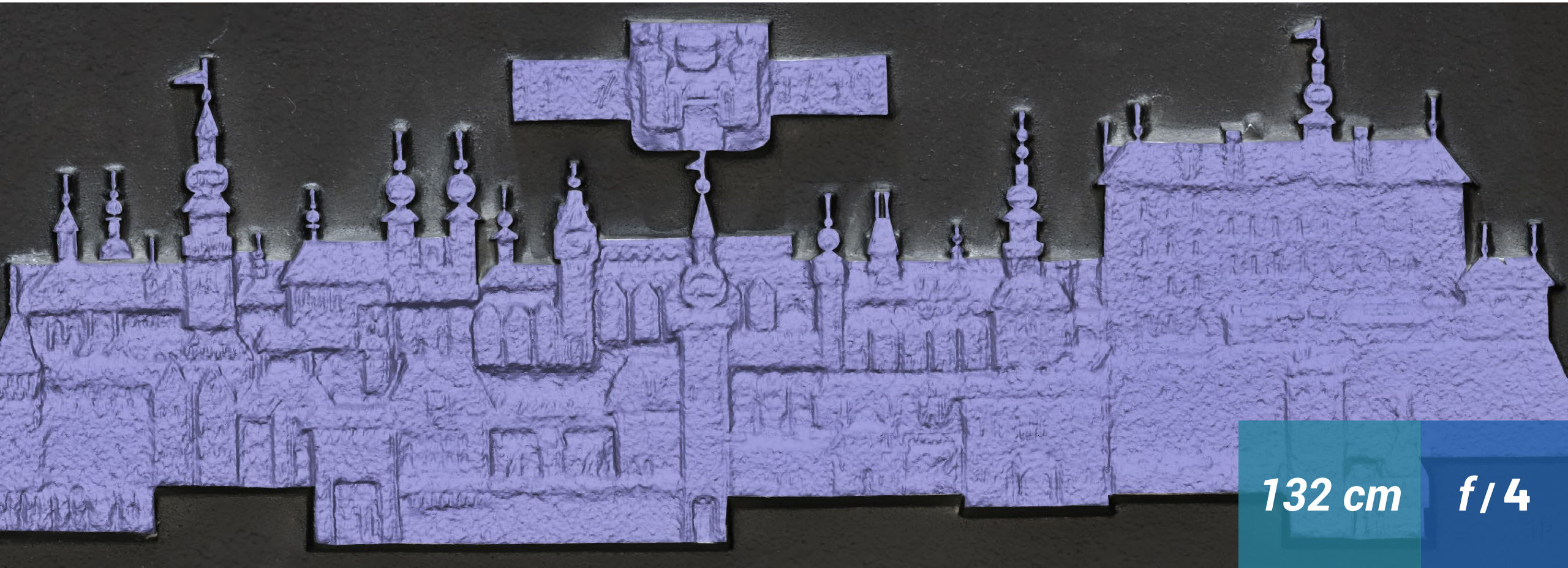
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

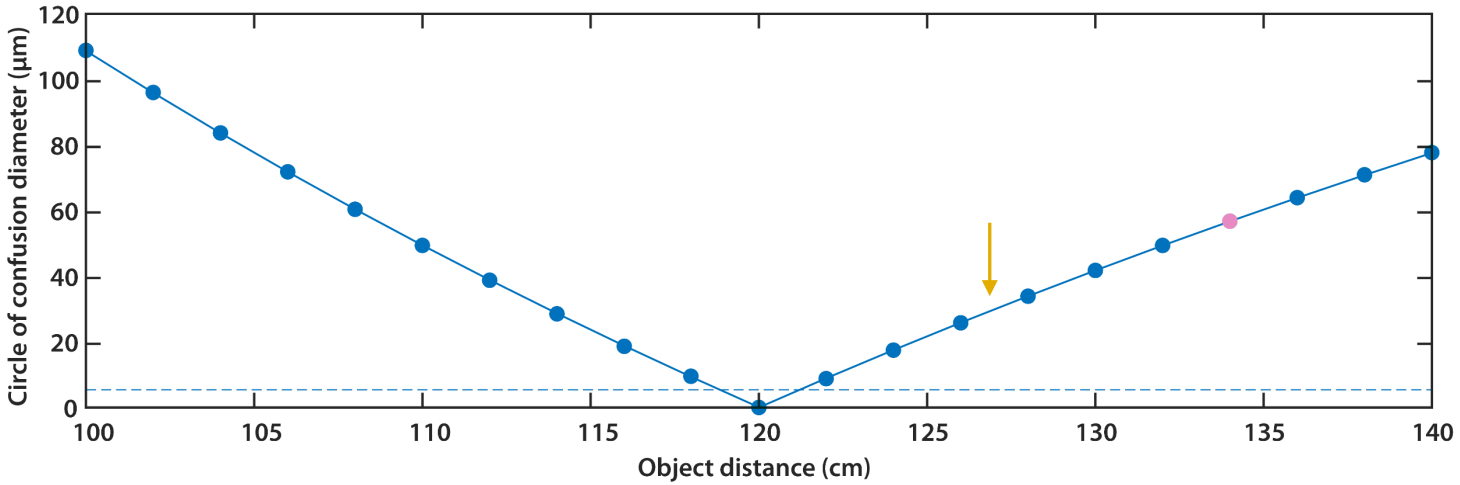

130 cm
f / 4

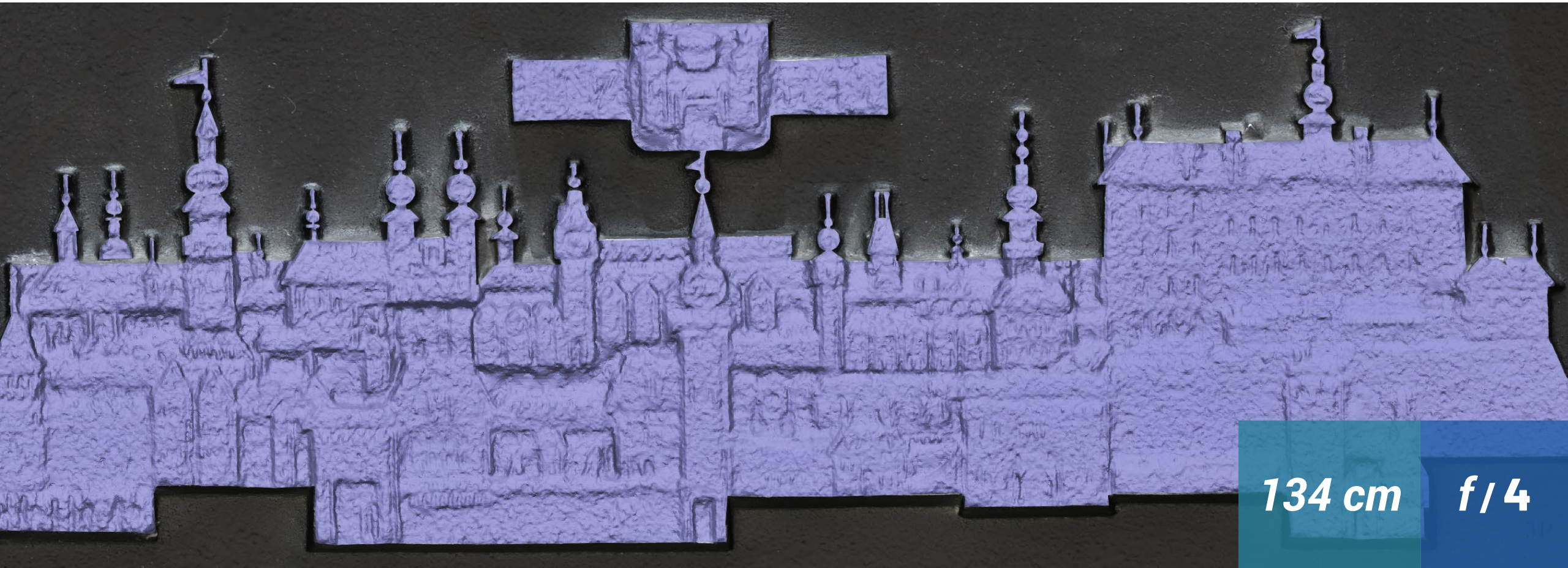
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

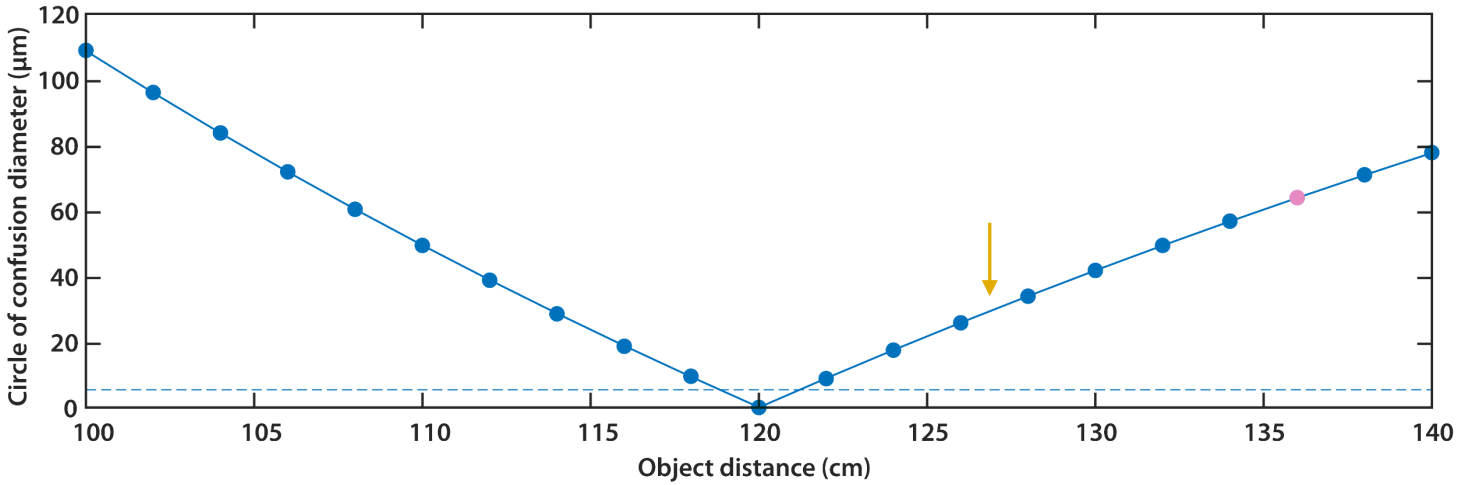

132 cm
f / 4

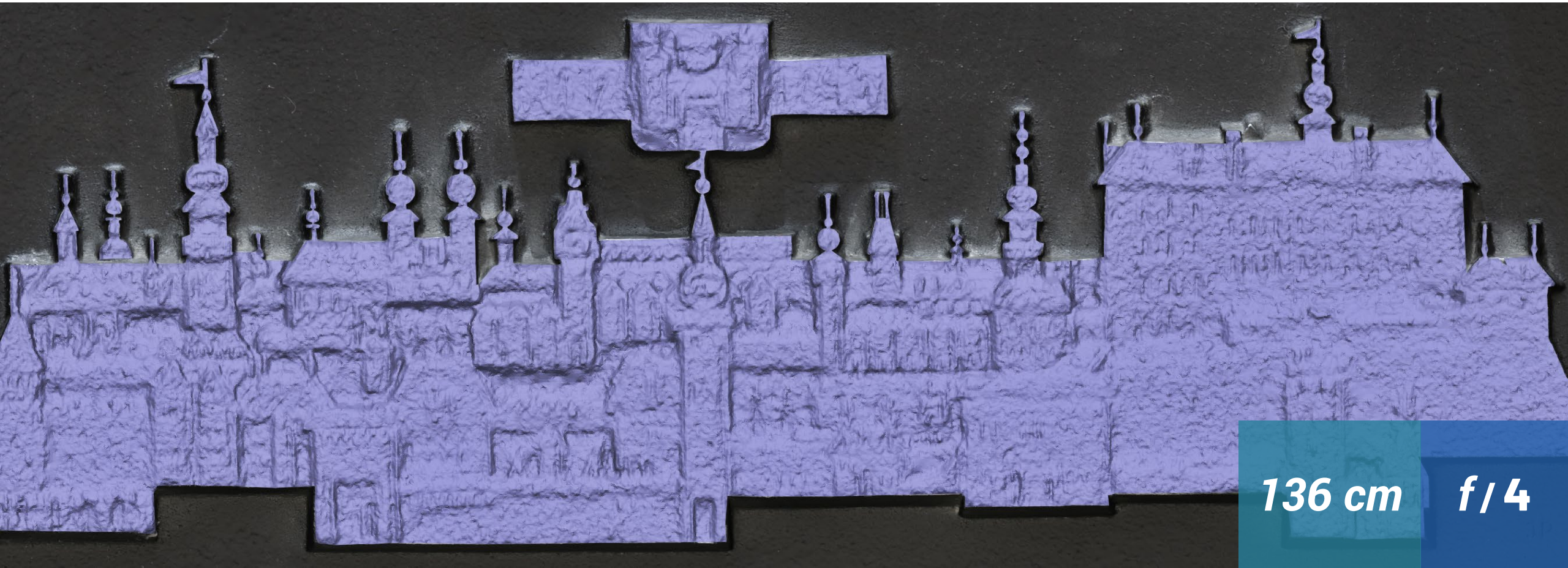
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

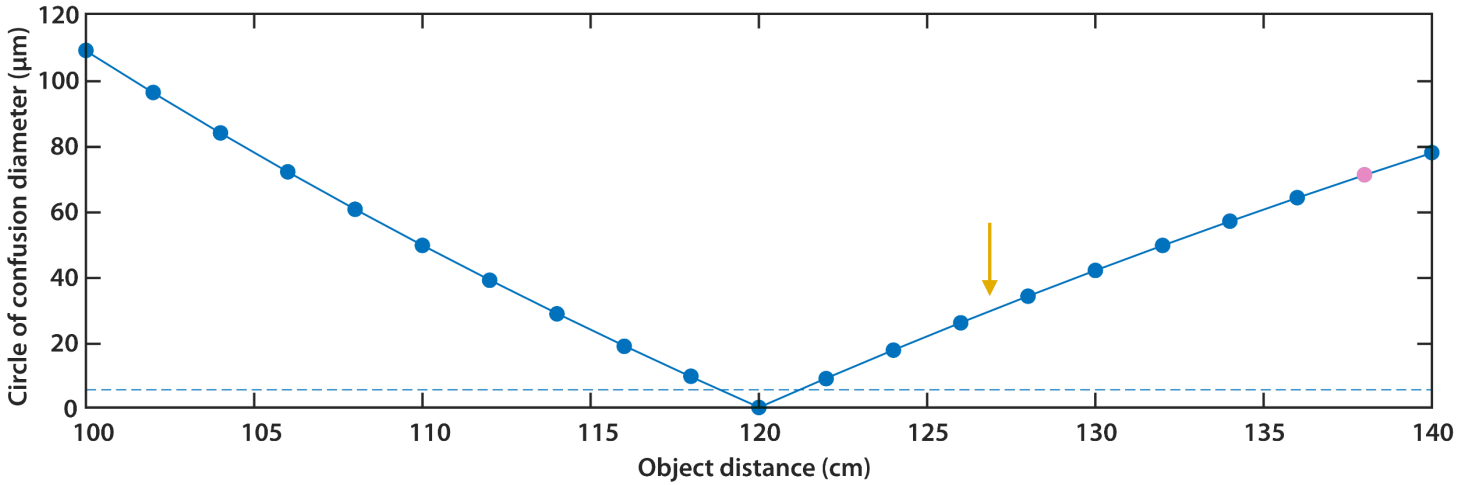

134 cm
f / 4

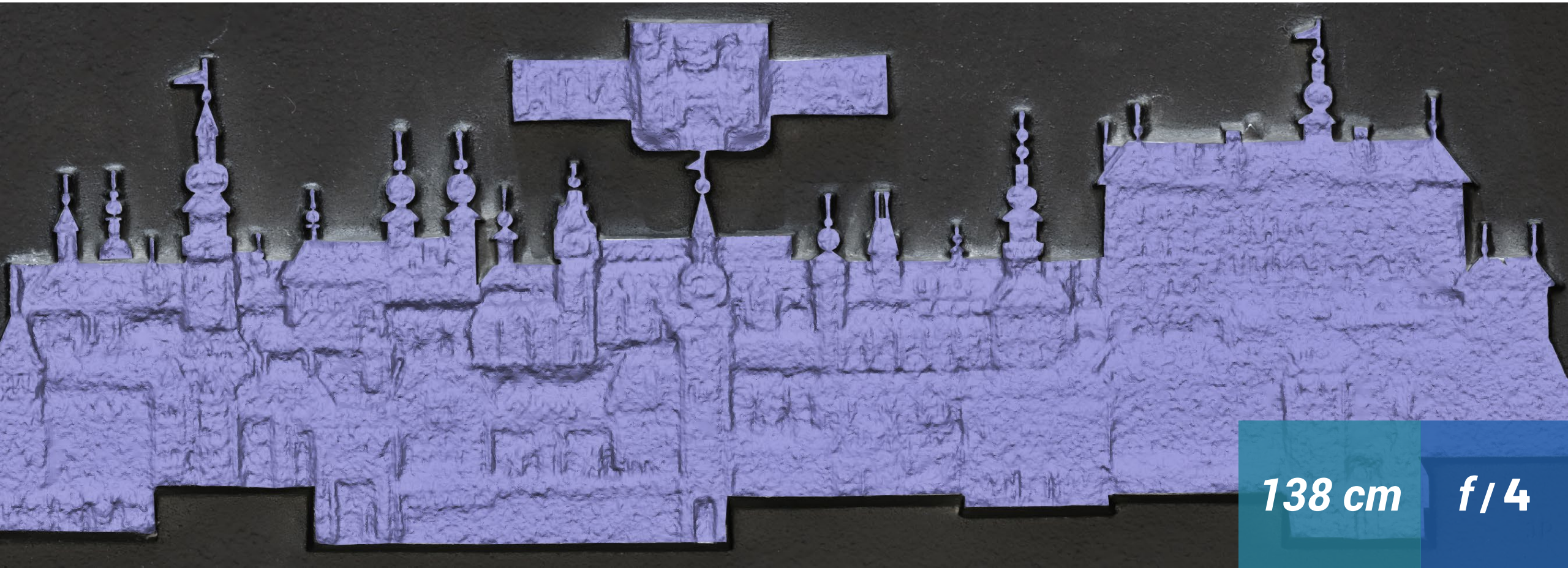
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

