重庆大学-辛辛那提大学联合学院

学生实验报告

CQU-UC Joint Co-op Institute (JCI)
Student Experiment Report

实验课程名称 Experiment Course Name College Physics Experiment II

开课实验室（学院）Laboratory (School) CQU-UC

学院 School JCI 年级专业班 Student Group 2018 ME01

学生姓名 Student Name 易弘睿 学号 Student Number 20186103

学年 Academic Year 2019——2020 学期 Semester Spring

成绩 Grade	
教师签名 Signature of Instructor	

批改说明 Marking instructions:

指导老师请用红色水笔批改，在扣分处标明所扣分数并给出相应理由，在封面的平时成绩处注明成绩。

Supervisors should mark the report with a **red ink pen**. Please write down **the points deducted** for each section when errors arise and specify the corresponding reasons. Please write down **the total grade** in the table on the cover page.

重庆大学-辛辛那提大学联合学院 实验报告

JCI Experiment Report

学院 School Chongqing University 年级专业班 Student Group 2018ME01
姓名 Name 易弘睿 学号 Student Number 20186103
开课学院、实验室 Academic School/ Laboratory CQU-UC
实验时间 Date of Experiment 2020 年 Year 5 月 Month 14 日 Day
报告时间 Date of Report 2020 年 Year 5 月 Month 17 日 Day

课程名称 Course Name	College Physics Experiment II	实验项目名称 Experiment Project	Equal Thickness Interference - Wedge and Newton's Ring	实验项目类型 Type of experiment project				
				验证 Verification	演示 Presentation	综合 Comprehensive	设计 Design	其他 Others
指导老师 Supervisor	边立功	成绩 Grade				√		

实验目的 Description/Instruction:

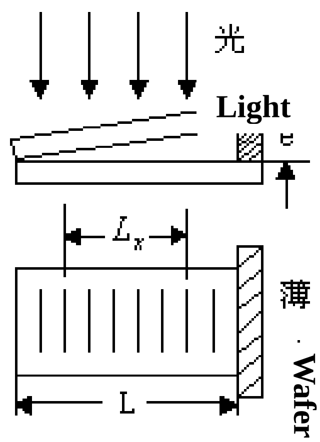
1. To master the principle and characteristics of equal thickness interference phenomenon;
2. To learn about the method to measure physical quantity such as the thickness and radius of curvature of the wafer by using equal thickness interference;
3. To learn to adjust and use reading microscope.

原理和设计 Principle and Design:

1. Wedge interference:

As is shown in Fig. 1, stacking up two optical level glass sheets, with a wafer or filament with a thickness of e inserted into one side. Therefore, an air wedge is formed between the upper and lower surfaces of the glass sheets. When a monochromatic light vertically irradiating, interference of the two light beams reflecting between the upper and lower surfaces occurs, and the interference image formed is straight lines that alternating with brightness and darkness and parallel to the edges on the boundary of the two slices.

The refractive index of air is denoted as n, then the optical path difference is:



$$\delta = 2ne + \lambda/2 \quad (1)$$

Figure 1: Wedge Interference

Where $\lambda/2$ is the additional optical path difference caused by the a mutation in phase πbecause of the reflection of the light which irradiating from a thinner medium into a denser medium on the interface, which is called half wave loss.

The relationship between the light and dark stripes and the optical path difference is:

$$\delta = \begin{cases} (2k+1)\frac{\lambda}{2} & (k = 0,1,2,\cdots;\ \text{dark stripe}) \\ k\lambda & (k = 1,2,\cdots;\ \text{light stripe}) \end{cases} \quad (2)$$

