Experiment

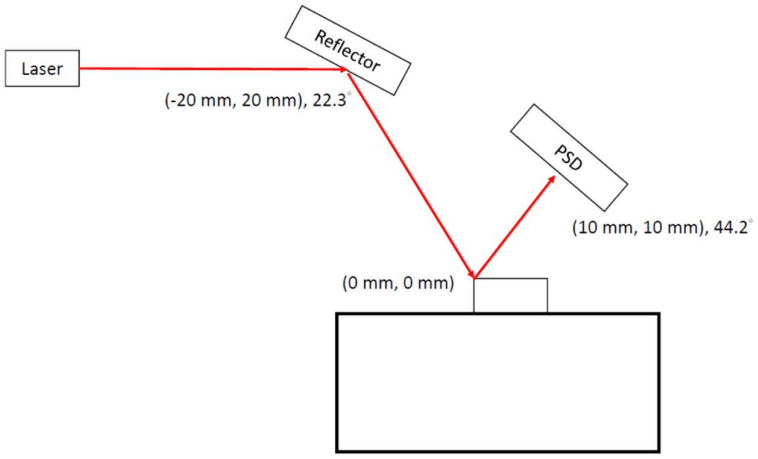
A1-1

中文 (Official)

Elasticity of cantilever

Part A. Alignment of light path

A1. 0.6 pt



A2. 0.8 pt

time (s)	position d (m)	time (s)	position d (m)	time (s)	position d (m)
3	-6.415×10^{-4}	48	1.198×10^{-4}	93	6.85×10^{-5}
6	5.261×10^{-4}	51	-4.46×10^{-5}	96	7.36×10^{-5}
9	4.843×10^{-4}	54	1.488×10^{-4}	99	8.73×10^{-5}
12	3.349×10^{-4}	57	-7.70×10^{-5}	102	7.93×10^{-5}
15	-5.386×10^{-4}	60	8.75×10^{-5}	105	6.39×10^{-5}
18	7.91×10^{-5}	63	1.604×10^{-4}	108	3.22×10^{-5}
21	-2.762×10^{-4}	66	-1.93×10^{-5}	111	6.05×10^{-5}
24	1.398×10^{-4}	69	1.159×10^{-4}	114	3.20×10^{-5}
27	-2.039×10^{-4}	72	7.10×10^{-5}	117	4.71×10^{-5}

30	-4.42×10^{-5}	75	3.6×10^{-6}	120	8.26×10^{-5}
33	-1.988×10^{-4}	78	-1.79×10^{-5}		
36	-2.77×10^{-5}	81	9.21×10^{-5}		
39	1.195×10^{-4}	84	6.00×10^{-5}		
42	1.960×10^{-4}	87	1.361×10^{-4}		
45	2.192×10^{-4}	90	5.72×10^{-5}		

A3. 1.0 pt

d (m)	$\bar{d}$ (m)	$d - \bar{d}$ (m)	standard deviation
6.85×10^{-5}	6.267×10^{-5}	5.5×10^{-6}	1.88×10^{-5}
7.36×10^{-5}		1.09×10^{-5}	
8.73×10^{-5}		2.46×10^{-5}	
7.93×10^{-5}		1.66×10^{-5}	
6.39×10^{-5}		1.2×10^{-6}	
3.22×10^{-5}		-3.05×10^{-5}	
6.05×10^{-5}		-2.2×10^{-6}	
3.20×10^{-5}		-3.07×10^{-5}	
4.71×10^{-5}		-1.56×10^{-5}	
8.26×10^{-5}		1.99×10^{-5}	

reference value of measurement (with standard deviation)：

$6.267 \times 10^{-5} \pm 1.88 \times 10^{-5}$ m

Experiment

A1-3

中文 (Official)

