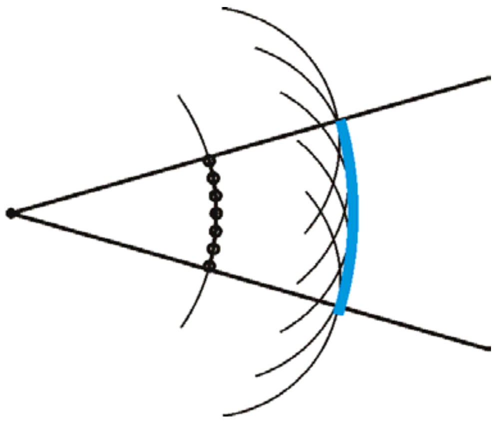
Physical or wave optics

(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.



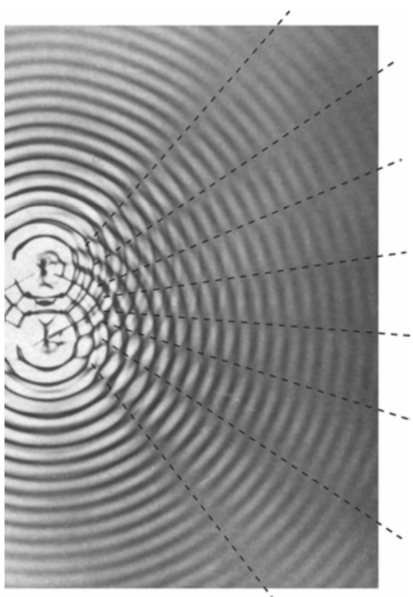
The laws of rectilinear propagation, the reflection and refraction can be described by this model as well.

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, λ).

„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, λ.

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Interference (two or more waves meet)

the most important phenomenon in connection with waves

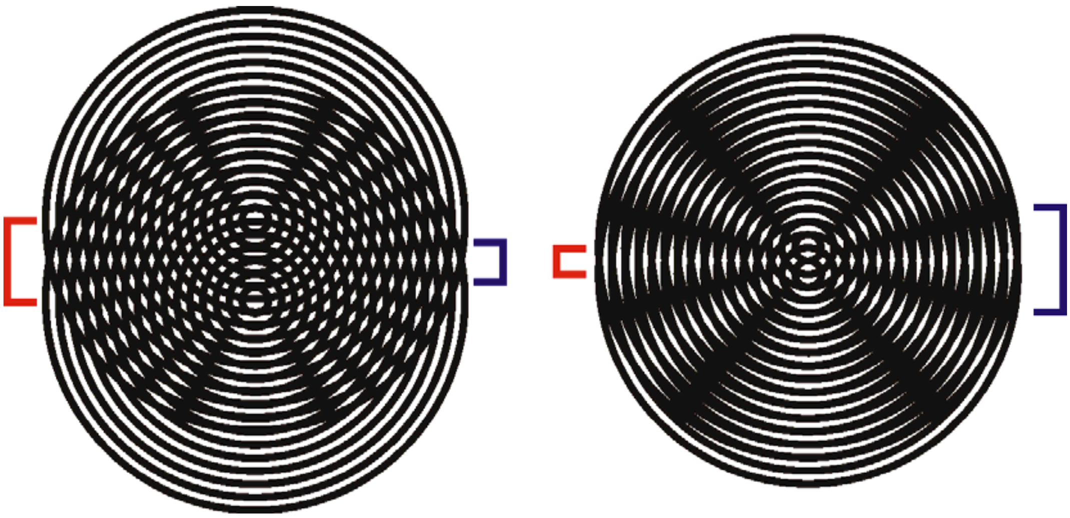
Incoherent and coherent waves

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:

