PSE605A (Photonics Lab Techniques)

Lab Report: Experiment 10

Michelson Interferometer

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1 Measurement of temporal coherence of different light source using Michelson interferometer

1.1 Objectives

To calculate temporal coherence using Michelson Interferometer of:

a) **He-Ne laser of λ = 632.8 nm**

b) **Solid state Laser of λ = 655 nm**

c) **Diode Laser of λ= 635 nm**

1.2 Apparatus

Lasers with power supply, Microscopic-objective, Spatial filter, Spherical beam splitter, Two plane mirrors, Translational stage, Screen, CCD camera, X-Y position controller and Computer.

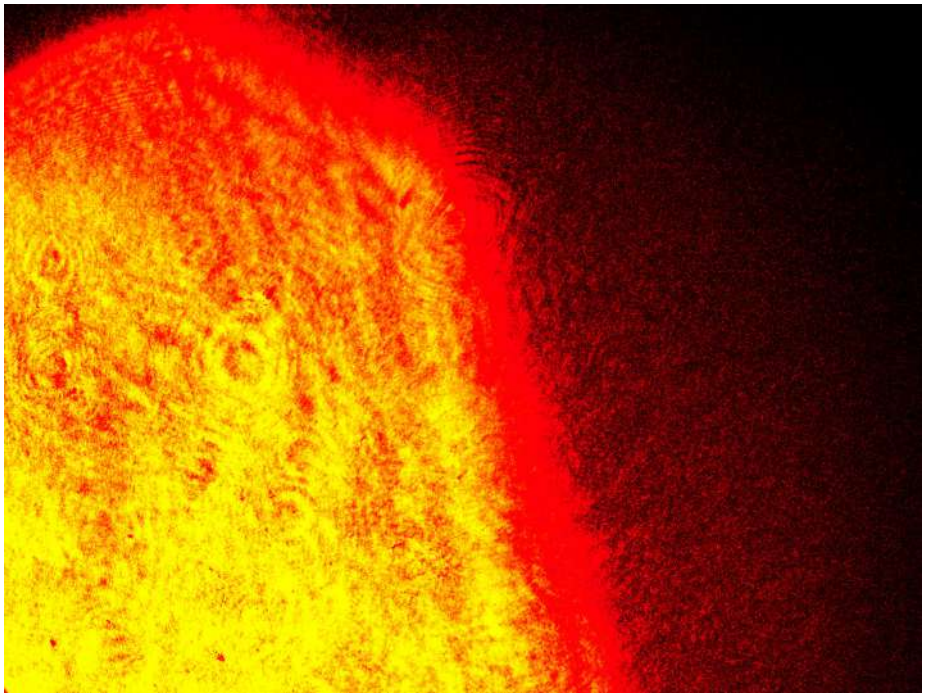
1.3 Procedure

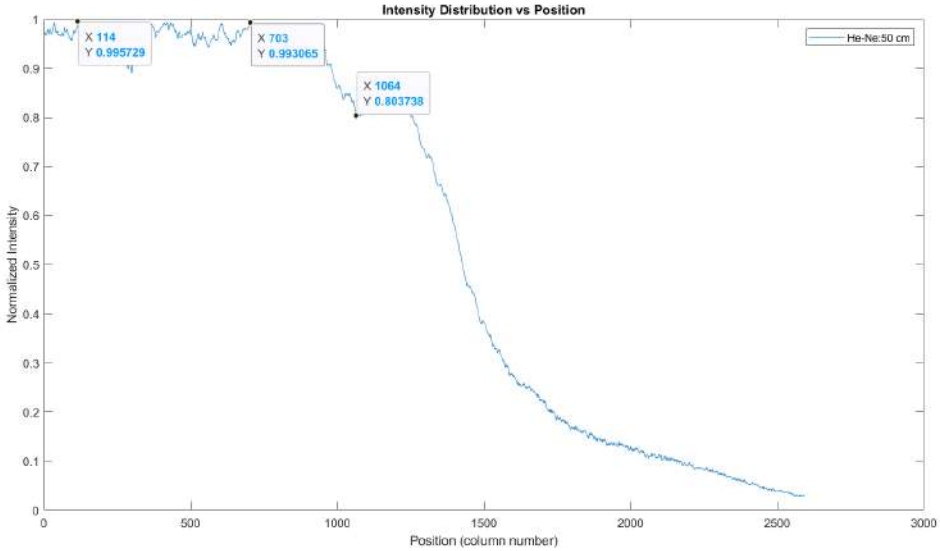
1. Laser is aligned to get the parallel beam. Proper care is required to make the beam strike at the centres of the mirrors.
2. Objective lens and pinhole arrangement (spatial filter) is used to filter out the higher spatial frequencies of the beam. Pinhole should be placed at the exact focus point of the objective lens. Uniform intensity light is falling on beam splitter.
3. Then the angle of the first beam splitter arrangement is aligned so that the reflected beam hits the first mirror at its centre. Similar has been done with the second mirror to get out reflected light which has to hit the second beam splitter also at its centre.
4. In this position two sets of bright patches come out in the screen from two mirrors simultaneously. Adjustment is done properly with the help of the movable mirrors and beam splitters to overlap these two patches finely.
5. Beams passing from beam splitter interfere and interference pattern is observed on screen.
6. Use CCD camera and lens arrangement to capture the interference pattern as lens focus the pattern on camera aperture.
7. CCD camera is triggered using computer.

