Q2 Exploring the spatial structure of the sample with optical methods

Solution

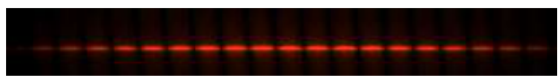
Part A. Collimation of light and sample

A.1 0.5 pt

$$(X_{sample}, Y_{sample}) = \underline{\textbf{(3700, -2900)}}$$

A.2 0.5 pt

Interference pattern:



Order, fringe	-2, Dark	-1, Dark	1, Dark	2, Dark
(x, y)	**(-0.98 , 0)**	**(-0.38, 0)**	**(0.34, 0)**	**(0.98, 0)**
S (cm)	**0.98**	**0.38**	**0.34**	**0.98**
ΔS (cm)	**0.65**			

Part B. Exploration of sample structure size

B.1 0.5 pt

$$\boldsymbol{d = \frac{m \times \lambda}{\sin\left(\tan^{-1}\left(\frac{S}{L}\right)\right)}}$$

B.2 1.5 pt

L = **60 cm**

$\boldsymbol{\lambda}$ = **488 nm**

Data	1	2	3	4	5
(x, y)	(-4.04, 4.68)	(3.00, 5.50)	(4.08, -4.60)	(5.76, 0.48)	(-5.68, 0.56)
S (cm)	**6.18**	**6.26**	**6.15**	**5.78**	**5.71**
$\bar{S}$ (cm)	$\mathbf{6.02 \pm 0.11}$				
$tan^{-1}\left(\frac{\bar{S}}{L}\right)$	$\mathbf{0.0999 \pm 0.0019}$				

$\boldsymbol{\lambda}$ = **514 nm**

Data	1	2	3	4	5
(x, y)	(3.32,5.64)	(6.16,0.48)	(4.46,-4.90)	(-3.12,-5.64)	(-6,-0.64)
S (cm)	**6.54**	**6.18**	**6.63**	**6.45**	**6.03**
$\bar{S}$ (cm)	$\mathbf{6.37 \pm 0.11}$				
$tan^{-1}\left(\frac{S}{L}\right)$	$\mathbf{0.1057 \pm 0.0019}$				

$\boldsymbol{\lambda}$ = **632.8 nm**

Data	1	2	3	4	5
(x, y)	(4.04,7.00)	(7.44,0.68)	(5.24,-5.96)	(-3.96,-7.04)	(-7.44,-0.68)
S (cm)	**8.08**	**7.47**	**7.94**	**8.08**	**7.47**
$\bar{S}$ (cm)	$\mathbf{7.81 \pm 0.14}$				
$tan^{-1}\left(\frac{S}{L}\right)$	$\mathbf{0.1294 \pm 0.0023}$				

λ = 694.3 nm

Data	1	2	3	4	5
(x, y)	(-5.84,6.50)	(8.20,0.76)	(-4.28,-7.72)	(5.96,-6.60)	(4.48,7.72)
S (cm)	**8.74**	**8.24**	**8.83**	**8.89**	**8.93**
$\bar{S}$ (cm)	$\mathbf{8.73 \pm 0.13}$				
$tan^{-1}\left(\frac{S}{L}\right)$	$\mathbf{0.1444 \pm 0.0021}$				

B.3 1.0 pt

$$a = 5.627 \text{ μm}$$

λ (nm)	***d* (μm)**	***a* (μm)**
488	**4.89**	**5.65**
514	**4.87**	**5.63**
632.8	**4.90**	**5.66**
$\bar{a}$ **(μm)**	$\mathbf{5.627 \pm 0.020}$	

Part C. Exploration of sample structure size

C.1 0.8 pt

λ = 488 nm

L=90 cm, Axis1				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(3.01, 1.46)**	**(3.67, 1.91)**	**(4.30, 2.24)**	**(5.00, 2.50)**
S (cm)	**3.35**	**4.14**	**4.85**	**5.59**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0372**	**0.0459**	**0.0538**	**0.0620**

L=90 cm, Axis 2				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(-1.64, 3.46)**	**(-2.07, 4.19)**	**(-2.41, 4.95)**	**(-2.87, 5.73)**
S (cm)	**3.83**	**4.67**	**5.51**	**6.41**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0425**	**0.0519**	**0.0611**	**0.0711**