Part B. Deformation of cantilever beam and deduction of Young's modulus

B1. answer sheet. 1.0 pt

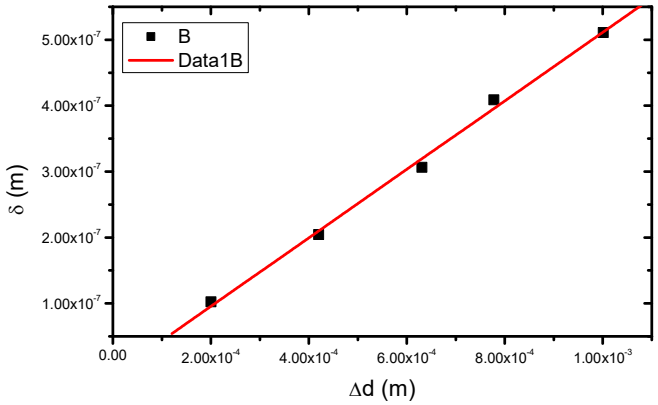
F (N)	d (m)	$\bar{d} = d_0$ (m)
0	-1.82×10^{-5}	-1.386×10^{-5}
	-1.09×10^{-5}	
	-6.69×10^{-5}	
	1.72×10^{-5}	
	9.5×10^{-6}	

F (N)	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
2.00×10^{-9}	1.9136×10^{-4}	2.0046×10^{-4}
	2.0016×10^{-4}	
	1.9766×10^{-4}	
	2.0096×10^{-4}	
	2.1216×10^{-4}	
4.00×10^{-9}	4.2336×10^{-4}	4.2018×10^{-4}
	4.1536×10^{-4}	
	4.3526×10^{-4}	
	4.0346×10^{-4}	
	4.2346×10^{-4}	
6.00×10^{-9}	6.4136×10^{-4}	6.3112×10^{-4}
	6.4646×10^{-4}	
	6.4256×10^{-4}	
	6.2186×10^{-4}	
	6.0336×10^{-4}	
8.00×10^{-9}	7.1906×10^{-4}	7.7770×10^{-4}
	7.8006×10^{-4}	
	8.0506×10^{-4}	
	7.7736×10^{-4}	
	8.0696×10^{-4}	

1.000×10^{-8}	1.01216×10^{-3}	1.00106×10^{-3}
	1.00076×10^{-3}	
	1.00336×10^{-3}	
	9.7846×10^{-4}	
	1.01076×10^{-3}	

B2. 1.0 pt

F (N)	δ (m)	$\overline{\Delta d}$ (m)
2.00×10^{-9}	1.022×10^{-7}	2.0046×10^{-4}
4.00×10^{-9}	2.044×10^{-7}	4.2018×10^{-4}
6.00×10^{-9}	3.066×10^{-7}	6.3112×10^{-4}
8.00×10^{-9}	4.088×10^{-7}	7.7770×10^{-4}
1.000×10^{-8}	5.109×10^{-7}	1.00106×10^{-3}



B3. 0.4 pt

$C_1 = 5.196 \times 10^{-4}$

Experiment

A1-5

中文 (Official)

Part C. Double layer cantilever beam

C1. 1.0 pt

T (K)	d (m)	$\bar{d} = d_0$ (m)
300	-2.28×10^{-5}	-2.836×10^{-5}
	-7.24×10^{-5}	
	-1.61×10^{-5}	
	-2.84×10^{-5}	
	-2.1×10^{-6}	

