1. Lumière

$V_{\text{lumière vide}}$: $c_0 = 299\,792\,458$ m/s

Energie d'une particule:

$$E = h \cdot f = \hbar \cdot \omega$$

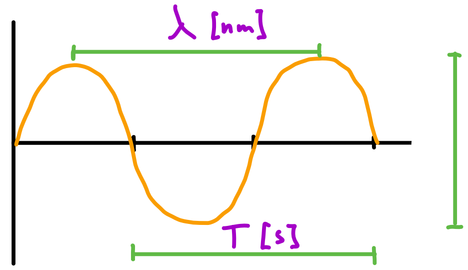
Const. Planque : $h = 6{,}625 \cdot 10^{-34}$ Js | f = fréquence

$\hbar = \frac{h}{2\pi}$ | $\omega = 2 \cdot \pi \cdot f$

Vitesse de propagation :

Période : $T = \frac{1}{f}$

$$c = f \cdot \lambda$$



$E_{\text{onde}} \approx A^2$

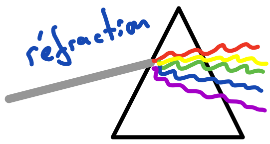
2. Propagation lumière

Indice de réfraction : $n = \frac{c_0}{c}$

c = vitesse lumière dans le milieu

Dispersion :

c diminue plus λ diminue



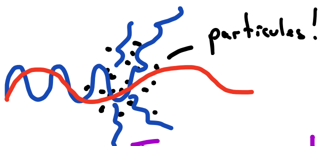
décomposition

Diffraction (Beugung)

$d \gg \lambda \Rightarrow$ négliger diffraction

$d \approx \lambda \Rightarrow$ pas négligable

Diffusion

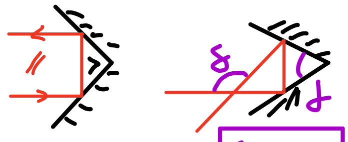


$d \approx \lambda \Rightarrow I_s$ pour tous λ égal !

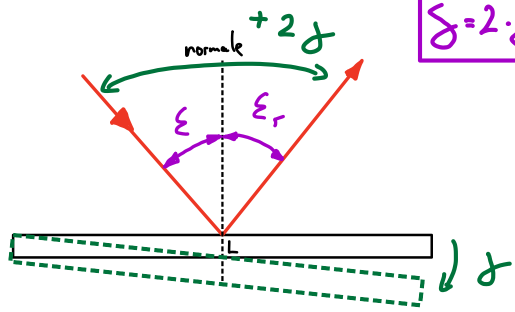
$d \ll \lambda \Rightarrow I_s \approx \frac{1}{\lambda^4} \approx f^4$

$I_s \hat{=}$ Intensité streuung

3. Réflexion

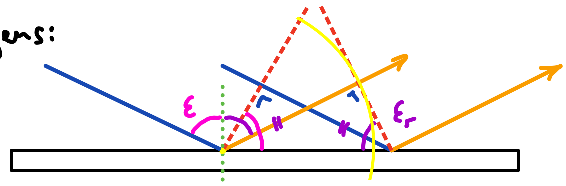


$$\delta = 2 \cdot \gamma$$

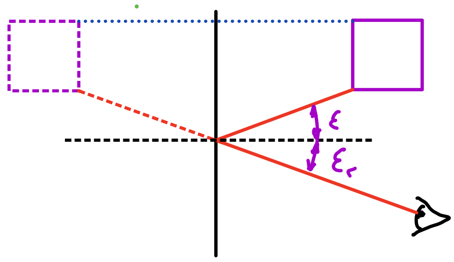


$$\varepsilon = \varepsilon_r$$

Huygens:



Miroir :

