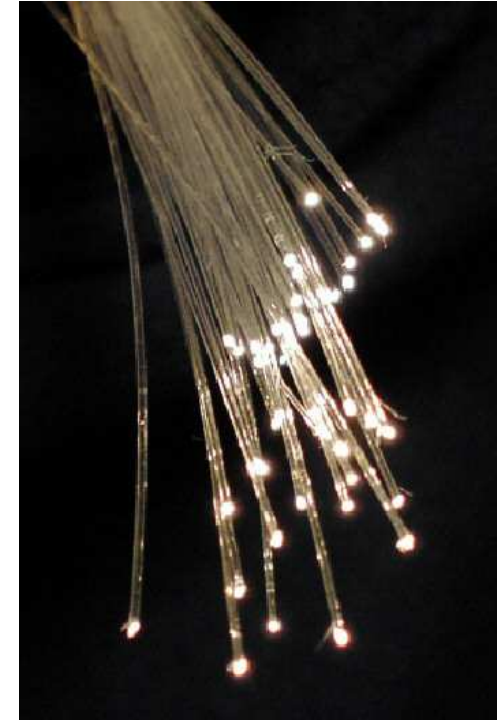
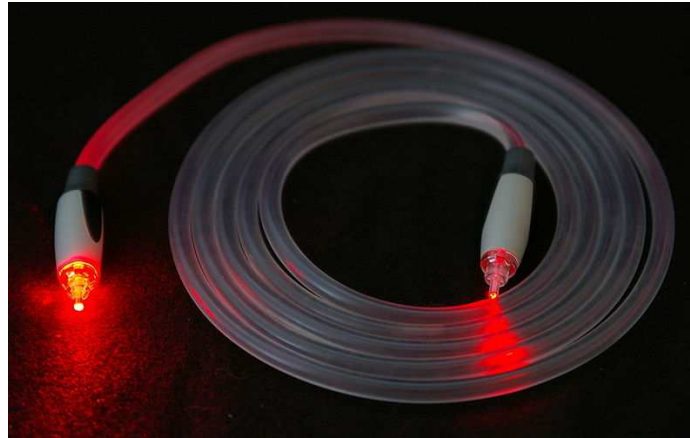


## Sensores Ópticos

*Medição de luz*

*Geração de luz*



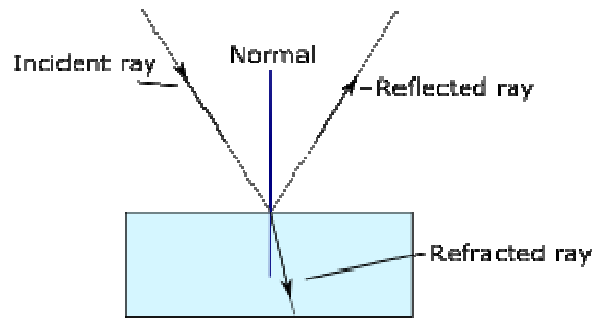
### O que é luz???



