

Optica II

(Optica ondulatorie)

Lector Dr. Iulian Ionita

Bibliografie

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Criteria pentru obtinerea creditelor

Rezolvarea temelor 15%

Activitate de laborator 20%

Partial I 20%, termen: sfarsitul interferentei

Partial II 20%, termen: sfarsitul difractiei

Final 25%

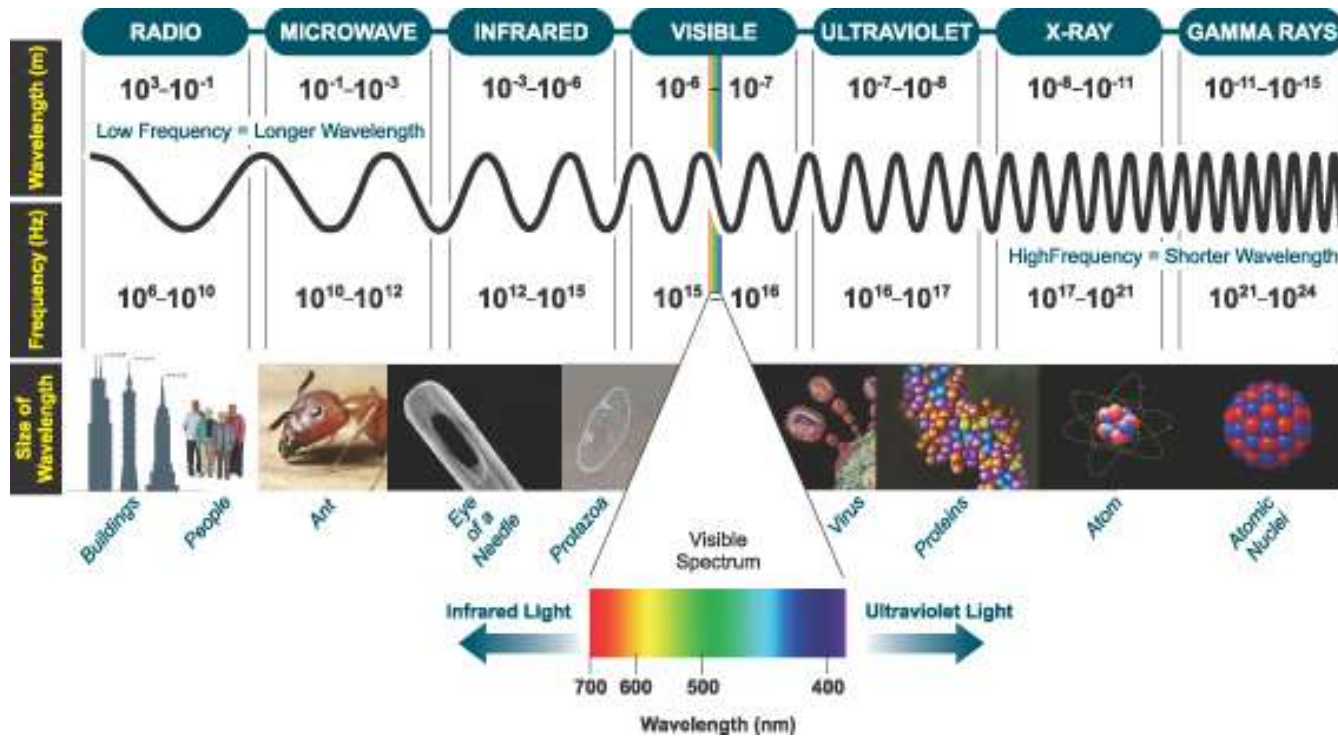
Prezenta este cruciala. Daca participi la toate cursurile si iti rezolvi temele vei obtine 10 sau 9, in general.

Daca doresti poti opta pentru prezentarea publica a unui referat pe un topic avansat pentru extra-credit.

Topicuri

- Introducere in optica, spectrul EM, generarea luminii
- Natura fotonica sau ondulatorie a luminii
- Unde optice
- Interferenta si interferometrie
- Difractie I: difractie Fraunhofer
- Difractie II: difractie Fresnel
- Coerenta
- Polarizarea

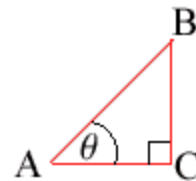
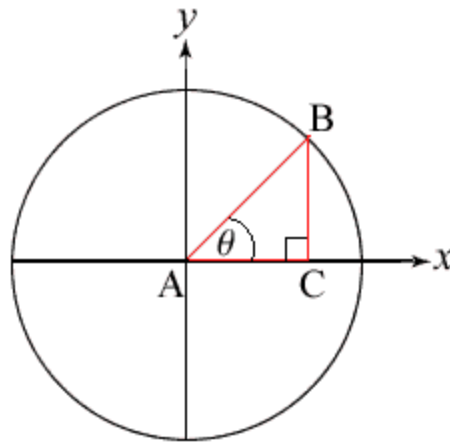
Spectrul electromagnetic



Cunostinte necesare

Absolut necesare

Funcțiile Trigonometrice



$$\sin \theta = \frac{BC}{AB}$$

$$\cos \theta = \frac{AC}{AB}$$

$$\tan \theta = \frac{BC}{AC}$$

$$\cot \theta = \frac{AC}{BC}$$

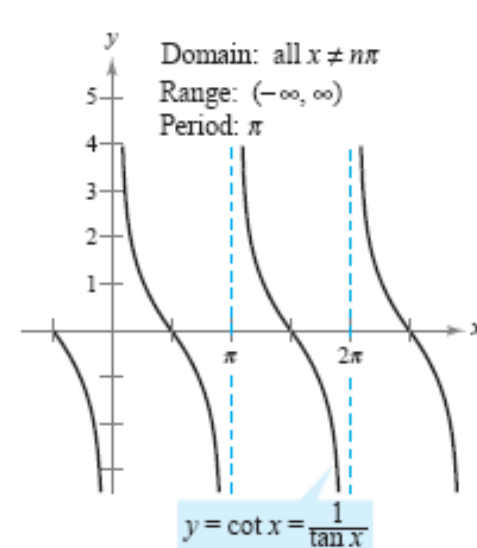
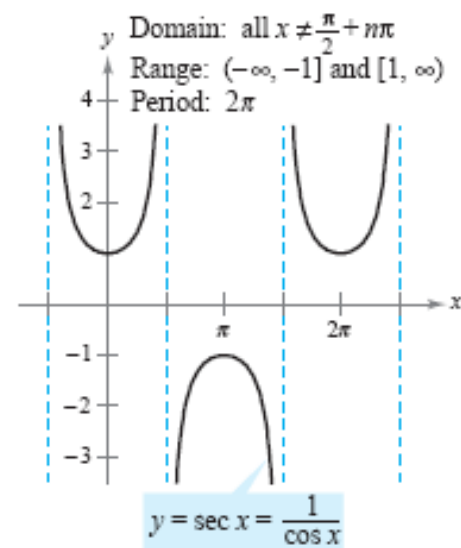
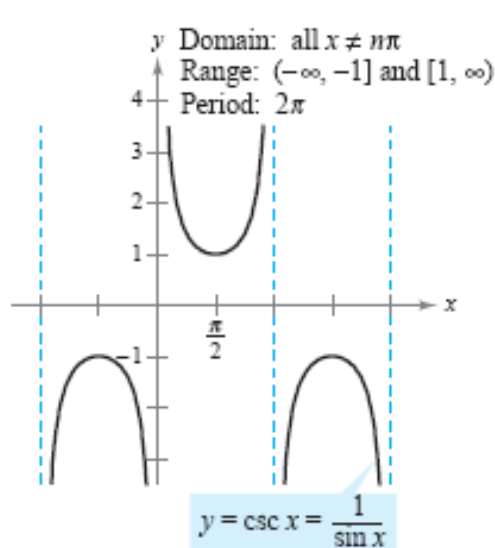
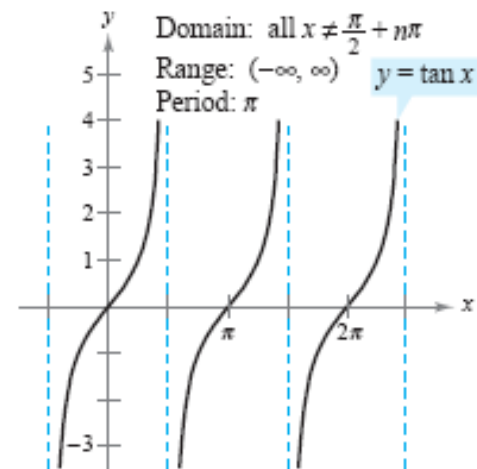
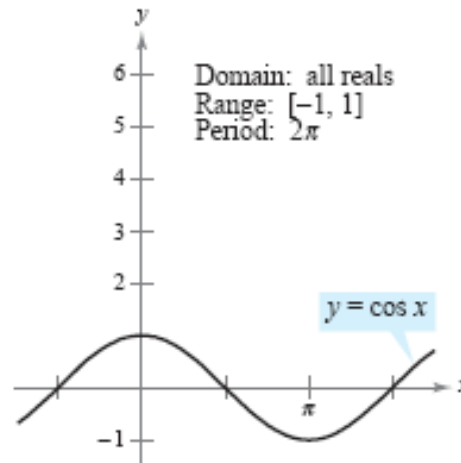
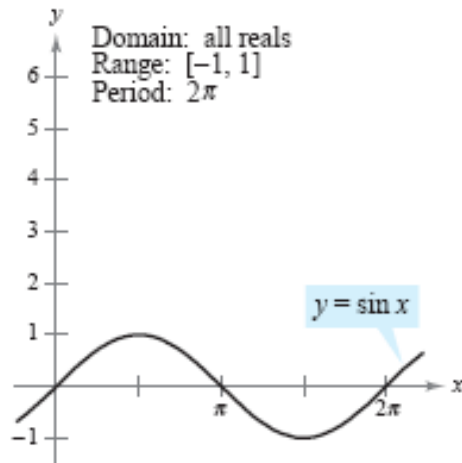
$$\sec \theta = \frac{AB}{AC}$$

$$\csc \theta = \frac{AB}{BC}$$

Cunostinte necesare

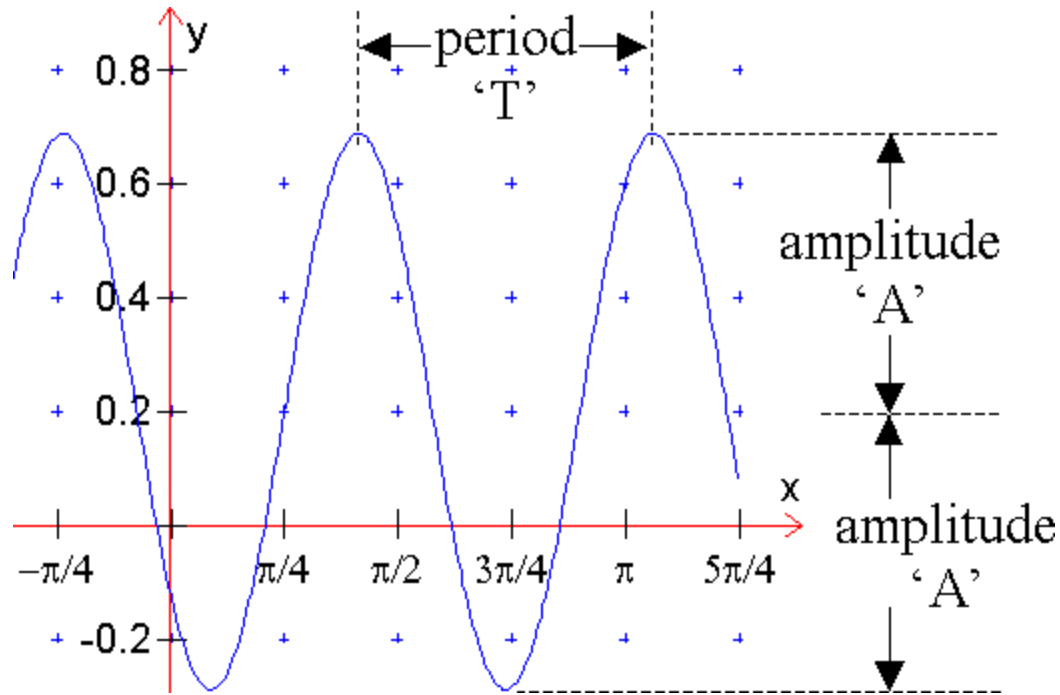
θ	0	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$
	0	30°	45°	60°	90°
$\sin(\theta)$	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1
$\cos(\theta)$	1	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	0
$\tan(\theta)$	0	$\frac{\sqrt{3}}{3}$	1	$\sqrt{3}$	U
$\csc(\theta)$	U	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1
$\sec(\theta)$	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	U
$\cot(\theta)$	U	$\sqrt{3}$	1	$\frac{\sqrt{3}}{3}$	0

Cunostinte necesare



The graphs of the six trigonometric functions

Cunostinte necesare



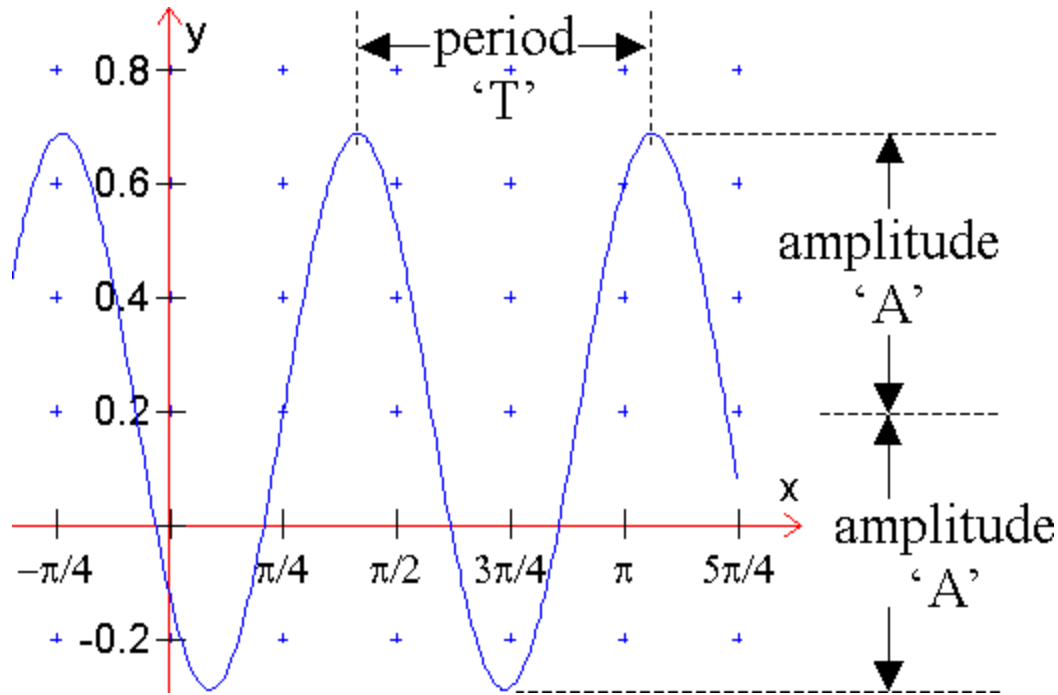
Perioada, T , este intervalul de timp dintre doua puncte de maxim ale functiei.

Amplitudinea, A , este distanta dintre punctul de mijloc si punctul cel mai de sus al functiei.

Faza este marimea deplasarii pe orizontala a functiei fata de pozitia initiala.

Aceste functii **periodice** pot fi scrise sub forma de sin sau cos.

Cunostinte necesare



**Forma generala a functiei
sin este:**

$$y = A \cdot \sin(Bx + C) + D$$

Natura luminii

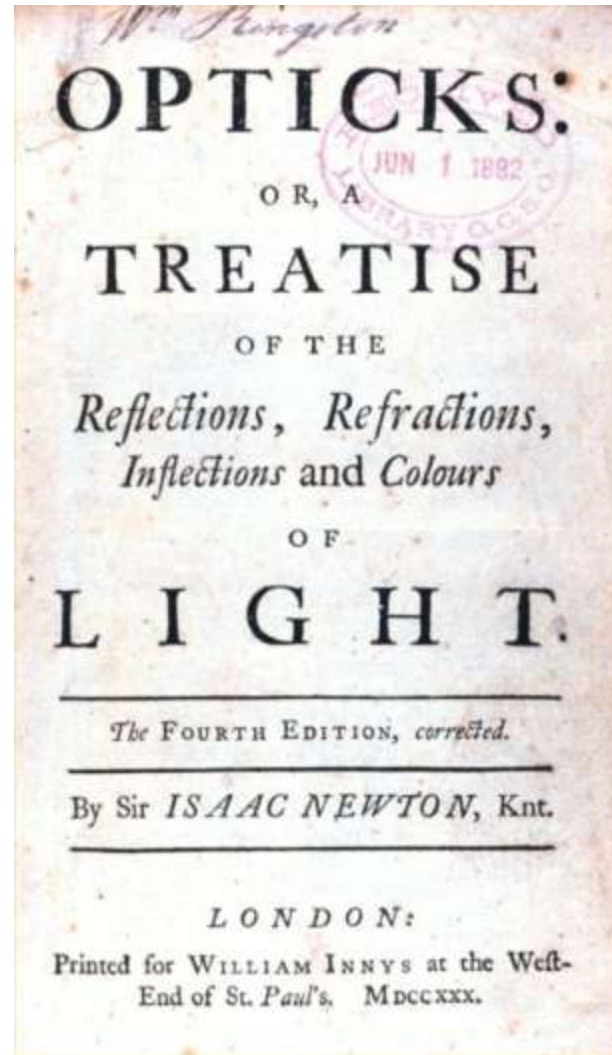


Sir Isaac Newton,
(January 4, 1643 - March 31, 1727)

Natura luminii



Sir Isaac Newton,
(January 4, 1643 - March 31, 1727)



1704 first edition

Natura luminii



Sir Isaac Newton

“Rays of light are very small bodies emitted from shining substances.”

“law of linear propagation” (**mediu omogen**)

- Reflexie
- refractie
- umbre

Natura luminii



By 1678 Huygens had returned to Paris. In that year his *Traité de la lumiere* appeared, in it Huygens argued in favour of a

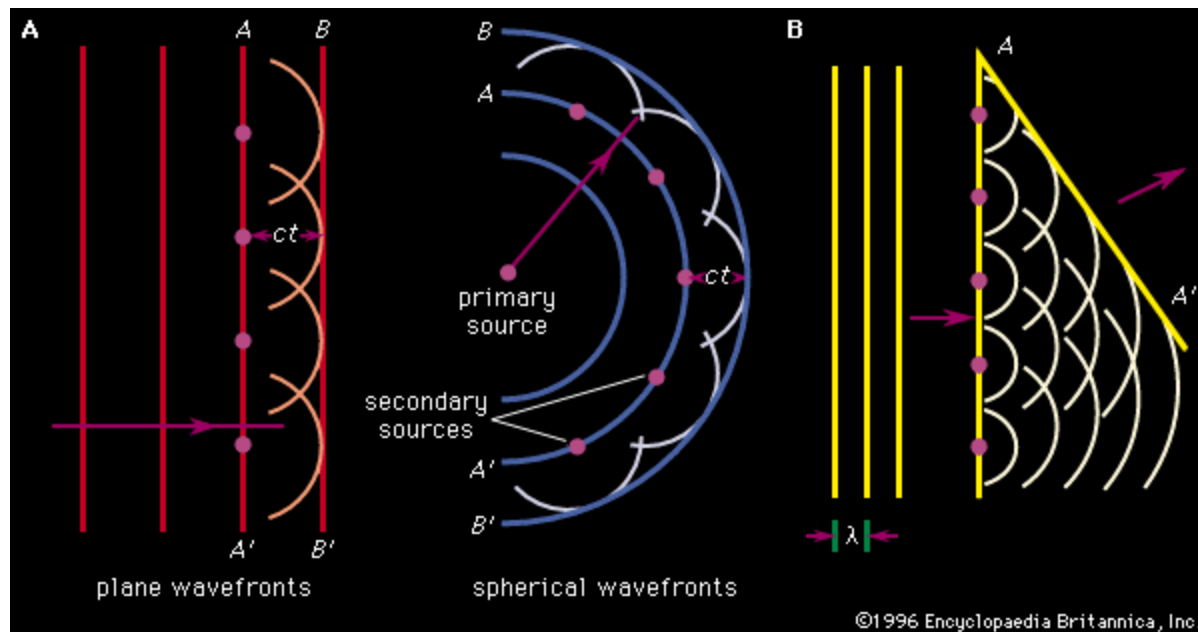
wave theory of light

Light is a wave motion

Christiaan Huygens (1629-1695)

Principiul lui Huygens

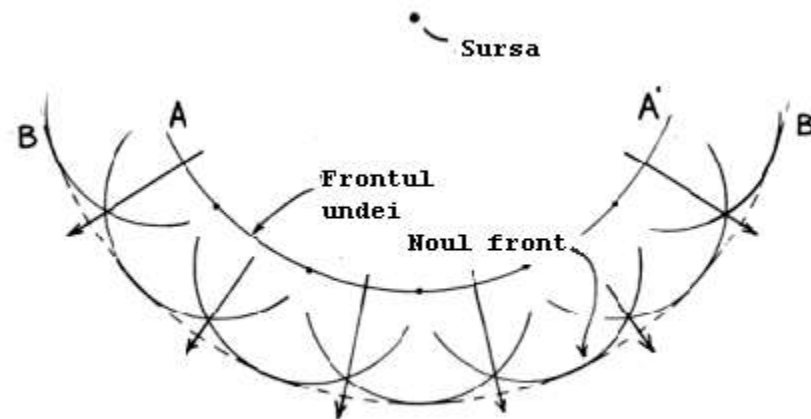
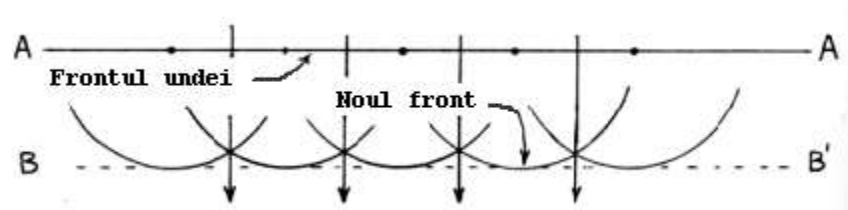
Huygens a afirmat ca o sfera de lumina in expansiune se comporta ca si cum fiecare punct al frontului de unda ar fi o sursa noua de radiatie de **aceeasi frecventa si faza**.



Principiul lui Huygens pentru:

Unda plana (sus)

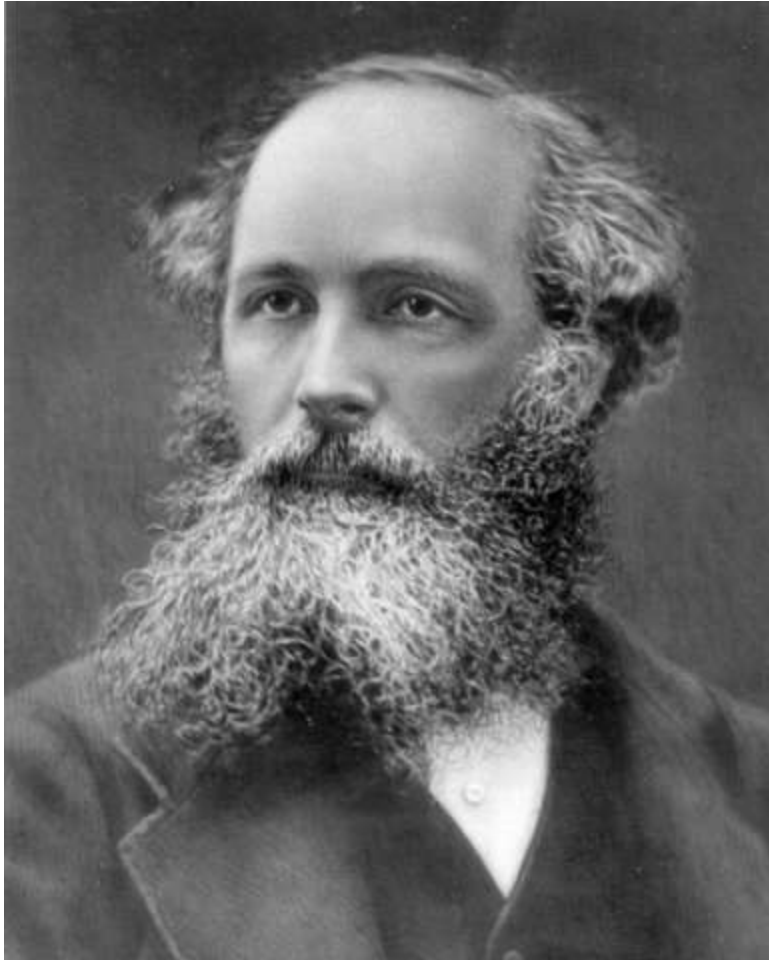
Unda sferica (jos)



Principiul lui Huygens

- Reflexie
- refractie
- interferenta
- difractie
- polarizare

Natura Electromagnetica a Luminii



El a afirmat ca (1864) : "We have strong reason to conclude that **light** itself - including radiant heat and other radiation, if any - is an **electromagnetic disturbance** in the form of **waves** propagated through the electromagnetic field according to electromagnetic laws."

James Clerk Maxwell (1831 - 1879)

Teoria Cuantica a Lumini



Fondatorul teoriei cuantice

Fotoni

Max Karl Ernst Ludwig *Planck*
(April 23, 1858 – October 4, 1947)

Optica:

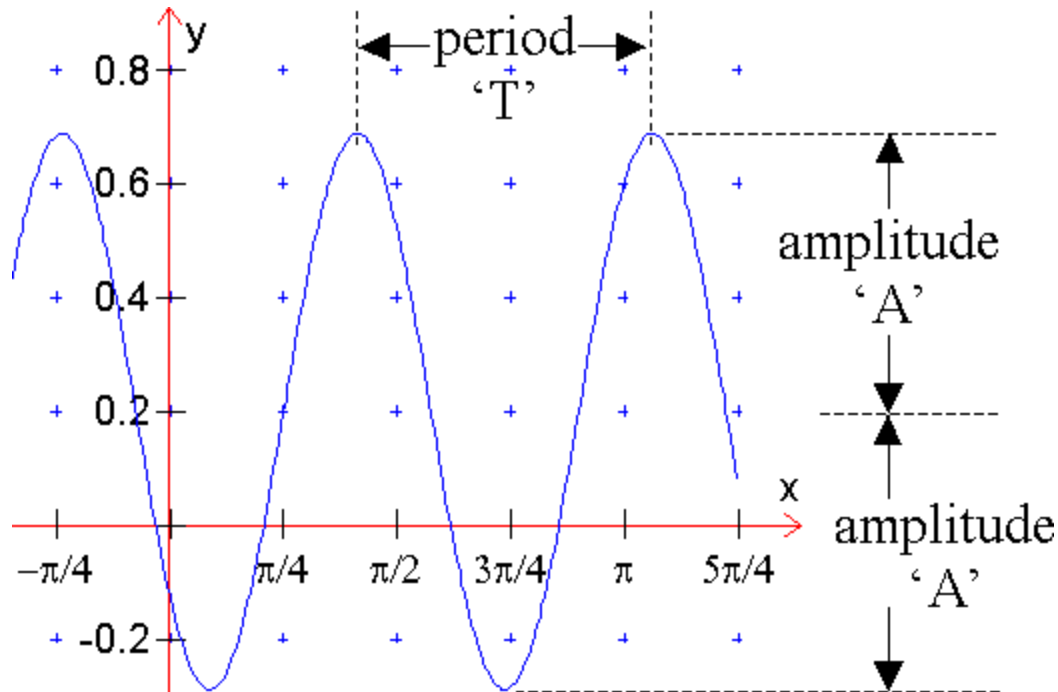
- Optica Geometrica
- Optica Ondulatorie
- Optica Electromagnetica
- Fotonica
- Optica Cuantica
- Optica Ne-lineara

C2. Oscilatii si unde

1. Oscilatie armonica
2. Marimi caracteristice
3. Reprezentari ale oscilatiei armonice

C2. Oscilatii si unde

1. Marimi caracteristice:



1.1. Amplitudine- A...

1.2. Frecventa- ν ...

1.3. Viteza unghiulara- ω

1.4. Perioada- T

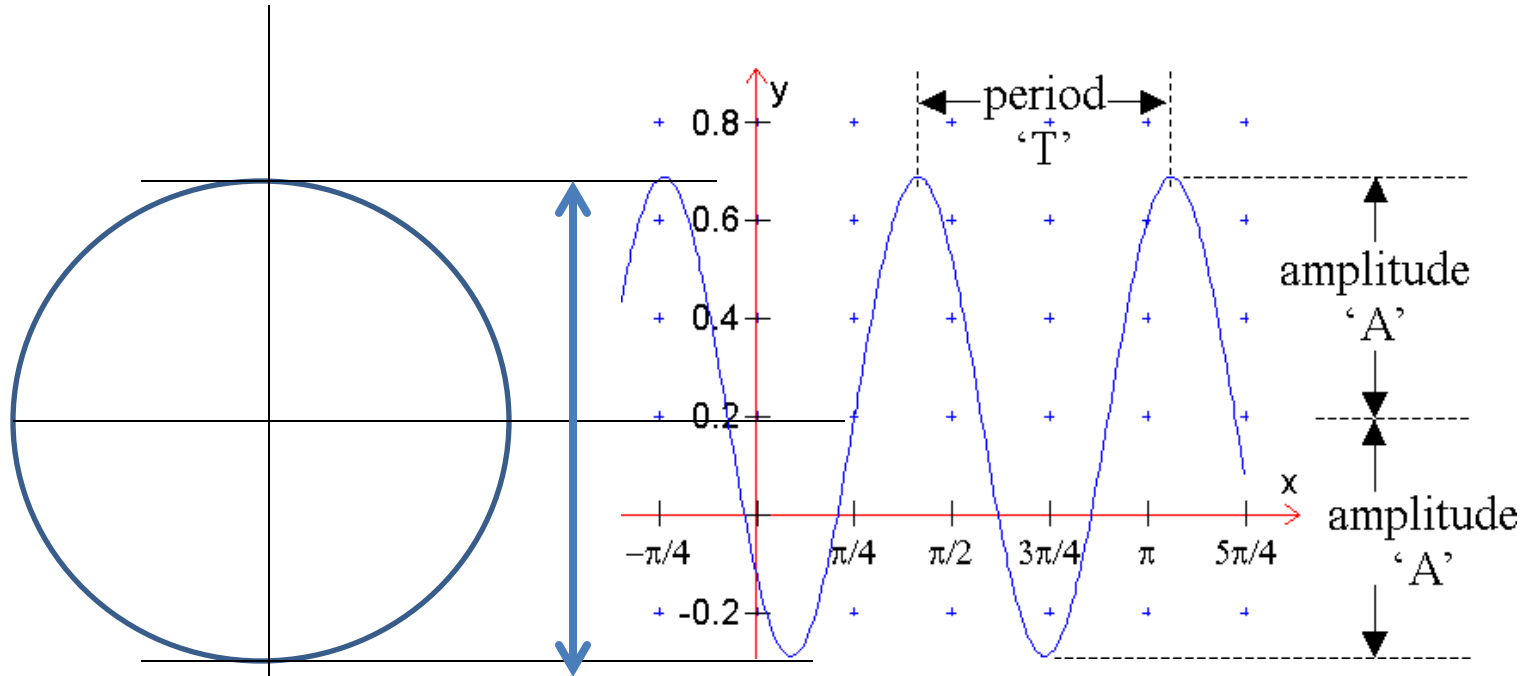
1.5. Faza- ϕ

$$\omega T = 2\pi$$

$$\omega = 2\pi\nu$$

C2. Oscilatii si unde

Miscarea oscilatorie este proiectia unei miscari circulare!



