Interference of light waves

Agenda Today

1. Two-slit experiment
2. Film interference
3. Newton’s rings

Conditions for interference

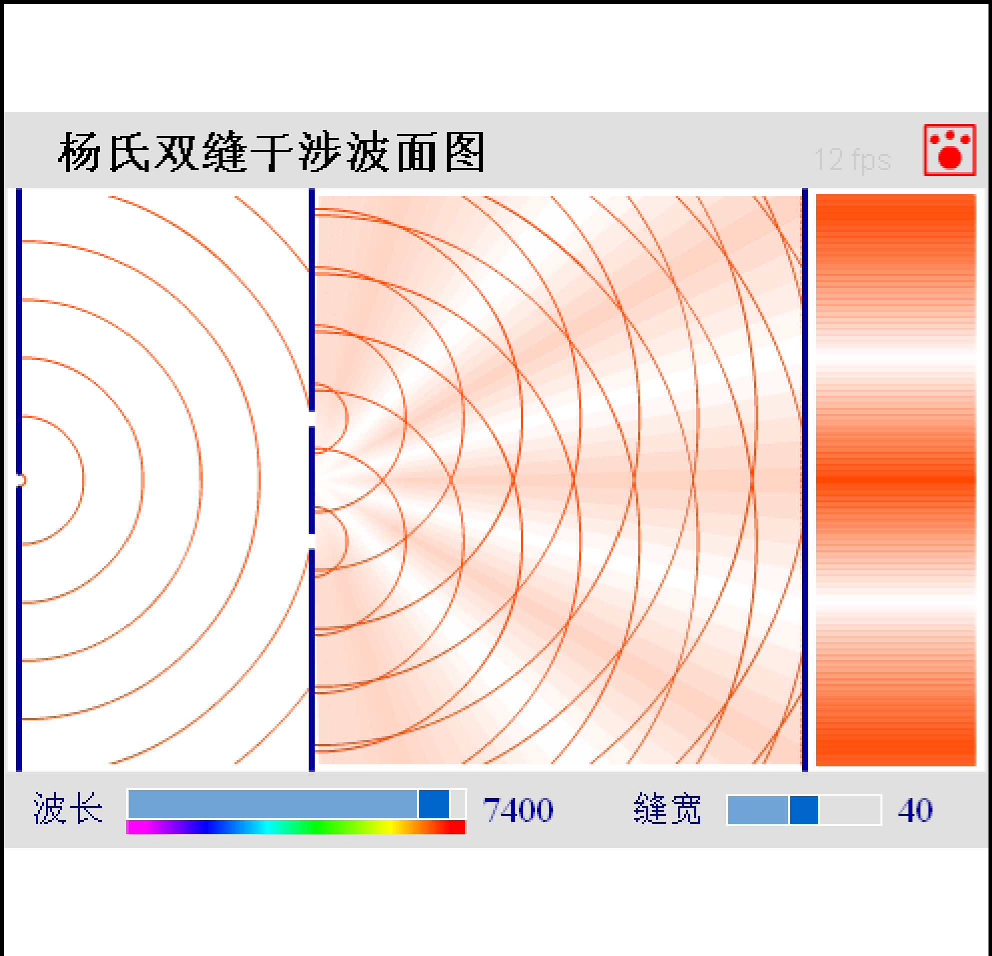
1 the source should be monochromatic(单色) same frequency

2 the sources must maintain a constant phase difference.

Why is there no interference pattern caused by two bulbs?

Young's double-slit experiment（杨氏双缝实验）

Thomas Young (1773-1829)

