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_____4_____月 Month_____24_____日 Day
报告时间 Date of Report________2020________年 Year_____4_____月 Month_____27_____日 Day

课程名称 Course Name	College Physics Experiment II	实验项目名称 Experiment Project	Michelson interferometer	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. Understandthestructuralcharacteristicsandopticalpathprincipleof Michelsoninterferometer.
2. Learn and master the adjustment method of Michelson interferometer.
3. LearntouseMichelsoninterferometerstocompletevarioustypesofopticalexperiments.

原理和设计 Principle and Design:

1.Basic optical path structure

The Michelson interferometer is a two-beam interferometer with split amplitude. The optical path is shown in Figure 1. The light emitted from the light source S is reflected by the semi-reflective mirror surface A (plated with a layer of silver (Film) is divided into two mutually perpendicular beams and the plants are reflected by the plane mirrors M1 and M2, respectively, and then formed by A to form two parallel lights that interfere with each other, and are imaged on the lens focal plane at E or enter the observer. It should be pointed

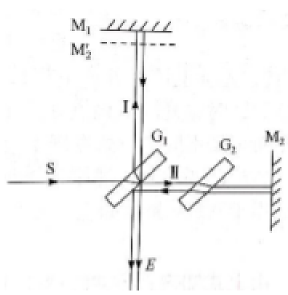


Figure 1 Schematic diagram of Michelson interferometer

out by the eye that the light beamIreflectedbyM1passed threetimesinG1, and the light reflected by M2: mirror II passed only once in G1. In order to compensate for this optical path difference, a plane parallel glass plate G2 (compensation plate) with the same material and thickness as G1 is added to the optical path of beam II at a position exactly parallel to G1, so that any wavelength on both arms ofG2 The light has the same optical path inG1. So white light can also interfere. With the addition of G2, when calculating the optical path difference between the beam I and the beam II, only the geometric distance difference between the two in the air need to be considered, and there is no need to calculate their optical path in the beam splitter. When the observer looks at G1 at E, he can not only see the M1 mirror, but also the virtual image M2' of M2 reflected by G1. The beam II seems to be reflected from M2'. Obviously, the light is reflected by M2 ' The optical path to point E is exactly the same as the optical path to point E after passing through M2, so the interference phenomenon observed at E can be considered to caused by the air film existing between M1 and M2’.

It can be seen that Michelson interference has only two advantages: first, the two coherent beams are far apart and do not interfere with each other, which is convenient to arrange other optical components in a light path for special experiments; Second, M2' is not For actual objects, the air layers of M1 and M2' can be adjusted arbitrarily or even completely coincide.

The Michelson interferometer has a high sensitivity band and is extremely susceptible to external interference. Therefore, the entire experimental optical path including interference only should be placed on a heavy optical experimental platform, and the interference caused by vibration and airflow should be shielded as much as possible during the experiment.

2.Non-local interference from point light sources

The interference process formed by the light emitted from the monochromatic point light source S on the light screen in the lower area after beam splitting and reflection can be illustrated by the equivalent optical path diagram shown in Figure 2. Both are at an angle of 45 to the beam splitter. The effect of the light they reflect can be equivalently seen by the two virtual mirrored light sources S1 and S2 at the symmetrical positions behind the two plane mirrors relative to the light sources, respectively. Yes, for convenience. The M2 mirror and the subsequent S2 can be rotated 90 counterclockwise to generate a virtual M2' mirror and S2' light source. After processing in this way, the effect of the final interference can be equivalently seen as being formed by the two virtual coherent light sources S1 and S2 ′ arranged vertically in the direction of the M1 optical path toward the area below the beam splitter and converging the interference.

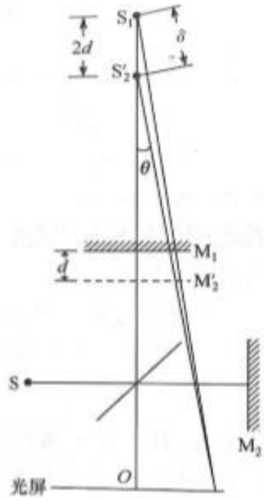


Figure 2 Interference process of monochromatic point light source

In the area where the light sources ofS1 and S2'intersect, the light from the two light sources at each spatial location point has a constant optical path difference. Therefore, there is a stable interference light intensity distribution at these points. In the two light intersection areas, no matter what posture or position the light screen is in, there is no need to add any devices. A stable interference pattern is generated on the screen. We call this interference non-local interference.

Now suppose the light screen is parallel toM1, then the optical path difference between two coherent lights at any point on the screen can be approximately written as

$$\delta = 2dcos\theta \tag{1}$$

Among them, d is the distance between M1 and M2', and the condition that this formula holds is θ is very small.

