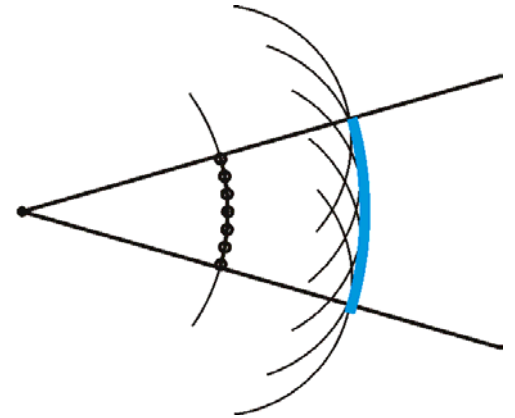


## Physical or wave optics

(other model)

Its bases: **Huygens–Fresnel-principle**

According to the **Huygens principle**, elementary waves originate from every point of a wavefront, and the new wavefront is the common envelope of these elementary waves.



The laws of rectilinear propagation, the reflection and refraction can be described by this model as well.

**Fresnel** supplemented this by observing that the **superposition principle is also in effect** during the formation of the new wave front, which is nothing else than the quantitative formulation of the empirical fact that waves will propagate through each other without disturbance. **Interference.**

**Waves** (we learned about them earlier; dynamics, „repetition”)

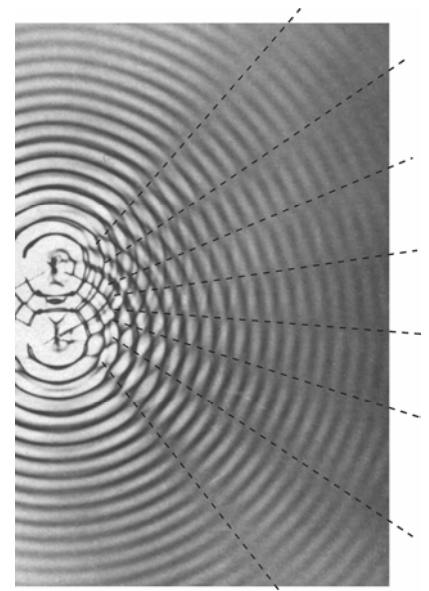
E.g. „water wave”: it can be observed directly.

Because it changes slowly enough (low frequency,  $f$ ) and the typical (wave) size is large enough (long wavelength,  $\lambda$ ).

„**Light waves**” are different.

At certain conditions **patterns** can be formed, which don't or slowly change in time, and their size is much larger than the wavelength,  $\lambda$ .

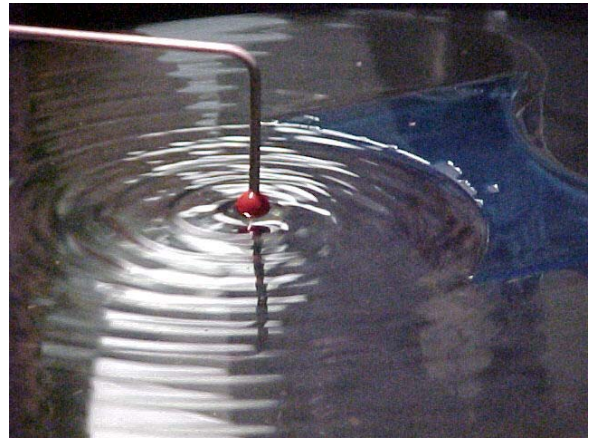
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**Interference** (two or more waves meet)