C2. Oscilatii si unde

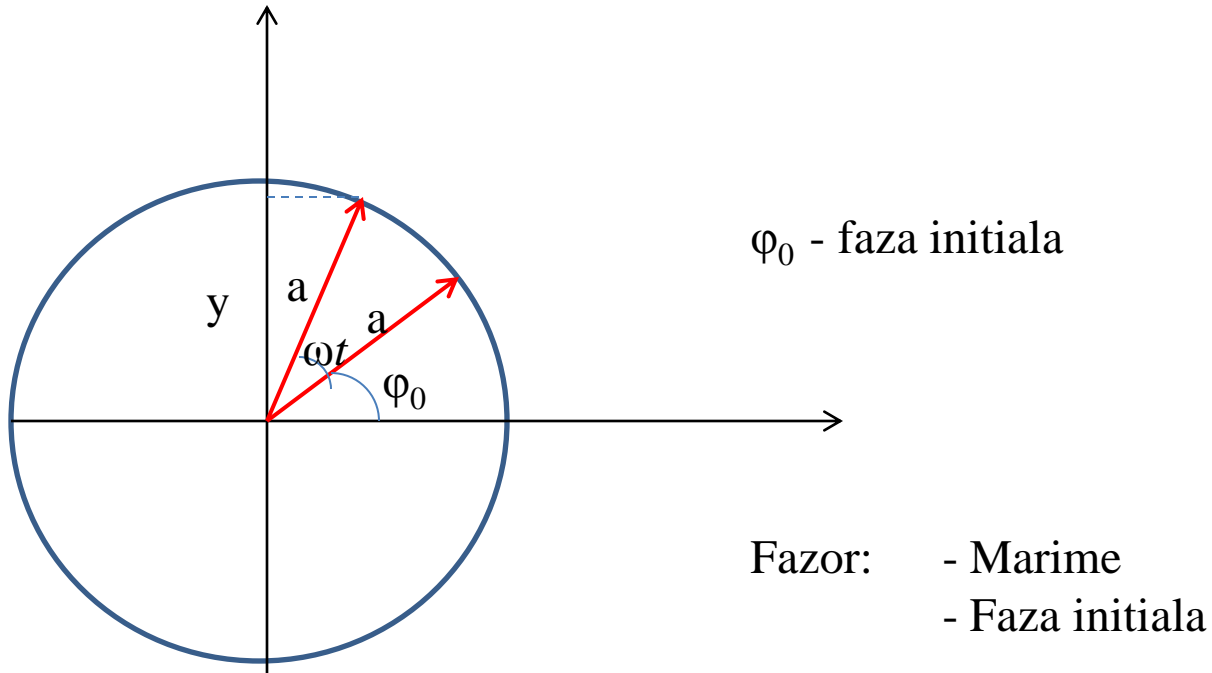
Reprezentari ale oscilatiei armonice

1. Reprezentarea fazoriala	2. Reprezentarea analitica reala	3. Reprezentarea grafica	4. Reprezentarea analitica complexa

C2. Oscilatii si unde

Reprezentari ale oscilatiei armonice

1. Reprezentarea fazoriala



C2. Oscilatii si unde

Reprezentari ale oscilatiei armonice

2. Reprezentarea analitica reala

$$y_{(t)}^{(r)} = a \sin(\omega t + \varphi_0)$$

$$\omega = 2\pi\nu = \frac{2\pi}{T}$$

$$\omega t + \varphi_0 =$$

$$\varphi_0 =$$

t	0	T/12	T/8	T/6	T/4	T/2	3T/4	T
ωt	0	$\pi/6$	$\pi/4$	$\pi/3$	$\pi/2$	π	$3\pi/2$	2π
sin	0	0.5	0.7	0.86	1	0	-1	0

C2. Oscilatii si unde

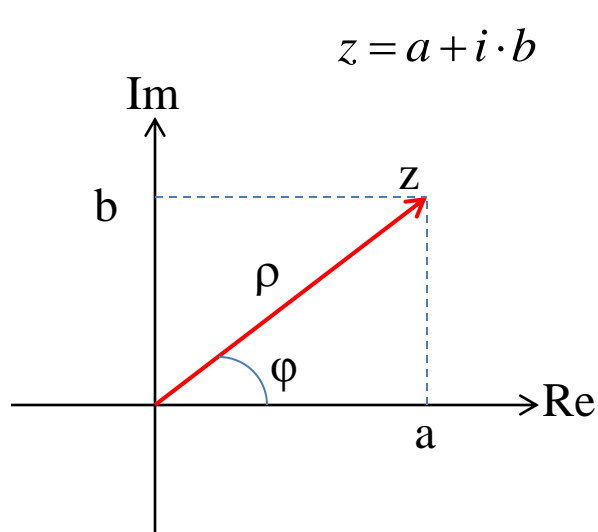
Reprezentari ale oscilatiei armonice

3. **Reprezentarea grafica**

C2. Oscilatii si unde

Reprezentari ale oscilatiei armonice

4. Reprezentarea analitica complexa



$$|z| = \rho = \sqrt{a^2 + b^2}$$

Formula lui Euler

$$e^{i\varphi} = \cos \varphi + i \cdot \sin \varphi$$

$$\left. \begin{aligned} y_{(t)}^{(r)} &= a \cos(\omega t + \varphi_0) \\ y_{(t)}^{(i)} &= a \sin(\omega t + \varphi_0) \end{aligned} \right\} \boxed{y_{(t)} = a \cdot e^{i \cdot (\omega t + \varphi_0)}}$$

C2. Oscilatii si unde

Compunerea a doua oscilatii armonice de **aceeasi frecventa** si **amplitudini egale**

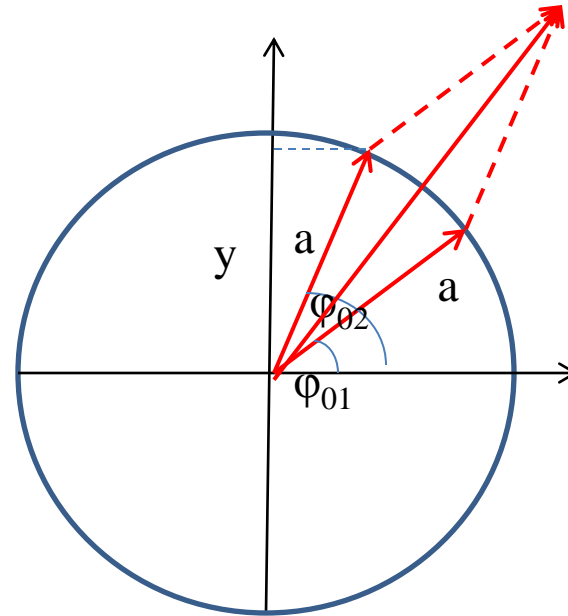
$$y_{(t)} = y_{1(t)} + y_{2(t)} = a \sin(\omega t + \varphi_{01}) + a \sin(\omega t + \varphi_{02}) = A \sin(\omega t + \varphi_0)$$

Compunerea fazoriala

$$y_{(t)} = A \sin(\omega t + \varphi_0)$$

$$A = 2a \cos\left(\frac{\Delta\varphi}{2}\right)$$

$$\varphi_0 = \frac{\varphi_{01} + \varphi_{02}}{2}$$



C2. Oscilatii si unde

Compunerea a doua oscilatii armonice de aceeasi frecventa si
amplitudini egale

Compunerea analitica

$$y_{(t)} = a \sin(\omega t + \varphi_{01}) + a \sin(\omega t + \varphi_{02}) =$$
$$y_{(t)} = \underbrace{2a \cos \frac{\Delta\varphi}{2}} \cdot \sin\left(\omega t + \underbrace{\frac{\varphi_{01} + \varphi_{02}}{2}}\right) =$$

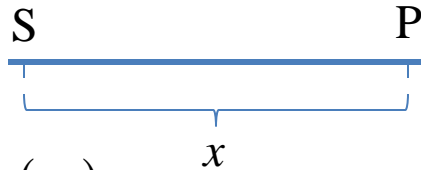
Cazuri particulare: $A = 2a$, daca $\frac{\Delta\varphi}{2} = 0$ oscilatii **in faza**

$A = 0$, daca $\frac{\Delta\varphi}{2} = \frac{\pi}{2}$ oscilatii **in opozitie**

C2. Oscilatii si unde

Unde armonice (monocromatice)

Unda...



$$y_{(t)} = a \sin(\omega t)$$

$$y_{P(t)} = a \cdot \sin \omega \left(t - \frac{x}{v} \right) =$$

$$y_{(x,t)} = a \cdot \sin(\omega t - kx) =$$

Deosebirea intre ecuatia undei si ecuatia oscilatiei...

C2. Oscilatii si unde

Unde armonice (monocromatice)

In 3D cele mai simple unde sunt:

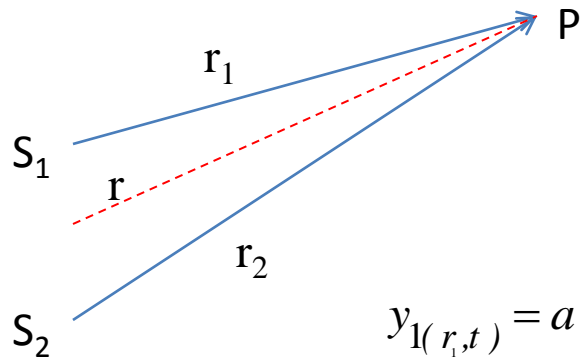
- Unda plana $y_{P(t)} = a \cdot \sin(\omega t - \vec{k} \cdot \vec{r})$

- Unda sferica $y_{P(t)} = \frac{a}{r} \cdot \sin(\omega t - kr)$

C2. Oscilatii si unde

Interferenta undelor

Interferenta a doua unde monocromatice, de **aceeasi amplitudine** si de **frecvente egale**



Sursele sunt coerente...

Caz particular: $\Delta\phi=0$...(in faza).

$$y_{1(r_1,t)} = a \cdot \sin(\omega t - kr_1)$$

$$y_{2(r_2,t)} = a \cdot \sin(\omega t - kr_2)$$

$$y_{P(t)} = y_{1(r_1,t)} + y_{2(r_1,t)}$$

$$y_{P(t)} = 2a \cos\left(\frac{k\Delta r}{2}\right) \cdot \sin(\omega t - k\bar{r})$$

C2. Oscilatii si unde

Interferenta undelor

Interferenta a doua unde monocromatice, de **aceeasi amplitudine** si de **frecvente egale**

$$y_{P(t)} = 2a \cos\left(\frac{k\Delta r}{2}\right) \cdot \sin(\omega t - k\bar{r})$$

Discutie: In optica $\omega = 10^{15} \text{ s}^{-1}$

Miscarea de oscilatie nu poate fi urmarita!

Ochiul nu poate vedea decat **intensitatea!!**

$$I = A^2 = 4a^2 \cos^2\left(\frac{k\Delta r}{2}\right)$$

$$I = 4a^2 \cos^2\left(\frac{\pi\Delta r}{\lambda}\right)$$

Toti detectorii optici sunt patratici
(detecteaza doar **intensitatea!!**)

C2. Oscilatii si unde

Interferenta undelor

Interferenta a doua unde monocromatice, de **aceeasi amplitudine** si de **frecvente egale**

$$I = 4a^2 \cos^2\left(\frac{\pi\Delta r}{\lambda}\right)$$

Cazuri particulare: $I_M = 4a^2 = 4I_1$ Daca $\frac{\pi\Delta r}{\lambda} = n\pi \Rightarrow \Delta r = n\lambda$

$I_m = 0$ Daca $\frac{\pi\Delta r}{\lambda} = (2n+1)\frac{\pi}{2} \Rightarrow \Delta r = (2n+1)\frac{\lambda}{2}$

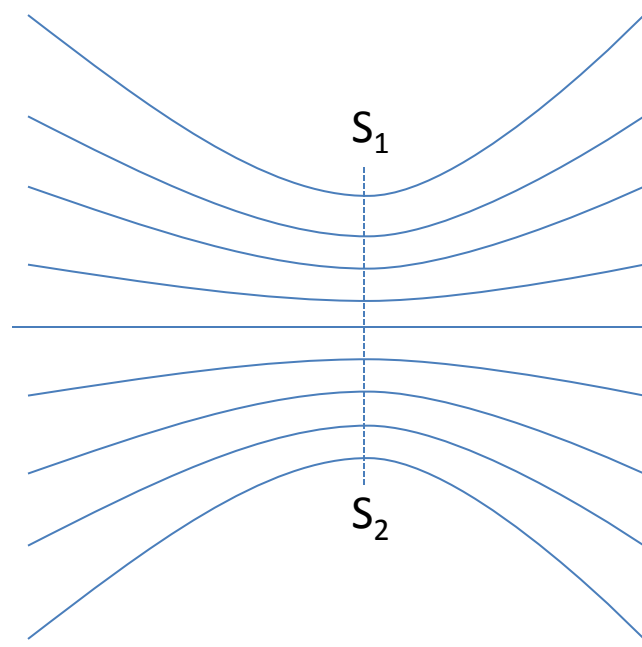
C2. Oscilatii si unde

Interferenta undelor

Interferenta a doua unde monocromatice, de **aceeasi amplitudine** si de **frecvente egale**

$$I = 4a^2 \cos^2\left(\frac{\pi\Delta r}{\lambda}\right)$$

$r = r_2 - r_1 = \text{ct hiperbola}$

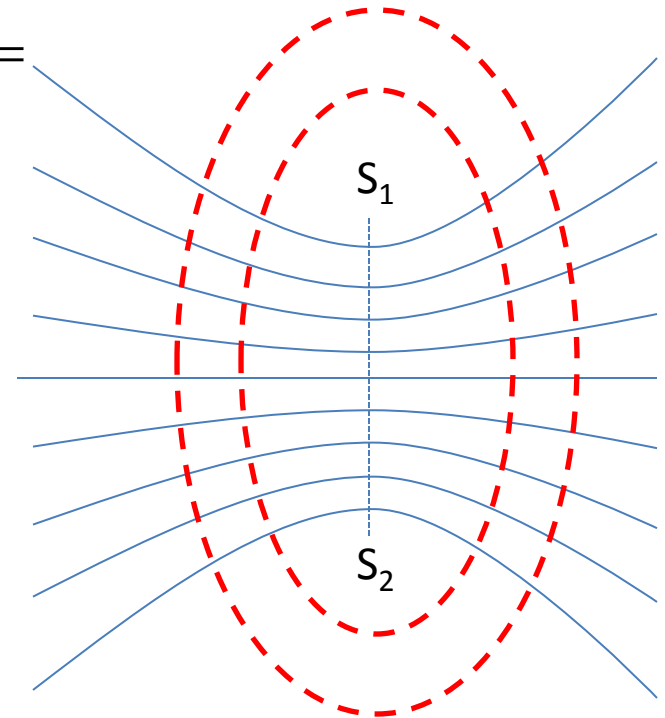


Imaginea de interferenta este formata din hiperboloizi confocali cu focarele in S_1 si S_2 !!!

C3. Interferenta undelor

Interferenta a doua unde **sferice** (de aceeasi frecventa)

$$\begin{aligned}y &= y_1 + y_2 = \frac{a}{r} e^{i(\omega t - kr_1)} + \frac{a}{r} e^{i(\omega t - kr_2)} = \\&= \frac{a}{r} e^{i\omega t} \left(e^{-ikr_1} + e^{-ikr_2} \right) = \\&= 2 \frac{a}{r} \cos\left(k \frac{\Delta r}{2}\right) e^{i\left(\omega t - k \frac{\bar{r}}{2}\right)} \\I &= 4 \frac{a^2}{r^2} \cos^2\left(k \frac{\Delta r}{2}\right)\end{aligned}$$



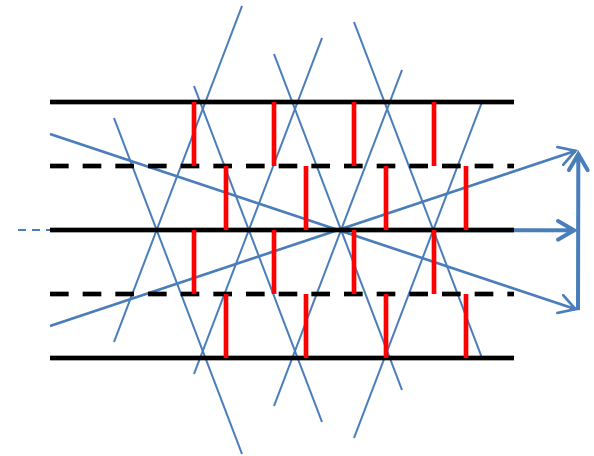
Suprafetele de **egala intensitate** sunt hiperboloizi de rotatie : $\Delta r = r_2 - r_1 = ct$
hiperbola

Suprafetele de **egala faza** (fronturile undei rezultante) sunt elipsoizi $\bar{r} = \frac{r_1 + r_2}{2} = ct$
de rotatie cu focarele in surse

C3. Interferenta undelor

Interferenta a doua unde **plane** (de aceeasi frecventa)

$$\begin{aligned}
 y &= y_1 + y_2 = ae^{i(\omega t - \vec{k}_1 \cdot \vec{r})} + ae^{i(\omega t - \vec{k}_2 \cdot \vec{r})} = \\
 &= ae^{i\omega t} e^{-i\frac{\vec{k}_1 + \vec{k}_2}{2} \cdot \vec{r}} \left(e^{-i\frac{\vec{k}_1 - \vec{k}_2}{2} \cdot \vec{r}} + e^{i\frac{\vec{k}_1 - \vec{k}_2}{2} \cdot \vec{r}} \right) = \\
 &= 2a \cos\left(\frac{\Delta\vec{k}}{2} \cdot \vec{r}\right) e^{-i(\omega t + \vec{k} \cdot \vec{r})} = \\
 I &= 4a^2 \cos^2\left(\frac{\Delta\vec{k}}{2} \cdot \vec{r}\right)
 \end{aligned}$$



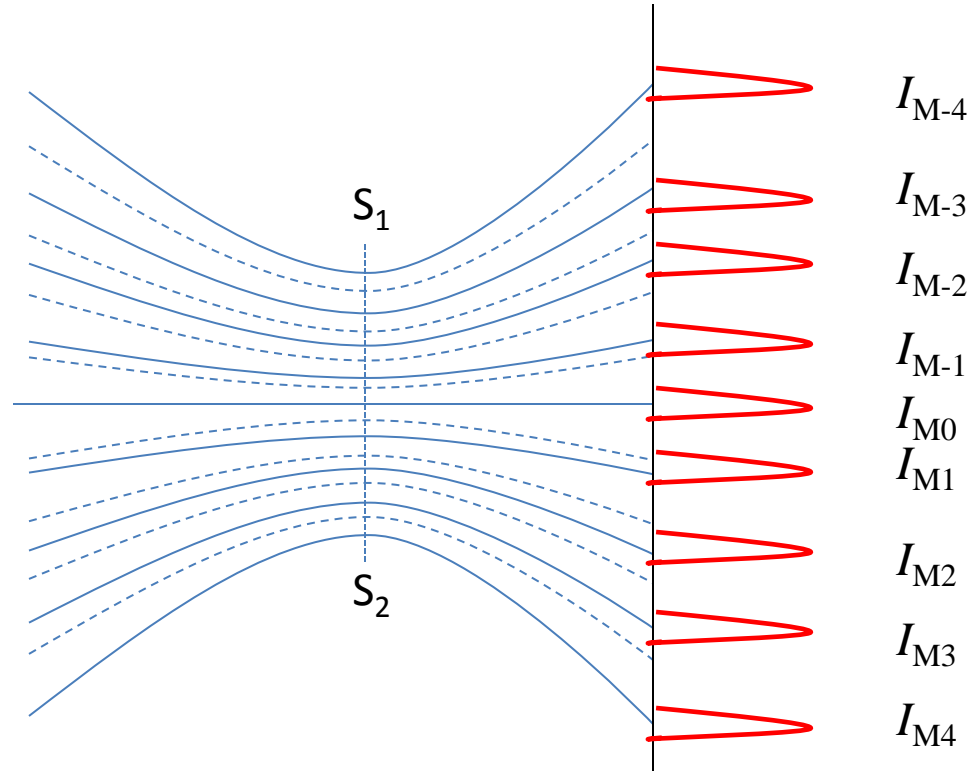
Suprafetele de **egala intensitate** sunt plane perpendiculare pe Δk $\Delta\vec{k} \cdot \vec{r} = ct$

Suprafetele de **egala faza** (fronturile undei rezultante) sunt plane perpendiculare pe k . $\vec{k} \cdot \vec{r} = ct$

C3. Interferenta undelor

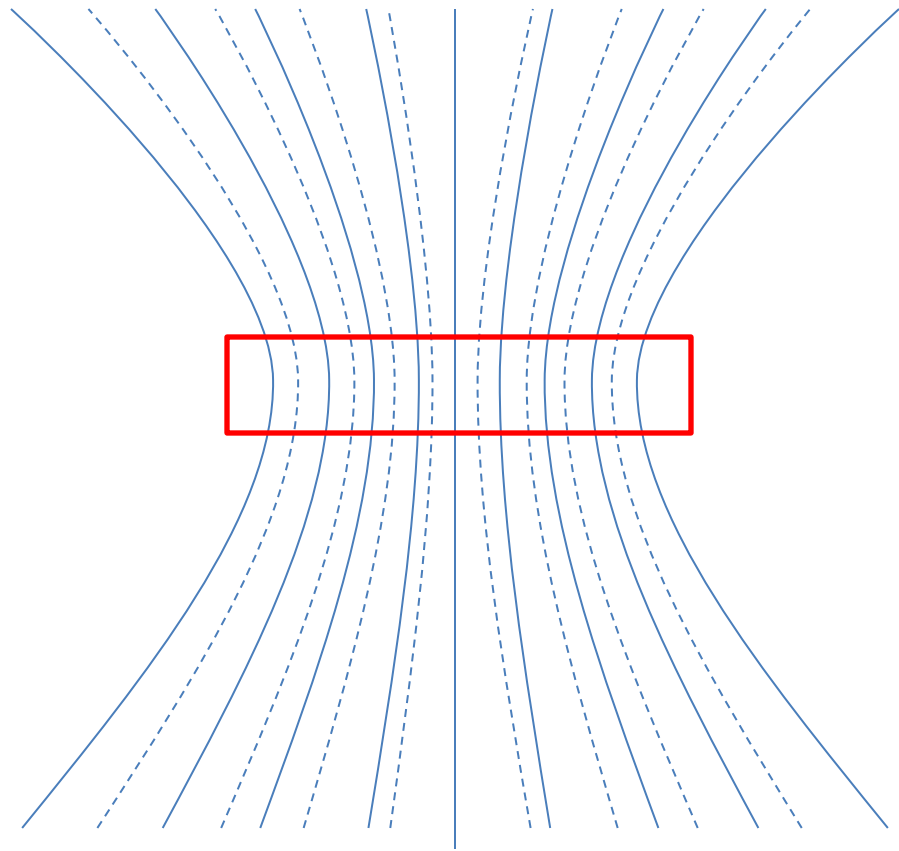
Interferenta a doua unde **sferice** (de aceeasi frecventa)

$$I = 4 \frac{a^2}{r^2} \cos^2 \left(k \frac{\Delta r}{2} \right)$$



Suprafetele de **egala intensitate** sunt hiperboloizi de rotatie : $\Delta r = r_2 - r_1 = ct$
hiperbola

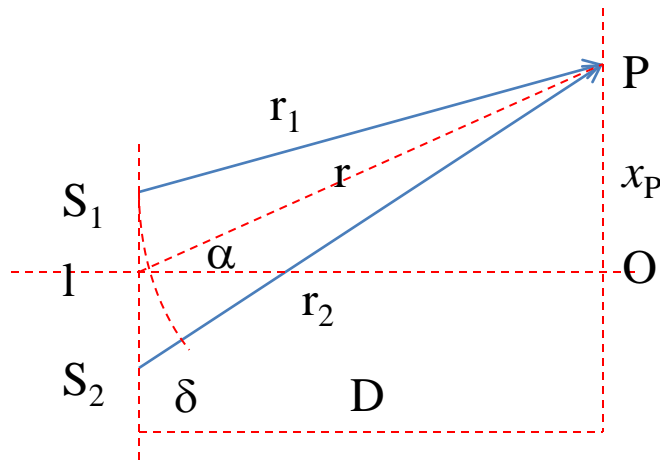
Pe ecran se obtin franje de interferenta (maxime)!



C3. Interferenta undelor

Diferenta de drum

$$\delta = r_2 - r_1 = l \sin \alpha \approx l \cdot \operatorname{tg} \alpha = l \cdot \frac{x_P}{D}$$



Pozitia maximelor: $x_P = \frac{\delta \cdot D}{l}$

$$\delta = n\lambda = 2n \frac{\lambda}{2} \Rightarrow x_P = \frac{n\lambda \cdot D}{l} = \text{maxim}$$

$$\delta = (2n+1) \frac{\lambda}{2} \Rightarrow x_P = \frac{(2n+1) \frac{\lambda}{2} \cdot D}{l} = \text{minim}$$

Distanta dintre doua maxime :

$$i = \frac{\lambda \cdot D}{l}$$

interfranja

$$I = 4a^2 \cos^2 \left(\frac{\pi l x}{\lambda D} \right)$$

C3. Interferenta undelor

Interferenta a doua unde de amplitudini diferite

$$I = \langle E_1^2 + E_2^2 + 2\vec{E}_1 \cdot \vec{E}_2 \rangle =$$

$$I = I_1 + I_2 + I_{12}$$

I_{12} este termenul interferential (interference term):

$$I_{12} = 2\sqrt{I_1 I_2} \cos(\Delta\varphi)$$

$$I_{MAX} = I_1 + I_2 + 2\sqrt{I_1 I_2}$$

$$I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$$

Visibility (contrast factor):
$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

C3. Interferenta undelor

Conditia de indepartare (distanța dintre surse): $\delta < \frac{\lambda}{2}$

$$\frac{\delta}{l} = \frac{x}{D} \Rightarrow D = \frac{x}{\delta} l > \frac{2xl}{\lambda}$$

Distanța dintre surse trebuie să fie foarte mică!

COERENTA:

- Condiția necesară pentru producerea interferenței este existența unui defazaj constant între cele două unde.

$$\Delta\varphi = \text{constant.}$$

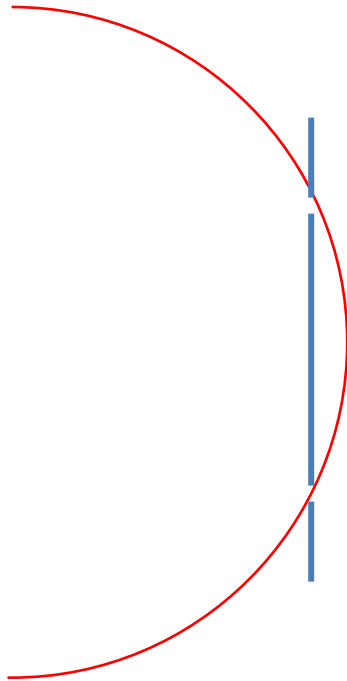
-Obținerea a două surse coerente:

- divizarea frontului de undă,
- divizarea amplitudinii.

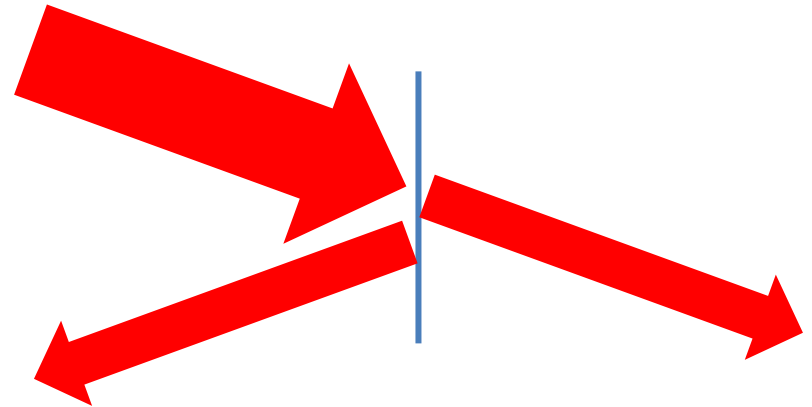
C5. Dispozitive interferentiale

Obtinerea a doua surse coerente:

- divizarea frontului de unda,



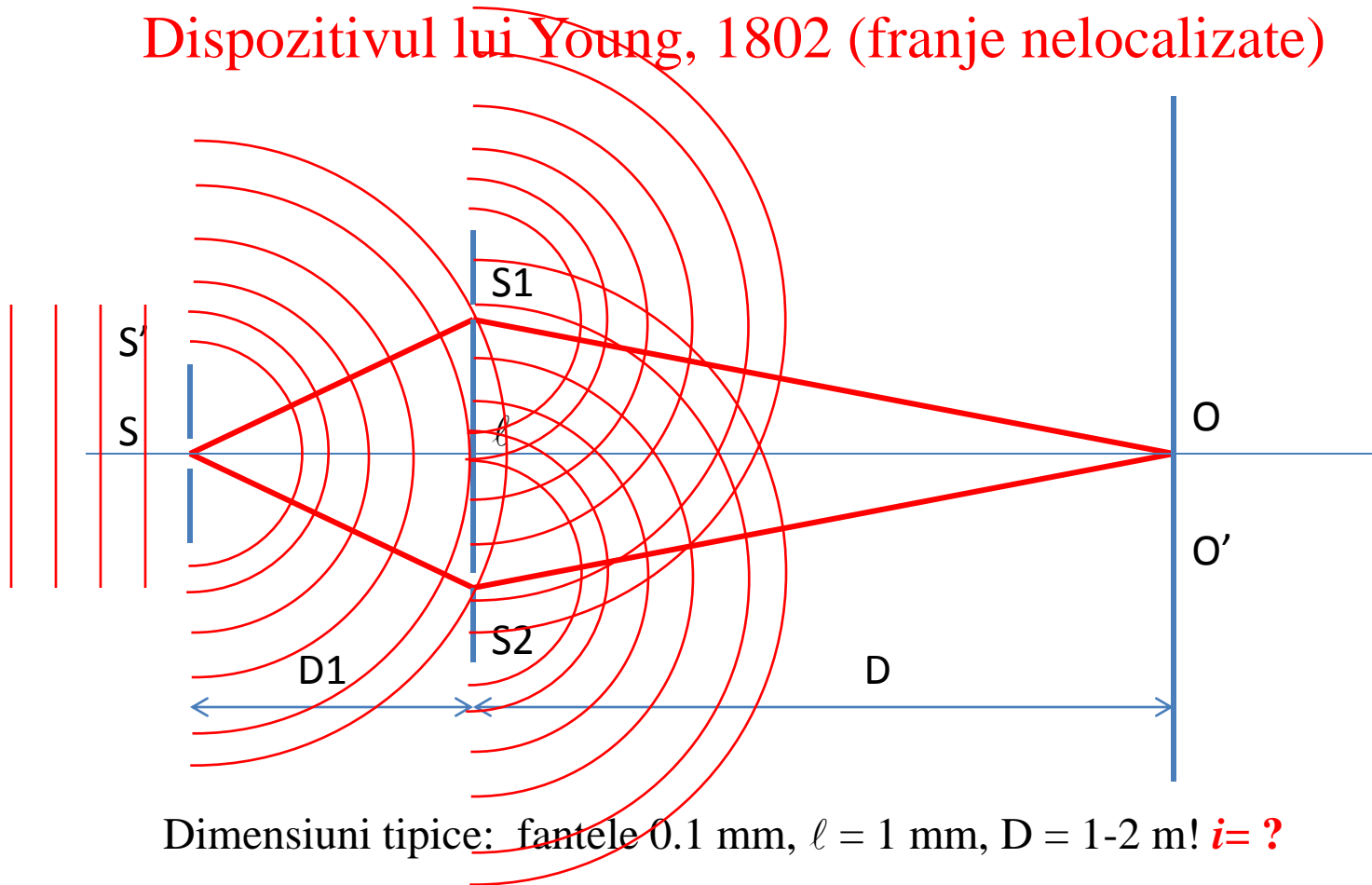
- divizarea amplitudinii.