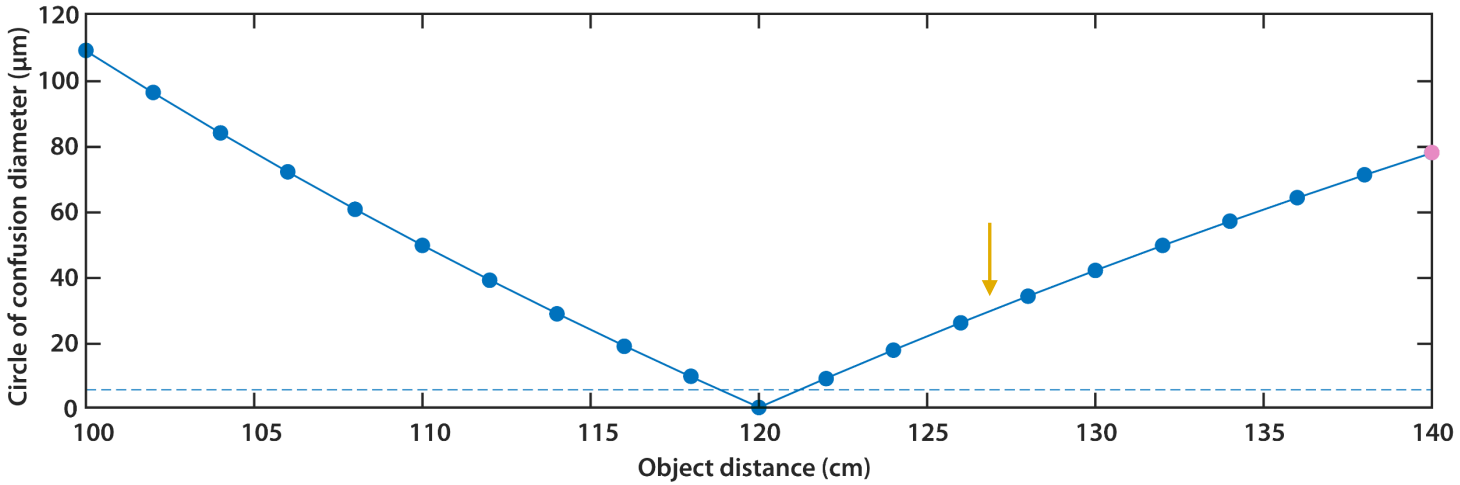

136 cm
f / 4

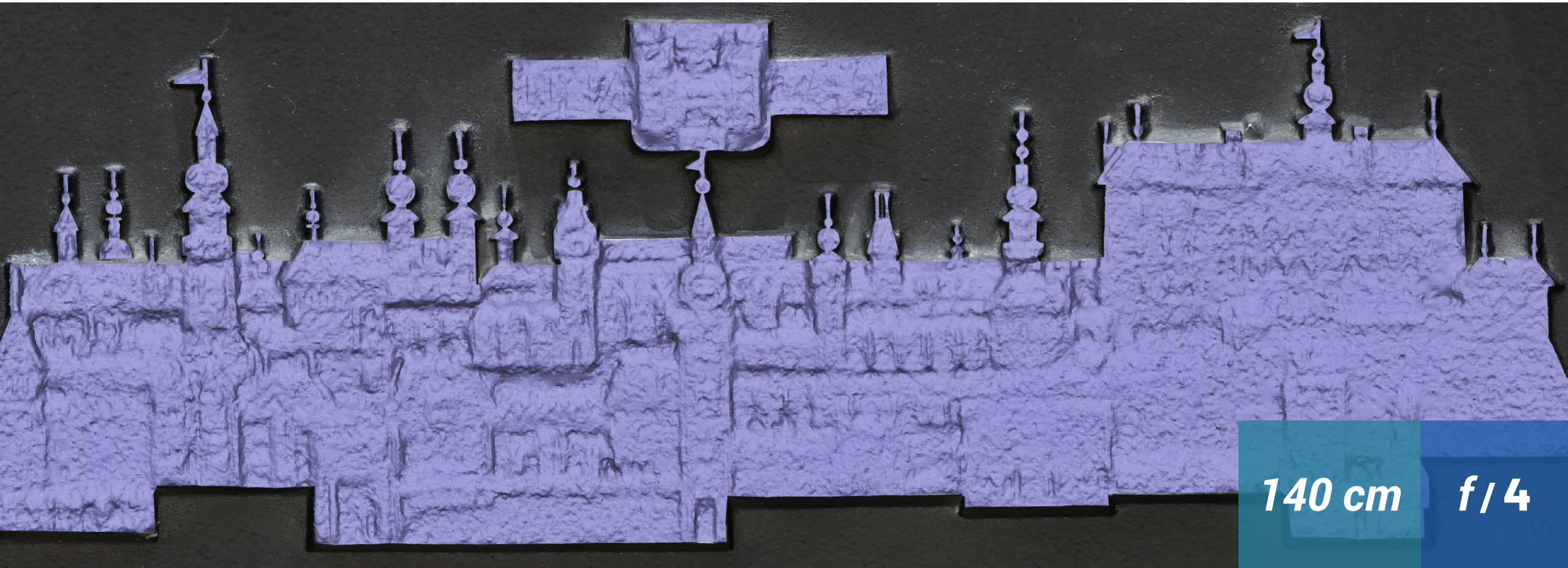
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

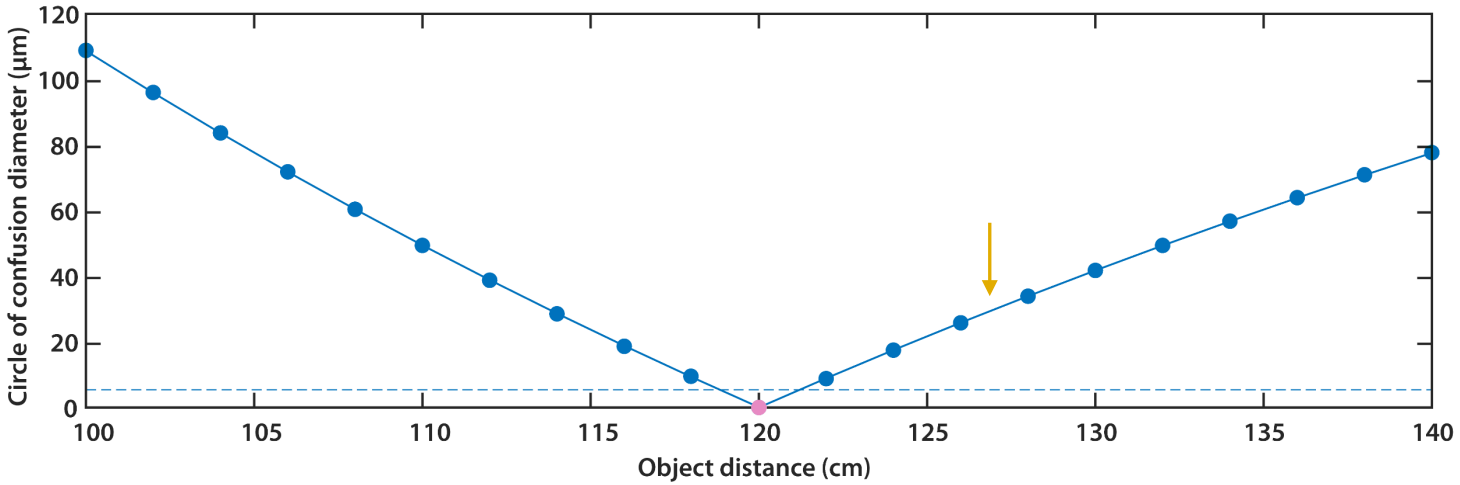

138 cm
f / 4

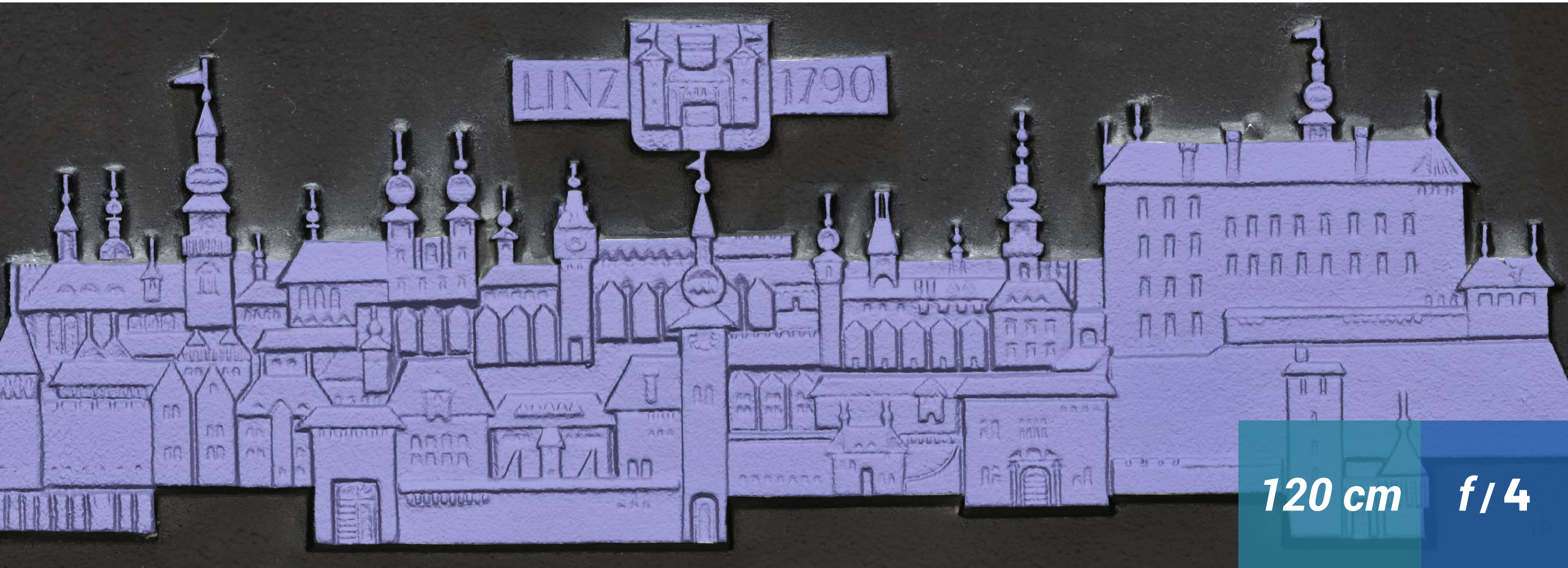
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

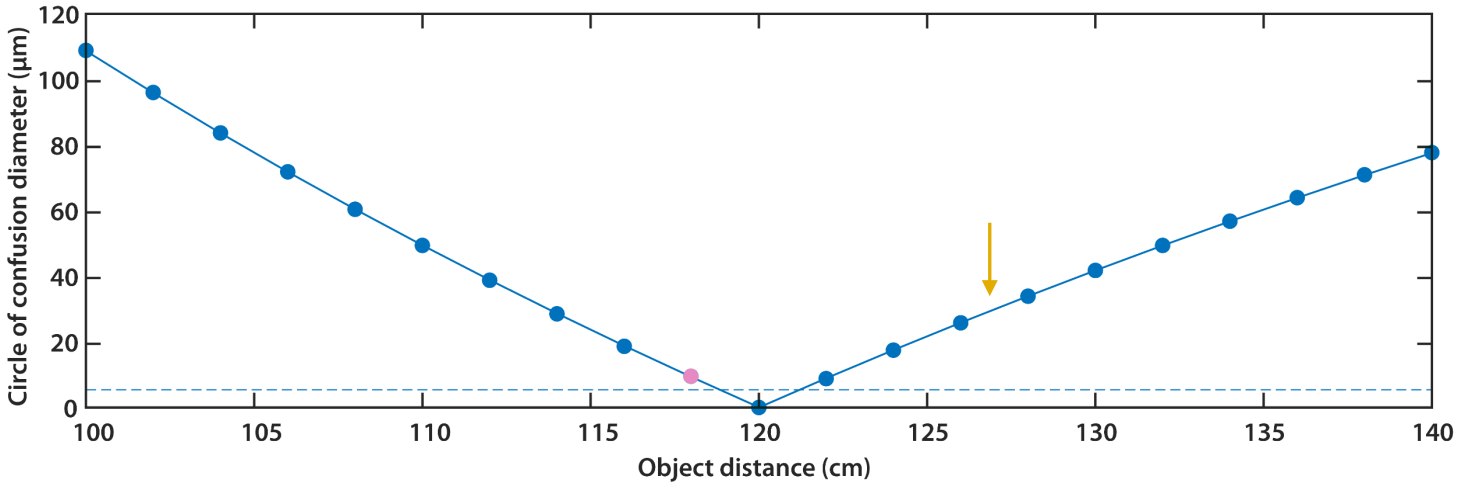

140 cm
f / 4

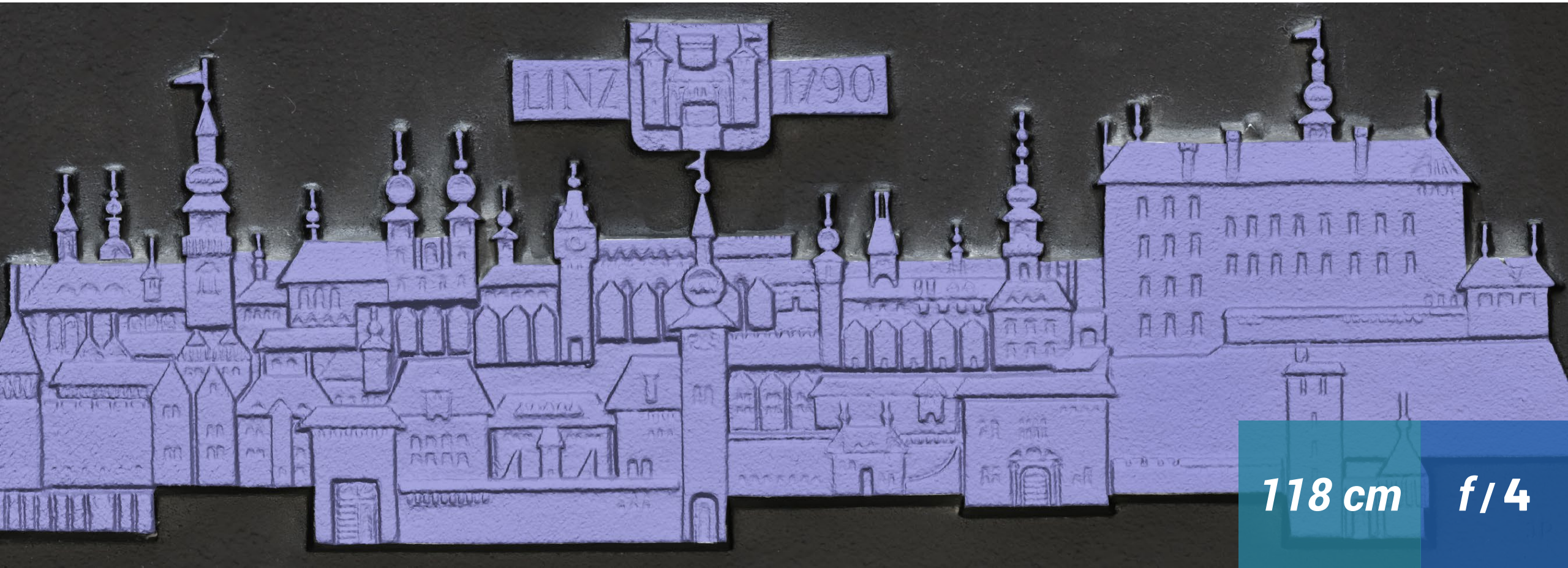
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

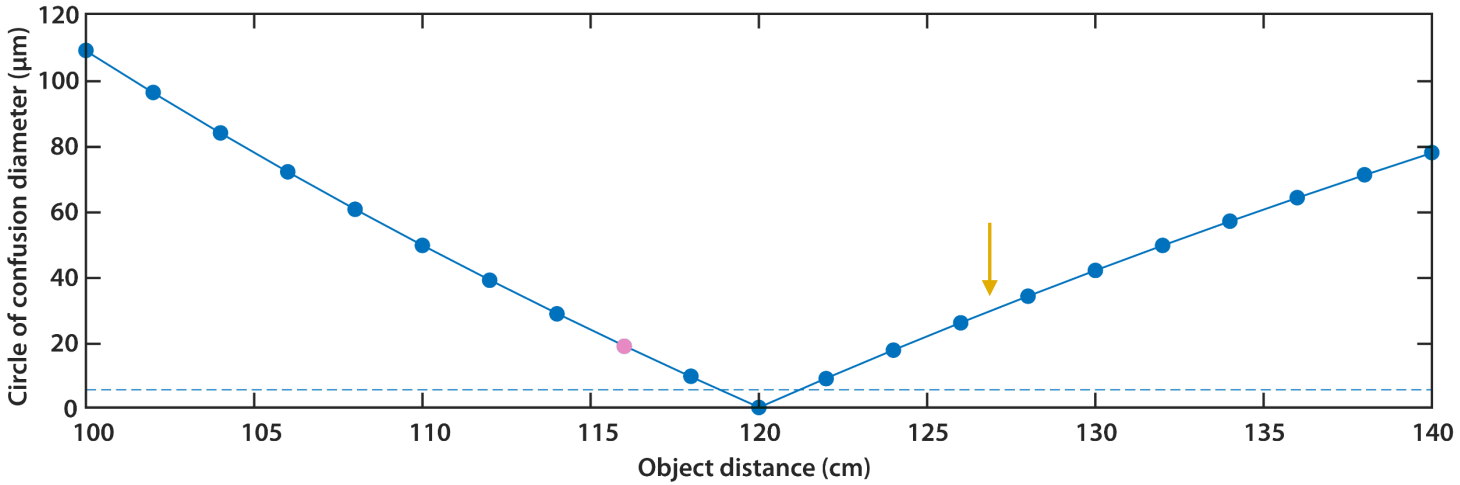

LINZ
1790
120 cm
f / 4

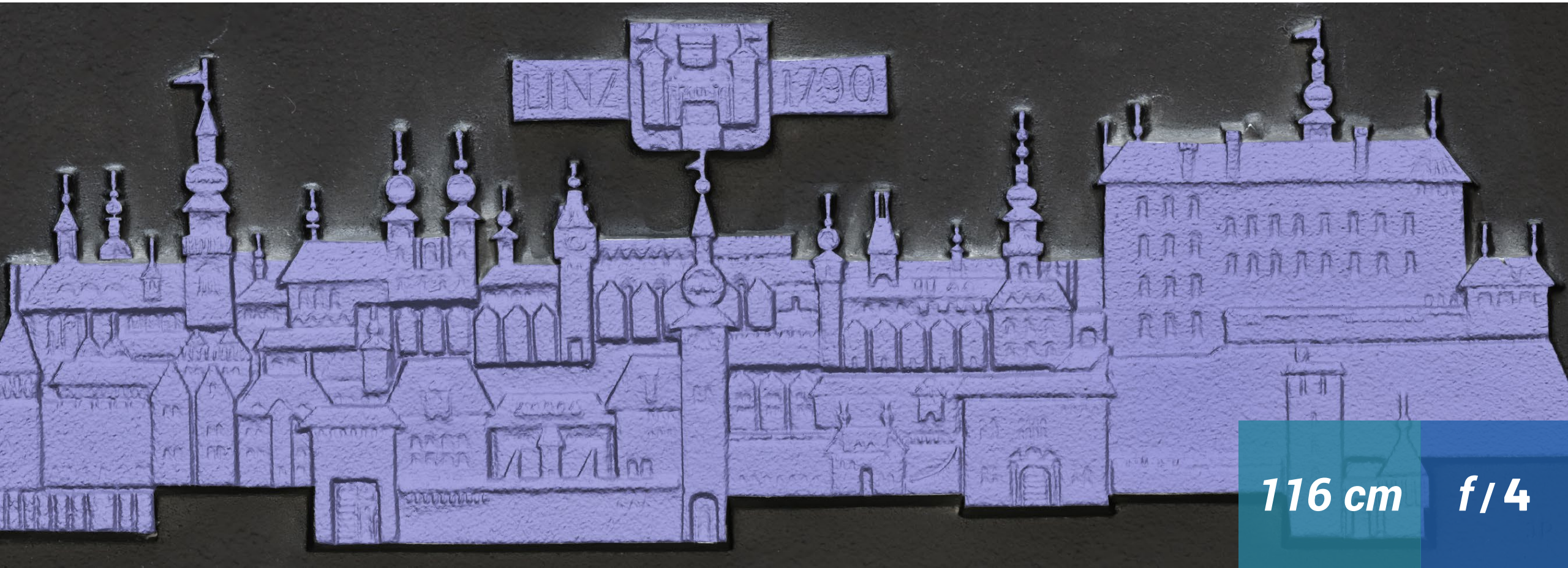
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

