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. For any experiment predictions of the measurement ranges and limits are important. In this experiment, the surface of the acrylic plate is heated by a laser beam and the surface is deformed. The deformed surface will become different heights which gives the path difference. When laser beam intensity is not high the interference pattern will be circular fringes with the same center. If you increase the intensity of the beam the number of the fringes will increase, and the size of the fringes will be bigger. When you reach the limit of the intensity there will be explosion-like change in the interference pattern, and many of the small fringes will appear. Sometimes there will be dark spots. In this case, the acrylic surface becomes too hot and the laser beam creates a volcano crater-like shape on the center of the deformed surface and the molten acrylic flows out.

Figure 4.67: Too strong laser beam creates concave shape on the center, and it destroys the interference pattern.

Caution: This interference pattern is temperature sensitive, therefore the pattern shape strongly depends on the temperature of the room, the climate of the region and even the airflow of the room. This experiment is conducted in the room with temperature $T_{room} = 20°$ C

I[mA]	V[V]	P[mW]	P_{av}[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	

Table 4.12: Upper limit of the reversibility or explosion power. $T_{room} = 20^{\circ}$ C

Determine the diameter of the outermost bright fringe when the laser power is set to the level associated with the yield strength. $L = 49.2$ cm

D_{out}[cm]	$\langle D_{out}\rangle$[cm]
27.0	27.5
26.0	
28.0	
28.5	
28.0	

To reduce the measurement error a fringe size must be as big as possible. But the screen must be placed at the position that fringe size not going out from the screen. This position is chosen by students; therefore, they must approximate the proper distance of the screen from the target themselves.

L [cm]	49.2	45	40	35	30	25	20	15	10	5
D_{out} [cm]	27.5	25.6	22.8	19.9	17.1	14.2	11.4	8.5	5.7	2.8

Table 4.13: D_{out} diameter dependence on L distance between target and screen

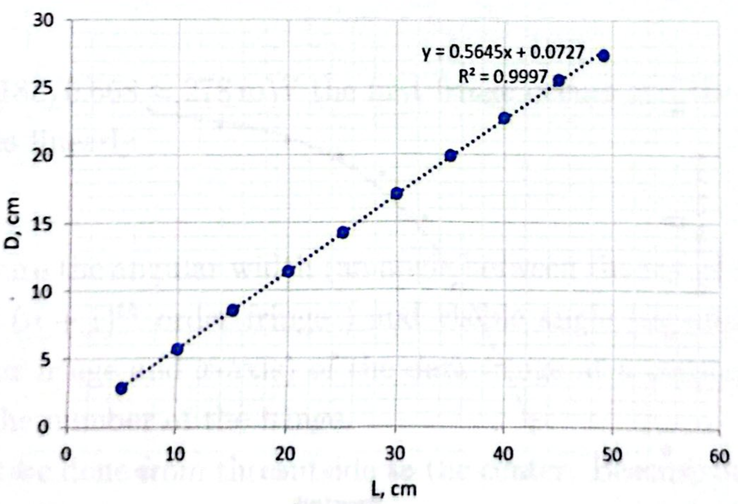

Figure 4.68: D_{out} diameter dependence on L distance between target and screen

From the Figure. 4.68 it is visible that the outermost fringe diameter D_{out} is directly proportional to the distance L and it will indicate that the width of the fringe is independent from the distance L. When distance L is increasing the bright and the dark fringes are not swapping. That means this interference pattern is created by parallel beams therefore, we can assume that this interference is obviously Fraunhofer's type.

Part B [3.5 points]

B.1 Let's study the relation to the power of the laser source, the diameter of the outermost light fringe and the number of fringes formed in this test.

№	I[mA]	U[V]	P[mW]	D[mm]	Number of max
1	80.0	3.55	284.0	20	4
2	81.3	3.56	289.4	66	7
3	82.3	3.57	293.8	106	10
4	83.3	3.57	297.4	150	14
5	84.5	3.58	302.5	180	17
6	85.7	3.59	307.7	192	20
7	87.5	3.59	314.1	202	24
8	89.2	3.61	322.0	212	29
9	91.0	3.63	330.3	224	35

Table 4.14: The relation to the power of the laser source, the diameter of the outermost light fringe and the number of fringes formed.

