

# 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

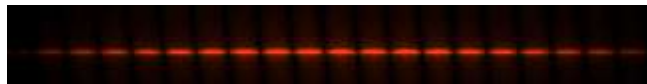
0.5 pt

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

A.2

0.5 pt

Interference pattern:



Order, fringe	-2, Dark	-1, Dark	1, Dark	2, Dark
$(x, y)$	<b>(-0.98, 0)</b>	<b>(-0.38, 0)</b>	<b>(0.34, 0)</b>	<b>(0.98, 0)</b>
$S$ (cm)	<b>0.98</b>	<b>0.38</b>	<b>0.34</b>	<b>0.98</b>
$\Delta S$ (cm)	<b>0.65</b>			

### Part B. Exploration of sample structure size

B.1

0.5 pt

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

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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)	<b>6.18</b>	<b>6.26</b>	<b>6.15</b>	<b>5.78</b>	<b>5.71</b>
$\bar{S}$ (cm)	<b>6.02 ± 0.11</b>				
$\tan^{-1}\left(\frac{\bar{S}}{L}\right)$	<b>0.0999 ± 0.0019</b>				

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

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)	<b>6.54</b>	<b>6.18</b>	<b>6.63</b>	<b>6.45</b>	<b>6.03</b>
$\bar{S}$ (cm)	<b>6.37 ± 0.11</b>				
$\tan^{-1}\left(\frac{\bar{S}}{L}\right)$	<b>0.1057 ± 0.0019</b>				

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

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)	<b>8.08</b>	<b>7.47</b>	<b>7.94</b>	<b>8.08</b>	<b>7.47</b>
$\bar{S}$ (cm)	<b>7.81 ± 0.14</b>				
$\tan^{-1}\left(\frac{\bar{S}}{L}\right)$	<b>0.1294 ± 0.0023</b>				

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

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)	<b>8.74</b>	<b>8.24</b>	<b>8.83</b>	<b>8.89</b>	<b>8.93</b>

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

B.3

1.0 pt

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

$\lambda$ (nm)	$d$ ( $\mu\text{m}$ )	$a$ ( $\mu\text{m}$ )
488	4.89	5.65
514	4.87	5.63
632.8	4.90	5.66
$\bar{a}$ ( $\mu\text{m}$ )	$5.627 \pm 0.020$	

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English



## Part C. Exploration of sample structure size

C.1

0.8 pt

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

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

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

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

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

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

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

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

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

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English



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

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

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

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C.2

0.7 pt

$\lambda$ (nm)	$\Delta S_\ell$ (cm)	$\ell$ ( $\mu\text{m}$ )	$\Delta S_w$ (cm)	$w$ ( $\mu\text{m}$ )
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