C5. Dispozitive interferentiale

1. Divizarea frontului de unda

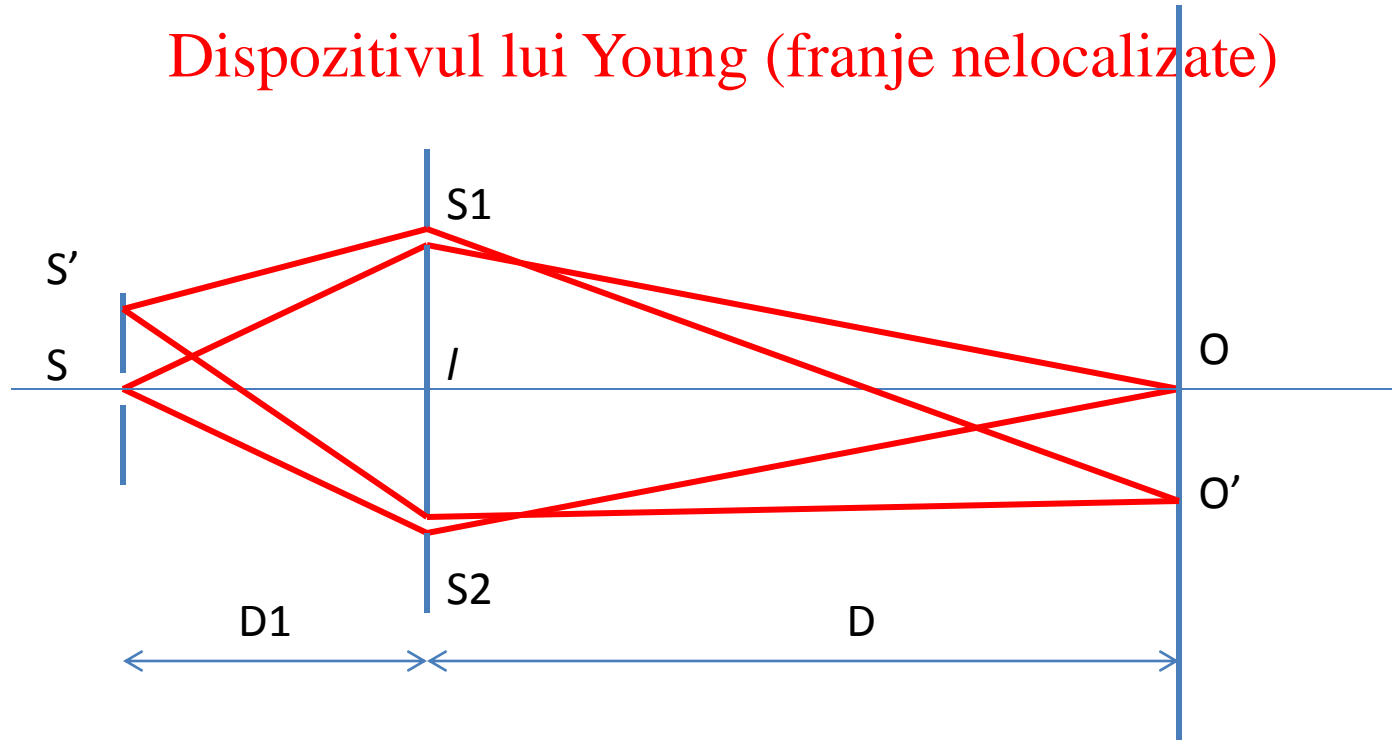
Dispozitivul lui Young, 1802 (franje nelocalizate)



C5. Dispozitive interferentiale

1. Divizarea frontului de unda

Dispozitivul lui Young (franje nelocalizate)



$$\delta_1 = l \cdot \sin \beta \approx l \cdot \operatorname{tg} \beta = l \frac{x_{S'}}{D_1}$$

$$\delta = l \cdot \sin \alpha \approx l \cdot \operatorname{tg} \alpha = l \frac{x_{O'}}{D}$$

$$\delta_{total} = \delta_1 + \delta = 2n \frac{\lambda}{2} = 0 \Rightarrow$$

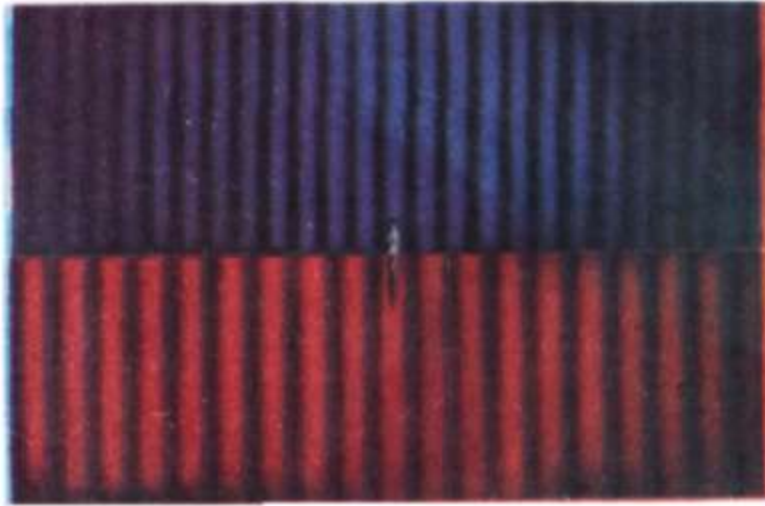
$$\delta_1 + \delta = 0 \Rightarrow$$

$$x_{O'} = \frac{D}{D_1} \cdot x_{S'}$$

Daca sursa se deplaseaza lateral fata de axa de simetrie, pozitia maximului central se deplaseaza in sens opus!

C5. Dispozitive interferentiale

Dispozitivul lui Young (divizarea frontului de unda)



Franjele: - paralele
- echidistante,
- nelocalizate

- Imaginea este foarte slaba si greu de vazut.
- Franjele se pot observa cu lupa!

Pentru a avea franje nete trebuie ca izvoarele de lumina sa fie cat mai mici (punctiforme $\ll \lambda$) \Rightarrow

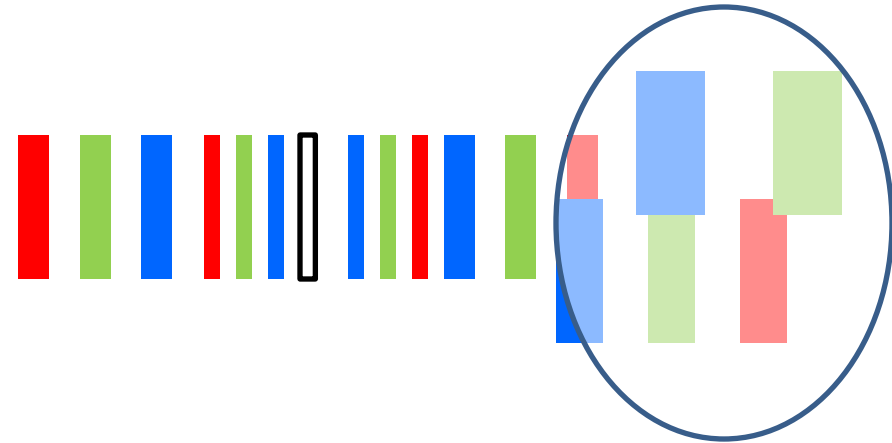
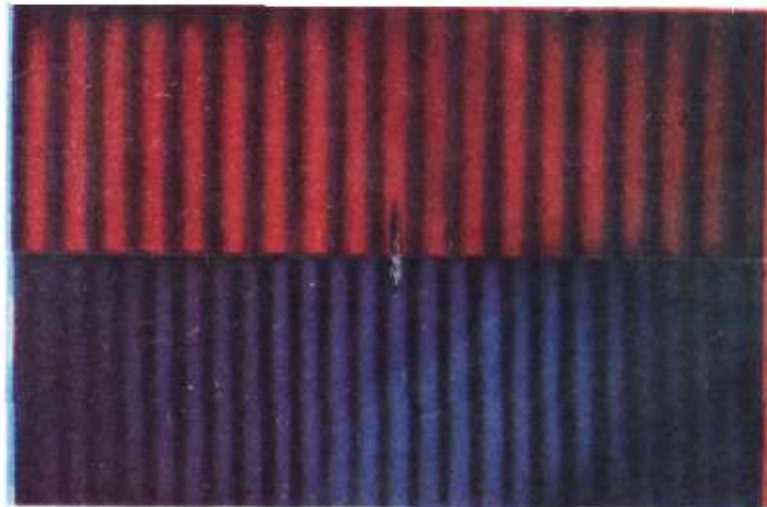
- Intensitati luminoase foarte mici.
- Difractie!

Se face un compromis intre **vizibilitate** si **claritate** utilizand fante *largi*.

C5. Dispozitive interferentiale

Dispozitivul lui Young (divizarea frontului de unda)

Interferenta in lumina alba:

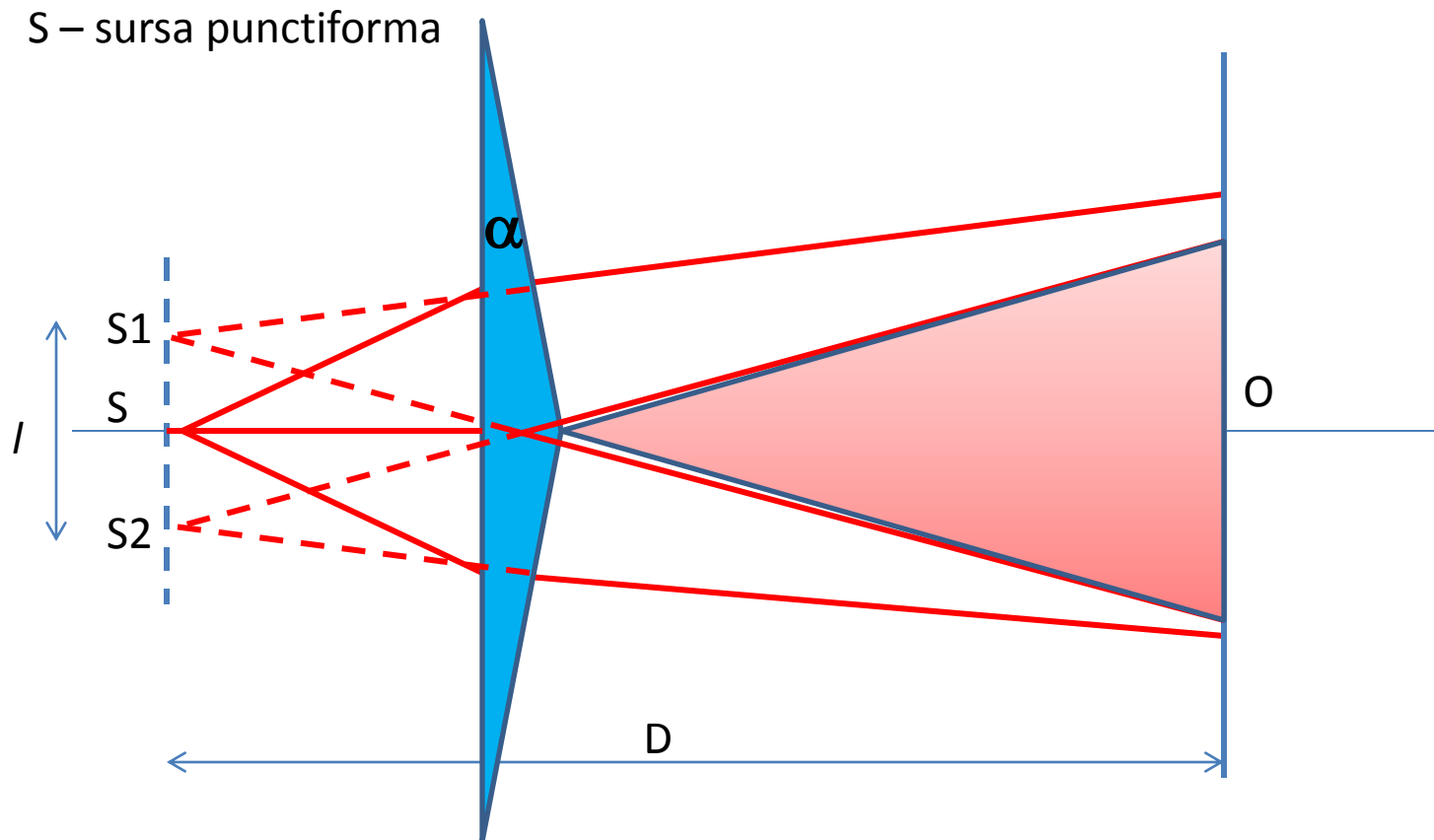


Alb de ordin superior

C5. Dispozitive interferentiale

1. Divizarea frontului de unda

Biprisma Fresnel (franje nelocalizate)



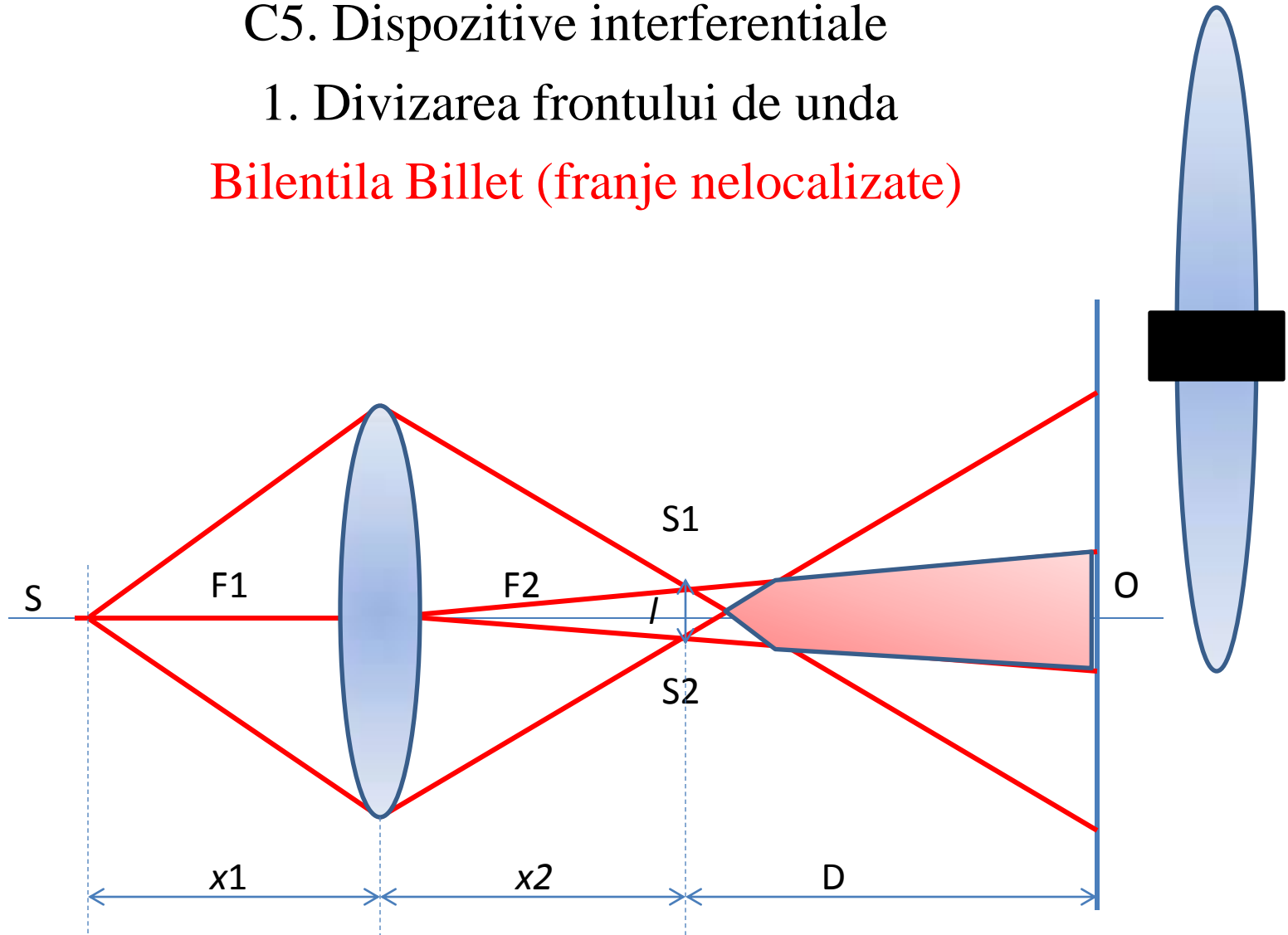
S_1 si S_2 sunt surse virtuale! Prisma are un unghi foarte mic ~ 1 grad.

Deviație minima: $\delta = \alpha(n-1) \Rightarrow \ell = 2d\alpha(n-1)$

C5. Dispozitive interferentiale

1. Divizarea frontului de unda

Bilenta Billet (franje nelocalizate)

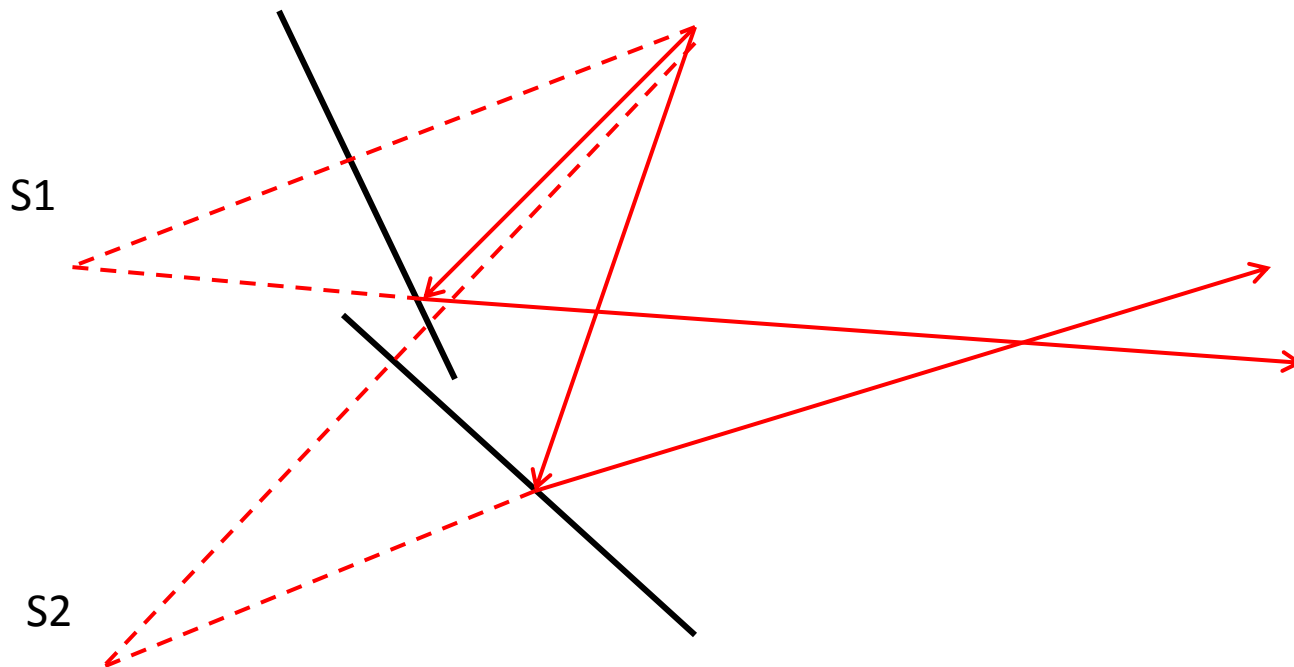


S_1 si S_2 sunt surse reale!

C6. Dispozitive interferentiale

1. Divizarea frontului de unda

Oglinzile Fresnel (franje nelocalizate)

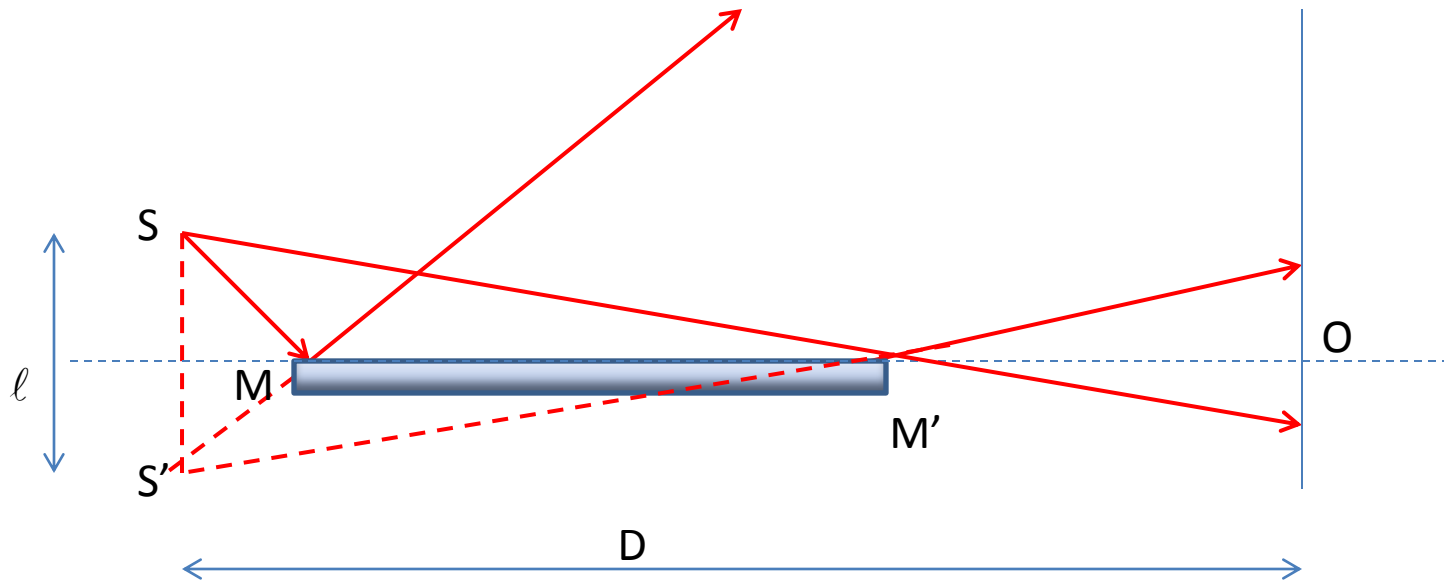


S1 si S2 sunt surse virtuale! Oglinzile fac intre ele un unghi foarte mic ~ 1 grad.

C6. Dispozitive interferentiale

1. Divizarea frontului de unda

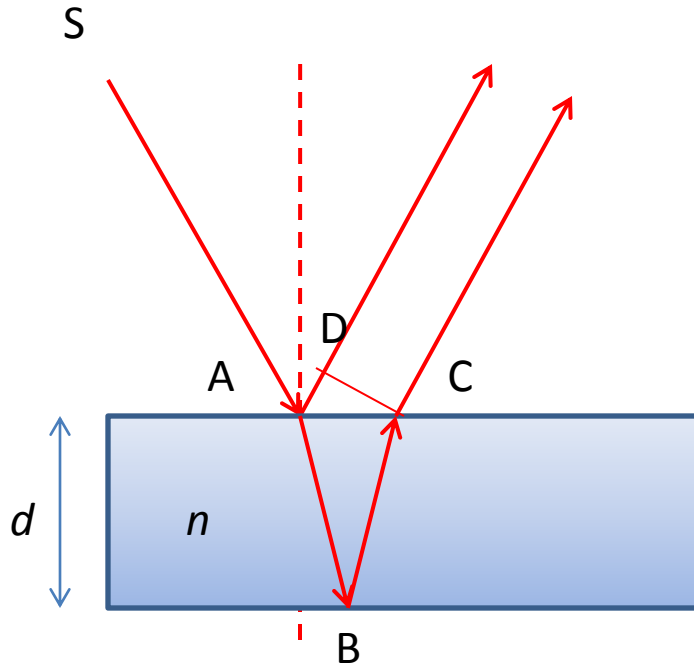
Oglinda Lloyd (franje nelocalizate)



Ecran = M' \Rightarrow O = maxim sau minin?

C6. Dispozitive interferentiale

2. Divizarea amplitudinii



$$\delta = (AB) + (BC) - \left(AD - \frac{\lambda}{2} \right)$$

$$\delta = 2nd \cdot \cos r + \frac{\lambda}{2}$$

$$\delta = 2nd + \frac{\lambda}{2}$$

$$\delta = 2nd \cdot \cos r + \frac{\lambda}{2} = k\lambda \quad \Rightarrow \text{maxime}$$

1. $\lambda, d = \text{ct}$

$r = \text{variabil}(i)$

franje de egala INCLINARE! (Haidinger)

2. $\lambda, r = \text{ct}$

$d = \text{variabil}$

franje de egala GROSIME!

3. $d, r = \text{ct}$

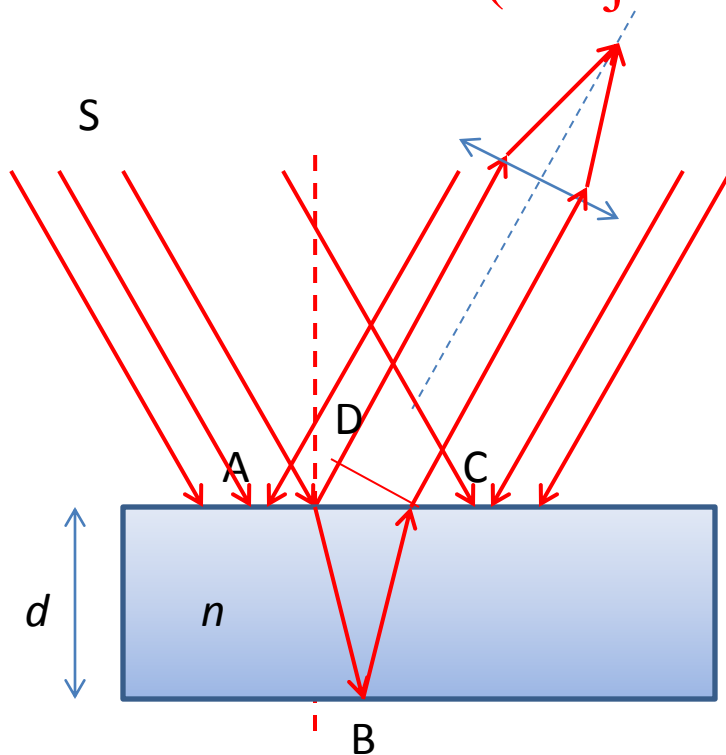
$\lambda = \text{variabil}$

franje CANELATE!

C6. Dispozitive interferentiale

2. Divizarea amplitudinii

Interferenta pe lame (pelicule dielectrice) (franje localizate la infinit)



$$\delta = (AB) + (BC) - \left(AD - \frac{\lambda}{2} \right)$$

$$\delta = 2nd \cdot \cos r + \frac{\lambda}{2}$$

$$\delta = 2nd + \frac{\lambda}{2}$$

Surse intinse

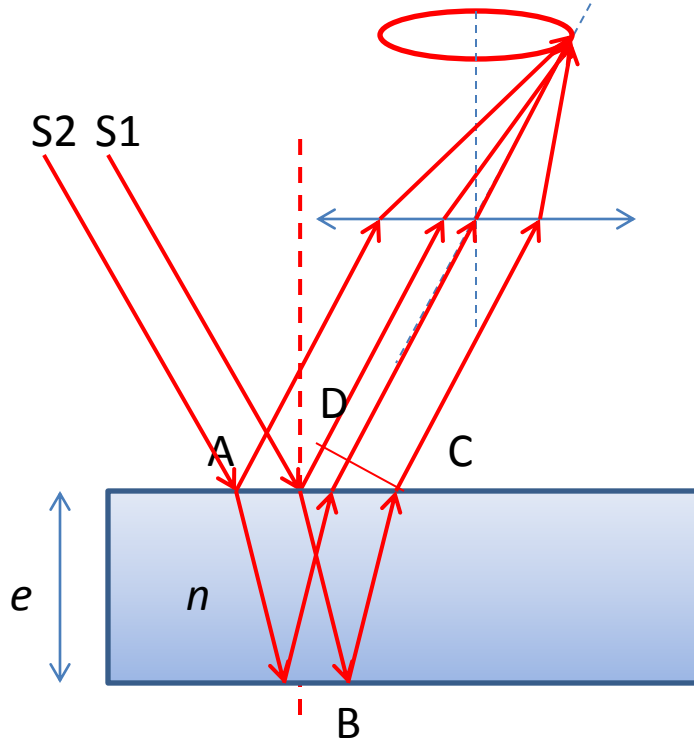
Toate razele incidente la acelasi unghi fata de normala vor forma in planul focal al lentilei un..... CERC! (inel)

Imaginea de interferenta este formata din inele de egala INCLINARE! (Haidinger) localizate la infinit.

C6. Dispozitive interferentiale

2. Divizarea amplitudinii

Interferenta pe lame (pelicule dielectrice) (franje localizate la infinit)



$$\delta = (AB) + (BC) - \left(AD - \frac{\lambda}{2} \right)$$

$$\delta = 2ne \cdot \cos r + \frac{\lambda}{2}$$

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

Surse intinse

Toate razele incidente la acelasi unghi fata de normala vor forma in planul focal al lentilei un..... CERC! (inel)

Imaginea de interferenta este formata din inele de egala INCLINARE! (Haidinger) localizate la infinit.

C6. Dispozitive interferentiale

2. Divizarea amplitudinii

**Interferenta pe lame (pelicule dielectrice)
(franje localizate la infinit)**

$$\delta = 2nd \cdot \cos r + \frac{\lambda}{2}$$

$$\delta = 2nd + \frac{\lambda}{2}$$

Raza inelului de ordin k

$$\rho_k = f \cdot \operatorname{tgi} i_k \approx f \cdot i_k$$

In centru $i=0, r=0 \Rightarrow \delta_{k_1} = 2nd + \frac{\lambda}{2} = 2k_1 \frac{\lambda}{2}$ Inelul are ordinul maxim

Alt inel $i, r \Rightarrow \delta_{k_2} = 2d \sqrt{n^2 - \sin^2 i_{k_2}} + \frac{\lambda}{2} = 2k_2 \frac{\lambda}{2}$

$$\delta_{k_1} - \delta_{k_2} = \left(2nd + \frac{\lambda}{2} \right) - \left(2d \sqrt{n^2 - \sin^2 i_{k_2}} + \frac{\lambda}{2} \right) = 2(k_1 - k_2) \frac{\lambda}{2}$$

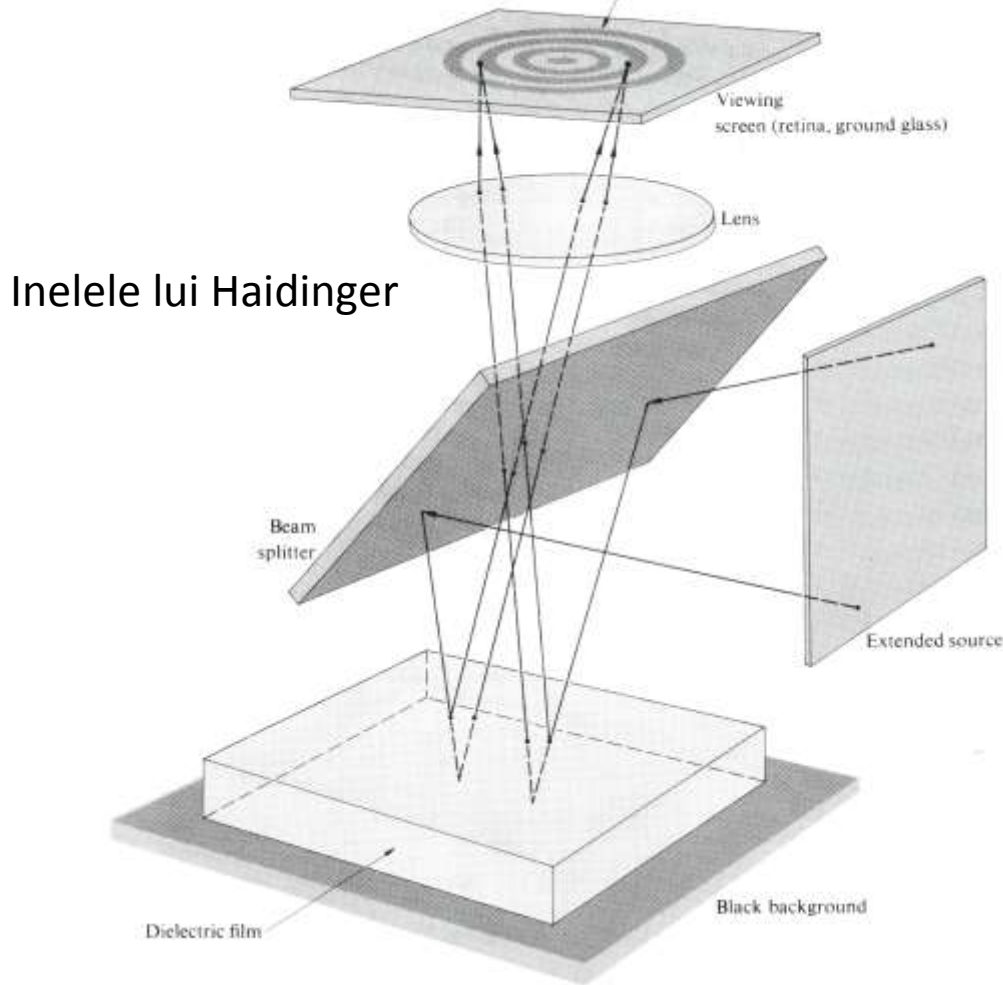
$$2nd - k\lambda = 2d \sqrt{n^2 - \sin^2 i_k}$$

$$4ndk\lambda = 4d^2 \sin^2 i_k \quad \rho_k = f \sqrt{k \frac{n\lambda}{d}} \quad \rho_k \propto \sqrt{k} \quad \text{Inelele se indeseasc spre margine}$$

$$\rho_k \propto \sqrt{\lambda} \quad \rho_{rosu} > \rho_{albastru}$$

C6. Dispozitive interferentiale

2. Divizarea amplitudinii



Interferenta pe lame
(pelicule dielectrice)
(franje localizate la infinit)

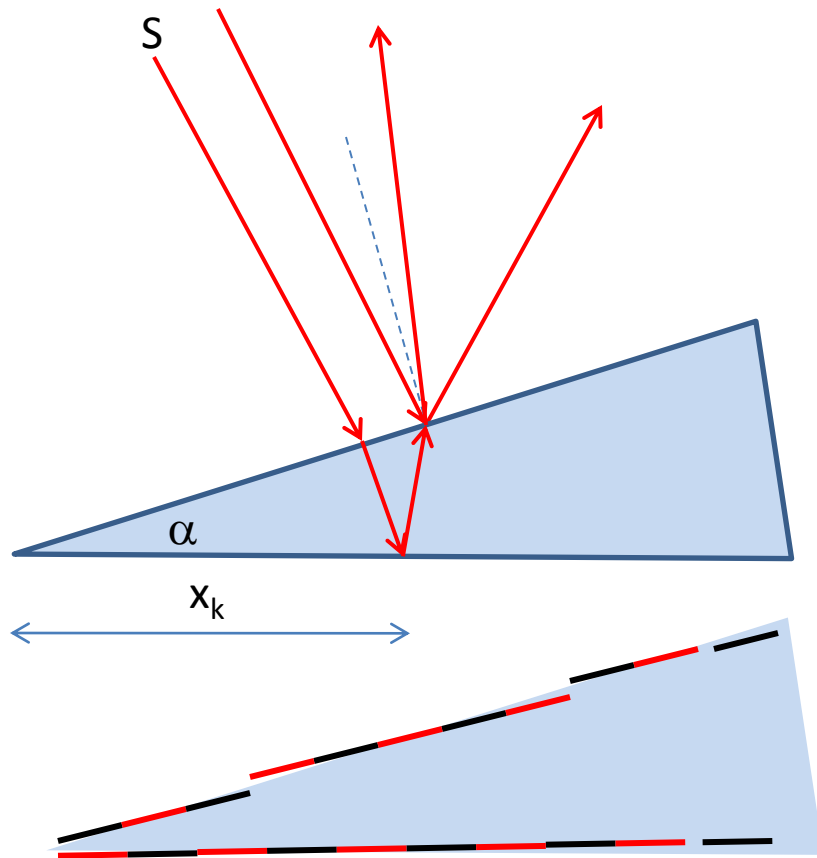
Imaginea este clara numai
daca lama are fete perfect
paralele.