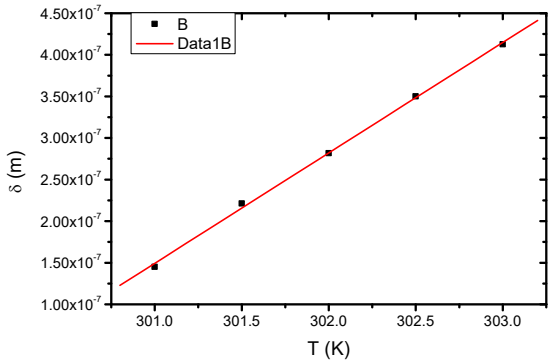
T (K)	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
301	2.8506×10^{-4}	2.7928×10^{-4}
	2.7186×10^{-4}	
	2.7466×10^{-4}	
	2.7436×10^{-4}	
	2.9046×10^{-4}	
301.5	4.1276×10^{-4}	4.2568×10^{-4}
	4.1336×10^{-4}	
	4.6276×10^{-4}	
	4.3956×10^{-4}	
	3.9996×10^{-4}	
302	5.4146×10^{-4}	5.4186×10^{-4}
	5.4676×10^{-4}	
	5.3386×10^{-4}	
	5.6706×10^{-4}	
	5.2016×10^{-4}	
302.5	6.9866×10^{-4}	6.7330×10^{-4}
	6.6726×10^{-4}	
	6.6416×10^{-4}	
	6.8296×10^{-4}	
	6.5346×10^{-4}	
303	7.6026×10^{-4}	7.9410×10^{-4}

	7.7046×10^{-4}	
	7.9706×10^{-4}	
	8.1346×10^{-4}	
	8.2926×10^{-4}	

C2. 1.0 pt

T (K)	$\overline{\Delta d}$ (m)	δ (m)
301	2.7928×10^{-4}	1.451×10^{-7}
301.5	4.2568×10^{-4}	2.212×10^{-7}
302	5.4186×10^{-4}	2.816×10^{-7}
302.5	6.7330×10^{-4}	3.499×10^{-7}
303	7.9410×10^{-4}	4.127×10^{-7}

Slope: 1.337×10^{-7}



C3. 0.6 pt

4.98×10^{10} N/m^2 (Pa)

Experiment

A1-7

中文 (Official)

Part D. Test of molecular-absorption-induced bending of a cantilever beam

D1. 0.6 pt

	d (m)	$\bar{d} = d_0$ (m)
Sample 0	3.4×10^{-6}	-7.2×10^{-6}
	-1.15×10^{-5}	
	-1.61×10^{-5}	
	2.09×10^{-5}	
	-3.25×10^{-5}	

	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
Sample 1	-8.2414×10^{-4}	-8.2552×10^{-4}
	-8.2884×10^{-4}	
	-8.2794×10^{-4}	
	-8.1934×10^{-4}	
	-8.2584×10^{-4}	

D2. Assume the function form of the displacement and coverage ratio (CR) 0.6 pt

can be expressed as： $\delta = C_2 \frac{CoverageRatio}{EI^*} L^4$. Estimate C_2 based on your data obtained in A9. You can use the correlation between δ and $\overline{\Delta d}$ in A6.

-7.89×10^{-2}

Experiment

A1-8

中文 (Official)

D3. 0.8 pt

	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
Sample 2	-6.1734×10^{-4}	-6.0866×10^{-4}
	-6.0434×10^{-4}	
	-6.0054×10^{-4}	
	-5.9884×10^{-4}	
	-6.2224×10^{-4}	
	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
Sample 3	-2.4924×10^{-4}	-2.4588×10^{-4}
	-2.6224×10^{-4}	
	-2.4764×10^{-4}	
	-2.4854×10^{-4}	
	-2.2174×10^{-4}	

D4. 0.6 pt

Sample 2: 0.738%

Sample 3: 0.298%

Experiment
Solution

A2

English

Q2 Exploring the spatial structure of the sample with optical methods

Solution

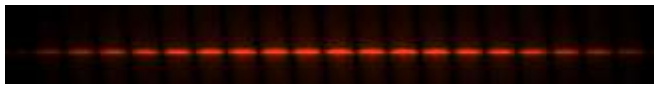
Part A. Collimation of light and sample

A.1 0.5 pt

(X_{sample}, Y_{sample})= **(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

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

Experiment
Solution

A2

English

B.2 1.5 pt

L = **60 cm**

λ = **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)	$\mathbf{6.02 \pm 0.11}$				
$tan^{-1}\left(\frac{\bar{S}}{L}\right)$	$\mathbf{0.0999 \pm 0.0019}$				