B.2 Let's construct a graph depicting the relationship between the diameter of the outermost light interference fringe on the screen and the corresponding power level. It shows that upper-degree fringes are very dense and the inclining angle of

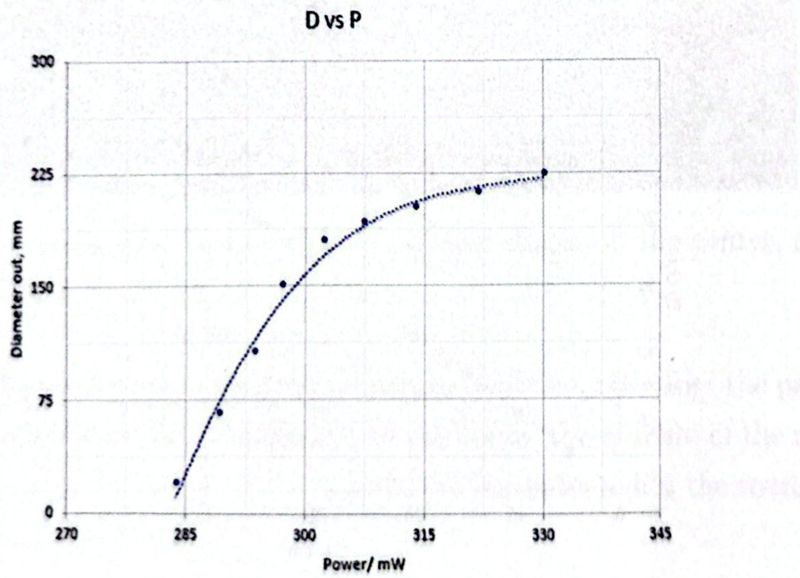

Figure 4.69: Outermost fringe's diameter depends on the power of laser source nonlinearly. .

the surface is saturating which is giving the interference.

B.3 Let's study the number of interference fringes on the screen is measured as a function of power.

The number of the formed fringes is counted while increasing the power of the laser source. At the center of the interference pattern, it will be difficult to count. For every power value students should avoid counting all fringes again and again. One of the such easy methods is at the fixed point, for example at the $x = 2.0\,\mathrm{cm}$ coordinate just count the fringes passing over, then count inside small fringes and summarize the counts. From Figure 4.70 it is visible that when the power of the

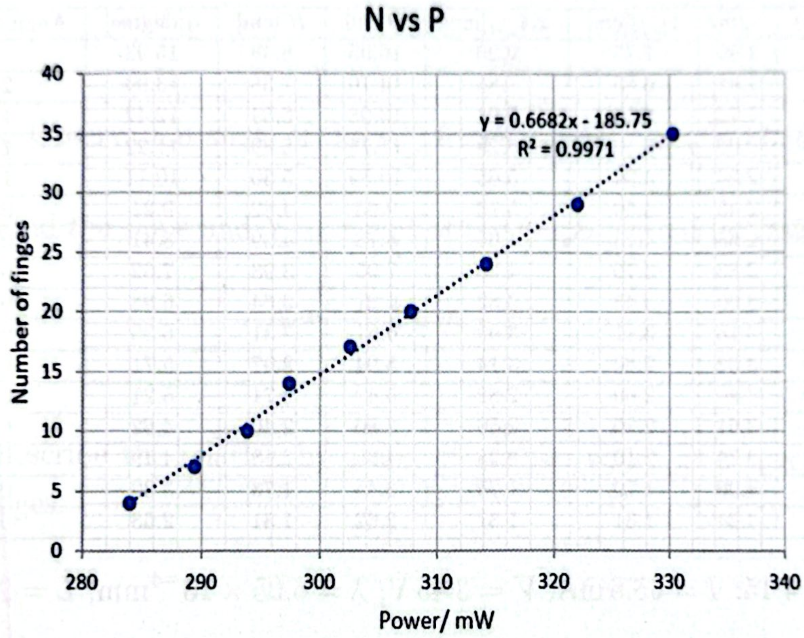

Figure 4.70: The number of fringes depends on the power of the laser source linearly.

laser source is $185/0.668 \approx 278\,\mathrm{mW}$ the first fringe occurs and the number of the fringes increases linearly.

Part C

C.1 Let's measure the angular width (an angle between the ray of n^{th} order fringe and the ray of $(n+1)^{th}$ order fringe) and visible angle (an angle between the ray of m^{th} order fringe and x-axis) of the dark fringe at a constant power level, depending on the number of the fringe.