1.4 Plots

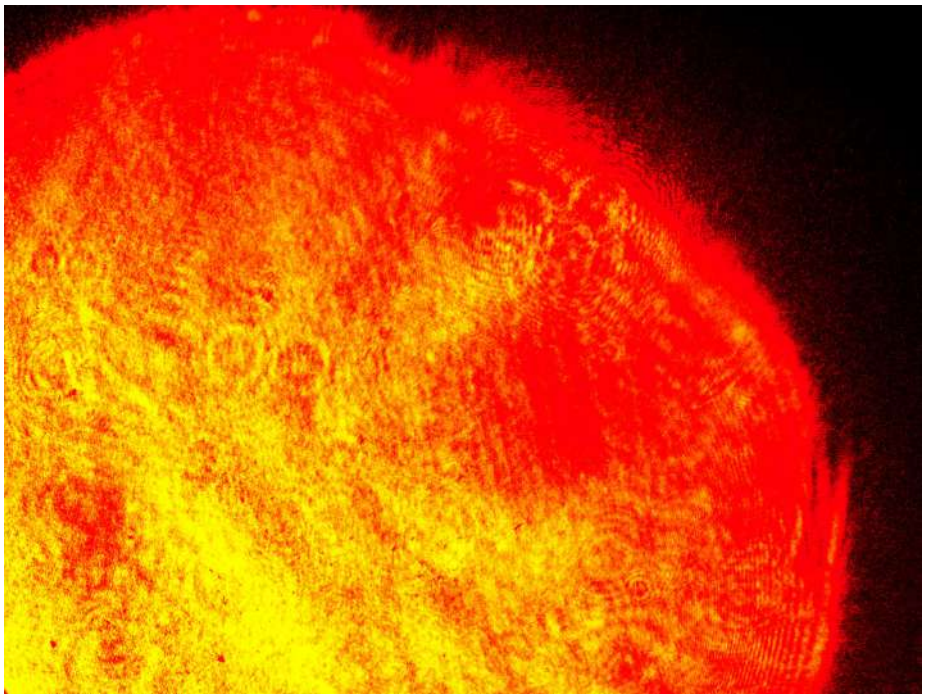
1.4.1 He-Ne laser

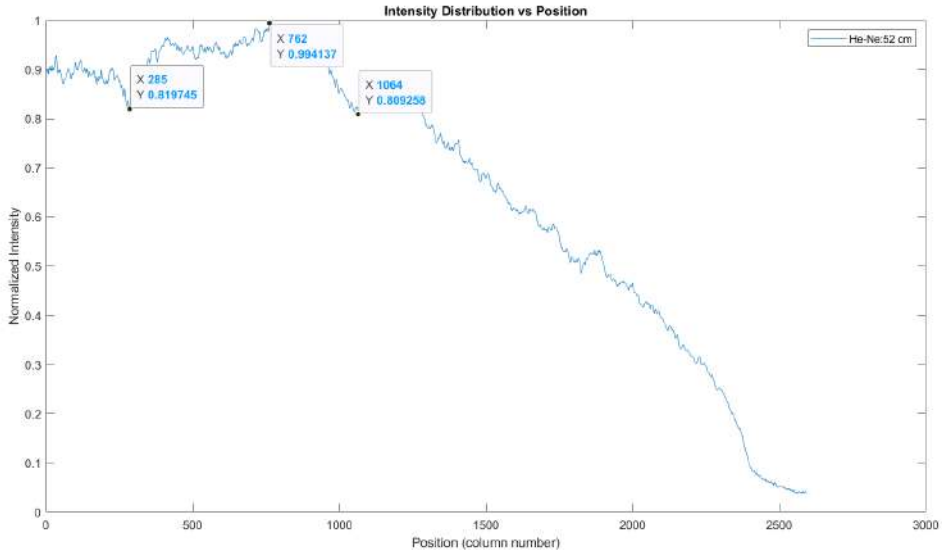
Distance=50 cm



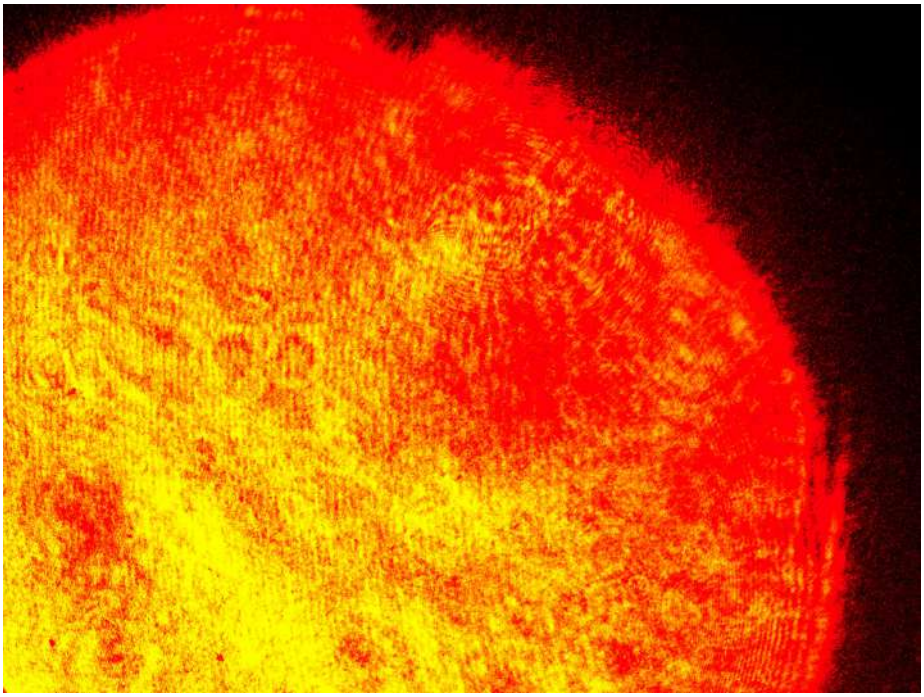


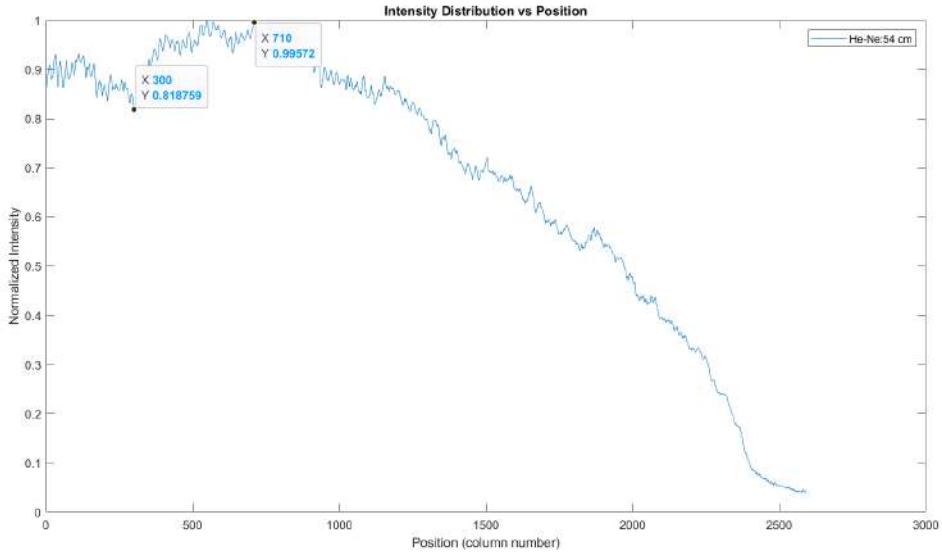
Distance=52 cm





Distance=54 cm





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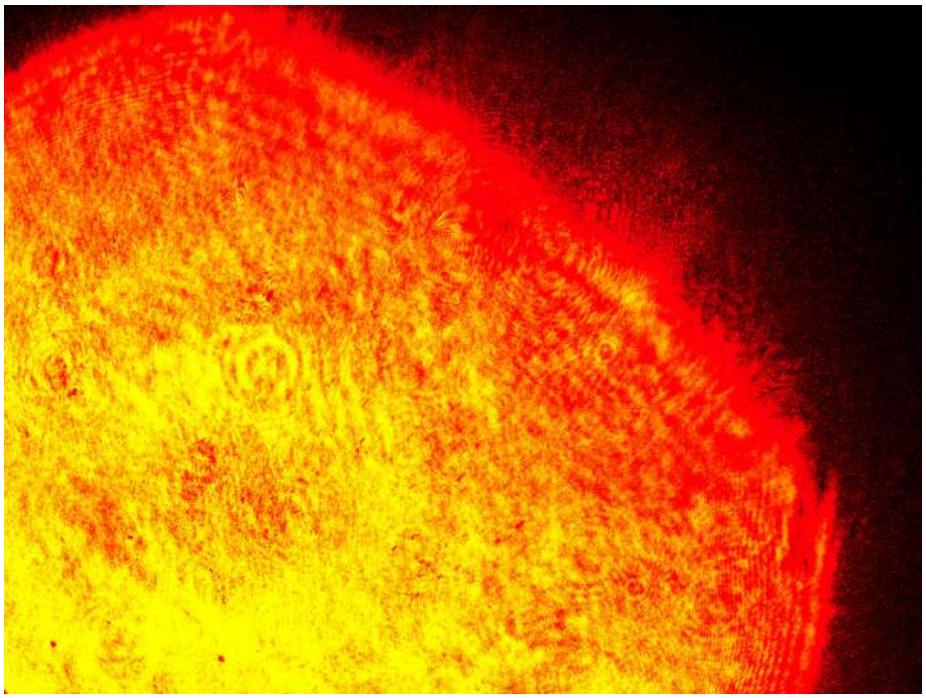
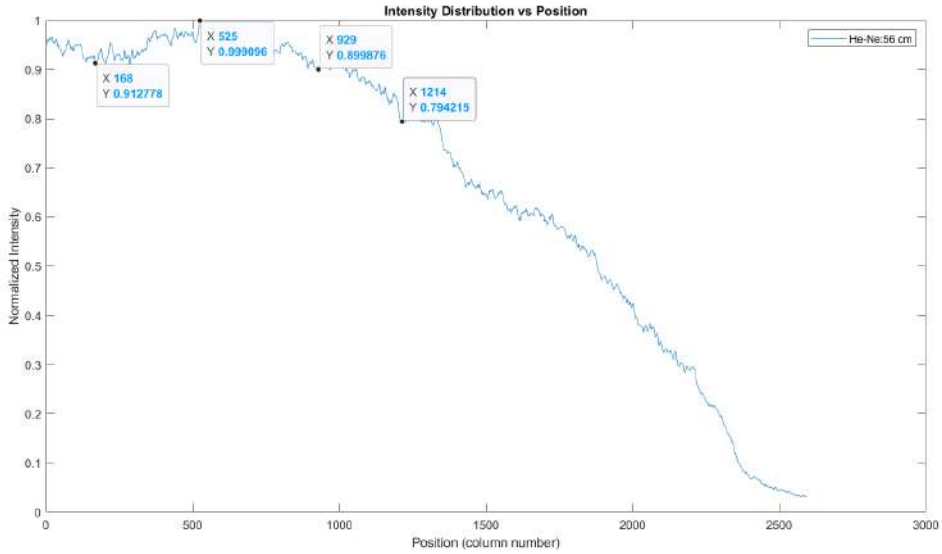
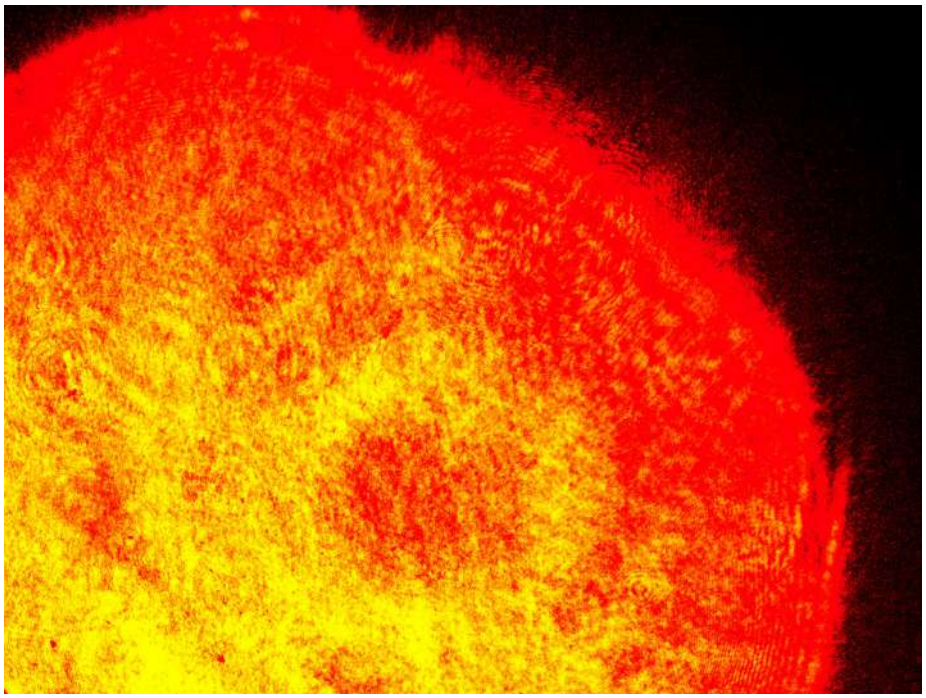
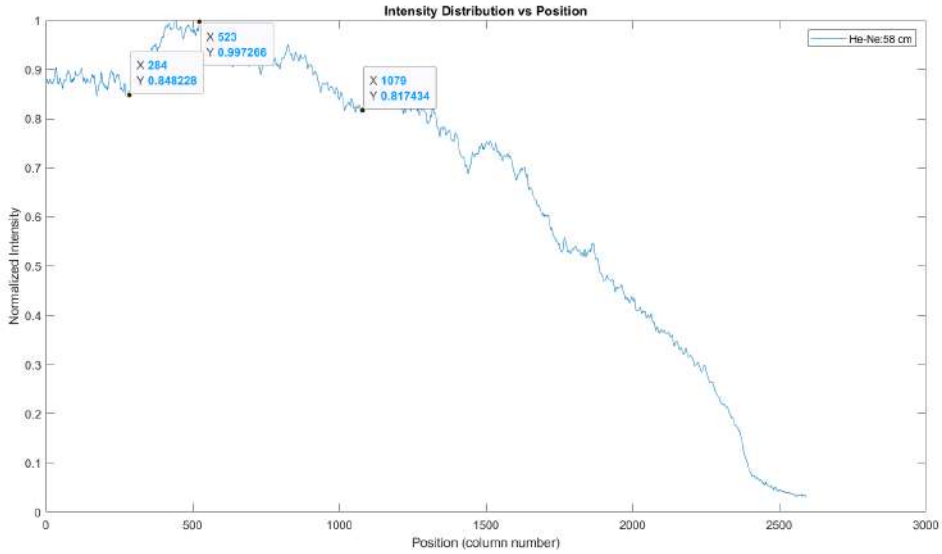