λ = **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)	$\mathbf{6.37 \pm 0.11}$				
$tan^{-1}\left(\frac{\bar{S}}{L}\right)$	$\mathbf{0.1057 \pm 0.0019}$				

λ = **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)	$\mathbf{7.81 \pm 0.14}$				
$tan^{-1}\left(\frac{\bar{S}}{L}\right)$	$\mathbf{0.1294 \pm 0.0023}$				

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)	$\mathbf{8.73 \pm 0.13}$
$tan^{-1}\left(\frac{\bar{S}}{L}\right)$	$\mathbf{0.1444 \pm 0.0021}$

B.3 1.0 pt

$$a = 5.627\ \mu m$$

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)	$\mathbf{5.627 \pm 0.020}$	

Experiment
Solution

A2

English

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**

$\lambda =$ **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**

Experiment
Solution

A2

English

λ = **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**

Experiment
Solution

A2

English

C.2 0.7 pt

λ (nm)	ΔS_ℓ (cm)	ℓ (µm)	ΔS_w (cm)	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

$$\ell = 58.59\ \mu\text{m}$$
$$w = 50.78\ \mu\text{m}$$

Experiment

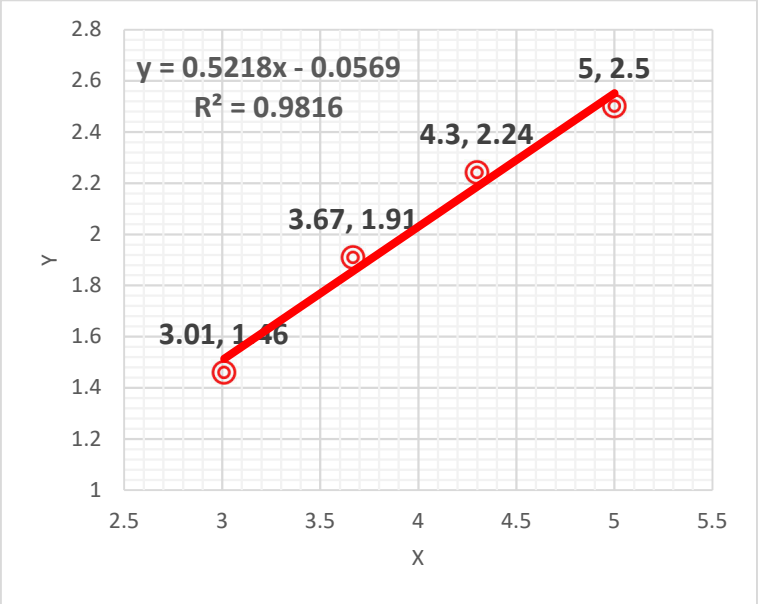
Solution

A2

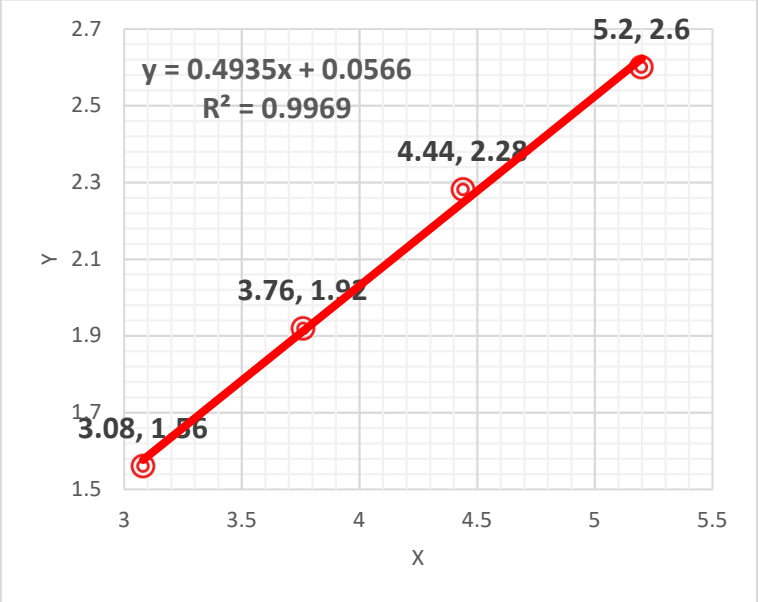
English

C.3 $\phi = 27°$ 1.0 pt

$\lambda =$ **488 nm** Axis 1 (long) $\phi =$ **27.6°**



