Problem 2: Interference from thermally deformed surface (thermos-deformation)

Part A [0.8 points]

The resulting pattern exhibits reversibility and shrinkage up to a certain power value. The upper boundary value corresponding to the thermo-elastic range which is known as yield strength should be determined.

A.1	Determine the power associated with this yield strength (p_{max}).	0.3pt
	For 350-400 mW 0.3 pts For 300-350 mW 0.2 pts For 400-450 mW 0.1 pts	

I, mA	V, V	P, mW	P_{avg}, mW
97.3	3.74	363.90	363.6
98.3	3.75	368.63	
97.6	3.74	365.02	
96.5	3.73	359.95	
96.7	3.73	360.69	

A.2	Determine the diameter of the outermost bright fringe when the laser power is set to the level associated with the yield strength.	0.5pt
	The outermost diameter determined by locating the screen farther from target as following: Determined the diameter value 0.3 pts Distance between the target and screen 0.2 pts	

$L = 49.2\ cm$

D_{out}, cm	$< D_{out} >$, cm
27.0	27.5
26.0	
28.0	
28.5	
28.0	

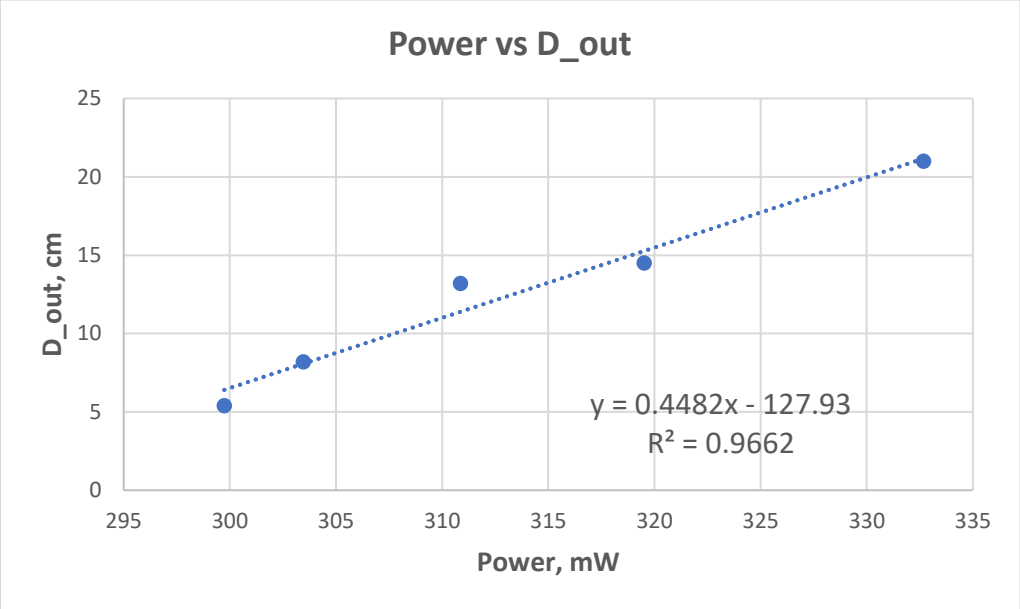
L, cm	49.2	45	40	35	30	25	20	15	10	5
D, cm	27.5	25.6	22.8	19.9	17.1	14.2	11.4	8.5	5.7	2.8

Part B [3.5 points]