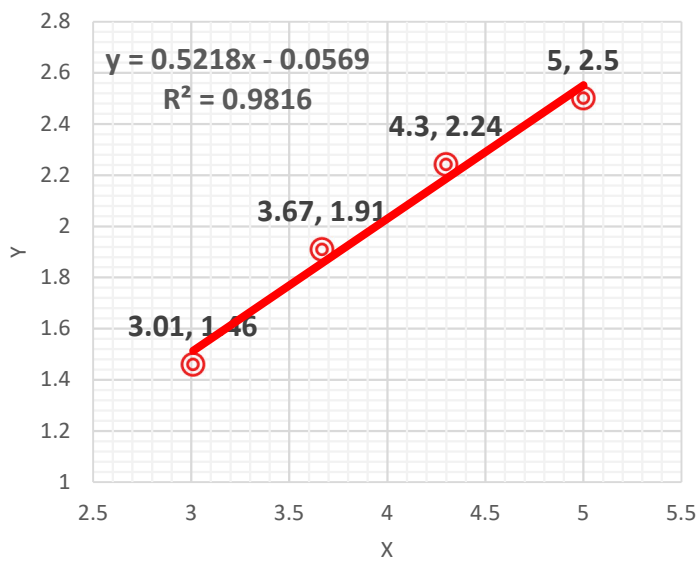
English



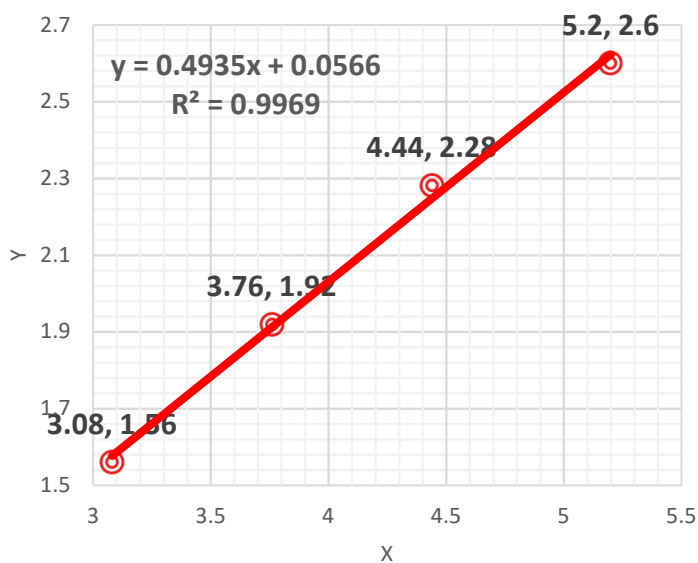
C.3  $\phi = 27^\circ$

1.0 pt

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



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





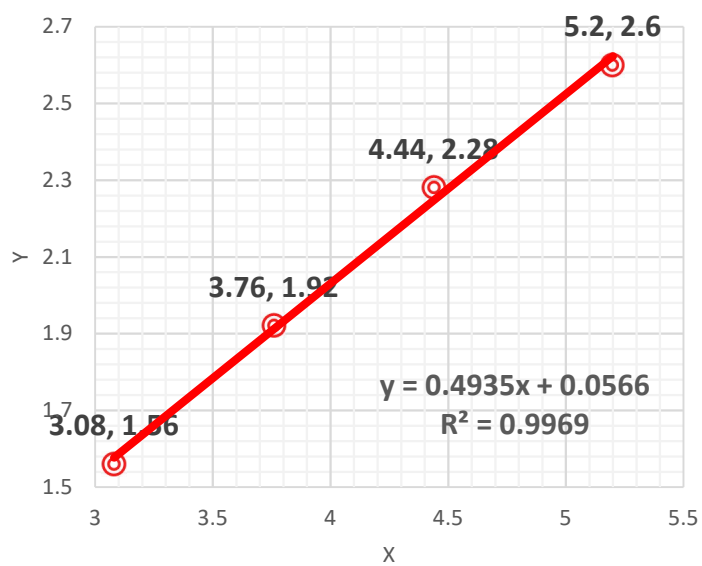
# Experiment Solution

# A2

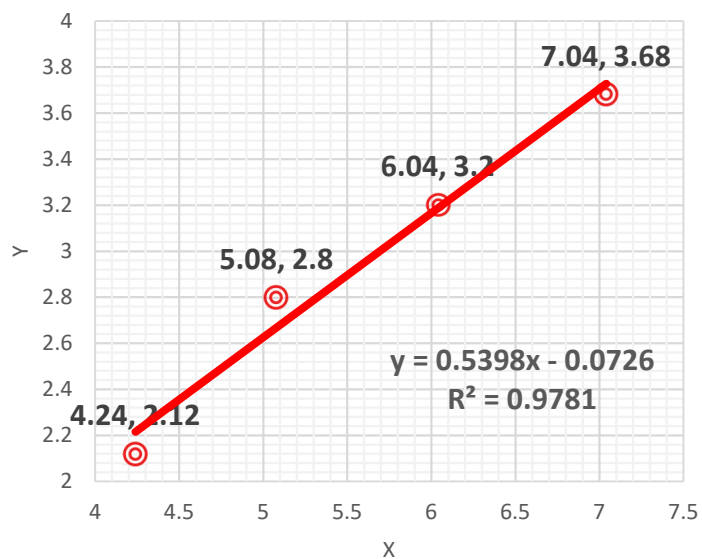
English



$\lambda = \underline{632.8 \text{ nm}}$  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  $\Delta S_x \cdot \Delta S_y$