the most important phenomenon in connection with waves

Incoherent and coherent waves



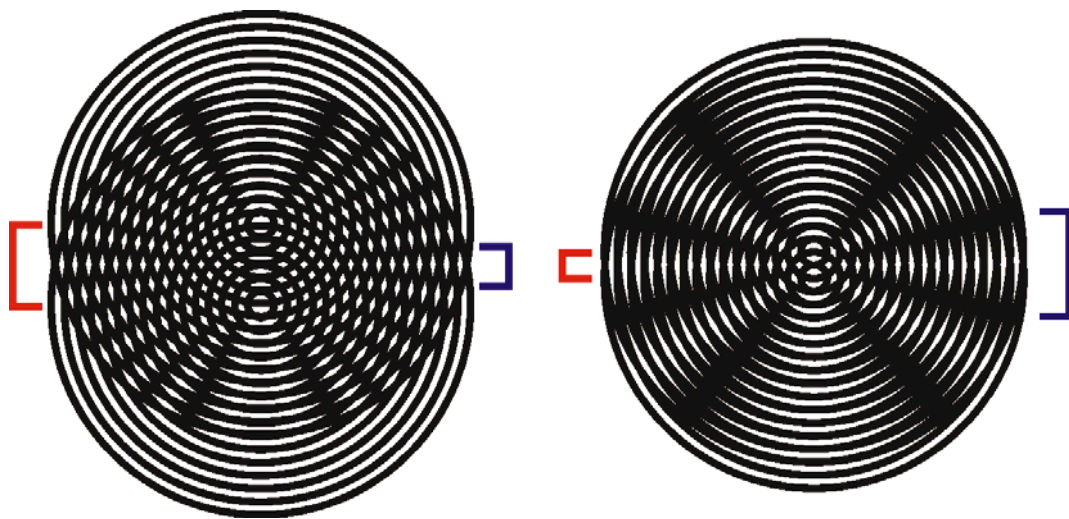
Rise of coherent waves is controlled in space and time, they are **synchronized** somehow.

## Light interference

Nothing but the produced **patterns** can be observed.

Conditions for existent of observable patterns in the case of point like sources:

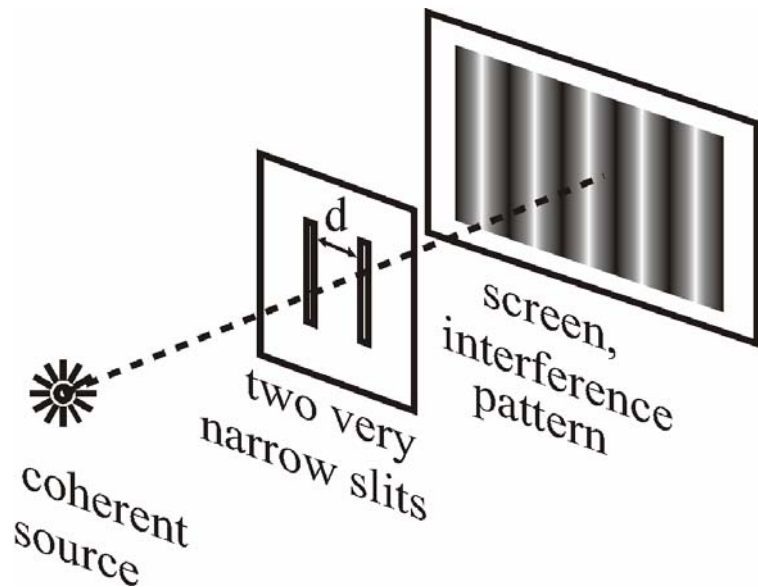
1. coherent waves (e.g. difference of phases ( $\Delta\phi$ ) is constant)
2. distance of sources is commensurable with the wavelength ( $\lambda$ ).



The smaller the distance of sources (**red mark**),  
the bigger the typical size of the pattern (**blue mark**).