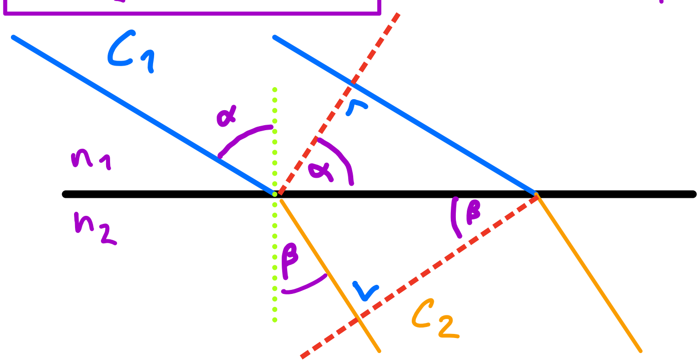


4. Réfraction

$$\frac{\sin \alpha_1}{\sin \alpha_2} = \frac{c_1}{c_2} = \frac{n_2}{n_1}$$

$\alpha_2 = \arcsin\left(\frac{\sin \alpha_1 \cdot n_1}{n_2}\right)$

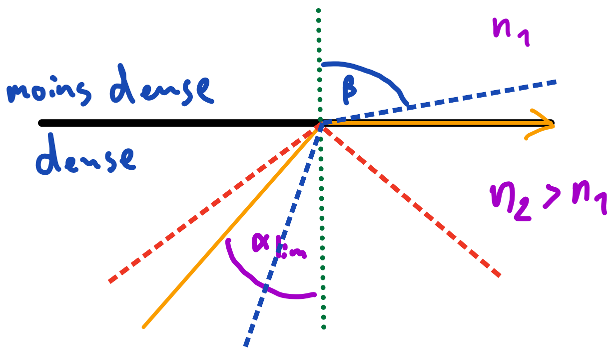
$\alpha_1 = \arcsin\left(\frac{\sin \alpha_2 \cdot n_2}{n_1}\right)$



4.2 Réflexion totale

Si: $\sin \beta = 1$

$$\sin(\alpha_{lim}) = \frac{n_1}{n_2}$$



5. Fibre Optique

$$NA = n_0 \cdot \sin(\phi) = \sqrt{n_1^2 - n_2^2}$$

⇒ environ 10° en général

Bandwidth (débit binaire)

Fiber Type	Bandwidth
Single-mode	100 GHz-km
Graded index	500 MHz-km @ 1300 nm 160 MHz-km @ 850 nm
Step index	20 MHz-km

Typical Optical Fiber Bandwidths

Atténuation

Pertes [dB] : $A = 10 \log\left(\frac{P_{in}}{P_{out}}\right)$

$P_{in/out}$ = puissance optique qui entre et sort de la fibre

Atténuation/km : $\alpha = \frac{A}{L}$ $\quad [\alpha] = \frac{dB}{km}$

↳ Multimode saut d'indice | 5-6 dB/km à 850 nm
gradient d'indice | 3 dB/km à 850 nm
Monomode | 0,4 dB/km à 1300 nm

Débit binaire × longueur (capacité d'une fibre)

$[B \cdot L] = Hz \cdot km$ $\quad \Delta t = \frac{1}{B}$ { temps entre deux impulsions quelconques

Dispersion des modes (multimode)

Multimode à saute d'indice

$$\Delta t = \frac{L \cdot n_1}{c_0} \cdot \Delta \qquad \Delta = \frac{n_1 - n_2}{n_2} \qquad B \cdot L = \frac{1}{\Delta t} \cdot L = \frac{c_0}{\Delta \cdot n_1}$$

Multimode à gradiant d'indice

$$\Delta t = \frac{L \cdot n_1}{c_0} \cdot \frac{\Delta^2}{2} \qquad B \cdot L = \frac{2 \cdot c_0}{\Delta^2 \cdot n_1}$$

→ $[km/s] = 299\,792,458$ km/s

Dispersion chromatique (monomode)

(dispersion du matériel)

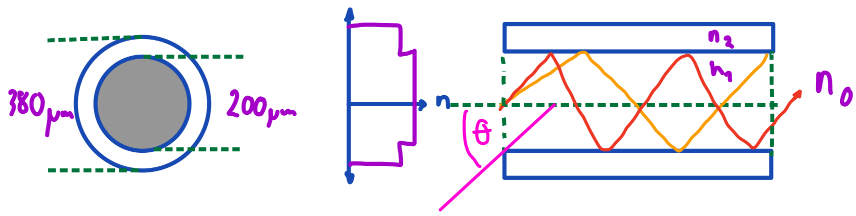
$$\Delta t = |D| \cdot L \cdot \Delta\lambda \qquad B \cdot L = \frac{1}{|D| \cdot \Delta\lambda} \qquad (\lambda \neq \lambda_0)$$