	$\Delta S_x$ (cm)	$\Delta S_y$ (cm)
long	0.346	0.410
short	0.348	0.428

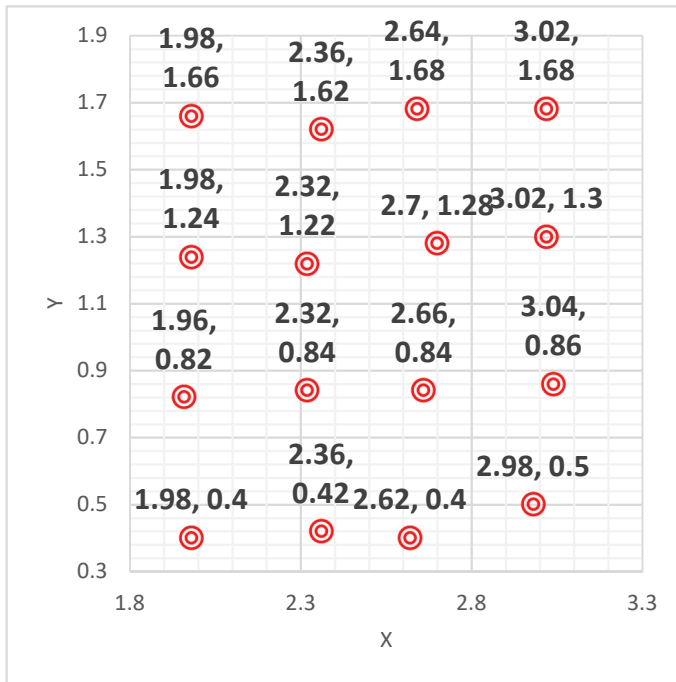
# Experiment Solution

# A2

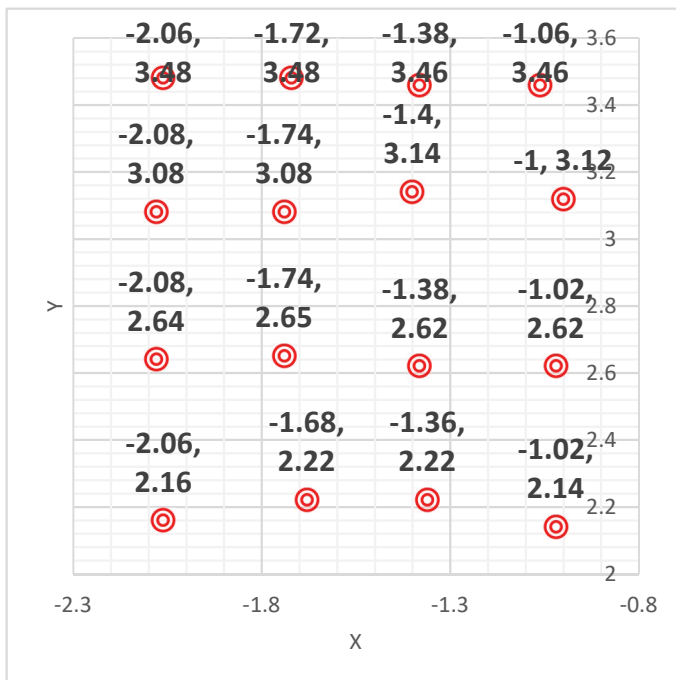
English



D.1.  
long



short



# Experiment Solution

# A2

English



Laser wavelength $\lambda = \underline{1152 \text{ nm}}$			
The center coordinates of the fine diffraction bright spot $(x, y)$ <b>long</b>			
<b>(2.16, 0.56)</b>	<b>(2.60, 0.56)</b>	<b>(3.04, 0.56)</b>	<b>(3.48, 0.56)</b>
<b>(2.12, 1.16)</b>	<b>(2.58, 1.16)</b>	<b>(3.06, 1.14)</b>	<b>(3.48, 1.12)</b>
<b>(2.12, 1.64)</b>	<b>(2.60, 1.66)</b>	<b>(3.04, 1.68)</b>	<b>(3.48, 1.66)</b>
<b>(2.14, 2.26)</b>	<b>(2.62, 2.22)</b>	<b>(3.08, 2.18)</b>	<b>(3.48, 2.24)</b>
The center coordinates of the fine diffraction bright spot $(x, y)$ <b>short</b>			
<b>(-3.44, 4.44)</b>	<b>(-2.68, 4.42)</b>	<b>(-2.20, 4.42)</b>	<b>(-1.78, 4.42)</b>
<b>(-3.10, 3.86)</b>	<b>(-2.70, 3.88)</b>	<b>(-2.24, 3.84)</b>	<b>(-1.82, 3.88)</b>
<b>(-3.20, 3.38)</b>	<b>(-2.74, 3.38)</b>	<b>(-2.22, 3.34)</b>	<b>(-1.76, 3.34)</b>
<b>(-3.14, 2.78)</b>	<b>(-2.68, 2.78)</b>	<b>(-2.22, 2.78)</b>	<b>(-1.76, 2.76)</b>
	$\Delta S_x$ (cm)	$\Delta S_y$ (cm)	
long	0.448	0.555	
short	0.452	0.550	

