# Expt. 10 Interference of light

## Ⅰ. Purpose

(1) Observe two kinds of interference phenomena: wedge interference and Newton Rings interference.

(2) Use the principle of wedge interference to measure the diameter of glass fiber; measure the radius of curvature of a lens by Newton Rings.

## Ⅱ. Apparatus

Measuring microscope, sodium vapour lamp, Newton Rings assembly, optically flat glass.

## Ⅲ. Principle

When two trains of monochromatic light with constant oscillation direction, frequency and phase difference are superimposed, the resulting oscillation is reinforced in some places and weakened in others. This is called the interference of light.

Interference is widely used in scientific research and engineering. For instance, interference of light can be used to accurately measure length and its variation, detect the quality of optical element surfaces, determine spectral wavelength and their fine structure, etc..

### 1. Wedge interference

Place the glass fiber between two pieces of flat glass, parallel to their intersecting edges as shown in Figure 10 – 1. When a monochromatic parallel beam of light arrives perpendicular ($i = 0$) at the air wedge ($n = 1$) formed by the two pieces of flat glass, the two beams of reflected light $a'$ and $b'$ at the wedge tip $C$ cause interference, forming fringes of interlaced light and shade. According to the thin film interference formulae, here

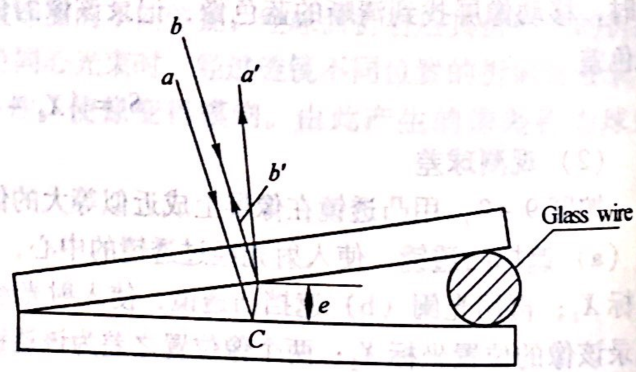


Figure 10 – 1 Principle of Wedge Interference

$$\begin{cases} \delta = 2e + \dfrac{\lambda}{2} = 2k\dfrac{\lambda}{2} & k = 1,2,3,\ldots \quad \textit{Bright fringe} \\ \delta = 2e + \dfrac{\lambda}{2} = (2k+1)\dfrac{\lambda}{2} & k = 0,1,2,\ldots \quad \textit{Dark fringe} \end{cases}$$

The thicknesses of air at various points of the same interference fringe are equal, so these are called interference fringes of equal thickness. Where the two pieces of glass touch, $e=0$, the optical path difference of the two beams of light $d=\lambda/2$, so there should be dark fringe. Take the air thickness of the $k_1^{th}$ dark fringe as $e_1$, the air thickness of the $(k_1+\Delta k)^{th}$ dark fringe as $e_2$, the horizontal distance of the two fringes as $x$, and the air thickness difference between the dark fringe as $\Delta d$, then we have:

$$\Delta d = e_2 - e_1 = \Delta k \frac{\lambda}{2}$$

$$\tan\alpha = \Delta d/x = \Delta k\lambda/2x$$

Glass fiber diameter $\quad D = 1 \cdot \tan\alpha = 1\lambda\Delta k/2x.$

**2. Newton Rings**

Newton Rings are shown in Figure 10-2. When the parallel light beam arrives at the air wedge formed by the lower surface of a lens of very large curvature radius and the upper surface of the optically flat glass we get interference of light. The interference fringes are concentric circles around the point of contact of the lens and the glass due to equal thickness interference. They are Newton Rings.

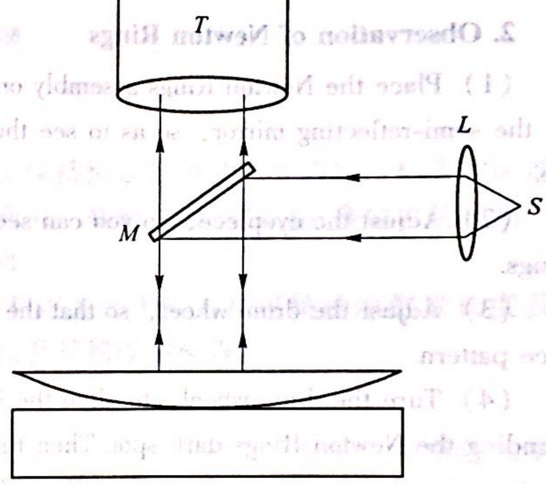

Figure 10-2 Setup of Newton Rings

Using the same interference principle as wedge interference, through analysis we can find that the relationship between the radius $r_k$ of the $k^{th}$ dark fringe of the Newton Rings and the radius $R$ of the lens curved surface is:

$$R = \frac{r_k^2}{k\lambda} \quad (k = 0,1,2,\ldots)$$

**Notes**: the centre of Newton Rings is not theoretically a dark point, but a dark spot, which means we cannot determine the exact centre and order $k$ of the Newton Rings. So we can take $k$ as any values of $m$ and $n$ (for example, $m=11$, $n=1$) so that

$$\begin{cases} r_m^2 = mR\lambda \\ r_n^2 = nR\lambda \end{cases}$$

This gives:

$$R = \frac{r_m^2 - r_n^2}{(m-n)\lambda}$$

The wavelength of the sodium vapor lamp used in the experiment is $\lambda = 589.3$ nm.