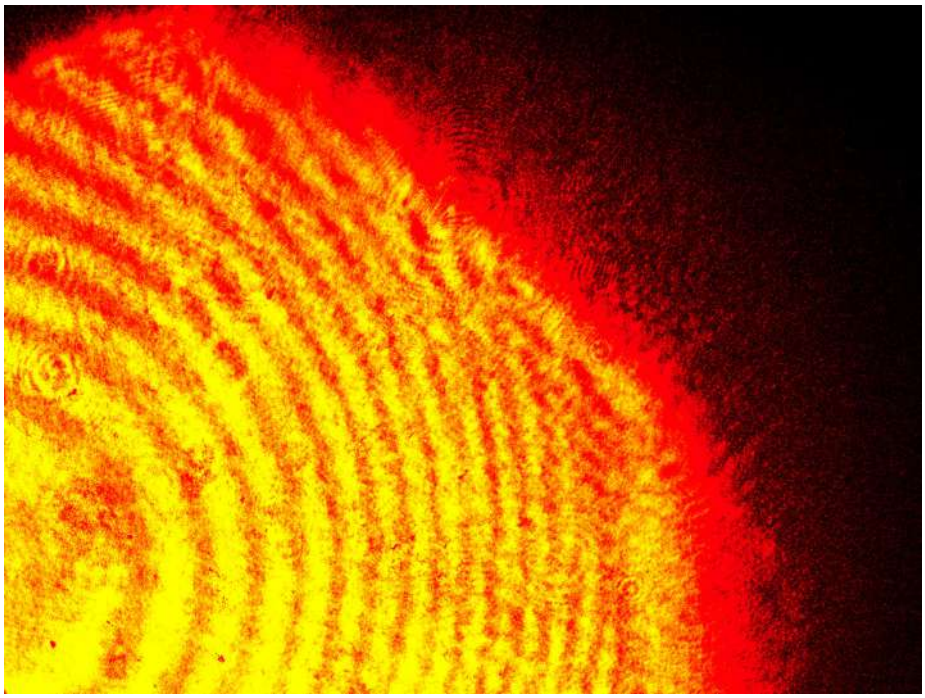


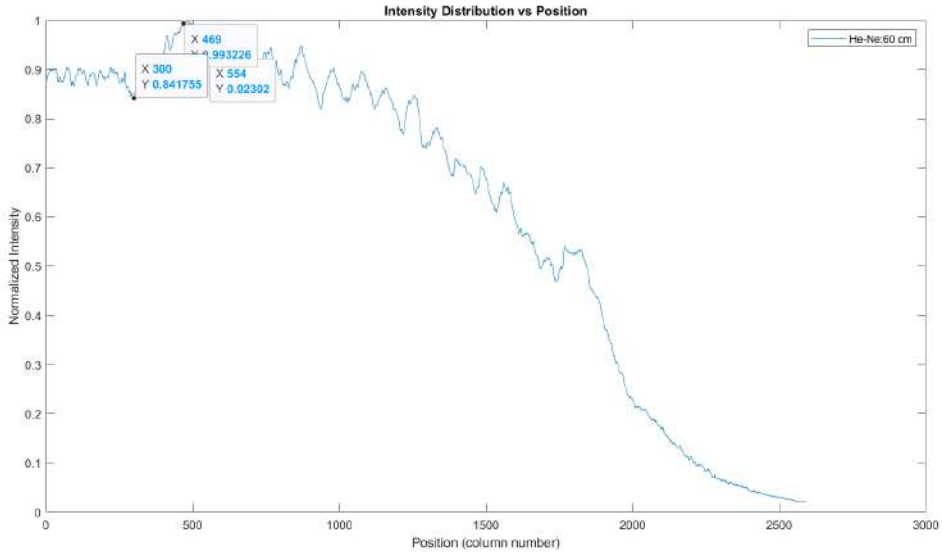
Distance=58 cm



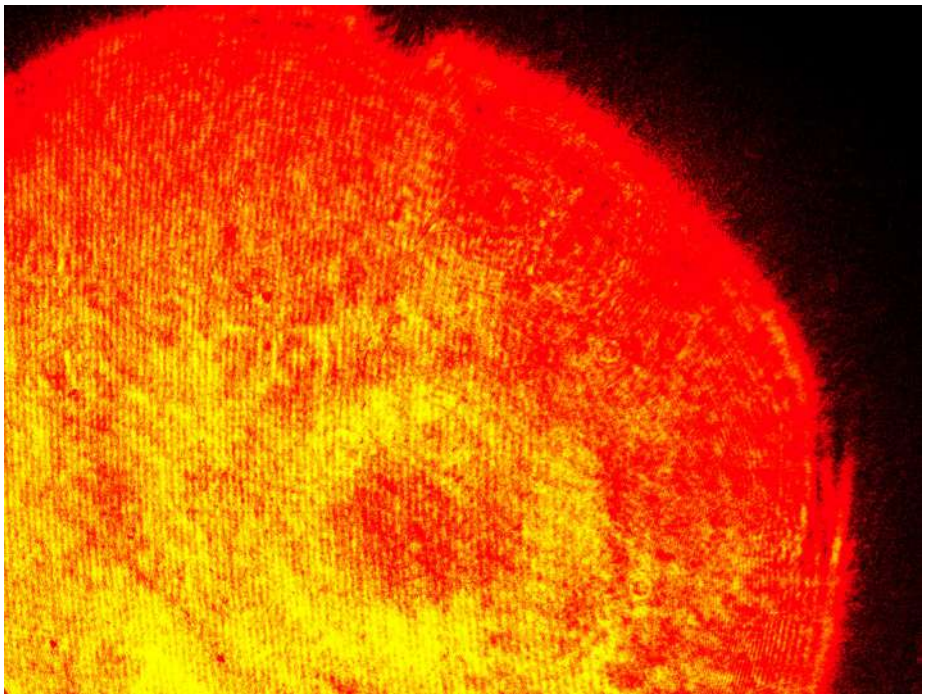


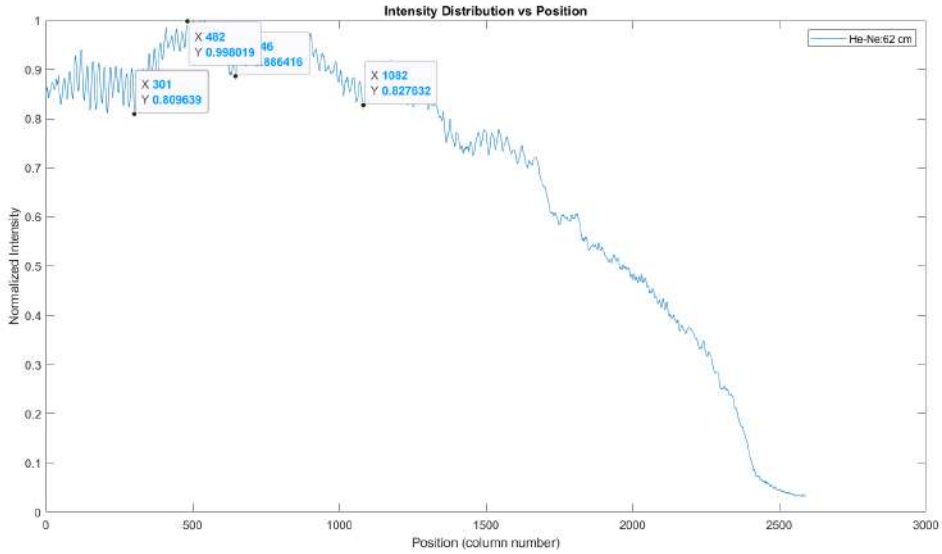
Distance=60 cm



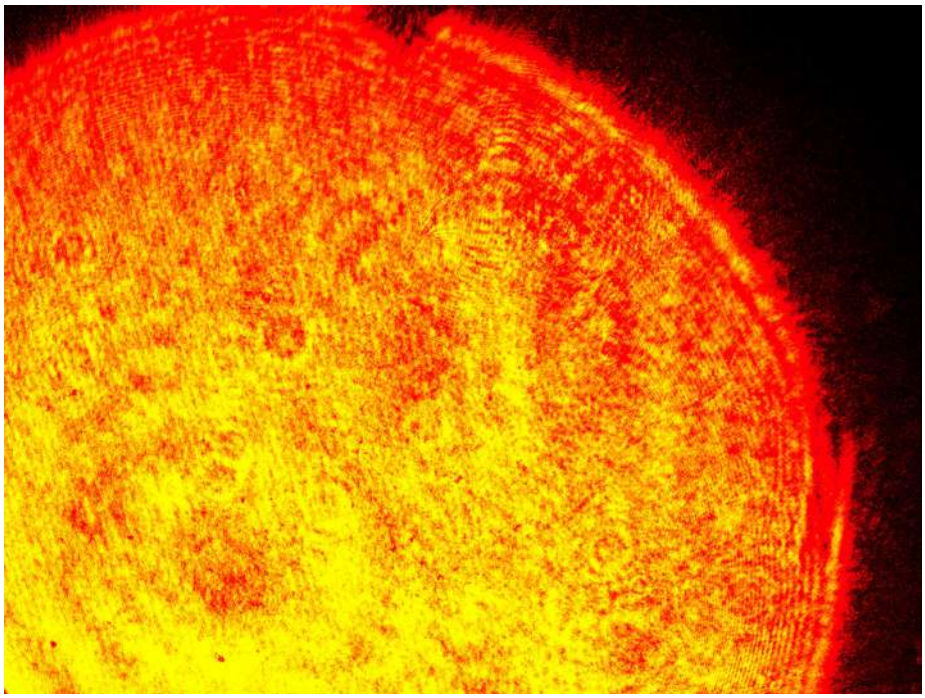


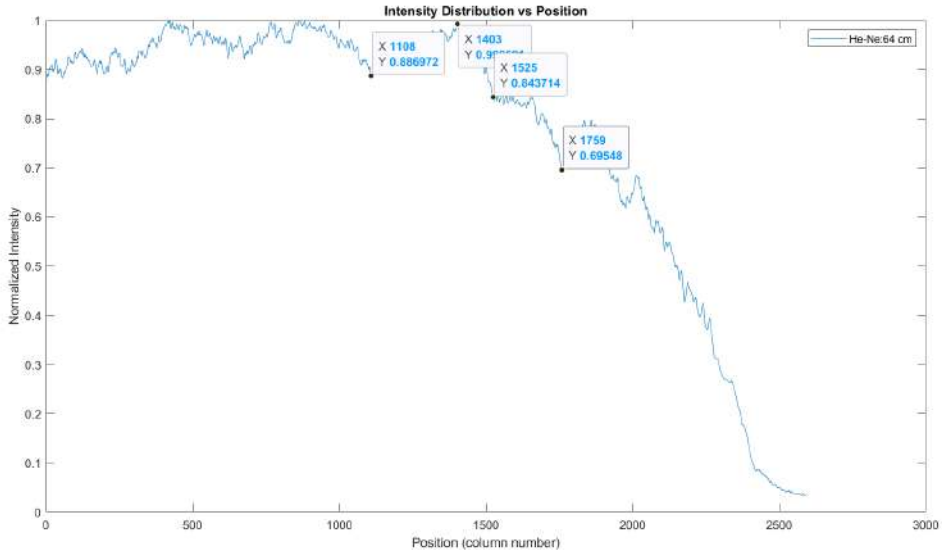
Distance=62 cm



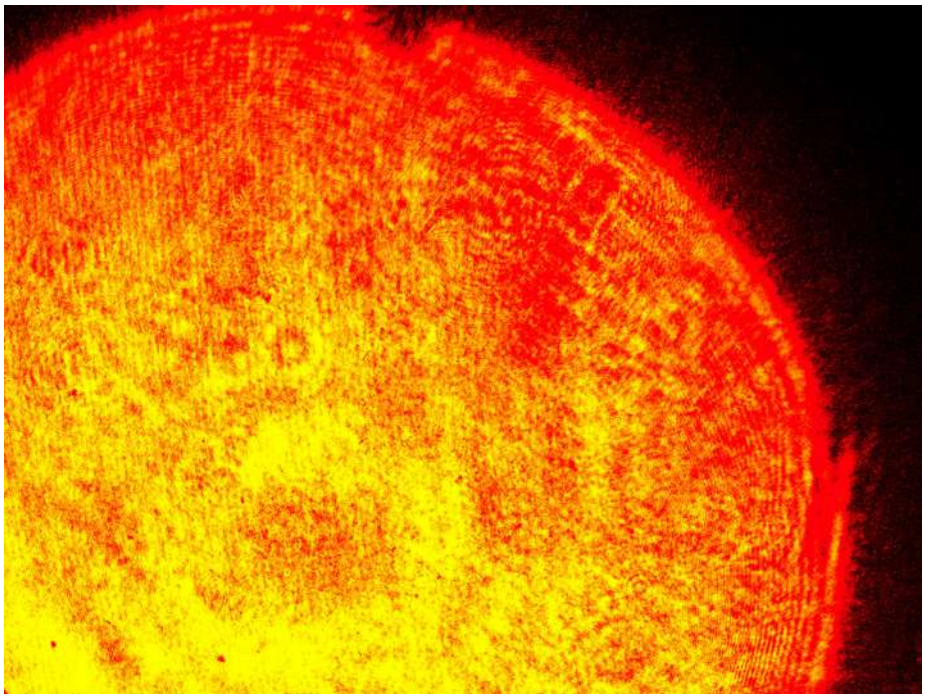


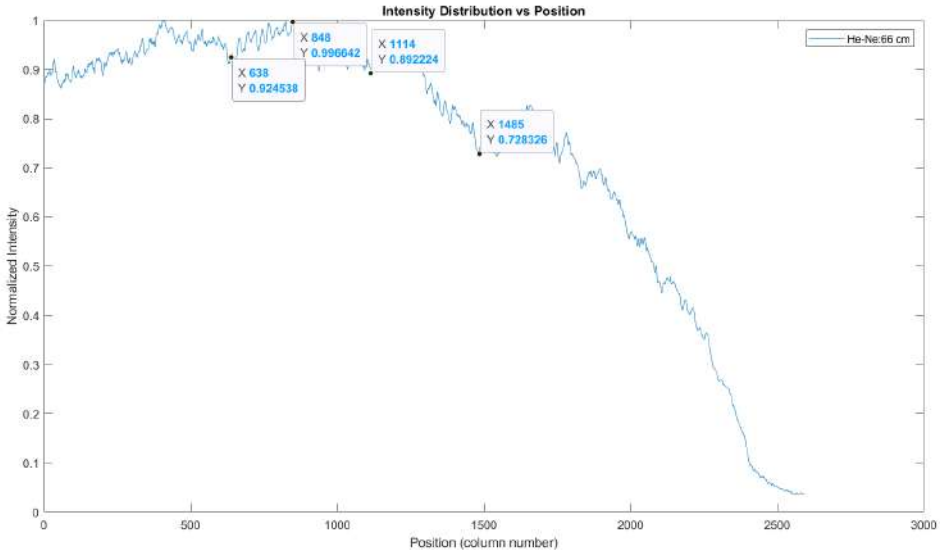
Distance=64 cm



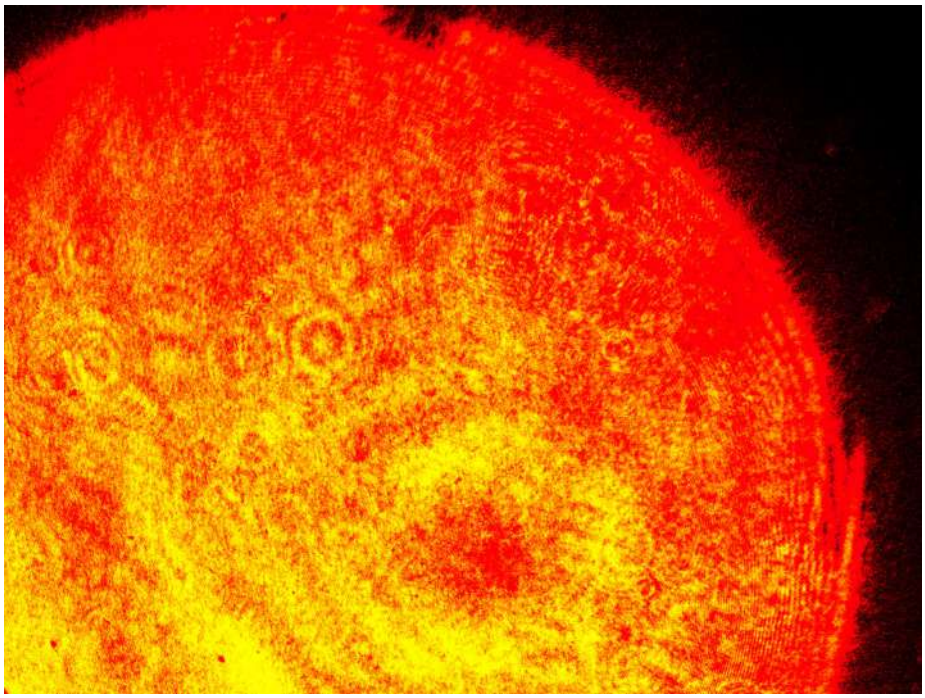


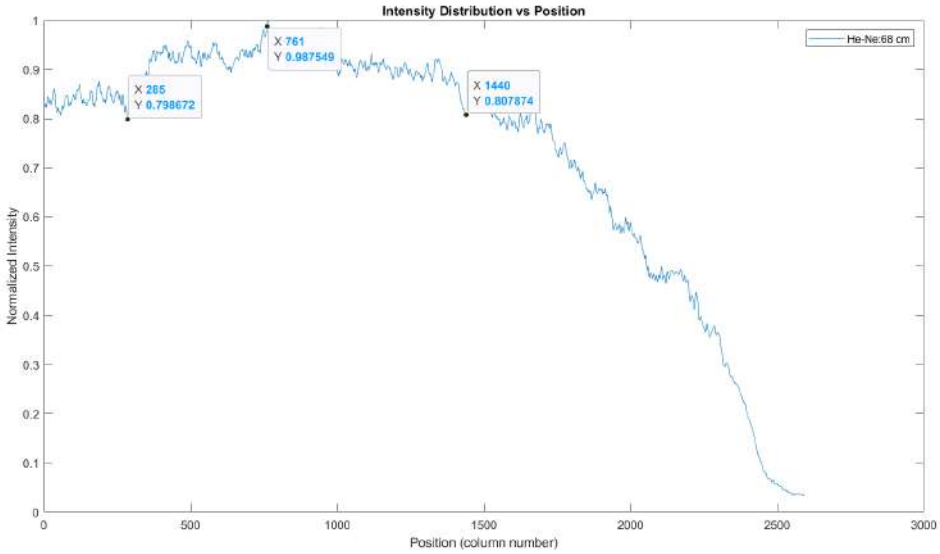
Distance=66 cm





Distance=68 cm





Since the Coherence length is the distance between two minima's, here from the visibility profile for He-Ne Laser it is found out that the coherence length is 80 cm. Hence the coherence time is $2.66 * 10^{-9}$ s