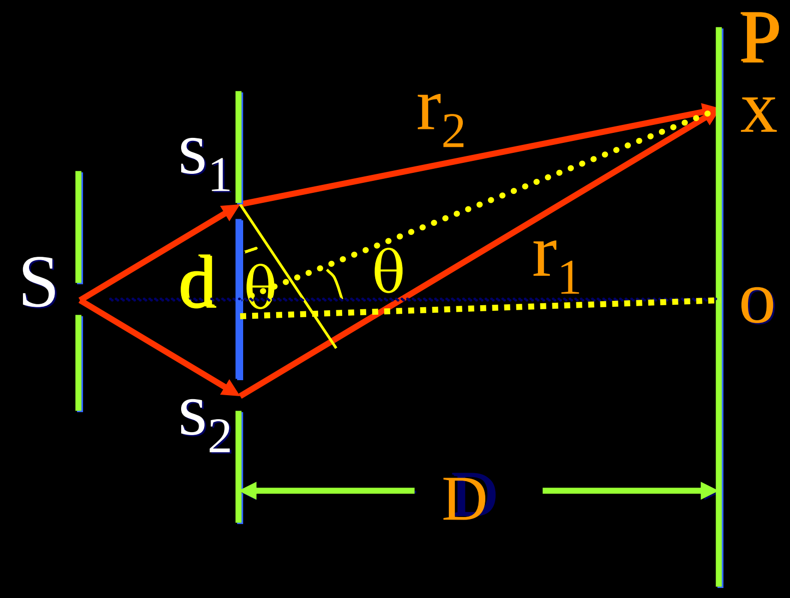


In the case the double slits：

$$\delta = r_2 - r_1 \approx d\sin\theta$$

$\because D >> a \quad , \theta\ is\ very\ small$

$$\therefore \sin\theta \approx tg\theta = d\frac{x}{D}$$



$$d\frac{x}{D} = \pm k\lambda \quad (k = 0,1,2,\cdots)$$

Constructive

bright fringes

$$d\frac{x}{D} = \pm(2k-1)\frac{\lambda}{2} \quad (k = 1,2,3,\cdots)$$

Destructive

dark fringes

Intensity distribution of the double-slit interference

$$\text{let } E_1 = E_0 \cos\omega t$$

$$E_2 = E_0 \cos(\omega t + \Delta\Phi)$$

$$E = E_1 + E_2 = 2E_0 \cos\left(\frac{\Delta\Phi}{2}\right)\cos\left(\omega t + \frac{\Delta\Phi}{2}\right)$$

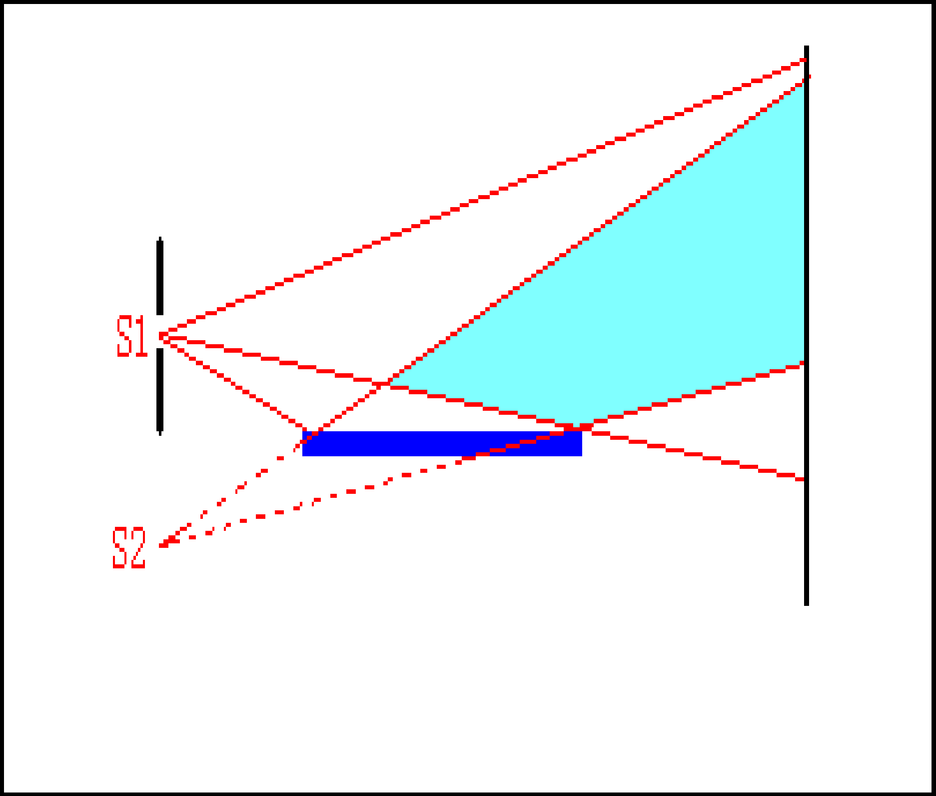
$$\because I \propto E^2$$

$$\therefore I = I_{max}\cos^2\left(\frac{\Delta\Phi}{2}\right) = I_{max}\cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$$