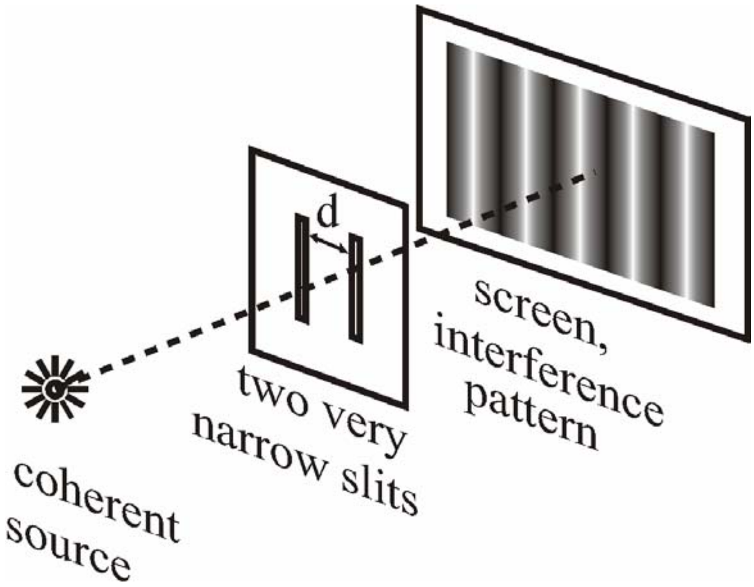
1. coherent waves (e.g. difference of phases ($\Delta\varphi$) is constant)
2. distance of sources is commensurable with the wavelength (λ).



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

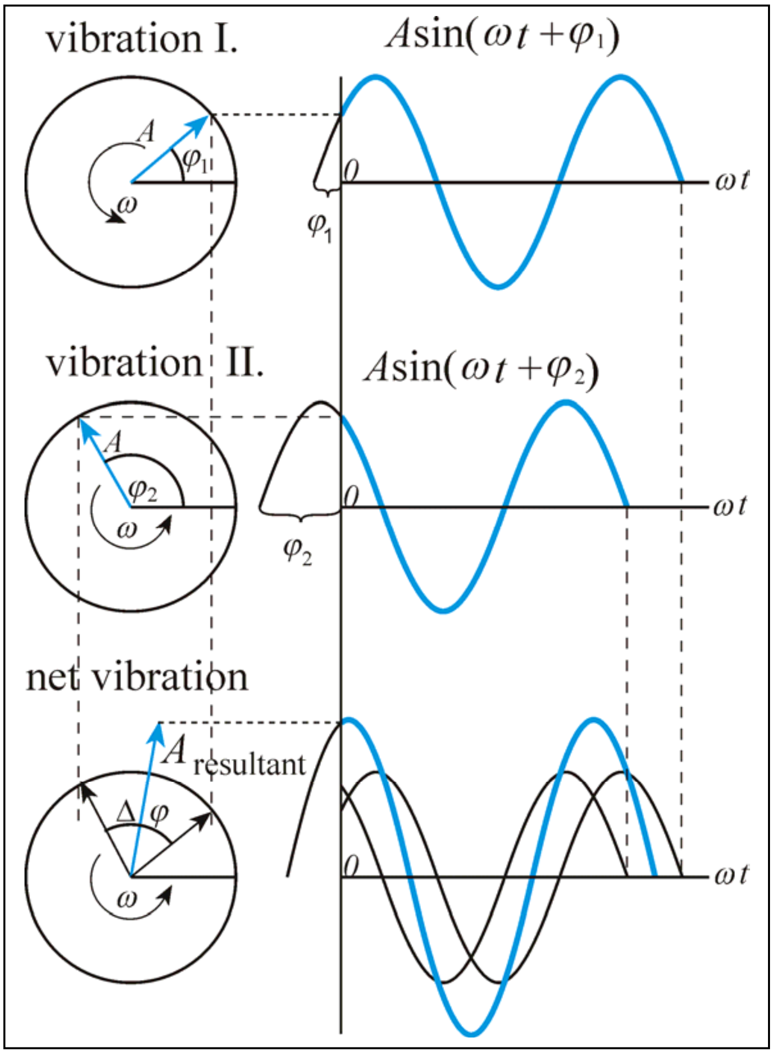
Typical experiment and pattern of light interference

Young's
double slit experiment
(diffraction)



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

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

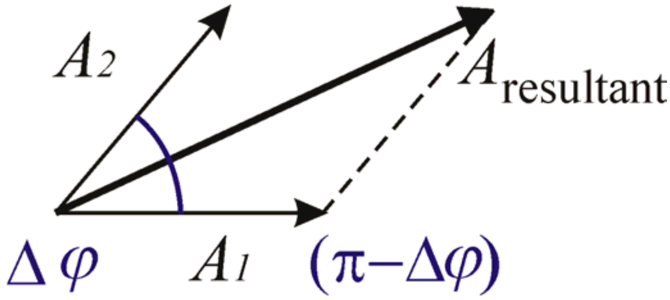


The amplitude of the net vibration ($A_{resultant}$) is given by the vector sum of the components (A).