Verificarea planeitatii!

C7. Dispozitive interferentiale

2. Divizarea amplitudinii

Interferenta pe pana (pelicule dielectrice) (franje de egala grosime, localizate)



$$\delta = 2nd + \frac{\lambda}{2} \begin{cases} = k\lambda = \text{maxim} \\ = (2k + 1)\frac{\lambda}{2} = \text{minim} \end{cases}$$

$$\delta = 2n\alpha \cdot x_k + \frac{\lambda}{2}$$

$$2n\alpha \cdot x_k + \frac{\lambda}{2} = k\lambda \Rightarrow i = \frac{\lambda}{2n\alpha}$$

Surse intinse

- Imaginea de interferenta este formata din
- franje paralele cu muchia penei,
- de aceeasi grosime ($i = ct$),
- localizate.

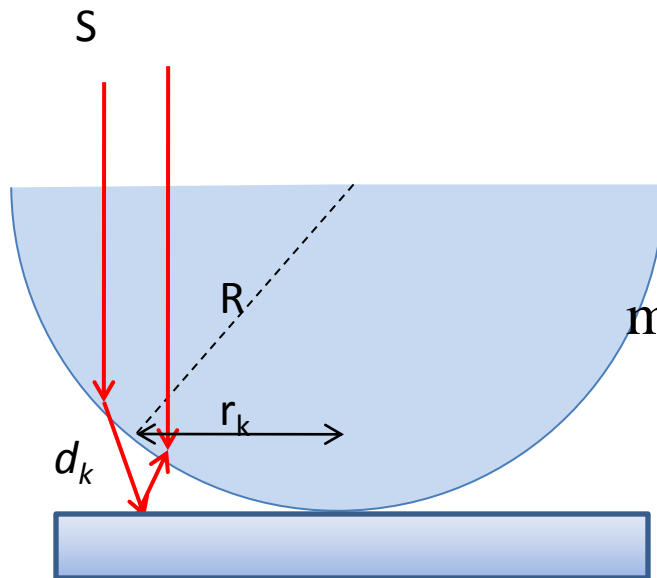
In varf ? $x_k = 0 \Rightarrow \delta = \dots$

C7. Dispozitive interferentiale

2. Divizarea amplitudinii

Inelele lui Newton

(inele de egala grosime, localizate)



$$R^2 = r_k^2 + (R - d_k)^2$$

$$r_k^2 = 2R \cdot d_k$$

$$\text{maxim } \delta = 2d_k + \frac{\lambda}{2} = k\lambda \quad r_k = \sqrt{(2k - 1) \frac{R\lambda}{2}}$$

$$\text{minim } \delta = 2d_k + \frac{\lambda}{2} = (2k + 1) \frac{\lambda}{2} \quad r_k = \sqrt{kR\lambda}$$

Surse intinse

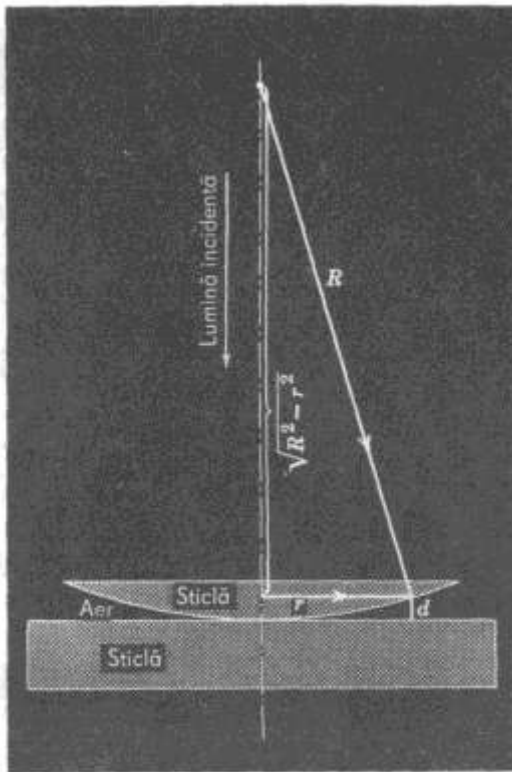
Imaginea de interferenta este formata din

- Inele concentrice,
- de aceeasi grosime ,
- localizate.

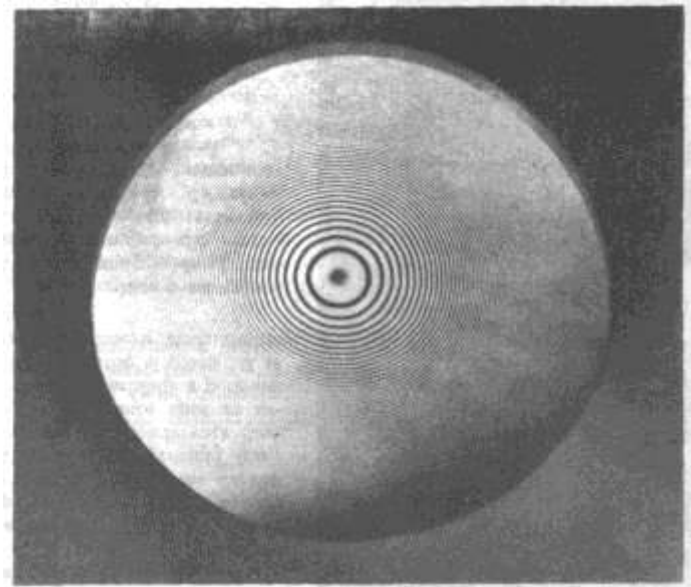
C7. Dispozitive interferentiale

2. Divizarea amplitudinii

Inelele lui Newton (inele de egala grosime, localizate)



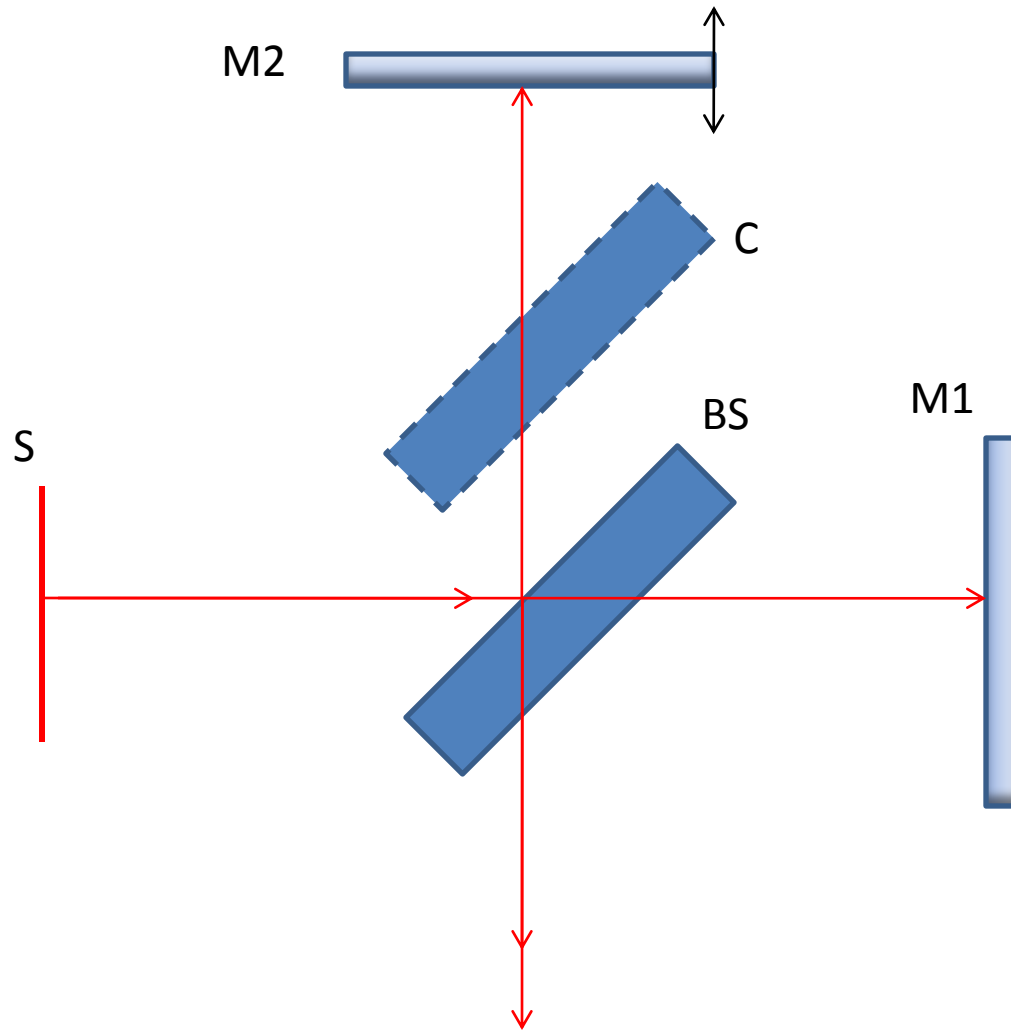
Inelele lui Newton



C7. Dispozitive interferentiale

Interferometrul Michelson

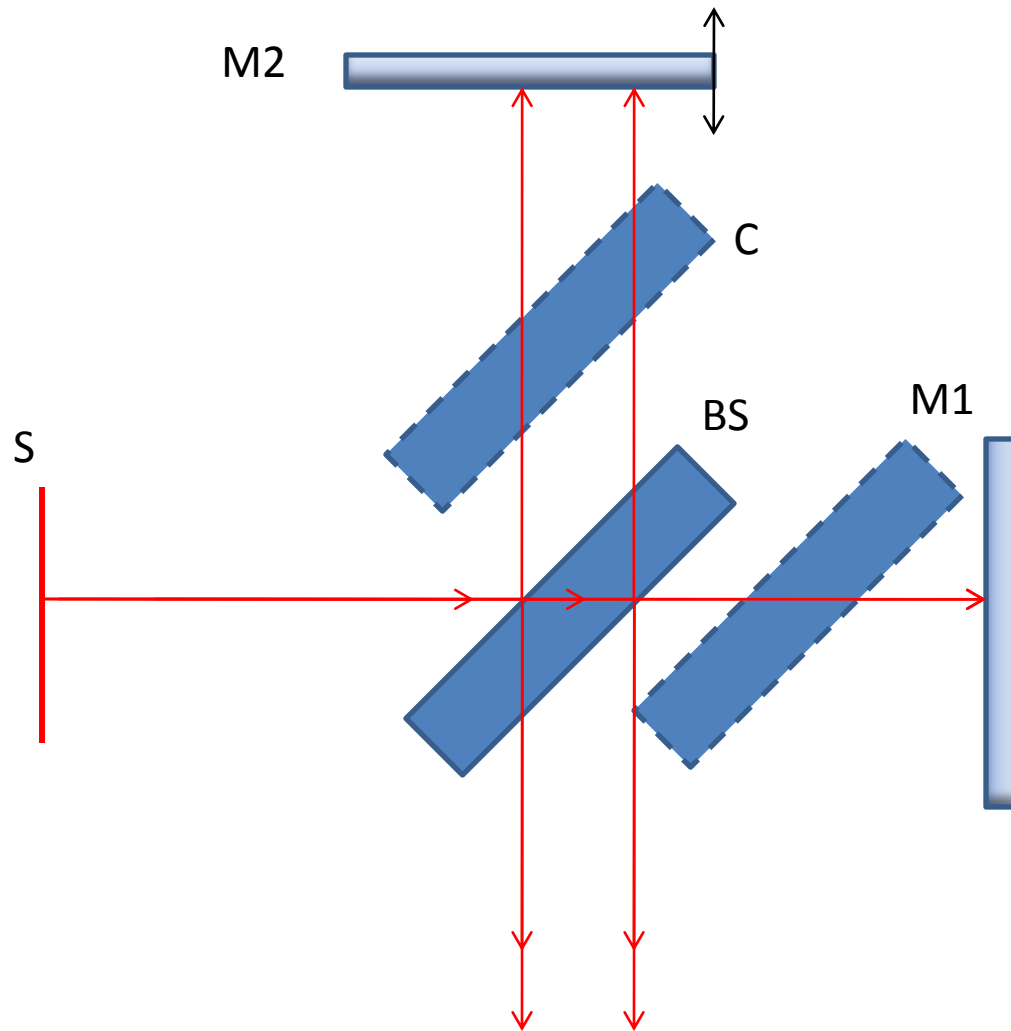
Albert Michelson 1881
rol important in dezvoltarea
fizicii moderne



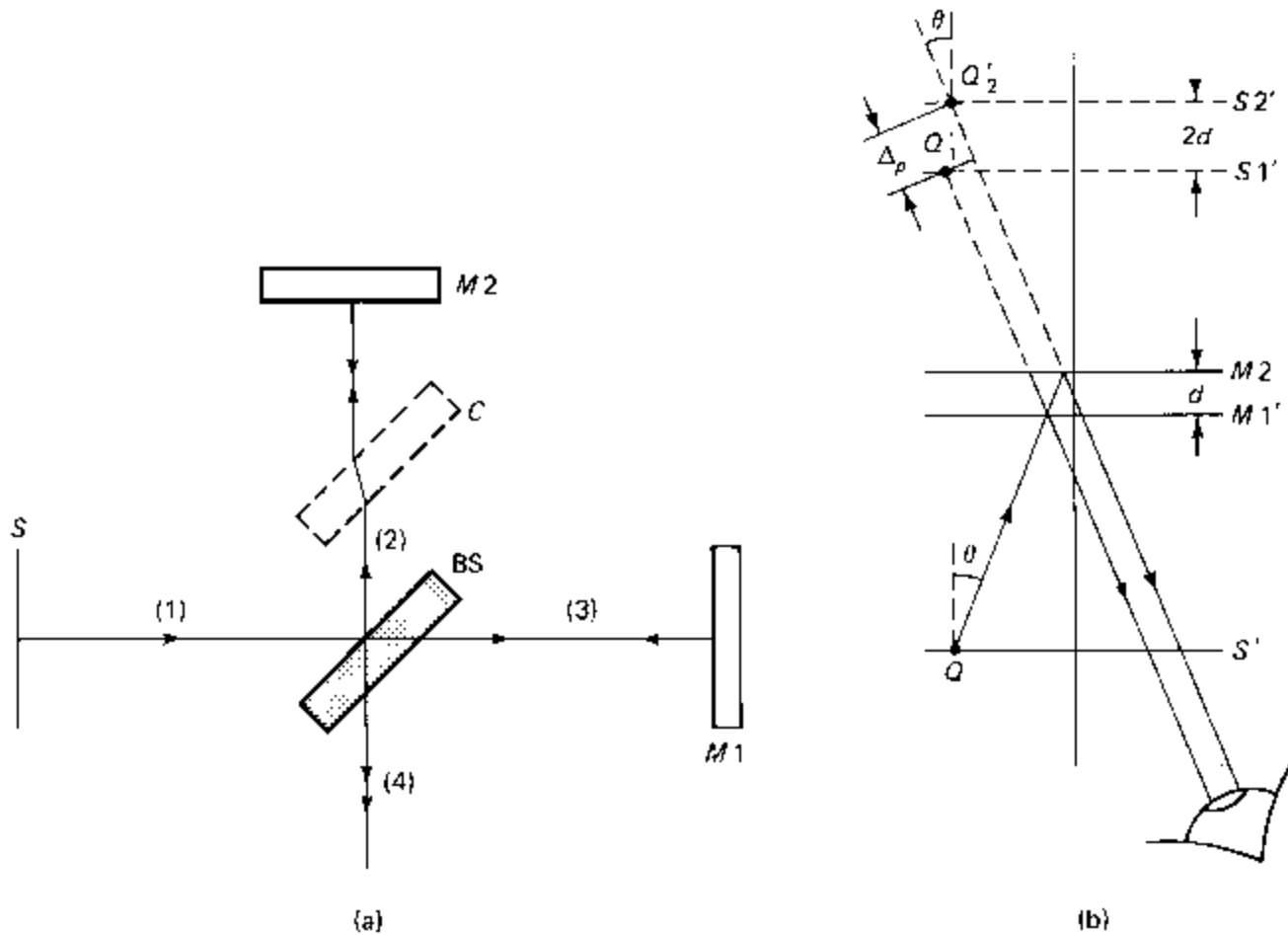
C7. Dispozitive interferentiale

Interferometrul Michelson

Albert Michelson 1881
rol important in dezvoltarea
fizicii moderne



C7. Dispositive interferentiale



A) The Michelson interferometer. B) Equivalent optics for the Michelson interferometer.

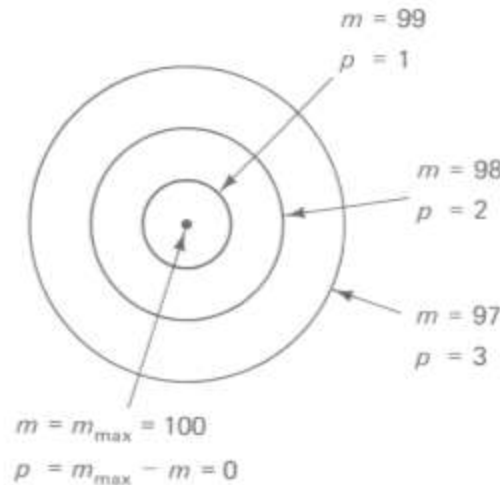
C7. Dispozitive interferentiale

Interferometrul Michelson

$$\Delta = 2d + \frac{\lambda}{2} = \left(m + \frac{1}{2}\right)\lambda \Rightarrow 2d = m\lambda$$

Conditia de
obtinere a
**franjelor
intunecate**

$$m_{max} = \frac{2d}{\lambda}$$



Oglinda se misca

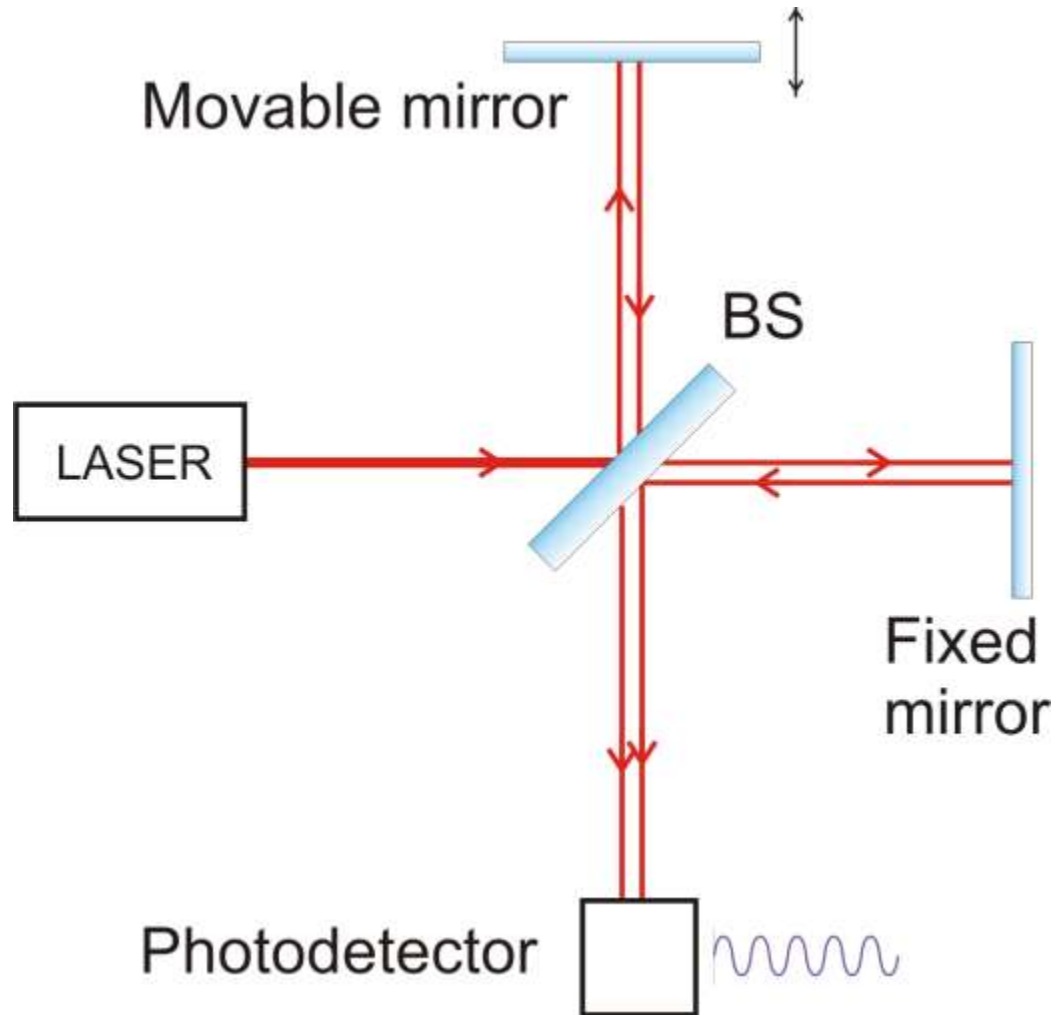
$$\Delta m = \frac{2\Delta d}{\lambda}$$

$$\Delta m, \Delta d \Rightarrow \lambda$$

Daca oglinda se misca pe distanta de 0.73 mm se observa o deplasare cu 300 franje. Care este lungimea de unda? Daca intr-un brat al interferometrului este plasata o lama subtire de sticla cu $n = 1.51$ si grosime 0.005 mm cat este deplasarea sistemului de franje?

C7. Dispozitive interferentiale

Interferometrul Michelson



C8. Dispozitive interferentiale

Interferometrul Michelson: determinarea “despicării”
emisiei galbene a sodiului

λ & λ' Coincidenta in centru $m\lambda = m' \lambda'$ imagine clara (sharp)

Prima coincidenta $m = (m' + N)$ imagine clara

$$\frac{2d_1}{\lambda} = \frac{2d_1}{\lambda'} + N$$

Deplasez oglinda cu Δd imagine uniforma

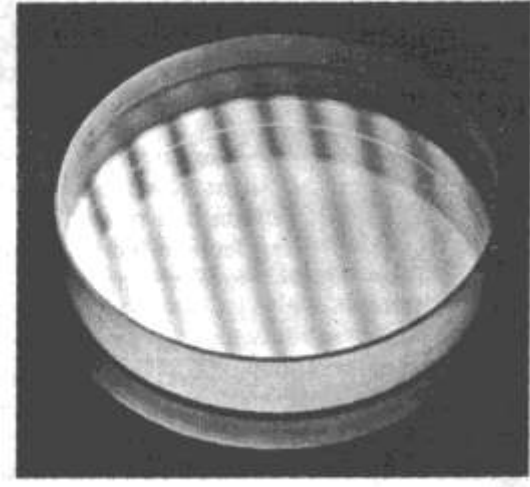
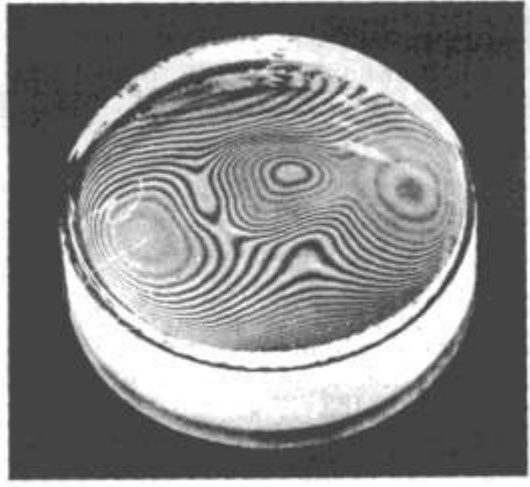
A doua coincidenta $m = m' + (N + 1)$ imagine clara

$$\frac{2d_2}{\lambda} = \frac{2d_2}{\lambda'} + N + 1$$

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

C8. Dispozitive interferentiale

Aplicatii ale dispozitivelor interferentiale



C8. Dispozitive interferentiale



**In lumina
alba**



In lumina rosie

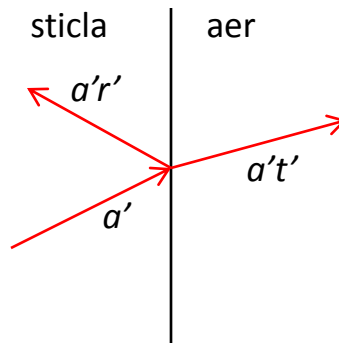
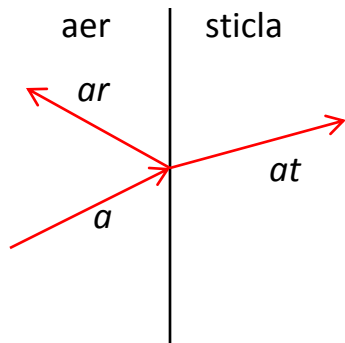
Interferenta pe o pelicula

C8. Dispozitive interferentiale

Relatiile lui Stokes (Interferenta multipla)

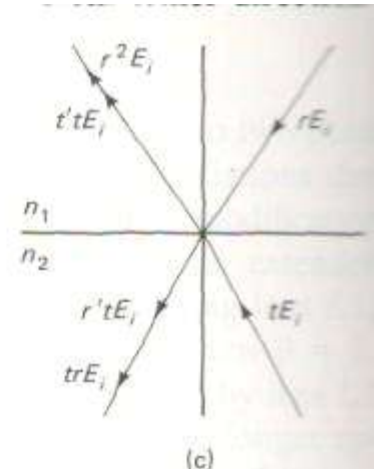
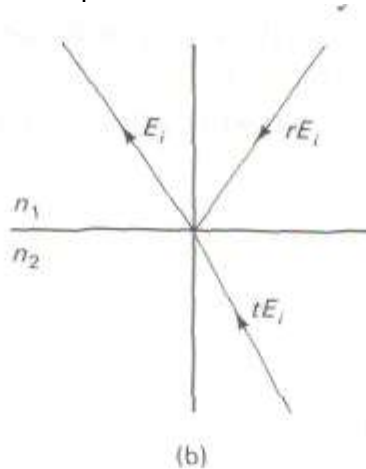
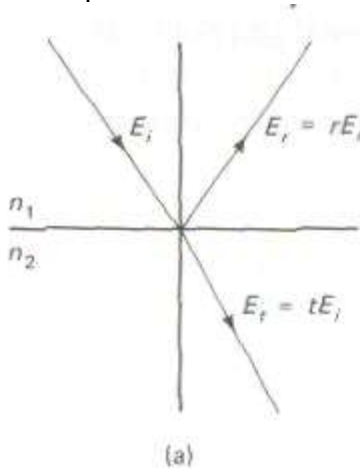
Coeficientul de reflexie $r = \frac{E_r}{E_i}$

Coeficientul de transmisie $t = \frac{E_t}{E_i}$



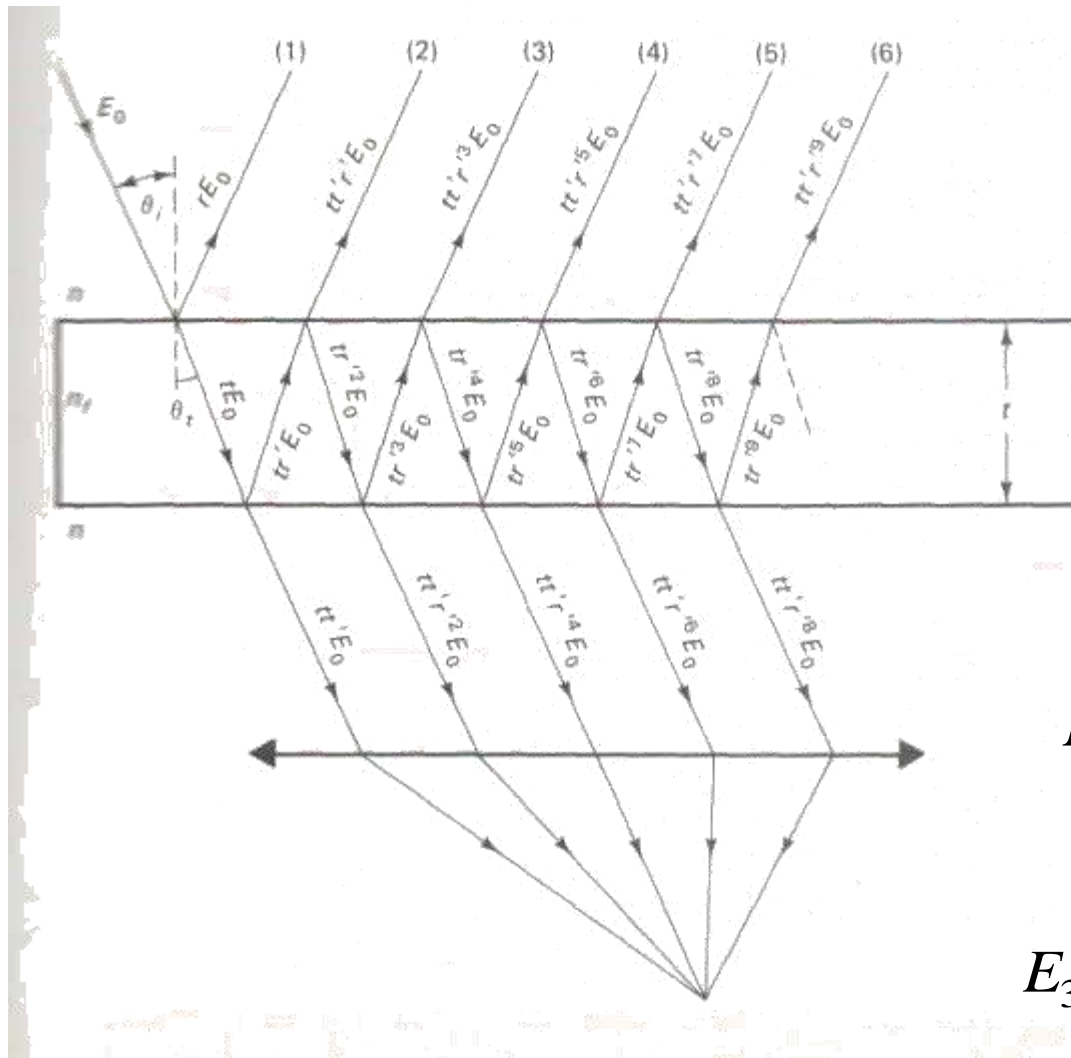
$$r = -r'$$

$$tt' + r^2 = 1$$



C8. Dispozitive interferentiale

Interferometrul Fabry-Perot



Diferenta de drum
dintre doua raze
reflectate succesiv:

$$\Delta = 2nd$$

Diferenta de faza
dintre doua raze
reflectate succesiv:

$$\delta = \frac{2\pi\Delta}{\lambda} = k\Delta$$

$$E_1 = (rE_0)e^{i\omega t}$$

$$E_2 = (tt' r' E_0)e^{i(\omega t - \delta)}$$

$$E_3 = (tt' r'^3 E_0)e^{i(\omega t - 2\delta)}$$

C8. Dispozitive interferentiale

Interferometrul Fabry-Perot

Suma a N raze reflectate:

$$E_R = rE_0 e^{i\omega t} + \sum_{N=2}^{\infty} \left(tt' r'^{(2N-3)} E_0 \right) e^{i[\omega t - (N-1)\delta]}$$

$$E_R = E_0 e^{i\omega t} \left[r + \sum_{N=2}^{\infty} tt' r'^{(2N-3)} e^{-i(N-1)\delta} \right]$$

$$E_R = E_0 e^{i\omega t} \left[r + tt' r' e^{-i\delta} \sum_{N=2}^{\infty} r'^{(2N-4)} e^{-i(N-2)\delta} \right]$$

$$x = r'^2 e^{-i\delta} \quad \sum = 1 + x + x^2 + x^3 + \dots = \frac{1}{1-x}$$

$$E_R = E_0 e^{i\omega t} \left[r + \frac{tt' r' e^{-i\delta}}{1 - r'^2 e^{-i\delta}} \right] \quad E_R = E_0 e^{i\omega t} \left[r - \frac{(1-r^2) r e^{-i\delta}}{1 - r'^2 e^{-i\delta}} \right]$$