λ = 514 nm

L=90 cm, Axis1				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(3.08, 1.56)**	**(3.76, 1.92)**	**(4.44, 2.28)**	**(5.20, 2.60)**
S (cm)	**3.45**	**4.22**	**4.99**	**5.81**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0383**	**0.0469**	**0.0554**	**0.0645**

L=90 cm, Axis 2				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(-1.76, 3.68)**	**(-2.26, 4.38)**	**(-2.58, 5.34)**	**(-3.22, 6.04)**
S (cm)	**4.09**	**4.92**	**5.93**	**6.84**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0454**	**0.0547**	**0.0658**	**0.0759**

λ = 632.8 nm

L=90 cm, Axis1				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(3.84, 1.96)**	**(4.68, 2.44)**	**(5.48, 2.88)**	**(6.44, 3.32)**
S (cm)	**4.31**	**5.28**	**6.19**	**7.25**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0479**	**0.0586**	**0.0687**	**0.0803**

L=90 cm, Axis 2				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(-2.28, 4.56)**	**(-2.84, 5.48)**	**(-3.36, 6.52)**	**(-3.84, 7.52)**
S (cm)	**5.10**	**6.17**	**7.33**	**8.44**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0566**	**0.0685**	**0.0813**	**0.0935**

$\boldsymbol{\lambda}$ = **694.3 nm**

L=90 cm, Axis 1				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(4.24, 2.12)**	**(5.08, 2.80)**	**(6.04, 3.20)**	**(7.04, 3.68)**
S (cm)	**4.74**	**5.80**	**6.84**	**7.96**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0526**	**0.0644**	**0.0758**	**0.0882**

L=90 cm, Axis 2				
Order, fringe	4, Bright	5, Bright	6, Bright	7, Bright
(x, y)	**(-2.48, 5.00)**	**(-3.08, 6.04)**	**(-3.60, 7.16)**	**(-4.16, 8.28)**
S (cm)	**5.58**	**6.78**	**8.01**	**9.27**
$tan^{-1}\left(\frac{S}{L}\right)$	**0.0619**	**0.0752**	**0.0888**	**0.103**

C.2 0.7 pt

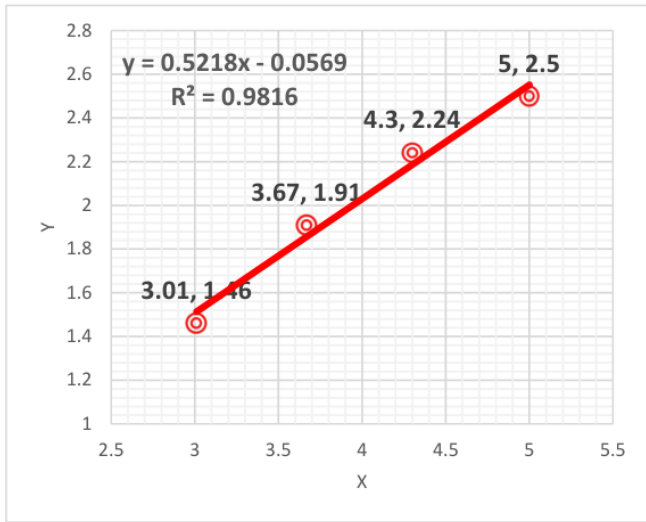
$\boldsymbol{\lambda}$ (nm)	$\boldsymbol{\Delta S_\ell}$ (cm)	$\boldsymbol{\ell}$ (µm)	$\boldsymbol{\Delta S_w}$ (cm)	$\boldsymbol{w}$ (µm)
488	**0.748**	**58.7**	**0.860**	**51.1**
	0.750	**58.5**	**0.842**	**52.1**
514	**0.787**	**58.8**	**0.920**	**50.3**
	0.794	**58.3**	**0.891**	**51.9**
632.8	**0.978**	**58.2**	**1.12**	**51.1**
	0.960	**59.3**	**1.11**	**51.4**
694.3	**1.07**	**58.2**	**1.23**	**50.9**
	1.07	**58.2**	**1.22**	**51.4**