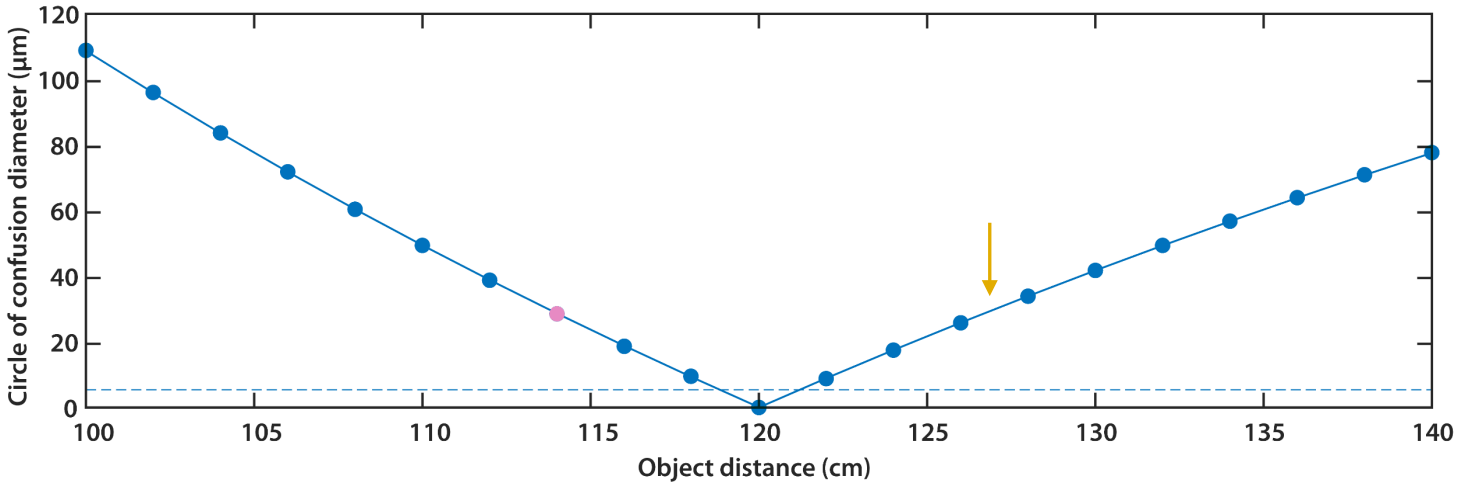

LINZ
1790
118 cm
f / 4

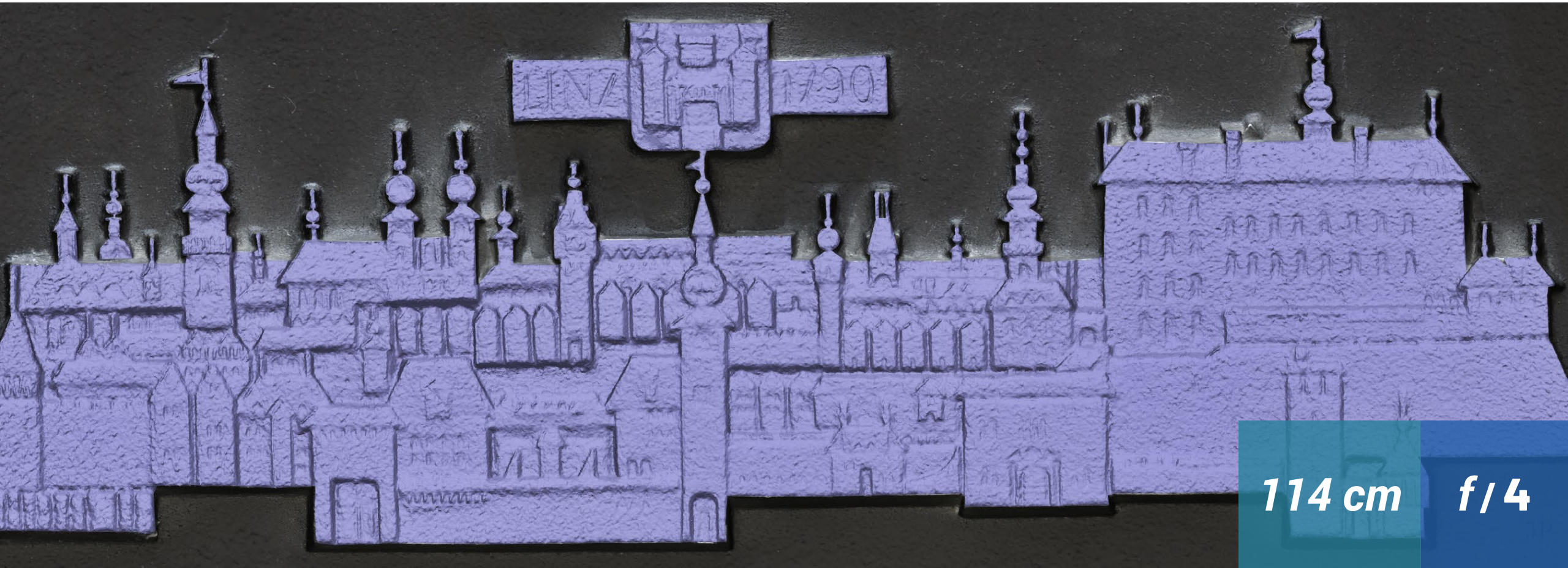
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

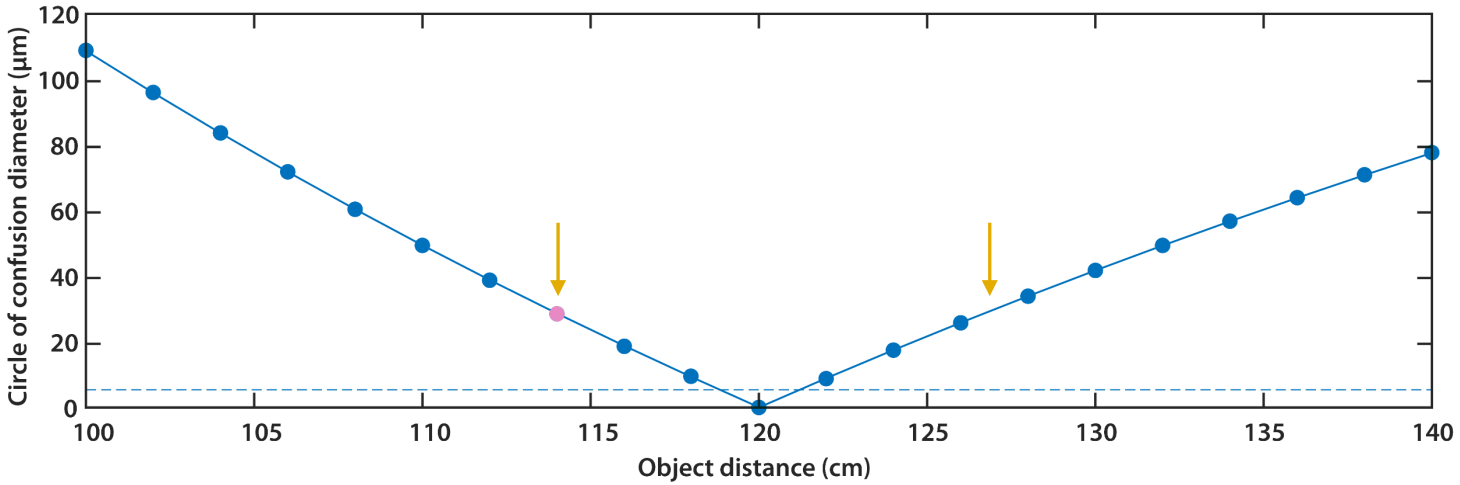

116 cm
f / 4

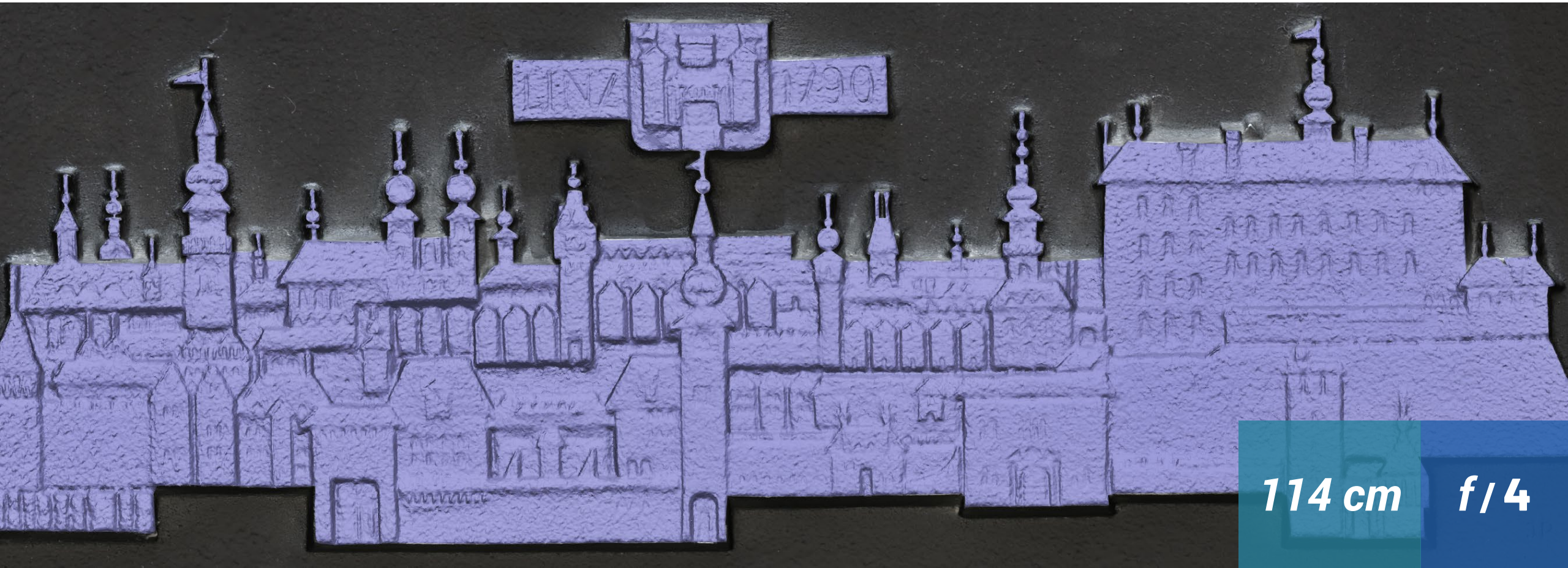
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

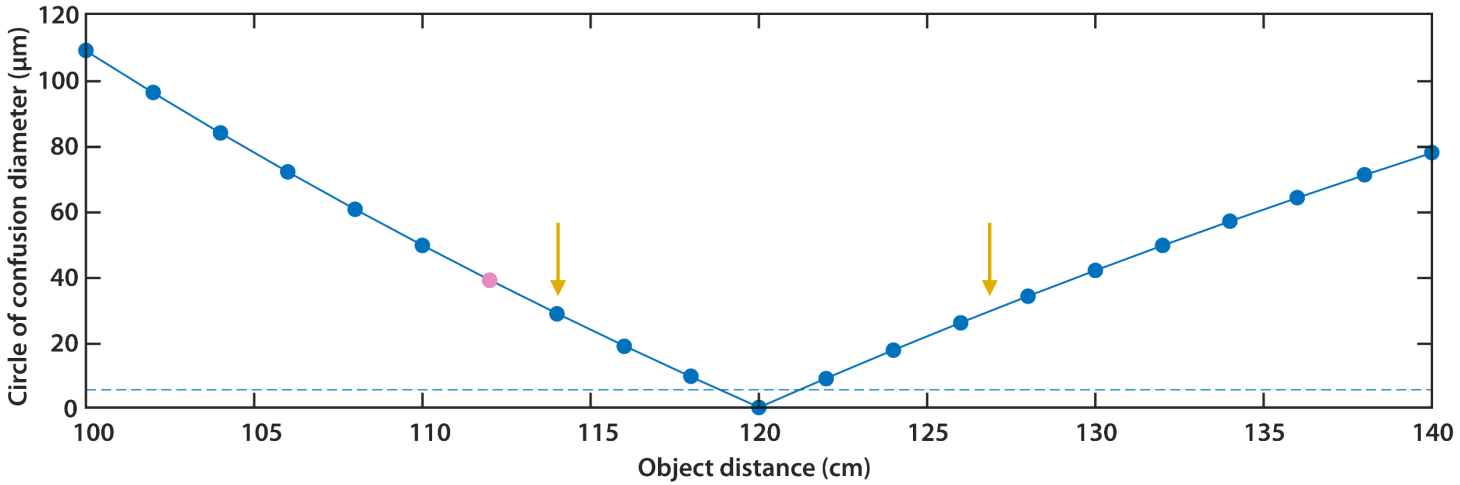

114 cm
f / 4

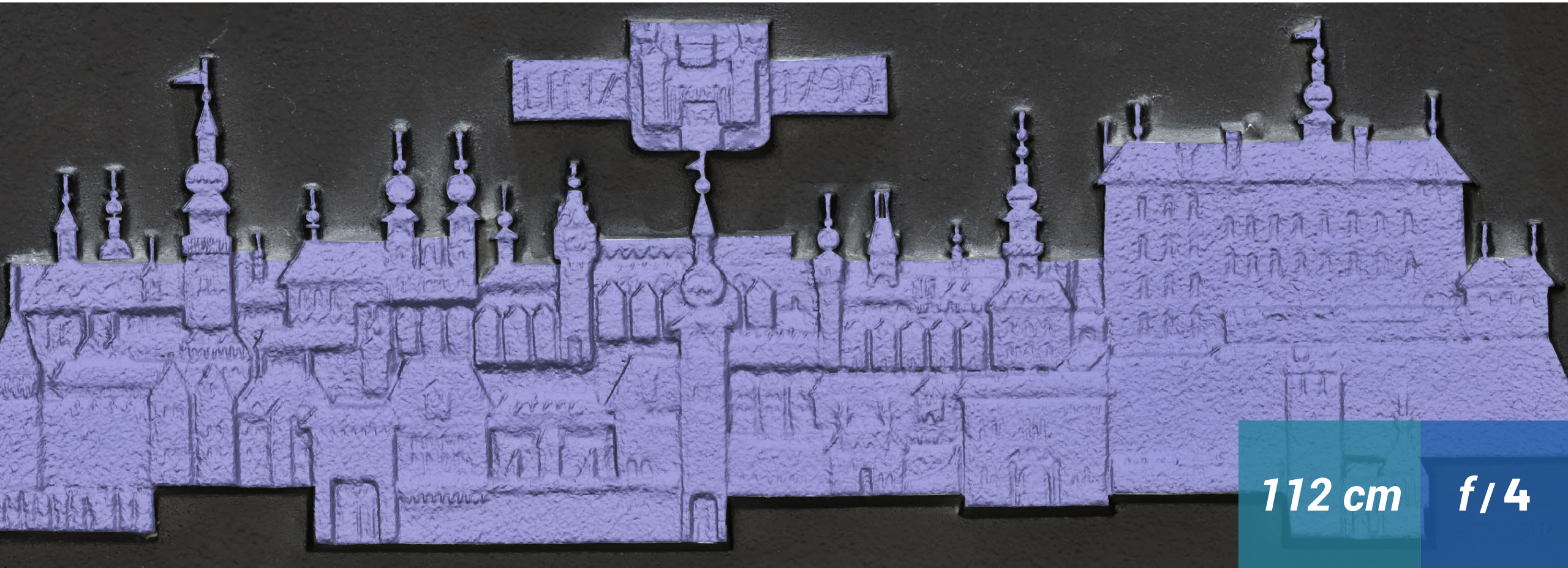
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

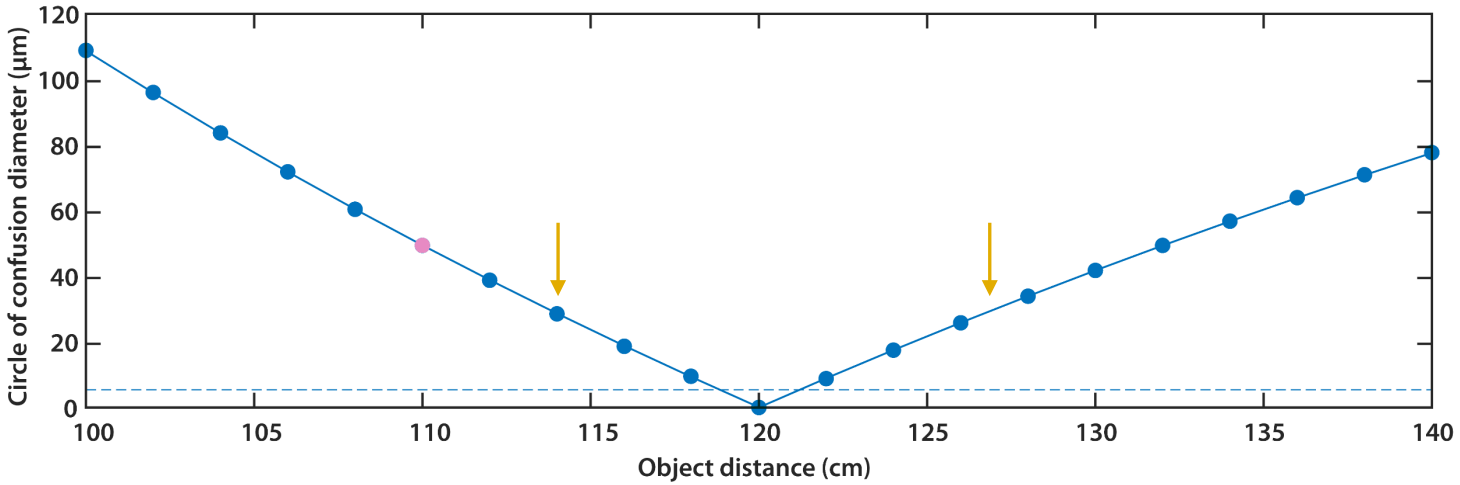

114 cm
f / 4

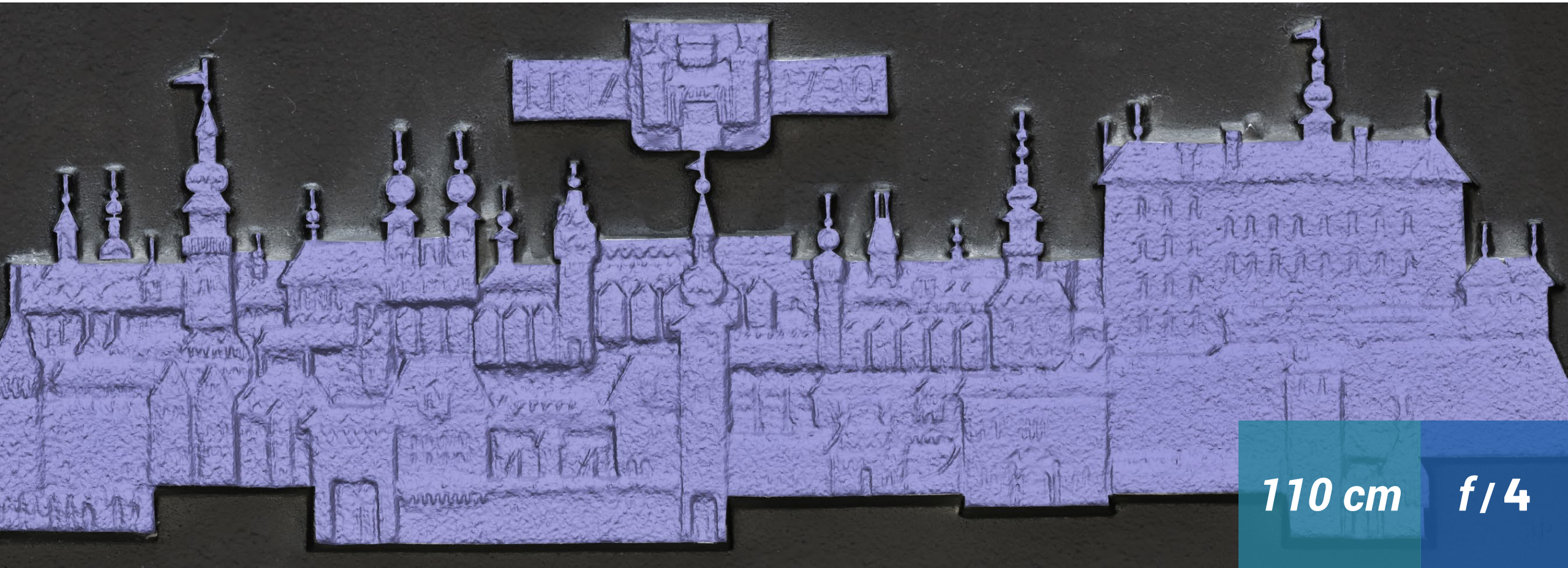
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