$[D] = \frac{ps}{nm \cdot km}$ Constante dispersion (dispersion matérielle + dispersion conducteur)

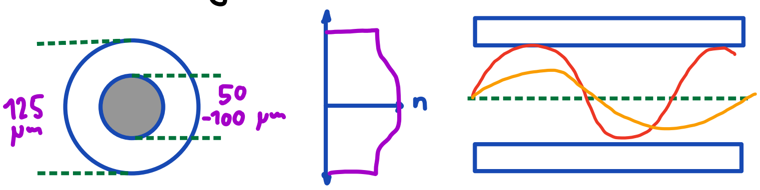
$$\Delta t = \frac{1}{8} \cdot L \cdot S_0 \cdot \Delta\lambda^2 \qquad B \cdot L = \frac{8}{S_0 \cdot \Delta\lambda^2} \qquad (\lambda = \lambda_0)$$

S_0 : pente de $D(\lambda)$ à λ_0 $\quad [S_0] = \frac{ps}{nm^2 \cdot km}$

Fibre saut d'indice (multimode)



Fibre gradient d'indice (multimode)



⇒ signal plus rapide

Longueurs d'onde

gamma	x	UV	IR	micro-onde	radio
1 pm	1 nm	400	800 nm	1 mm	1 m

Trigo

$\cos(90 - \alpha) = \sin(\alpha)$

$\sin(90 - \alpha) = \cos(\alpha)$

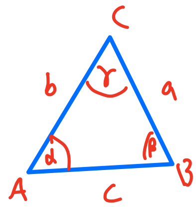
$\cos\alpha = \sqrt{1 - \sin^2\alpha}$

$\sin\alpha = \sqrt{1 - \cos^2\alpha}$

$\cos^2\alpha + \sin^2\alpha = 1$

Thm sinus

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}$$



Thm cosinus :

$$a^2 = b^2 + c^2 - 2 b \cdot c \cos\alpha$$

$\sin(2\alpha) = 2\sin(\alpha)\cos(\alpha)$

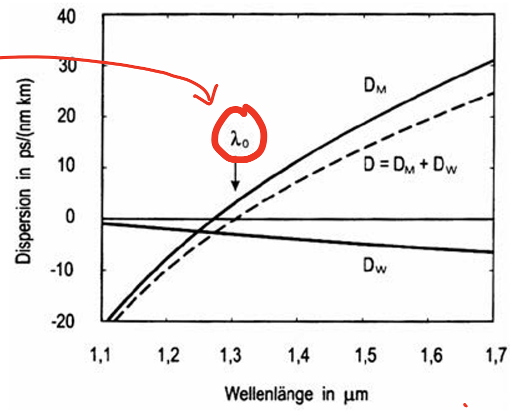
$\cos(2\alpha) = 1 - 2\sin^2(\alpha)$

$\cos(a+b) = \cos(a)\cos(b) - \sin(a)\sin(b)$

$\cos(a-b) = \cos(a)\cos(b) + \sin(a)\sin(b)$

$\sin(a+b) = \sin(a)\cos(b) + \cos(a)\sin(b)$

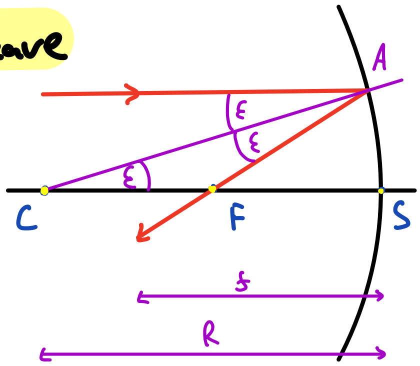
$\sin(a-b) = \sin(a)\cos(b) - \cos(a)\sin(b)$