When d is unchanged, the light path difference of all the same drug points on the screen at θ is the same. The result of interference at these points will form a continuous stripe there, with the change of θ corresponding to different stripes formed by the effect light path diagram It is a concentric interference ring with the point where S1 and S2 intersect with the screen as the center, as shown in Figure (c). When

$\delta = k\lambda$ (k = 0, ±1, ±2, ..., is the interference series), constructive interference occurs at this point on the light screen, the light intensity is enhanced, and it is a bright ring. Conversely, when $\delta = (2k + 1)\lambda/2$, destructive interference occurs at this point on the light screen, and the light intensity is weakened, which is a dark ring. The light and dark interference rings alternately appear on the screen in a concentric manner with different radii. The difference in d at the center of the circle may be a bright spot or a dark spot.

The distribution and change of the light and dark rings are the same. Now take the light ring as an example:

$$2dcos\theta = k\lambda \qquad (2)$$

It can be seen that the distribution of the interference ring is sparsely spaced in the center region and the interference ring is large. As the radius increases, the outer ring gradually becomes denser.

We can also know that when moving the mirror M1 to increase d, the optical path difference of each point on the light screen will increase, all the rings will expand outward, and at the same time, the rings will continue to emerge from the center. Conversely, when d decreases, all four rings shrink toward the center, and the ring continuously shrinks into the small place and eventually disappears.

Let the center of the circle be exactly a bright spot, where $\theta = 0$. Therefore, 2d = kλ. It can be seen that every half of d changes, the center of the circle indents or gushes out a circle. Gush out Δm rings and measure the change of dat the same time Δd, then the light wave length

$$\lambda = 2\Delta d/\Delta m \qquad (3)$$

It can be seen that when d is reduced to close to zero (that is, M1 and M2' are close to coincidence), the central region will become very coarse, and generally no obvious light and dark stripe distribution can be seen in the observable area.

实验器材 List of instruments and materials:

The main instruments include Michelson interferometer, ammonia neon laser, beam lens, aperture stop, low-pressure sodium light, white light source (low-pressure mercury lamp or fluorescent lamp), thin-film dielectric sheet, and gas refractive index measurement kit.

实验步骤 Implementation:

1. Light path regulation:

(1) Place the He-Ne laser and the short focal lens.

(2) Click the power switch to turn on the laser power.

(3) Adjust the height, and pay attention to the interferometer on the desktop. When the laser just can shine on the interferometer through the aperture, stop the adjustment and close the adjustment window.

(4) Adjust the direction of the M2 mirror to make the two rows of points coincide.

2. Measuring the wavelength of He-Ne laser:

(1) Remove the aperture and place the beam extender. Bright interference fringes were seen on the interferometer. Carefully adjust the knob on the M2 mirror so that the center of the striped ring is in the

center of the frosted glass.
(2) Adjust the coarse adjustment knob to make the stripes in a more easily counted thickness, and then select a position as the starting position, record the reading at this time, click the fine-tuning knob to adjust, when the image "swallow" 30 stripes down the current reading, record the data for 6 consecutive times.
(3) The differential method is used to process the data and calculate the result.

3. Measuring the wavelength difference between the sodium light and the sodium light double line:
(1) Replace the He-Ne laser with Na source and remove the beam extender. In the Michelson interferometer large view, right - click the frosted glass and switch the observation mode to "eyes". Click the eyes icon to open the view window.
(2) Adjust the coarse knob to make the interference clear. The wavelength of Na light is then measured in the same way as the wavelength of the He-Ne laser.
(3) Turn the coarse adjustment knob to record the change of the reading from the least clear state to the next least clear state. Record several sets of data in succession. Then the wavelength difference of Na optical double lines is calculated by the method of difference by difference.

4. Measure the refractive index of the transparent sheet:
(1) Using the He-Ne laser, adjust the light path so that the center of the interference fringe is located in the center of the frosted glass. Then turn the coarse knob, so that the interference fringes in the thickest state (at this time can not see the fringe). Remove the He-Ne laser and beam extender, replace with a white light source and turn on the power.
(2) Careful adjustment of the coarse knob will result in colored dry stripes appearing in the viewing window at a nearby location. If the stripe is too thick or too thin, you can gently adjust the knob on the M2 mirror to make the stripe in the appropriate thickness. Turn the fine-tuning knob to place the central black stripe in the center of the field of view and record the current reading.
(3) To place the sheet, adjust the fine-tuning knob to bring the stripe back to the center of view again and record the reading. The refractive index of the fringe is calculated according to the specific formula.