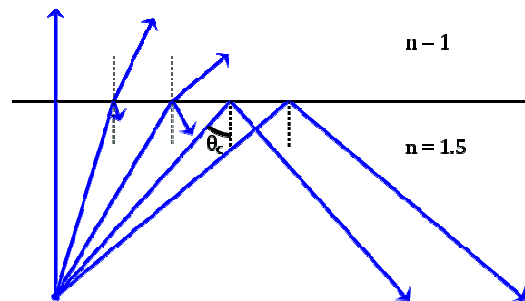
*Raio*  
*Onda*  
*Partícula*

# Raios

## Propagação retilínea

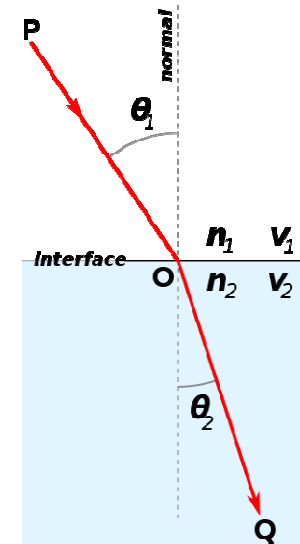


## Reflexão total



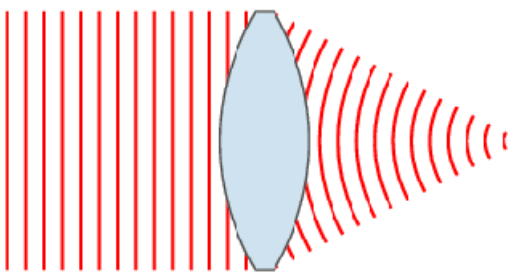
## Lei de Snell

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

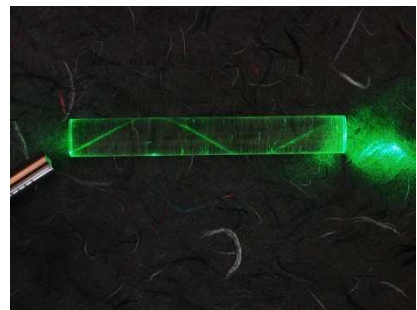


# Raios

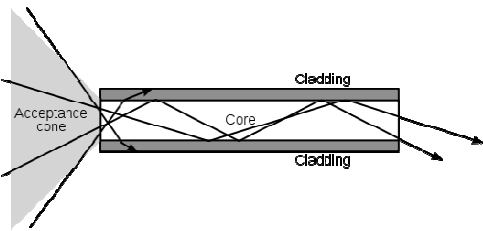
## Focalização e colimação



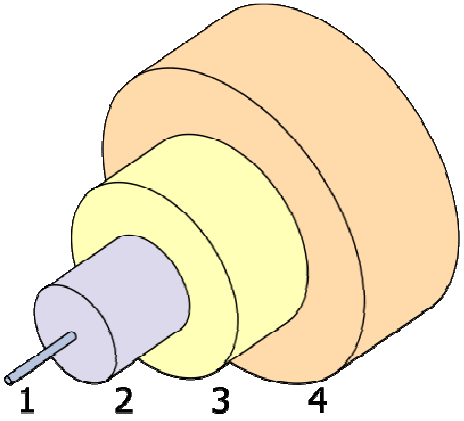
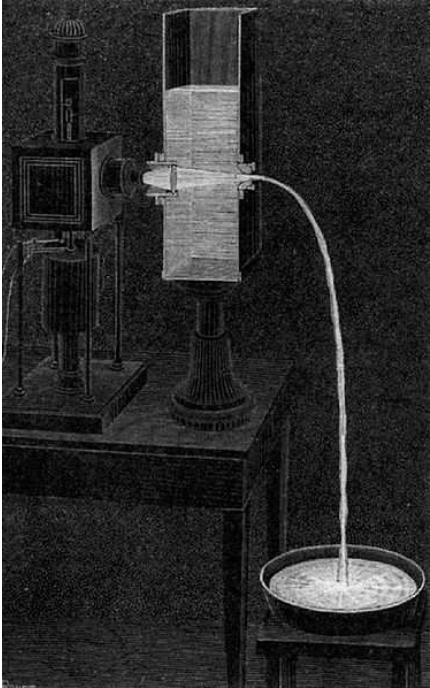
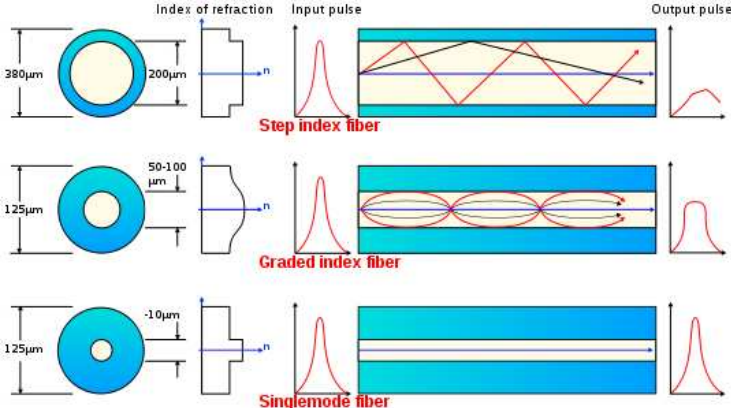
## Confinamento de luz