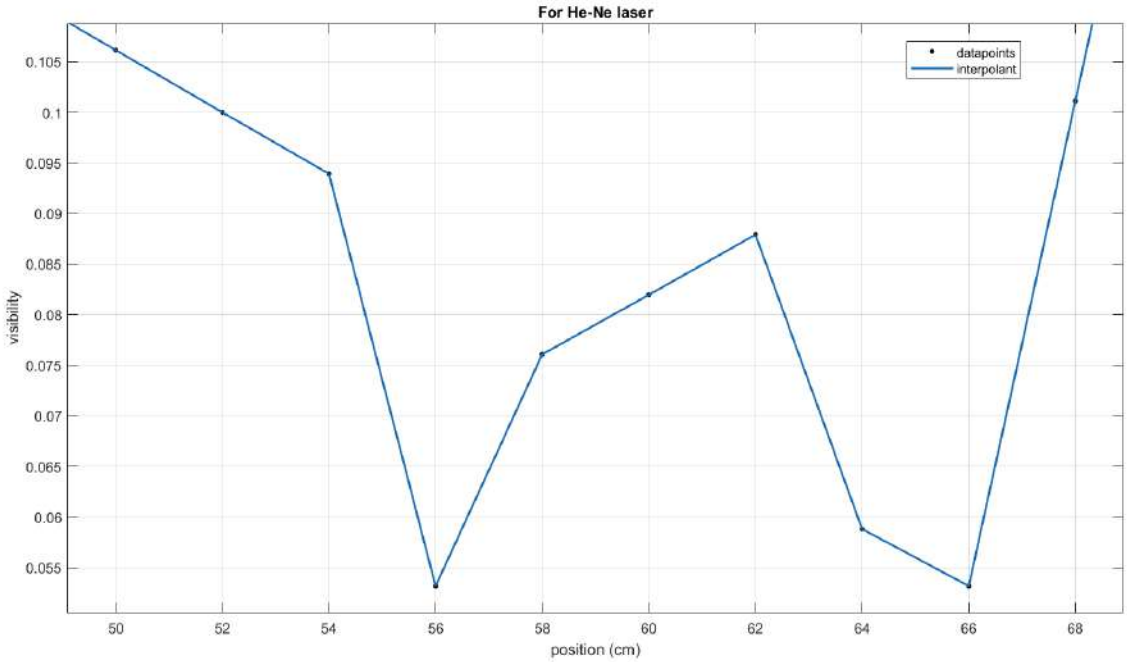
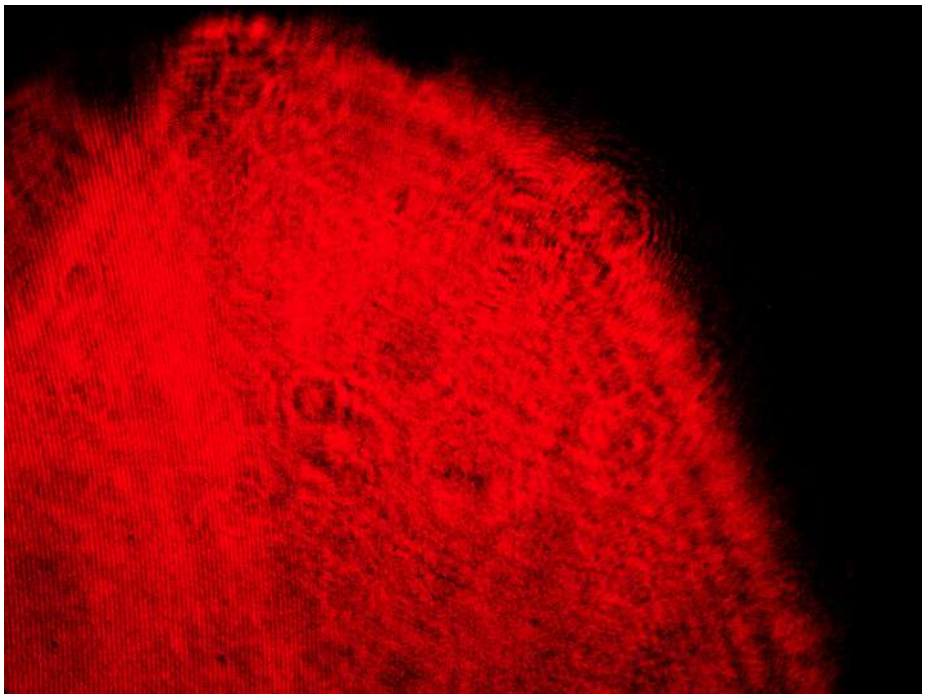
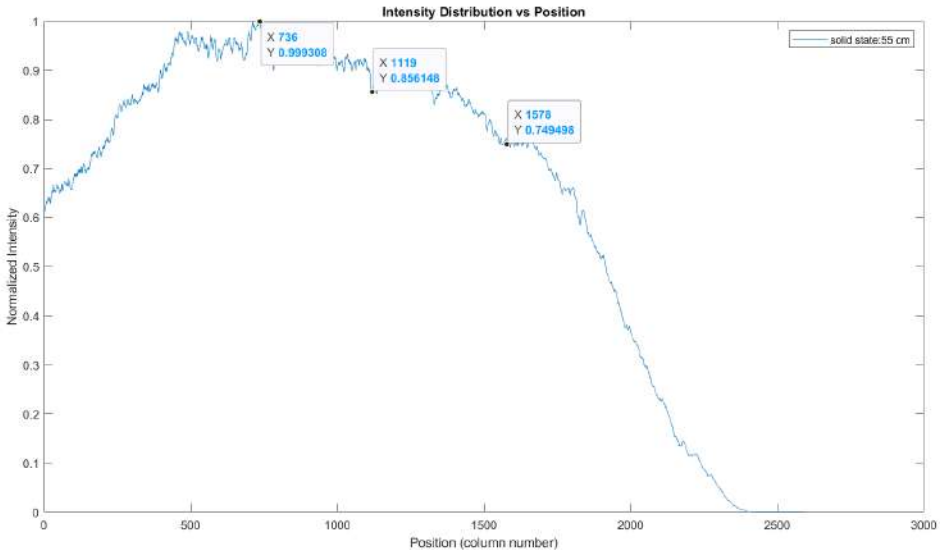