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

$$u_A = t_P\sqrt{\frac{\sum_{i=1}^{3}(\Delta \mathrm{d}_i - \overline{\Delta \mathrm{d}})}{2\times 3}};u_B = \sqrt{\Delta_{仪}^2 + \Delta_{估}^2}$$

From the table, t_P=4.3 when k=3;
1. The wavelength of He-Ne laser

Number	1	2	3	4	5	6
D(mm)	30.4	30.40915	30.41872	30.42818	30.4377	30.44715

Number	1	2	3
ΔD(mm)	0.02818	0.02855	0.02843

$\Delta d1$=0.00939; $\Delta d1$=0.00952; $\Delta d3$=0.00948;

$\overline{\Delta \mathrm{d}}$=0.00946mm; $\Delta_{仪} = 0.0001mm$; $\Delta_{估} = 0.00001mm.$

u_A=0.000165 mm; u_B=0.0001mm; $u_{\overline{\Delta \mathrm{d}}}$=$\sqrt{u_A^2 + u_B^2}$=0.0001929;

Δd =$\overline{\Delta \mathrm{d}} \pm u_{\Delta d}$=(0.00946 ±0.0001929)mm.

$\overline{\lambda_{measured}} = \frac{2\overline{\Delta d}}{30}$=0.00063067mm;

$E_{\overline{\lambda_{measured}}}$=$\sqrt{(\frac{u_{\overline{\Delta d}}}{\overline{\Delta d}})^2}$=0.02039mm;

$u_{\overline{\lambda_{measured}}}$=$E_{\overline{\lambda_{measured}}} \times \overline{\lambda_{measured}} = 0.00001286mm$;

$\lambda_{measured}$=$\overline{\lambda_{measured}} \pm u_{\overline{\lambda_{measured}}}$=(0.00063067±0.00001286)mm

Error=(632.8-630.67)/632.8=0.33%

2. The wavelength of sodium light

Number	1	2	3	4	5	6
D(mm)	30.5479	30.558	30.56685	30.5757	30.5846	30.59365

Number	1	2	3
ΔD(mm)	0.0278	0.0266	0.0268

$\Delta d1$=0.00927mm; $\Delta d1$=0.00887mm; $\Delta d3$=0.00893mm;

$\overline{\Delta d}$=0.009022mm; $\Delta_{仪} = 0.0001mm$; $\Delta_{估} = 0.00001mm$.

u_A=0.000536 mm; u_B=0.0001mm; $u_{\overline{\Delta d}}$=$\sqrt{u_A^2 + u_B^2}$=0.000545mm;

Δd =$\overline{\Delta d} \pm u_{\Delta d}$=(0.00902 ±0.000545)mm.

$\overline{\lambda_{measured}} = \frac{2\overline{\Delta d}}{30}$=0.00060148mm;

$E_{\overline{\lambda_{measured}}}$=$\sqrt{(\frac{u_{\overline{\Delta d}}}{\overline{\Delta d}})^2}$=0.06029mm;

$u_{\overline{\lambda_{measured}}}$=$E_{\overline{\lambda_{measured}}} \times \overline{\lambda_{measured}} = 0.00003626mm$;

$\lambda_{measured}$=$\overline{\lambda_{measured}} \pm u_{\overline{\lambda_{measured}}}$=(0.00060148±0.00003626)mm

Error=(601.48-589.3)/589.3=2.07%

3. The wavelength difference between the sodium light and the sodium light double line

Number	1	2	3	4
D(mm)	31.5458	32.838	32.118	32.418

Number	1	2
ΔD(mm)	0.57	0.58

$\Delta d1$=0.285mm; $\Delta d1$=0.29mm;
$\overline{\Delta d} = 0.2875mm$;

$\Delta\lambda = \overline{\lambda_{measured}}^2/(2\times \overline{\Delta d}^2)$ =0.63nm

Error=(0.63-0.6)/0.6=5%

4. The refractive index of the transparent sheet
(1) Glass

Number	1	2
D(mm)	30.81752	30.80242

N=1+l/Δd=1.67

(2) Crystal

Number	1	2
D(mm)	30.8195	30.806

N=1+l/Δd=1.74

实验讨论 Discussions:

1. Error
(1) The experimental hollow process could not be completely eliminated;
(2) The experiment has errors in the determination of the counting point at the beginning and the counting point at the end of each hundred stripes;
(3) There is a random error in the reading in the experiment;
(4) The experimental equipment is subject to the interference of vibration and other factors in the environment.

2. Discussion
(1) When light is reflected from the sparse medium to the surface of the light dense medium, a half-wave loss phenomenon occurs, which may cause additional optical path differences in some experiments. Is it exist here?

A: NO. Although there is actually a half-wave loss in the specular reflection of the two mirrors, the two half-wave losses will cancel each other out, so that the final result does not contain a half-wave loss term.

(2) What is return difference? How did it happen? Why can one-direction movement avoid return difference?