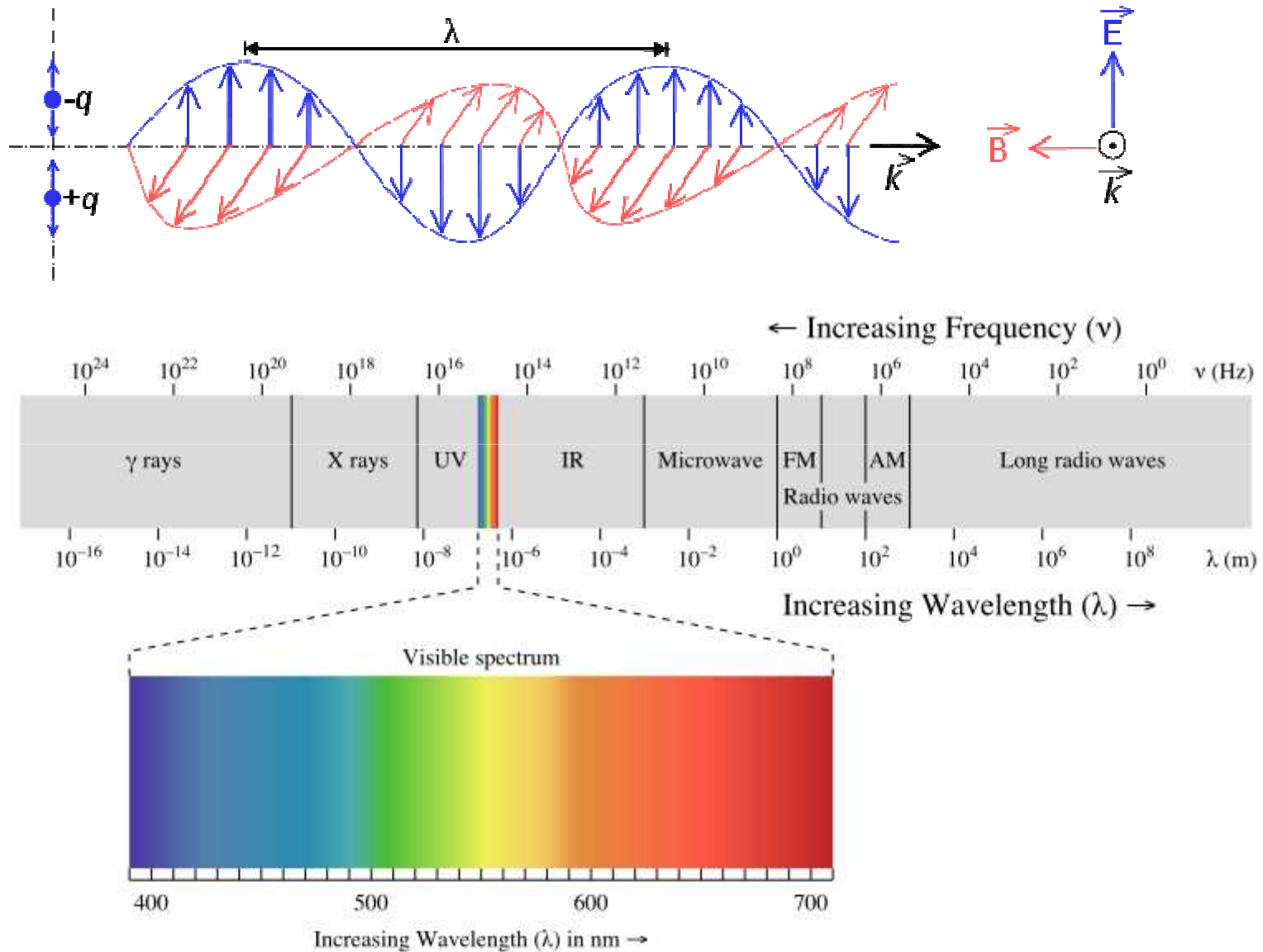
## Fibra óptica



# Fibra óptica

