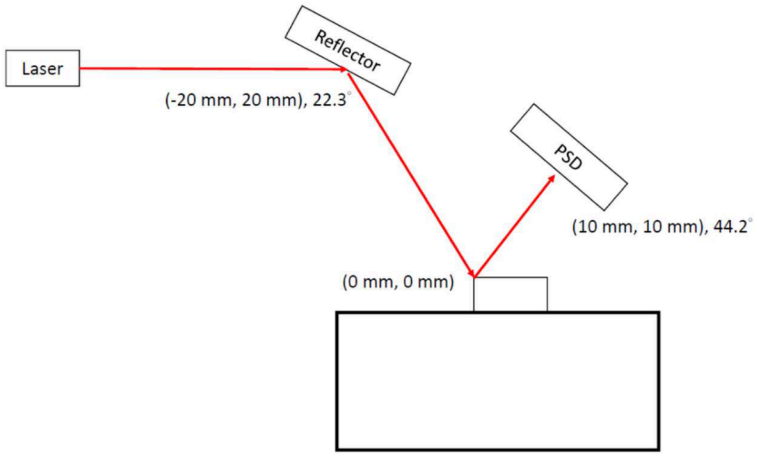
Experiment

A1-1

한국어 **(Official)**

외팔보의 탄성
파트 A. 광로의 정렬

A1. 0.6 pt



A2. 0.8 pt

시간 (s)	위치 d (m)	시간 (s)	위치 d (m)	시간 (s)	위치 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)	표준 편차
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}	

측정 기준값 (표준 편차와 함께):

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

파트 B. 외팔보의 변형과 영률의 유도

B1. 답안지. 1.0 pt

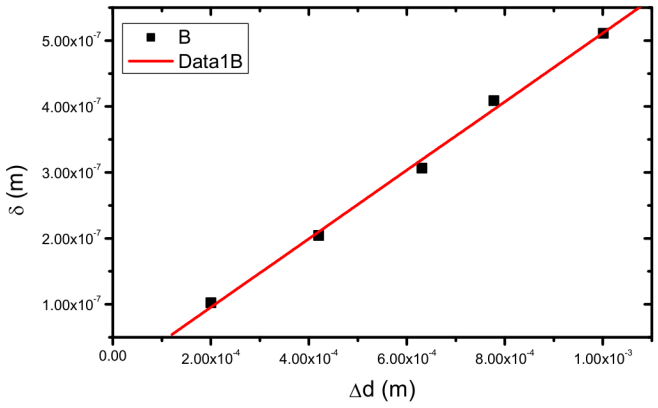
F (N)	d (m)	$\bar{d} = d_0$ (m)
0	-1.82×10^{-5}	-1.386×10^{-5}
	-1.09×10^{-5}	
	-6.69×10^{-5}	
	1.72×10^{-5}	
	9.5×10^{-6}	

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}	

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

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

파트 C. 이중층 외팔보

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}	

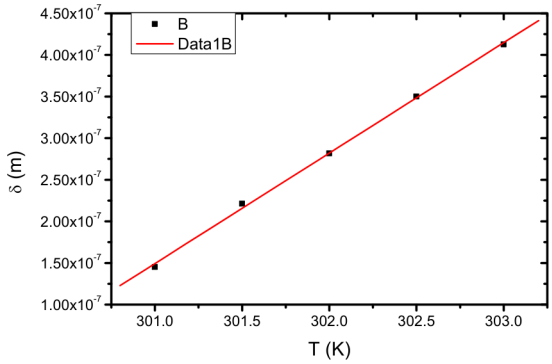
T (K)	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
301	2.8506×10^{-4}	2.7928×10^{-4}
	2.7186×10^{-4}	
	2.7466×10^{-4}	
	2.7436×10^{-4}	
	2.9046×10^{-4}	
301.5	4.1276×10^{-4}	4.2568×10^{-4}
	4.1336×10^{-4}	
	4.6276×10^{-4}	
	4.3956×10^{-4}	
	3.9996×10^{-4}	
302	5.4146×10^{-4}	5.4186×10^{-4}
	5.4676×10^{-4}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

기울기: 1.337×10^{-7}



C3. 0.6 pt

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

파트 D. 분자 흡착에 의한 외팔보 굽힘의 시험

D1. 0.6 pt

	d (m)	$\bar{d} = d_0$ (m)
시료 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)
시료 1	-8.2414×10^{-4}	-8.2553×10^{-4}
	-8.2884×10^{-4}	
	-8.2794×10^{-4}	

D2. 휨 변위와 피복률(CR)의 함수 꼴이 다음과 같이 나타난다고 하자. 0.6 pt

$\delta = C_2 \dfrac{Coverage\ Ratio}{EI^*} L^4$. A9에서 얻은 데이터를 바탕으로 C_2 를 어림하시오. A6의 δ 와 $\overline{\Delta d}$ 사이의 관계를 쓸 수 있다.