Figure 1: visibility for He-Ne laser

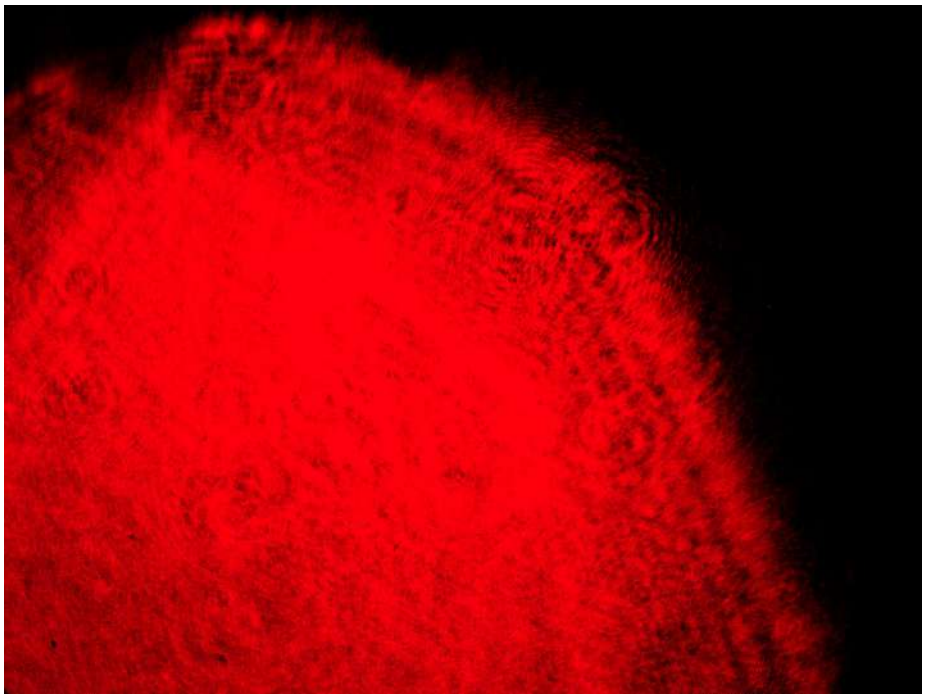
1.4.2 Solid State laser

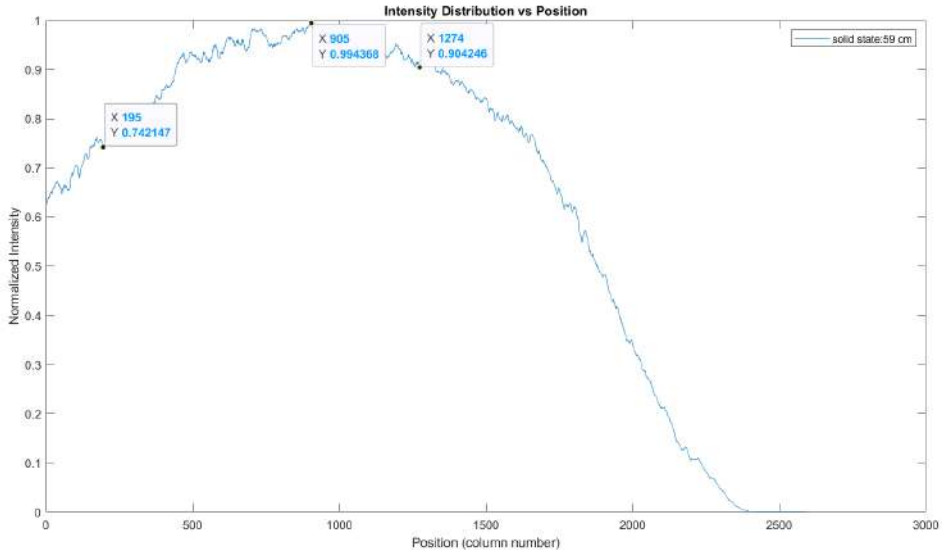
Distance=55 cm



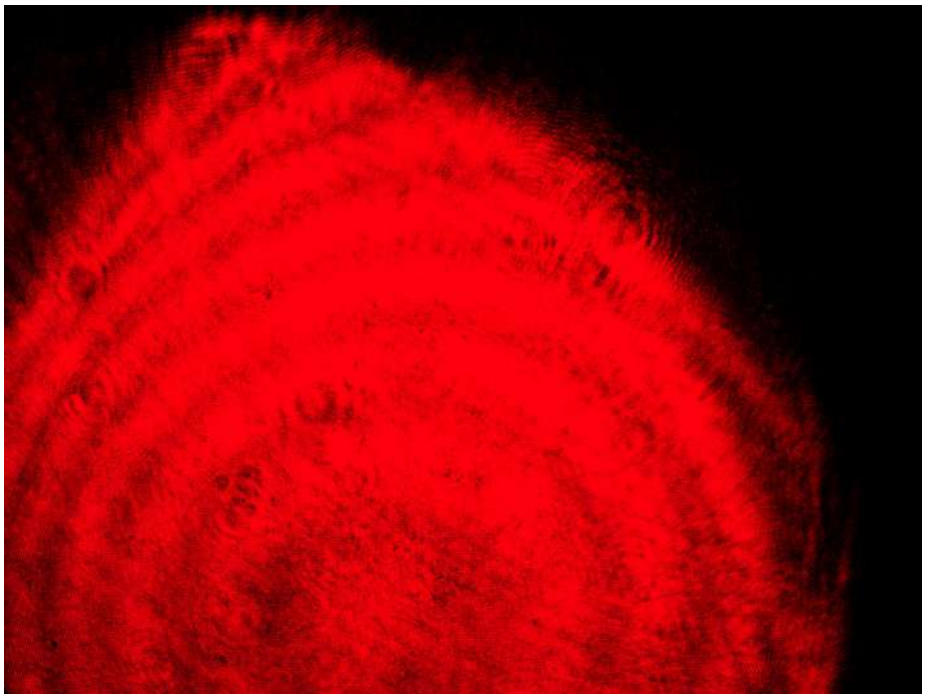


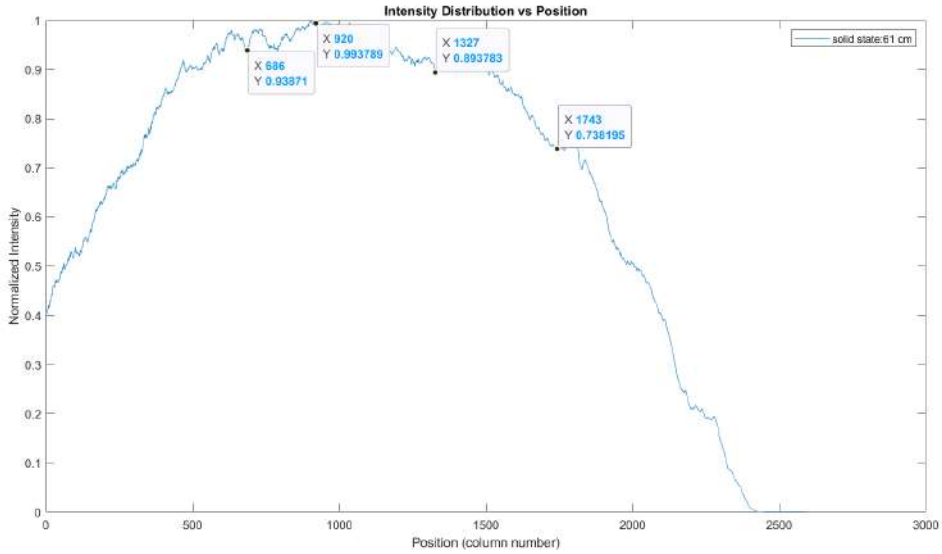
Distance=59 cm



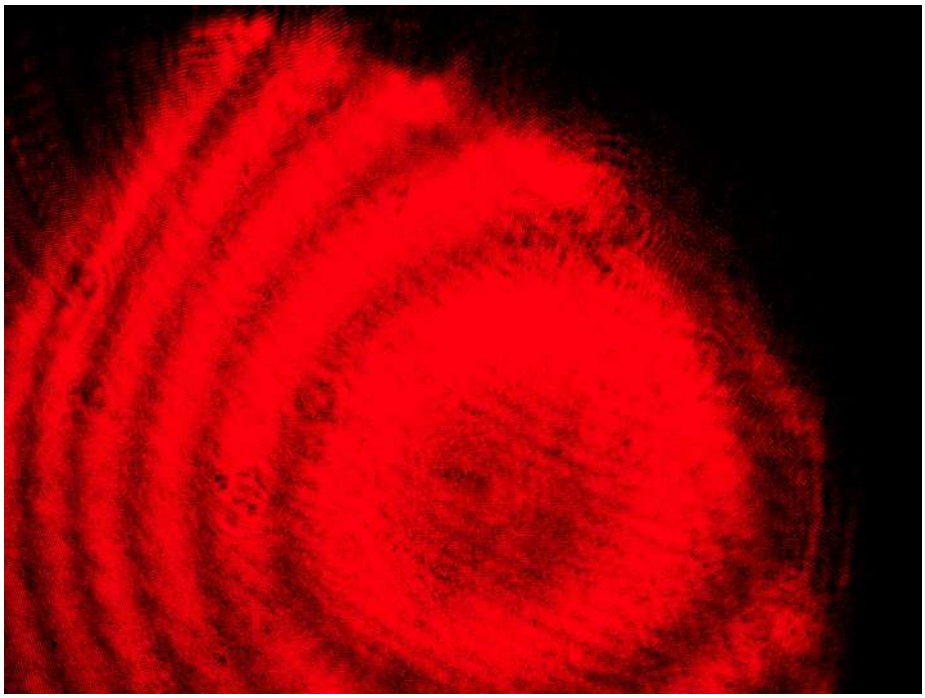


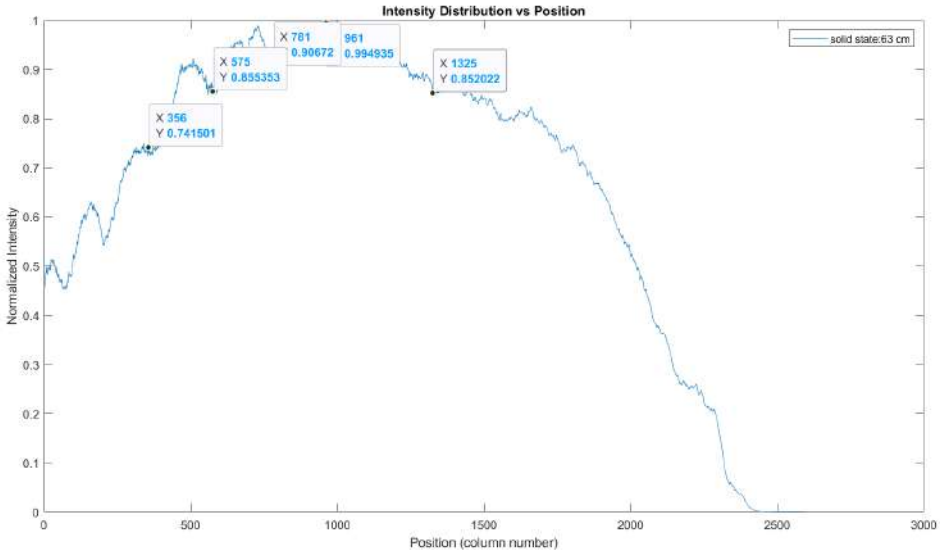
Distance=61 cm



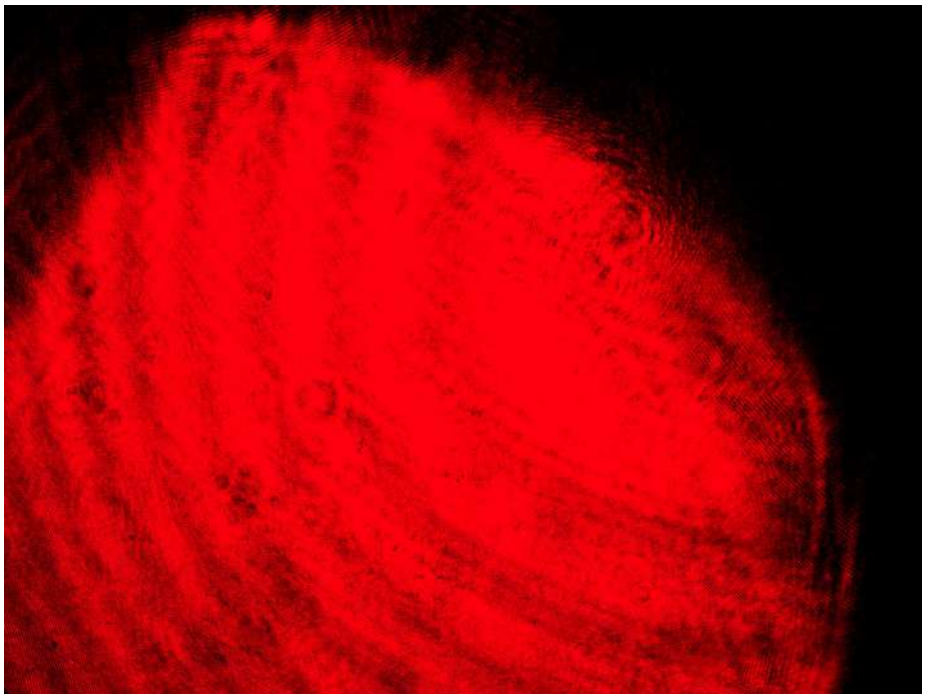


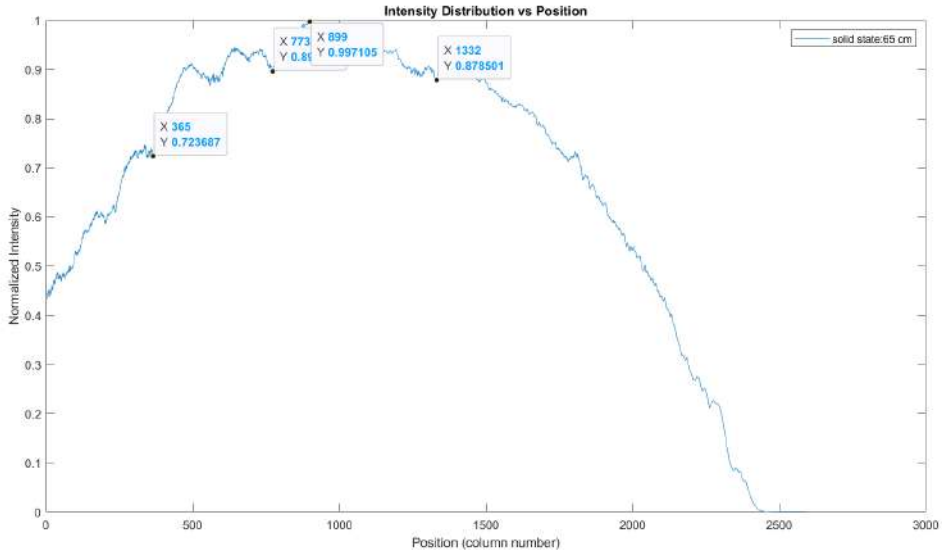
Distance=63 cm



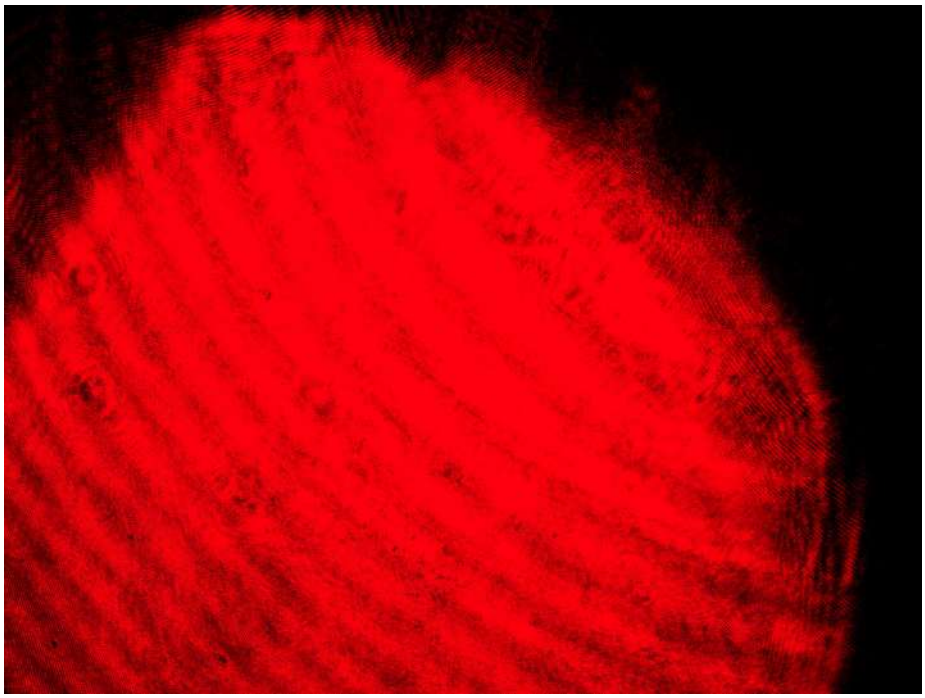


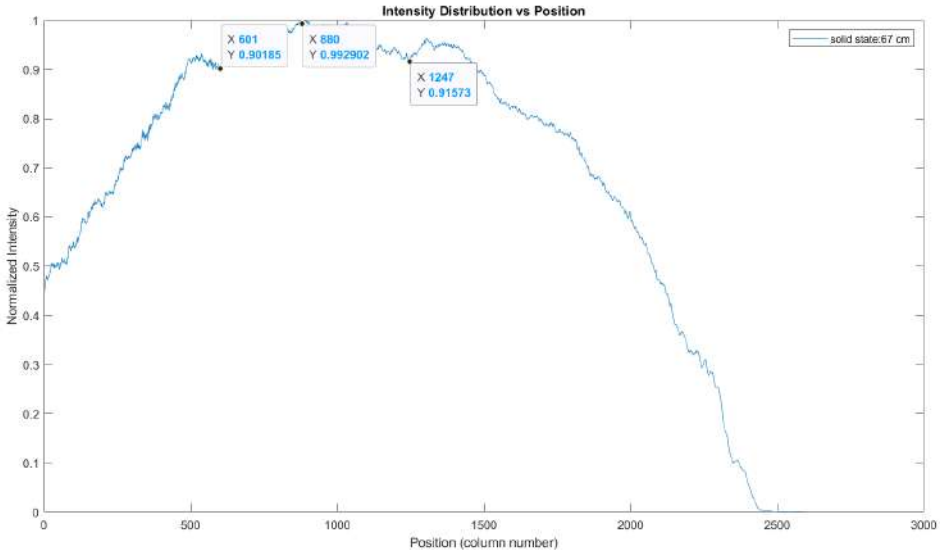
Distance=65 cm





Distance=67 cm





The coherence length of a solid state laser, representing the separation between two successive minima in its visibility profile, has been determined to