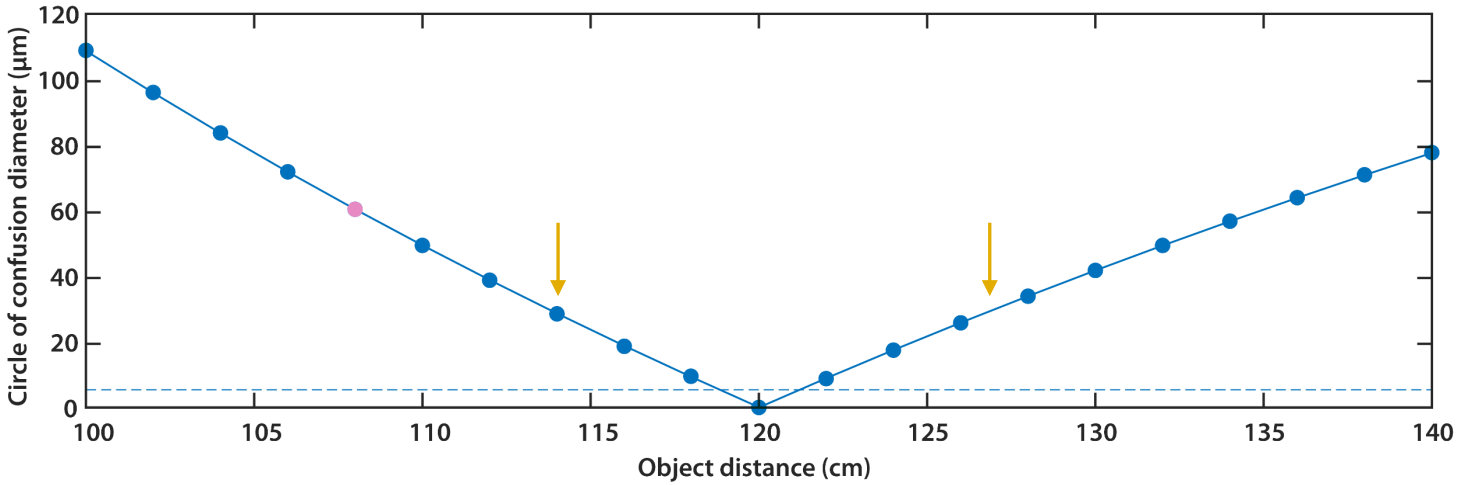

112 cm
f / 4

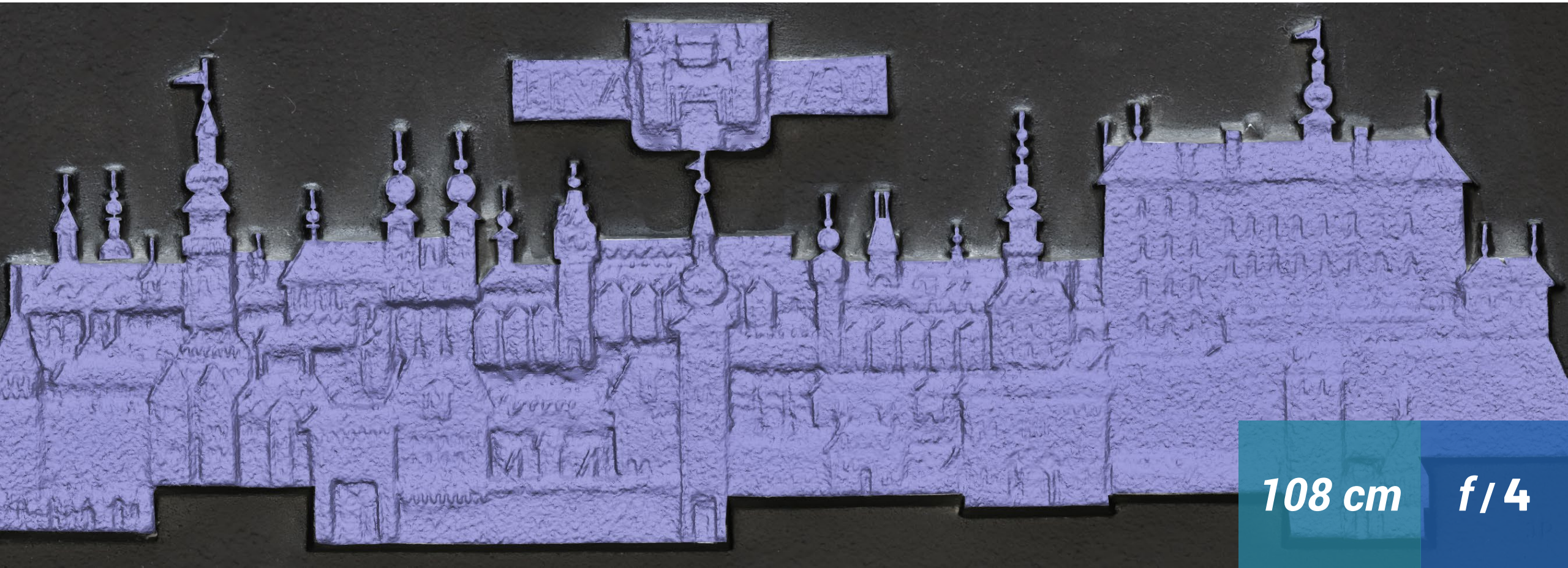
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

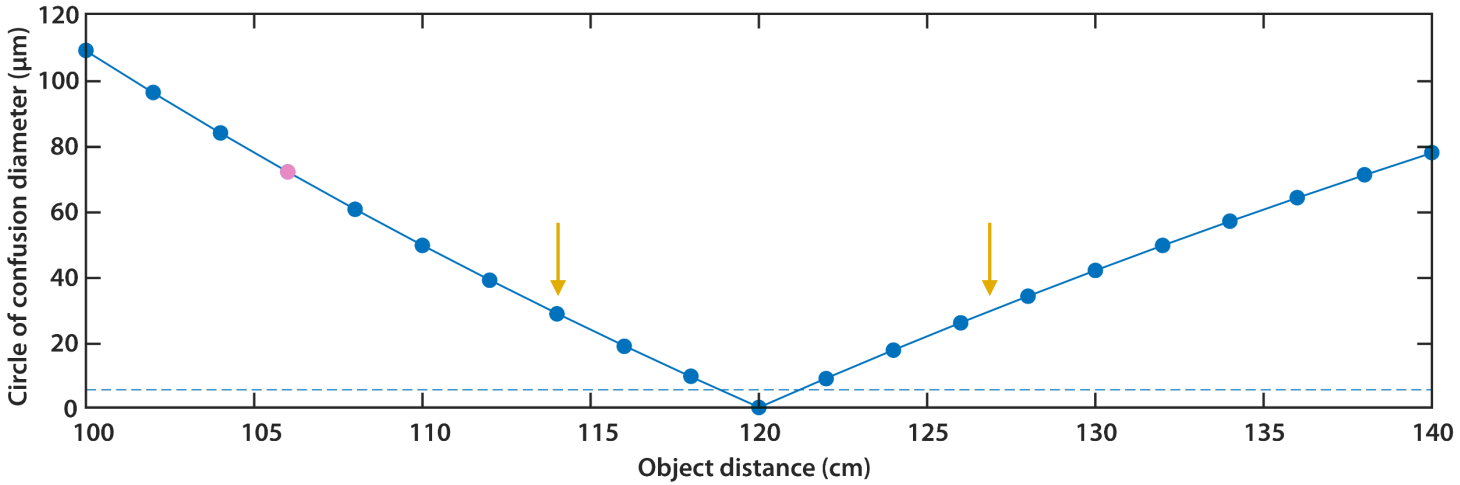

110 cm
f / 4

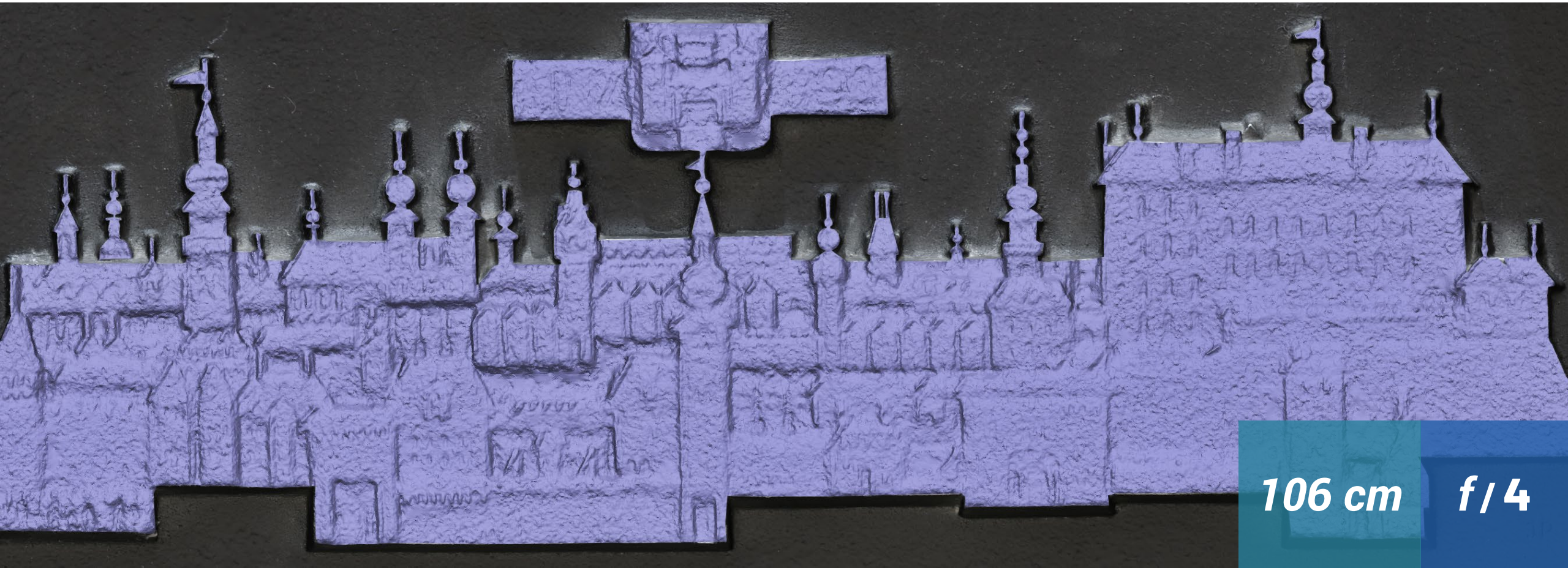
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

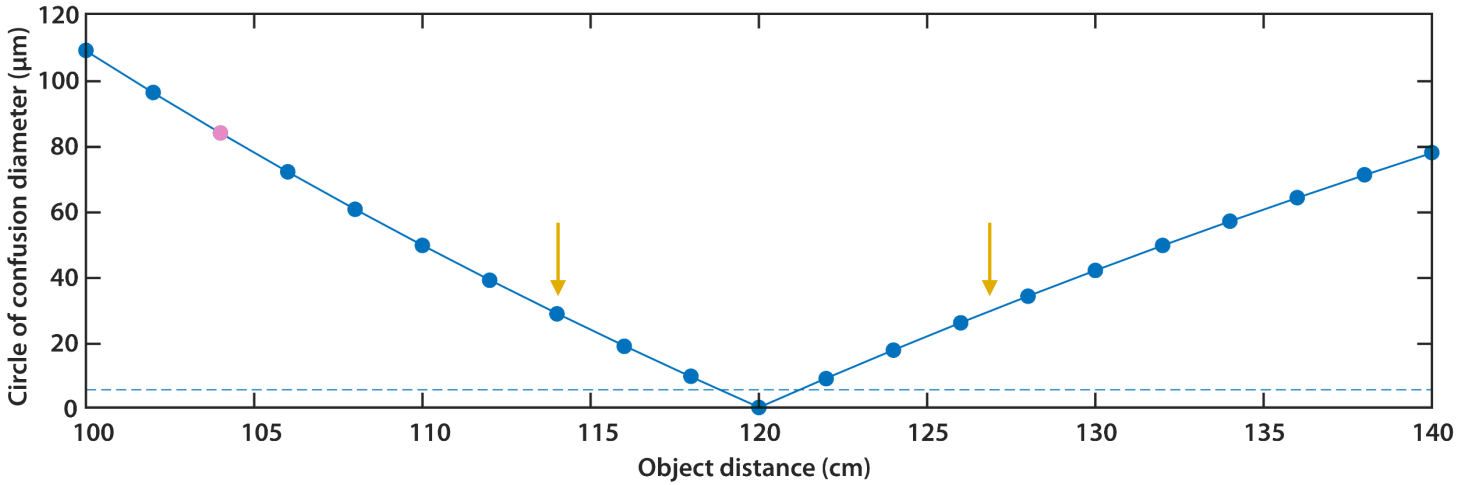

108 cm
f / 4

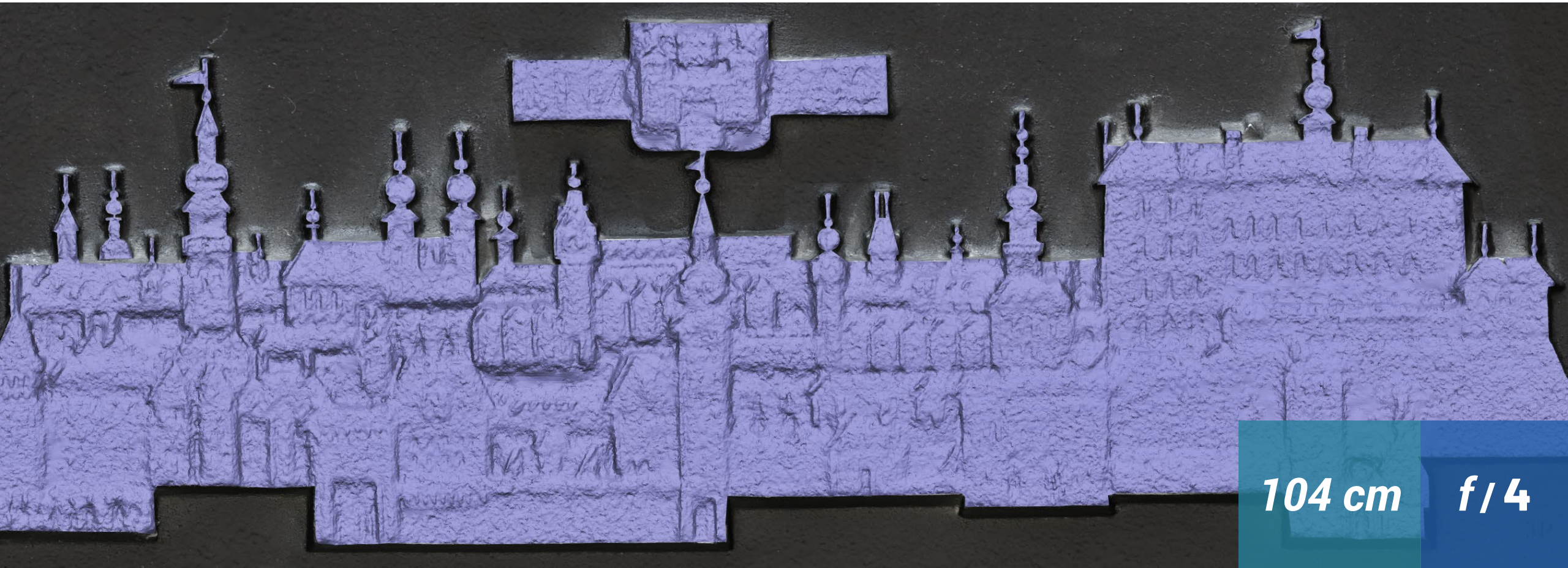
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