## Ⅳ. Experimental

Under the microscope of the experiment system, there is a semi-reflecting mirror that can reflect the parallel light to the microscope workbench. By turning drum wheels workbench can be moved along $X$ axis and $Y$ axis respectively. The drum wheel can be read to 0.01mm.

**1. Observation of wedge interference**

(1) Place the glass plate on the microscope workbench, and clip a piece of glass fiber between the two pieces of glass.

**Notes**: ① make the glass fiber parallel to the edge; ② away from the wedge tip; ③ the direction of the wedge tip should be perpendicular to the moving direction of the workbench.

(2) Focus the microscope, until you can see clear interference fringes.

(3) Make the intersection point of the cross hair nearly at the end of the wedge. Record the position of a certain dark fringe, then count 30 dark fringes (take $\Delta k$ as 30), and measure the distance $X$ of the 30 dark fringes. Repeat this experiment for five times continuously counting in the same direction, totally counting $5 \times 30$ fringes. This avoids the backlash effect of back and forth motion of the microscope.

(4) Measure the distance $L$ from the wedge tip to the glass fiber.

**2. Observation of Newton Rings**

(1) Place the Newton Rings assembly on the workbench, turn on the sodium vapour lamp and set the semi-reflecting mirror, so as to see the visual field through the eyepiece as bright as possible.

(2) Adjust the eyepiece, so you can see the cross hair clearly, and then focus on the Newton Rings.

(3) Adjust the drum wheel, so that the cross hair goes through the central spot of the interference pattern.

(4) Turn the drum wheel, to align the intersection point of the cross hair on the first ring surrounding the Newton Rings dark spot. Then turn the drum wheel again, and count to the 11th ring moving toward right. To eliminate the effect of backlash (lost motion), you should move the cross hair further to the right, and then return to the position of the 11th ring. Record the position ($X_{11}$) here, and then move leftward to the 1st ring, record the position ($X_1$). Continue to move leftward to the 1st ring at the other side of the central spot (recorded as $X_1'$), and then continue to move leftward to the 11th ring (recorded as $X_{11}'$). In this way you have measured 4 positions and from $(X_{11} - X_{11}')/2$ and $(X_1 - X_1')/2$ you can get $r_{11}$ and $r_1$. Repeat above steps six times.

## V. Questions

1. In the Newton Rings experiment, what is the difference between the interference fringes formed by reflected light and transmitted light?

2. Interference fringes generated in the wedge interference experiment are not totally parallel to the edge. Explain what causes this?

3. When measuring the plano-convex lens radius of curvature $R$ using Newton Rings does it matter if you do not cross the centre of the circular interference fringes while measuring $r_m$ and $r_n$? Can you still use the formula $R = \dfrac{r_m^2 - r_n^2}{(m-n)\lambda}$?

# 实验十　光的干涉

## 一、实验目的

（1）观察劈尖干涉和牛顿环这两种光的干涉现象。
（2）练习利用劈尖干涉原理测量玻璃丝的直径；用牛顿环测量球面曲率半径。

## 二、实验仪器

测量显微镜，钠光灯，牛顿环，光学平面玻璃。

## 三、实验原理

当两列振动方向相同，频率相同，而且位相差保持恒定的单色光相遇后，相遇的区域内有些地方由于两列波的叠加，振动总是加强的，而另一些地方由于振动的叠加总是减弱，形成的这种稳定的强度不均匀的现象，称为光的干涉。

干涉在科研和工程技术方面有广泛应用，如利用光的干涉方法可精确地测量长度及变化，检测光学元件表面的光洁度，测定谱线的波长及其精细结构等。

### 1. 劈尖干涉

如图 10－1 所示，放置玻璃丝于两平面玻璃之间，且平行于相交之棱边。当单色的平行光垂直（$i=0$）入射到两平面玻璃形成的空气劈（$n=1$）时，在劈尖 $C$ 点的两束反射光 $a'$、$b'$产生干涉，形成明暗相间的条纹，根据薄膜干涉的公式，有

$$\begin{cases} \delta = 2e + \dfrac{\lambda}{2} = 2k\dfrac{\lambda}{2} & k = 1,2,3,\cdots \quad \text{明条纹} \\ \delta = 2e + \dfrac{\lambda}{2} = (2k+1)\dfrac{\lambda}{2} & k = 0,1,2,\cdots \quad \text{暗条纹} \end{cases}$$

