

Experiment



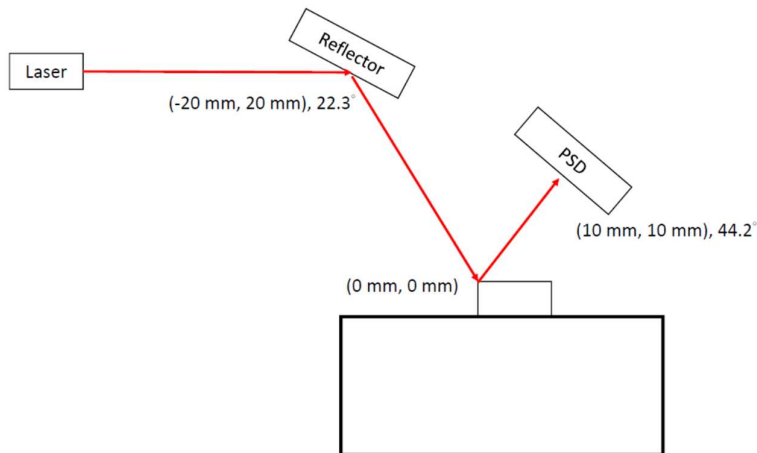
A1-1

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}

Experiment



A1-2

中文 (Official)

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) :

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

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}	

Experiment



A1-4

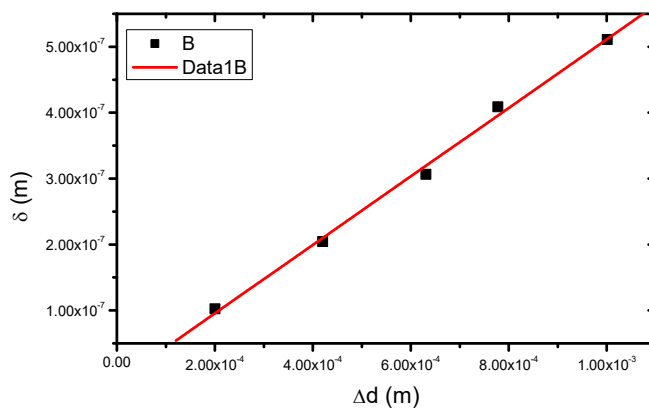
中文 (Official)

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}	

Experiment



A1-6

中文 (Official)

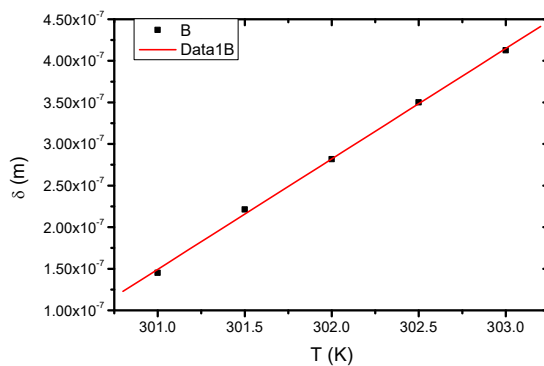
	7.7046×10^{-4}	
	7.9706×10^{-4}	
	8.1346×10^{-4}	
	8.2926×10^{-4}	

C2.

1.0 pt

T (K)	Δd (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

$4.98 \times 10^{10} \text{ N/m}^2$ (Pa)

Experiment



A1-7

中文 (Official)

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

D1.

0.6 pt

Sample 0	d (m)	$\bar{d} = d_0$ (m)
	3.4×10^{-6}	-7.2×10^{-6}
	-1.15×10^{-5}	
	-1.61×10^{-5}	
	2.09×10^{-5}	
	-3.25×10^{-5}	
Sample 1	$d - d_0 = \Delta d$ (m)	$\bar{\Delta d}$ (m)
	-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 $\bar{\Delta d}$ in A6.

$$\underline{-7.89 \times 10^{-2}}$$

Experiment



A1-8

中文 (Official)

D3.

