EXPERIMENT – 4

Aim of the experiment: Determination of wavelength of light from a sodium vapor discharge lamp using Newton's rings interference pattern.

Apparatus required: Travelling microscope, planoconvex lens r = 80 to 120 cm, flat glass plate, beam splitter (glass plate), sodium vapor lamp and power supply, lens 15cm.

Experimental Setup: For the determination of wavelength of a monochromatic light an arrangement as shown in fig-1 is setup, wherein a flat glass plate and a planoconvex lens of large radius of curvature are kept in contact in such a way that the bulged part of the lens faces the flat glass plate. This combination is put under a traveling microscope. A beam splitter is introduced between the lens-glass plate combination and the traveling microscope so as to incident the beam of light from a monochromatic source, without obstructing the field of view. The beam splitter may be a glass plate with one surface semi-silvered. However, a plane flat glass plate works well. If the source of light is not strong enough then a condensing (bi-convex) lens may be used as shown in fig-1. An adjustable light-stop, that usually is a part of the discharge lamp housing may be used for improving the contrast of the interference fringes formed.

When a beam of monochromatic light is incident normally on the planoconvex lens & glass plate combination, it gets reflected from the all the surfaces, 1, 2, 3, and 4, that are duly marked in fig-1. However, due to limited coherence length of the monochromatic beam of light used in the lab, light reflected from surfaces 2 and 3 interfere in a sustained manner to produce interference fringes as shown in fig-2.

The air-film between the two surfaces introduces a small optical path difference that is uniform all over a circular location at any specific distance from the center.

of varying thickness as we move away from the centre. The fringes

These fringes are Newton's rings, alternating bright and dark arising out of interference of light waves. This interference occurs because of the varying thickness of the air film between the convex surface of a lens and the flat surface of a glass plate. Measuring the diameter of the rings, one can determine the wavelength of light, provided the radius of curvature of the lens is known.

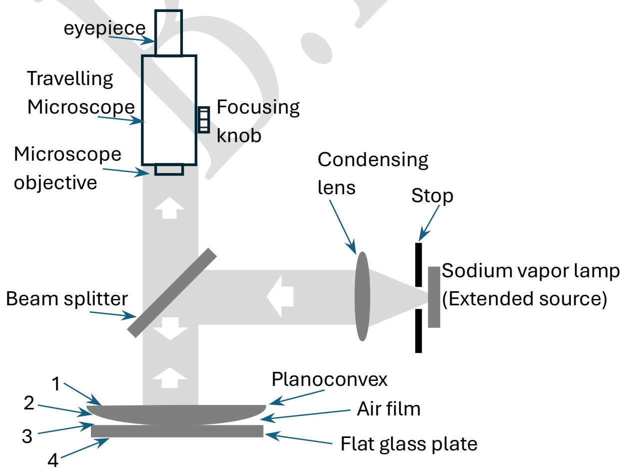


Fig-1. Experimental arrangement for the determination of wavelength of light from a sodium vapor discharge lamp by producing

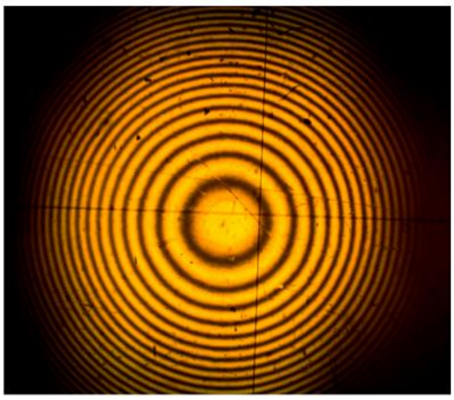


Fig-2. Newton's rings as seen under a microscope.

Theory:

The radius r_m of the rings in the interference pattern is related to the wavelength of light λ, and the radius of curvature R, of the plano-convex lens according to the relation:

$$r_m^2 \approx \frac{R\, m\, \lambda}{\mu} \qquad \ldots\ldots(1)$$

where,

μ is the refractive index of the medium between surfaces 2 and 3

m is the order of the rings

In case of air (between surfaces 2 and 3), μ is 1.

Then it is easy to see that

$$\lambda = \frac{\left(D_{m+p}^2 - D_m^2\right)}{4pR} \qquad \ldots\ldots(2)$$

where,

D_m is the diameter of the m^{th} ring, and

D_{m+p} is the diameter of the $(m+p)^{th}$ ring

p is an integer of our choice, the usual choice being any number from 2 to 5.

Once the diameter of the rings has been determined experimentally, the wavelength of light used can be easily determined by using the above relation, provided we know the radius of curvature R, of the planoconvex lens. R of the lens can very well be determined using a spherometer.