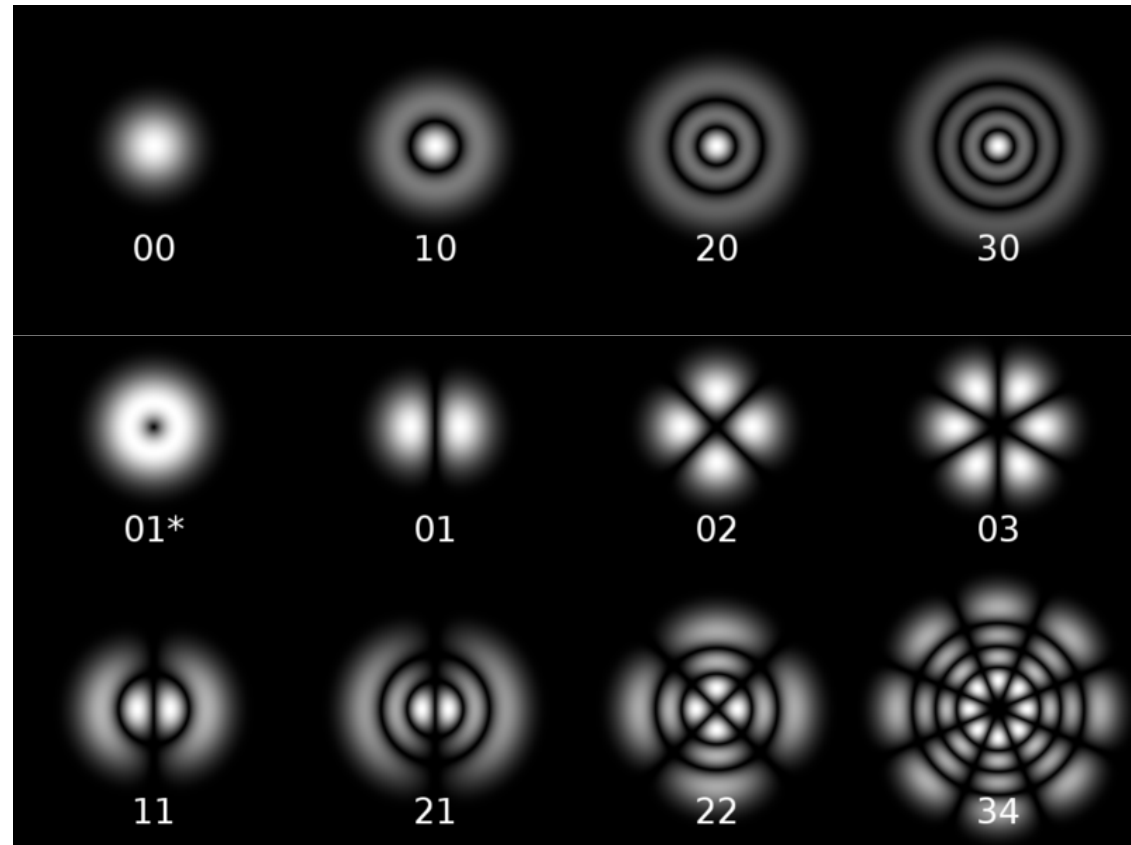
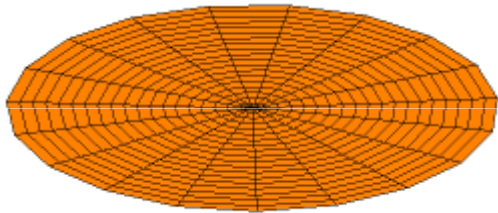