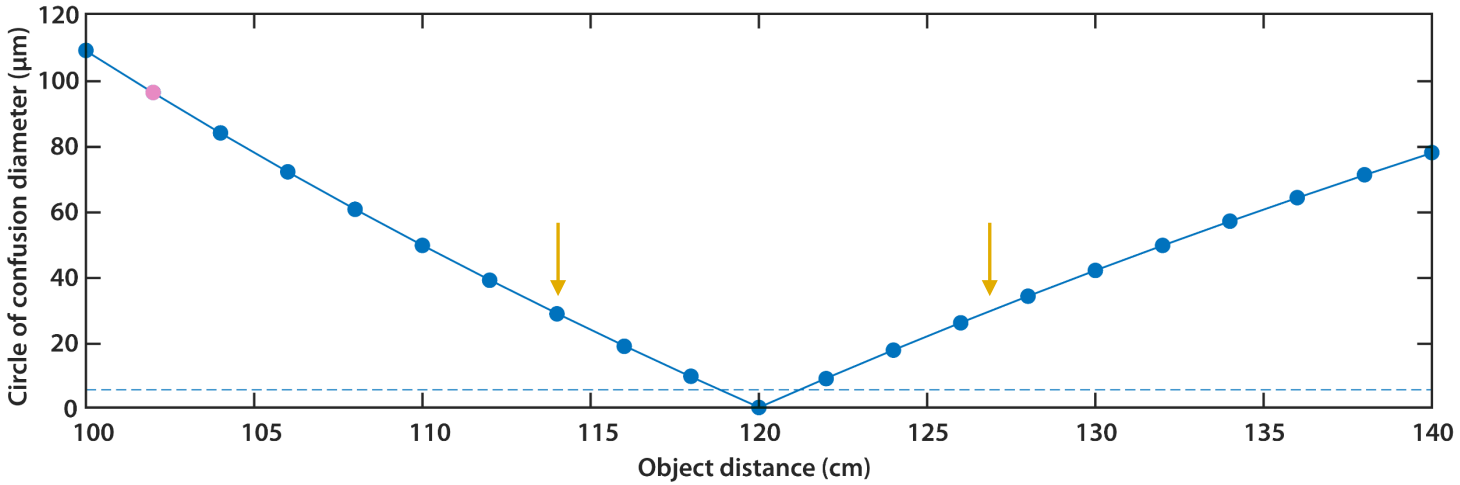

106 cm
f / 4

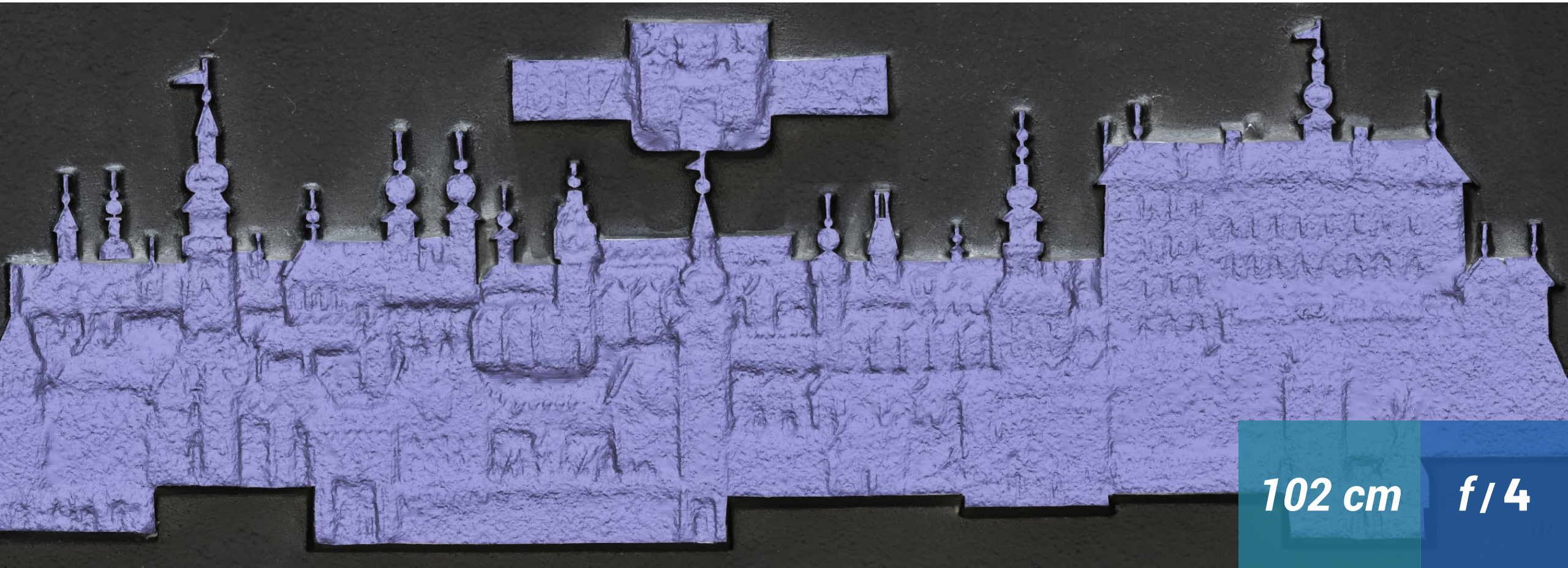
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

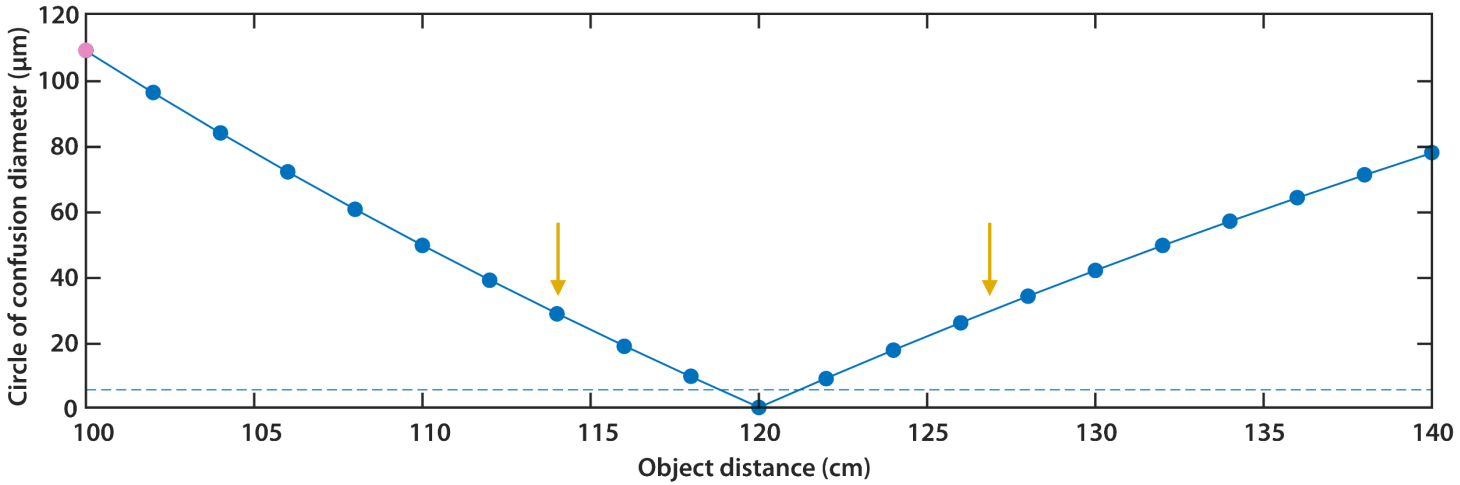

104 cm
f / 4

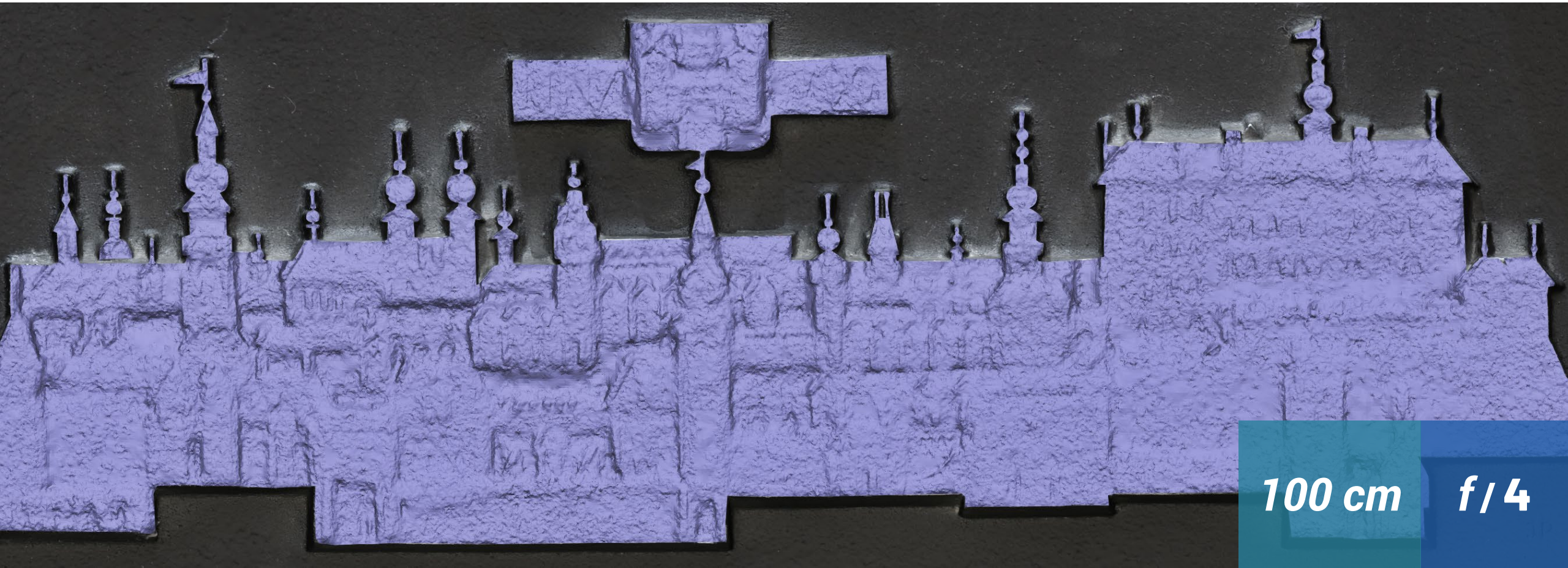
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

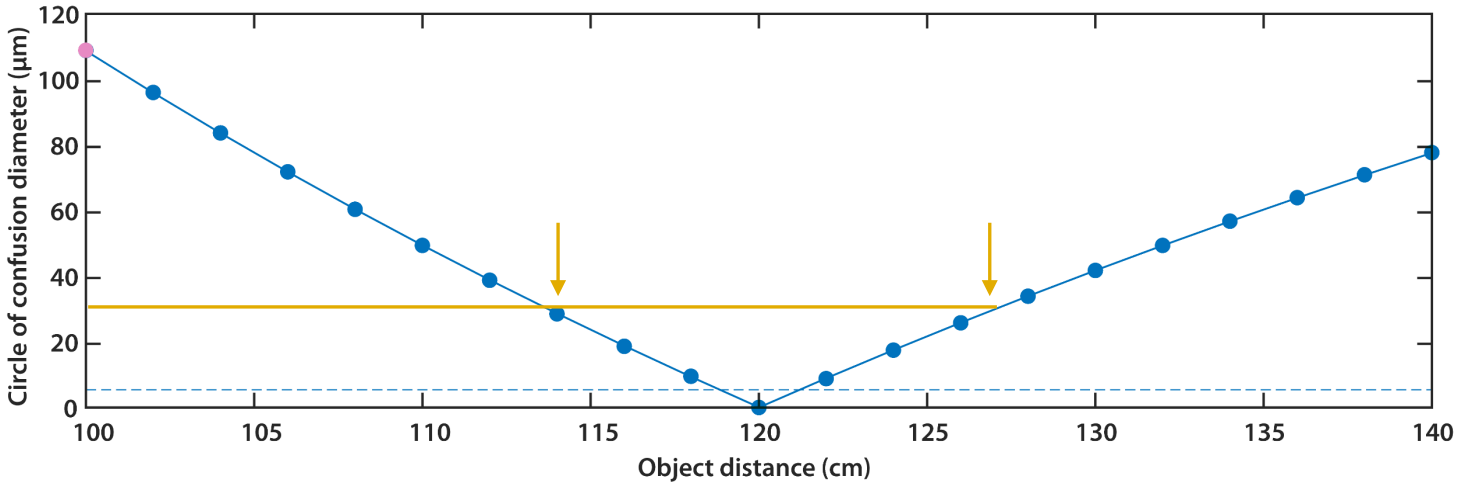

102 cm
f / 4

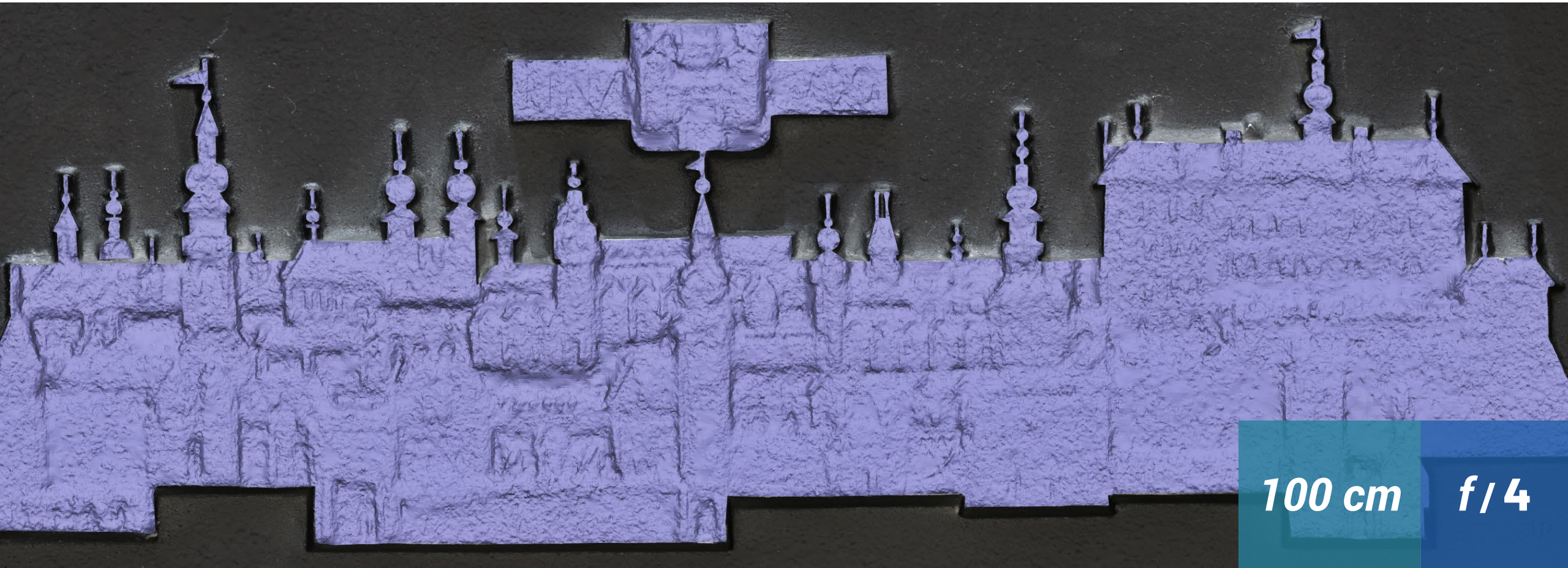
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

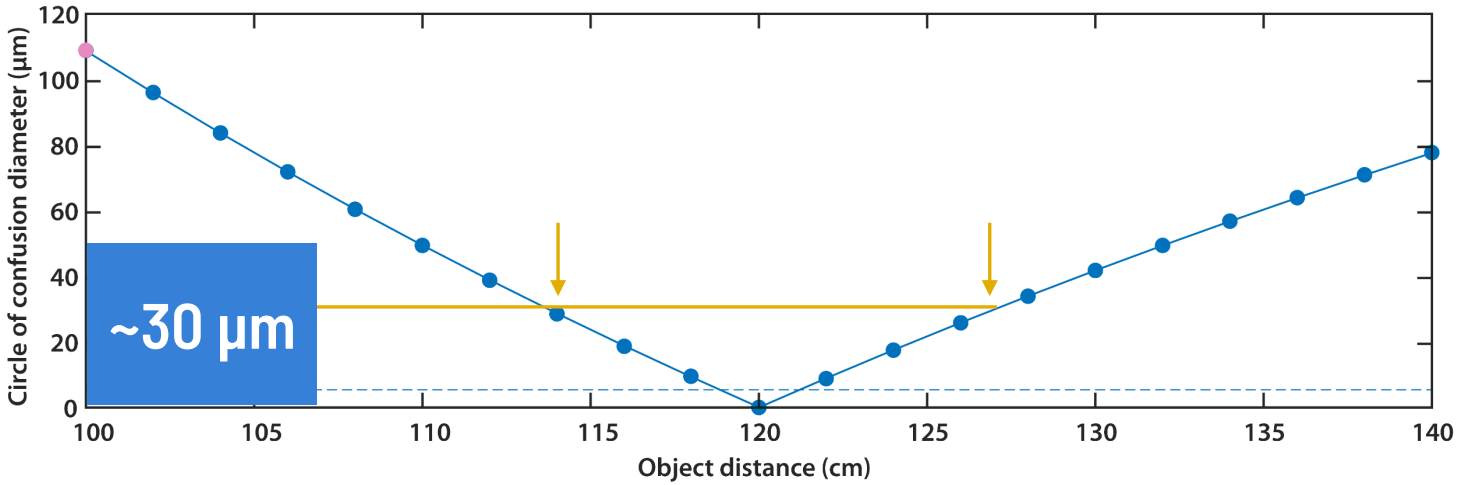

100 cm
f / 4

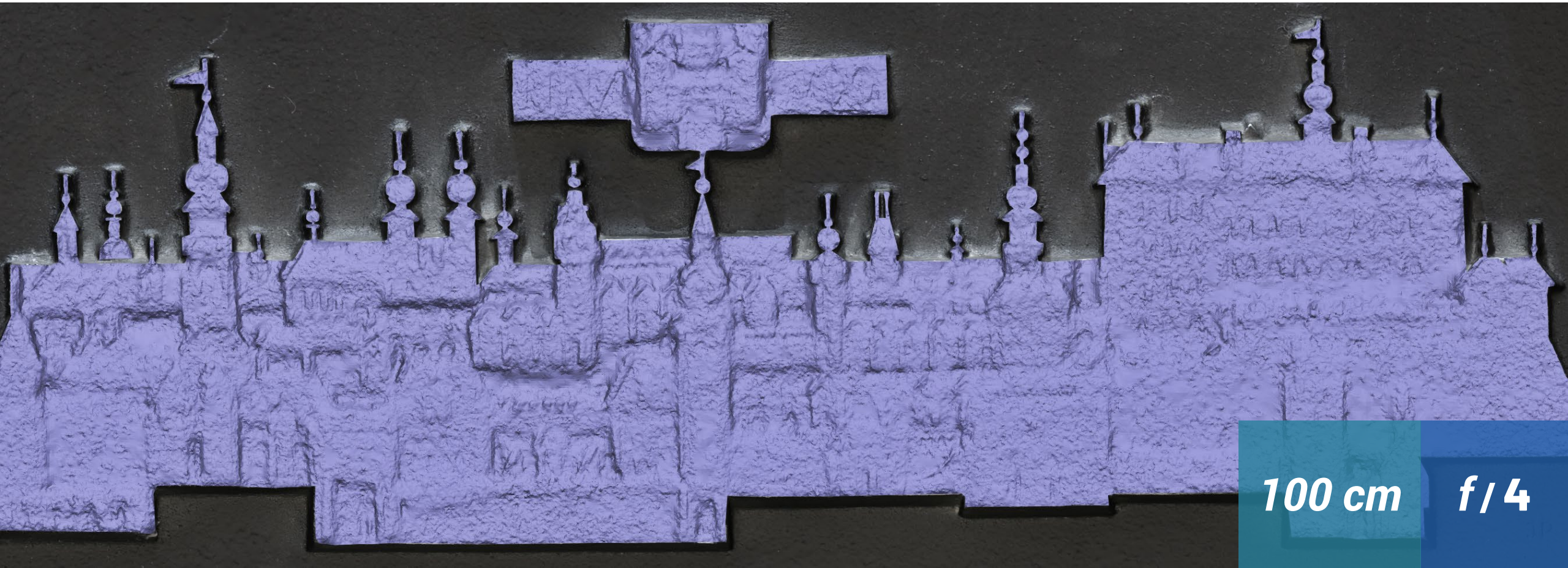
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