C8. Dispozitive interferentiale

Interferometrul Fabry-Perot

Suma a N raze reflectate:

$$E_R = E_0 e^{i\omega t} \left[r - \frac{(1-r^2)re^{-i\delta}}{1-r^2e^{-i\delta}} \right] \quad E_R = E_0 e^{i\omega t} \left[\frac{r(1-e^{-i\delta})}{1-r^2e^{-i\delta}} \right]$$

Intensitatea:

$$I_R = |E_R|^2 = E_R E_R^* = E_0^2 r^2 \left[\frac{e^{i\omega t}(1-e^{-i\delta})}{1-r^2e^{-i\delta}} \right] \left[\frac{e^{-i\omega t}(1-e^{i\delta})}{1-r^2e^{i\delta}} \right]$$

$$I_R = \left[\frac{2r^2(1-\cos\delta)}{1+r^4-2r^2\cos\delta} \right] I_i$$

$$I_T = \left[\frac{(1-r^2)^2}{1+r^4-2r^2\cos\delta} \right] I_i$$

C8. Dispozitive interferentiale

Interferometrul Fabry-Perot

$$I_R = \left[\frac{2r^2(1 - \cos \delta)}{1 + r^4 - 2r^2 \cos \delta} \right] I_i$$

Intensitatea reflectata este minima: $\cos \delta = 1$

$$\delta = 2\pi m \Rightarrow \Delta = 2nd \cos \vartheta = m\lambda$$

Intensitatea transmisa este maxima: $I_T = I_i$

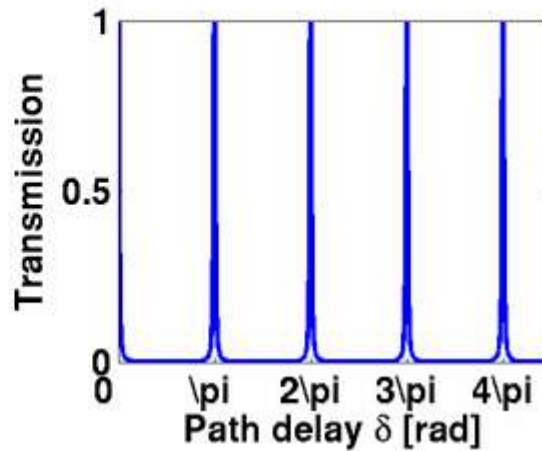
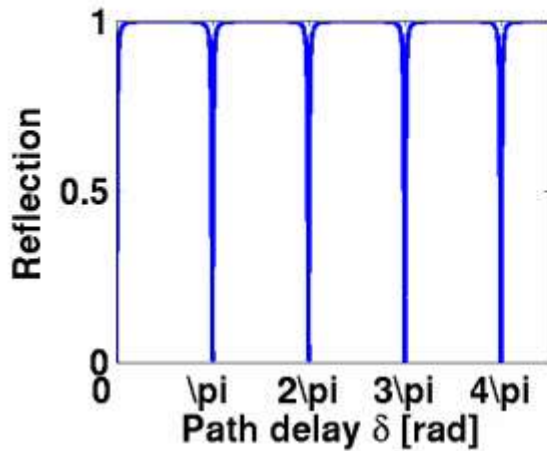
Sticla $n=1.5 \Rightarrow r = 0.04$ $\left| \frac{E_2}{E_1} \right| = 1 - r^2 \approx 1$ Interferenta a doua fascicule
cazul lamei

Interferometrul Fabry-Perot: imaginea de interferenta este formata din inele

C8. Dispozitive interferentiale

Interferometrul Fabry-Perot

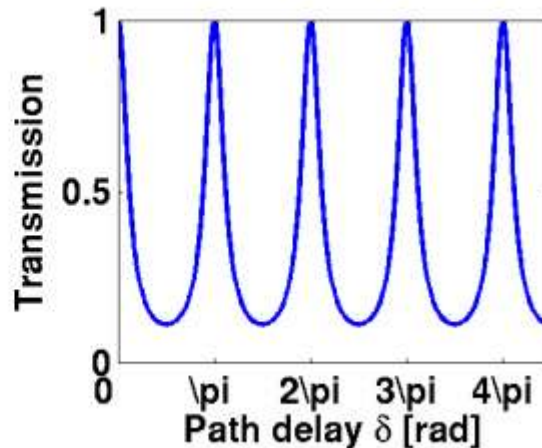
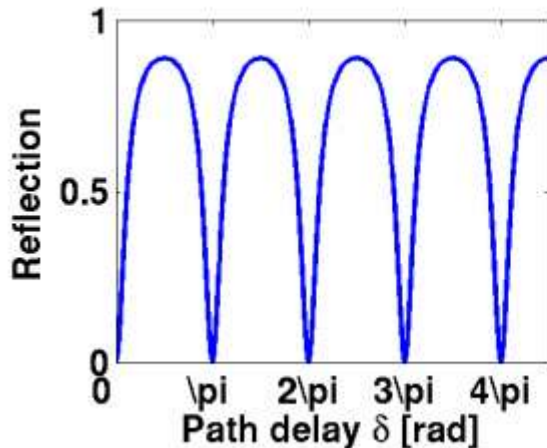
Interferometrul Fabry-Perot: imaginea de interferenta este formata din inele



$$I_T = \left[\frac{(1-r^2)^2}{1+r^4-2r^2 \cos \delta} \right] I_i$$

$r=0.95$

$$R \equiv \frac{\lambda}{(\Delta\lambda)_{min}}$$



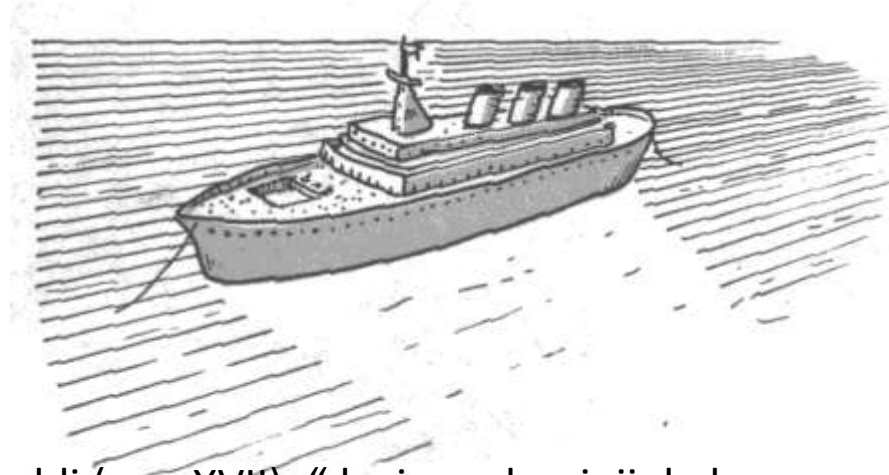
$$R = \left(\frac{\pi}{2} \right) m \sqrt{F}$$

$r=0.5$

$$F = \frac{4r^2}{(1-r^2)^2}$$

coeficientul de finete

C9. Difractia luminii



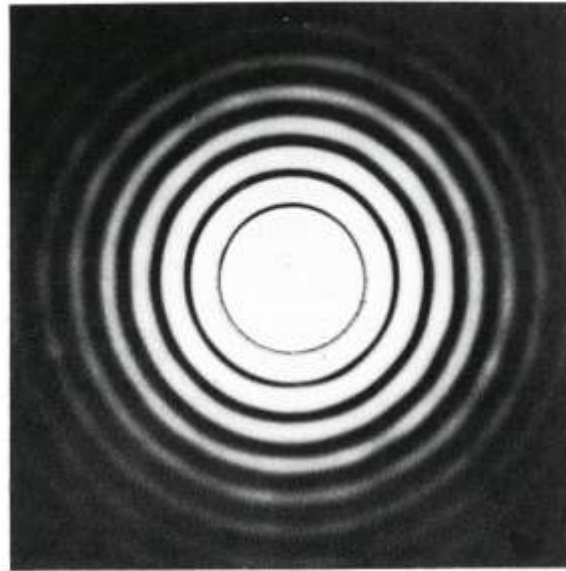
Francesco Grimaldi (sec. XVII): “devierea luminii de la propagarea rectilinie”= *diffractio* .

Conditie de observare: sursa puternica de lumina.

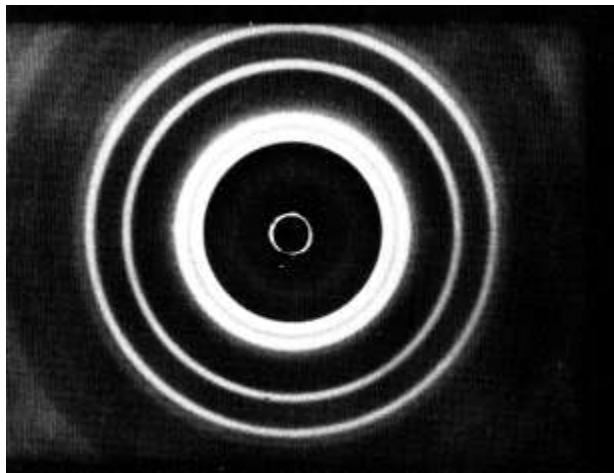
Principiul Huygens: nu poate explica difractia. De ce? Propagarea luminii se face doar prin construirea infasuratorii undelor secundare emise de fiecare punct de pe frontul de unda. Nu tine cont de lungimea de unda! “In spatele copacilor este umbra dar sunetele se aud!”

Principiul Huygens-Fresnel: orice punct neobturat al frontului de unda este sursa de unde sferice secundare (*wavelets* = ondulete) cu aceeasi frecventa ca unda primara. Amplitudinea campului in orice punct este superpozitia tuturor acestor ondulete (luam in considerare amplitudinile si fazele lor). Deci propagarea luminii este rezultatul interferentei undelor secundare!

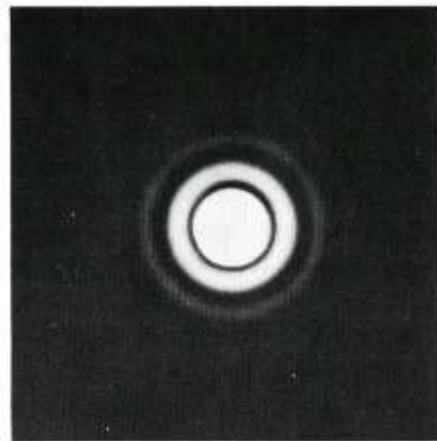
C9. Difractia luminii



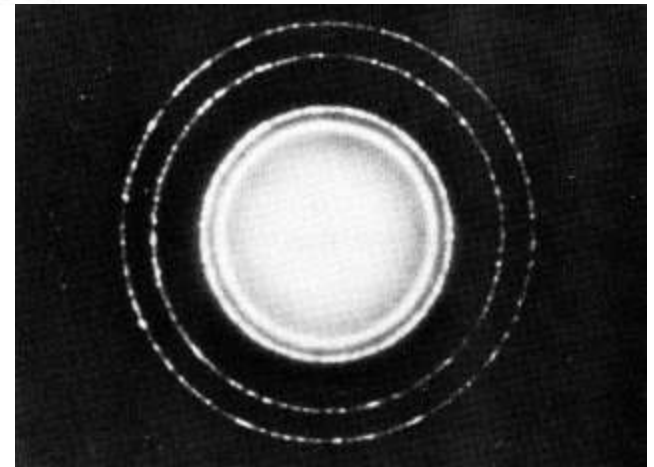
(a)



Difractia razelor X la trecerea printr-o foita de aluminiu policristalin



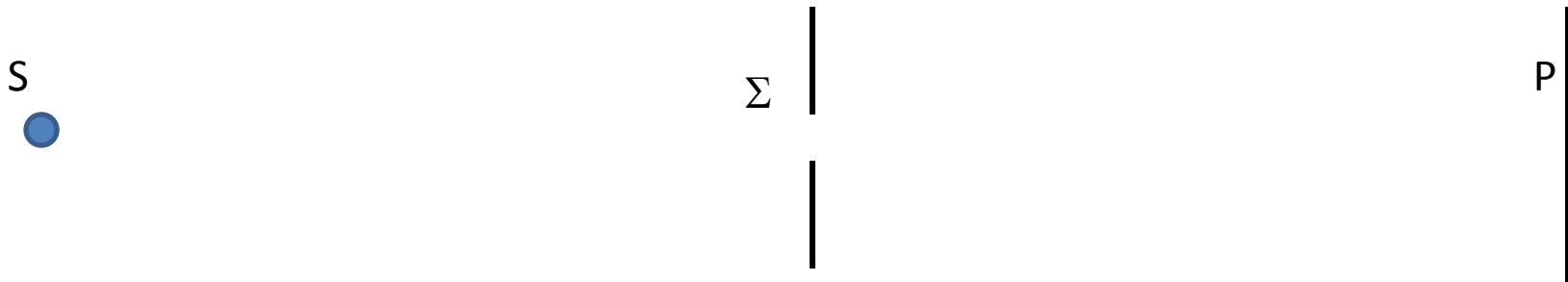
(b)



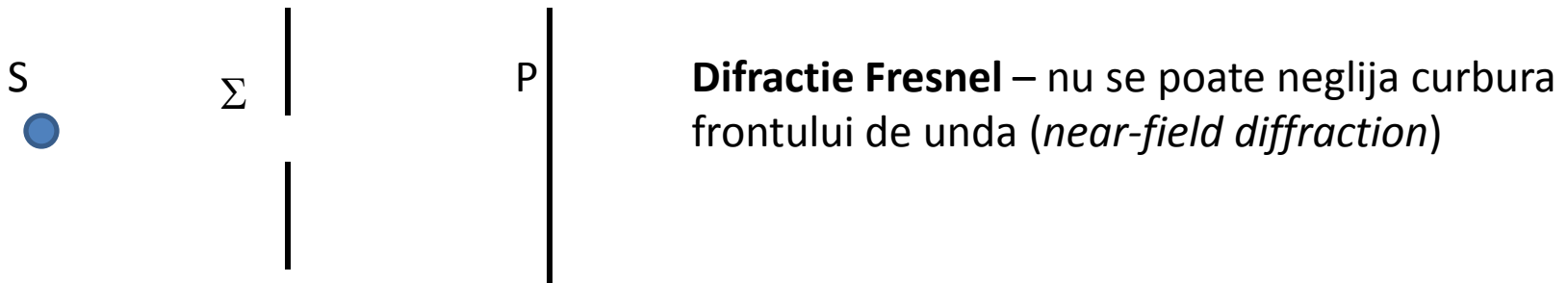
Difractia electronilor la trecerea prin aceeași foita de aluminiu

C9. Difractia luminii

Difractia Fraunhofer si difractia Fresnel



Difractie Fraunhofer – se poate neglija curbura frontului de unda, unde plane (*far-field diffraction*)

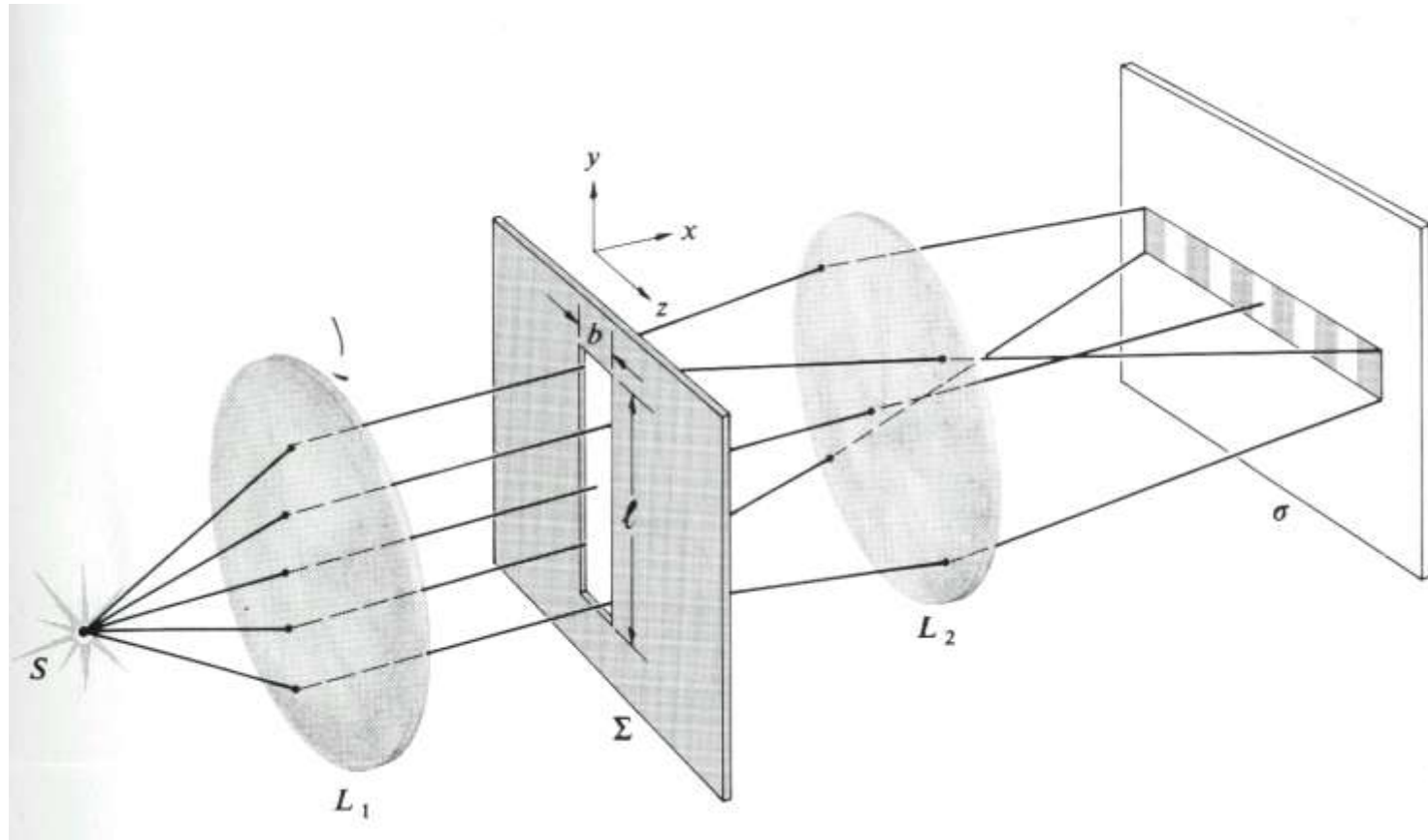


Difractie Fresnel – nu se poate neglija curbura frontului de unda (*near-field diffraction*)

Cum se realizeaza practic difractia Fraunhofer?

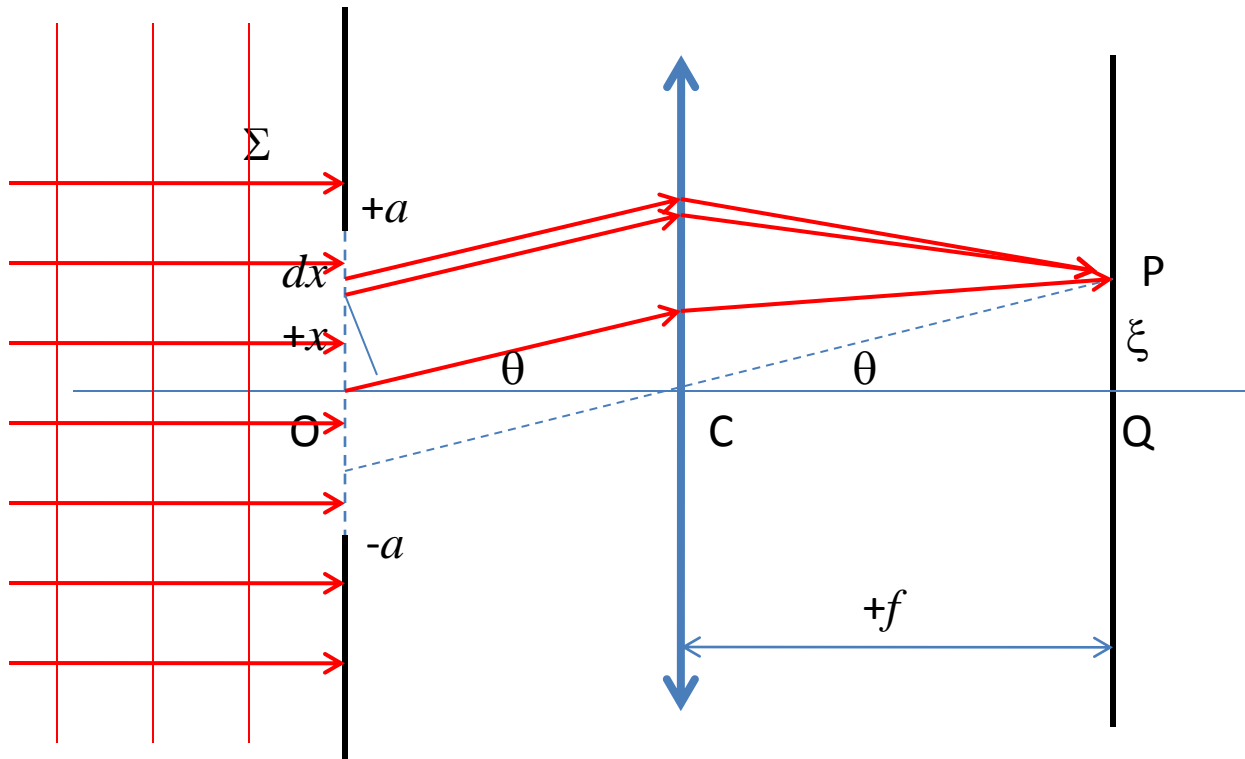
C9. Difractia luminii

Difractia Fraunhofer



C9. Difractia luminii

Difractia Fraunhofer pe o fanta



In P campul rezultat se determina prin aplicarea principiului superpozitiei!

Elongatia rezultanta in P :

$$y(\xi, t) = A \int_{-a}^{+a} e^{i(\omega t - \varphi(x))} dx$$

Diferenta de drum dintre raza centrala si raza din x :

$$\delta = x \cdot \theta = x \frac{\xi}{f}$$

Diferenta de faza: $\Delta\varphi = \frac{2\pi}{\lambda} x \frac{\xi}{f} = B \cdot x$

C9. Difractia luminii

Difractia Fraunhofer pe o fanta

Elongatia rezultanta in P : $y(\xi, t) = A \int_{-a}^{+a} e^{i(\omega t - Bx)} dx =$

$$= Ae^{i\omega t} \int_{-a}^{+a} e^{-iBx} dx = Ae^{i\omega t} \left. \frac{1}{-iB} e^{-iBx} \right|_{-a}^{+a} = Ae^{i\omega t} \frac{e^{-iBa} - e^{+iBa}}{-iB} = Ae^{i\omega t} \frac{e^{iBa} - e^{-iBa}}{iB} =$$

$$= Ae^{i\omega t} \frac{2i \sin Ba}{iB} = (2Aa) e^{i\omega t} \frac{\sin Ba}{Ba}$$

Iradianta rezultanta in P : $I = \left(\frac{\varepsilon_0 c}{2} \right) E_R^2 \approx \left[(2Aa) e^{i\omega t} \frac{\sin Ba}{Ba} \right]^2 = I_0 \left(\frac{\sin Ba}{Ba} \right)^2 =$

$$I = I_0 \frac{\sin^2 \beta}{\beta^2} = I_0 \sin^2 c^2 \beta$$

$$\beta = \frac{2\pi}{\lambda} \frac{\xi}{f} a = \frac{ka}{f} \xi \quad \boxed{I = I_0 \sin^2 c^2 \left(\frac{ka}{f} \xi \right)} \quad \boxed{I = I_0 \sin^2 c^2 (ka \sin \theta)}$$

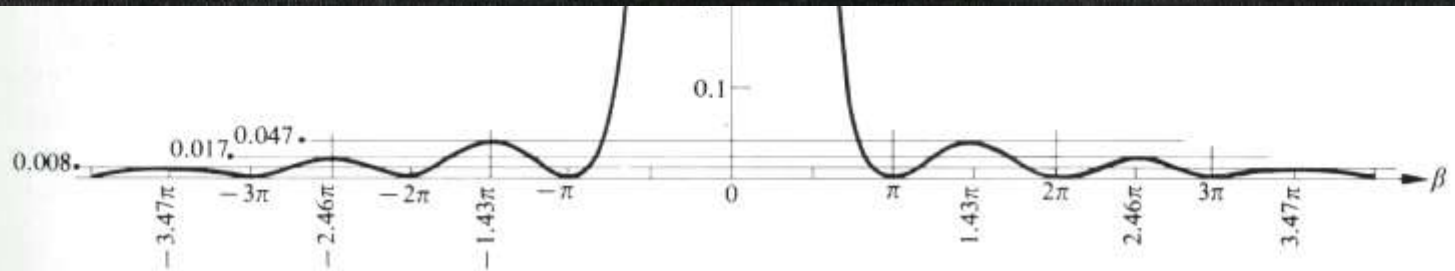
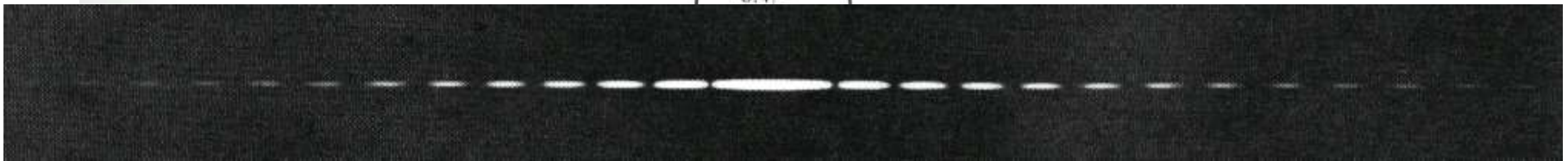
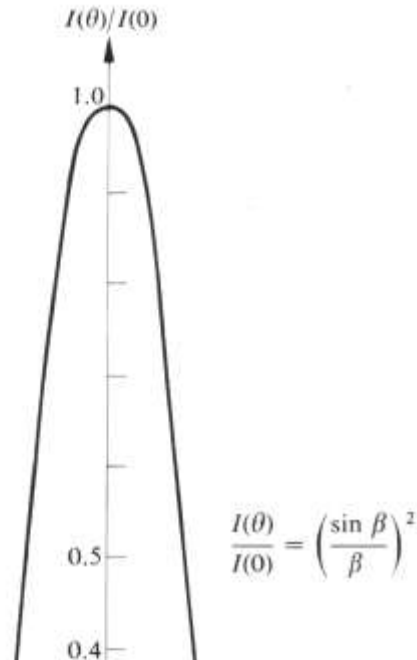
C9. Difractia luminii

Difractia Fraunhofer pe o fanta

Iradianta rezultanta in P :

$$I = I_0 \left(\frac{\sin \beta}{\beta} \right)^2$$

$$I = 0; \beta = \pi, 2\pi, 3\pi, 4\pi \dots$$

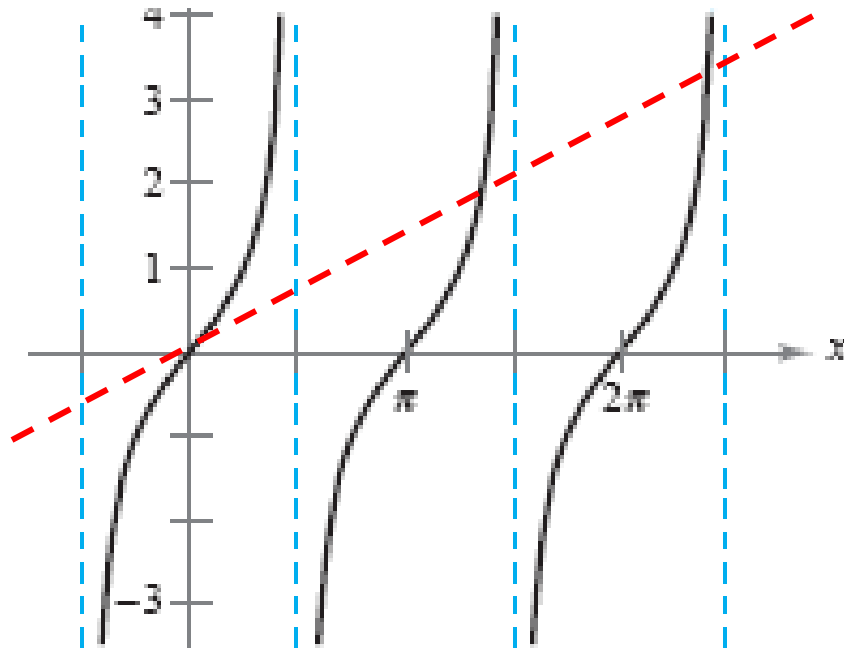


C9. Difractia luminii

Difractia Fraunhofer pe o fanta

$$I = I_0 \left(\frac{\sin \beta}{\beta} \right)^2$$

$$I = \text{maxim ?} \quad \frac{dI}{d\beta} = \frac{(\cos \beta)\beta - \sin \beta}{\beta^2} = 0 \quad \text{tg} \beta = \beta \quad \text{Ecuatie transcendentala}$$



Primul maxim se produce la **1.43π**

Al doilea maxim se produce la **2.46π**

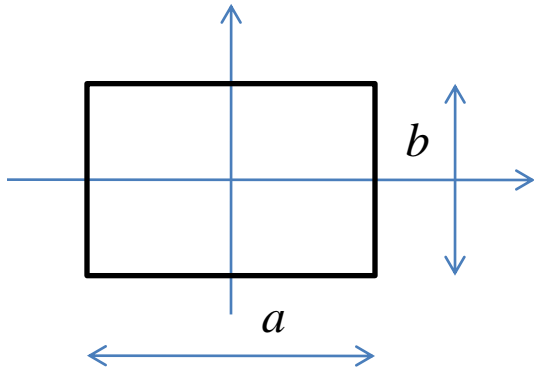
Al treilea maxim se produce la **3.47π**

Cu cat β este mai mare cu atat pozitiile maximelor se apropie de asimptote: **1.5π, 2.5π, 3.5π ...**

TEMA: Care este raportul dintre intensitatea maximului central si intensitatea primului maxim secundar?