$\boldsymbol{\ell} = 58.59$ µm

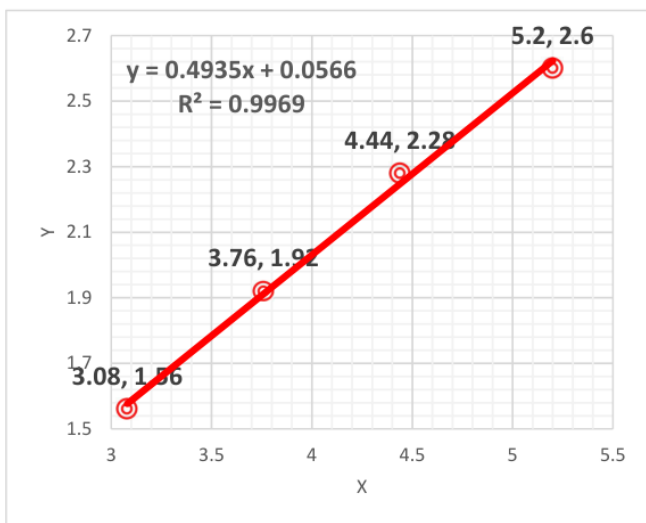
$w = 50.78$ µm

C.3 $\phi = 27°$ 1.0 pt

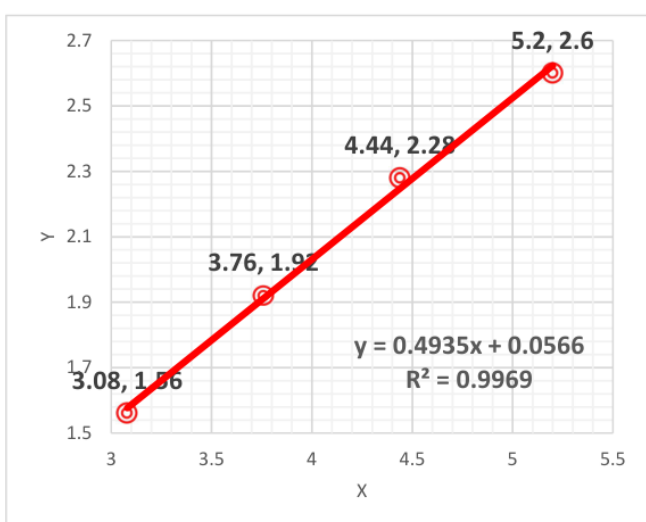
$\boldsymbol{\lambda}$ = **488 nm** Axis 1 (long) ϕ = **27.6°**



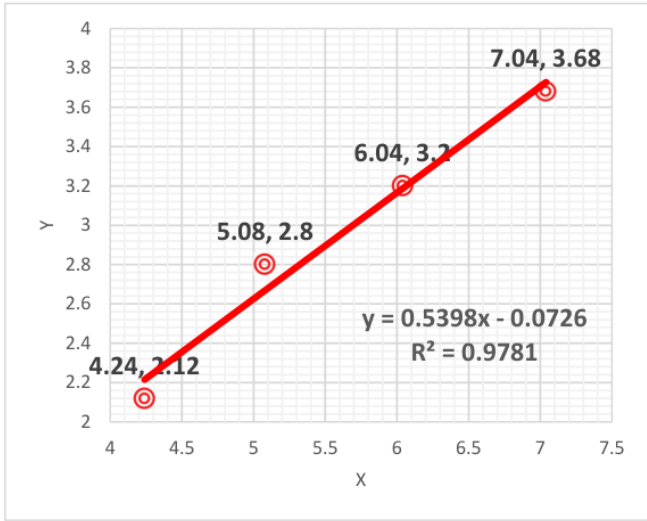
λ = **514 nm** Axis 1 (long) ϕ = **26.2°**