# Onda

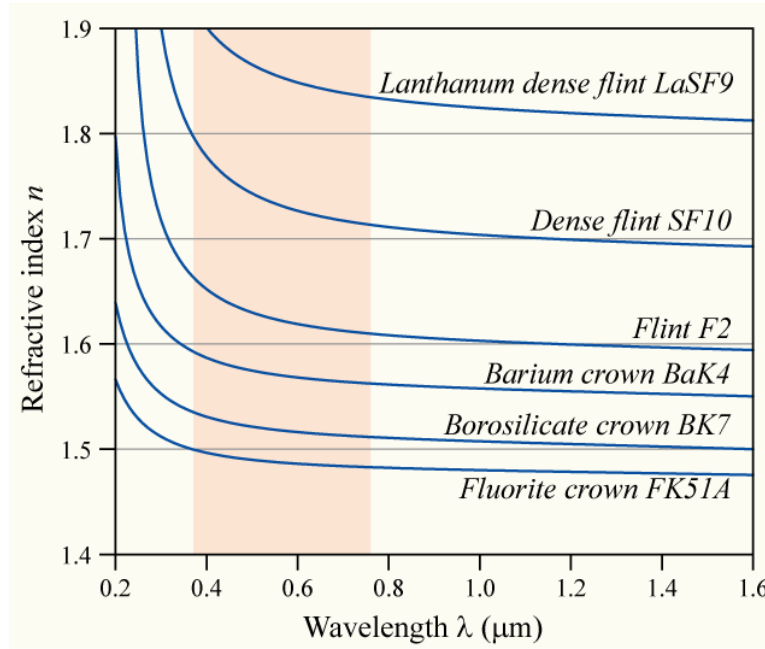


# Onda

## Modos transversais



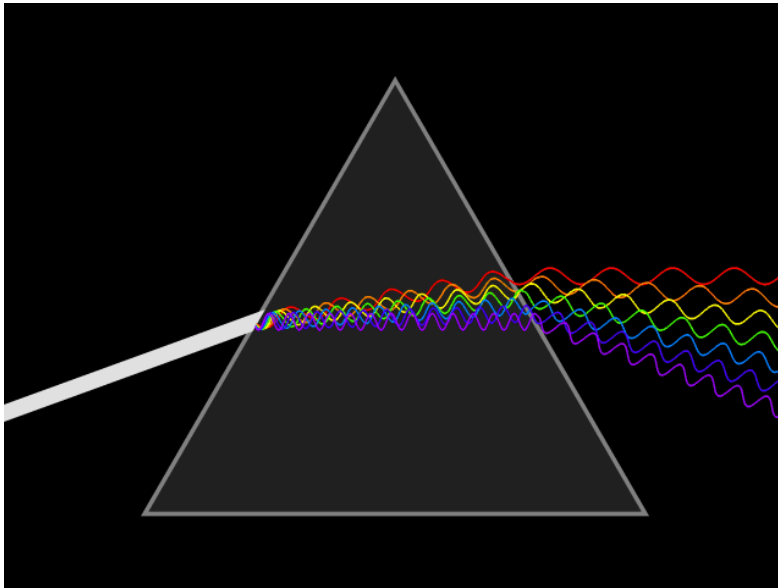
# Lei de Snell



## Equação de Sellmeier

$$n^2(\lambda) = A + \frac{B_1\lambda^2}{\lambda^2 - C_1} + \frac{B_2\lambda^2}{\lambda^2 - C_2}$$