$\lambda =$ **514 nm** Axis 1 (long) $\phi =$ **26.2°**



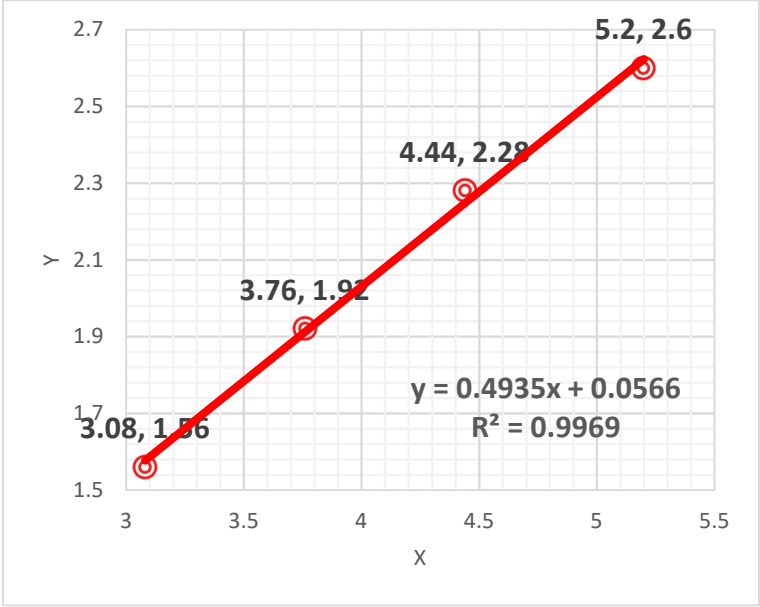
Experiment

Solution

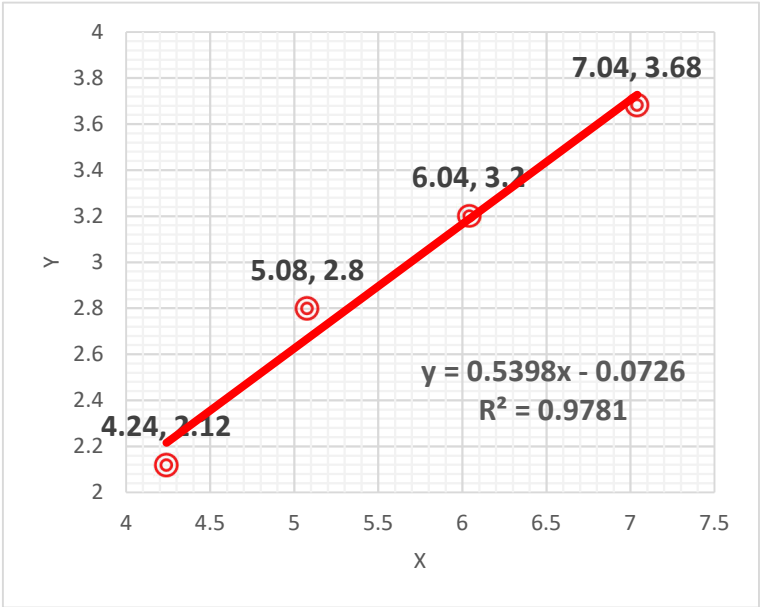
A2

English

$\lambda =$ **632.8 nm** Axis 1 (long) $\phi =$ **27.7**



$\lambda =$ **694.3 nm** Axis 1 (long) $\phi =$ **28.4**



Experiment
Solution

A2

English

Part D. Exploration of sample structure size

D.1 1.9 pt

Laser wavelength λ = **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			

	ΔS_x (cm)	ΔS_y (cm)
long	**0.346**	**0.410**
short	**0.348**	**0.428**

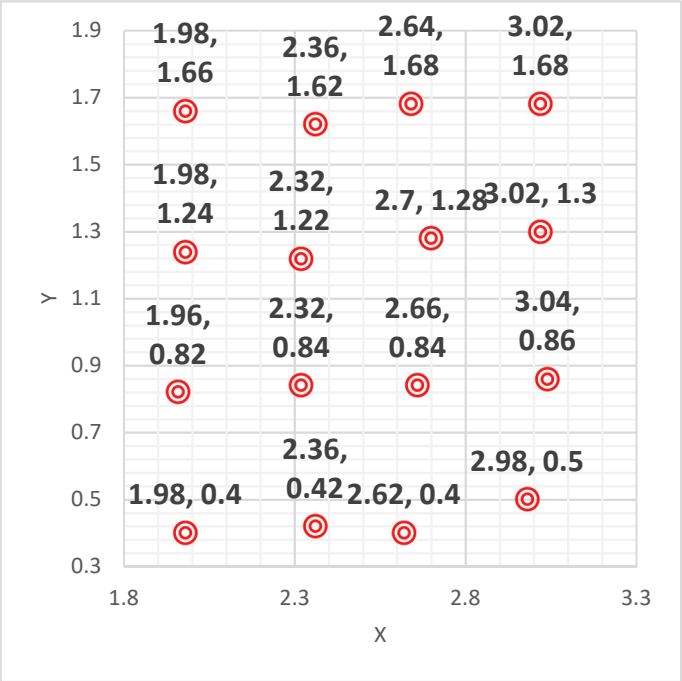
Experiment Solution

A2

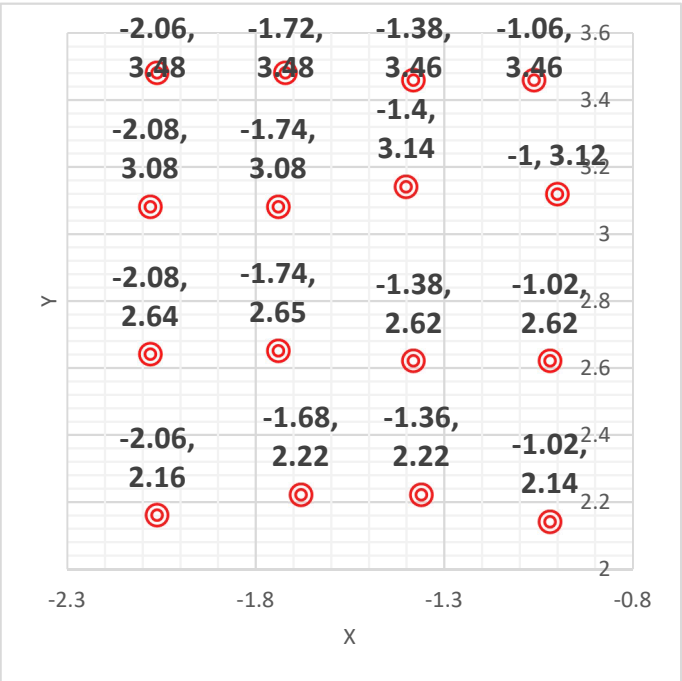
English

D.1.