λ = **632.8 nm** Axis 1 (long) ϕ = **27.7**



λ = **694.3 nm** Axis 1 (long) ϕ = **28.4**



Part D. Exploration of sample structure size

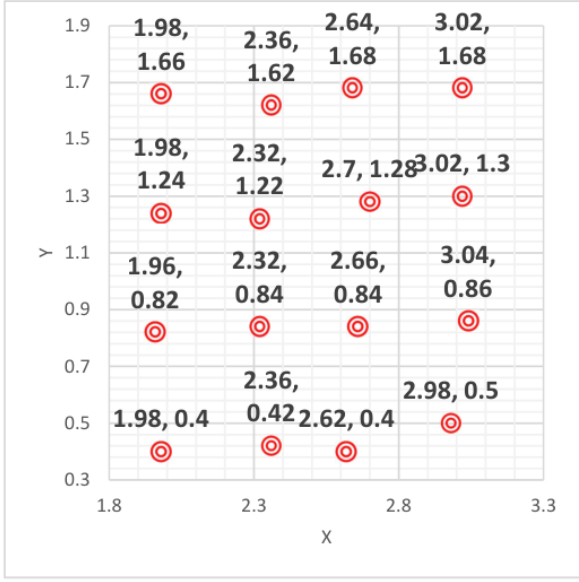
D.1 1.9 pt

Laser wavelength $\boldsymbol{\lambda}$ = **914 nm**			
The center coordinates of the fine diffraction bright spot (x, y) long			
(1.98, 0.40)	**(2.36, 1.62)**	**(2.64, 1.68)**	**(3.02, 1.68)**
(1.96, 0.82)	**(2.32, 1.22)**	**(2.70, 1.28)**	**(3.02, 1.30)**
(1.98, 1.24)	**(2.32, 0.84)**	**(2.66, 0.84)**	**(3.04, 1.66)**
(1.98, 1.66)	**(2.36, 0.42)**	**(2.62, 0.40)**	**(2.98, 0.50)**
The center coordinates of the fine diffraction bright spot (x, y) short			
(-2.06, 3.48)	**(-1.72, 3.48)**	**(-1.38, 3.46)**	**(-1.06, 3.46)**
(-2.08, 3.08)	**(-1.74, 3.08)**	**(-1.40, 3.14)**	**(-1.00, 3.12)**
(-2.08, 2.64)	**(-1.74, 2.65)**	**(-1.38, 2.62)**	**(-1.02, 2.62)**
(-2.06, 2.16)	**(-1.68, 2.22)**	**(-1.36, 2.22)**	**(-1.02, 2.14)**
Calculate the distances between adjacent spots ΔS_x 、ΔS_y			

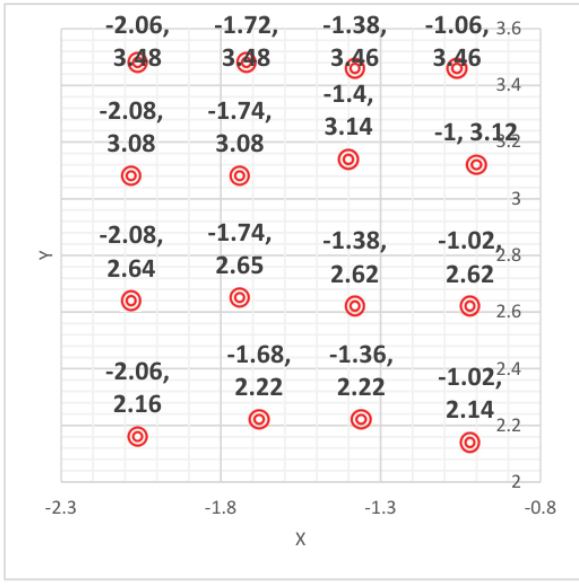
	$\boldsymbol{\Delta S_x}$ **(cm)**	$\boldsymbol{\Delta S_y}$ **(cm)**
long	**0.346**	**0.410**
short	**0.348**	**0.428**

D.1.

long



short



Laser wavelength $\boldsymbol{\lambda}$ = **1152 nm**

The center coordinates of the fine diffraction bright spot (x, y) long

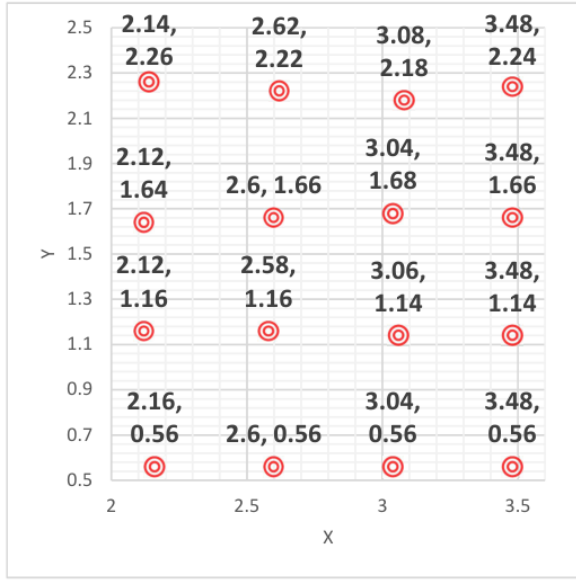
(2.16, 0.56)	**(2.60, 0.56)**	**(3.04, 0.56)**	**(3.48, 0.56)**
(2.12, 1.16)	**(2.58, 1.16)**	**(3.06, 1.14)**	**(3.48, 1.12)**
(2.12, 1.64)	**(2.60, 1.66)**	**(3.04, 1.68)**	**(3.48, 1.66)**
(2.14, 2.26)	**(2.62, 2.22)**	**(3.08, 2.18)**	**(3.48, 2.24)**