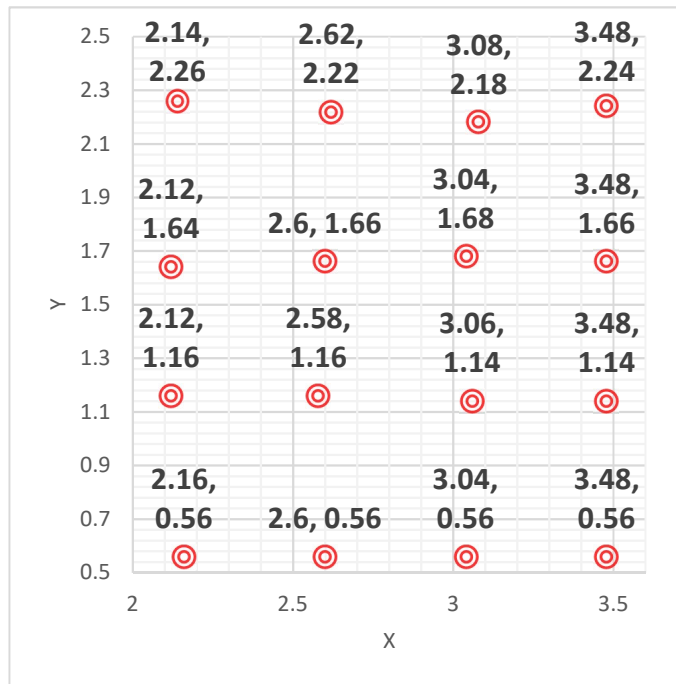
# Experiment Solution

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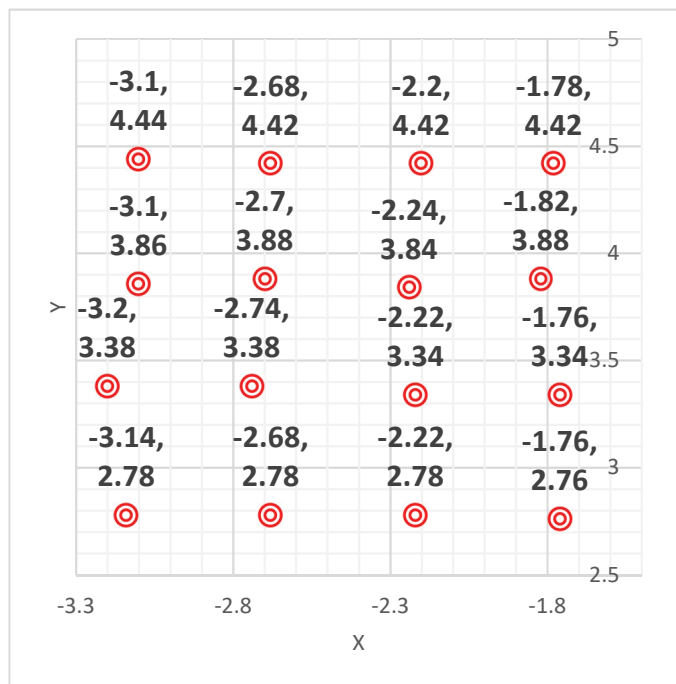
English