0.8 pt

Sample 2	$d - d_0 = \Delta d \text{ (m)}$	$\overline{\Delta d} \text{ (m)}$
	-6.1734×10^{-4}	-6.0866×10^{-4}
	-6.0434×10^{-4}	
	-6.0054×10^{-4}	
	-5.9884×10^{-4}	
	-6.2224×10^{-4}	
Sample 3	$d - d_0 = \Delta d \text{ (m)}$	$\overline{\Delta d} \text{ (m)}$
	-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

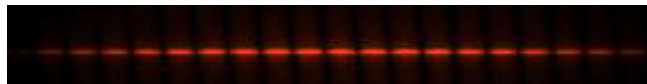
0.5 pt

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

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

$$L = \underline{\underline{60 \text{ cm}}}$$

$$\lambda = \underline{\underline{488 \text{ nm}}}$$

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)	6.02 ± 0.11				
$\tan^{-1}\left(\frac{\bar{S}}{L}\right)$	0.0999 ± 0.0019				

$$\lambda = \underline{\underline{514 \text{ nm}}}$$

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)	6.37 ± 0.11				
$\tan^{-1}\left(\frac{\bar{S}}{L}\right)$	0.1057 ± 0.0019				

$$\lambda = \underline{\underline{632.8 \text{ nm}}}$$

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)	7.81 ± 0.14				
$\tan^{-1}\left(\frac{\bar{S}}{L}\right)$	0.1294 ± 0.0023				