The center coordinates of the fine diffraction bright spot (x, y) **short**

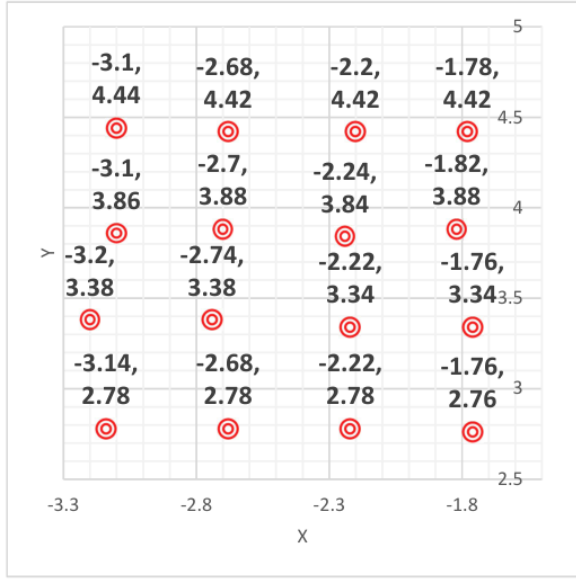
(-3.44, 4.44)	**(-2.68, 4.42)**	**(-2.20, 4.42)**	**(-1.78, 4.42)**
(-3.10, 3.86)	**(-2.70, 3.88)**	**(-2.24, 3.84)**	**(-1.82, 3.88)**
(-3.20, 3.38)	**(-2.74, 3.38)**	**(-2.22, 3.34)**	**(-1.76, 3.34)**
(-3.14, 2.78)	**(-2.68, 2.78)**	**(-2.22, 2.78)**	**(-1.76, 2.76)**

	ΔS_x (cm)	ΔS_y (cm)
long	**0.448**	**0.555**
short	**0.452**	**0.550**

long


2.14, 2.26
2.62, 2.22
3.08, 2.18
3.48, 2.24
2.12, 1.64
2.6, 1.66
3.04, 1.68
3.48, 1.66
2.12, 1.16
2.58, 1.16
3.06, 1.14
3.48, 1.14
2.16, 0.56
2.6, 0.56
3.04, 0.56
3.48, 0.56
2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
Y
2
2.5
3
3.5
X

short


-3.1, 4.44
-2.68, 4.42
-2.2, 4.42
-1.78, 4.42
-3.1, 3.86
-2.7, 3.88
-2.24, 3.84
-1.82, 3.88
-3.2, 3.38
-2.74, 3.38
-2.22, 3.34
-1.76, 3.34
-3.14, 2.78
-2.68, 2.78
-2.22, 2.78
-1.76, 2.76
5
4.5
4
3.5
3
2.5
Y
-3.3
-2.8
-2.3
-1.8
X

Laser wavelength $\boldsymbol{\lambda}$ = **1444 nm**

The center coordinates of the fine diffraction bright spot (x, y) long

(3.34, 0.02)	**(3.86, 0.02)**	**(4.42, 0.02)**	**(4.94, 0.04)**
(3.34, 0.70)	**(3.84, 0.72)**	**(4.42, 0.70)**	**(4.94, 0.74)**
(3.36, 1.42)	**(3.86, 1.42)**	**(4.44, 1.40)**	**(5.00, 1.46)**
(3.34, 2.08)	**(3.86, 2.08)**	**(4.48, 2.08)**	**(5.00, 2.10)**