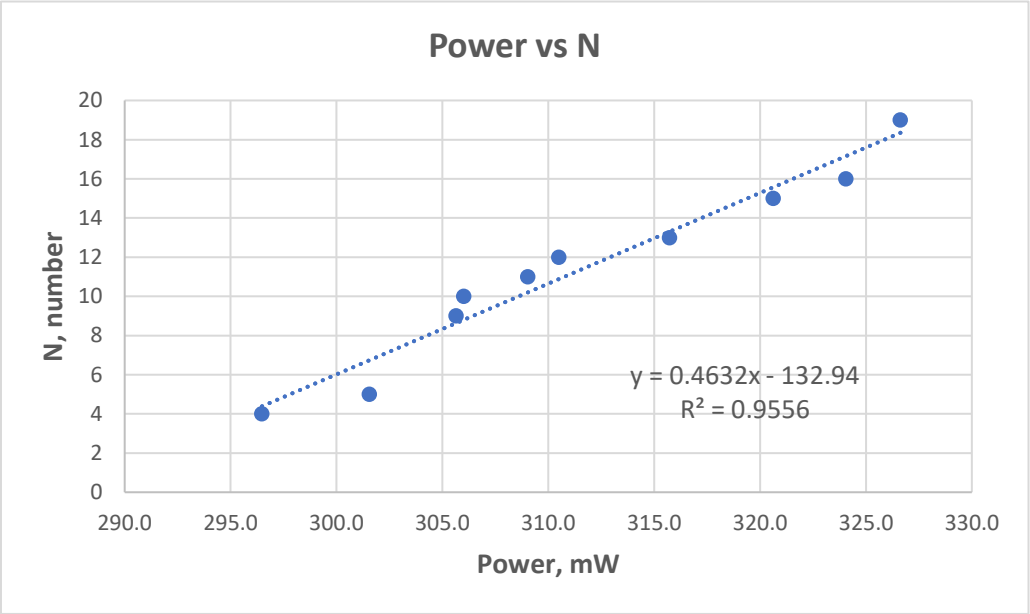
B.1	The diameter of the outermost light fringe and the number of fringes formed in this test are measured in relation to the power and the results should be recorded in an Answer sheet table.	1.5pt
	• At least 10 measurement points 0.3 pts For 7-9 points 0.2 pts For 5-6 points 0.1 pts For 150-300 mW 0.3 pts For 100-150 mW 0.2 pts • Measured voltage for all rows in the table 0.2 pts For 7-9 points 0.1 pts • Measured current for all rows in the table 0.2 pts For 7-9 points 0.1 pts • Calculated power for all rows in the table 0.2 pts For 7-9 points 0.1 pts • Significant figure all same number 0.3 pts	

№	I, mA	U, V	P, mW	N
1	81.9	3.62	296.5	4
2	83.3	3.62	301.5	5
3	84.2	3.63	305.6	9
4	84.3	3.63	306.0	10
5	84.9	3.64	309.0	11
6	85.3	3.64	310.5	12
7	86.5	3.65	315.7	13
8	87.6	3.66	320.6	15
9	88.3	3.67	324.1	16
10	89.0	3.67	326.6	19
11	92.1	3.70	340.8	20
12	94.3	3.72	350.8	21

B.2	Construct a graph depicting the relationship between the diameter of the outermost light interference fringe on the screen and the corresponding power level.	1.0pt
	At least 10 measured points appear in the graph 0.4 pts The data covers at least 75% of each coordinate length 0.4 pts There are labels in each axis 0.2 pts	



B.3	Plot the number of interference fringes on the screen is measured as a function of power.	1.0pt
	At least 10 measured points appear in the graph 0.4 pts The data covers at least 75% of each coordinate length 0.4 pts There are labels in each axis 0.2 pts	



Part C [3.7 points]

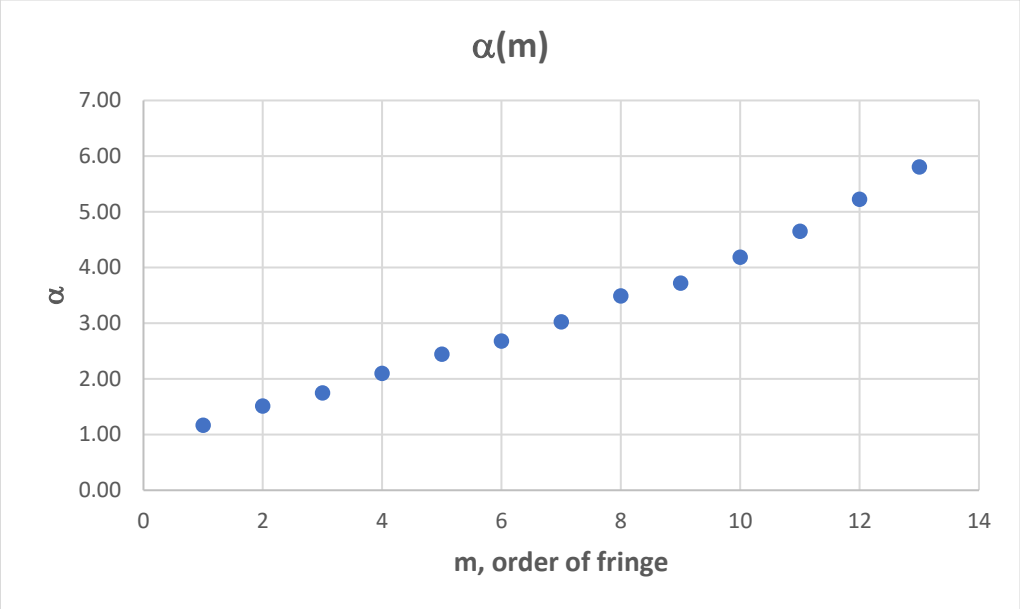
C.1	Measure the angular width (an angle between the ray of nth order fringe and the ray of $n+1$th order fringe) and visible angle (an angle between the ray of nth order fringe and x-axis) of the dark fringe at a constant power level, depending on the number of the fringe, and record the results in Answer Sheet Table.	1.2pt
	At least 10 measurement points 0.4 pts For 7-9 points 0.2 pts For 5-6 points 0.1 pt The power determined 0.1 pts The visible angle values determined 0.2 pts The angular width values determined 0.3 pts Significant figure all same number 0.2 pts	