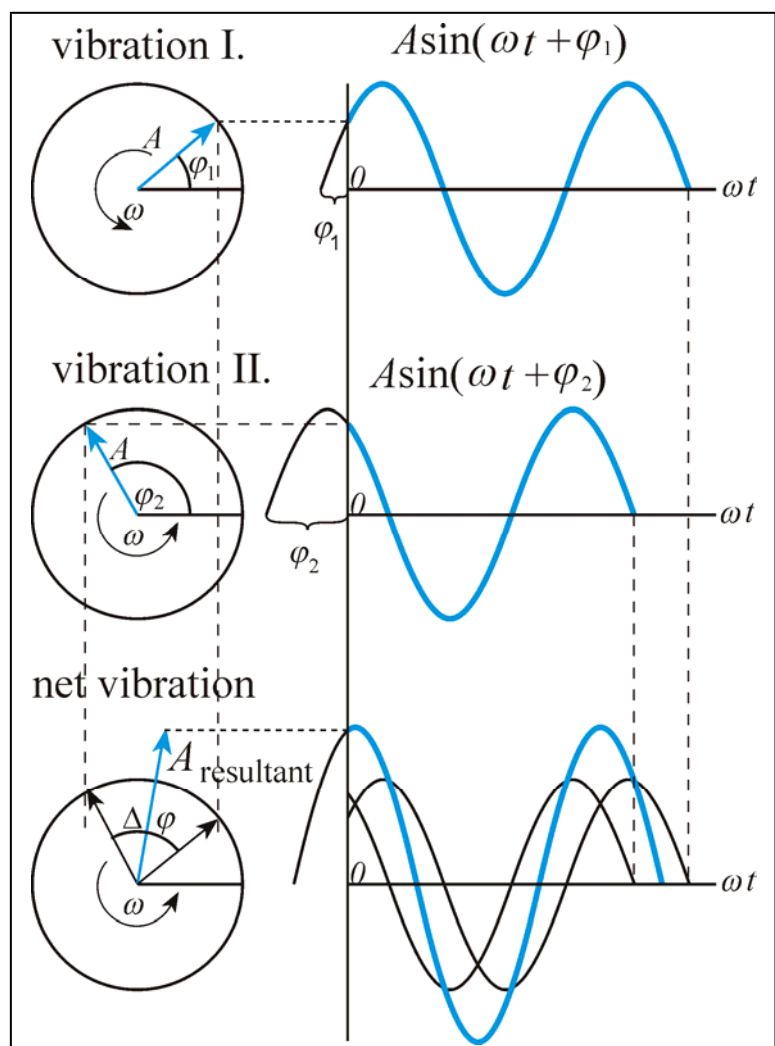
## Typical experiment and pattern of light interference

### Young's double slit experiment (diffraction)



The places of **constructive** and **destructive** interference are determined by the **difference in phase** ( $\Delta\phi$ ).

At a certain place the vibrational states are demonstrated by rotating vectors:

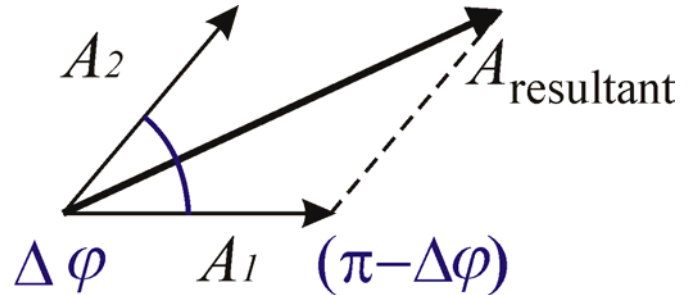


The amplitude of the net vibration ( $A_{\text{resultant}}$ ) is given by the **vector sum** of the components ( $A$ ).

Our eyes are sensitive to the **light-power** ( $P$ ), that is proportional to the square of the amplitude.

Thus  $A_{\text{resultant}}^2 \sim P_{\text{res.}}$ , and  $A_{\text{res.}} = A_1 + A_2$  hence  $P_{\text{res.}} \neq P_1 + P_2$ .

Resultant ( $A_{\text{resultant}}$ ) of two vectors ( $A_1, A_2$ ), or the square of it, if the angle between them is  $\Delta\varphi$ :



$$P \sim A_{\text{resultant}}^2 = A_1^2 + A_2^2 - 2A_1 A_2 \cos(\pi - \Delta\varphi) \quad (\text{cosine theorem})$$