long



short



Experiment Solution

A2

English

Laser wavelength λ = **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)**

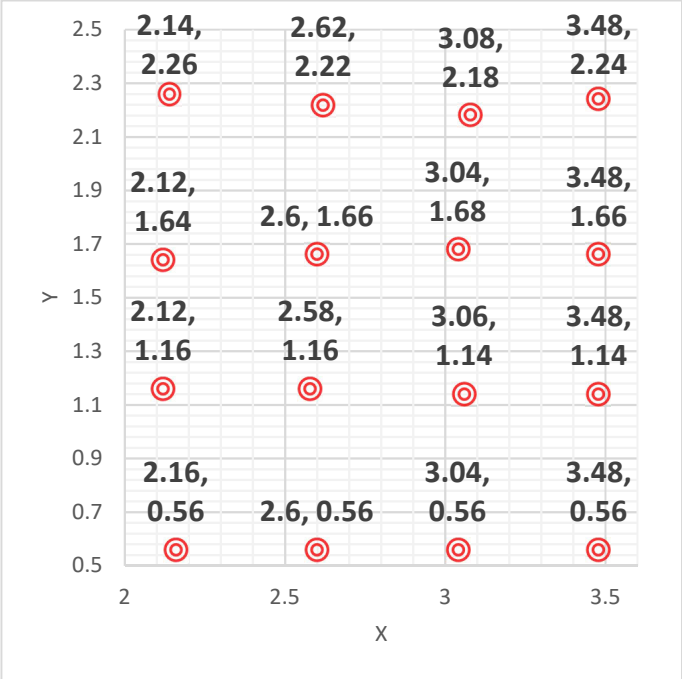
	ΔS_x (cm)	ΔS_y (cm)
long	**0.448**	**0.555**
short	**0.452**	**0.550**

Experiment Solution

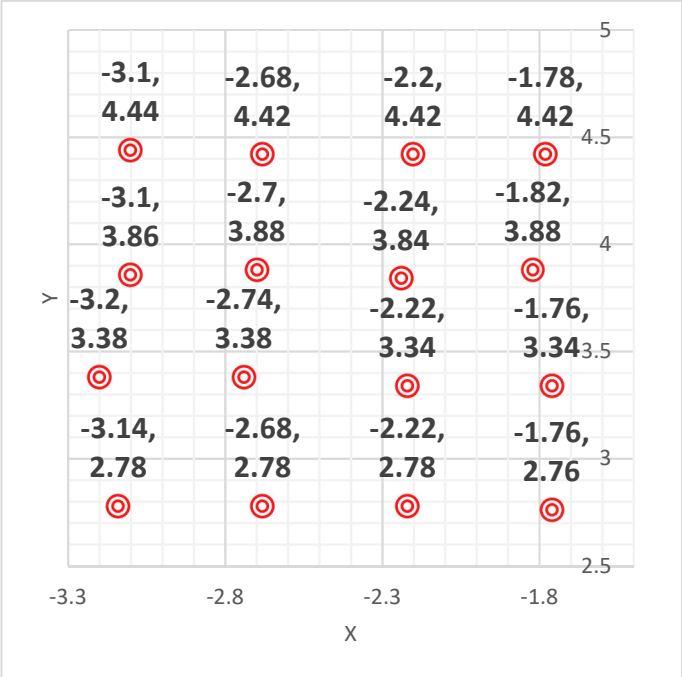
A2

English

long



short



Experiment Solution

A2

English

Laser wavelength λ = **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**

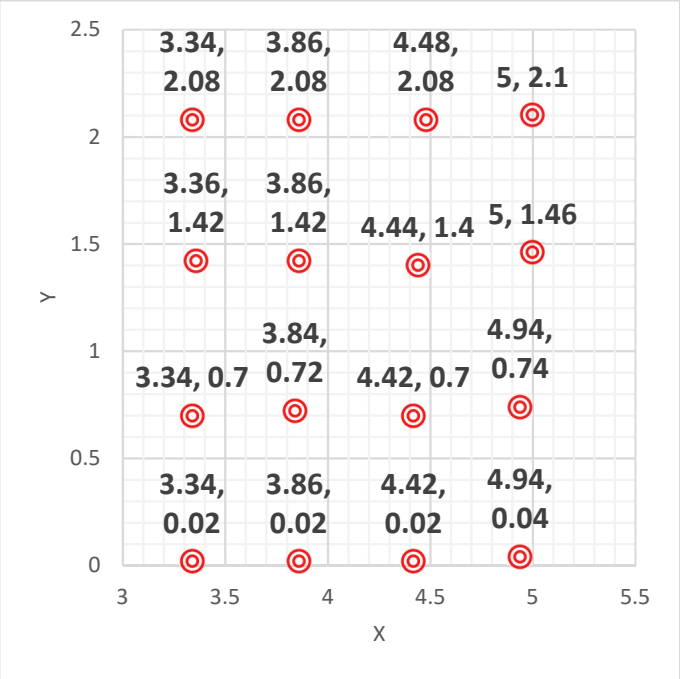
	ΔS_x (cm)	ΔS_y (cm)
long	**0.542**	**0.687**
short	**0.575**	**0.713**