m	R, cm	L, cm	$\tan(\alpha_m)$	α_m, °	α_m, mrad	$\Delta\alpha_m$, °	$\Delta\alpha_m$, mrad
1	1.0	49.2	0.020	1.16	20.3	0.35	6.1
2	1.3		0.026	1.51	26.4	0.23	4.0
3	1.5		0.030	1.75	30.6	0.35	6.1
4	1.8		0.037	2.10	36.7	0.35	6.1
5	2.1		0.043	2.44	42.6	0.23	4.0
6	2.3		0.047	2.68	46.8	0.35	6.1
7	2.6		0.053	3.03	52.9	0.46	8.0
8	3.0		0.061	3.49	60.9	0.23	4.0
9	3.2		0.065	3.72	65.0	0.46	8.0
10	3.6		0.073	4.18	73.0	0.46	8.0
11	4.0		0.081	4.65	81.2	1.04	18.2
12	4.5		0.100	5.69	99.3	1.04	18.2
13	5.0		0.118	6.72	117.3		

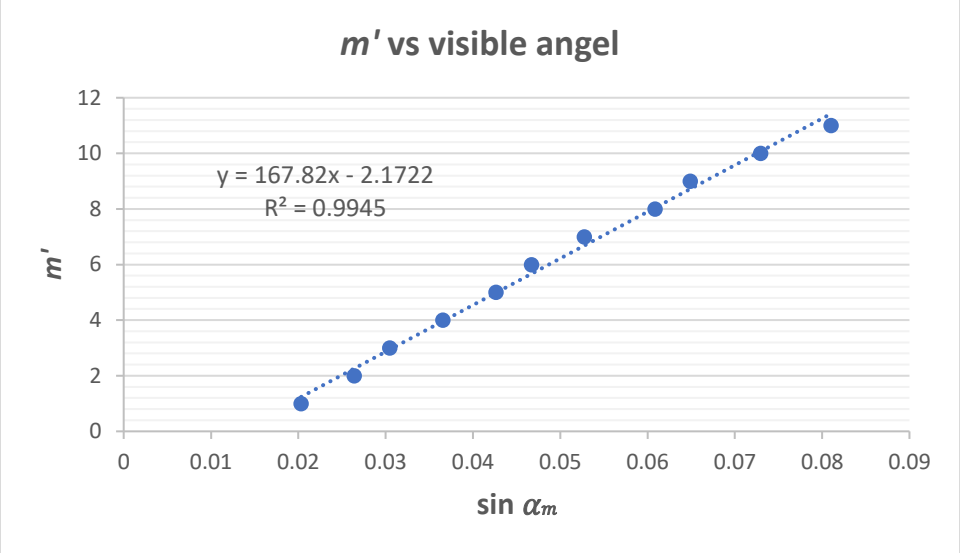
C.2. Plot a linear graph of the relationship between the visible angle vs order of fringe.

C.2	Plot a linear graph of the relationship between the visible angle vs order of fringe.	1.0pt
	At least 10 measured points appear in the graph 0.4 pts The data covers at least 75% of each coordinate length 0.4 pts There are labels in each axis 0.2 pts	