7. Images optiques

Miroir concave

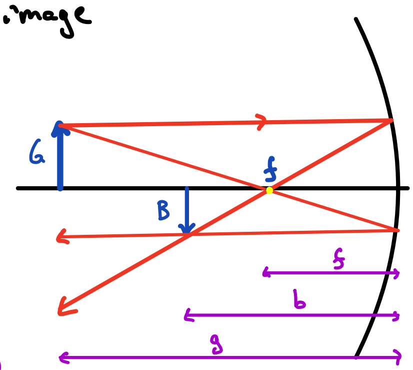
$f = \frac{1}{2} R$



Formation d'image

$\frac{1}{f} = \frac{1}{g} + \frac{1}{b}$

G = taille objet
B = taille image



Grandissement

$\beta = -\frac{b}{g} = -\frac{B}{G}$

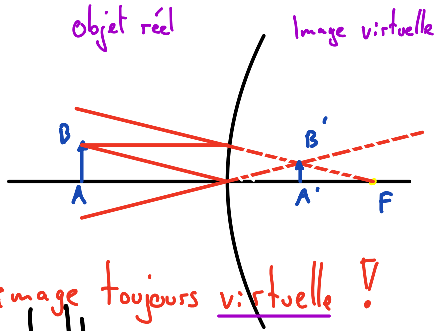
$\beta > 0$ ⇒ image debout
$\beta < 0$ ⇒ image renversée

$g = 2f$ ⇒ image taille 1:1
$g > f$ ⇒ image réelle inversée
$g = f$ ⇒ image à l'infini
$g < f$ ⇒ image virtuelle derrière miroir

Miroir convexe

Même formules
⚠ signe négatif si image virtuelle

objet réel — Image virtuelle



Objet réel ⇒ image toujours virtuelle !

Types de lentilles

Les types de lentille les plus importants:

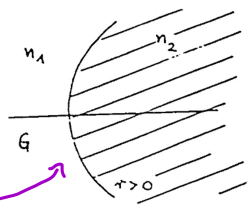
forme						
nom	bi-convexe	plano-convexe	ménisque positif	bi-convave	plano-concave	ménisque négatif

rayon négatif !!
⇒ distance focale négative

Dioptre sphérique

$\frac{n_2 - n_1}{r} = \frac{n_1}{g} + \frac{n_2}{b}$ $\beta = -\frac{n_1}{n_2} \frac{b}{g}$

r positif si convexe vers n_1



Lentilles minces — dans l'air n = 1

Convergente

$\frac{1}{f} = \frac{1}{g} + \frac{1}{b}$

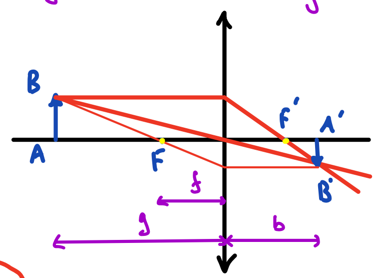
$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$\beta = -\frac{b}{g} = \frac{B}{G}$

formule miroir valide

négatif si point virtuel (image virtuelle)

Objet réel — Image réelle



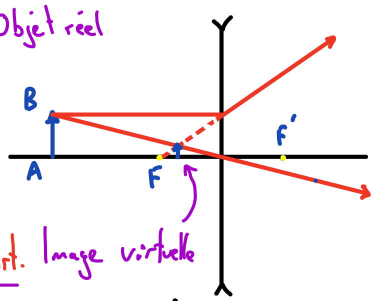
Puissance d'une lentille

$B = \frac{1}{f}$ $[B] = \frac{1}{m} = dp$ ⇒ Dioptrie

Divergente

⚠ signe négatif si image virtuelle

Objet réel



Obj. réel ⇒ image tjrs virt.