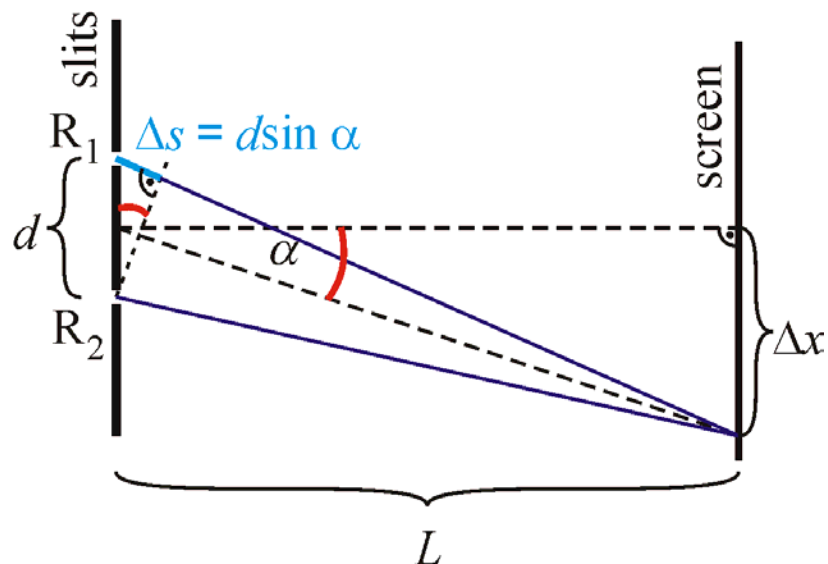
$$P \sim A_{\text{resultant}}^2 = A_1^2 + A_2^2 + 2A_1 A_2 \cos\Delta\varphi$$

$$\text{If } A_1 = A_2 = A, \text{ then } A_{\text{resultant}}^2 = 2A^2 (1 + \cos\Delta\varphi)$$

The **difference in phase** ( $\Delta\varphi$ ) is determined by the relation of **difference in path length** ( $\Delta s$ ) and the **wavelength** ( $\lambda$ ).

$$\text{If } L \gg d,$$

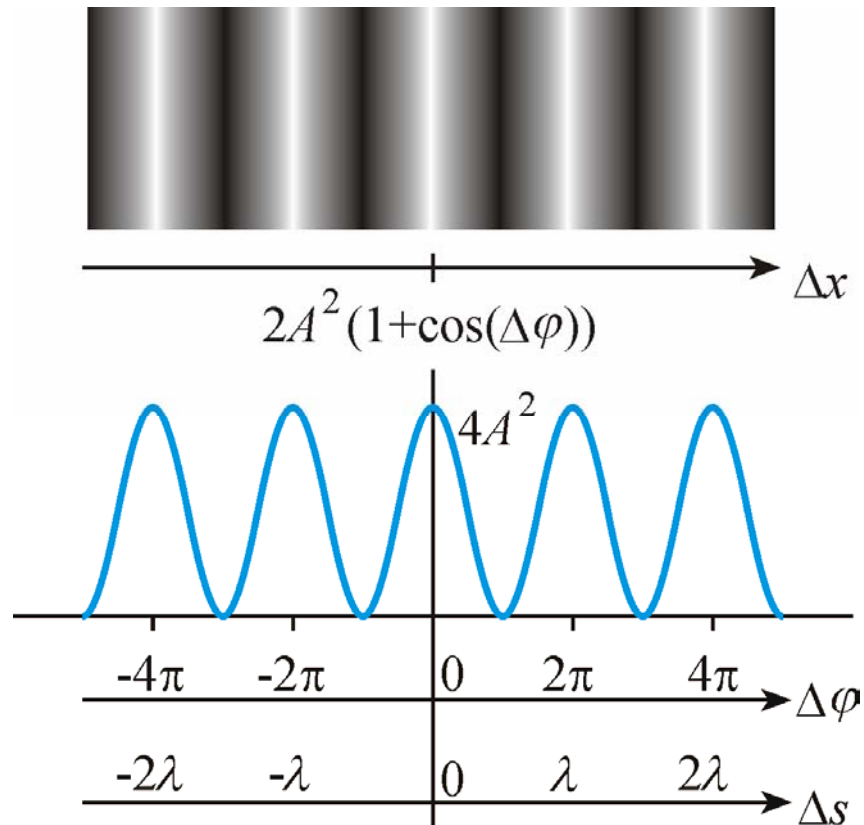
the **difference in path length**  
 $\Delta s = d \sin\alpha$ .