Now considering the dark stripes. According to equation (1) and (2):

$$\delta = 2ne + \frac{\lambda}{2} = (2k+1)\frac{\lambda}{2}$$

The thickness of wedge where the dark stripes locate is:

$$e = k\lambda/2n \quad (k = 0,1,2,3,\cdots) \qquad (3)$$

Therefore, as long as the total number k of dark stripes located from the edge on the interface of the two glass sheets to the edge of the wafer inside the air wedge is known, the value of e can be obtained. Because the total number k of stripes is considerably large, in order to avoid misreading, during this experiment, measure the distance L_x of X number of stripes first, thus the distance between two adjacent stripes is L_x / X. If the total length of the wedge is L, then the total number of interference dark stripes k = XL / L_x. Plugging in equation (3), the thickness of the wafer can be calculated:

$$e = \lambda XL/2nL_x \quad (4)$$

2. Newton's ring:

Newton's ring is a typical equal thickness interference, which is a localized interference produced using separate amplitude method. When the torus of a level convex lens with a large radius of curvature is placed on a level glass (Fig.2), a thin air layer that gradually becomes thicker from its center to the outward direction is formed between the two. When the incident light vertically irradiates towards the level convex lens, because of the commutative interference between the reflected light of the lower surface of the lens and the upper surface of the level glass piece, it results in the formation of the interference stripes. If the light beam is monochromatic light, dark-spot-centered cyclic stripes that vary in width can be observed, which is called Newton's ring.

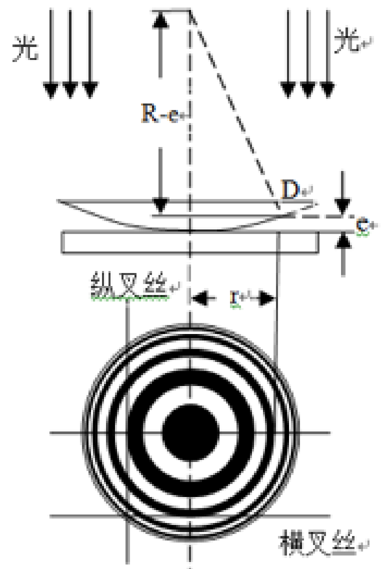


Figure 2: Newton's Rin and Its Devices

Suppose that the radius of curvature is R, the radius of the kth order of dark stripe is r, the thickness of the air layer (whose refractive index is n) corresponding to the position of the cyclic stripe is e, the according to the interference condition:

$$2ne + \lambda/2 = (2k+1)\lambda/2 \quad (k = 0,1,2,3,\cdots) \qquad (5)$$

According to the geometrical relationship in Fig.2:

$$R^2 = r^2 + (R-e)^2 = r^2 + R^2 - 2eR + e^2 \qquad (6)$$

Because $R >> e$, the e2 in the equation above can be neglected. Therefore:

$$e = r^2/2R \qquad (7)$$

Plug the value of e into equation (5), then simplify it:

$$nr^2 = k\lambda R \qquad (8)$$

The equation (8) implies that, when the wavelength λ is known, as long as the radius of the kth order of ring is measured, the radius of curvature of the lens can be calculated. On the contrary, when R is known, the value λ of can be calculated.

However, because of the elastic deformation of glass and because the contact surface is not clean, it is impossible for the contact position to be a geometric point. The result of interference of the ring is a comparatively large dark spot, which may contains of several rings (suppose the number of rings is p_0). The ring at the position of the center of the circle is fuzzy and coarse, making it difficult to determine the position of the center and precisely measure its radius and interference order. Directly using equation (8) when measuring in practice will increase the error. So in order to reduce the error and increase the precision, equation (8) is deducted in following steps:

$$nD_p{}^2 = 4\lambda R(p + p_0)$$

$$nD_q{}^2 = 4\lambda R(q + p_0)$$

Where Dp and Dq are respectively the diameter of the dark rings of the order of p + p0 and q + p0. Subtracting one equation to the other, then:

$$R = \frac{n(D_p{}^2 - D_q{}^2)}{4\lambda(p - q)} \qquad (9)$$

Use equation (9) to measure the radius of curvature R. Although the position of the center of the dark ring cannot be easily determined precisely, the difference (p - q) between the orders of two dark rings is precise. Therefore, the radius of curvature R of the level convex lens can be calculated using equation (9).