Procedure and precautions:

1. Place the Newton's rings apparatus in front of a sodium vapor lamp housed in a metal or wooden housing. The small window in the housing must face the setup.
2. Ensure that the plane glass plate serving as a beam splitter at the same level as the window in the housing and the sodium vapor lamp.
3. Make the glass plate reflect light vertically down at the planoconvex-flat glass plate arrangement.
4. Bring the microscope to the centre of the entire span of its movement.
5. Place the planoconvex-flat glass plate arrangement centrally just below the microscope.
6. Ensure that the frame of the arrangement is not at all tightened. The three screws holding the combination must be left loose. *Otherwise, you press the planoconvex lens and change its radius of curvature.*
7. While looking through the microscope bring the ring system to the center of the field of view and make the crosshair coincident with the center of the rings as closely as possible.
8. Then using the micrometer screw, shift the crosshair to the 21st ring on any one side of your choice and start moving to the other side gradually while recording the data on table-1, for all the rings that you come across. Move to the 21st ring on the other side. While doing this rotate the micrometer screw in only one direction, either clockwise or anticlockwise. *Rotating it in either direction while sweeping through the rings would produce considerable backlash error.*
9. Once you have the diameter of all the rings, proceed with the plot and the calculations.

Observations:

Least count of travelling microscope micrometer.

There are 50 circular scale divisions (CSD) on the micrometer. When we give the circular scale one complete rotation, it advances through a distance known as its pitch and that is equal to the smallest main scale division, that is 0.5 mm.

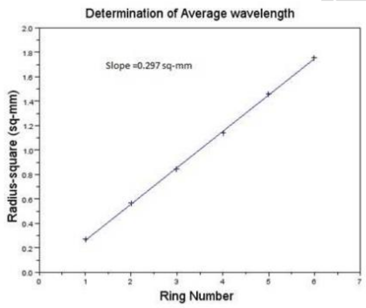
The least count

$$LC = \frac{Pitch}{total\ number\ of\ CSD}$$

$$LC = \frac{0.5\ mm}{50} = 0.01\ mm$$

Table-1: Traveling microscope micrometer readings for the determination of diameter of Newton's rings

S.No.	Rings No. (m)	Travelling microscope readings (mm)						$D_m = \lvert a-b \rvert$	D_m^2	$D_{m+p}^2 - D_m^2$	$\lambda = \frac{(D_{m+p}^2 - D_m^2)}{4pR}$	$(\lambda - \bar{\lambda})^2$
		a (mm)			b (mm)							
		MSR	VSRxLC	Total	MSR	VSRxLC	Total	(mm)	(mm)^2	(mm)^2	Å	
1.	20											
2.	19											
3.	18											
...	...											
...	...											
20.	1											
											$\bar{\lambda} =$	



Calculations:

$$\lambda = \frac{(D_{m+p}^2 - D_m^2)}{4pR}$$

$$Standard\ deviation \quad \sigma = \sqrt{\frac{\sum_1^n (\lambda - \bar{\lambda})^2}{n-1}}$$

$$Standard\ error \quad \bar{\sigma} = \sqrt{\frac{\sum_1^n (\lambda - \bar{\lambda})^2}{n(n-1)}}$$

Results and discussion:

The wavelength of light determined using Newton's rings method is,

$$\lambda = (\bar{\lambda} \pm \bar{\sigma})\text{Å}$$

$$\lambda = (5940 \pm 80)\text{Å}$$

Mention whether the result obtained falls well within acceptable limits of errors or not. Discuss the underlying reasons also.

Viva voce:

1. Why does the sodium lamp show a pale pink color initially and after some time it becomes bright yellow?
2. What is sodium light? Can we have iron lamp or other metal lamps?
3. What is interference of light?
4. Do light beams from two separate windows interfere?
5. Difference between interference and diffraction.
6. What do you understand by the division of wavefront and division of amplitude?
7. How are Newton’s rings are formed? By the division of wavefront or by the division of amplitude?
8. What are fringes of equal thickness and fringes of equal inclination?
9. Are Newton’s rings fringes of equal thickness or fringes of equal inclination?
10. What are Haidinger fringes?
11. Why do we use an extended source?
12. Role of diffuser, stop, beam expander, extended source, condensing lens?
13. What measures would you take to enhance the contrast of the Newton’s rings?
14. If you were to semi-silver surfaces, what all surfaces would you choose? And how much?
15. What would happen if the planoconvex lens is replaced with a flat glass plate with a hair in between.
16. What if you keep the planoconvex lens upside down?
17. What if you invert the planoconvex and flat glass plate arrangement?
18. What if you look from beneath? What would you see if you try to observe the fringes in transmitted light?
19. What will happen if in place of a planoconvex lens, a biconvex lens is used?
20. What will happen if a combination of two biconvex or planoconvex lenses are placed in contact with the bulged side in contact?
21. Why does the phase change of π occur upon reflection of light?
22. How can we make arrangements to obtain straight line fringes?
23. Can we use a thin laser beam to produce Newton’s rings? If so, how?
24. What is the difference observed in the rings with laser and non-laser source?
25. What is the pattern observed if white light like mercury or sunlight is used?
26. In the planoconvex-flat glass plate arrangement how many surfaces reflect light? Do all combinations of the surfaces produce fringes?
27. Where are the Newton’s rings formed / localized?
28. Can we get it on a screen as in the case of biprism?
29. If the fringes are not perfectly circles, what might be the reason?
30. What is the effect of wavelength on the rings?
31. Is sodium monochromatic?
32. How are coherent sources created?
33. What is spatial and temporal coherence?
34. Advantages and applications of Newton’s rings.
35. Does diameter and n have a linear relationship?