-7.89×10^{-2}

D3. 0.8 pt

	$d - d_0 = \Delta d$ (m)	$\overline{\Delta d}$ (m)
시료 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)
시료 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

시료 2: 0.738%

시료 3: 0.298%

Experiment

Solution

A2

English

Q2 광학적 방법으로 시료의 공간 구조 탐구하기

풀이

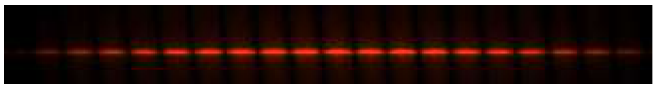
파트 A. 빛과 시료의 정렬

A.1 0.5 pt

(X_{sample}, Y_{sample}) = **(3700, -2900)**

A.2 0.5 pt

간섭 무늬:



차수, 무늬	-2, 어두움	-1, 어두움	1, 어두움	2, 어두움
(*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**			

파트 B. 시료 구조 크기의 탐구

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)	6.02 ± 0.11				
$\tan^{-1}\left(\frac{\bar{s}}{L}\right)$	0.0999 ± 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)	6.37 ± 0.11				
$\tan^{-1}\left(\frac{\bar{s}}{L}\right)$	0.1057 ± 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.**
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				

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)**	**(4.48,7.7**
S (cm)	**8.74**	**8.24**	**8.83**	**8.89**	**8.93**

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

B.3 1.0 pt

$\bar{a} = 5.627$ 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)		5.627 ± 0.020

Experiment

Solution

A2

English

파트 C. 시료 구조 크기의 탐구

C.1 0.8 pt

λ = **488 nm**

L=90 cm, 축 1				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 2				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 1				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 2				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 1				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 2				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 1				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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, 축 2				
차수, 무늬	4, 밝음	5, 밝음	6, 밝음	7, 밝음
(*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