同一干涉条纹所在处的各点空气劈的厚度都是相等的，因此称为等厚干涉条纹。在两块玻璃相接处，$e=0$，两光束的光程差为 $\delta=\lambda/2$，所以应看到暗纹。设第 $k_1$ 条暗条纹处的劈尖厚度为 $e_1$，第 $k_1+\Delta k$ 暗纹处的劈尖厚度为 $e_2$，这两条暗纹间的横向水平距离为 $x$，而两暗纹处劈尖厚度差为 $\Delta d$：

$$\Delta d = e_2 - e_1 = \Delta k \frac{\lambda}{2}$$

$$\tan\alpha = \Delta d/x = \Delta k\lambda/2x$$

玻璃丝直径　　$D=1\cdot\tan\alpha=1\lambda\Delta k/2x.$

### 2. 牛顿环

牛顿环装置如图 10－2 所示，当平行光束垂直照射到曲率半径很大的透镜下表面与平面玻璃上表面形成的空气劈时产生光的干涉现象，干涉条纹是属于等厚干涉的许多同心圆环，

称为牛顿环。

干涉原理同劈尖干涉，分析可得牛顿环第 $k$ 级暗纹半径 $r_k$ 与透镜曲面半径 $R$ 的关系为：

$$R = \frac{r_k^2}{k\lambda} \quad (k = 0, 1, 2, \cdots)$$

**注意**：牛顿环中心不是理论上的一个暗点而是一个暗斑，这样造成牛顿环的中心及级数 $k$ 无法确定，因此可以使 $k$ 分别取任意的 $m$ 与 $n$ 值，例如取 $m = 11$，$n = 1$，则有

$$\begin{cases} r_m^2 = mR\lambda \\ r_n^2 = nR\lambda \end{cases}$$

可得：

$$R = \frac{r_m^2 - r_n^2}{(m-n)\ \lambda}$$

实验所用钠光灯的波长为 $\lambda = 589.3\text{nm}$。

## 四、实验内容和步骤

在实验系统的显微镜下面有一个半反射镜可以将平行光线反射到显微镜工作台上，旋转两个鼓轮可以使工作台分别在 $X$、$Y$ 轴方向移动，鼓轮上有刻度，每个小格为 0.01mm。

**1. 观测劈尖的干涉**

（1）将玻璃片放在显微镜工作台上，在两玻璃之间夹上一根玻璃丝。

**注意**：① 让玻璃丝平行于棱边；② 远离劈尖；③ 劈尖的移动方向与工作台移动方向垂直。

（2）给显微镜调焦，直到看到清晰的干涉条纹。

（3）使叉丝的交点移到靠近劈尾一边，注意空程的影响，记录某一暗纹的位置，然后数 30 条暗纹（$\Delta k$ 取 30）记录位置，同时测量 30 条暗纹间的距离 $X$，本实验要求重复 5 次，可以连续朝一个方向不断数下去，共数 5 个 30 条，这样可以避免来回数时每次都要考虑空程的影响。

（4）测量从劈尖到玻璃丝的距离 $L$。

**2. 观测牛顿环干涉**

（1）把牛顿环放到工作台上，打开钠光灯，转动半透镜，使从目镜中看到的视野最亮。

（2）调节目镜，使能看清叉丝，将镜筒降低靠近牛顿环，然后再向上调节直到牛顿环清晰为止。

（3）调节鼓轮，使叉丝通过干涉圆斑中心。

（4）转动鼓轮，使叉丝的交点对准牛顿环圆斑外第一个环，然后再转动鼓轮，数到右边第 11 个环处，为了消除空程的影响，必须多移一些距离，然后再返回到第 11 个环处，记下此处的位置（$X_{11}$），然后再向左移动数到第 1 个环，记下位置（$X_1$）。再继续向左移动到圆斑另外一侧第一环处（记为 $X_1'$），继续向左，再到左边第 11 个环处（记为 $X_{11}'$）。这样就测到了 4 个位置，由（$X_{11} - X_{11}'$）/2 和（$X_1 - X_1'$）/2 可得到 $r_{11}$ 及 $r_1$。按以上步骤重复测 6 次，测量过程中注意消除空程的影响。

## 五、思考题

1. 在牛顿环实验中，反射光与透射光所形成的干涉条纹有什么不同？

2. 劈尖干涉实验中所得到的干涉条纹并不与棱完全平行，解释这是什么原因造成的。

3. 在测量牛顿环的平凸透镜曲率半径 $R$ 时，如果在实验中测 $r_m$ 与 $r_n$ 时，未通过干涉圆条纹中心，是否仍可以使用公式 $R=\dfrac{r_m^2-r_n^2}{(m-n)\lambda}$？