long



short



# Experiment Solution

# A2

English



Laser wavelength $\lambda =$ <u>1444 nm</u>			
The center coordinates of the fine diffraction bright spot $(x, y)$ <b>long</b>			
<b>(3.34, 0.02)</b>	<b>(3.86, 0.02)</b>	<b>(4.42, 0.02)</b>	<b>(4.94, 0.04)</b>
<b>(3.34, 0.70)</b>	<b>(3.84, 0.72)</b>	<b>(4.42, 0.70)</b>	<b>(4.94, 0.74)</b>
<b>(3.36, 1.42)</b>	<b>(3.86, 1.42)</b>	<b>(4.44, 1.40)</b>	<b>(5.00, 1.46)</b>
<b>(3.34, 2.08)</b>	<b>(3.86, 2.08)</b>	<b>(4.48, 2.08)</b>	<b>(5.00, 2.10)</b>
The center coordinates of the fine diffraction bright spot $(x, y)$ <b>short</b>			
<b>(-3.86, 4.16)</b>	<b>(-3.32, 4.18)</b>	<b>(-2.74, 4.18)</b>	<b>(-2.14, 4.16)</b>
<b>(-3.84, 3.48)</b>	<b>(-3.28, 3.48)</b>	<b>(-2.72, 3.48)</b>	<b>(-2.12, 3.48)</b>
<b>(-3.80, 2.78)</b>	<b>(-3.26, 2.78)</b>	<b>(-2.72, 2.78)</b>	<b>(-2.12, 2.80)</b>
<b>(-3.78, 2.02)</b>	<b>(-3.26, 2.06)</b>	<b>(-2.70, 2.06)</b>	<b>(-2.00, 1.98)</b>
計算圖形斑點間距 $\Delta S_x$ 、 $\Delta S_y$ <b>0.5 pt</b>			
	<b><math>\Delta S_x</math> (cm)</b>	<b><math>\Delta S_y</math> (cm)</b>	
<b>long</b>	<b>0.542</b>	<b>0.687</b>	
<b>short</b>	<b>0.575</b>	<b>0.713</b>	

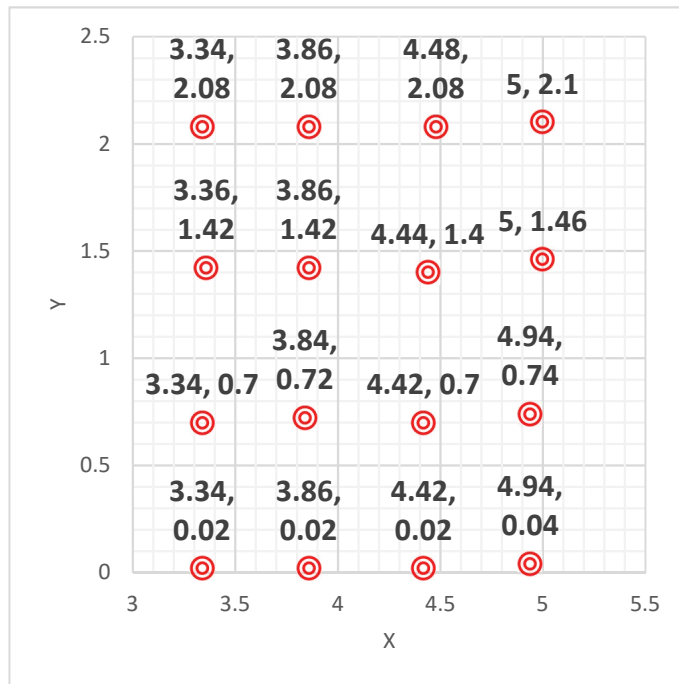
# Experiment Solution

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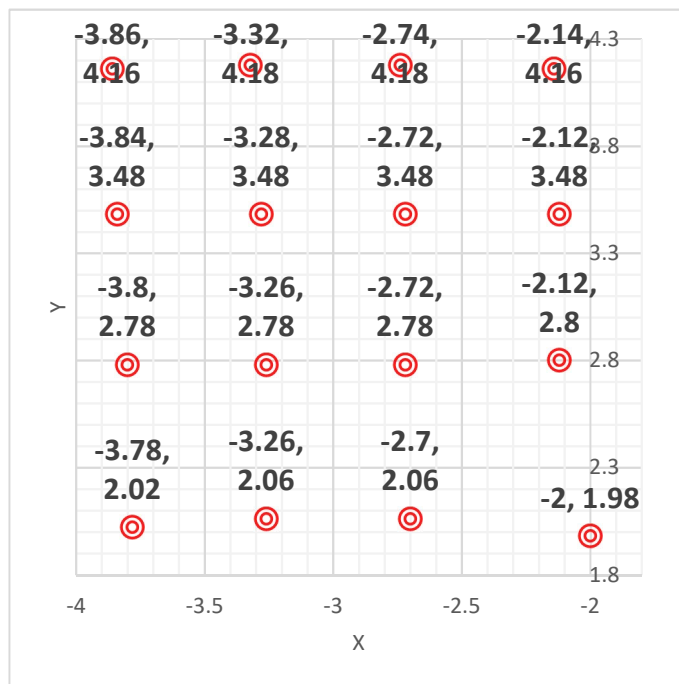
English