C10. Difractia luminii

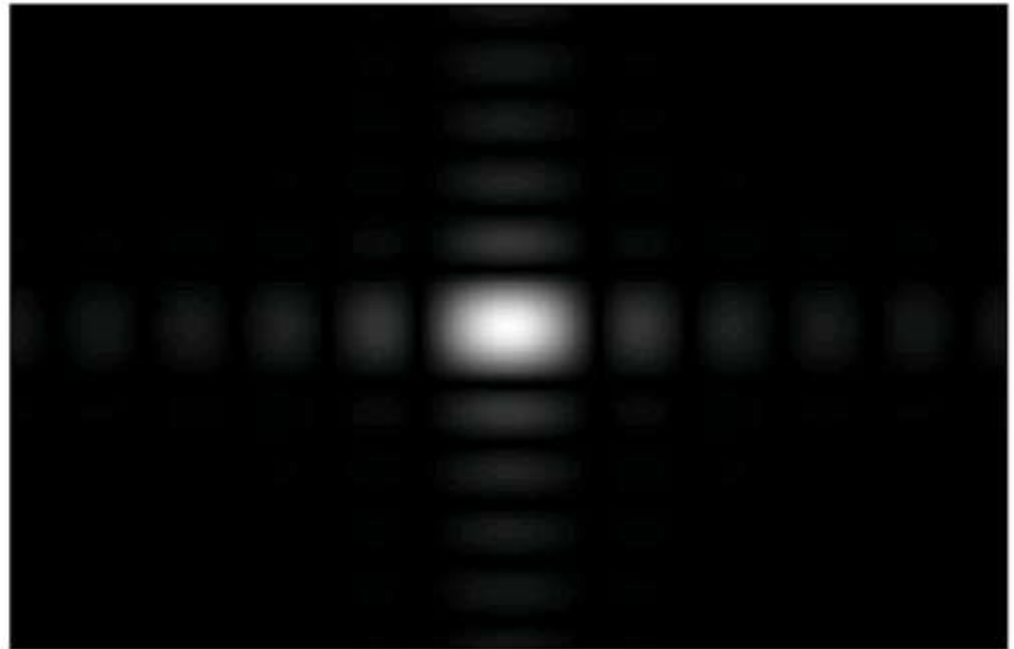
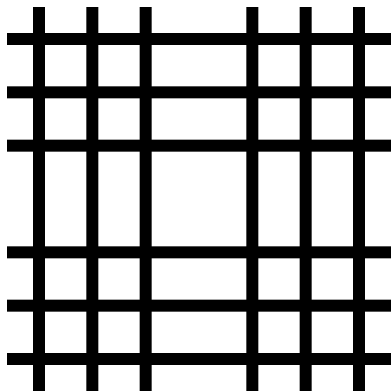
Difractia Fraunhofer pe o apertura rectangulara



$$I = I_0 \left(\frac{\sin \alpha}{\alpha} \right)^2 \left(\frac{\sin \beta}{\beta} \right)^2$$

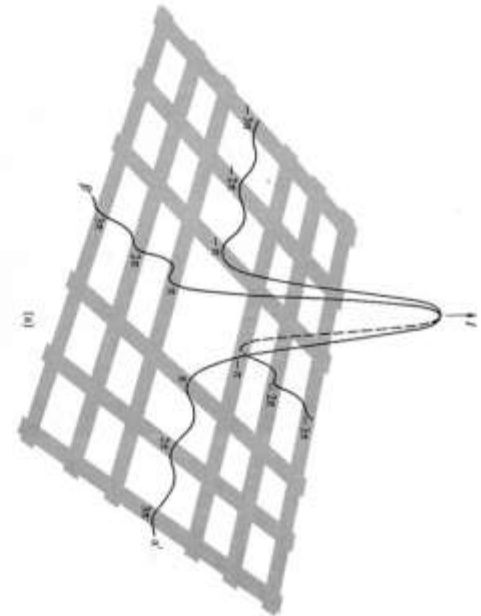
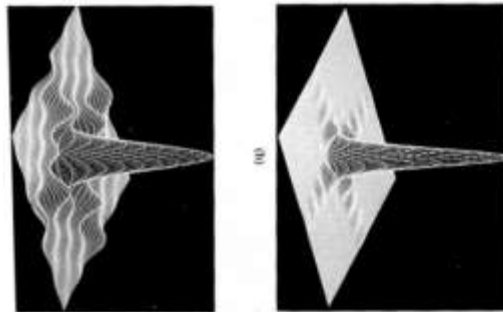
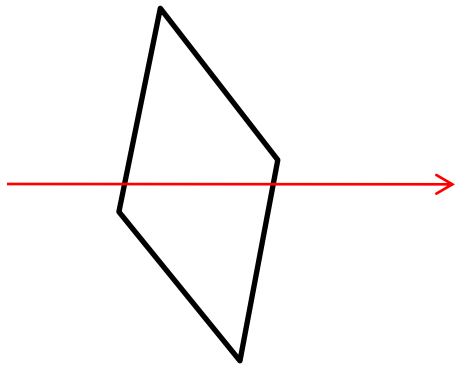
$$\alpha = \frac{1}{2} k a \sin \varphi$$

$$\beta = \frac{1}{2} k b \sin \theta$$



C10. Difractia luminii

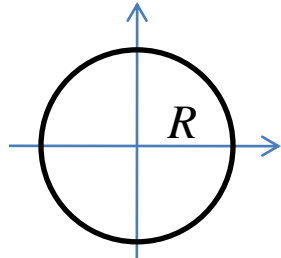
Difractia Fraunhofer pe o apertura rectangulara



Distributia de intensitate intr-un plan perpendicular pe axa optica a aperturii.

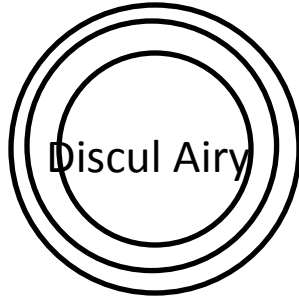
C10. Difractia luminii

Difractia Fraunhofer pe o apertura circulara



$$I = I_0 \left(\frac{2J_1(\rho)}{\rho} \right)^2$$

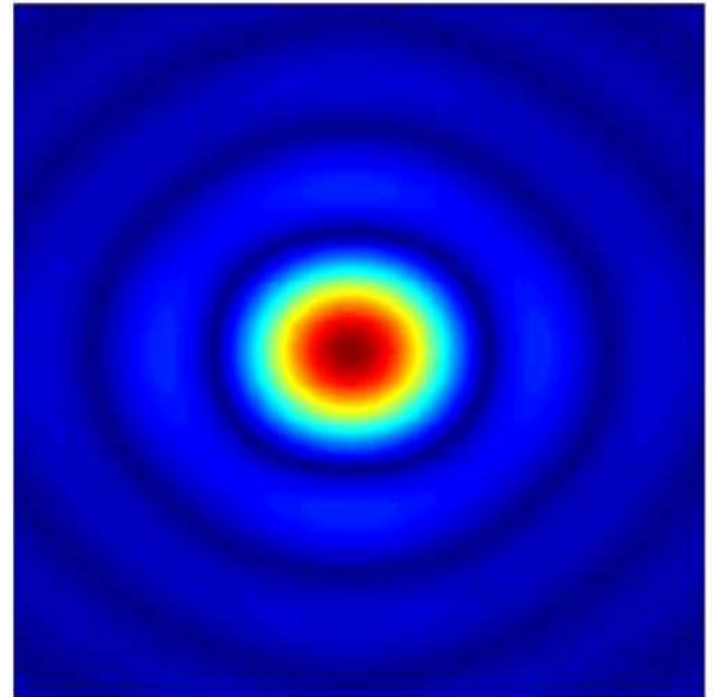
$$\rho = kR \sin \theta$$



Dimensiunea
discului Airy

$$\sin \theta = \frac{3.832}{kR} = \frac{1.22\lambda}{D} \approx \theta$$

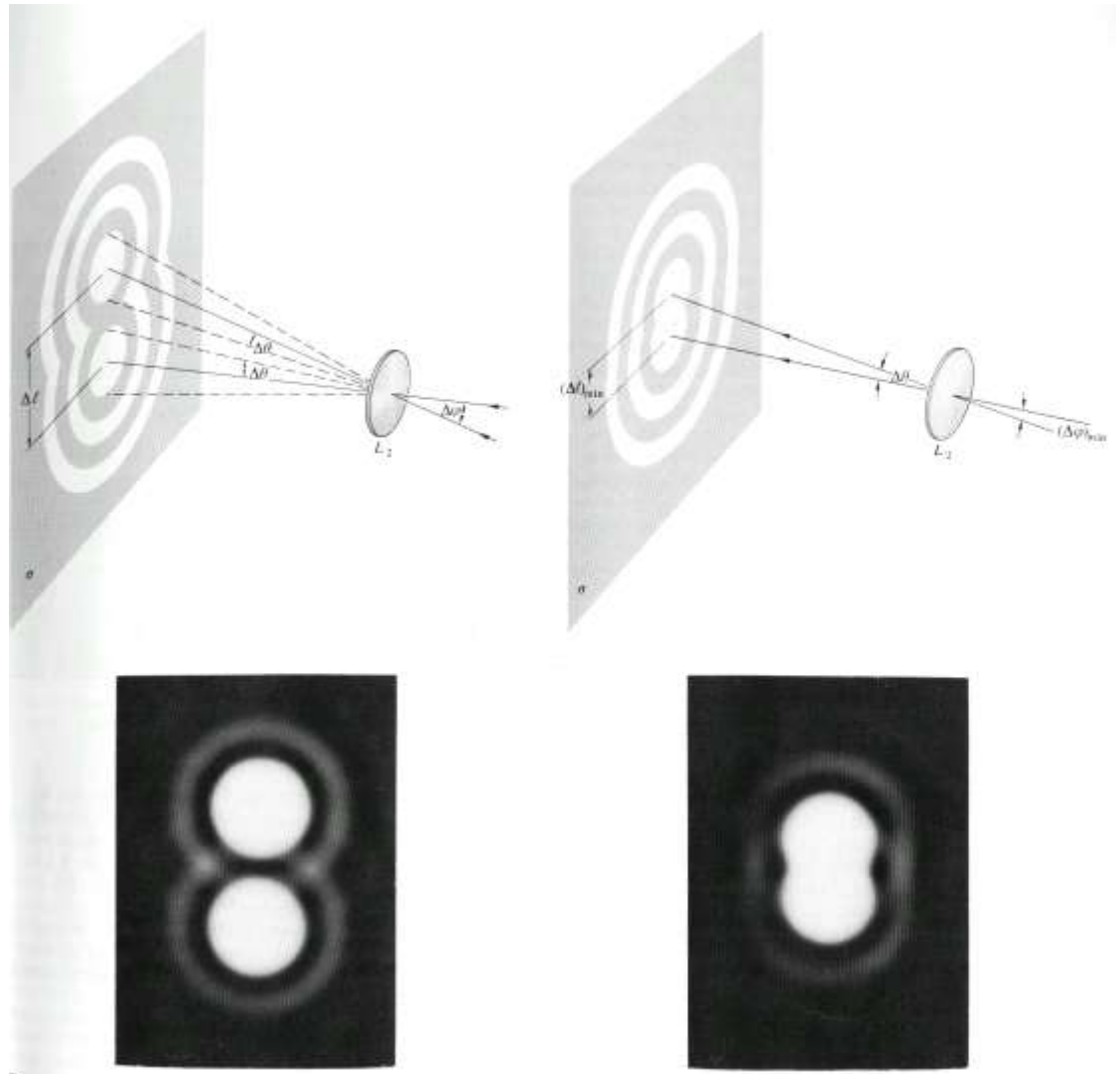
Raza unghiulara a primului
cerc intunecos (discul Airy)



C10. Difractia luminii

Difractia Fraunhofer pe o apertura circulara

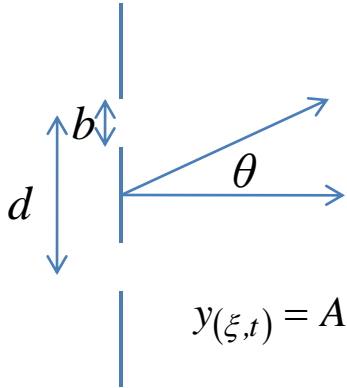
Aplicatie: **REZOLUTIA OPTICA** – imaginea unui punct aflat la distanta mare se formeaza in planul focal al unei lentile si este o figura de difractie Fraunhofer. Imaginea unei surse extinse este o superpozitie de discuri Airy. Rezolutia depinde de marimea discurilor Airy. Imaginile a doua puncte vecine pot fi vazute separat daca maximul central al uneia cade in locul primului minim al celeilalte. **D este diametrul lentilei.**



Limita unghiulara a rezoluției

C10. Difractia luminii

Difractia Fraunhofer pe doua fante



Elongatia rezultanta in P:

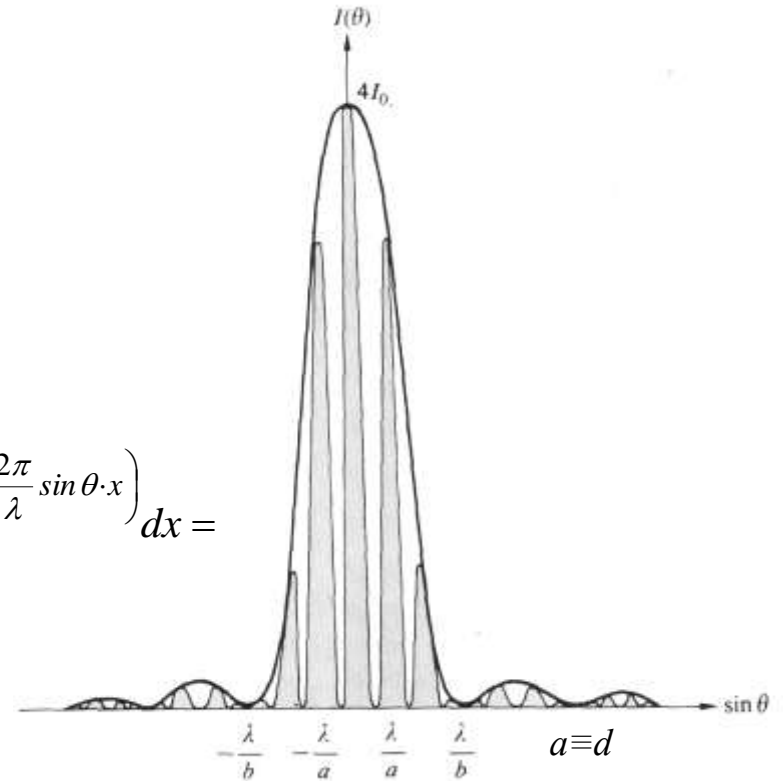
$$y(\xi, t) = A \int_{-\frac{d+b}{2}}^{-\frac{d-b}{2}} e^{i\left(\omega t - \frac{2\pi}{\lambda} \sin \theta \cdot x\right)} dx + A \int_{+\frac{d-b}{2}}^{+\frac{d+b}{2}} e^{i\left(\omega t - \frac{2\pi}{\lambda} \sin \theta \cdot x\right)} dx =$$

$$I = 4I_0 \left(\frac{\sin \beta}{\beta} \right)^2 \cos^2 \gamma$$

$$\beta = \frac{1}{2} k b \sin \theta$$

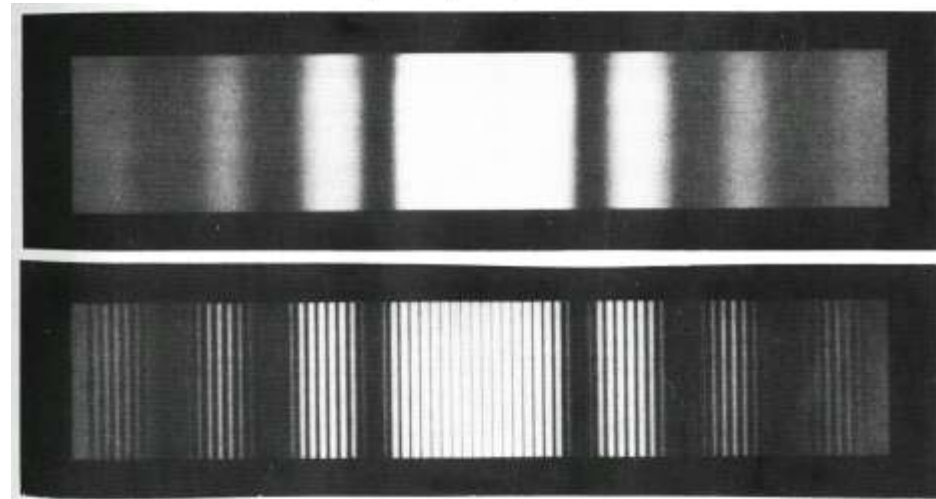
$$\gamma = \frac{1}{2} k d \sin \theta$$

Difractia moduleaza
imaginea de interferenta



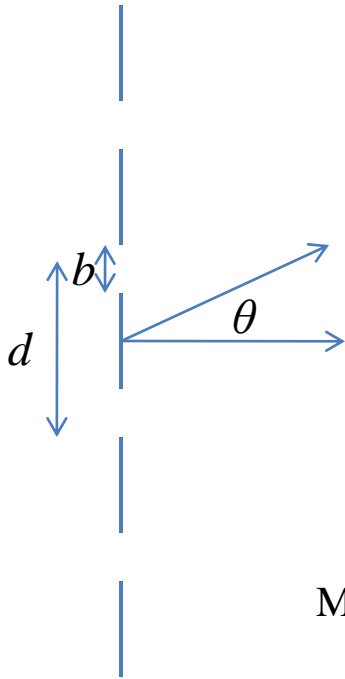
1 fanta

2 fante



C10. Difractia luminii

Difractia Fraunhofer - Reteaua de difractie



$$I = I_0 \left(\frac{\sin \beta}{\beta} \right)^2 \left(\frac{\sin N\gamma}{N \sin \gamma} \right)^2 \quad \beta = \frac{1}{2} kb \sin \theta$$
$$\gamma = \frac{1}{2} kd \sin \theta$$

N – numărul total de fante, d – distanța dintre două fante

Maximele principale: $\gamma = n\pi$, $n = 0, 1, 2, \dots$

$$\frac{1}{2} \frac{2\pi}{\lambda} d \sin \theta = n\pi \Rightarrow$$

$$d \sin \theta = n\lambda$$

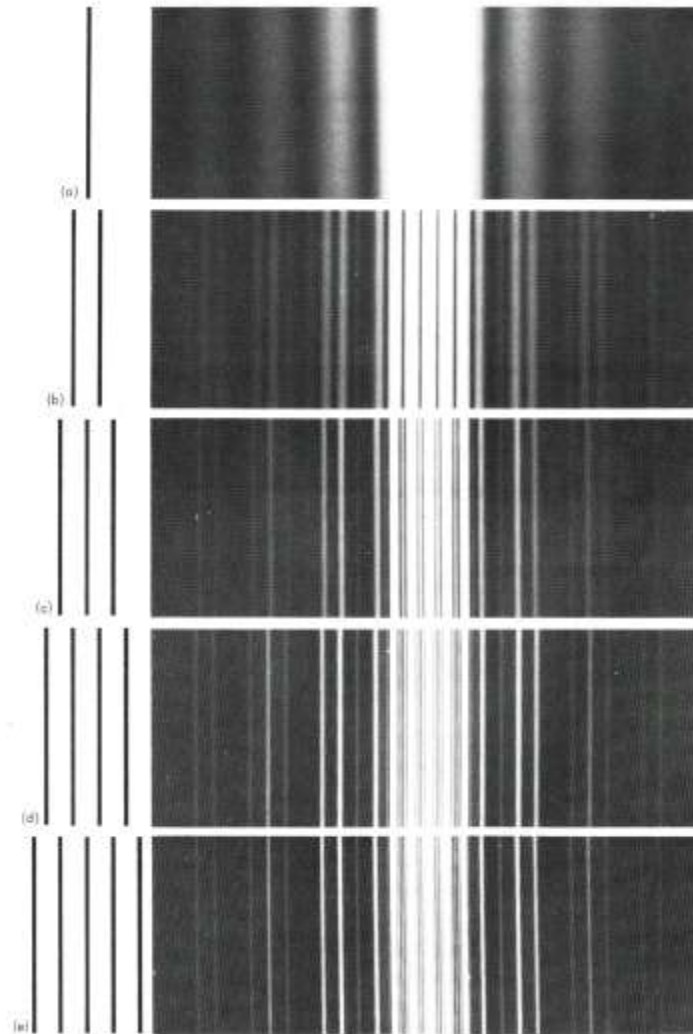
Formula fundamentală a rețelei de difracție

Maximele secundare: $\gamma = \frac{3\pi}{2N}, \frac{5\pi}{2N}, \frac{7\pi}{2N}, \frac{9\pi}{2N} \dots$

Minime: $\gamma = \frac{\pi}{N}, \frac{2\pi}{N}, \frac{3\pi}{N}, \frac{4\pi}{N} \dots$

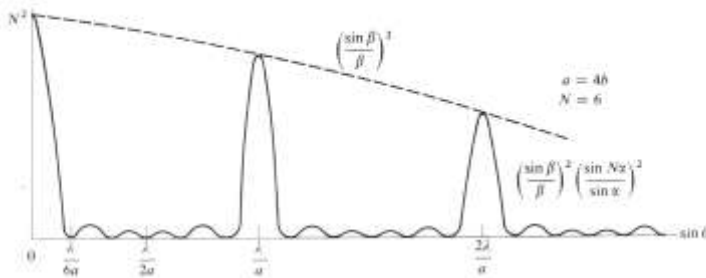
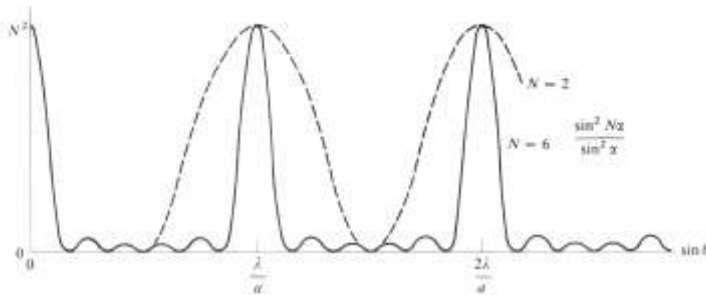
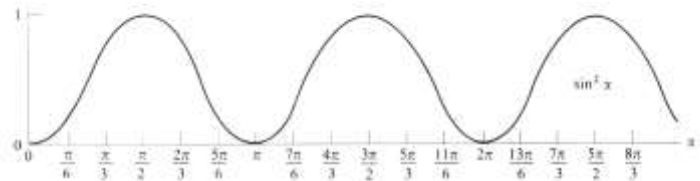
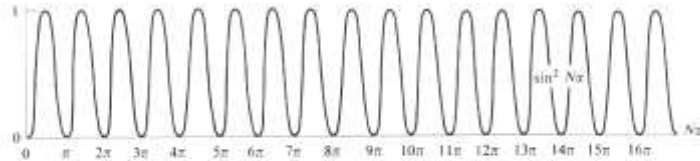
C10. Difractia luminii

Difractia Fraunhofer - Reteaua de difractie



C10. Difractia luminii

Difractia Fraunhofer - Reteaua de difractie

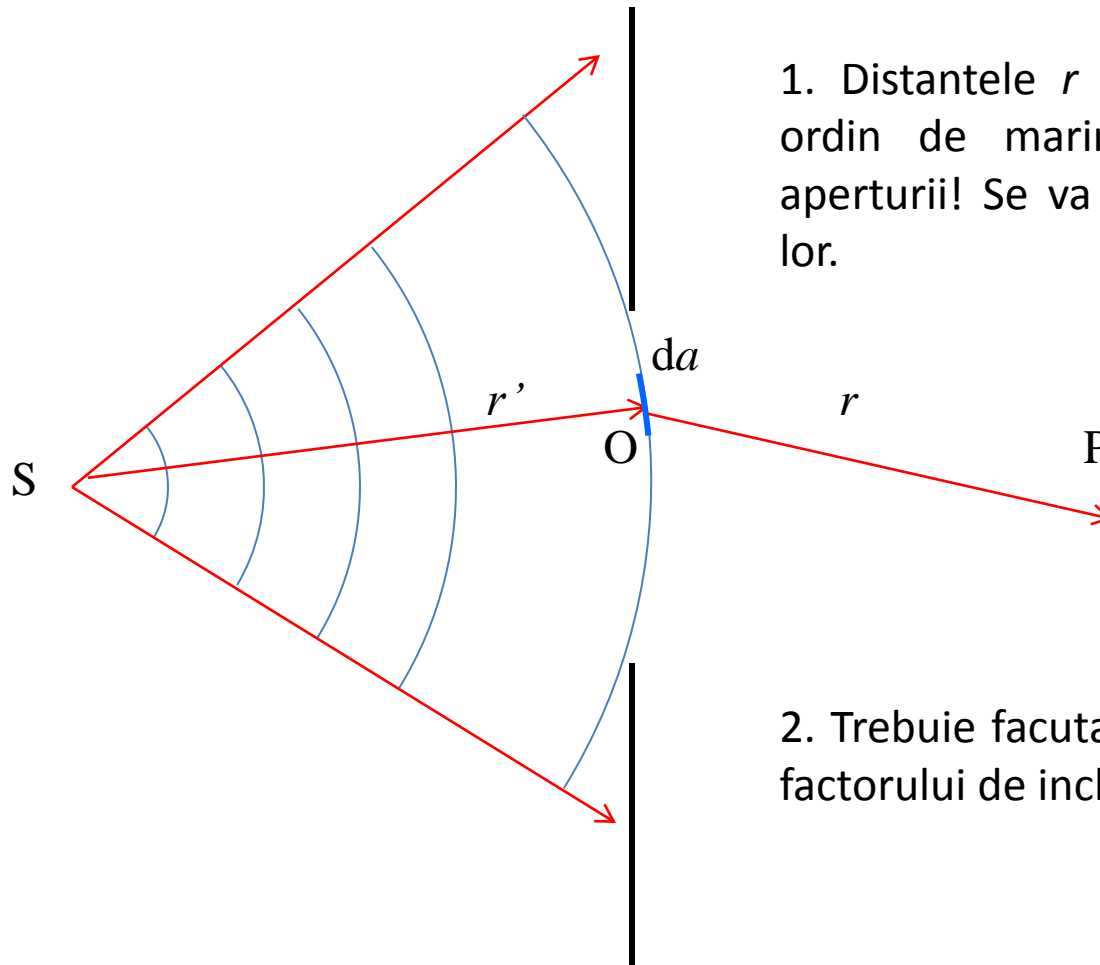


Difractia Fraunhofer pe N fante
($d = 4b, N = 6$)

C11. Difractia luminii

Difractia Fresnel (*near field diffraction*)

Difractia Fresnel – sursa de lumina si ecranul de observatie sunt **aproprite de apertura**, astfel incat trebuie sa se tina cont de **curbura frontului** de unda.



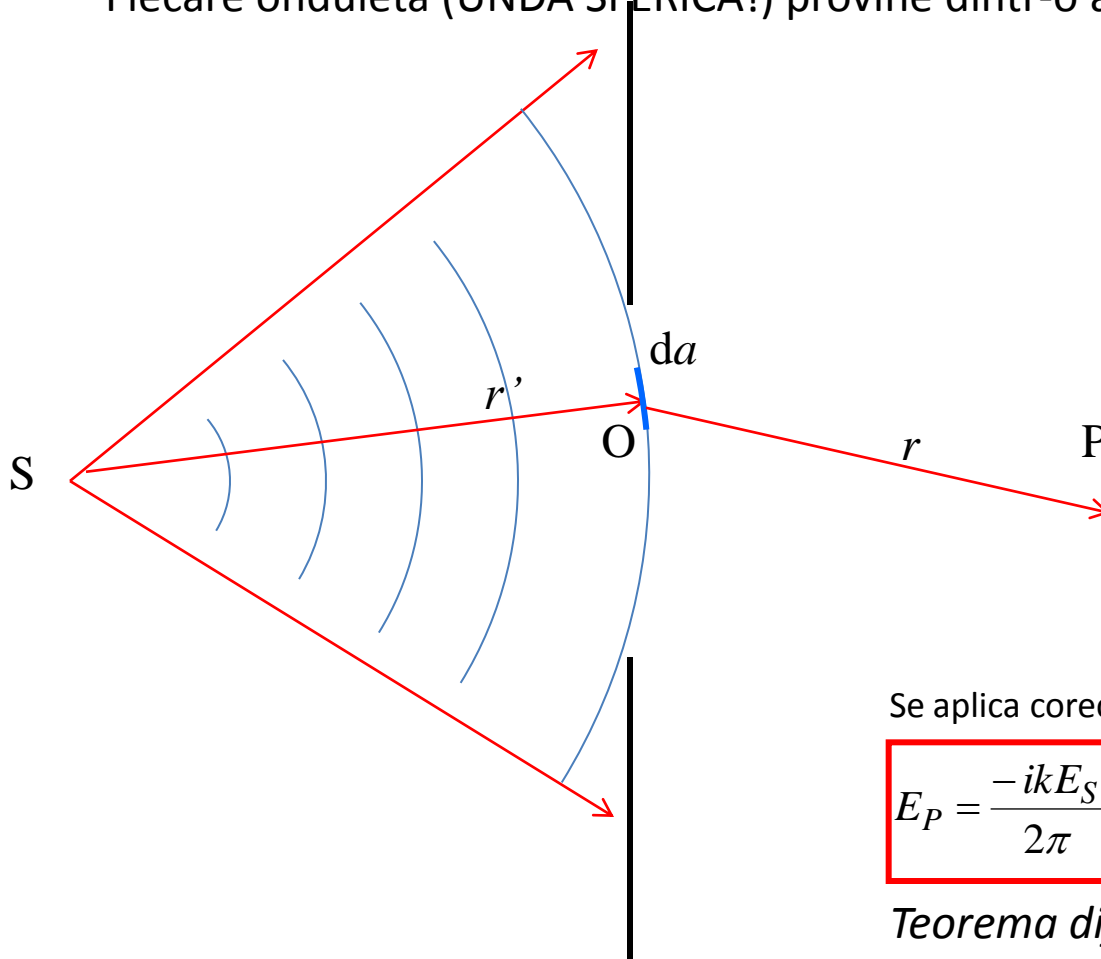
1. Distantele r si r' sunt de acelasi ordin de marime cu dimensiunea aperturii! Se va tine cont de variatia lor.