1. **Non-linear graph (0.2pts)**



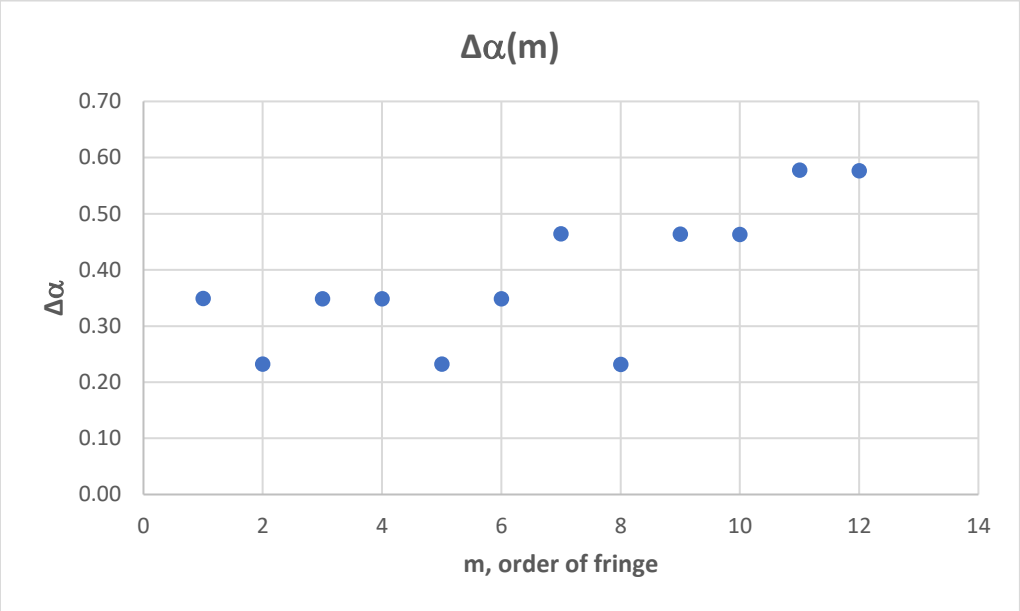
2. Linearized graph (0.8pts)



C.3	Find the slope and Y-intercept of the graph plotted in Task C.2.	0.5pt
	Plotted regression line and calculate slope 0.3 pts Value of grad 0.2 pts	

$$m' = 167.82 \cdot \sin \alpha_m - 2.1722$$

C.4	Construct a graph of angular width as a function of the order of fringes.	1.0pt
	At least 10 measured points appear in the graph 0.2 pts The data covers at least 75% of each coordinate length 0.2 pts There are labels in each axis 0.2 pts Plotted regression line and calculate slope 0.2 pts Value of grad 0.2pts	

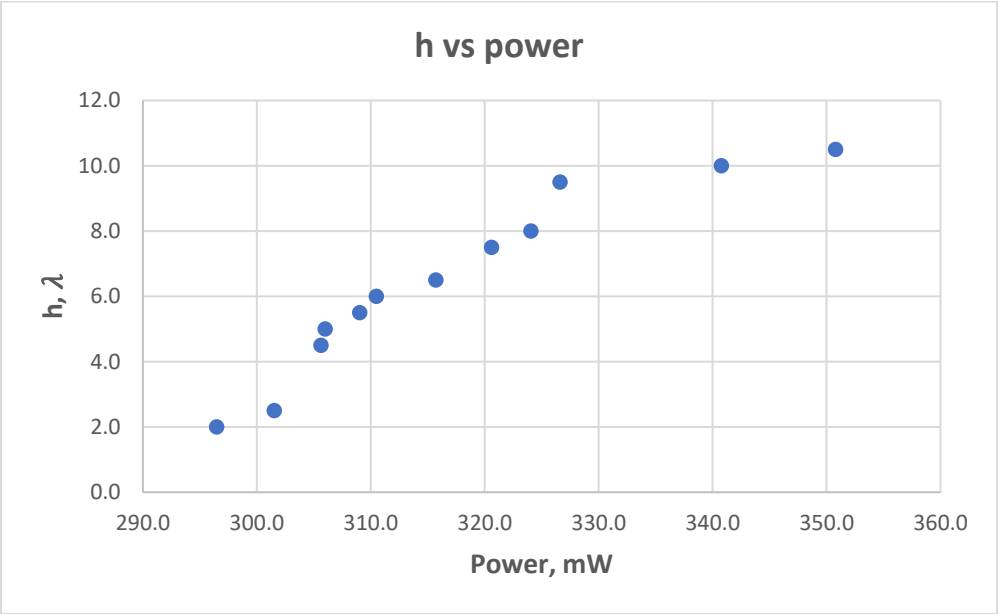


Part D [2.0 points]

D.1	By counting the number of the fringes determine the highest order of the fringes. Determine the height of the thermal deformation in terms of the laser wavelength as a function of the laser power. Plot a graph of your data. Hint: ensure your data includes the range of $200mW$ to $400mW$.	1.4pt
	Each data point 0.1 pt (10 datas) At least 8 measured points appear in the graph 0.2 pts There are labels in each axis 0.2 pts	