Example: white light passes through two slits 0.50 mm apart and an interference pattern is observed on a screen 2.5 m away. The first-order fringe resembles a rainbow with violet and red light at either end. The violet light falls about 2.0 mm and the red 3.5 mm

Change of phase due to reflection

Lloyd's mirror（洛埃镜）:



An electromagnetic wave undergoes a phase change of π upon reflection from a medium that has a higher index of refraction than the one in which the wave is traveling

Interference in thin films（薄膜干涉）:

Two things must be noted:

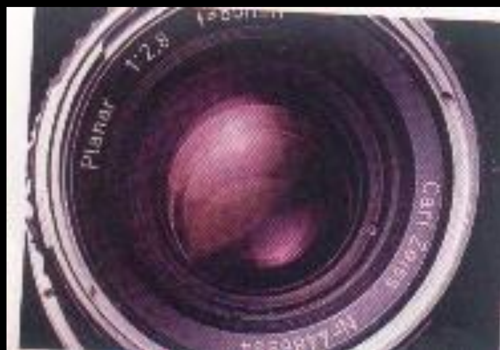
1. The phase shift due to reflection.

2. The wavelength of light λ_n in a medium whose refraction index is n is

$$\lambda_n = \frac{\lambda}{n}$$

Where λ is the wavelength of the light in free space

Antireflective coatings(增透膜）



A coating material must have an index of refraction between that of air and the glass to be coated.

$$d_{\min} = \frac{\lambda}{4n}$$

Where λ is the wavelength in vacuum of the rays that we want pass through the coating , n is the refraction index.

The colors of this kind of butterfly do not resemble the same pattern on each side of the wings.

Example:a certain soap film is in the air （n_1=1.33）, its thickness is 0.32μm。If a beam of white rays incident on it normally, what is the color of the film when we look downward?

solution:
$$2n_1 e+\frac{\lambda}{2}=k\lambda \qquad \rightarrow \lambda=\frac{2n_1 e}{k-1/2}$$

$$k=1 \quad , \quad \lambda_1=4n_1 e=1.70\mu m=17000\dot{A}$$

$$k=2 \quad , \quad \lambda_1=\frac{4}{3}n_1 e=0.567\mu m=5670\dot{A}$$

$$k=3 \quad , \quad \lambda_1=\frac{4}{5}n_1 e=0.341\mu m=3410\dot{A}$$

λ_2=5670A（黄光）

Quiz: Two flat glass plates of length $L=10$ cm touch at one end but are separated by a wire of diameter $d=0.01$mm at the other end , light shines almost perpendicularly on the glass and is reflected into the eyes, what is the distance x between two bright fringes when $\lambda=400$nm?

Newton’s rings

$$2ne+\frac{\lambda}{2}=k\lambda$$

Bright fringes

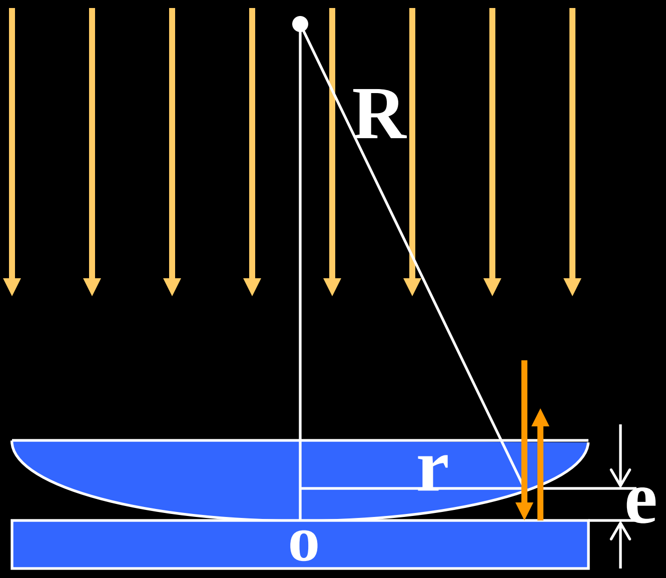
$$2ne+\frac{\lambda}{2}=(2k+1)\frac{\lambda}{2}$$