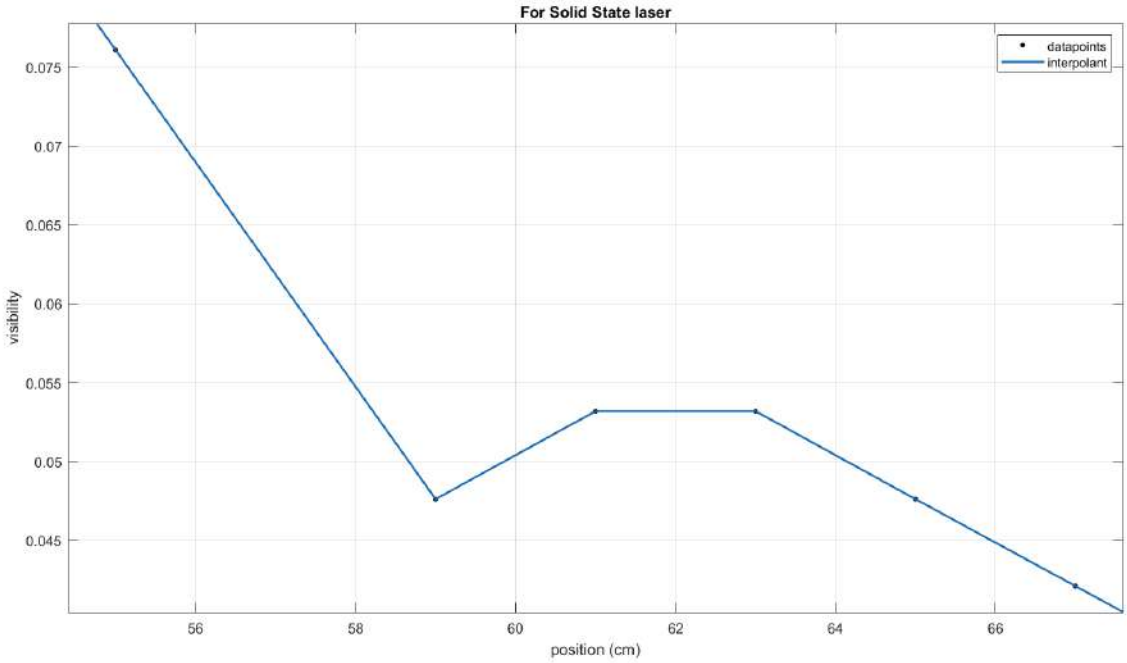
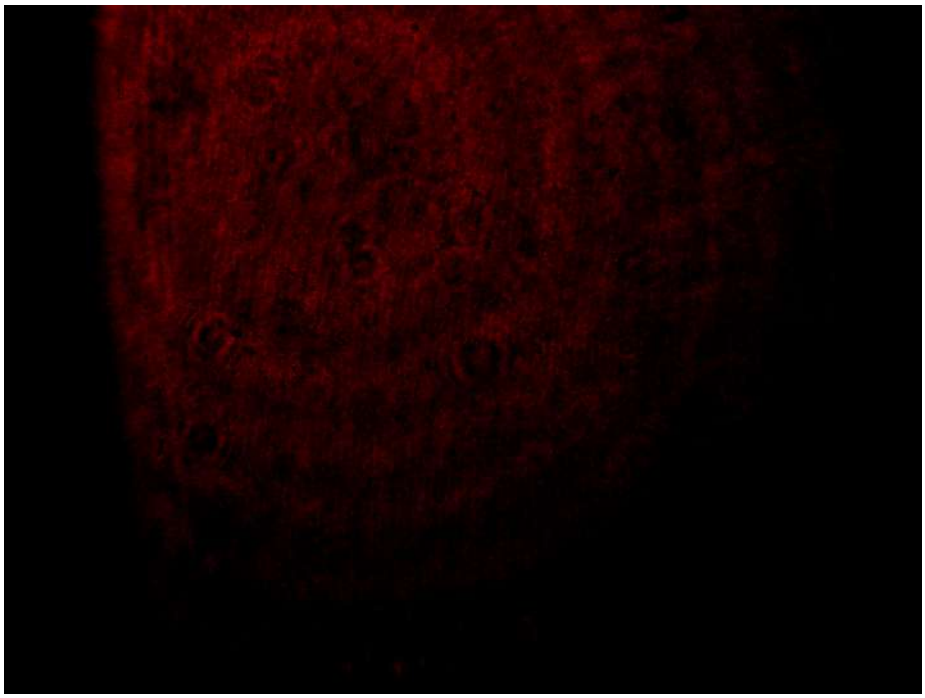


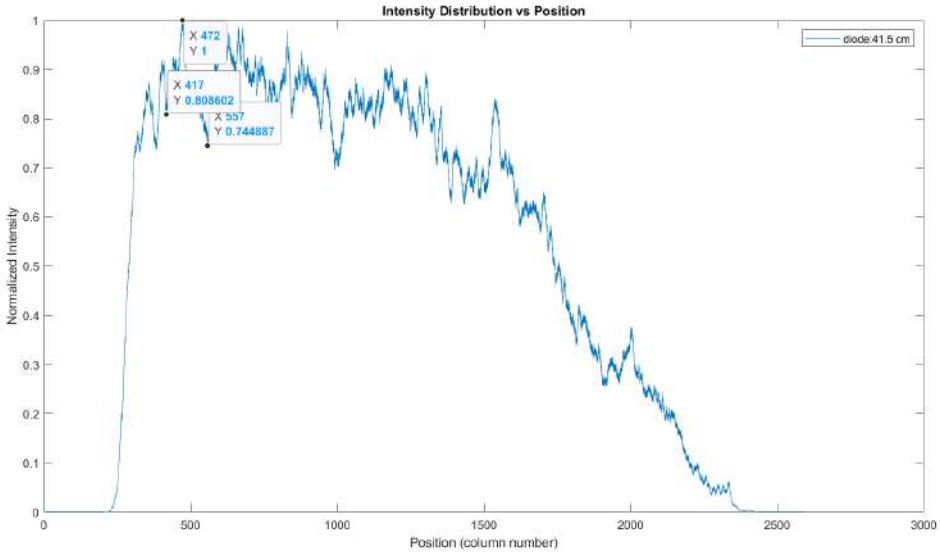
Figure 2: visibility for Solid state laser

be 9 centimeters. This measurement indicates that the coherence time, which signifies how long the laser light maintains its phase relationship, is calculated to be $3 * 10^{-10}$ *seconds*.