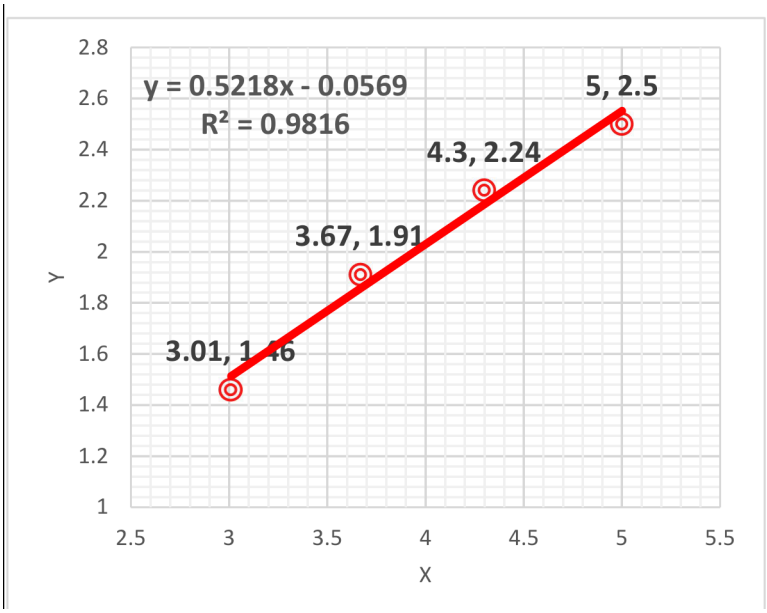
Solution

A2

English

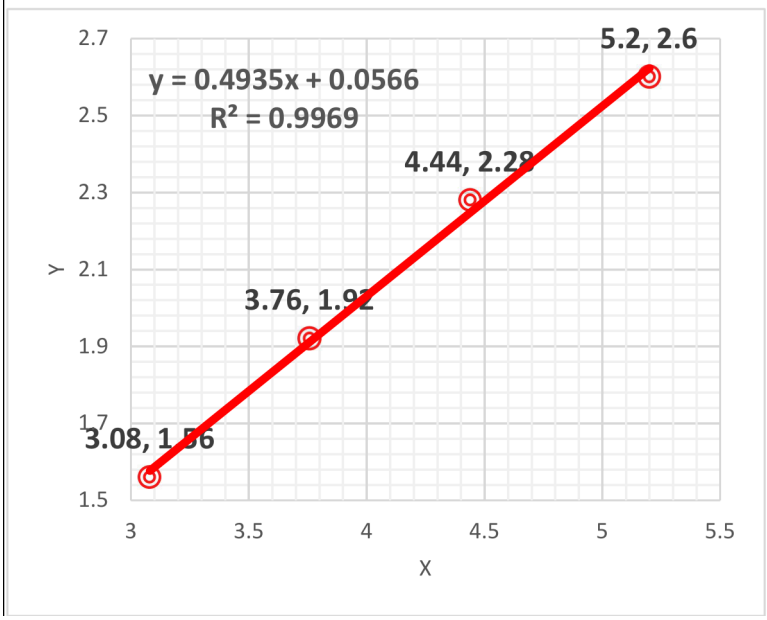
C.3 $\phi = 27°$ 1.0 pt

λ = **488 nm** 축 1 (긴 변) ϕ = **27.6°**



λ = **514 nm** 축 1 (긴 변) ϕ = **26.2°**

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



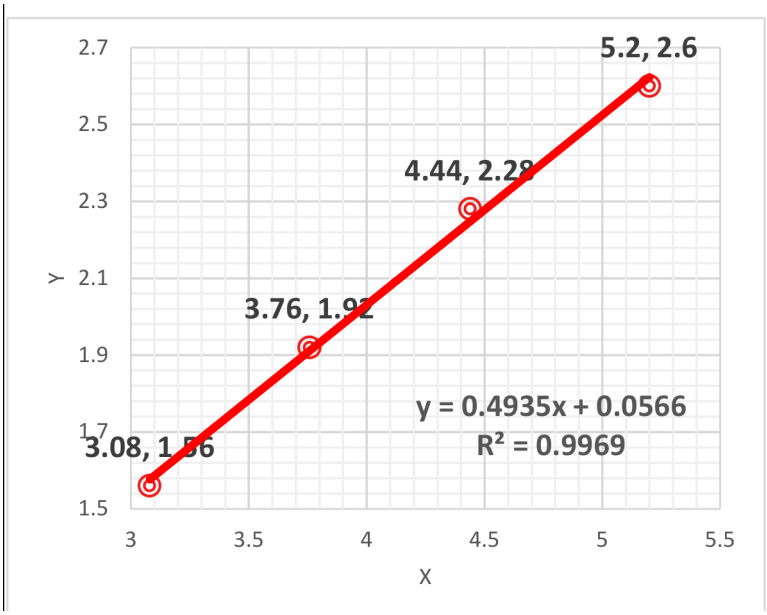
Experiment

Solution

A2

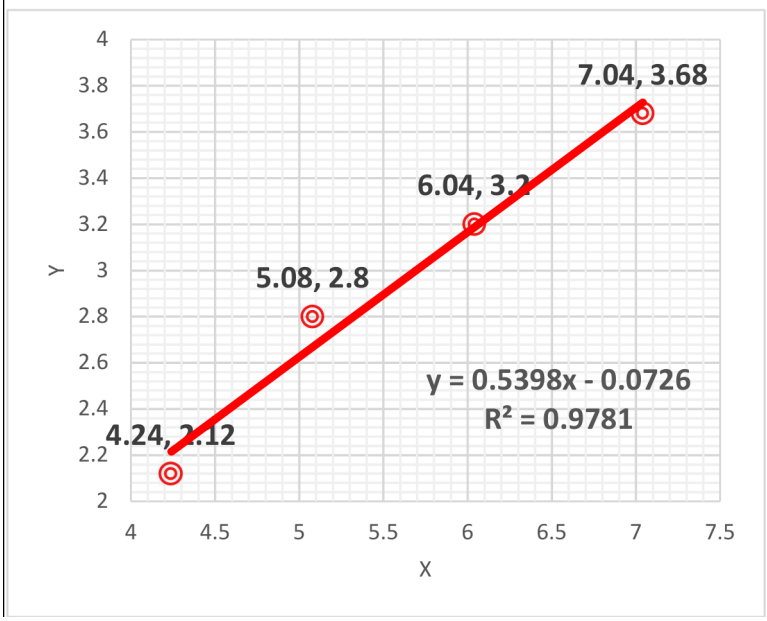
English

λ = **632.8 nm** 축 1 (긴 변) ϕ = **27.7**



λ = **694.3 nm** 축 1 (긴 변) ϕ = **28.4**

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