$$\lambda = \underline{\underline{694.3 \text{ nm}}}$$

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

Experiment Solution

A2

English



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

B.3

1.0 pt

$$a = 5.627 \mu\text{m}$$

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)	5.627 ± 0.020	

Experiment Solution

A2

English



Part C. Exploration of sample structure size

C.1

0.8 pt

$\lambda =$ 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

$\lambda =$ 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

Experiment

Solution

A2

English



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

$\lambda = \underline{\underline{632.8 \text{ nm}}}$

L=90 cm, Axis 1				
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



$$\lambda = \underline{\underline{694.3 \text{ nm}}}$$

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

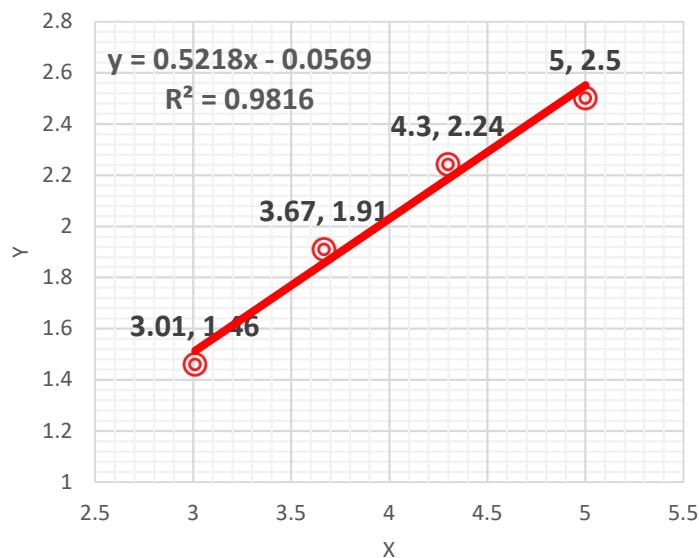
English



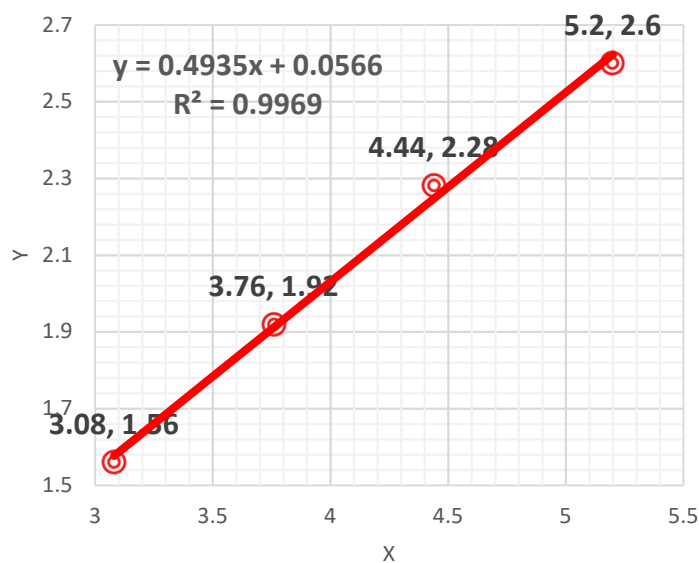
C.3 $\phi = 27^\circ$

1.0 pt

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



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



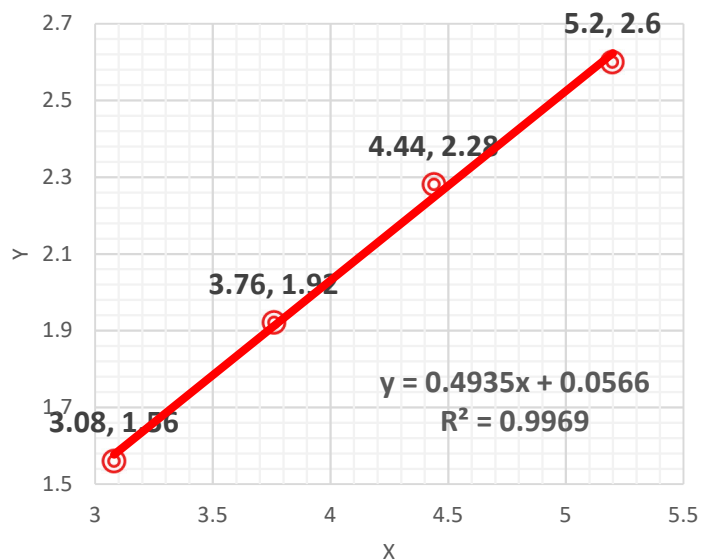
Experiment Solution

A2

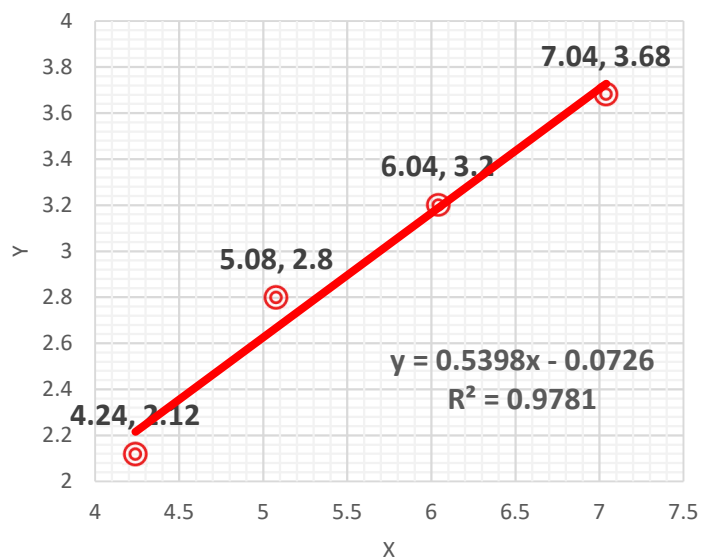
English



$\lambda = \underline{632.8 \text{ nm}}$ Axis 1 (long) $\phi = \underline{27.7}$



$\lambda = \underline{694.3 \text{ nm}}$ Axis 1 (long) $\phi = \underline{28.4}$



Experiment

Solution

A2

English



Part D. Exploration of sample structure size

D.1

1.9 pt

Laser wavelength $\lambda = \underline{914 \text{ nm}}$			
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