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

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

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



$P \sim A^2_{resultant} = A^2_1 + A^2_2 - 2A_1 A_2\cos(\pi\text{-}\Delta\varphi)$ (cosine theorem)

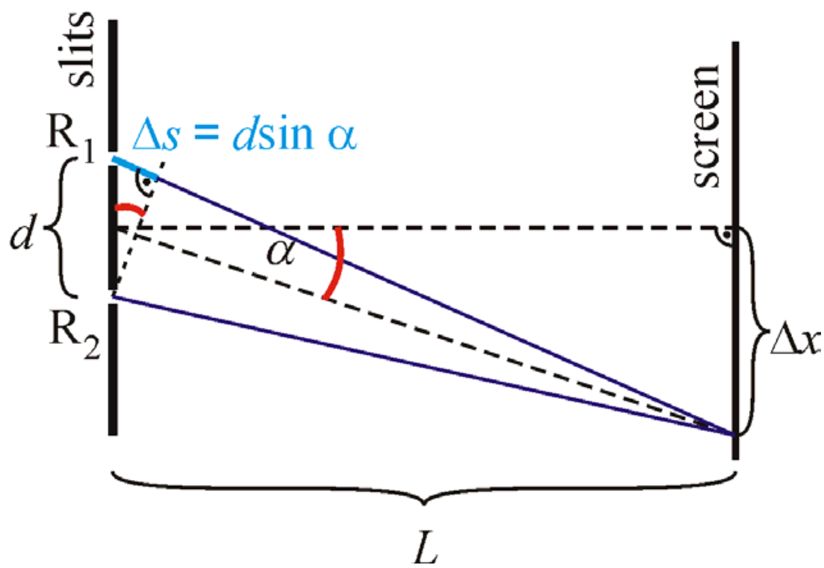
$P \sim A^2_{resultant} = A^2_1 + A^2_2 + 2A_1 A_2\cos\Delta\varphi$

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

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

If $L >> d$,

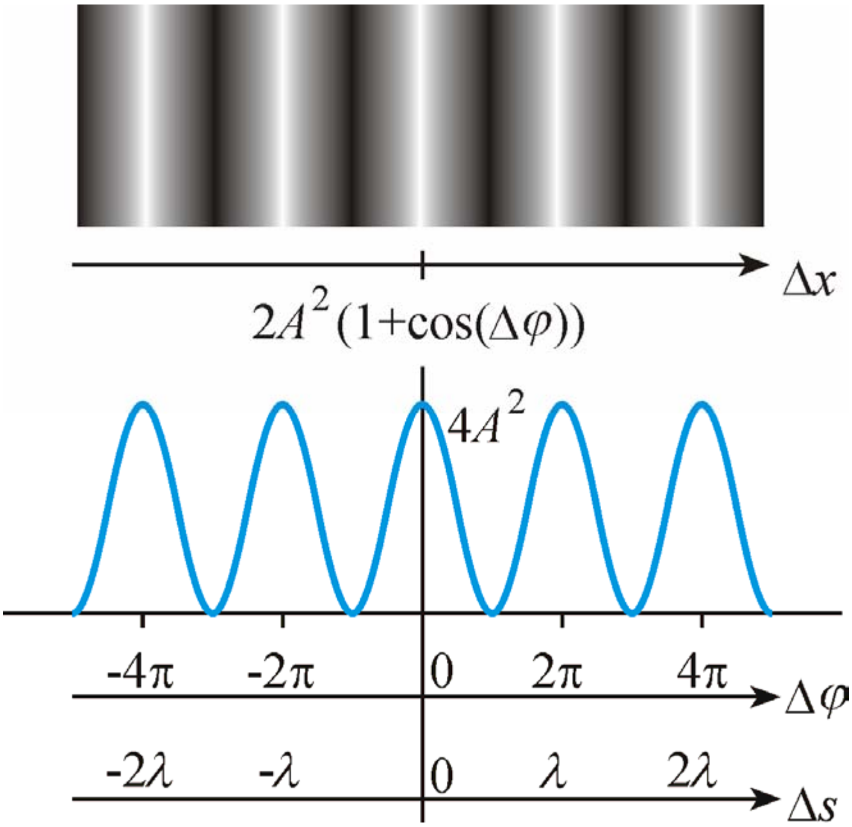
the difference in path length
$\Delta s = d\sin\alpha$.