The count must be done from the outside to the center. Because outermost fringe is the first fringe. Then first minimum and second maximum so on. The first fringe is related to almost zero path difference; therefore, the number is $m = 0$ which means middle part with the biggest inclining angle of a heat created bump is creating the first fringe. Table 4.15 shows diameters of the m^{th} minimum, ob-

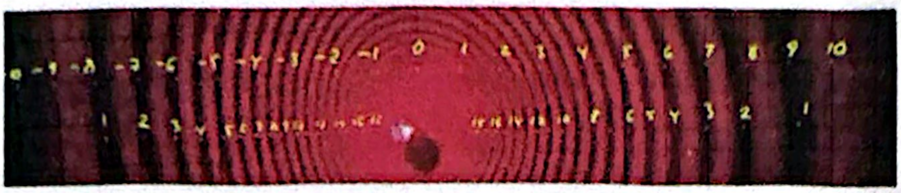

Figure 4.71: Photograph may help to count the fringes without mistake. Upper numbers are for distance from the center. Lower numbers are number of the minimums (dark fringes).

serving angle, angular width of the fringes for one fixed power.

$m(dark)$	$\sqrt{m}$	x_{left}(cm)	x_{right}(cm)	D(cm)	R (cm)	α(degree)	Angular width
1	1.00	7.75	9.20	16.95	8.48	15.93	
2	1.41	6.85	7.85	14.70	7.35	13.90	2.03
3	1.73	6.14	6.94	13.08	6.54	12.42	1.48
4	2.00	5.50	6.28	11.78	5.89	11.22	1.20
5	2.24	4.94	5.65	10.59	5.30	10.11	1.11
6	2.45	4.50	5.13	9.63	4.82	9.21	0.90
7	2.65	4.13	4.65	8.78	4.39	8.41	0.80
8	2.83	3.70	4.25	7.95	3.98	7.62	0.79
9	3.00	3.45	3.82	7.27	3.64	6.98	0.65
10	3.16	3.11	3.50	6.61	3.31	6.35	0.63
11	3.32	2.80	3.14	5.94	2.97	5.71	0.64
12	3.46	2.60	2.82	5.42	2.71	5.21	0.50
13	3.61	2.30	2.50	4.80	2.40	4.62	0.59
14	3.74	2.10	2.25	4.35	2.18	4.19	0.43
16	4.00	1.70	1.75	3.45	1.73	3.32	0.86
18	4.24	1.31	1.31	2.62	1.31	2.53	0.80

Table 4.15: $I = 66.6\,\text{mA}$, $V = 3.45\,\text{V}$, $\lambda = 6.05 \times 10^{-4}\text{mm}$, $L = 29.7\,\text{cm}$

C.2 Let's plot graph of the relationship between the visible angle vs order of fringe.

1. Non-linear graph

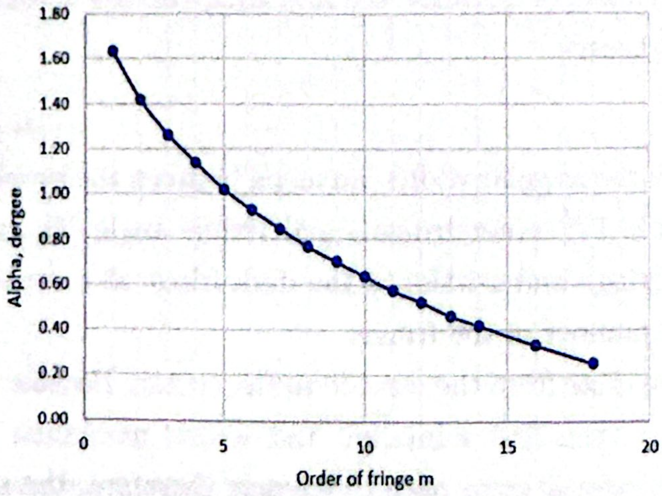

Figure 4.72: Visible angle vs order of fringe.

2. **Linearized graph**

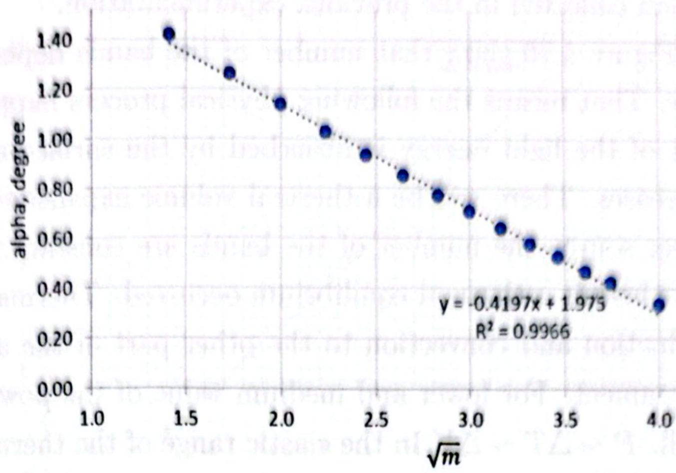

Figure 4.73: Observation angle of the m^{th} fringe depends on $\sqrt{m}$ almost linearly.