Experiment

Solution

A2

English

파트 D. 시료 구조 크기의 탐구

D.1 1.9 pt

레이저 파장 λ = **914 nm**

미세 회절 밝은 점의 중심 좌표 (*x*, *y*) 긴 변			
(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)**
미세 회절 밝은 점의 중심 좌표 (*x*, *y*) 짧은 변			
(-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)**

이웃한 점 사이의 거리 ΔS_x, ΔS_y 를 계산하시오

	ΔS_x (cm)	ΔS_y (cm)
긴 변	**0.346**	**0.410**
짧은 변	**0.348**	**0.428**

Experiment

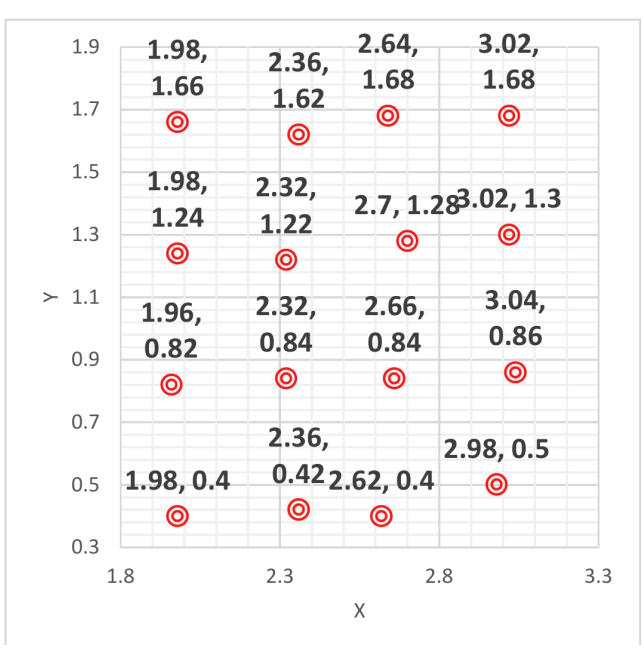
Solution

A2

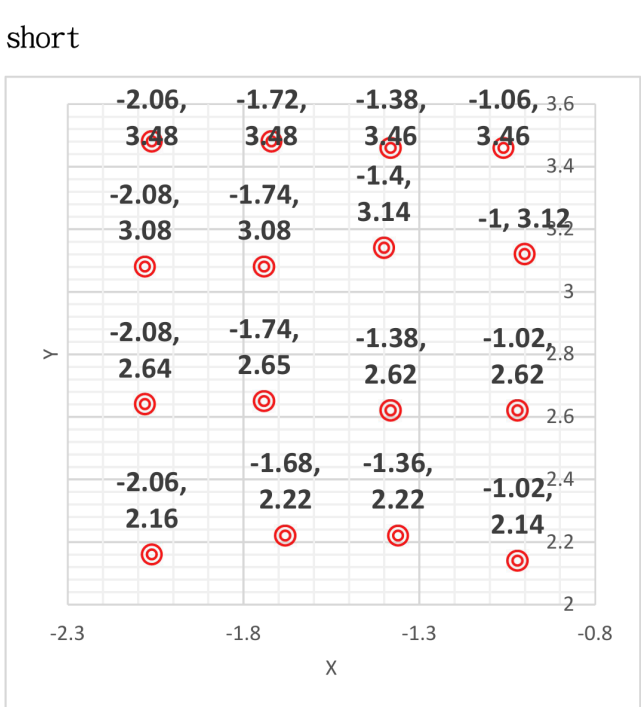
English

D.1.