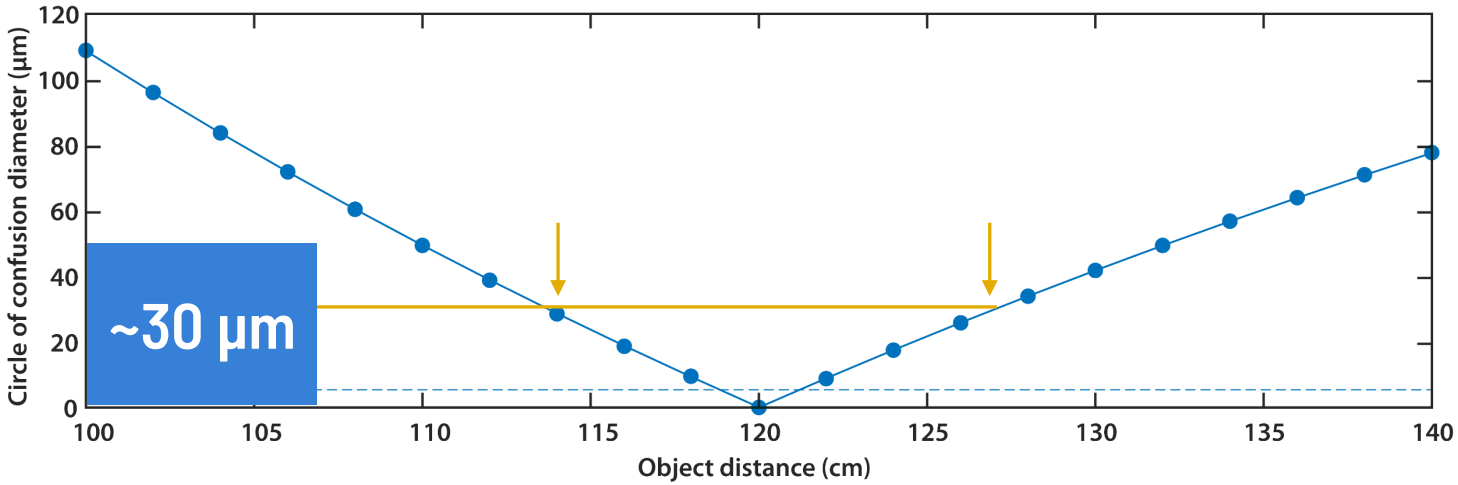

100 cm
f / 4

CASE STUDY 4

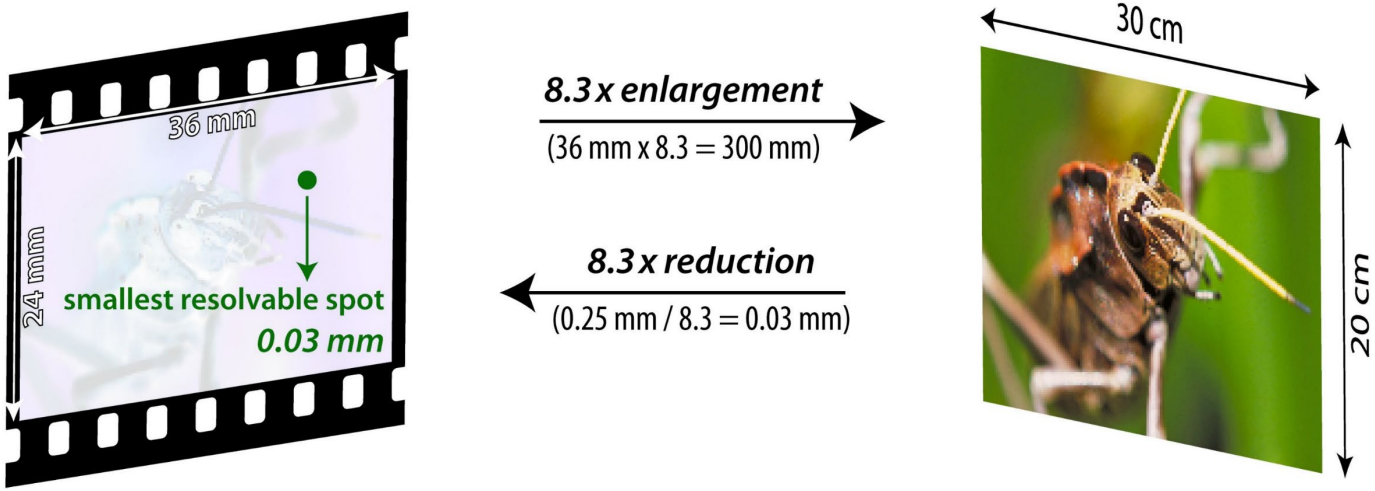

Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
~30 µm


100 cm
f / 4

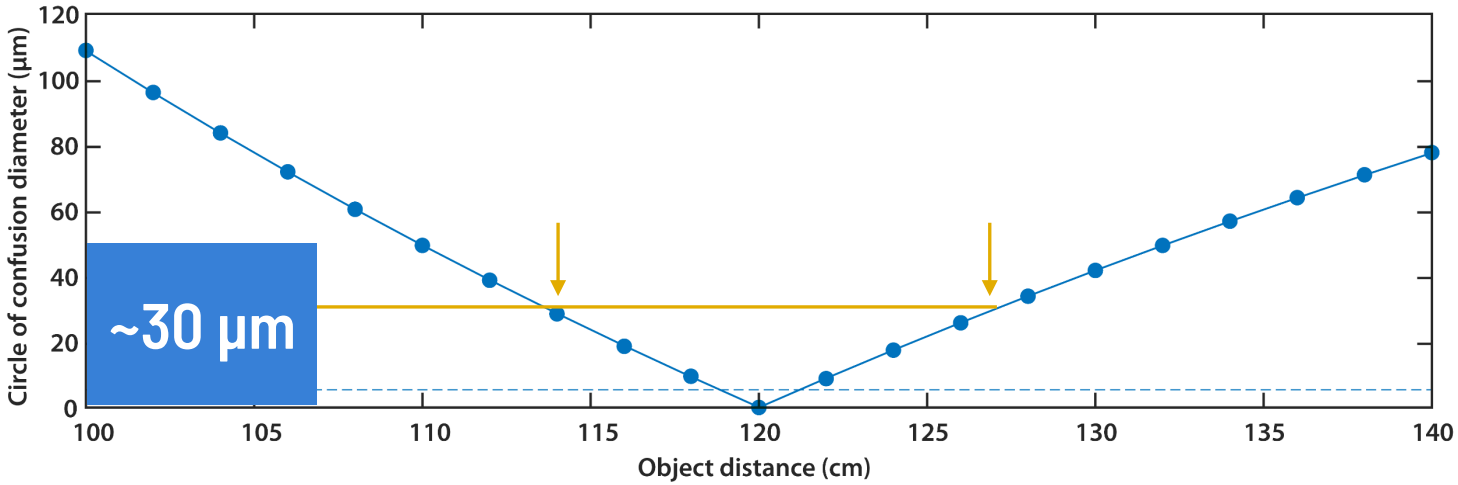
CASE STUDY 4



sensor diagonal / 1500

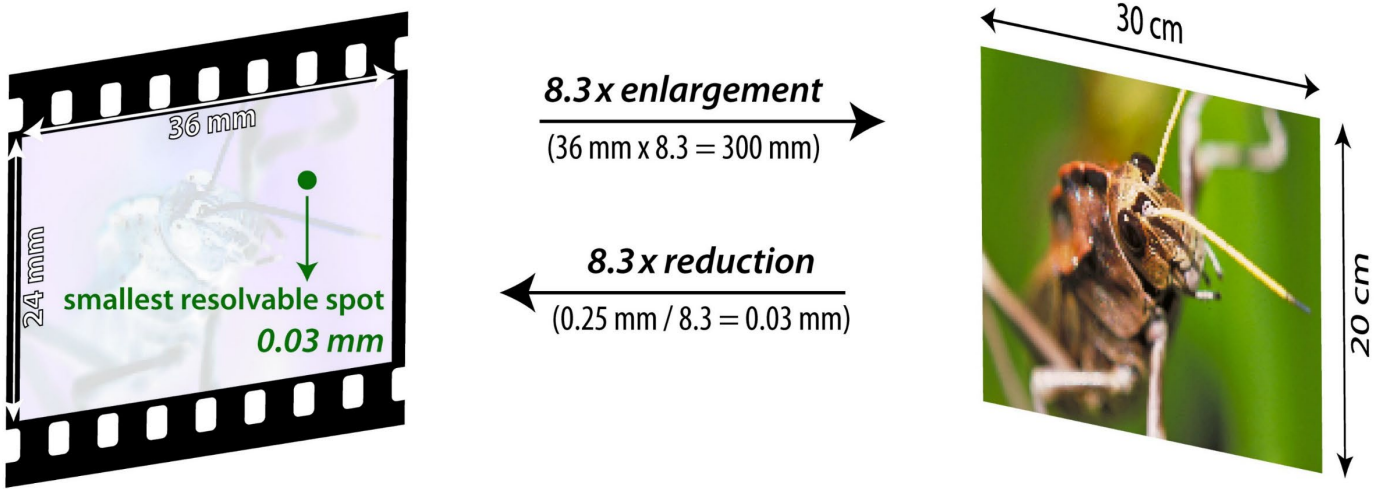


CASE STUDY 4

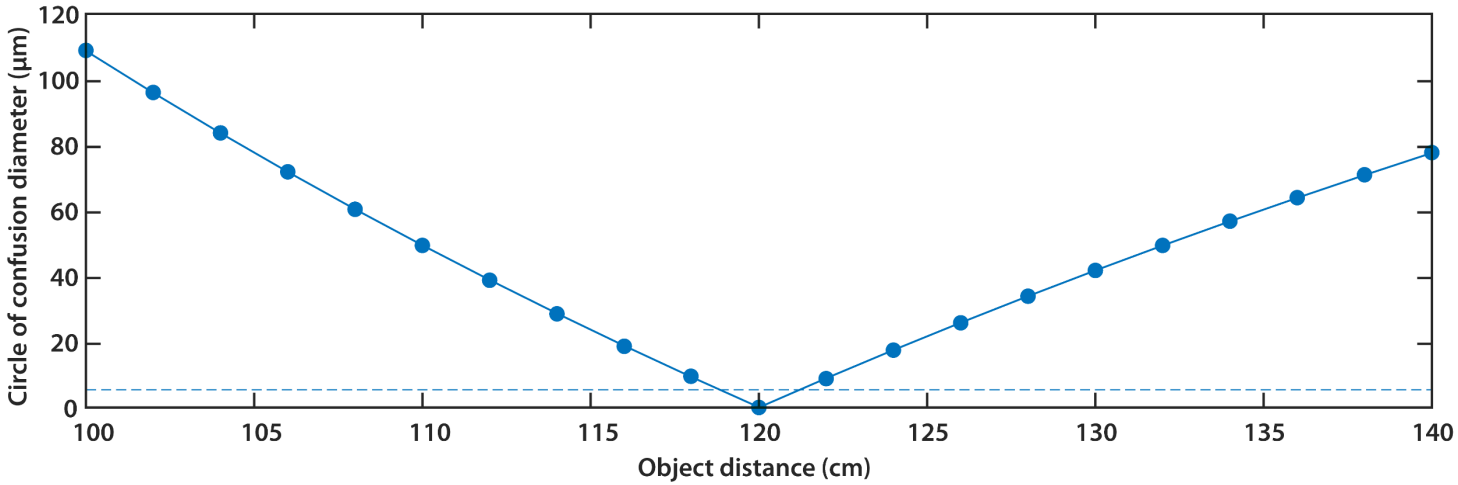


sensor diagonal / 1500

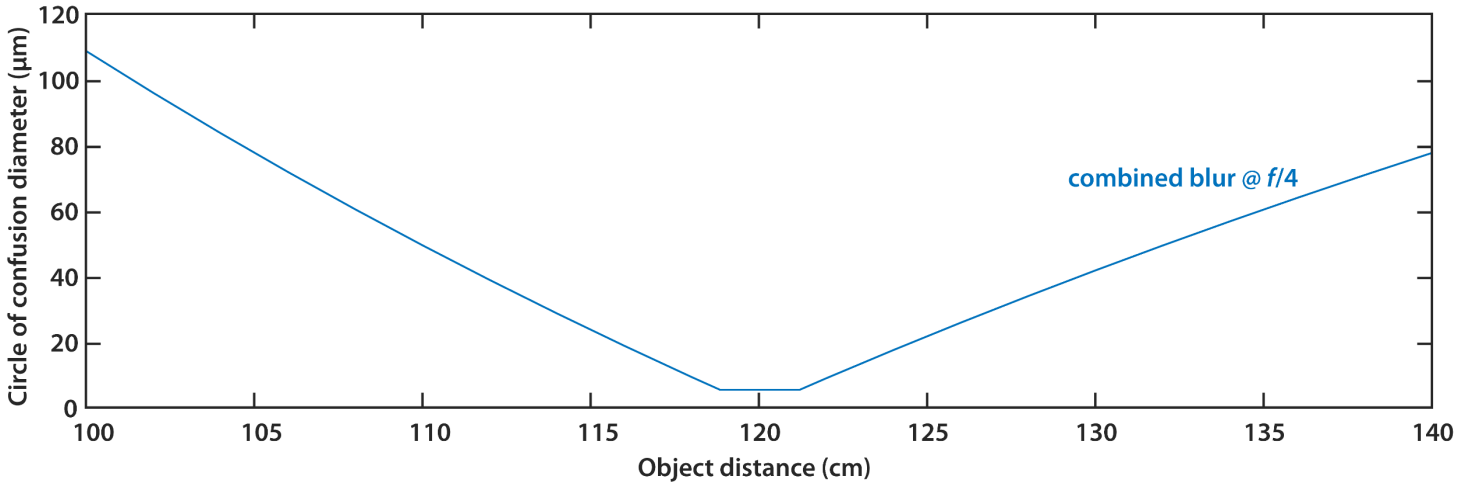
aperture ≤ *f*/ 22



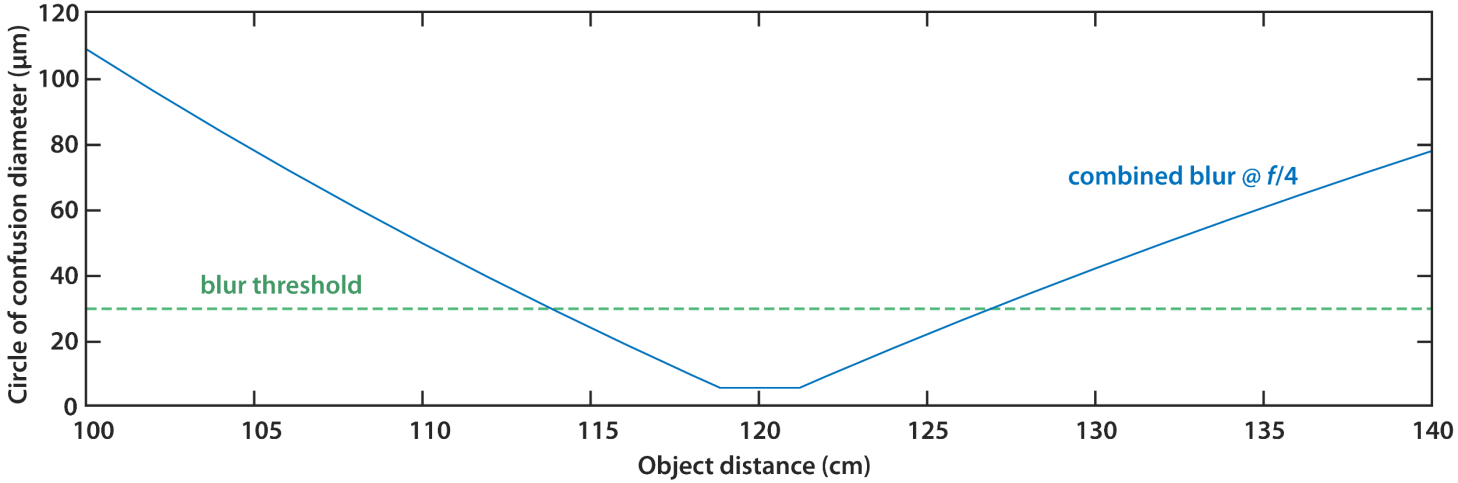
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)

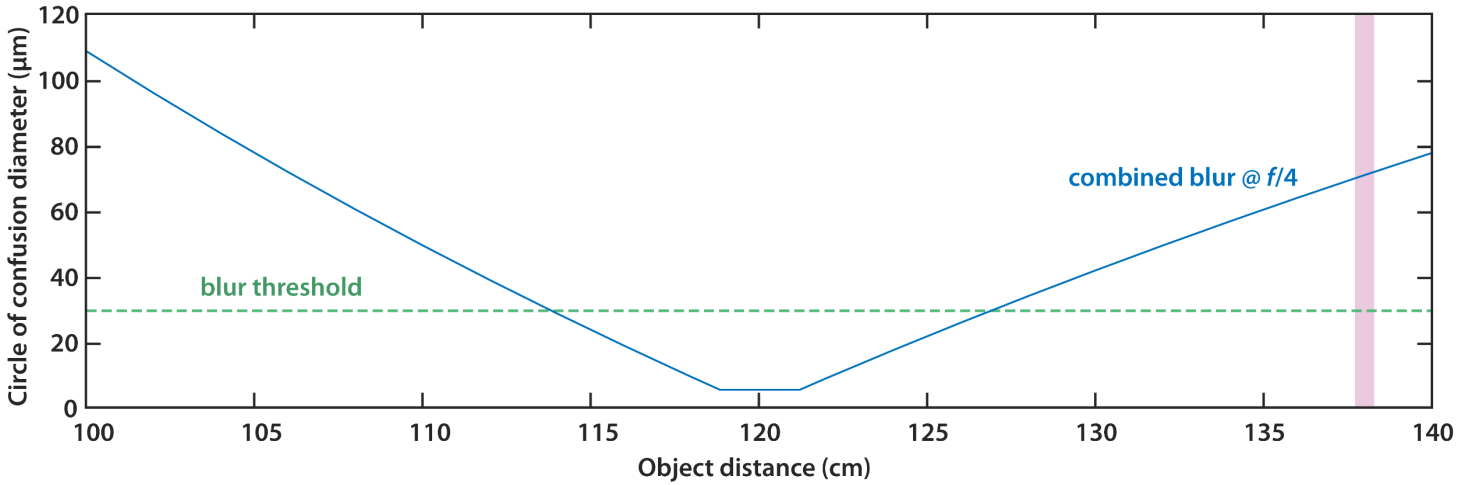
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
combined blur @ f/4