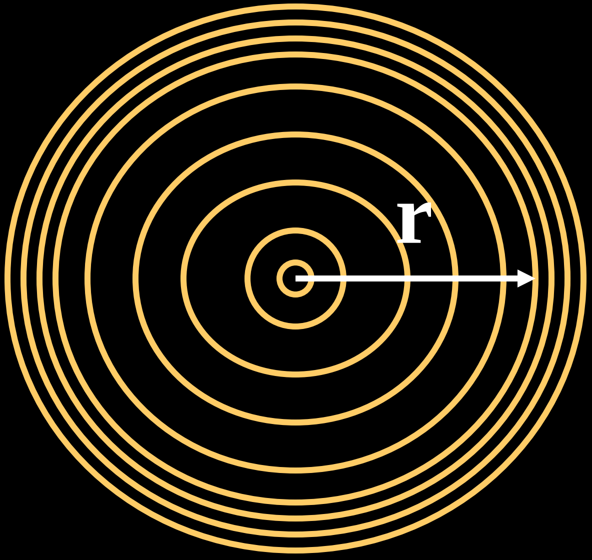
Dark fringes

$$r^2=R^2-(R-e)^2=2Re-e^2$$

Q $\quad R>>e\rightarrow 2Re>>e^2$

$$e=\frac{r^2}{2R}$$





$$r = \sqrt{\frac{(2k-1)R\lambda}{2n}}$$ $(k = 1,2,\cdots)$ **Bright rings**

$$r = \sqrt{\frac{kR\lambda}{n}}$$ $(k = 0,1,2,\cdots)$ **Dark rings**

A certain lamp is used （λ = 5893A）to observe Newton's rings， the radius of dark ring of kth order is r = 4mm， while that of k+5th order is r = 6mm，find the curvature of the lens。