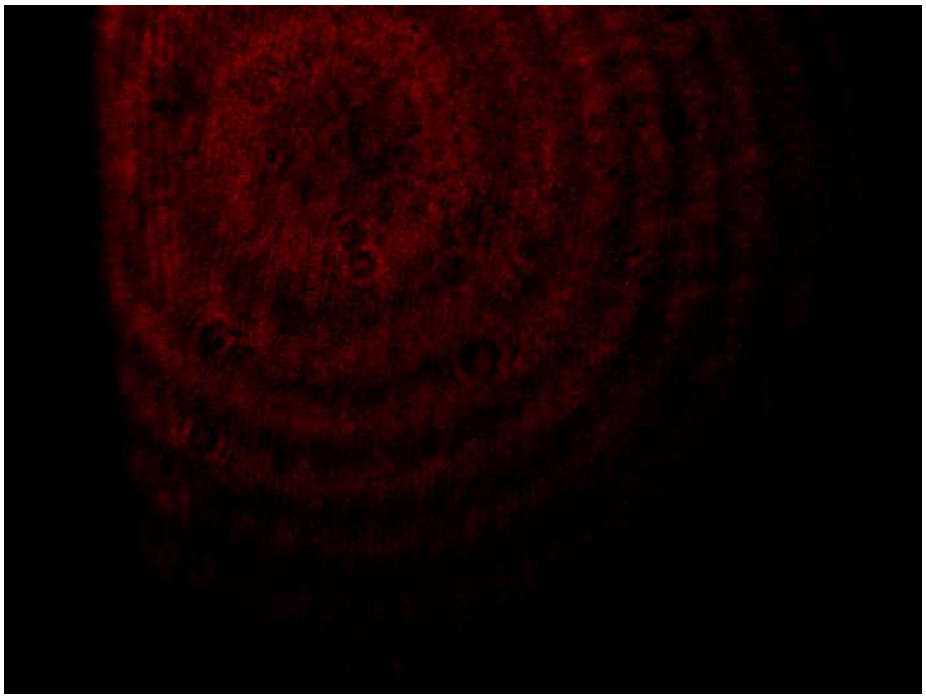
1.4.3 Diode laser

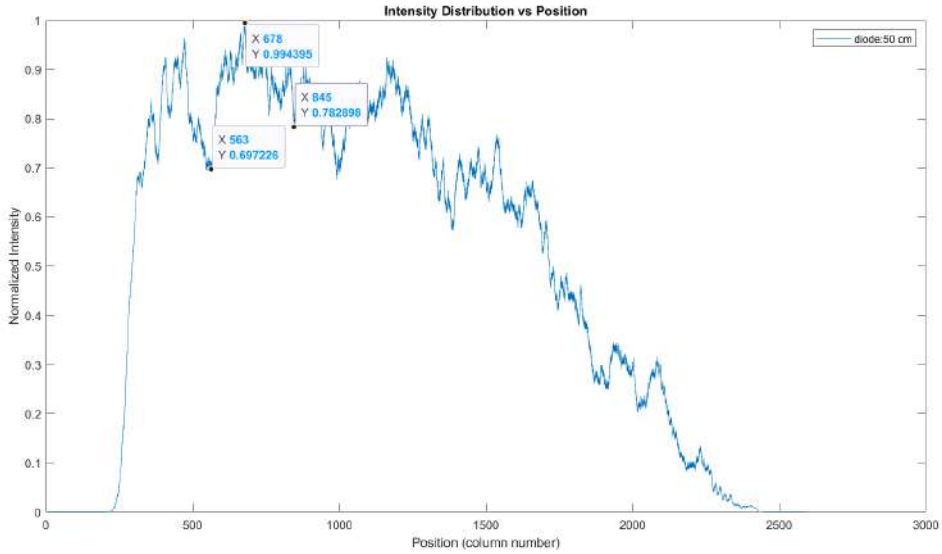
Distance=41.5 cm



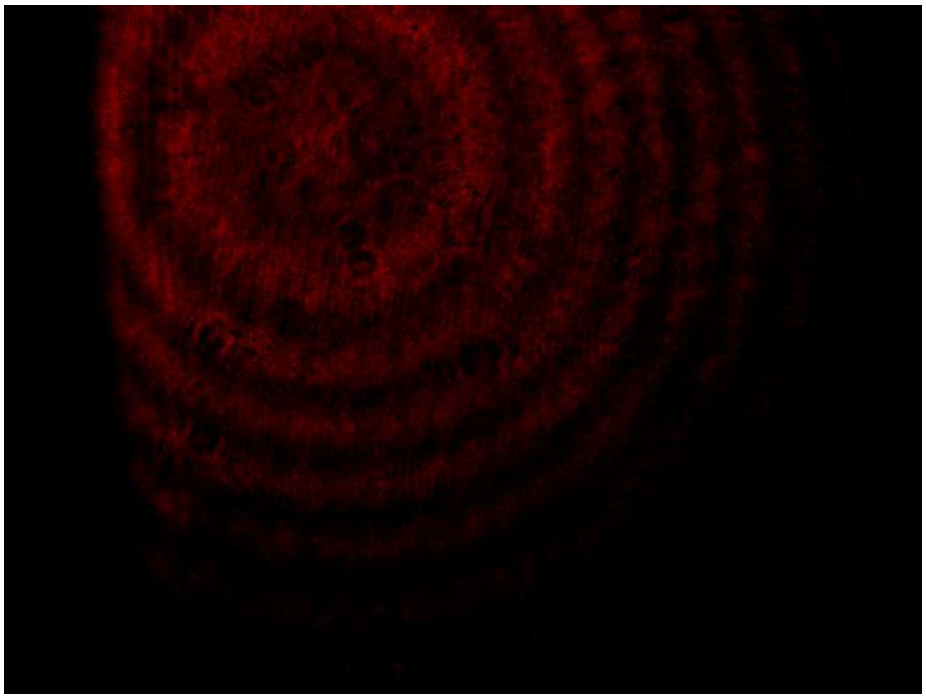


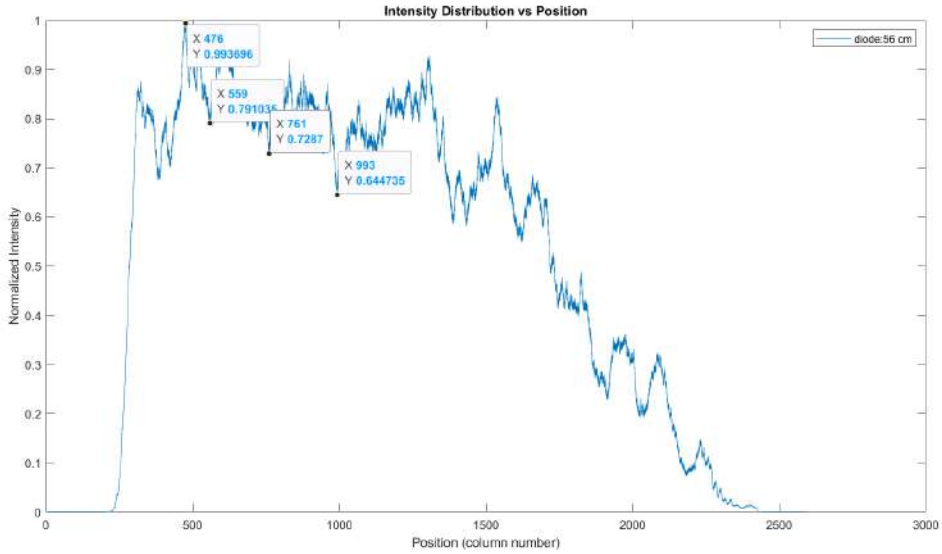
Distance=50 cm



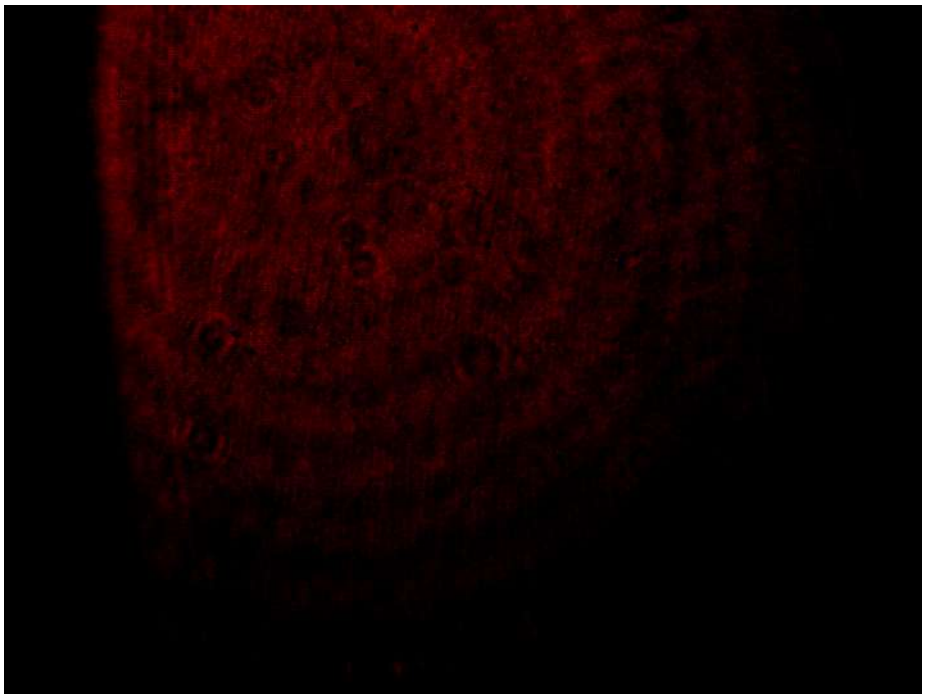


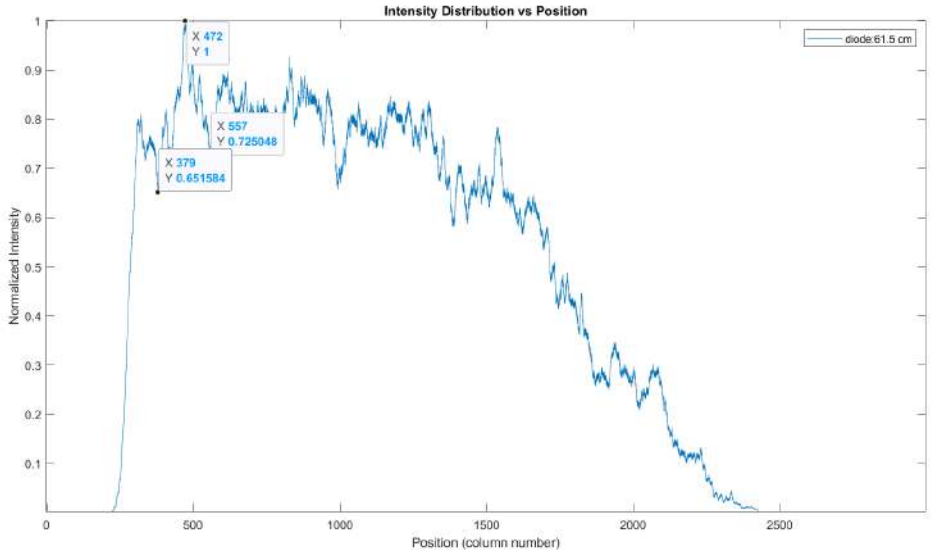
Distance=56 cm



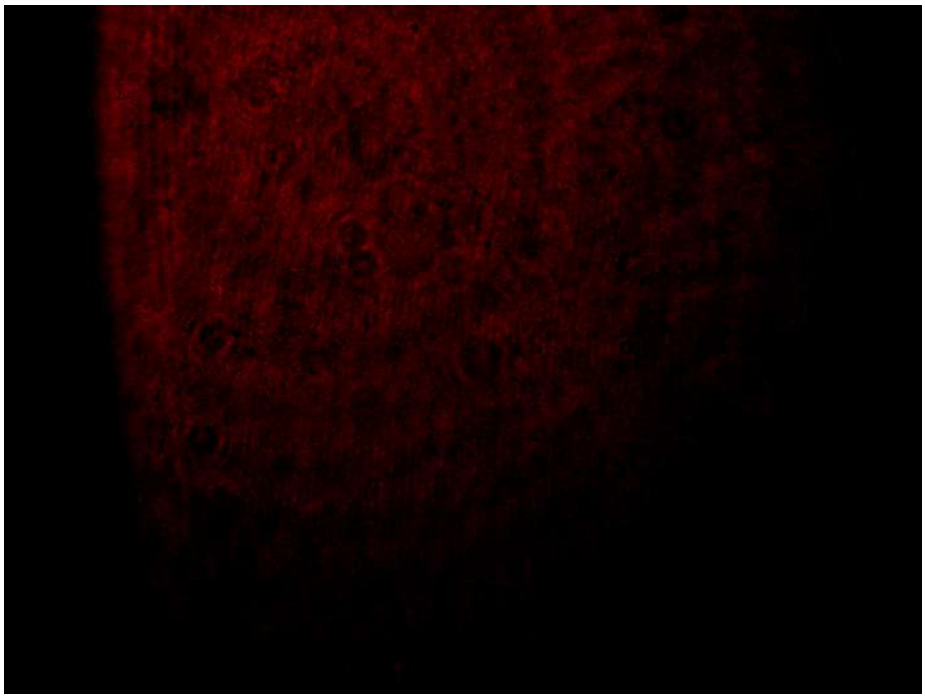


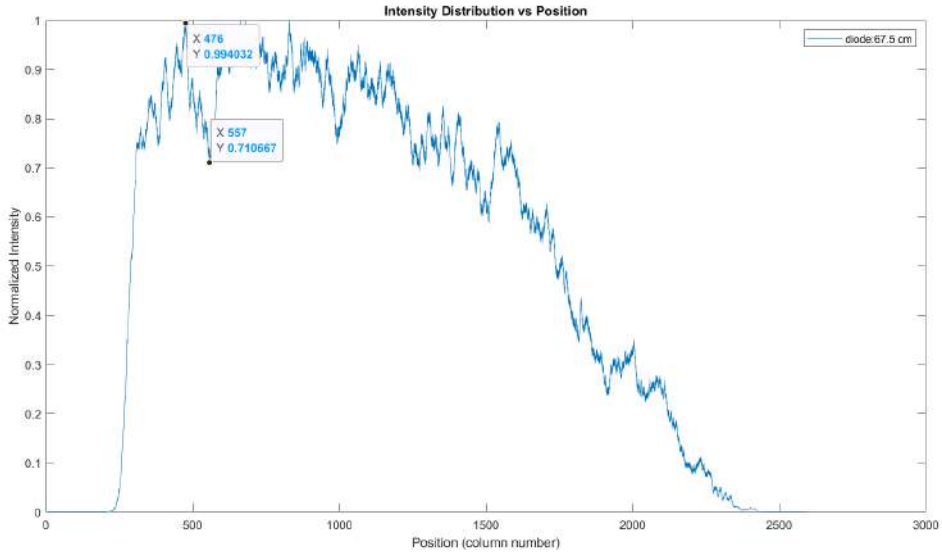
Distance=61.5 cm



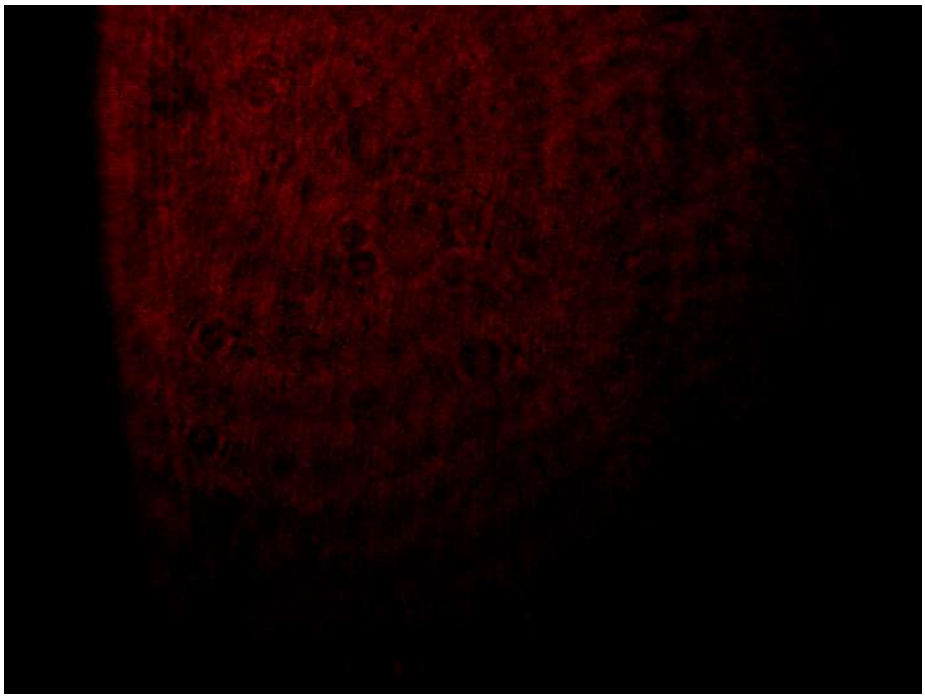


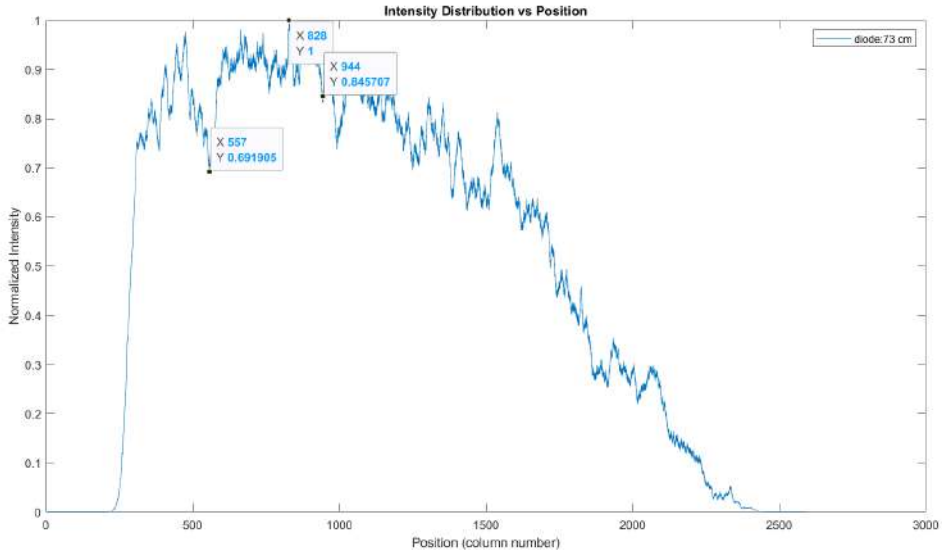
Distance=67.5 cm





Distance=73 cm





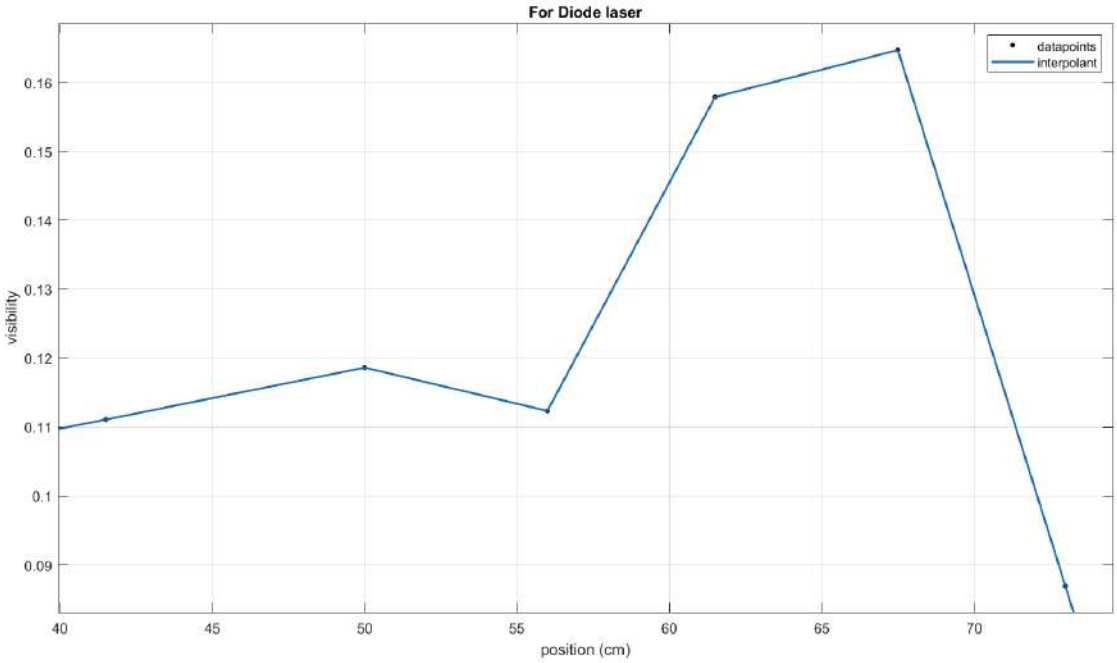


Figure 3: visibility for Diode laser laser

The coherence length of a Diode laser, which denotes the separation between two successive minima in its visibility profile, has been determined to be 9 millimeters. This measurement indicates that the coherence time, representing the duration for which the laser light maintains its phase relationship, is calculated to be $3 * 10^{-11}$ *seconds*.