2. Trebuie facuta o corectie din cauza factorului de inclinare.

C12. Difractia luminii

Difractia Fresnel (*near field diffraction*)

Folosind principiul Huygens-Fresnel amplitudinea campului electric este o superpozitie a tuturor onduletelor din frontul de unda care trece prin apertura. Fiecare onduleta (UNDA SFERICA!) provine dintr-o arie elementara da



$$dE_P = \left(\frac{dE_0}{r} \right) e^{ikr}$$

$$dE_0 \propto E_0 da$$

$$E_0 = \left(\frac{E_S}{r'} \right) e^{ikr'}$$

$$dE_P = \left(\frac{E_S}{rr'} \right) e^{ik(r+r')} da$$

$$E_P = E_S \iint_{Ap} \left(\frac{1}{rr'} \right) e^{ik(r+r')} da$$

Se aplica corectia de faza (90°) si corectia de inclinare

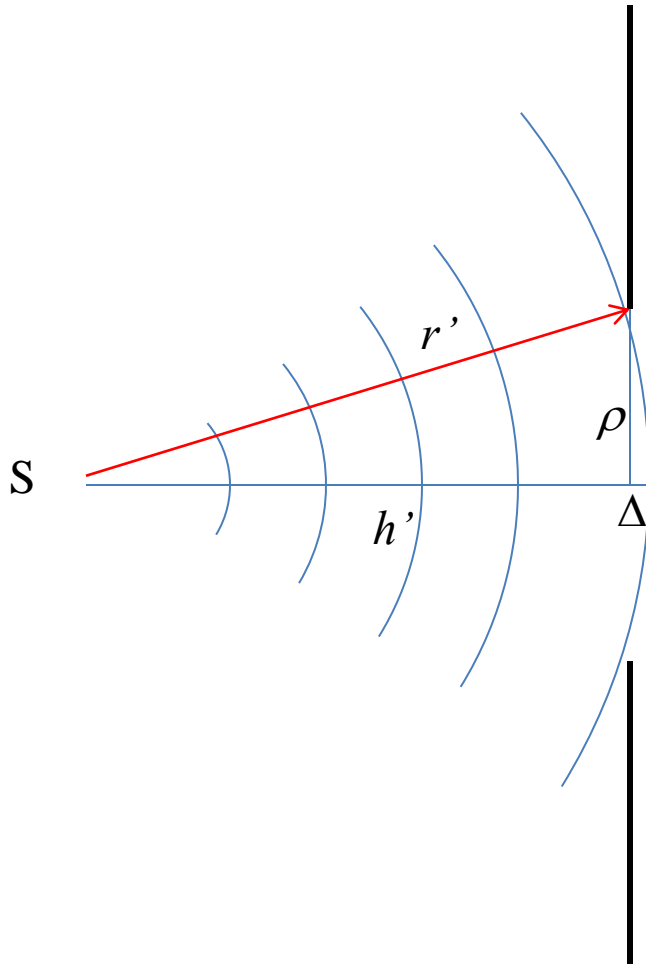
$$E_P = \frac{-ikE_S}{2\pi} \iint_{Ap} \left(\frac{1 + \cos \theta}{2} \right) \frac{e^{ik(r+r')}}{rr'} da$$

Teorema difractiei Fresnel-Kirchhoff

C12. Difractia luminii

Difractia Fresnel

Criteriul pentru difractia Fresnel



$$\Delta = h' - \sqrt{r'^2 - \rho^2} = h' - r' \sqrt{1 - \frac{\rho^2}{r'^2}} \approx h' - r' \left(1 - \frac{\rho^2}{2r'^2} \right)$$

$$\Delta = \frac{\rho^2}{2h'} > \lambda$$

Analog pentru partea dreapta

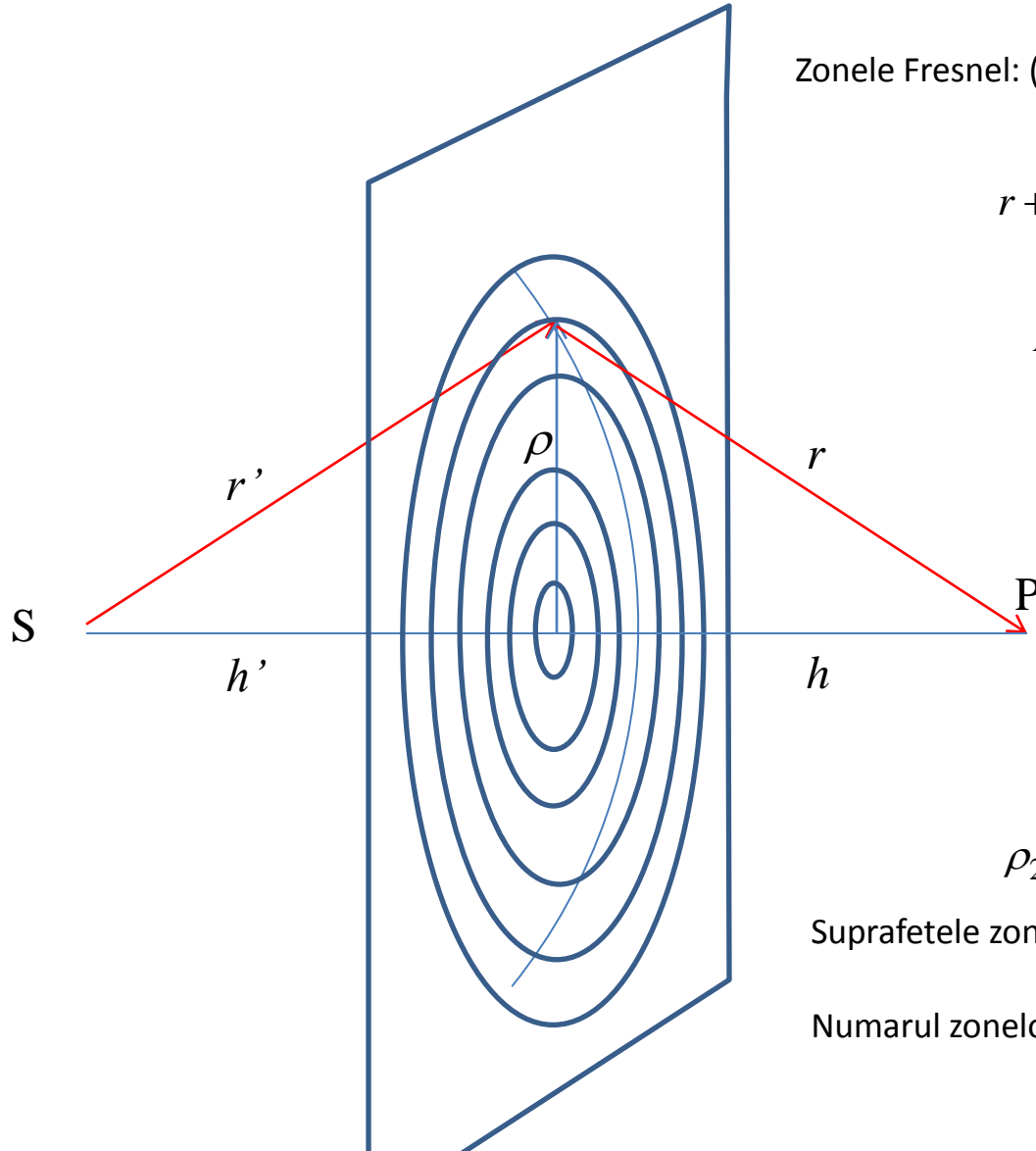
$$\Delta = \frac{\rho^2}{2h} > \lambda$$

Criteriul pentru difractia Fresnel:

$$\frac{1}{2} \left(\frac{1}{h} + \frac{1}{h'} \right) \rho^2 > \lambda$$

C12. Difractia luminii

Difractia Fresnel pe apertura circulara



Zonele Fresnel: $(r+r')$ difera cu $\lambda/2$ intre doua cercuri adiacente.

$$r + r' \approx h + h' + \frac{1}{2} \left(\frac{1}{h} + \frac{1}{h'} \right) \rho^2$$

$$L \equiv \left(\frac{1}{h} + \frac{1}{h'} \right)^{-1} = \frac{hh'}{h+h'}$$

Razele zonelor Fresnel.

$$(r + r')_0 = h + h'$$

$$(r + r')_1 = h + h' + \frac{1}{2L} \rho_1^2 \Rightarrow \rho_1 = \sqrt{\lambda L}$$

$$(r + r')_1 = (r + r')_0 + \frac{\lambda}{2}$$

$$\rho_2 = \sqrt{2\lambda L}$$

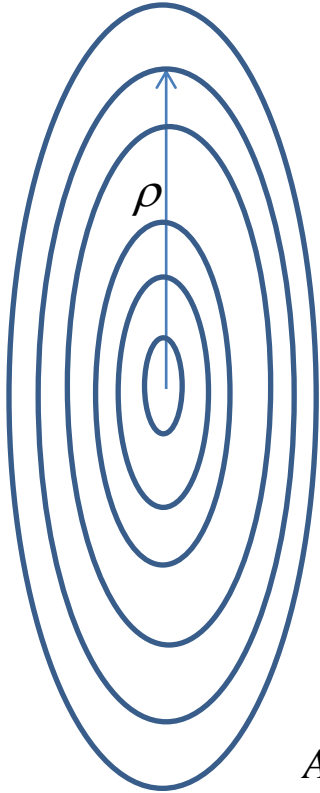
$$\rho_n = \sqrt{n\lambda L}$$

Suprafetele zonelor Fresnel: $S = \pi \rho_{n+1}^2 - \pi \rho_n^2 = \pi \lambda L = c t$

Numarul zonelor Fresnel: $n = \frac{\rho_n^2}{\lambda L} = \frac{\rho_n^2}{\lambda} \left(\frac{1}{h} + \frac{1}{h'} \right)$

C12. Difractia luminii

Difractia Fresnel pe apertura circulara



$$n = \frac{\rho_n^2}{\lambda L} = \frac{\rho_n^2}{\lambda} \left(\frac{1}{h} + \frac{1}{h'} \right) = \frac{D^2}{\lambda} \left(\frac{1}{h} + \frac{1}{h'} \right)$$

O1: Sursa este fixa $h' = ct \Rightarrow n = f(h)$ **numarul zonelor Fresnel depinde de pozitia punctului de observatie**. P este departe \Rightarrow sunt putine zone.

Intre zone este o **diferenta de faza de π (180°)**.

$$A = a_1 - a_2 + a_3 - a_4 + a_5 - \dots$$

O2: Daca apertura contine exact n zone:

$A \approx 0$ daca n este par;

$A \approx a_1$ daca n este impar.

O3: cand nu exista apertura $n \rightarrow \infty$ a_n scade lent datorita factorului de inclinare:

$$A = \frac{1}{2}a_1 + \left(\frac{1}{2}a_1 - a_2 + \frac{1}{2}a_3 \right) + \left(\frac{1}{2}a_3 - a_4 + \frac{1}{2}a_5 \right) \dots = \frac{1}{2}a_1$$

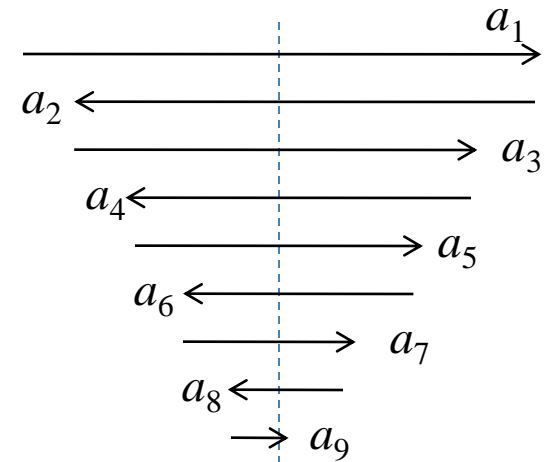


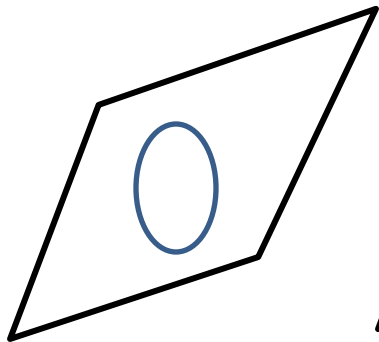
Diagrama fazoriala a zonelor Fresnel

O4: In cazul unui **obstacol** circular zonele Fresnel incep de la marginea obstacolului in centrul umbrei apare un spot luminos cu aceeasi intensitate ca in lipsa obiectului!

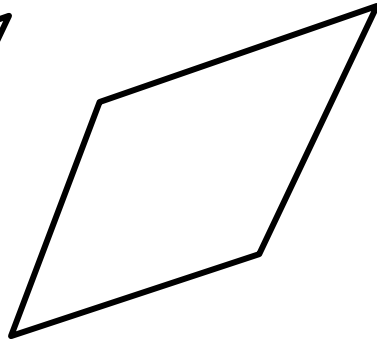
$$A = \frac{1}{2}a_1$$

C12. Difractia luminii

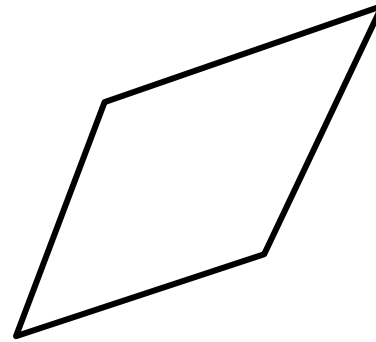
Difractia Fresnel pe apertura circulara



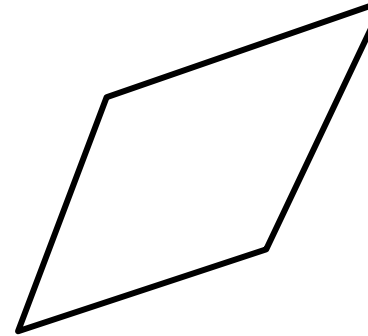
$2r_0 = 10 \text{ mm}$



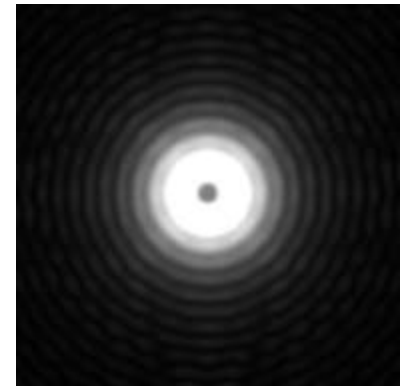
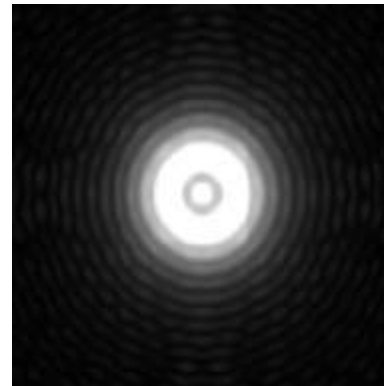
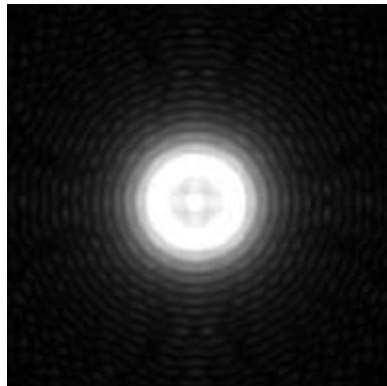
12 m



15 m

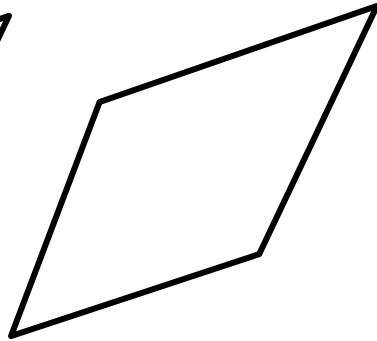
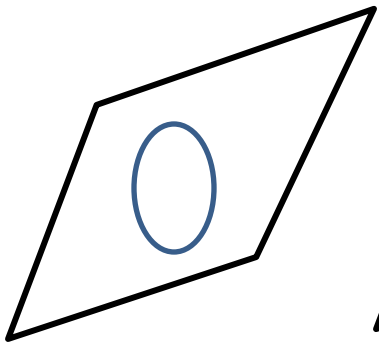


18 m

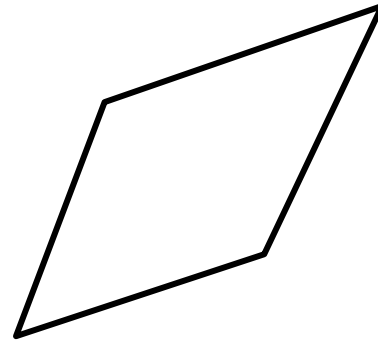


C12. Difractia luminii

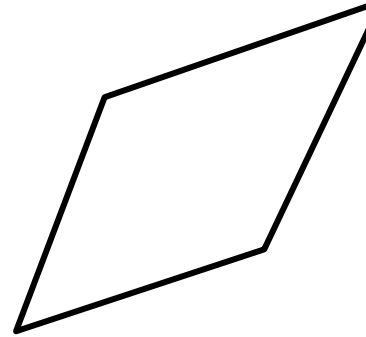
Difractia Fresnel pe apertura circulara



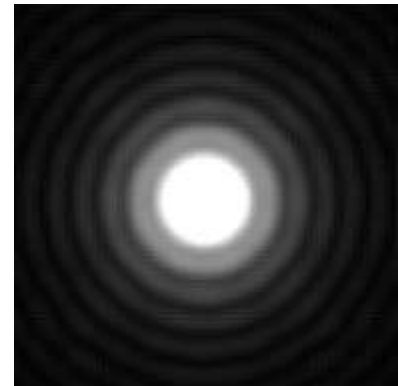
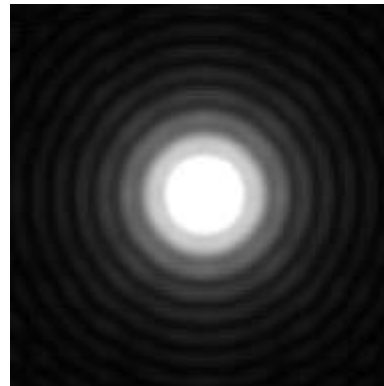
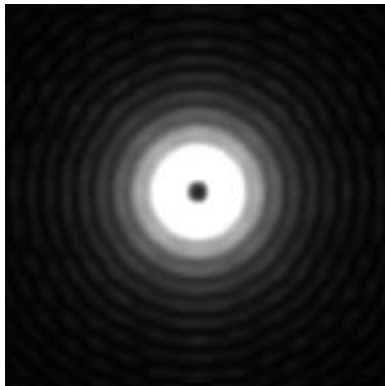
20 m



25 m

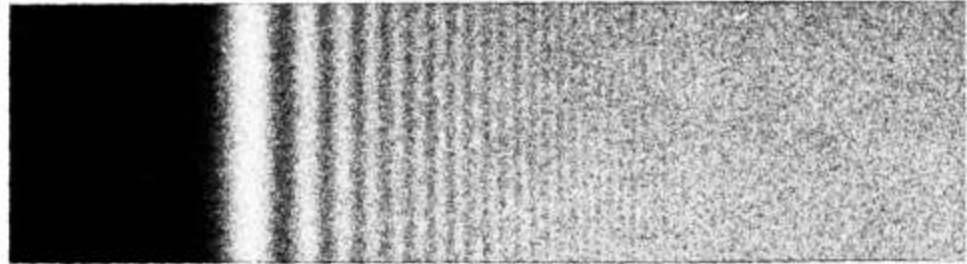


30 m

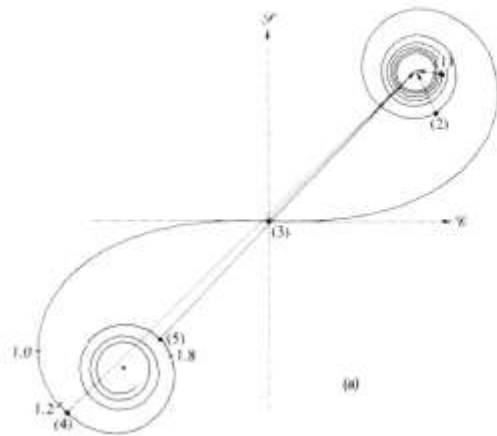


C12. Difractia luminii

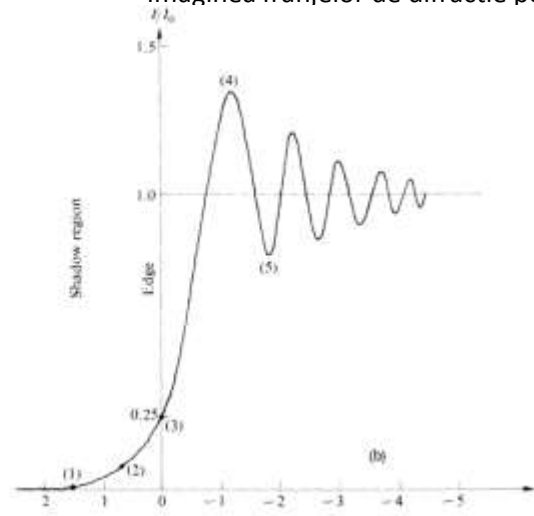
Difractia Fresnel (*near field diffraction*)



Imaginaa franjelor de difractie pe marginea unui ecran



a) Spirala Cornu pentru un plan semi-infinit



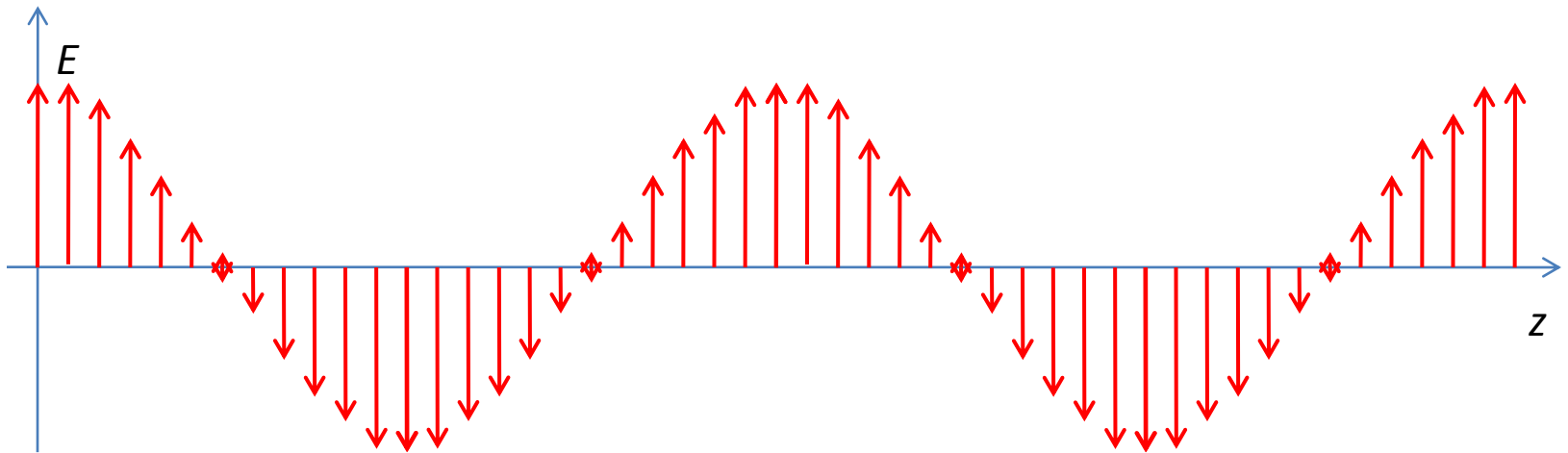
b) Distributia iradiantei

C13. Polarizarea luminii

Polarizarea liniara

Lumina este o unda transversala. Campul electric si campul magnetic vibreaza perpendicular pe directia de propagare.

Lumina naturala este nepolarizata. Lumina nepolarizata este un amestec de componente polarizate liniar in toate directiile posibile!

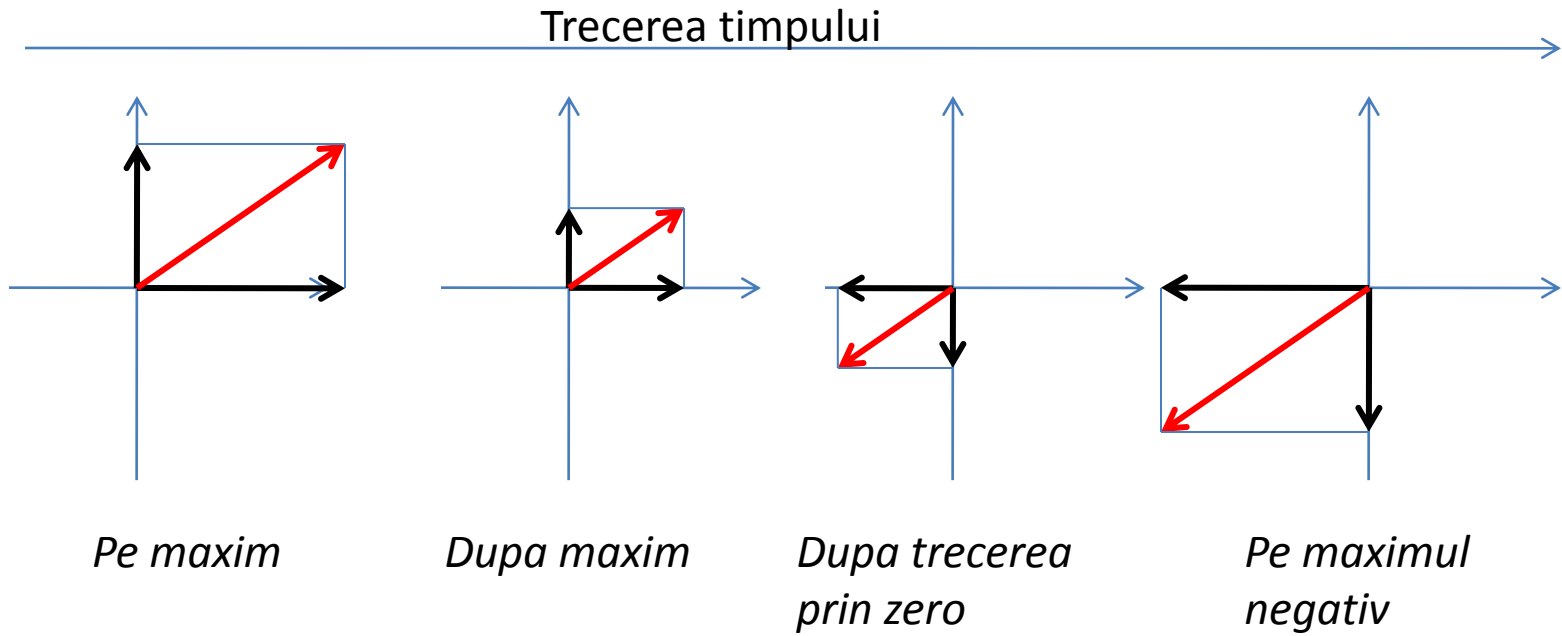


C13. Polarizarea luminii

Suprapunerea a doua unde polarizate liniar , in faza

Doua unde polarizate liniar in faza se aduna si dau tot o unda polarizata liniar cu planul de polarizare diferit.

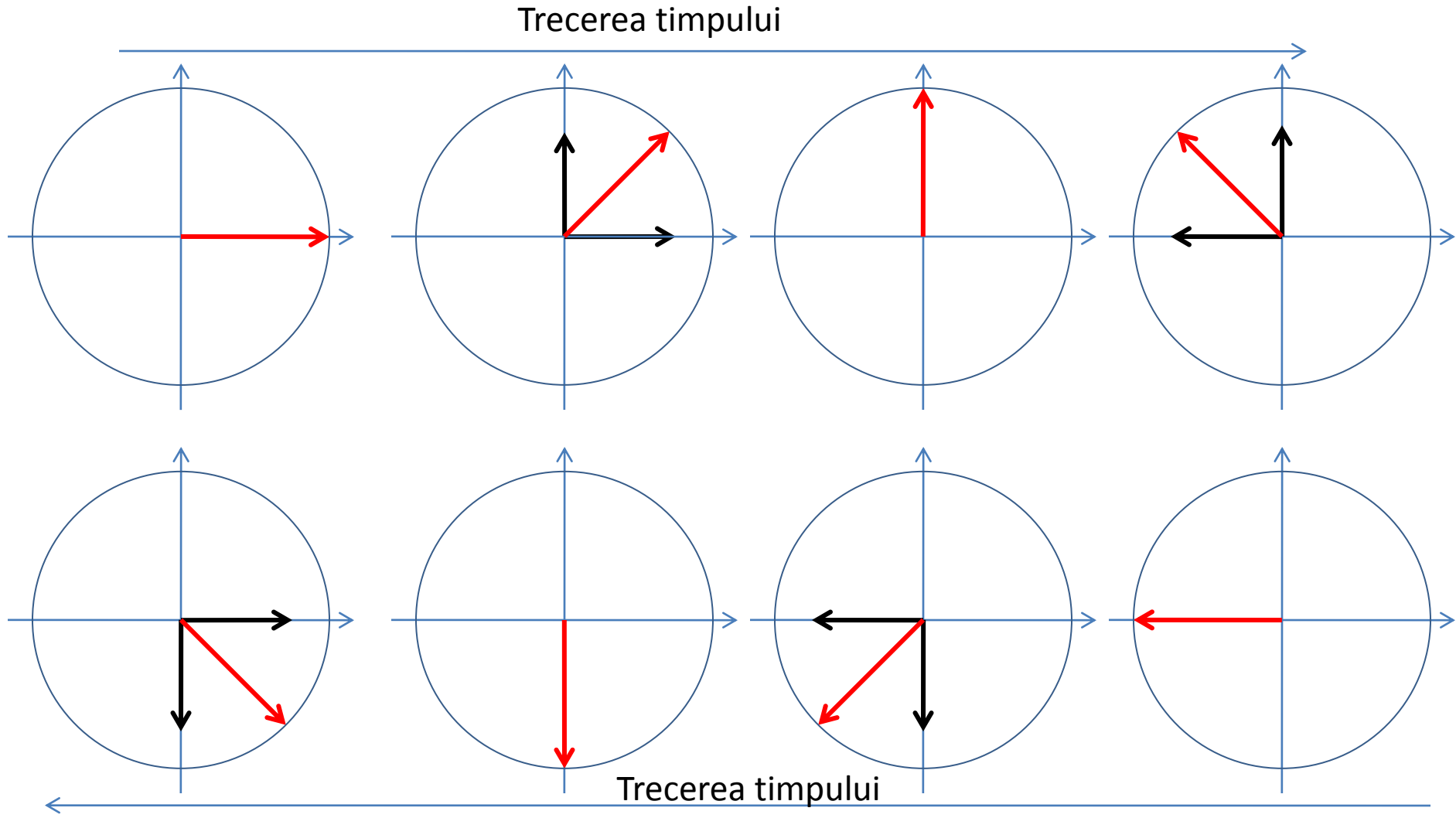
Orice unda polarizata liniar poate fi vazuta ca suma a doua unde polarizate liniar.



C13. Polarizarea luminii

Polarizarea circulara

Doua unde polarizate liniar si defazate cu $\pi/2$ se aduna si dau o unda polarizata circular.



C13. Polarizarea luminii

Metode de obtinere a luminii polarizate

- reflexie;
- birefringenta (refractie);
- dicroism;
- imprastiere (scattering).

C13. Polarizarea luminii

1. Polarizarea prin reflexie (la o suprafata dielectrica)

Raza incidenta este nepolarizata.

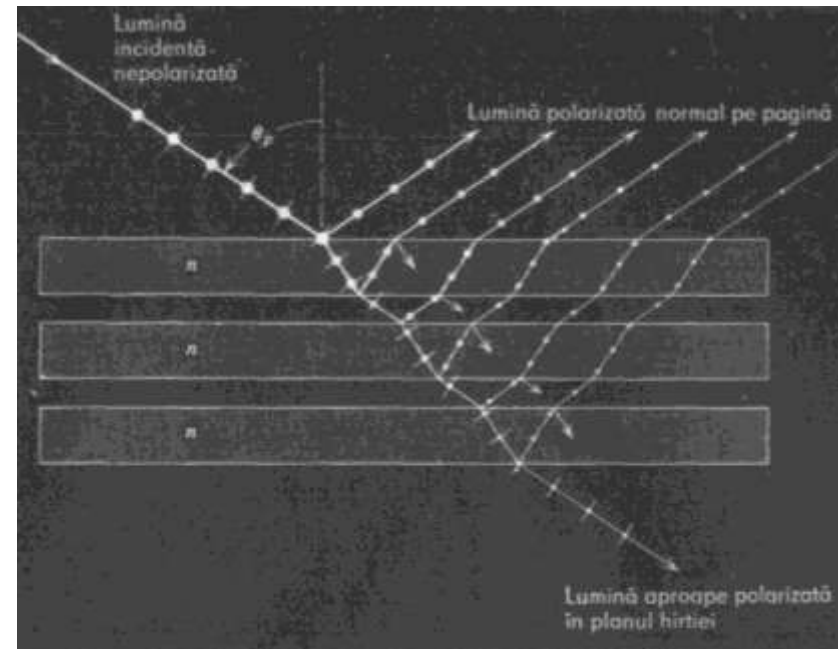
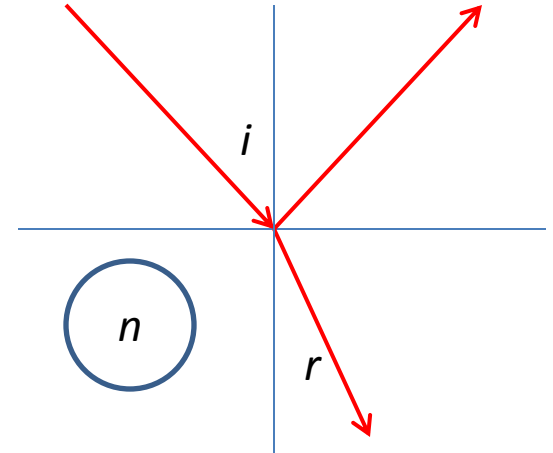
Raza reflectata este partial polarizata in directia perpendiculara pe hartie.

Raza refractata este partial polarizata in planul hartiei.

La incidenta Brewster reflectata si refractata sunt perpendiculare intre ele ($i + r = 90^\circ$).