A: The difference in return is due to the thread pitch of the micrometer screw, and there is a gap during transmission, which causes the active device to move, but the passive device does not produce movement.Intheexperiment,thereadingchanged,butthedevicedidnotmove.Themethodtoavoid is not to invert the micrometer screw.

物理实验 原始实验数据记录

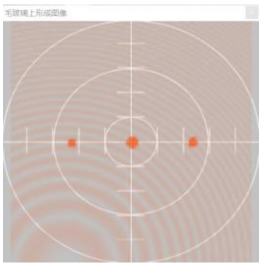
Experiment Data

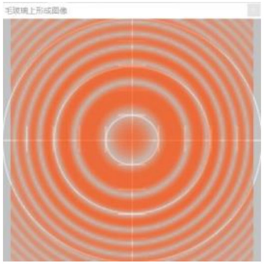
姓名 Name 易弘睿 学号 Student Number 20186103 实验时间 2020.4.24

实验名称 Name of experiment: Michelson interferometer

仪器名称	量程	最小量	估读误差	仪器误差	零位误差
Michelson interferometer	0~200mm	0.0001mm	0.00001mm	0.00005mm	
Helium-neon laser					
Spectroscope					
Screen					

实验数据 Experiment Data （表格自拟）





转动鼓轮，观察到干涉条纹中"吞""吐"变化。中心每"生成"或"吞进"30个干涉条纹记录一次数据，连续记录6次。

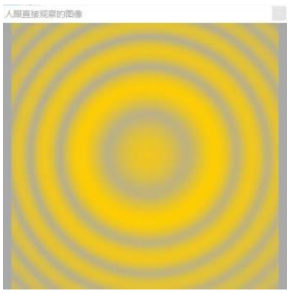
选择M1镜的一个初始位置，作为第一列填入表格，然后将中心每"生出"或"吞进"30个条纹时M1镜的位置填入表格其他列中。

测量编号	1	2	3	4	5	6
D(mm)	30.4000	30.40915	30.41872	30.42818	30.43770	30.44715

利用逐差法，根据上面的数据算出三组差值，并填入下表

测量编号	1	2	3
ΔD(mm)	0.02818	0.02855	0.02843

用逐差法处理数据，根据相应公式计算He-Ne激光的波长λ（nm）= 630.67



换钠光光源，调节鼓轮，观察到条纹的吞吐状况，中心每"生成"或"吞进"30个干涉条纹记录一次数据，连续记录6次。

选择M1镜的一个初始位置，作为第一列填入表格，然后将中心每"生出"或"吞进"30个条纹时M1镜的位置填入表格其他列中。

测量编号	1	2	3	4	5	6
D(mm)	30.54790	30.55800	30.56685	30.57570	30.58460	30.59365

利用逐差法，根据上面的数据算出三组差值，并填入下表

测量编号	1	2	3
ΔD(mm)	0.0278	0.0266	0.0268

用逐差法处理数据，根据相应公式计算钠光的波长λ（nm）= 601.48

再移动M1，观察到条纹的可见度周期变化，记录条纹从不可见到次不可见时M1的位置读数，连续记录4次。

选择M1镜的一个条纹不可见位置，作为第一列填入表格，然后将条纹从不可见到次不可见时M1的位置读数填入表格其他列中。

测量编号	1	2	3	4
D(mm)	31.54580	32.83800	32.11800	32.41800

利用逐差法，根据上面的数据算出两组差值，并填入下表

测量编号	1	2
ΔD(mm)	0.57	0.58

用逐差法处理数据，根据相应公式计算钠光双线的波长差 d（nm）= 0.69

换白光源，移动M1，找到d=0的位置，观察到中央是直线黑纹两边对称分布彩色花纹的直线干涉条纹，开始测量玻璃薄片的折射率。

将中央黑纹移到中间，然后点击按钮保存状态

完成操作请点击按钮确认 确定状态 状态已保存...

此时M1的位置(mm) 30.81752

放置玻璃薄片，再将中央黑纹移动至中心，点击按钮保存状态

完成操作请点击按钮确认 确定状态 状态已保存...

此时M1的位置(mm) 30.81242

移除玻璃薄片，移动M1，找到d=0的位置，观察到中央是直线黑纹两边对称分布彩色花纹的直线干涉条纹，开始测量水晶薄片的折射率。

将中央黑纹移到中间，然后点击按钮保存状态

完成操作请点击按钮确认 确定状态 状态已保存...

此时M1的位置(mm) 30.81950

放置水晶薄片，再将中央黑纹移动至中心，点击按钮保存状态

完成操作请点击按钮确认 确定状态 状态已保存...

此时M1的位置(mm) 30.81210

根据上面测量出的数据和薄片的厚度（0.01mm），计算出两种薄片的折射率。

将计算结果填入下表

透明薄片	玻璃	水晶
折射率N	1.51	1.74

指导教师：边立功