The **difference in phase** is given as:

$$\Delta\varphi = \frac{2\pi}{\lambda} \Delta s = 2\pi \frac{d \sin \alpha}{\lambda} \approx 2\pi \frac{d \Delta x}{\lambda L}$$

## Demonstration:



In the case of many uniform slits, namely **optical grating**, very **sharp maxima** can be observed at places correspond to  $\Delta\varphi = 2k\pi$  or  $\Delta s = k\lambda$ ;  $k = 0, 1, 2, \dots$  condition.

$$2k\pi = \Delta\varphi \approx 2\pi \frac{d\Delta x}{\lambda L}$$

$L$  and  $\Delta x$  macroscopically measurable. If  $\lambda$  is known, the microscopic  $d$  can be determined, consequently in general:

**we can get microscopic data from macroscopic diffraction pattern.**

**Applications:** determination of the resolving power of microscopes,  
but this is the bases of any diffraction methods as well (x-ray diffraction; determination of **protein structure**).

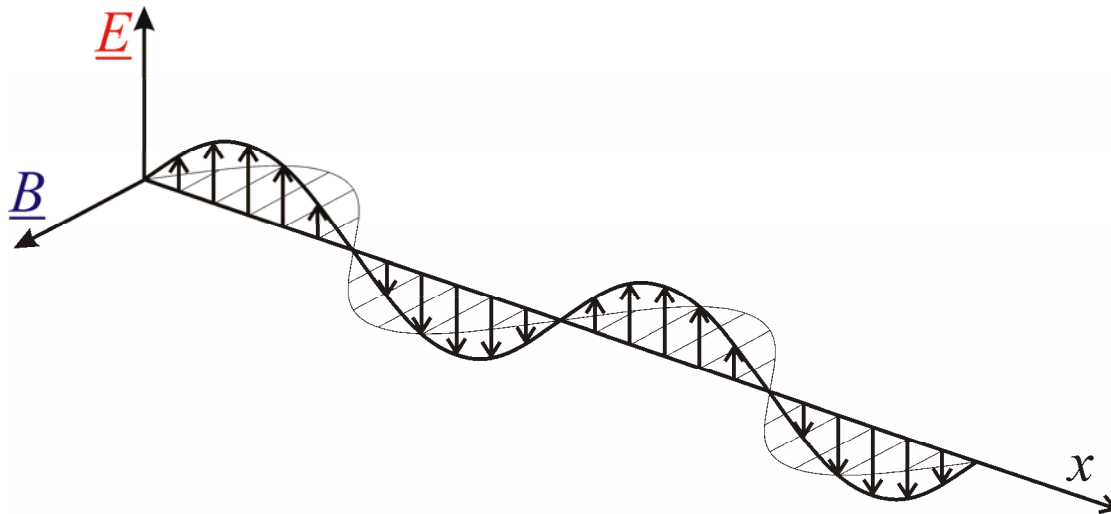


Light is **electromagnetic wave**

**transversal**

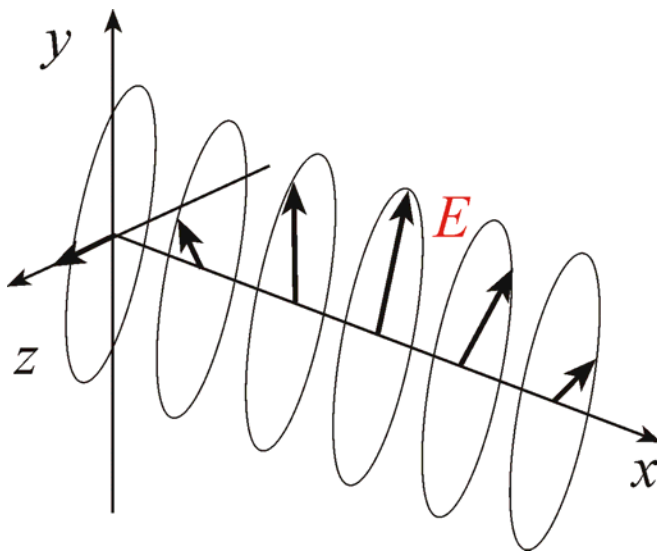
thus can be **polarized**

**linearly** polarized light  
or **plane** polarized light



But

**elliptically** polarized light also exists.



## Optical anisotropy

E.g. in an „anisotropic matter” the **speed of a suitably linearly polarized light depends on the direction of propagation.**

The reason of it is connected to the structure of matter.

**Consequences, applications:** double refraction, polarization microscope