long



short



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English



D.2

0.6 pt

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

$\lambda$ (nm)		$d_x$ ( $\mu\text{m}$ )	$d_y$ ( $\mu\text{m}$ )
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



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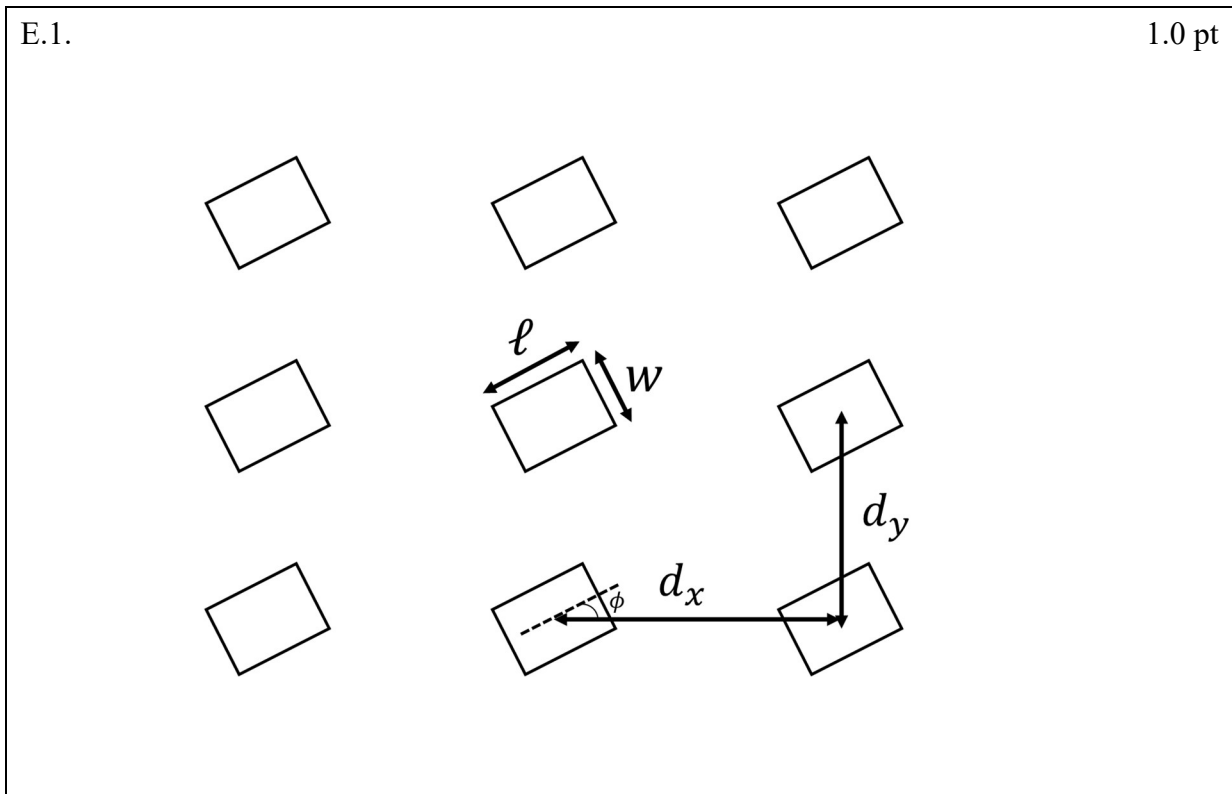
English



## Part E. Exploration of sample structure size

E.1.

1.0 pt



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

(5.627  $\mu\text{m}$ , 58.59  $\mu\text{m}$ , 50.78  $\mu\text{m}$ , 249.3  $\mu\text{m}$ , 198.2  $\mu\text{m}$ , 27 degree)