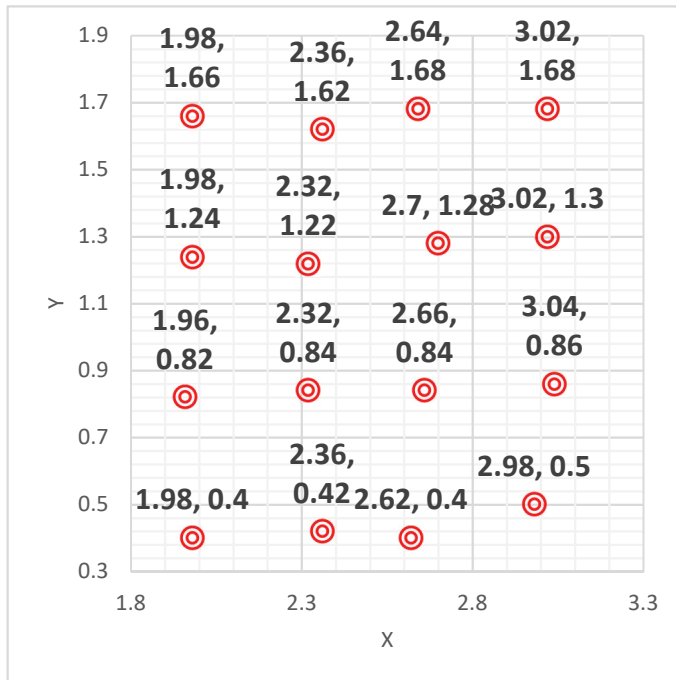
A2

English

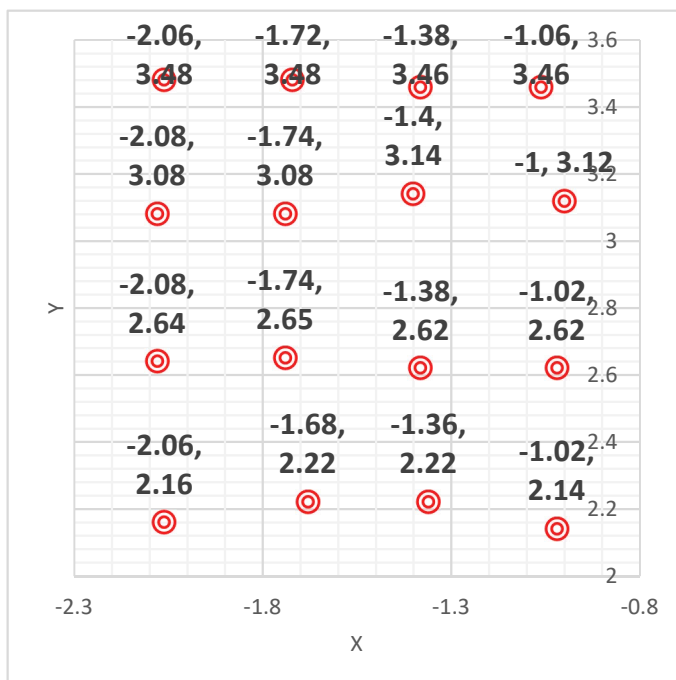


D.1.

long



short



Experiment Solution

A2

English



Laser wavelength $\lambda =$ 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