solution：

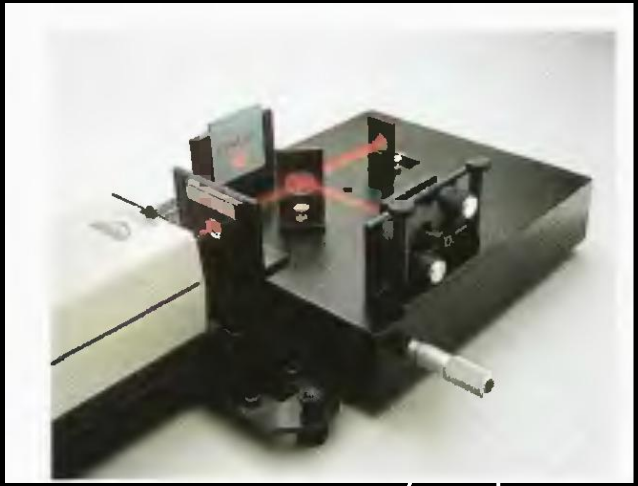
$$r_k = \sqrt{k\lambda R}$$

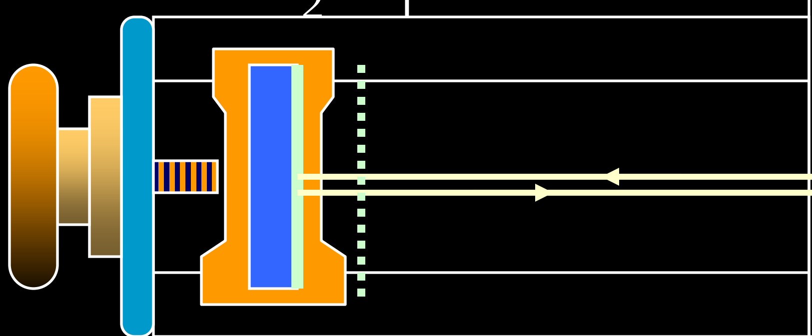
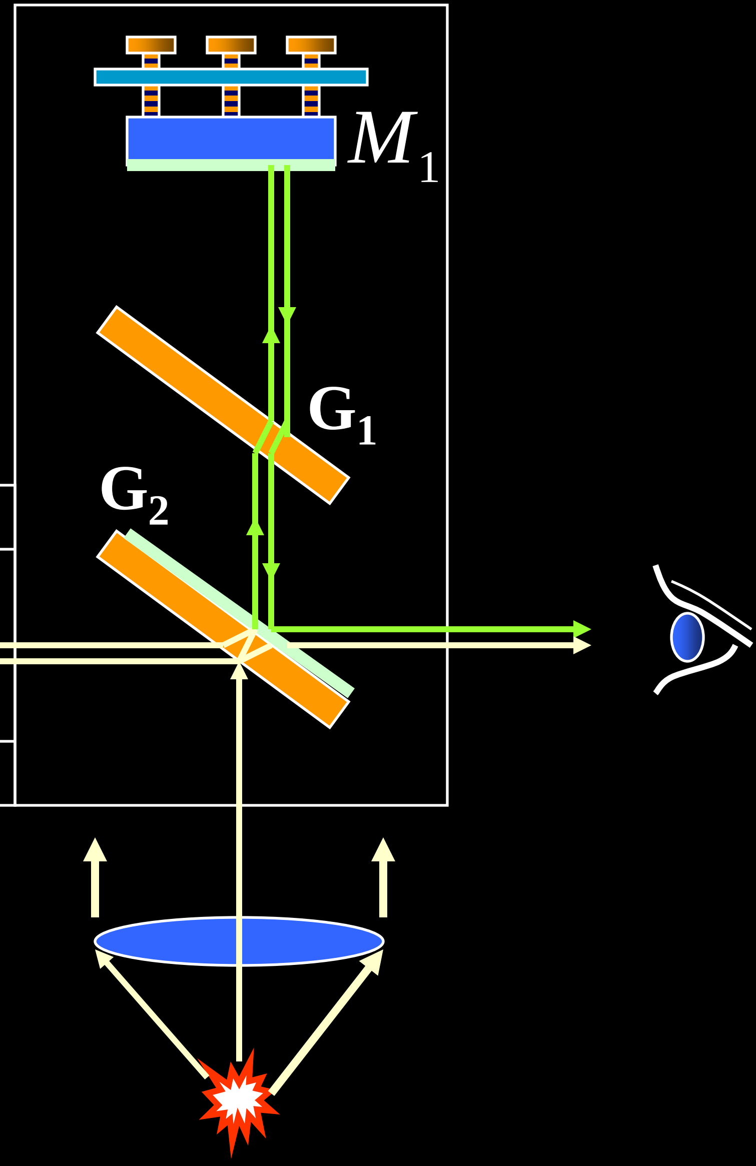
$$r_{k+5} = \sqrt{(k+5)\lambda R}$$