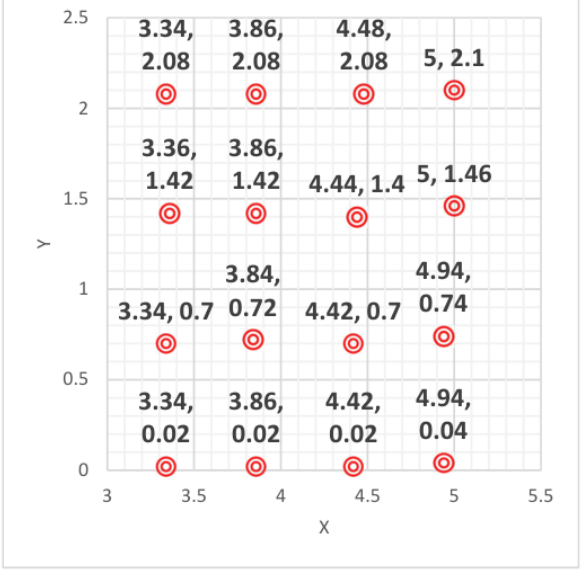
The center coordinates of the fine diffraction bright spot (x, y) **short**

(-3.86, 4.16)	**(-3.32, 4.18)**	**(-2.74, 4.18)**	**(-2.14, 4.16)**
(-3.84, 3.48)	**(-3.28, 3.48)**	**(-2.72, 3.48)**	**(-2.12, 3.48)**
(-3.80, 2.78)	**(-3.26, 2.78)**	**(-2.72, 2.78)**	**(-2.12, 2.80)**
(-3.78, 2.02)	**(-3.26, 2.06)**	**(-2.70, 2.06)**	**(-2.00, 1.98)**

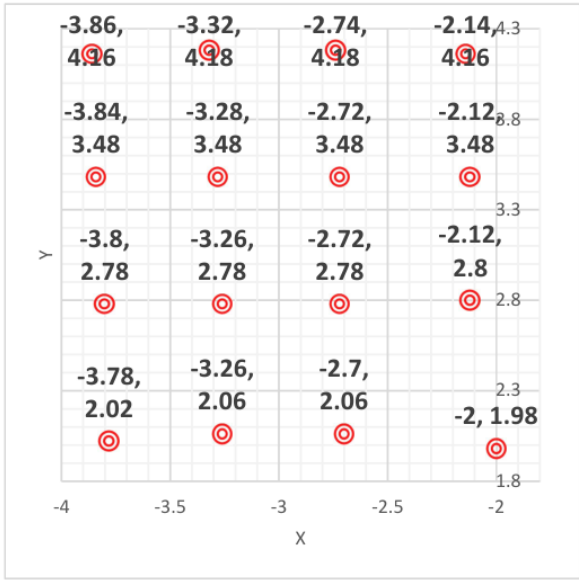
計算圖形斑點間距 ΔS_x 、ΔS_y **0.5 pt**

	$\boldsymbol{\Delta S_x}$ **(cm)**	$\boldsymbol{\Delta S_y}$ **(cm)**
long	**0.542**	**0.687**
short	**0.575**	**0.713**

long



short



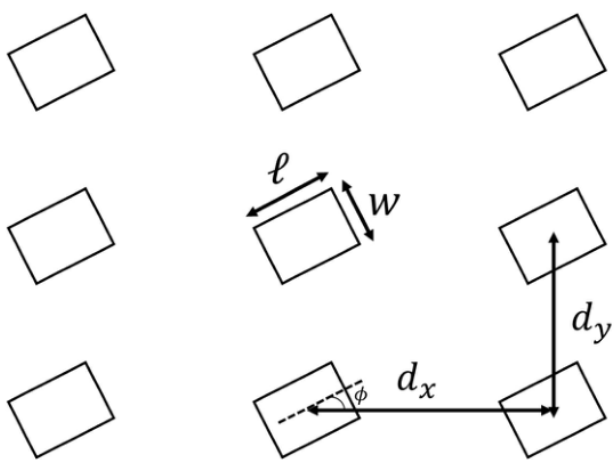
D.2 0.6 pt

$d_x = 249.3$ μm $d_y = 198.2$ μm

λ (nm)		**d_x (μm)**	**d_y (μm)**
914	**long Axis**	**251**	**211**
	short Axis	**250**	**203**
1152	**long Axis**	**244**	**197**
	short Axis	**242**	**199**
1444	**long Axis**	**253**	**199**
	short Axis	**239**	**192**

Part E. Exploration of sample structure size

E.1. 1.0 pt



$(a, \ell, w, d_x, d_y, \phi) =$
(5.627 um, 58.59 um, 50.78 um, 249.3 um, 198.2 um, 27 degree)