实验器材 List of instruments and materials:

1 reading microscope, 1 Natrium lamp, 2 level glass sheets, devices of Newton's ring.

实验步骤 Implementation:

1. Switch in the monochromatic light source. This sends a parallel beam of light.
2. Look down vertically from above the lens and see whether the center is well illuminated. On looking through the microscope, a spot with rings around it can be seen on properly focusing the microscope.
3. Once good rings are in focus, rotate the eyepiece such that out of the two perpendicular cross wires, one has its length parallel to the direction of travel of the microscope. Let this cross wire also passes through the center of the ring system.
4. Now, move the microscope to focus on a ring (the 20th order dark ring). On one side of the center (left). Set the crosswire tangential to one ring. Note down the microscope reading (Make sure that you correctly read the least count of the vernier in mm units).
5. Move the microscope to make the crosswire tangential to the next ring nearer to the center and note the reading. Repeat it till you reach to the 20th dark ring on the right. Take readings for an equal number of rings on the both sides of the center.
6. Use Equation to find the Radius R of plano convex lens by least square fitting.

实验结果和数据处理 Results and Data processing:

1. Wedge interference

$\lambda = 589nm$ L=0.04m R_{standard}： $0.2mm{\sim}0.4mm$

Table 1: Data Recording of the Wedge Interference Experiment

Number	1	2	3
The width of 20 dark stripes	1.18	1.16	1.14

According to Table 1 and equation (4):

$$e = \frac{589.3 \times 20 \times 40}{2 \times 1 \times （1.18 + 1.16 + 1.14） \div 3} \times 10^{-9} = 2.03 \times 10^{-4} m$$

Comparing with the standard radius R_{standard}： $0.2mm \sim 0.4mm$，the result is in the standard area.:

2. Newton's ring

$$\lambda = 589nm \qquad R_{\text{standard}}: 1.2m \sim 1.3m$$

Table 2: Data Recording of the Newton's Ring Experiment

Number of circle	5	10	15	20	25	30	35	40
Left	53.632	52.812	52.202	51.672	51.222	50.812	50.432	49.072
Right(mm)	57.272	58.084	58.704	59.224	59.685	60.095	60.47	60.97
Dm(mm)	3.64	5.272	6.502	7.552	8.463	9.283	10.038	11.898

According to Table 2, the radius of curvature can be calculated by the least square method. According to the following equation:

$$n{D_m}^2 = 4\lambda R(m + m_0)$$

Suppose $x = m,\ y = n{D_m}^2,\ a = 4\lambda R,\ b = 4\lambda R m_0$, then:

Table 3: Data of the Least Square Method

$x = m$	5	10	15	20	25	30	35	40
$y = n{D_m}^2$	13.2496	27.79398	42.276	57.0327	71.62237	86.17409	100.7614	141.5624
x*y	66.248	277.9398	634.1401	1140.654	1790.559	2585.223	3526.651	5662.496
x^2	1	4	9	16	25	36	49	64

According to the data, *a* and *b* can be calculated by the least square method:

$$a = 3.0584 \times 10^{-6},\ b = -1.2549 \times 10^{-6}$$

Then the curvature radius *R* can be calculated:

$$R = \frac{a}{4\lambda} = \frac{3.0584 \times 10^{-6}}{4 \times 5.89 \times 10^{-7}} = 1.298m = 1298mm$$

Comparing with the standard radius $R_{\text{standard}}: 1.2m \sim 1.3m$, the result is in the standard area.:

实验讨论 Discussions:

1. Errors

Errors can come from two parts: measurement errors and instrumental errors.

①In the Newton's ring experiment, the experimental results are within the error range, but slightly small. The biggest source of error in this experiment was reading.Because the stripes are dense and the instruments are more accurate, a small movement can cause a big change.We need to use our eyes, not our tools, to tell us where the line between light and darkness lies.This will lead to the error value of the basic data is very large, affecting the subsequent calculation value.

②Other errors may come from equipment, such as aging and wear.