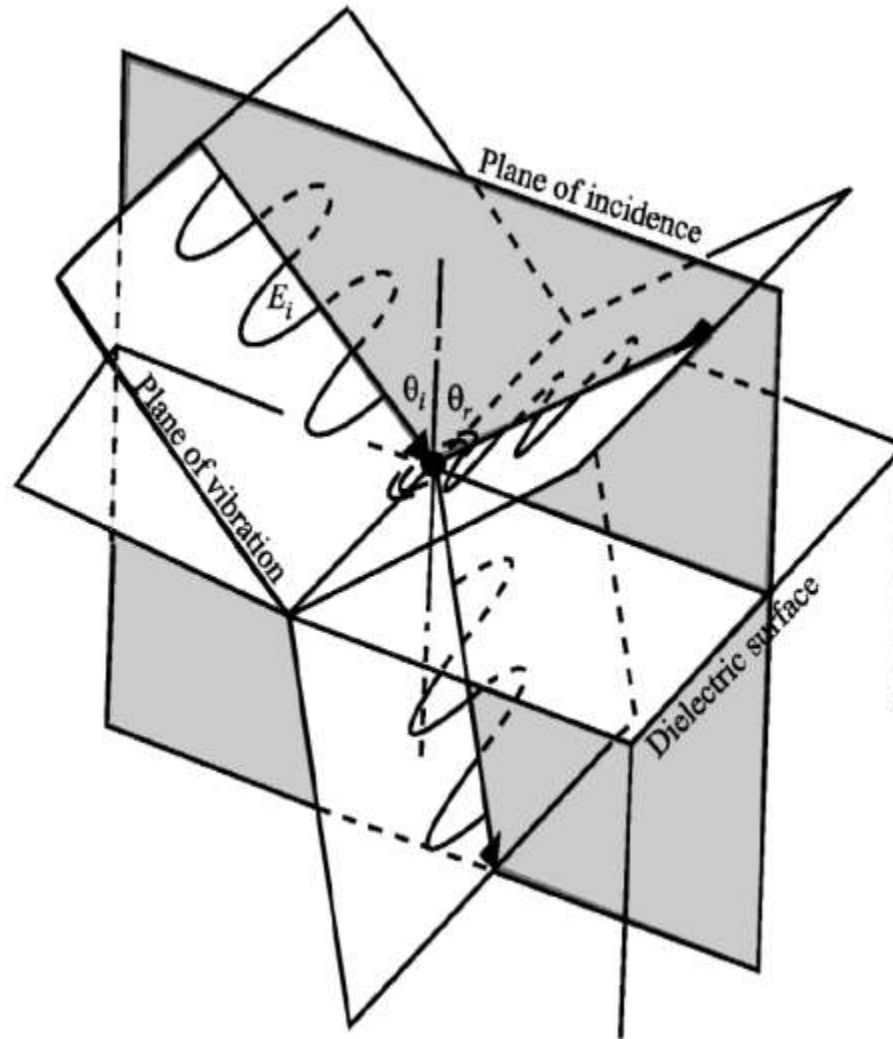
La incidenta Brewster reflectata este complet polarizata.

$$\operatorname{tgi}_B = n$$



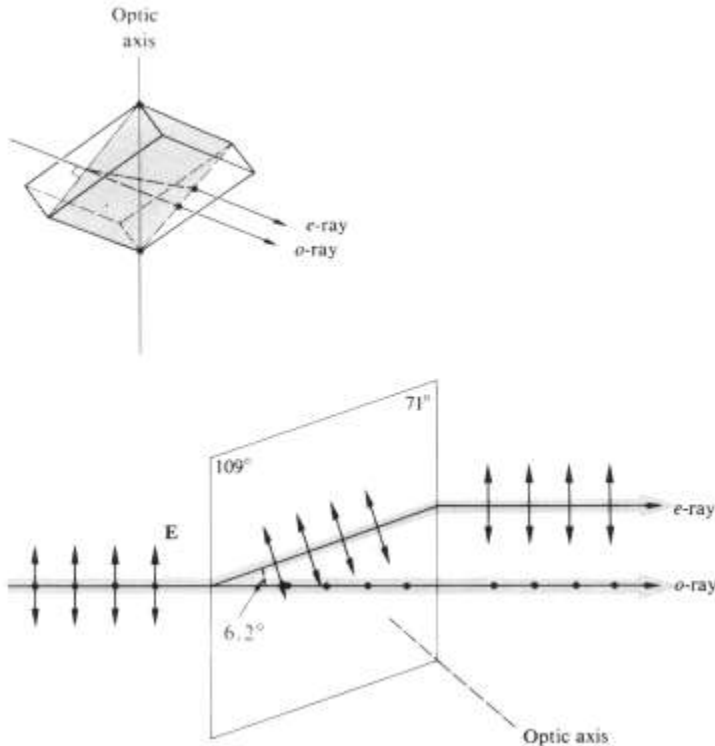
C13. Polarizarea luminii

1. Polarizarea prin reflexie (la o suprafata dielectrica)



C13. Polarizarea luminii

2. Polarizarea prin refractie - Birefringenta



Un fascicul de lumina cu doua componente ortogonale traversand sectiunea principala a calcitei

Birefringenta = dubla refractie

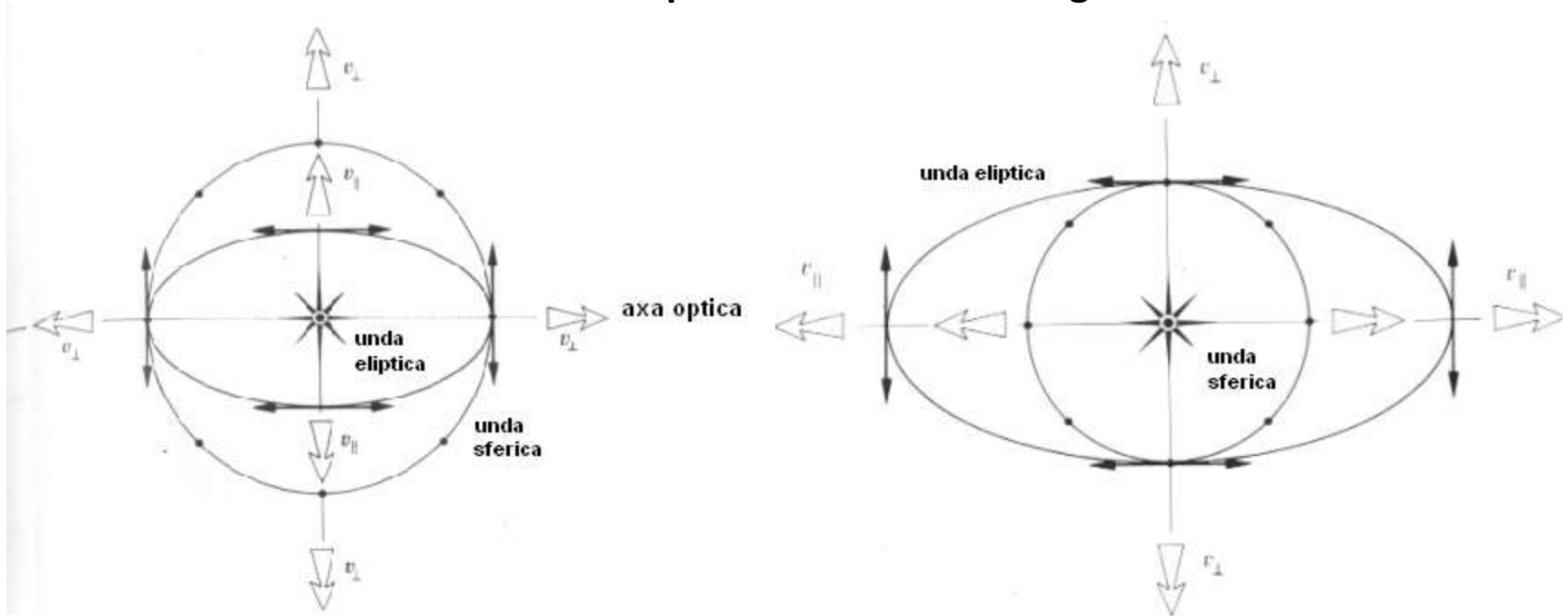
In multe cristale asupra electronilor actioneaza forte diferite pe diferite directii. Aceste cristale se numesc anizotrope.

Viteza luminii in aceste cristale depinde de directia de propagare.

Indicele de refractie depinde de directia de propagare.

C13. Polarizarea luminii

2. Polarizarea prin refractie - Birefringenta



Polarizare in cristal pozitiv

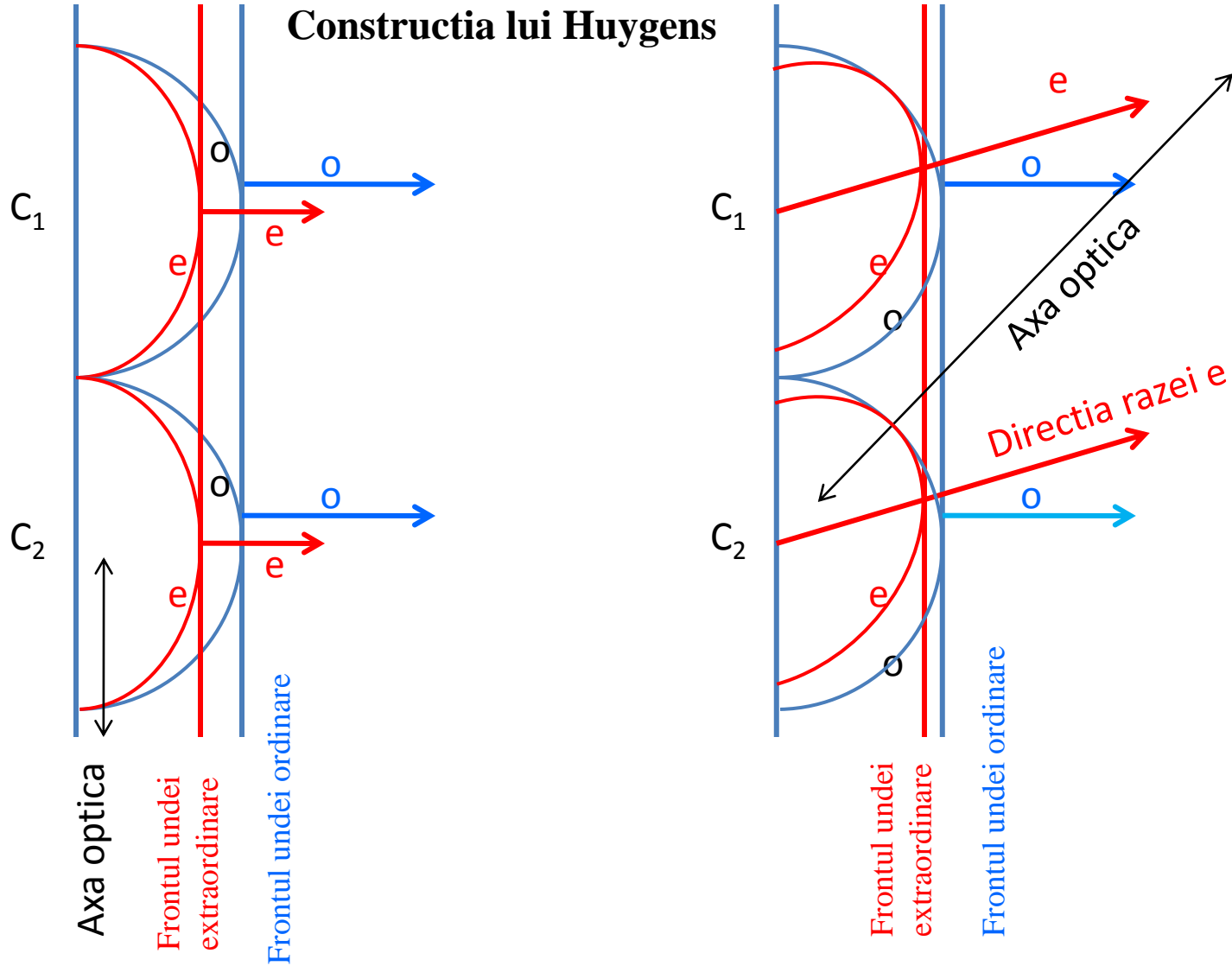
$$v_o > v_e \Rightarrow n_e > n_o \Rightarrow \Delta n = n_e - n_o > 0$$

Polarizare in cristal negativ

$$v_o < v_e \Rightarrow n_e < n_o \Rightarrow \Delta n = n_e - n_o < 0$$

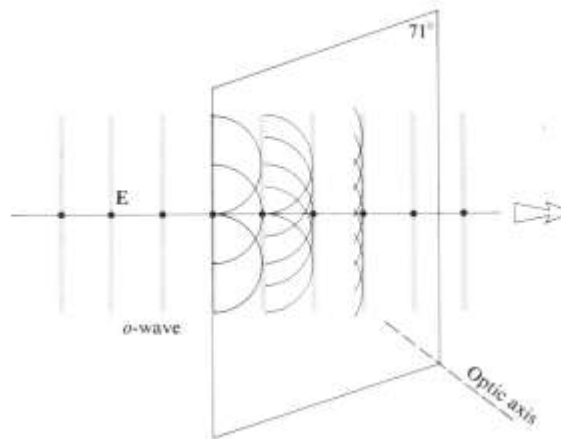
C13. Polarizarea luminii

2. Polarizarea prin refractie - Birefringenta

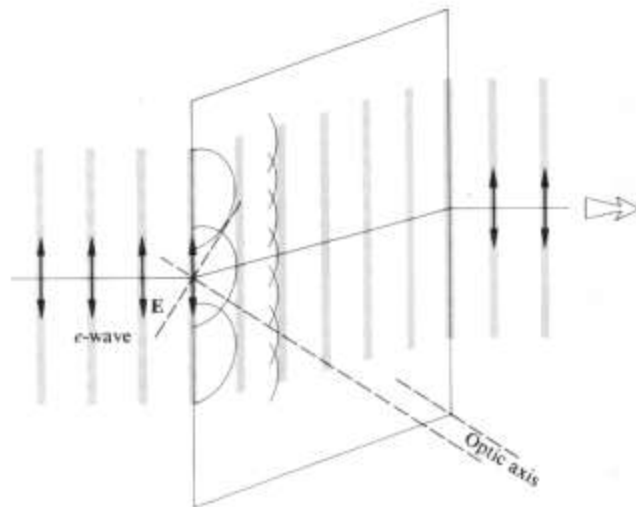


C13. Polarizarea luminii

2. Polarizarea prin refractie - Birefringenta



Incidenta unei unde plane polarizata perpendicular pe sectiunea principala

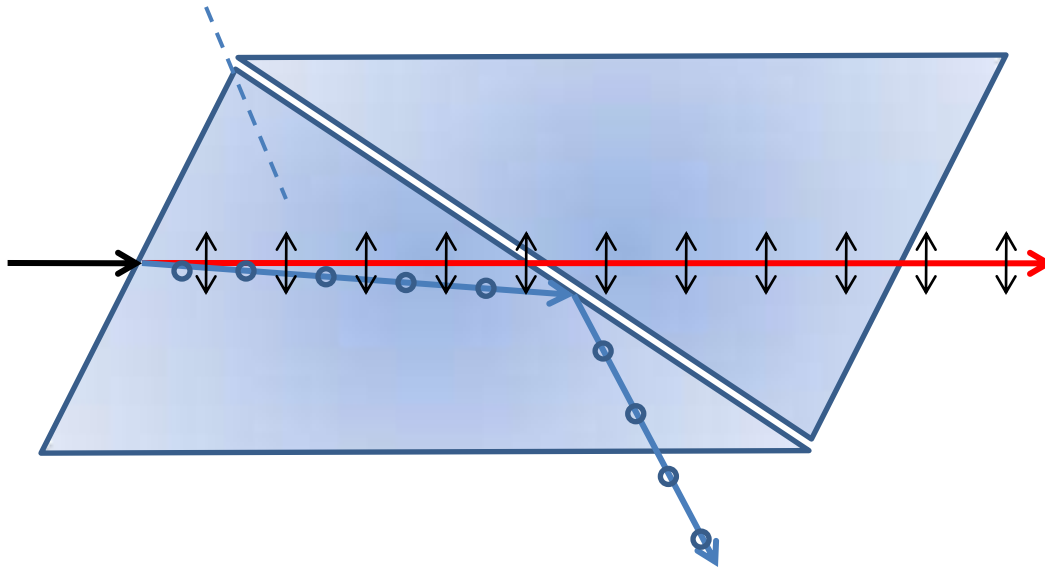


Incidenta unei unde plane polarizata paralel cu sectiunea principala

C13. Polarizarea luminii

2. Polarizarea prin refractie - Birefringenta

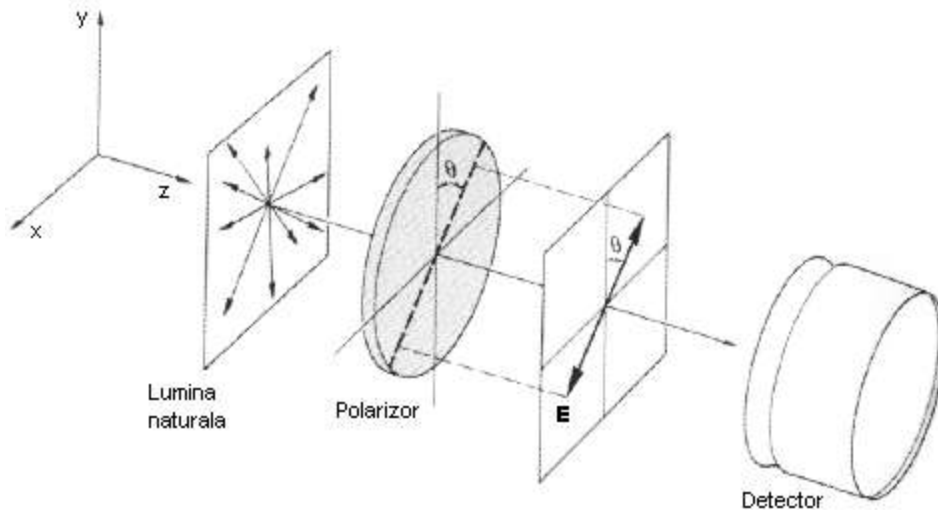
Lumina polarizata se obtine folosind prisma Nicol. Este un ansamblu de doua prisme de calcita ($n_o = 1.65$ si $n_e = 1.48$) lipite cu balsam de Canada ($n = 1.55$).



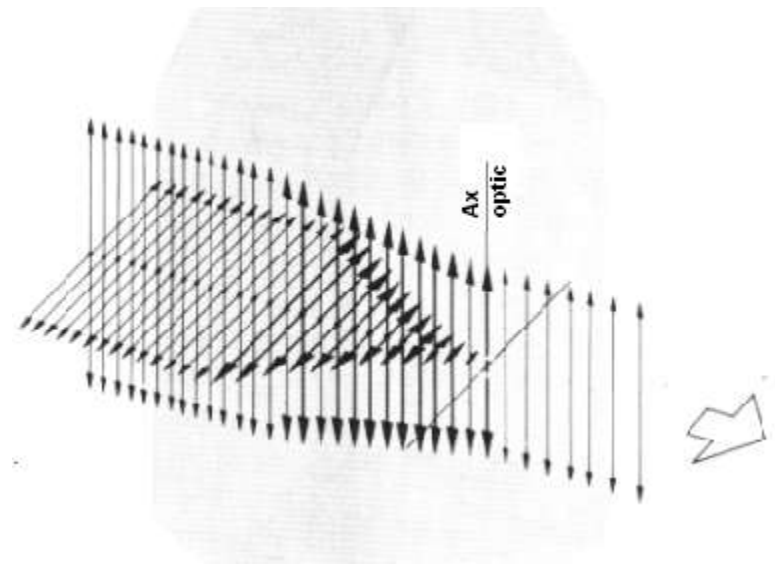
C13. Polarizarea luminii

Polarizare prin dicroism

Dicroism = absorbtia selectiva a uneia dintre cele doua componente ortogonale ale fasciculului incident.



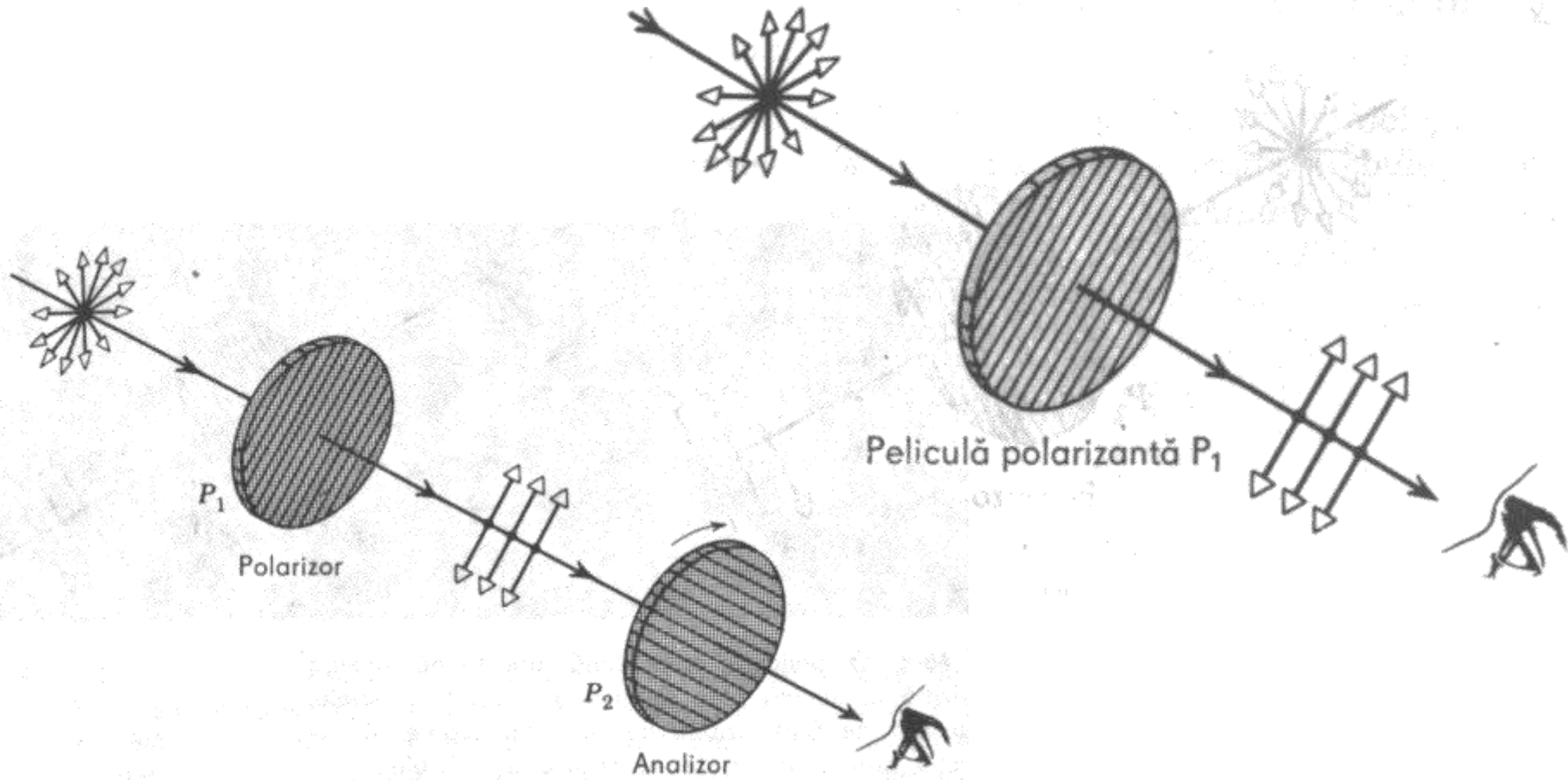
Un filtru polaroid



Un cristal dicroic

C13. Polarizarea luminii

Metode de polarizare



C13. Polarizarea luminii

Placi retardoare

Se folosesc la modificarea starii de polarizare a undei incidente. Se taie dintr-un cristal de calcita cu **fetele paralele cu axa optica**.

Unda incidenta se descompune in ordinara si extraordinara, care au polarizari ortogonale si aceeasi directie de propagare, dar **viteze diferite**. La iesirea din cristal ele recombina (interfera) iar rezultatul depinde de defazajul introdus de lama.

$$\delta = (n_e - n_o)l \Rightarrow \Delta\varphi = \frac{2\pi}{\lambda}(n_e - n_o)l$$

Lama unda (λ)

$$\delta = \lambda \Rightarrow \Delta\varphi = 2\pi$$

Cele doua unde sunt in faza la iesire. Nu se modifica starea de polarizare a undei incidente. Plasata intre doi nicoli incrucisati se obtine intuneric dupa analizor. In lumina alba apare un spectru "canelat", pentru ca indicii de refractie n_e si n_o depind de lungimea de unda.

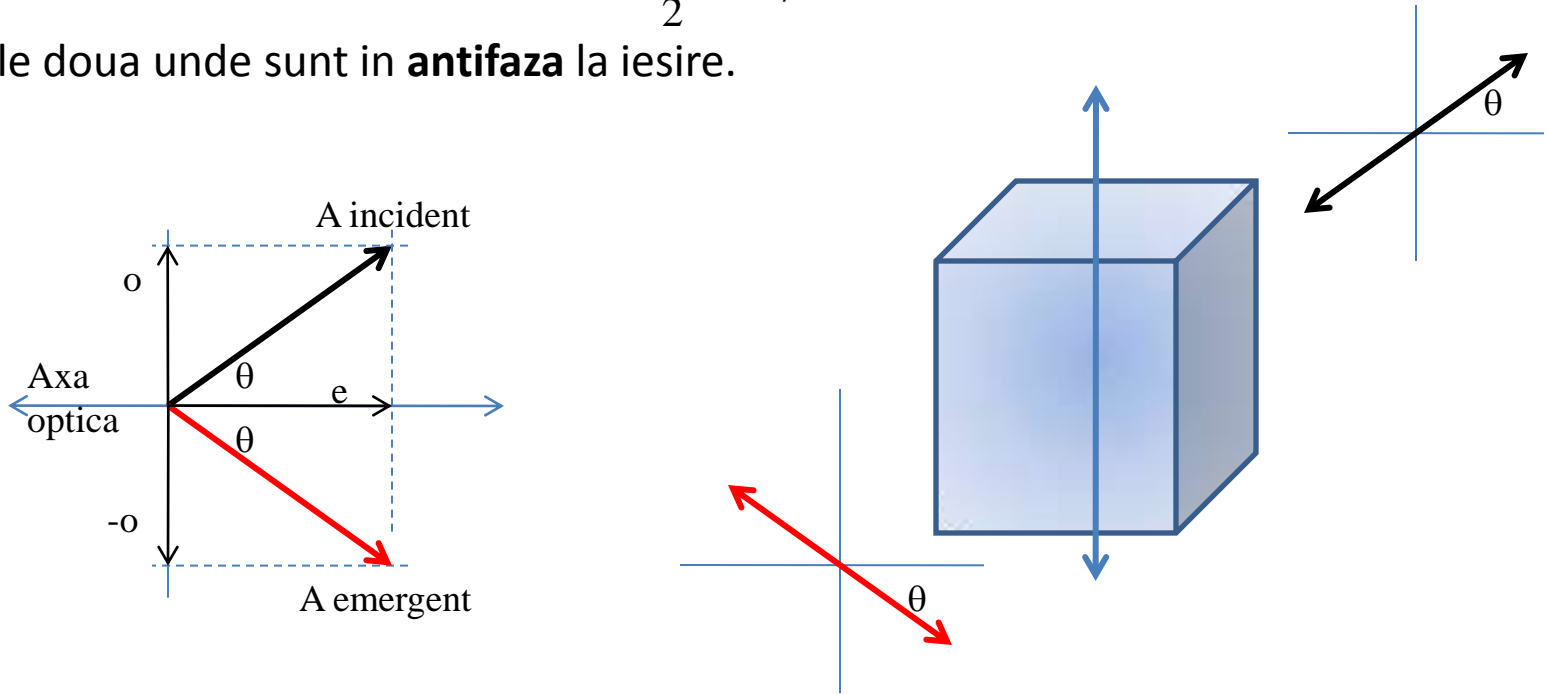
C13. Polarizarea luminii

Placi retardoare

Lama semi-unda ($\lambda/2$)

$$\delta = \frac{\lambda}{2} \Rightarrow \Delta\varphi = \pi$$

Cele doua unde sunt in **antifaza** la iesire.



Lumina incidenta polarizata liniar iese tot polarizata liniar, dar cu directia de polarizare simetrica fata de axa optica (rotita cu 2θ).

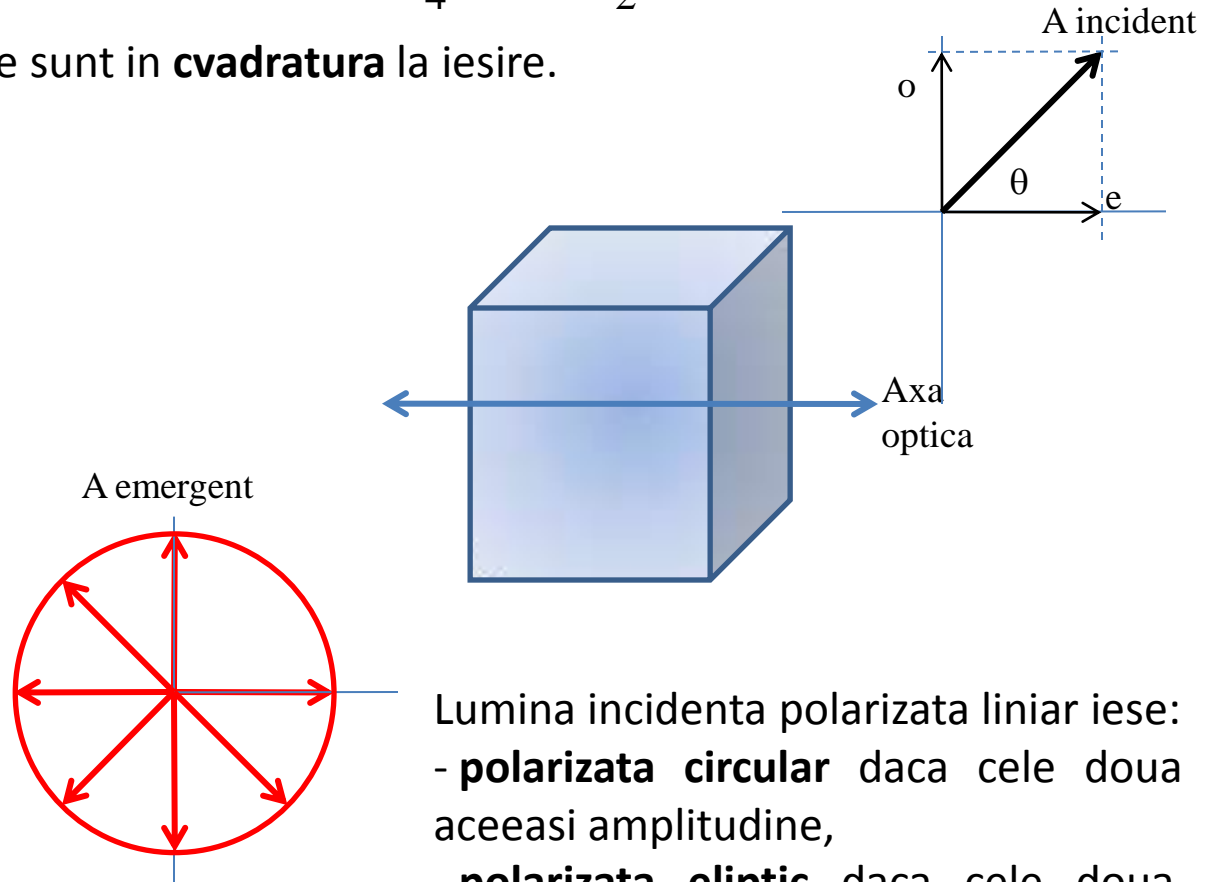
C13. Polarizarea luminii

Placi retardoare

Lama sfert de unda ($\lambda/4$)

$$\delta = \frac{\lambda}{4} \Rightarrow \Delta\varphi = \frac{\pi}{2}$$

Cele doua unde sunt in **cvadratura** la iesire.



Lumina incidenta polarizata linear iese:

- **polarizata circular** daca cele doua unde au aceeasi amplitudine,
- **polarizata eliptic** daca cele doua unde au amplitudini diferite.

C13. Polarizarea luminii

Polarizarea rotatorie