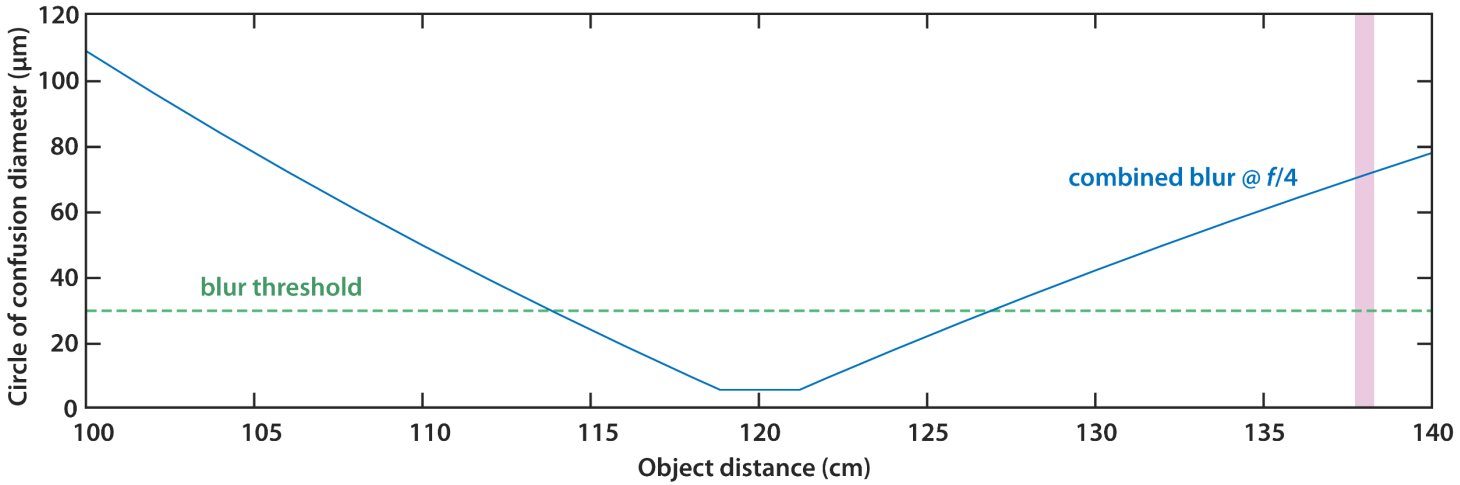
CASE STUDY 4

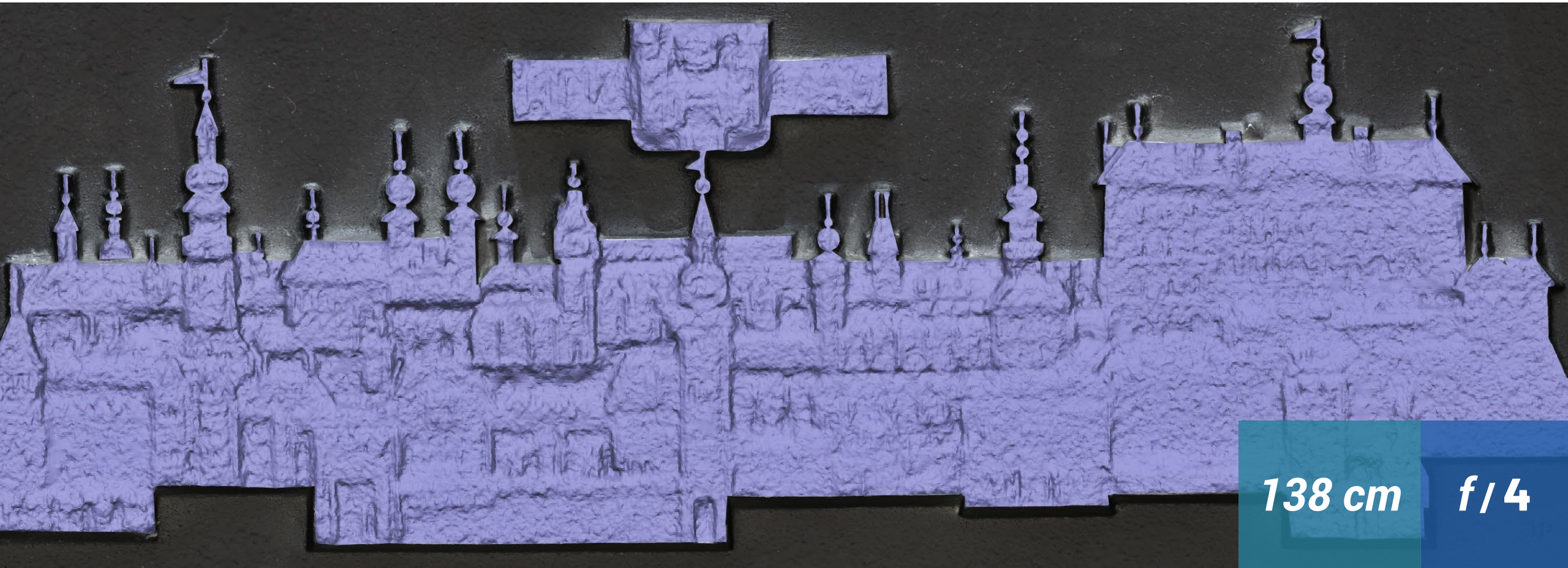

Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/4

CASE STUDY 4

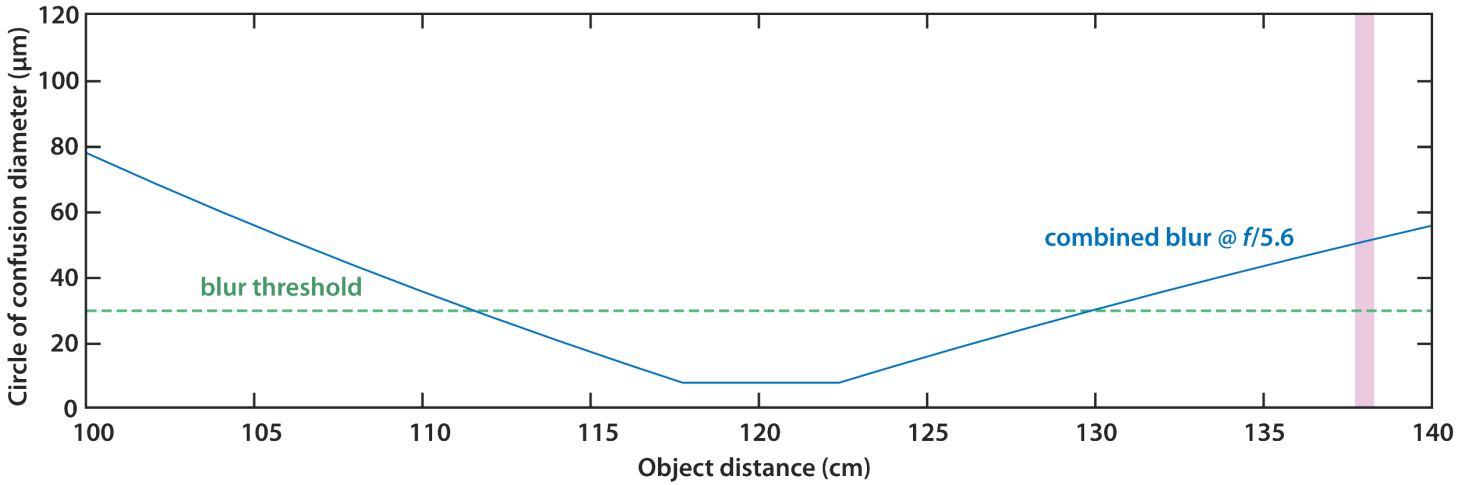

Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/4

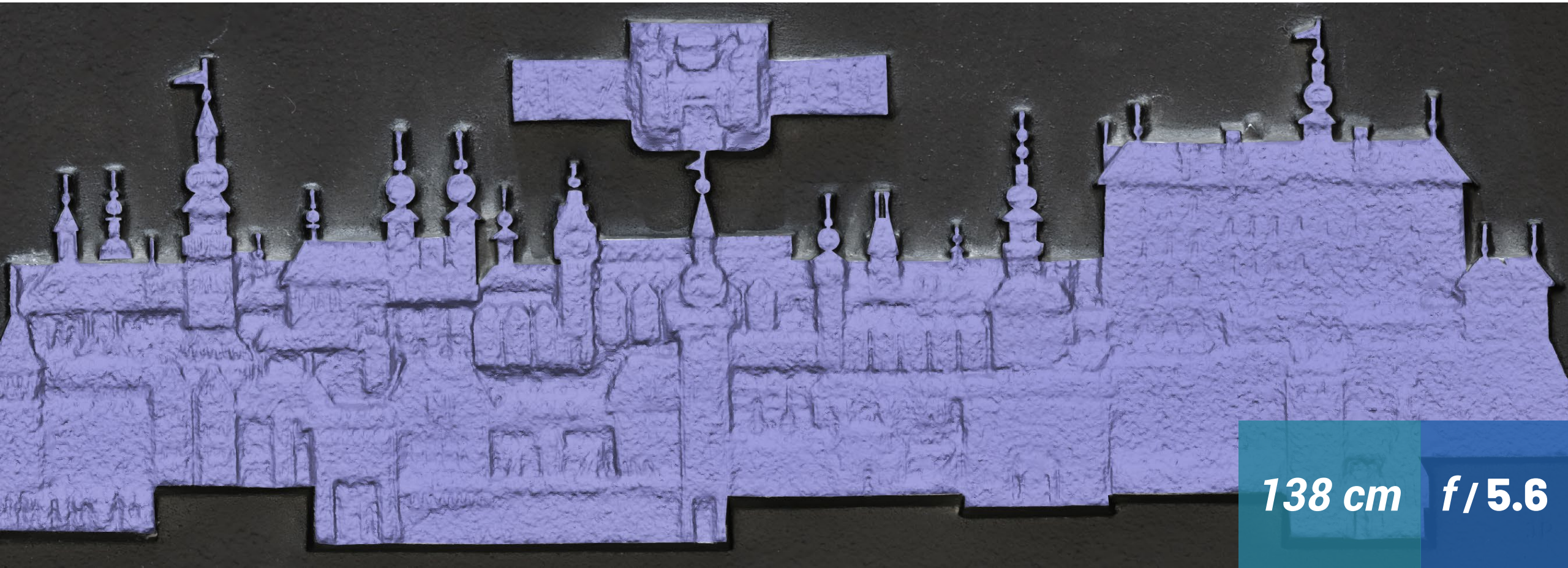
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/4

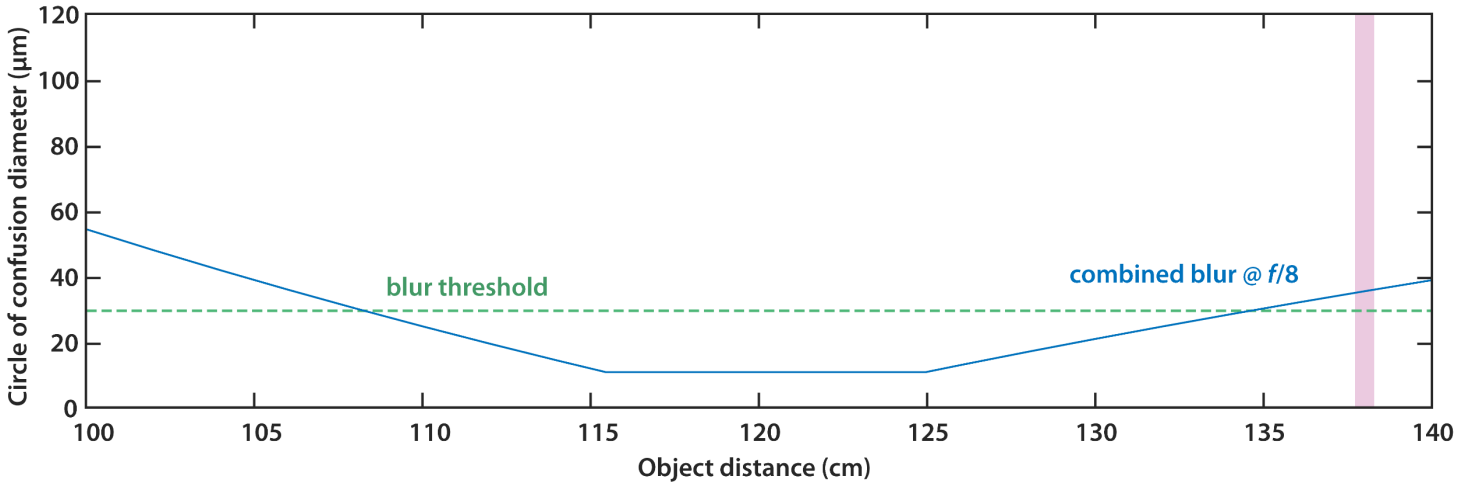

138 cm
f / 4

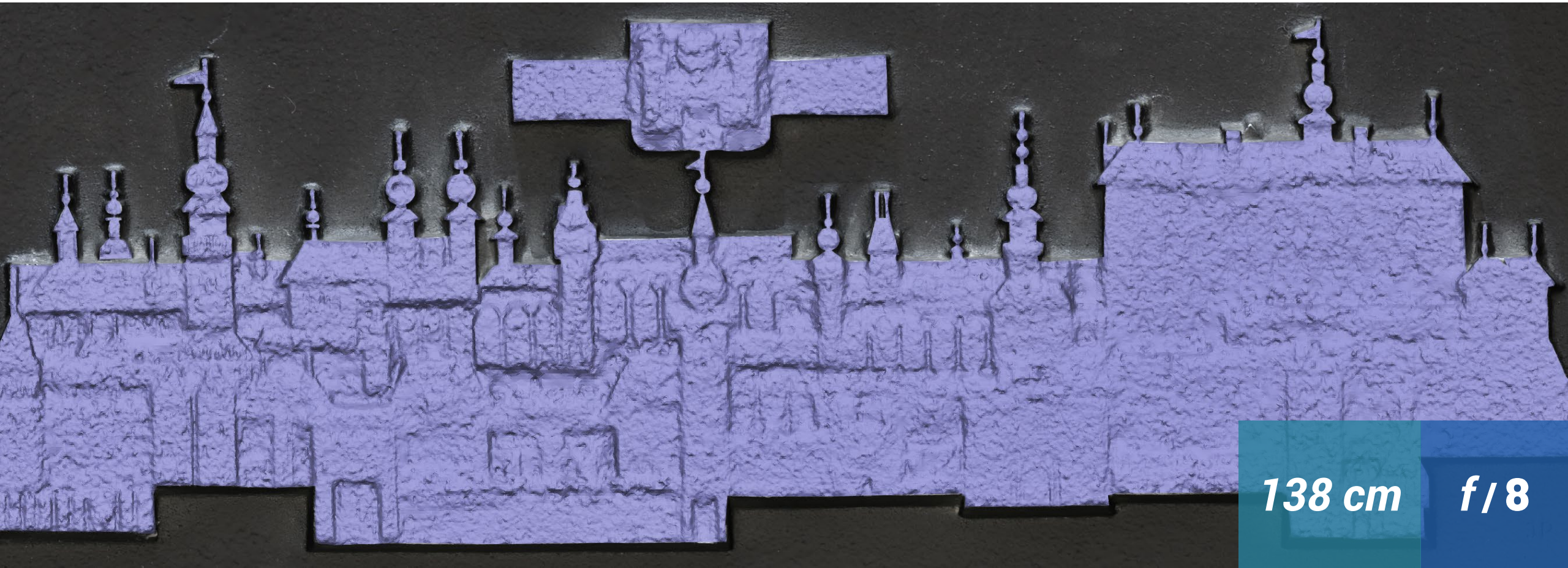
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/5.6

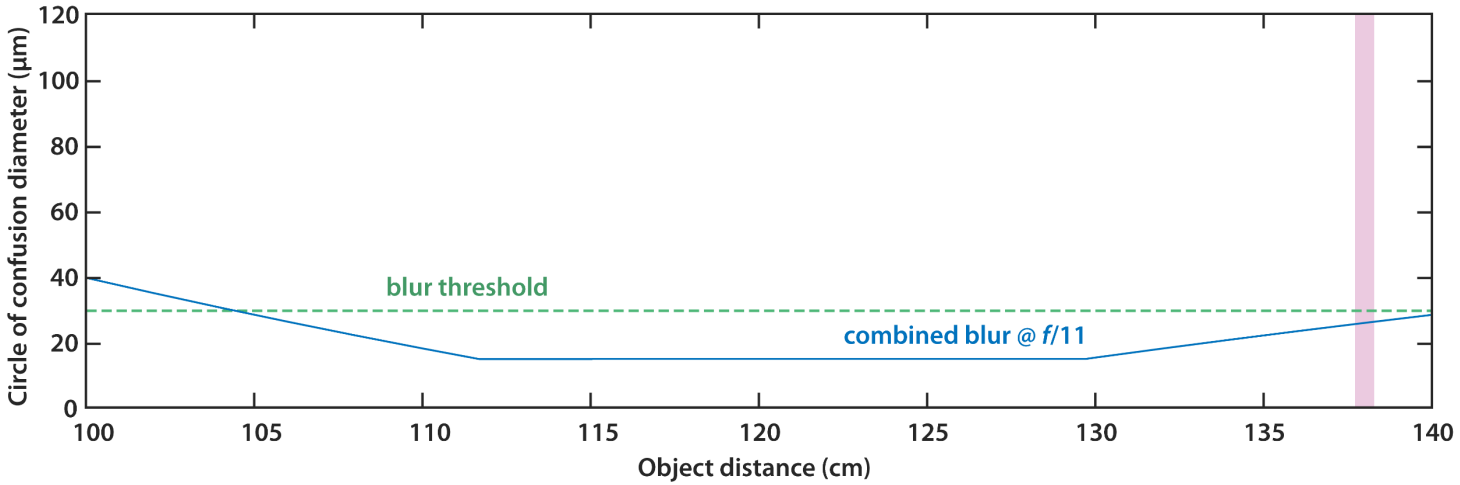

138 cm
f / 5.6

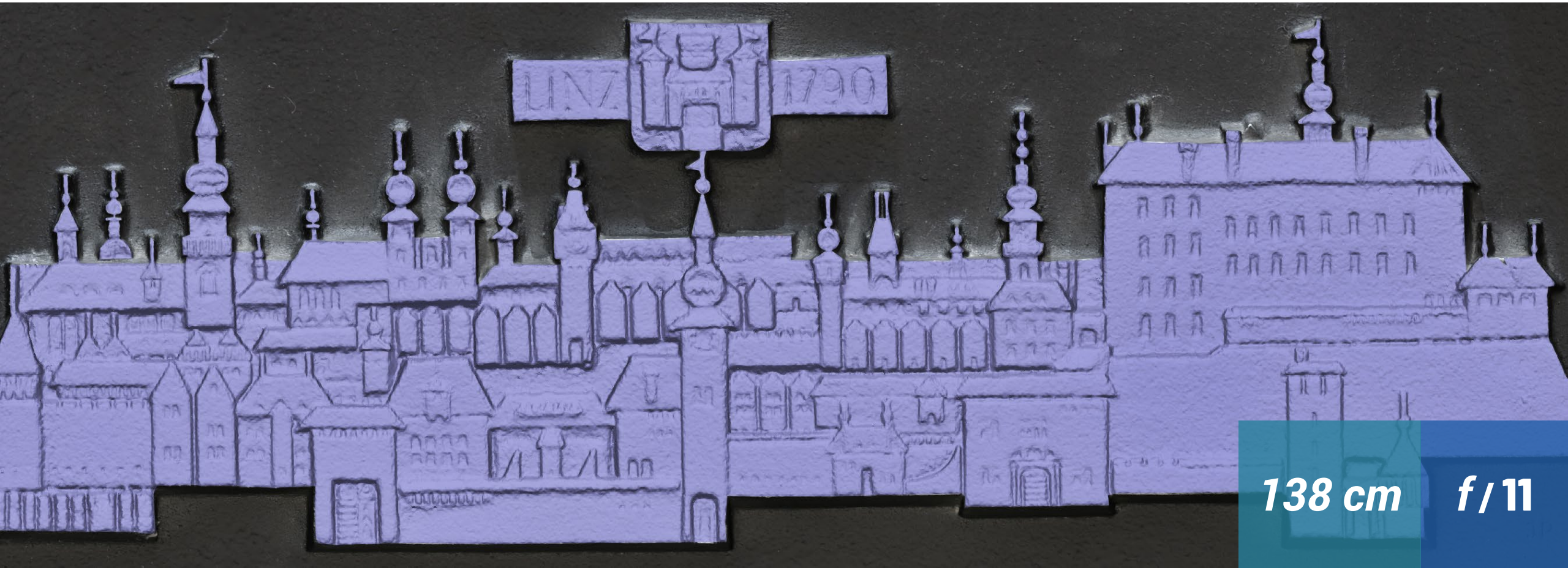
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/8