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,… condition.

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

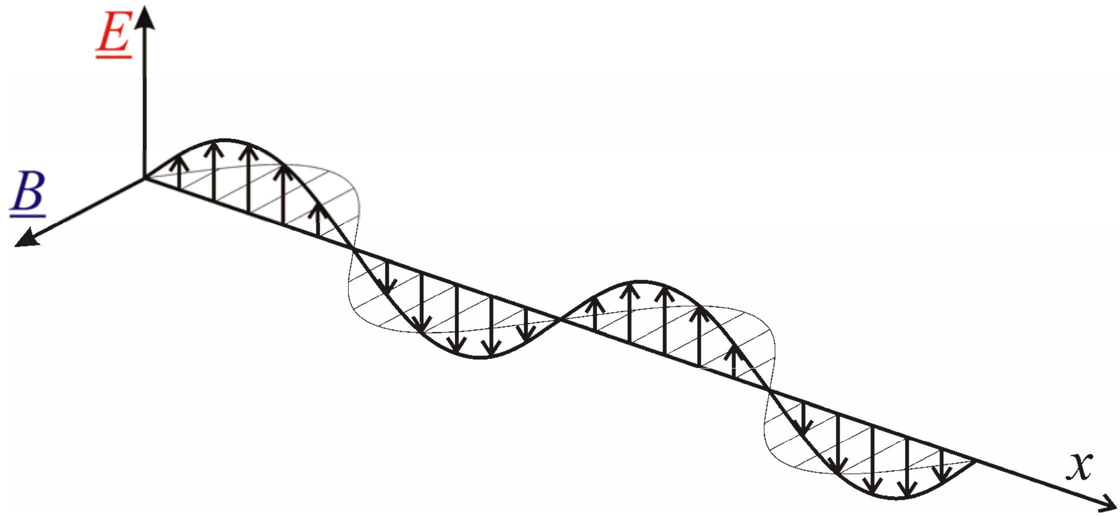
L and Δx macroscopically measurable. If λ is known, the microscopic d can be determined, consequently in general:

we can get microscopic data from macroscopic diffraction pattern.

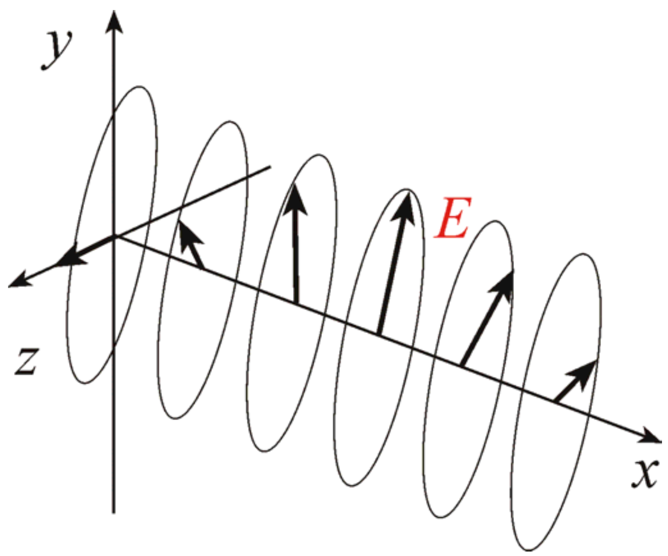
Applications: determination of the resolving power of microscopes,
but this is the bases of any diffraction methods as well (x-ray diffraction; determination of protein structure).

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