1.5 Discussions & Conclusions

- In this experiment, the alignment of the laser beam is crucially important. All optical components must be positioned properly and not moved during the experiment. Even the slightest movement can distort the fringe pattern that is formed.
- By using MATLAB's image processing tool, we can extract the intensity pattern from the fringe pattern image. With the maximum and minimum intensity values, we can calculate the visibility of each mirror position.
- In a solid-state laser and a diode laser, the coherence length is typically small. Therefore, to move the mirror, we are supposed to use the position controller suite installed on the computer. However, in our experiment,

the position controller suite is not functioning properly, so we had to move the mirror manually to observe the pattern.

- The intensity of the solid-state laser (SSL) is calculated using an image processing tool in MATLAB. Among all the positions of the mirror, the minimum intensity is found at zero. This means that when calculating visibility, we get unity for all positions, resulting in an infinite coherence length. To find the approximate coherence length, we assume that the minimum intensity is one for all positions. Then, we determine the visibility profile for the SSL, as shown in Figure 4. From the figure, we find that the coherence length is 9 cm and the coherence time is $3 * 10^{-10}$ s.

  The large coherence length is due to our assumption that the minimum intensity is unity, which leads to an error. The visibility becomes large for the range of the mirror position that we take, resulting in a broad Gaussian profile.

  For the diode laser, the process of finding the coherence length is the same as that of the SSL. It is found that the coherence length is 9 mm, and the coherence time is $3 * 10^{-11}$ s..

1.6 Appendix

1.6.1 He-Ne laser

Mirror Position (cm)	Normalized Max. Intensity	Normalized Min. Intensity	Visibility
50	0.99	0.8	0.106145251
52	0.99	0.81	0.1
54	0.99	0.82	0.093922652
56	0.99	0.89	0.053191489
58	0.99	0.85	0.076086957
60	0.99	0.84	0.081967213
62	0.99	0.83	0.087912088
64	0.99	0.88	0.058823529
66	0.99	0.89	0.053191489
68	0.98	0.8	0.101123596

Table 1: Intensity for He-Ne laser

1.6.2 Solid State laser

Mirror Position (cm)	Normalized Max. Intensity	Normalized Min. Intensity	Visibility
55	0.99	0.85	0.076086957
59	0.99	0.9	0.047619048
61	0.99	0.89	0.053191489
63	0.99	0.89	0.053191489
65	0.99	0.9	0.047619048
67	0.99	0.91	0.042105263

Table 2: Intensity for Solid state laser

1.6.3 Diode laser

Mirror Position (cm)	Normalized Max. Intensity	Normalized Min. Intensity	Visibility
41.5	1	0.8	0.111111111
50	0.99	0.78	0.118644068
56	0.99	0.79	0.112359551
61.5	0.99	0.72	0.157894737
67.5	0.99	0.71	0.164705882
73	1	0.84	0.086956522

Table 3: Intensity for Diode laser

1.6.4 Error analysis

During the experiment on Diode and Solid-State Lasers, we encountered some possible sources of error. One such error was the manual adjustment of the mirror. Since the coherent length of both the lasers is smaller compared to He-Ne laser, we were supposed to use a position controller suite installed in the computer. However, as the suite was not functioning, we had to adjust the mirror manually. This resulted in inaccurate readings due to the least count of the main scale, making it difficult to obtain precise position readings for small changes. This led to incorrect matches between visibility and position, resulting in a broader Gaussian beam, which has a larger coherent length. Another significant source of error was due to the resolution of the camera. We calculated the changes and errors in visibility in a table.

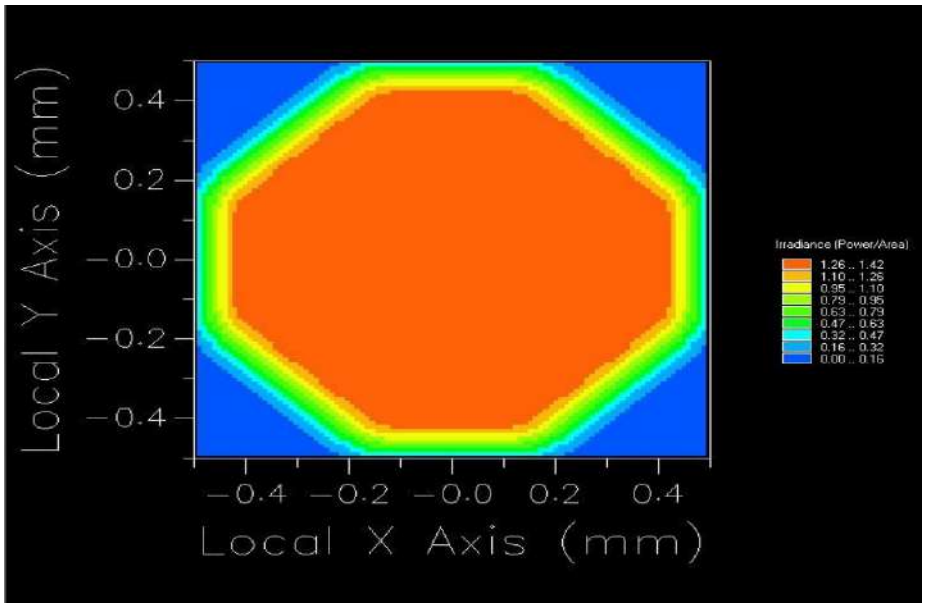
2 To find the coherence length of He-Ne laser.

2.1 apparatus

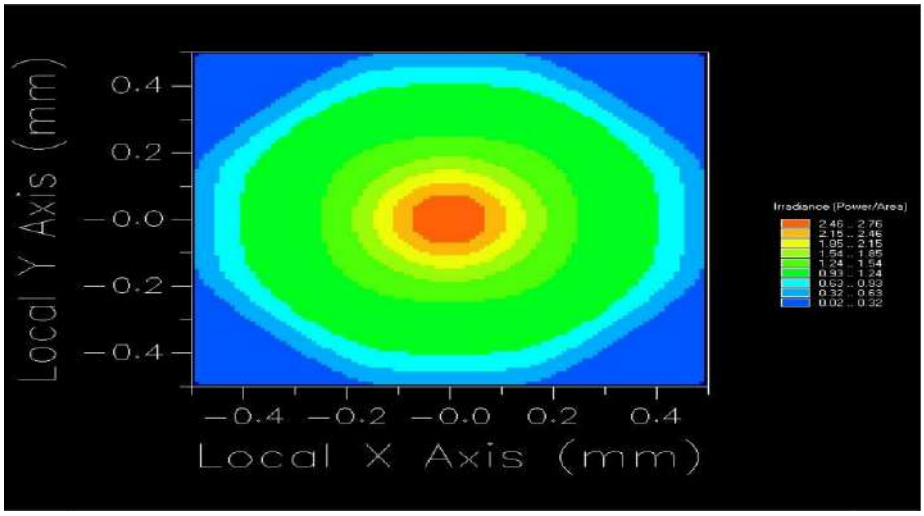
Fred software and Computer

2.2 plots

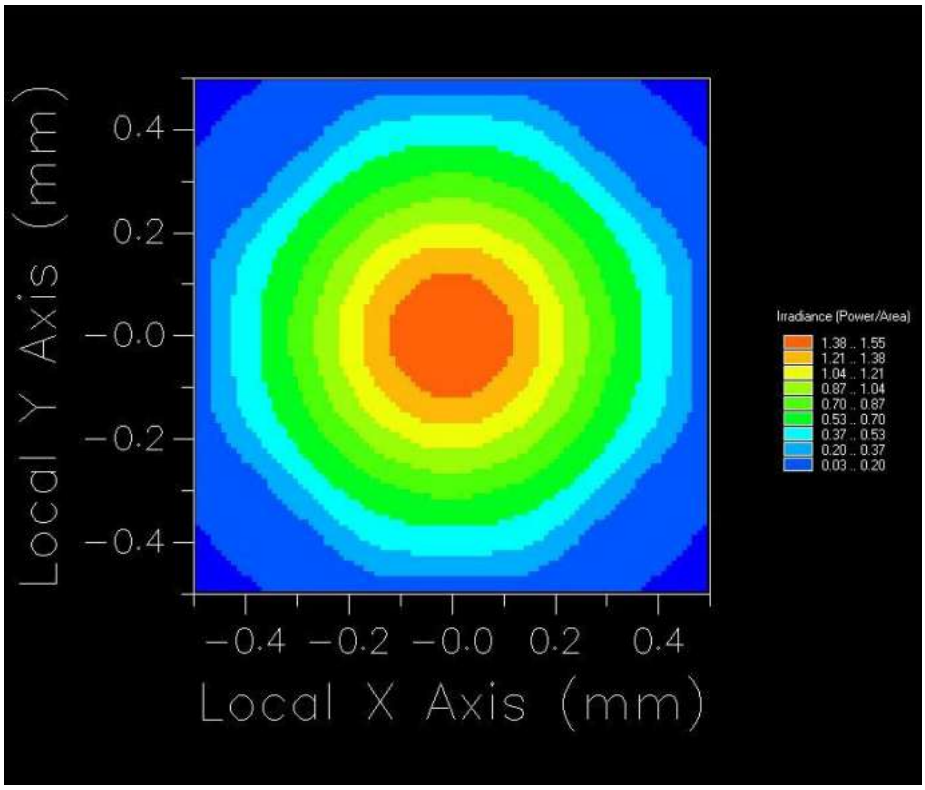
2.2.1 4 mm



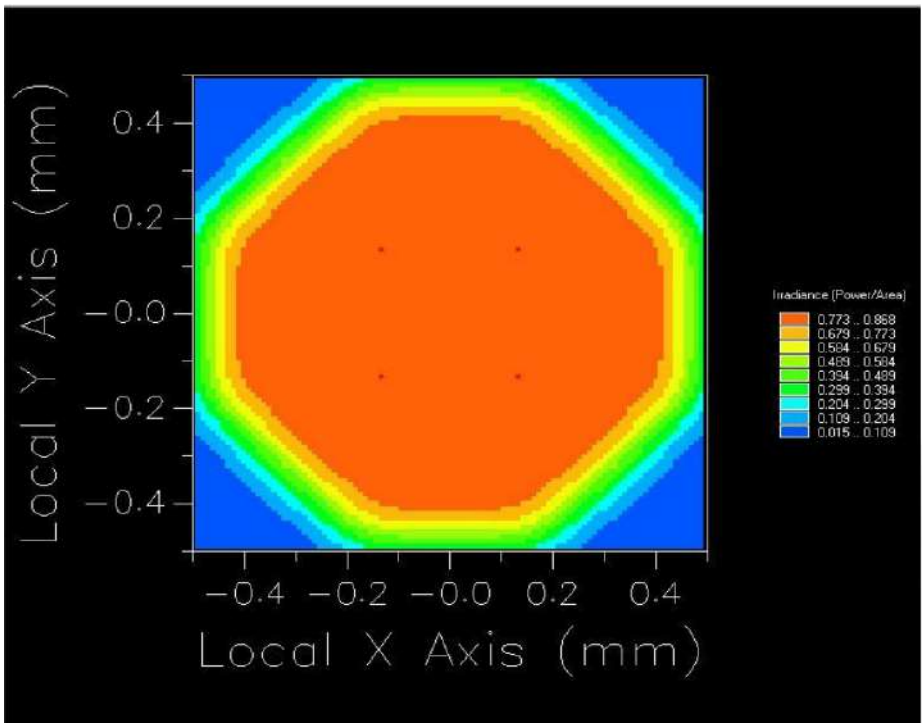
2.2.2 200 mm



2.2.3 400 mm



2.2.4 500 mm



2.3 Dicussions & Conclusions

- The coating is done to the beam splitter surface 5
- Initially when both the mirrors were at same position, no fringes will be present.
- When we slightly move the position of the test mirror, we start getting the fringes.
- We again find the position of the test mirror at which the fringes disappear again.
- The difference between these two positions where the fringes disappear is the coherence length of the He-Ne laser and it is found out to be 49.6 cm. And the coherence length time is $1.6533 * 10^{-9}$ s

2.4 References

- "Optical electronics" by Ajoy Ghatak and K. Thyagarajan,
- Cambridge University Press, 1st Edition (2009)