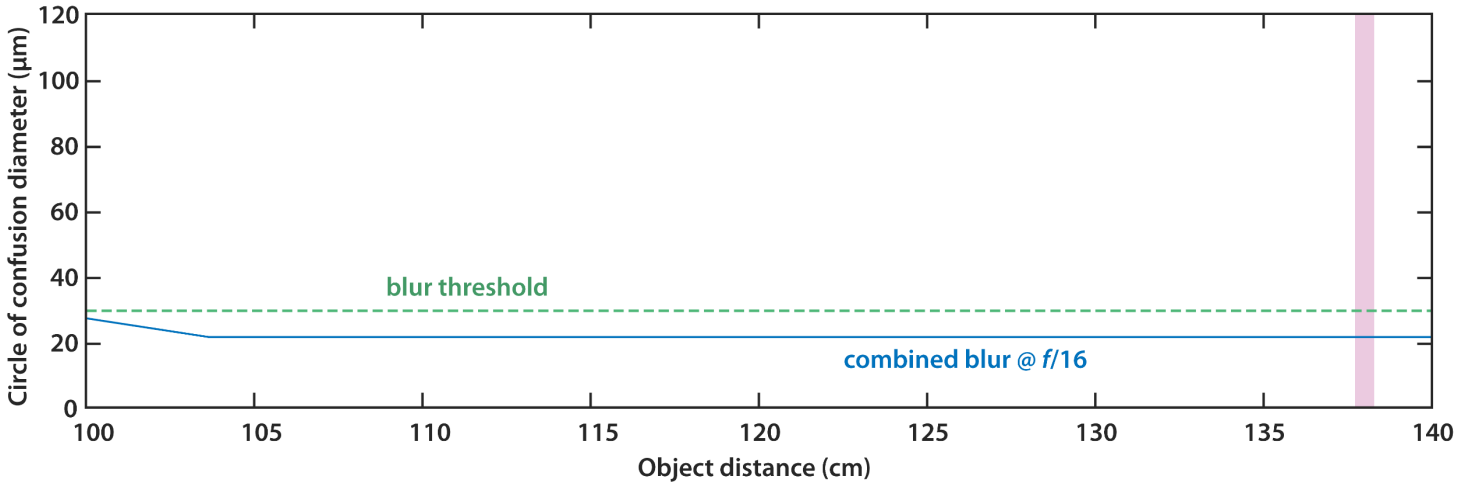

138 cm
f / 8

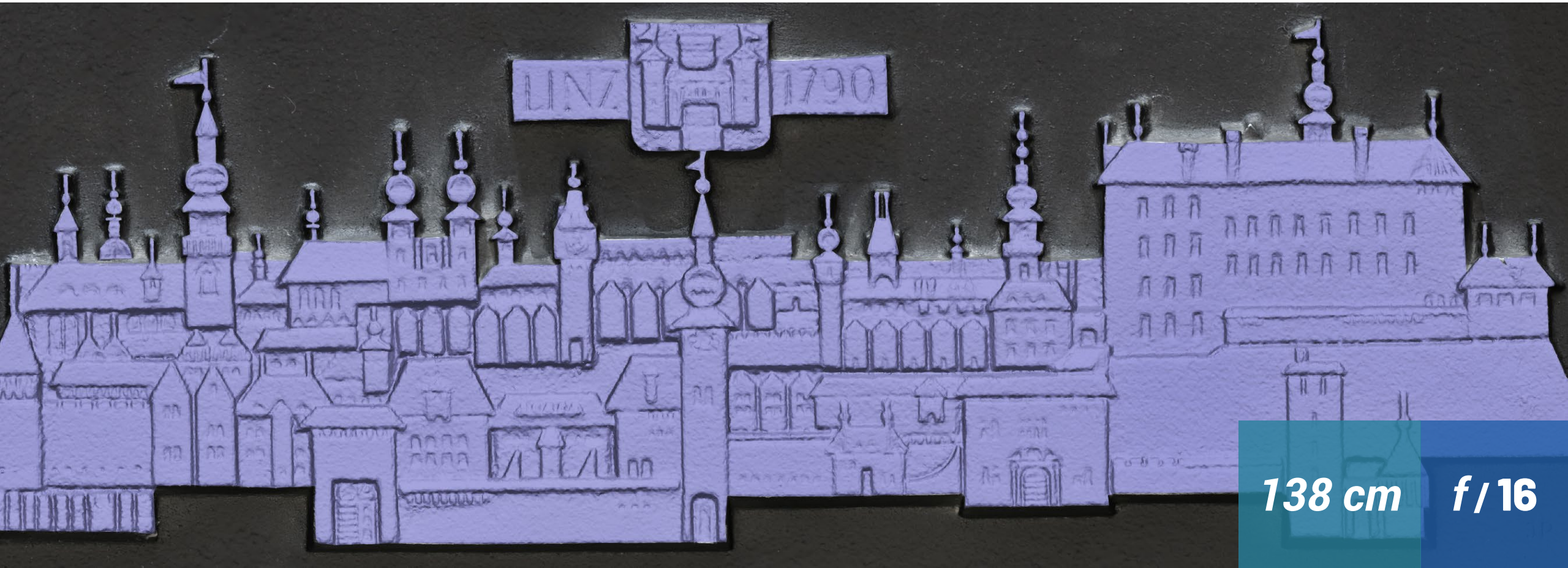
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/11

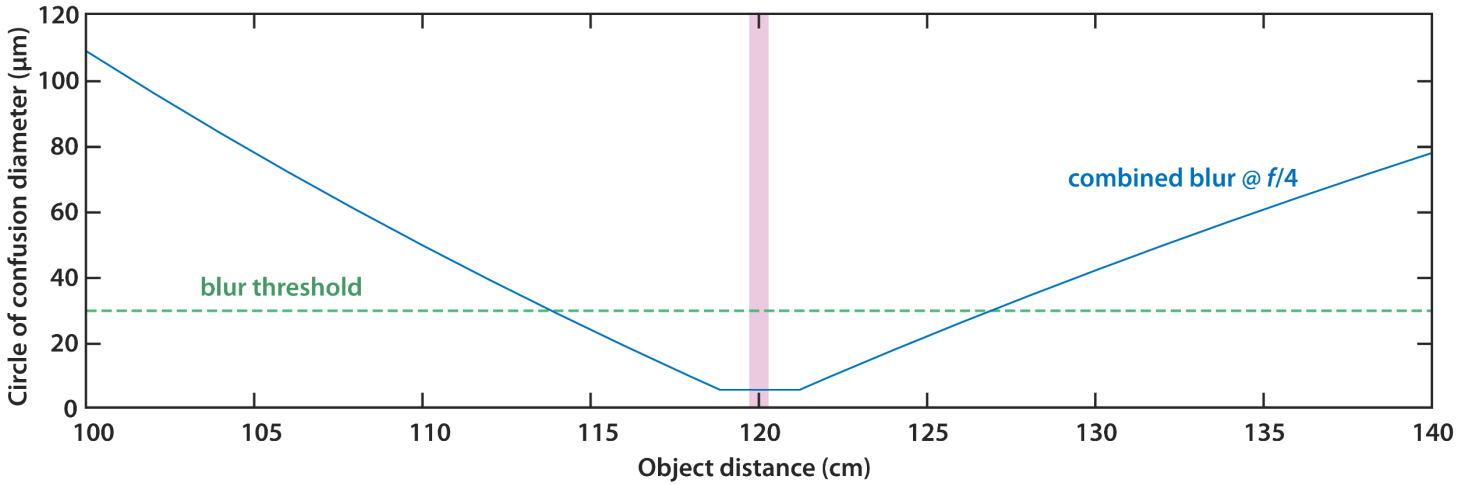

138 cm
f / 11

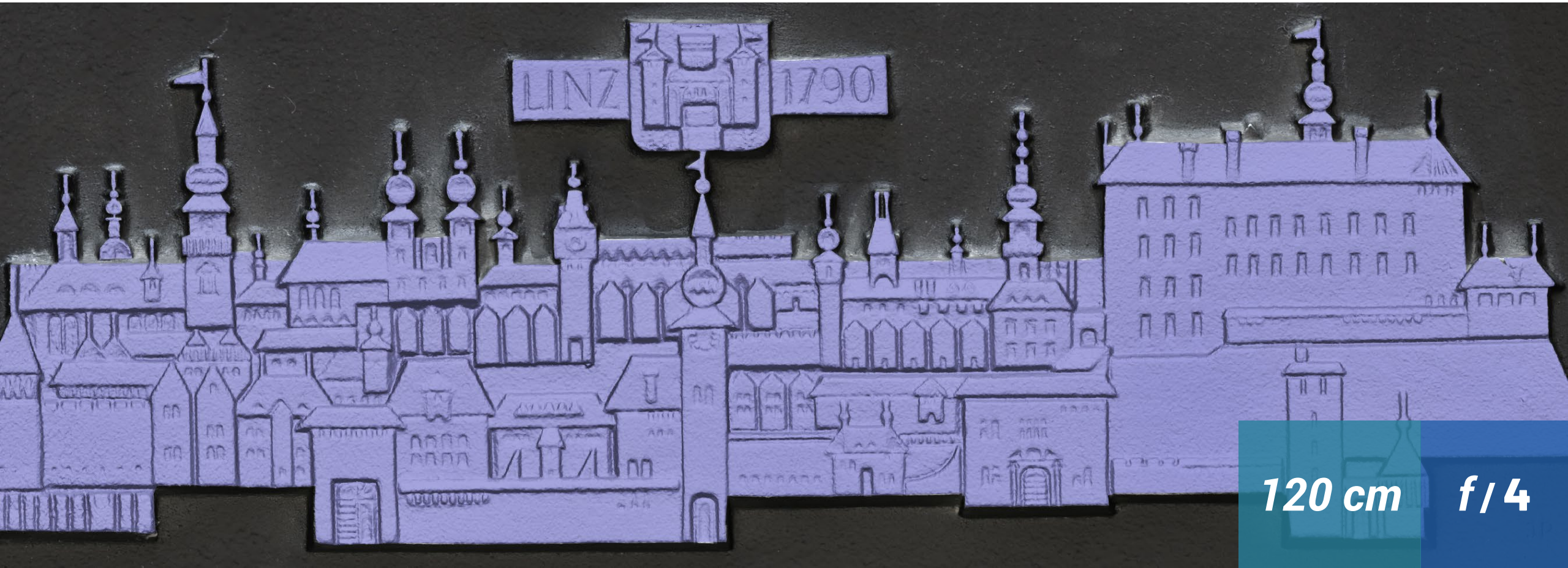
CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
blur threshold
combined blur @ f/16
100
105
110
115
120
125
130
135
140
Object distance (cm)


138 cm
f / 16

CASE STUDY 4


Circle of confusion diameter (µm)
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Object distance (cm)
blur threshold
combined blur @ f/4


LINZ
1790
120 cm
f / 4

MIND THAT ...

MIND THAT ...



qualitative

MIND THAT ...



qualitative



MVS ~~SfM~~ ~~texturing~~

MIND THAT ...



qualitative



MVS ~~SfM~~ ~~texturing~~



small object distance

UNACCOUNTED FOR ...

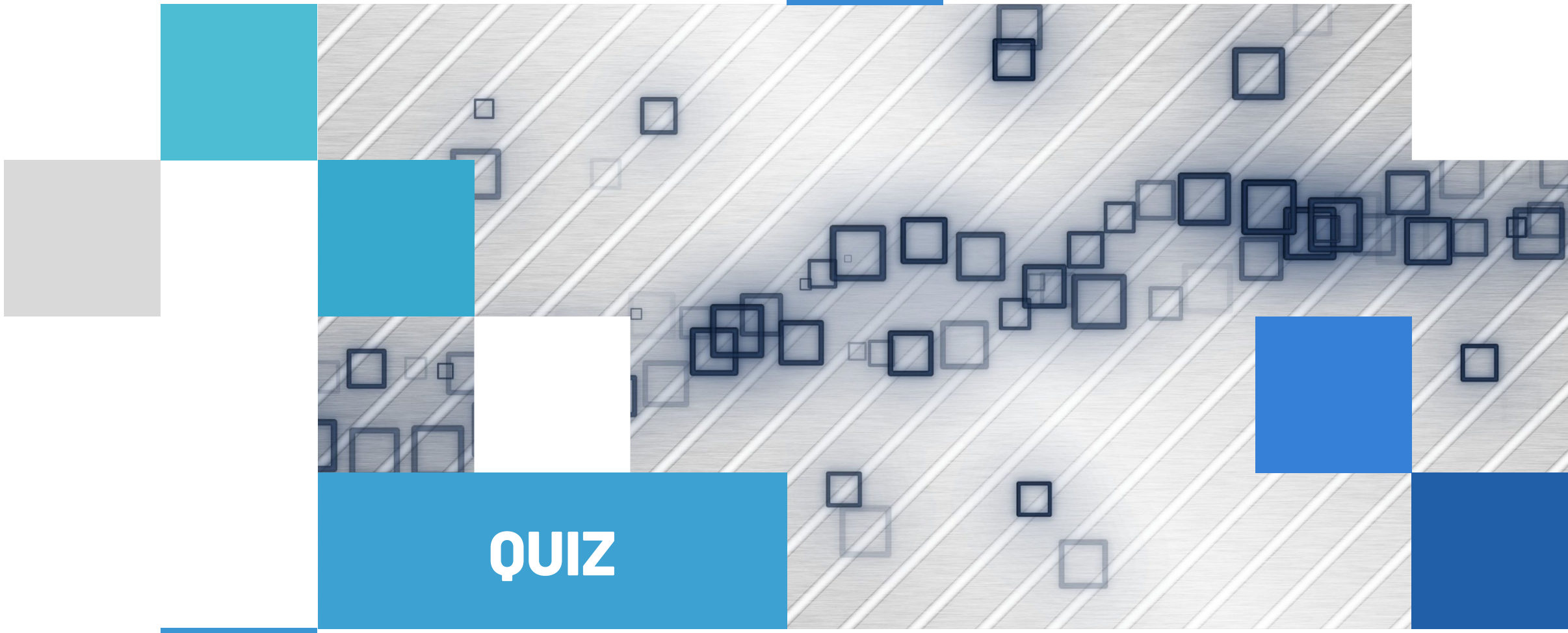
- varying GSD

UNACCOUNTED FOR ...

- varying GSD
- sensor photosite pitch

UNACCOUNTED FOR ...

- varying GSD
- sensor photosite pitch
- object structure


QUIZ

MAXIMUM INTEREST POINTS



8-bit TIFF



8-bit JPG | quality 12



8-bit JPG | quality 5

MAXIMUM INTEREST POINTS



8-bit TIFF

64k



8-bit JPG | quality 12

65k



8-bit JPG | quality 5

80k

MAXIMUM INTEREST POINTS

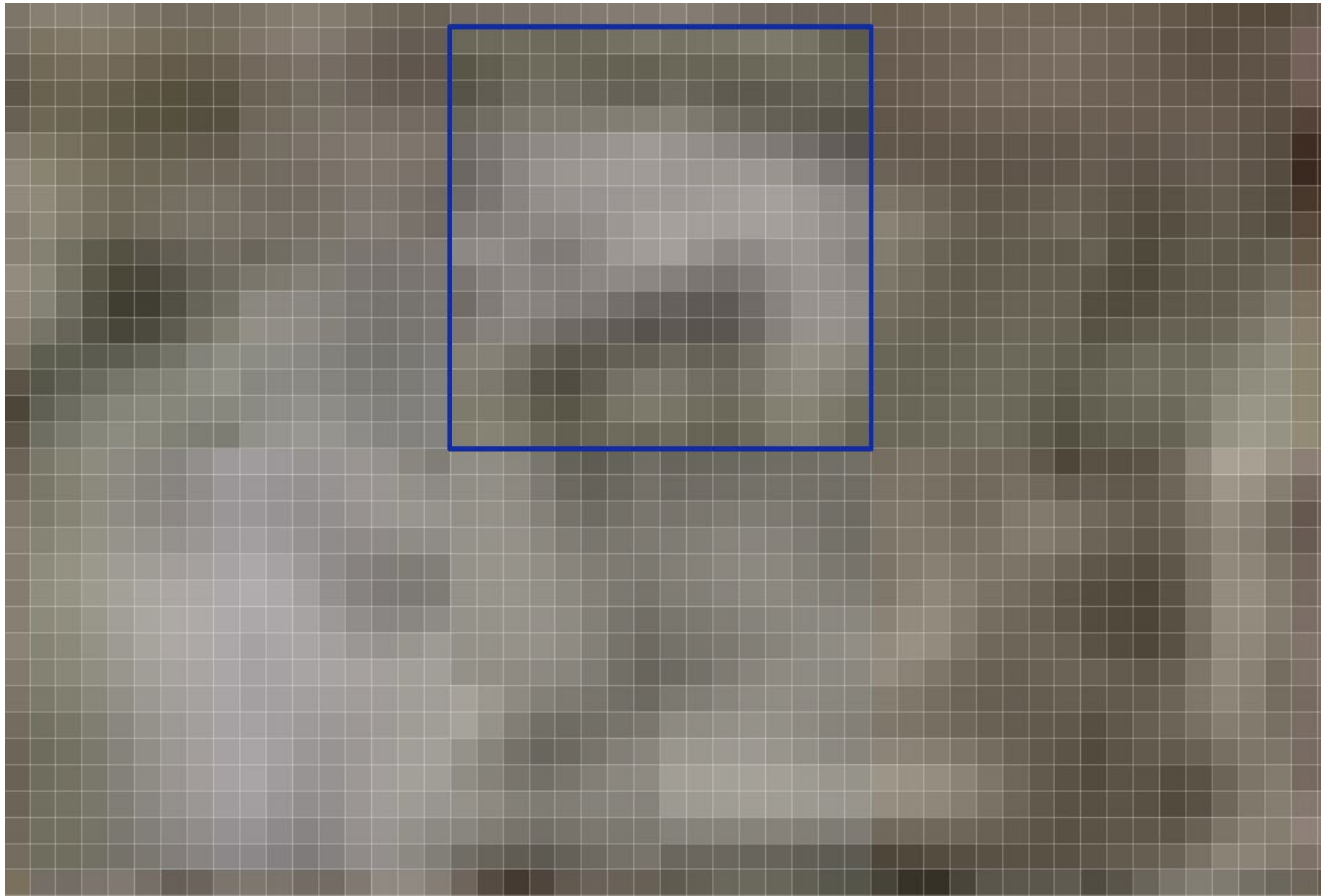




8-bit JPG | quality 5

80k

MAXIMUM INTEREST POINTS





8-bit JPG | quality 5

80k

stay parasite-free

21/02/2024 | 3D-ARCH

Geert Verhoeven

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