C.3 Let's Find the slope and Y-intercept of the graph plotted in Task C.2.

$$\alpha = -0.42\sqrt{m} + 2.0 \tag{4.255}$$

C.4 Let's describe the relation by graph of angular width as a function of the order of fringes.

Figure 4.74: Interference fringes of upper degree are dense with smaller angular width.

Part D

D.1 This part is related to the second purpose. The properties of the surface shape which is thermally deformed by a laser beam must be determined and modelled by the information collected in the previous experimentation.

Table 4.14 and Figure 4.70 show that number of the bands depend on power of the laser linearly. That means the following physical process happened.

The proper part of the light energy is absorbed by the surface and the surface temperature increases. There will be a thermal volume expansion. For the same power of the laser source the number of the bands are constant. Therefore, we can assume that there is a thermal equilibrium occurred. Thermal energy is lost by thermal conduction and convection to the other part of the acrylic material and to the environment. For lower and medium value of the power thermal loss is relatively small. $P \sim \Delta T \sim \Delta V$ In the elastic range of the thermo-deformation the acrylic surface should have the shape shown in Figure 4.77. Therefore, the height and the diameter of a bumpy shape are directly proportional to the power of the laser beam.

$P \sim \Delta T \sim hV$ The diameter can be determined by diameter of the central bright part of the interference pattern which is not creating the interference.

№	I[mA]	U[V]	P[mW]	D[mm]	Number of max	h/λ
1	80.0	3.55	284.0	20	4	2.0
2	81.3	3.56	289.4	66	7	3.5
3	82.3	3.57	293.8	106	10	5.0
4	83.3	3.57	297.4	150	14	7.0
5	84.5	3.58	302.5	180	17	8.5
6	85.7	3.59	307.7	192	20	≈ 10.0
7	87.5	3.59	314.1	202	24	≈ 12.0
8	89.2	3.61	322.0	212	29	≈ 14.5
9	91.0	3.63	330.3	224	35	≈ 17.5

Table 4.16: The dependence of the shape height on power of the laser.

D.2 What are the thermal deformation heights for the following input laser powers?

- 200 mW
- 300 mW
- 400 mW

From Figure 4.75 it clear that at 200 mW power the interference is not created yet, therefore, the height is almost zero. At 300 mW the height is about 7λ, at 400 mW it is about 22 which is over the elasticity of the material. Therefore, the shape will become a volcano like shape.

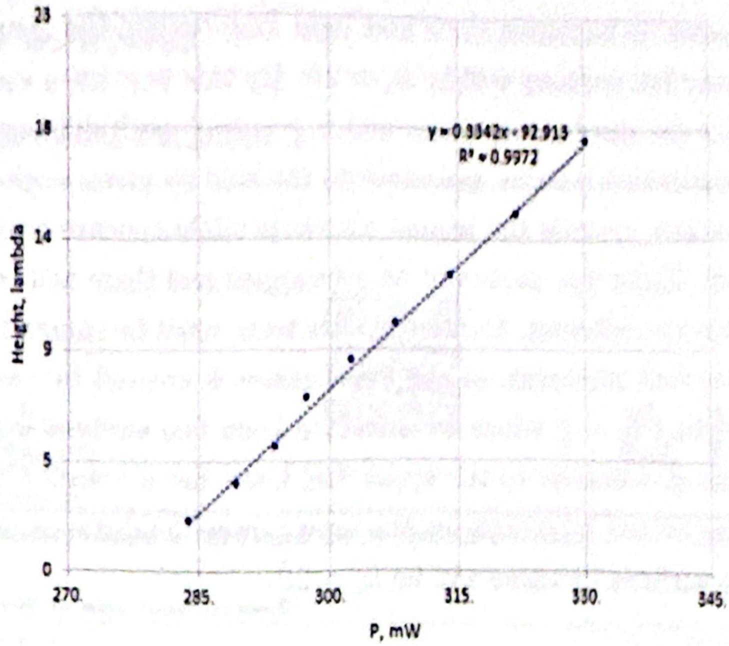

Figure 4.75: The dependence of the shape height on power of the laser is linear.