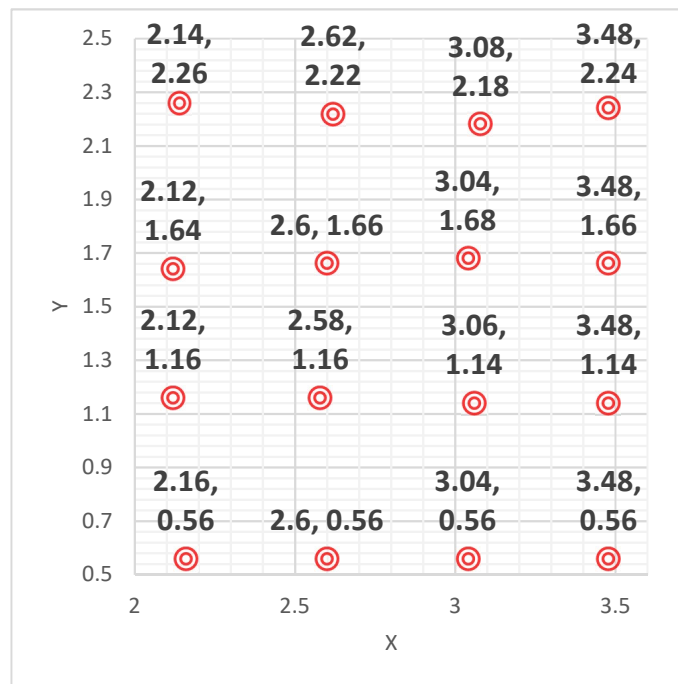
Experiment Solution

A2

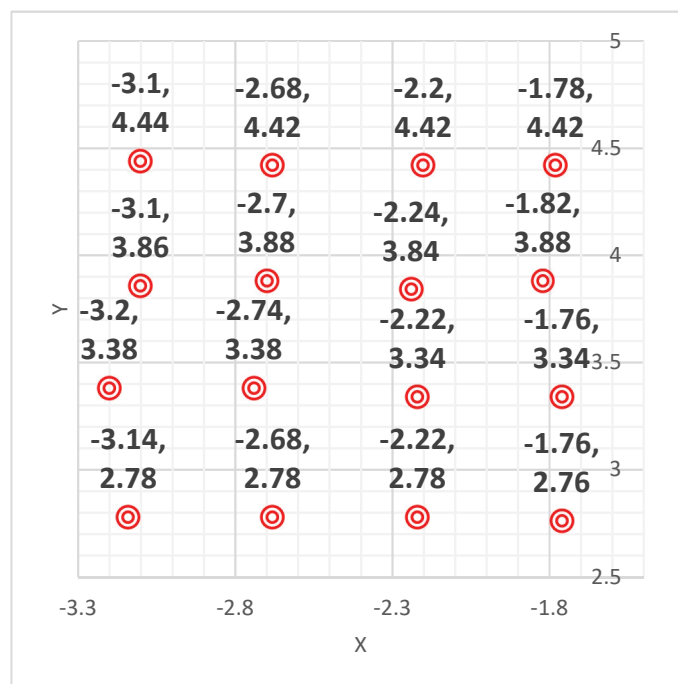
English



long



short



Experiment Solution

A2

English



Laser wavelength $\lambda =$ <u>1444 nm</u>			
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	