№	m_{max}	P, mW	h, λ
1	4	296.5	2.0
2	5	301.5	2.5
3	9	305.6	4.5
4	10	306.0	5.0

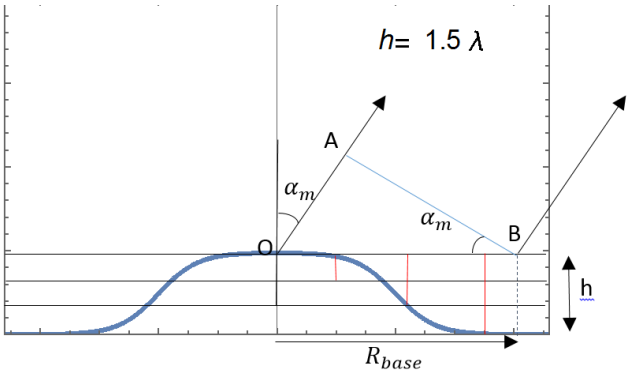
5	11	309.0	5.5
6	12	310.5	6.0
7	13	315.7	6.5
8	15	320.6	7.5
9	16	324.1	8.0
10	19	326.6	9.5
11	20	340.8	10.0
12	21	350.8	10.5



D.2	What are the thermal deformation heights for the following input laser powers? Give your answers in units of the number of laser wavelengths. • 200 mW • 300 mW • 400 mW	0.6pt
	For 200 mW 0.2 pts For 300 mW 0.2 pts For 400 mW 0.2 pts	

P, mW	h, λ
200	-12.6
300	3.6
400	19.8

Appendix



Maximum optical path difference of rays is 2h for central maximum.

For m[th] fringe which is observed by visible angle α_m, the optical path difference for the rays from the top and bottom of a bump is:

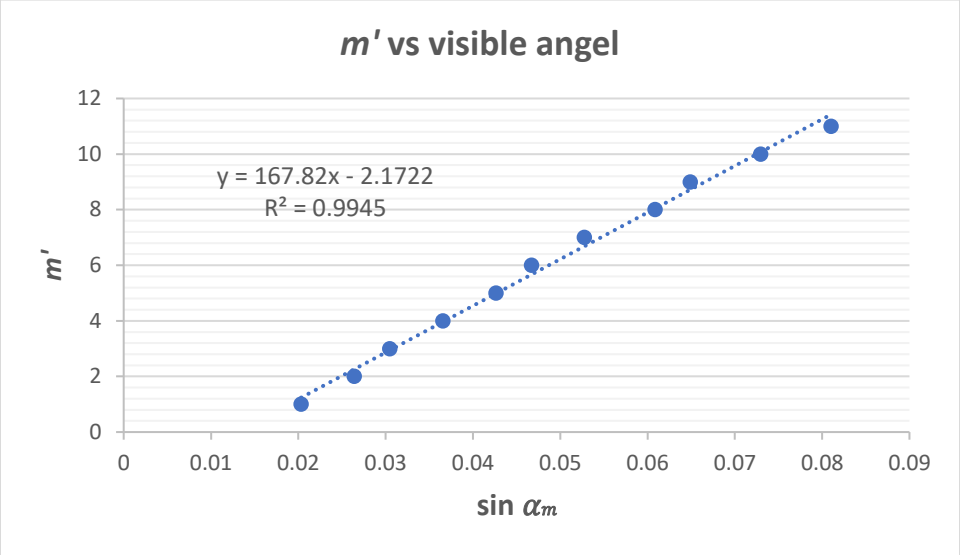
$$\Delta s_m \approx 2h - OA = n\lambda - R\ \sin\alpha_m = n\lambda - m\lambda$$

$$R\sin\alpha_m = m\lambda\ \Rightarrow R = \frac{m\lambda}{\sin\alpha_m}$$

Data obtained in Part C.1 were used.

m'	R, cm	L, cm	$\tan\alpha_m$	$\sin\alpha_m$
1	1.0	49.2	0.0203	0.0203
2	1.3		0.0264	0.0264
3	1.5		0.0305	0.0305
4	1.8		0.0366	0.0366
5	2.1		0.0427	0.0426
6	2.3		0.0467	0.0467
7	2.6		0.0528	0.0528
8	3.0		0.0610	0.0609
9	3.2		0.0650	0.0649
10	3.6		0.0732	0.0730
11	4.0		0.0813	0.0810
12	4.5		0.0915	0.0911
13	5.0		0.1016	0.1011

Here, m' and m are observed and real number of fringes, respectively.



$$m' = 167.82 \cdot \sin \alpha_m - 2.1722$$

From the above equation, it shows that difference between m' and m is 2.1722≈2 which is the number of fringes hidden in the central circle. From our data, $m = m' + 2 = 15$.

From the experiment, height of the bump is calculated to be 7.5λ and the base radius is $R_{base} \approx 167.82\lambda$.