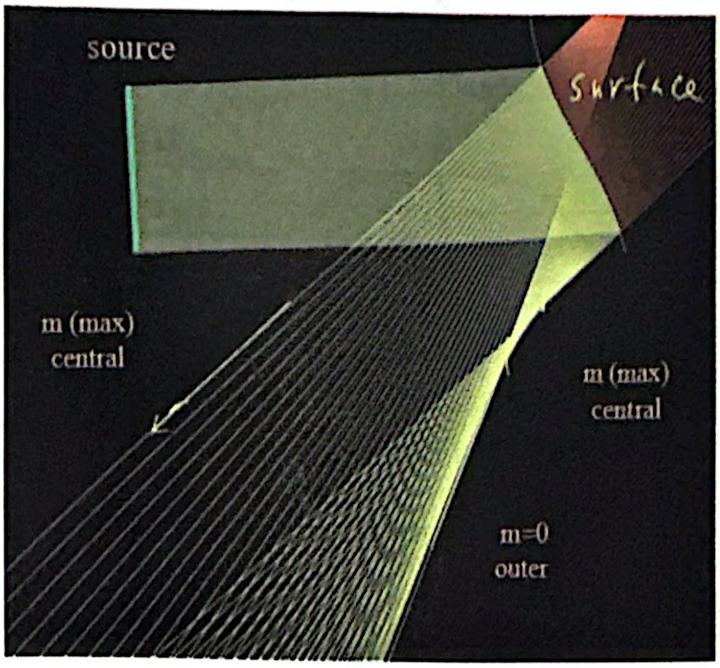

Figure 4.76: Light reflection from the shape. While the convex edge of the shape spreads the beams outward, the concave part is reflecting the beams inward. These beams are overlapped and create the interference pattern.

When the acrylic surface starts warming up the surface expands. To the edge of the shape the inclination increases gradually, then it reaches the maximum inclination. From this part the beam with α_{max} angle reflects and creates first light fringe ($m = 0(1)$). Then surface temperature decreases to the outward and shape becomes concave (Figure 4.76).

If the laser power is increased until first light ring occurs, the distance between upper and lower flat surfaces will be $h_1 = 2\frac{\lambda}{2}$. By this way when surface temperature increases the distance increases and $h_m = 2m\frac{\lambda}{2}$ path difference is created. Therefore, interference pattern can move to the side by given angle. The convex part of the surface spreads the beams outwards while concave part spreads the beams inwards. These two parts will be overlapped and there will be interference since the beams are coherent. Interference patterns must be counted from outside to inside. The first minimum of the interference is created by two waves with the path difference $\Delta = \frac{\lambda}{2}$ which are reflected from two surfaces with very small inclining angles and nearest to the upper and lower flat surfaces.
When first ring occurs by increasing the laser power the distance between upper and lower flat surfaces distance will be $h_1 = 2\frac{\lambda}{2}$.

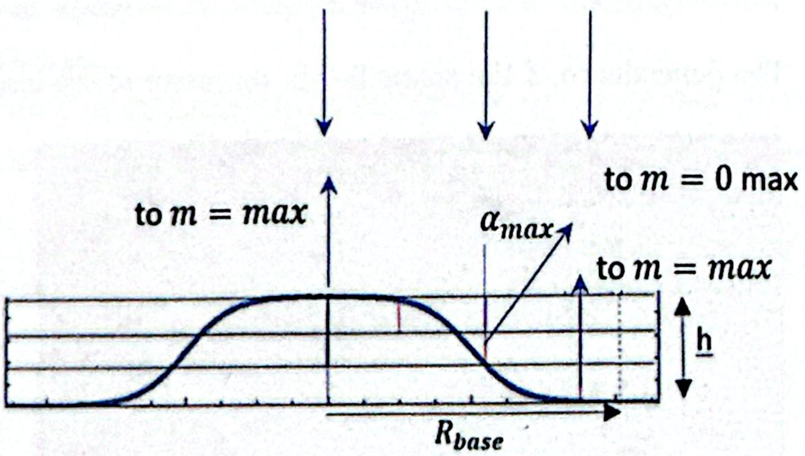

Figure 4.77: Similarly on all side of the surfaces from the center will be same pattern of the interference. The ring shape will show that if the bump shape is symmetrical or not.