긴 변



짧은 변



Experiment

Solution

A2

English

레이저 파장 λ = **1152 nm**

미세 회절 밝은 점의 중심 좌표 (*x*, *y*) 긴 변			
(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)**
미세 회절 밝은 점의 중심 좌표 (*x*, *y*) 짧은 변			
(-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)
긴 변	**0.448**	**0.555**
짧은 변	**0.452**	**0.550**

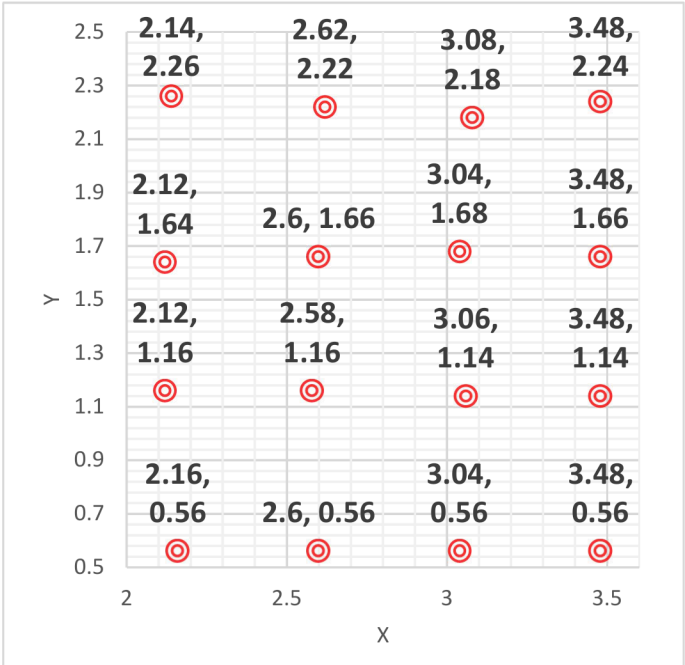
Experiment

Solution

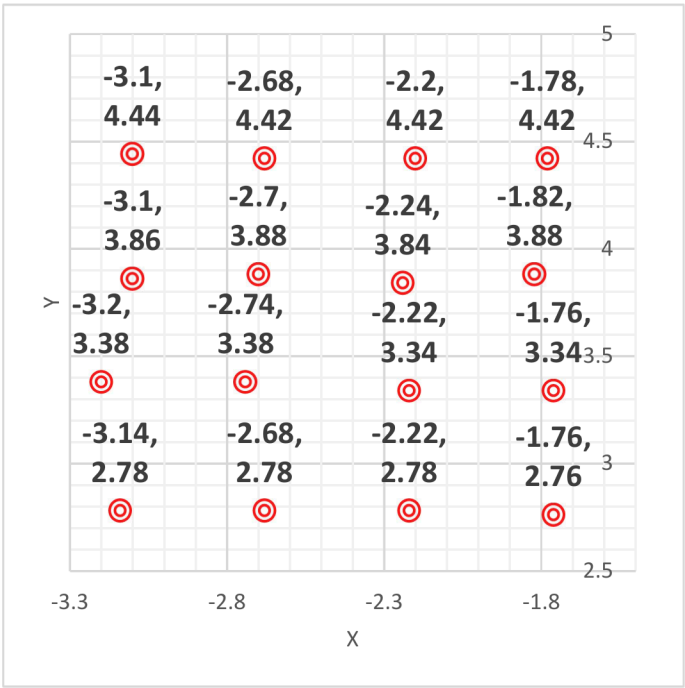
A2

English

긴 변



짧은 변



Experiment

Solution

A2

English

레이저 파장 λ = **1444 nm**

미세 회절 밝은 점의 중심 좌표 (*x*, *y*) 긴 변			
(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)**
미세 회절 밝은 점의 중심 좌표 (*x*, *y*) 짧은 변			
(-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)**