By solving the equations , we will find

$$k = 4 \qquad R = 6.79\ m$$

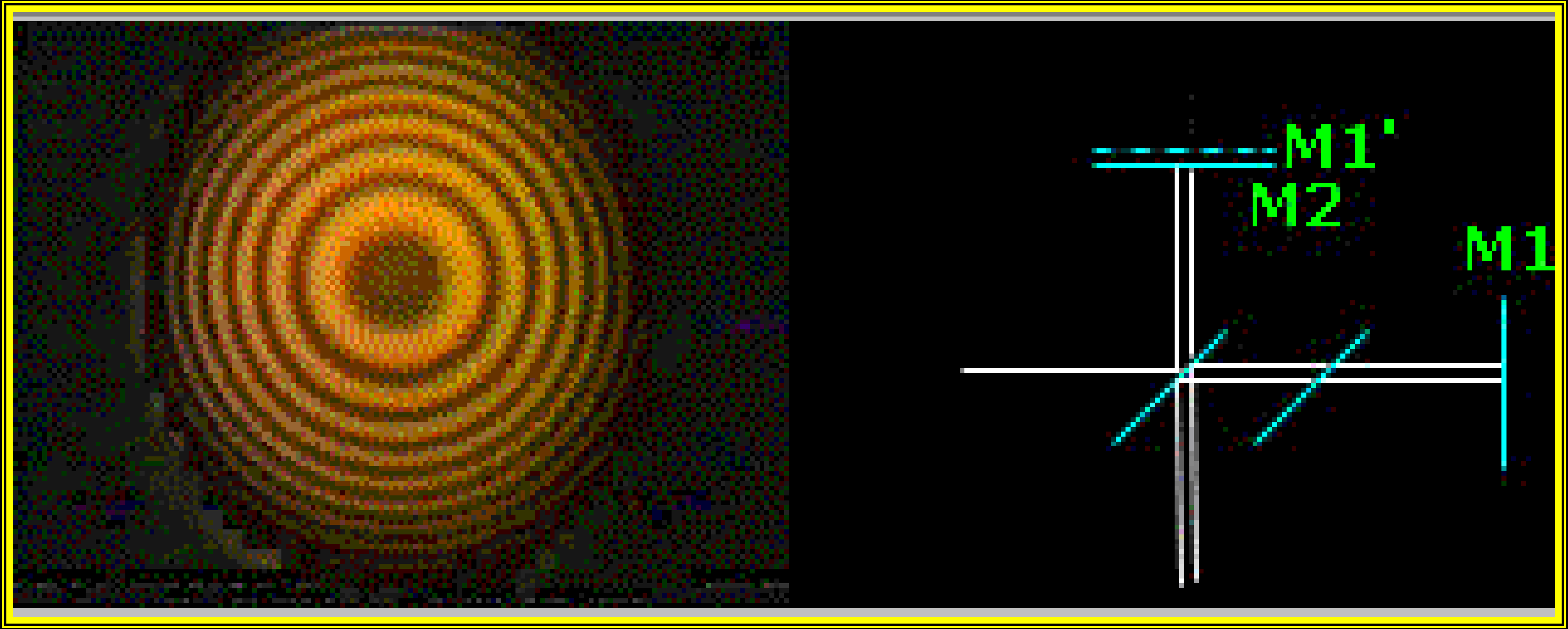
Michelson interferometer(迈克尔逊干涉仪）



$$\Delta d = N \frac{\lambda}{2}$$

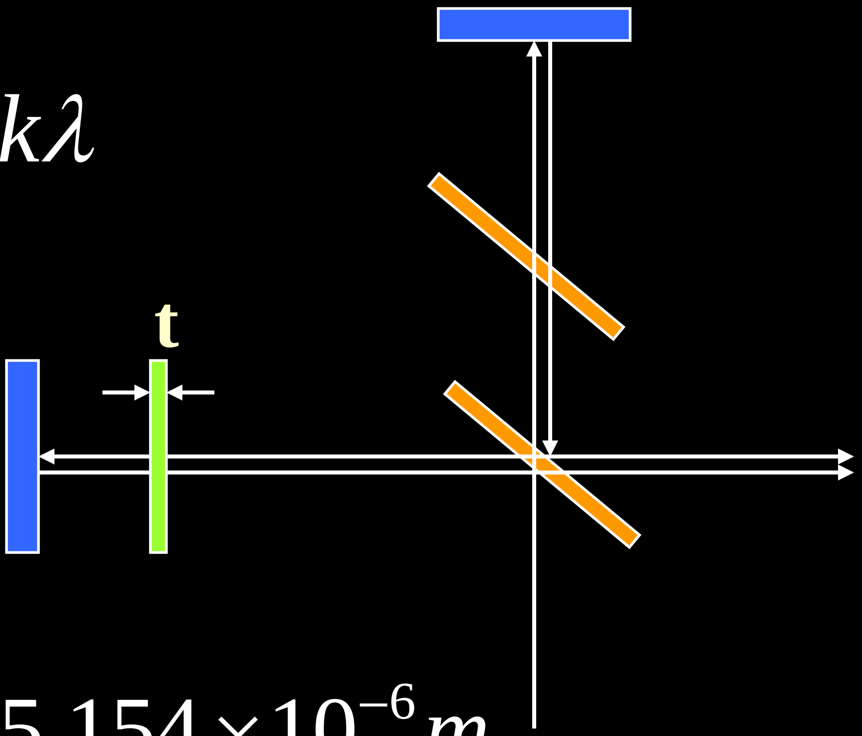
The interference pattern of Michelson interferometers



Example A certain film with index of refraction 1.4 is put into one arm of the interferometer， the fringes move 7 orders, find the thickness of the film(assuming the wavelength λ = 5893A）

solution

$$\Delta\delta = 2(n-1)t = \Delta k\lambda$$



$$t = \frac{\Delta k \cdot \lambda}{2(n-1)}$$

$$= \frac{7 \times 5893 \times 10^{-10}}{2(1.4-1)} = 5.154 \times 10^{-6} m$$