2. Question

(1) What are the factors that cause the split-tip stripes to change from straight to curved? Changing the position of the sheet on the two glass sheets, how will the stripes change?

A: Uneven glass or paper can cause streaks to bend. The unevenness of the glass or paper surface will cause the distance between the paper surface and the glass to be changed compared to the flat area, and the variation of the optical path difference will cause the stripes to bend. When the sheet moves towards the split tip, the stripes become denser, otherwise the stripes become sparse. When the sheet moves towards the split tip, the angle of the two glasses opens. At the same lateral distance, the optical path difference changes greatly, the interference of light changes rapidly at the same lateral distance, and the stripes are dense. Conversely, the stripes are sparse.

(2) What are the reasons for the different widths of Newton's ring stripes? If the center is a bright spot, what is the reason? Imagine the difference between a transmitting Newton ring and a reflecting one.

A: In simple terms, the Newton's ring is a kind of interference phenomenon caused by the intersection of two or more different rays of light. At the point where the curvature is close, the interference of light is dense, and the image is stronger (shown as a larger and thicker space); the closer to the periphery, the light interference is weakened, and the image is weaker (shown as a small and thin space). The center of the Newton's ring was supposed to be a dark spot, but due to the pressure of the glass, the middle contact area became large and became a dark spot. However, in the experiment, due to dust and other reasons between the optical glasses, the optical path difference is not zero, which causes bright spots. If we use transmitted light instead of reflected light during the experiment, it will also cause a bright spot in the center. The halo of transmitted light and the halo of reflected light are complementary, that is, where the transmitted light is bright, the reflected light is dark, and where the transmitted light is dark, the reflected light is bright.

(3) When the longitudinal fork wire moves along the main ruler, if a certain ring tangent to the transverse fork wire is no longer tangent to it, how does this affect the measurement result? How to eliminate it?

A: It will cause the measurement result to be too small. Need to re-measure again after adjustment.

(4) How to measure the refractive index of a gas or liquid using a Newton ring device?

A: The Newton ring is immersed in the liquid or gas to be measured, so that the Newton ring's plano-convex lens and flat glass plate are the liquid or gas to be measured. Repeat this experiment to measure its refractive index.

物理实验 原始实验数据记录

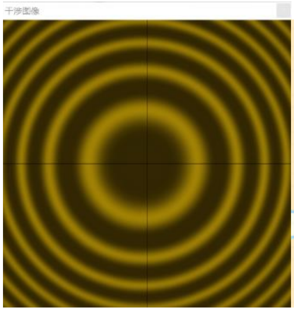
Experiment Data

姓名 Name 易弘睿 学号 Student Number 20186103 实验时间 2020.5.7

实验名称 Name of experiment: Equal Thickness Interference - Wedge and Newton's Ring

仪器名称	量程	最小量	估读误差	仪器误差	零位误差
Reading microscope	0~50mm	0.01	0.001	0.04	
Cleft tip					
Newton's rings					
Natrium lamp					

实验数据 Experiment Data （表格自拟）



调整并确定牛顿环在显微镜载物台的位置，然后开始测量实验数据。注意在以后的数据测量过程中，请勿再次调整牛顿环在载物台的位置。

实验测量结果记录下表：

环数	第5环	第10环	第15环	第20环	第25环	第30环	第35环	第40环
左(读数mm)	53.632	52.812	52.202	51.672	51.222	50.812	50.432	49.072
右(读数mm)	57.272	58.084	58.704	59.224	59.685	60.095	60.47	60.97

根据以上测量的值来计算得出如下数据：

牛顿环的曲率半径值R(m) 1.298

调整并确定劈尖在显微镜载物台的位置，然后开始测量实验数据。注意在以后的数据测量过程中，请勿再次调整劈尖在载物台的位置。

实验测量结果记录下表：

序号	1	2	3
20条暗条纹的宽度(mm)	1.18	1.16	1.14

根据以上测量的值来计算得出以下值：

计算劈尖中细丝的直径值D(m) 0.000203

指导教师：边立功