이웃한 점 사이의 거리 ΔS_x, ΔS_y 계산 0.5 pt

	ΔS_x (cm)	ΔS_y (cm)
긴 변	**0.542**	**0.687**
짧은 변	**0.575**	**0.713**

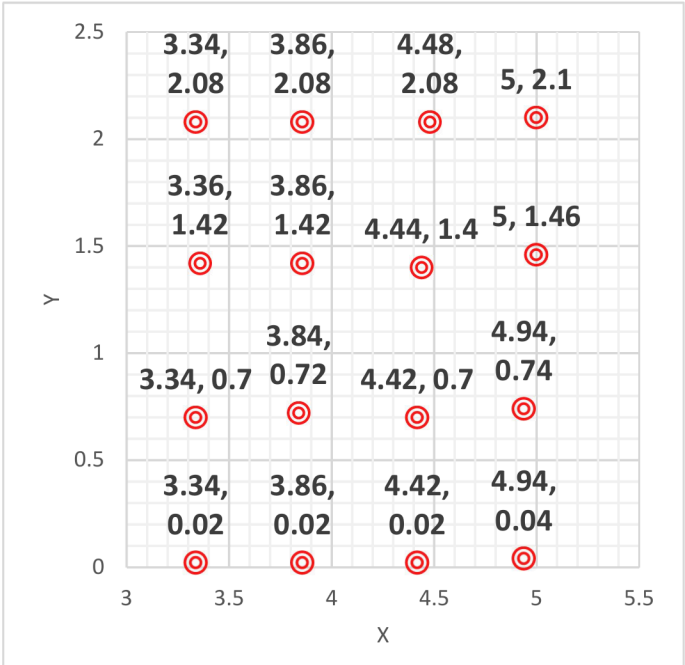
Experiment

Solution

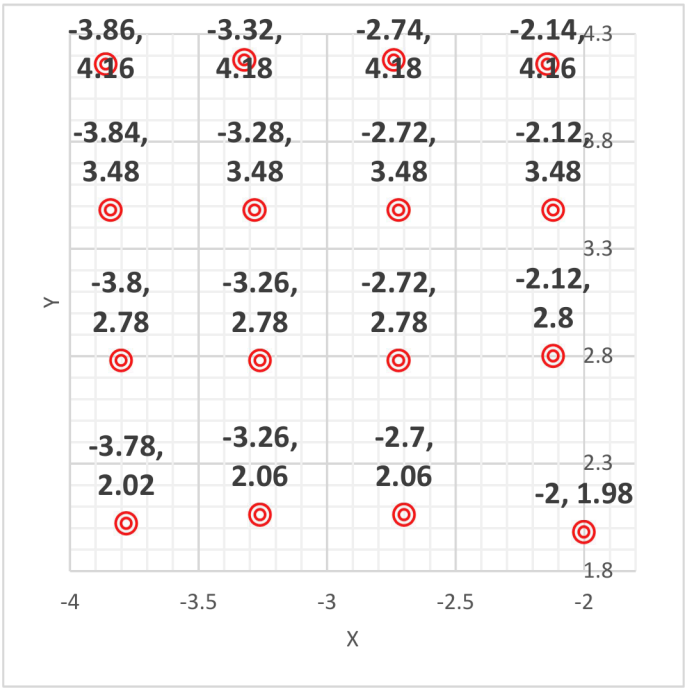
A2

English

긴 변



짧은 변



D.2 0.6 pt

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

λ (nm)	축	d_x (μm)	d_y (μm)
914	긴 축	**251**	**211**
	짧은 축	**250**	**203**
1152	긴 축	**244**	**197**
	짧은 축	**242**	**199**
1444	긴 축	**253**	**199**
	짧은 축	**239**	**192**

Experiment

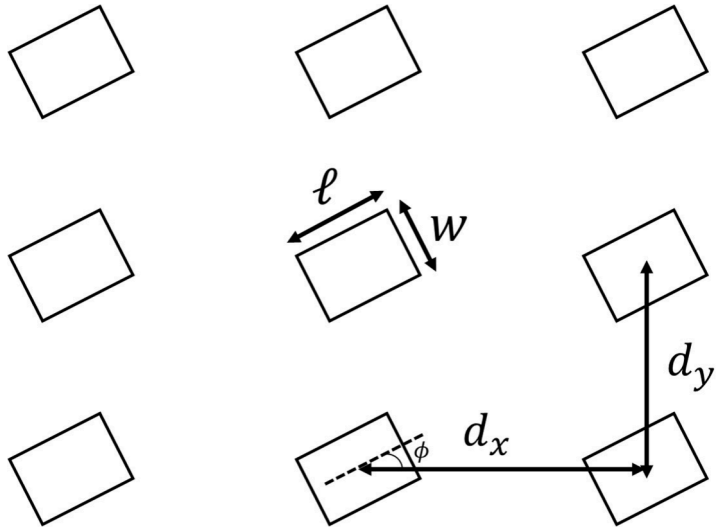
Solution

A2

English

파트 E. 시료 구조 크기의 탐구

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)