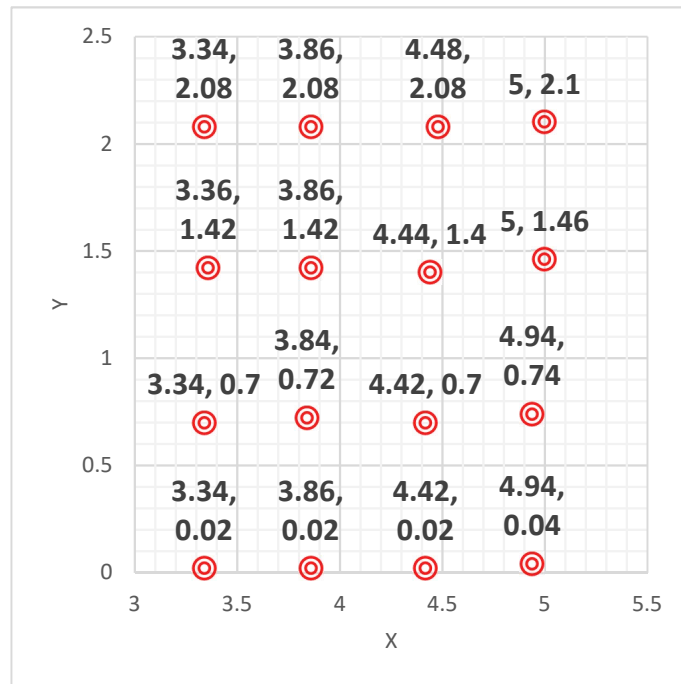
Experiment Solution

A2

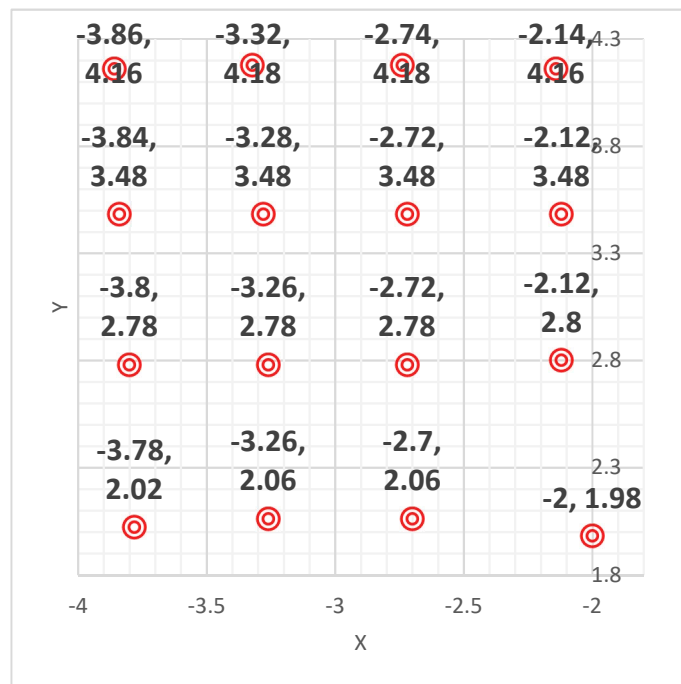
English



long



short



Experiment Solution

A2

English



D.2

0.6 pt

$$d_x = 249.3 \mu\text{m} \quad d_y = 198.2 \mu\text{m}$$

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

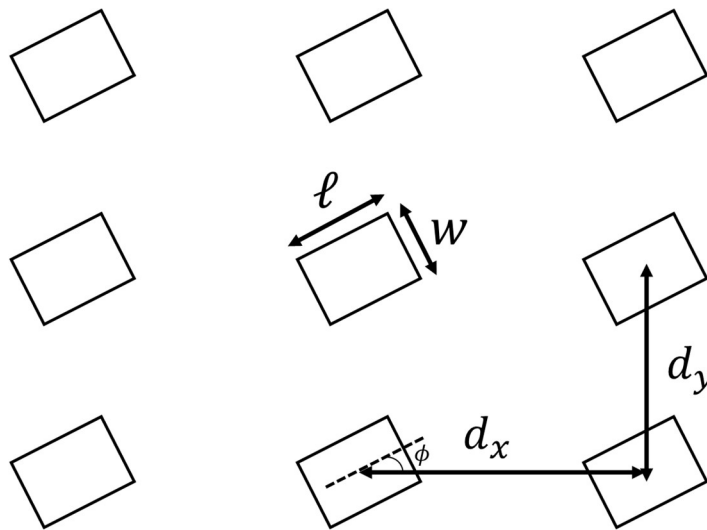
English



Part E. Exploration of sample structure size

E.1.

1.0 pt



$(a, \ell, w, d_x, d_y, \phi) =$

(5.627 μm , 58.59 μm , 50.78 μm , 249.3 μm , 198.2 μm , 27 degree)