Système lentilles distante

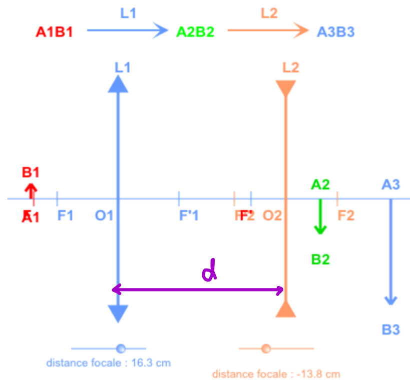
$\frac{1}{b_1} = \frac{1}{f_1} - \frac{1}{g_1}$

$\frac{1}{b_2} = \frac{1}{f_2} - \frac{1}{g_2}$

$\beta = \beta_1 \beta_2 = \left(-\frac{b_1}{g_1}\right)\left(-\frac{b_2}{g_2}\right)$

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 \cdot f_2}$

→ focale total



Lentilles en contact

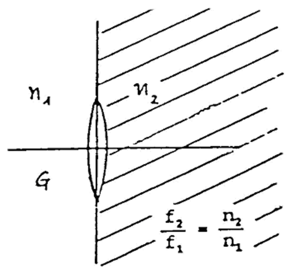
$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

car d est petit on considère ça comme une lentille mince

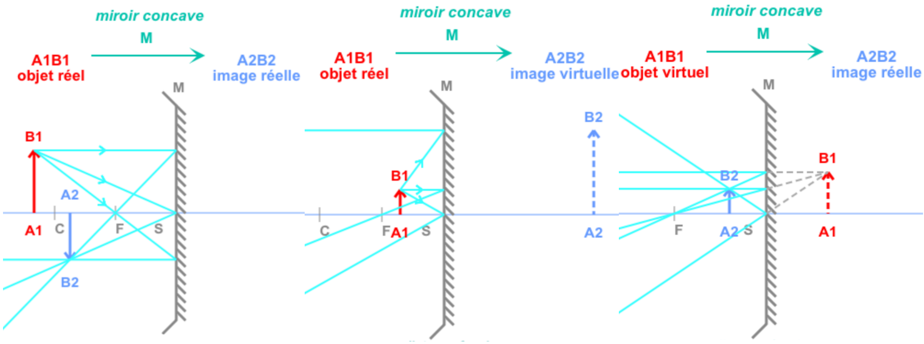
Lentilles mince milieux différents

$\frac{n_2 - n_1}{r} = \frac{n_1}{g} + \frac{n_2}{b}$

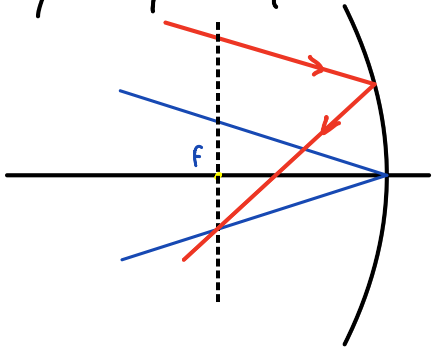
$\beta = -\frac{n_1}{n_2} \cdot \frac{b}{g}$