Experiment Solution

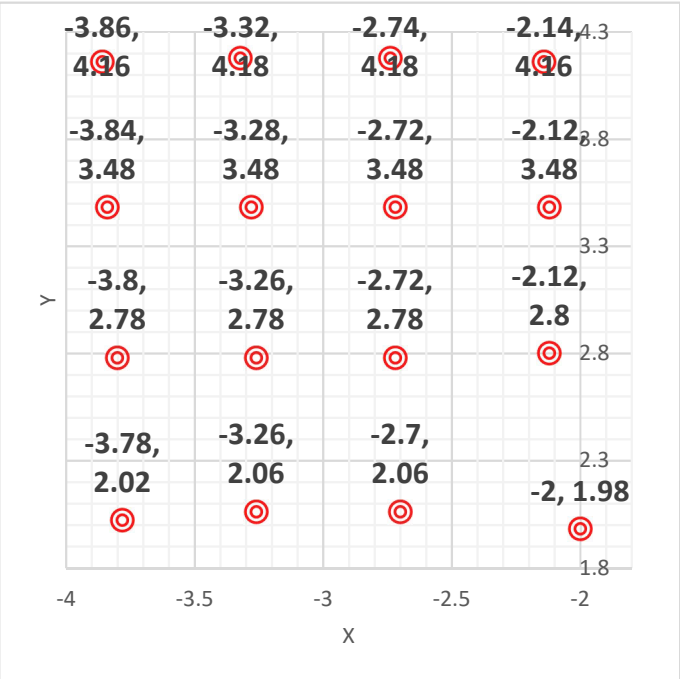
A2

English

long



short



Experiment

Solution

A2

English

D.2 0.6 pt

$d_x = 249.3\ \mu m$ $d_y = 198.2\ \mu m$

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

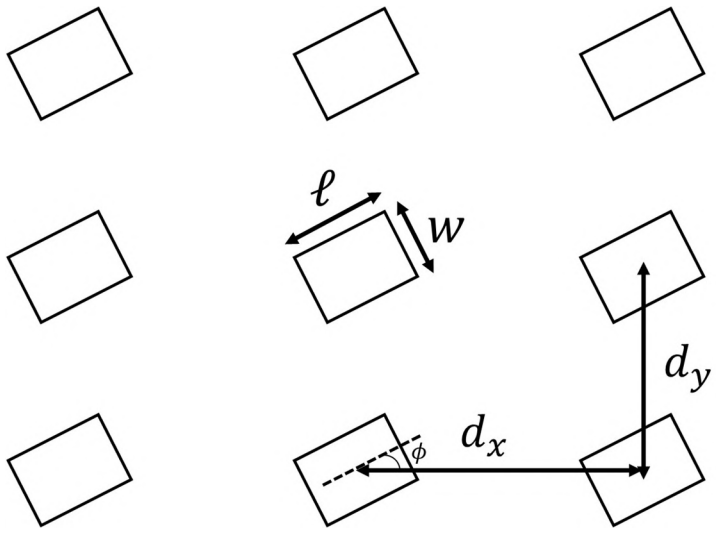
Experiment
Solution

A2

English

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)