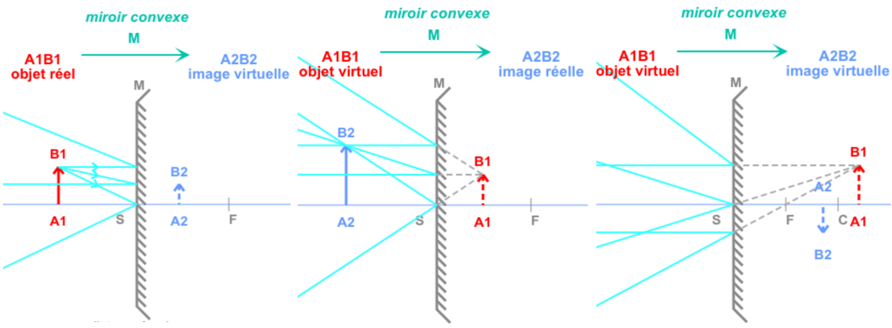
Miroir concave

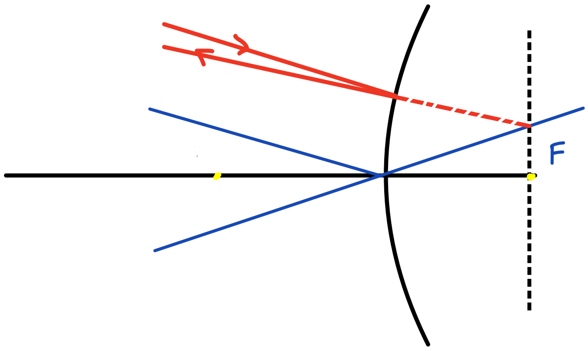


Rayon quelconque

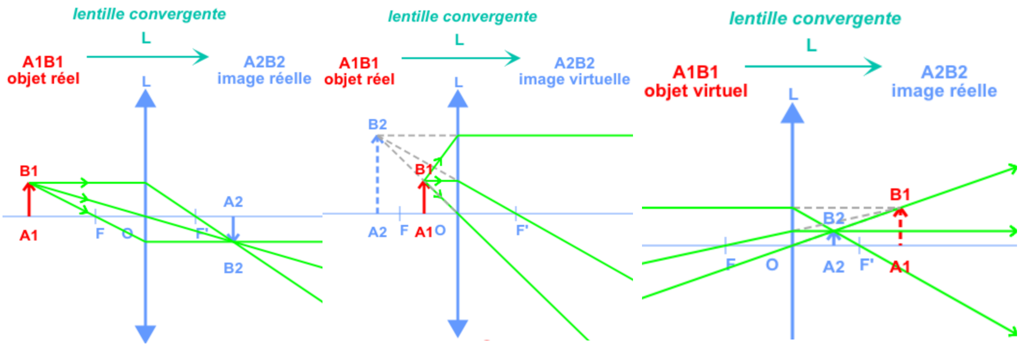


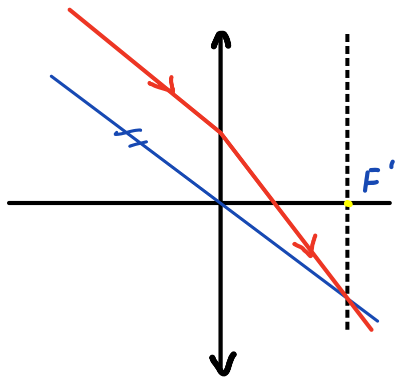
Miroir convexe



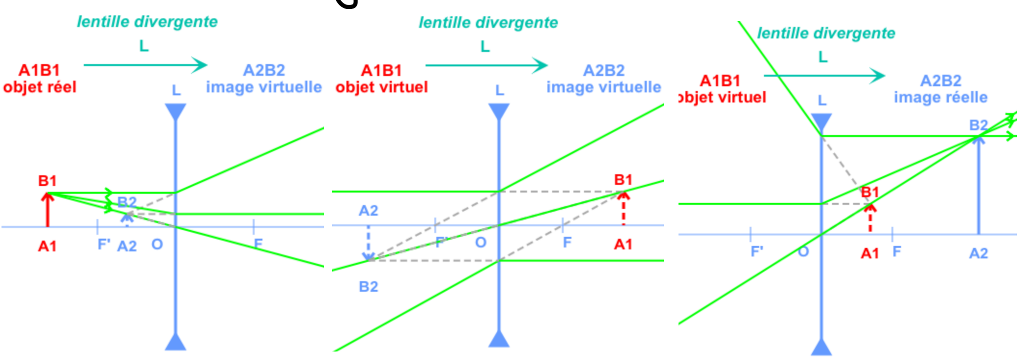


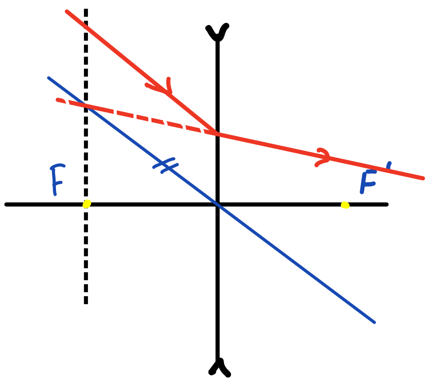
Lentille convergente





Lentille divergente





Objet à l'infini => image toujours à la distance focale

Alphabet grec angles

- α alpha
- β bêta
- γ gamma
- δ delta
- ε epsilon
- η êta
- θ thêta
- μ mu
- φ phi
- ω oméga