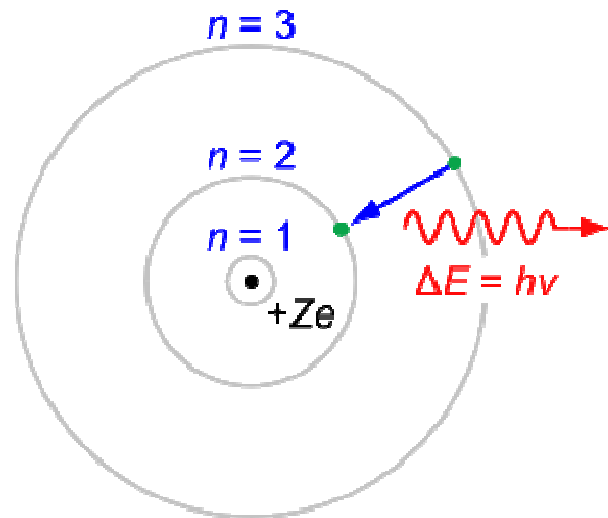
## Dispersão



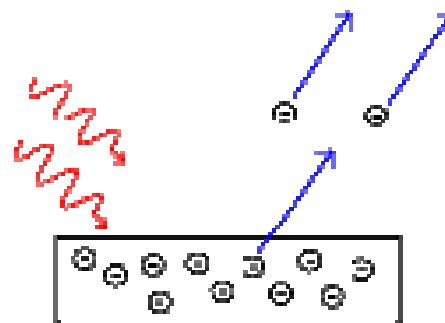
## Aberração cromática

**TESTE**

# Partícula



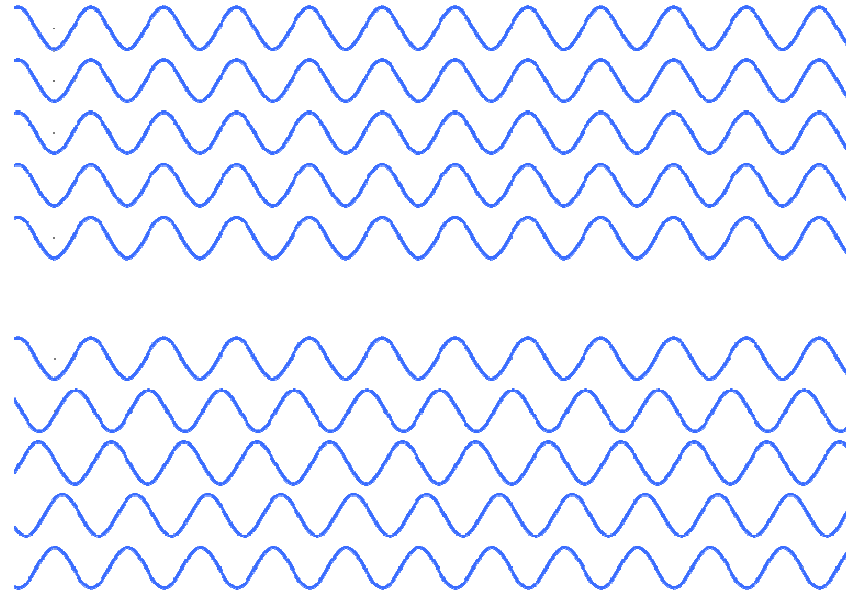
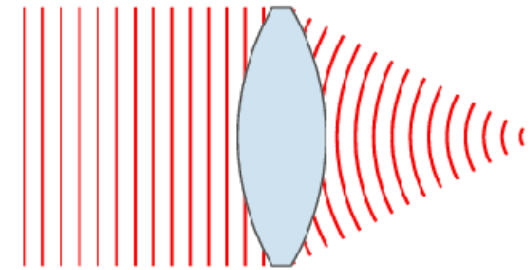
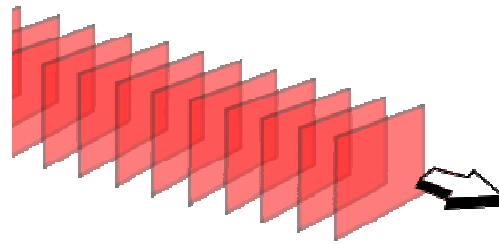
$$E = hf = \frac{hc}{\lambda}$$





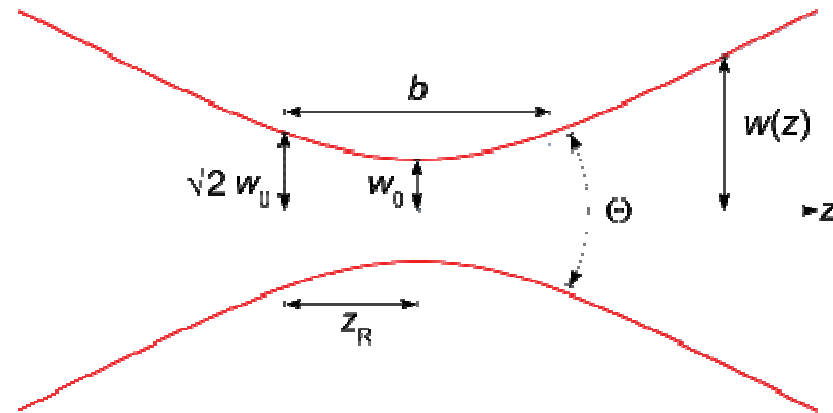
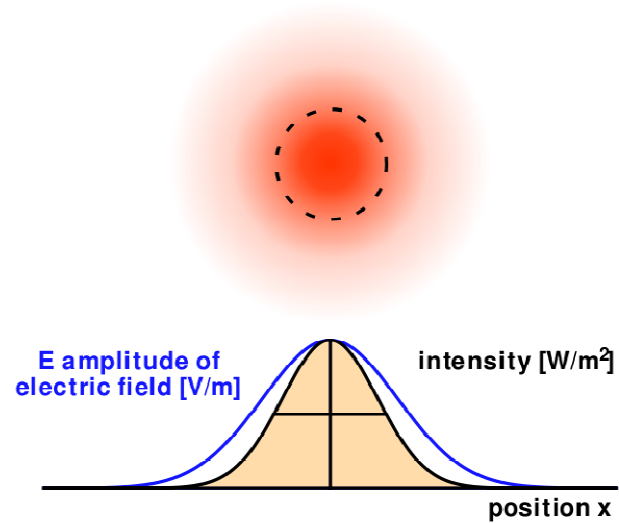
# Onda

Frente de onda



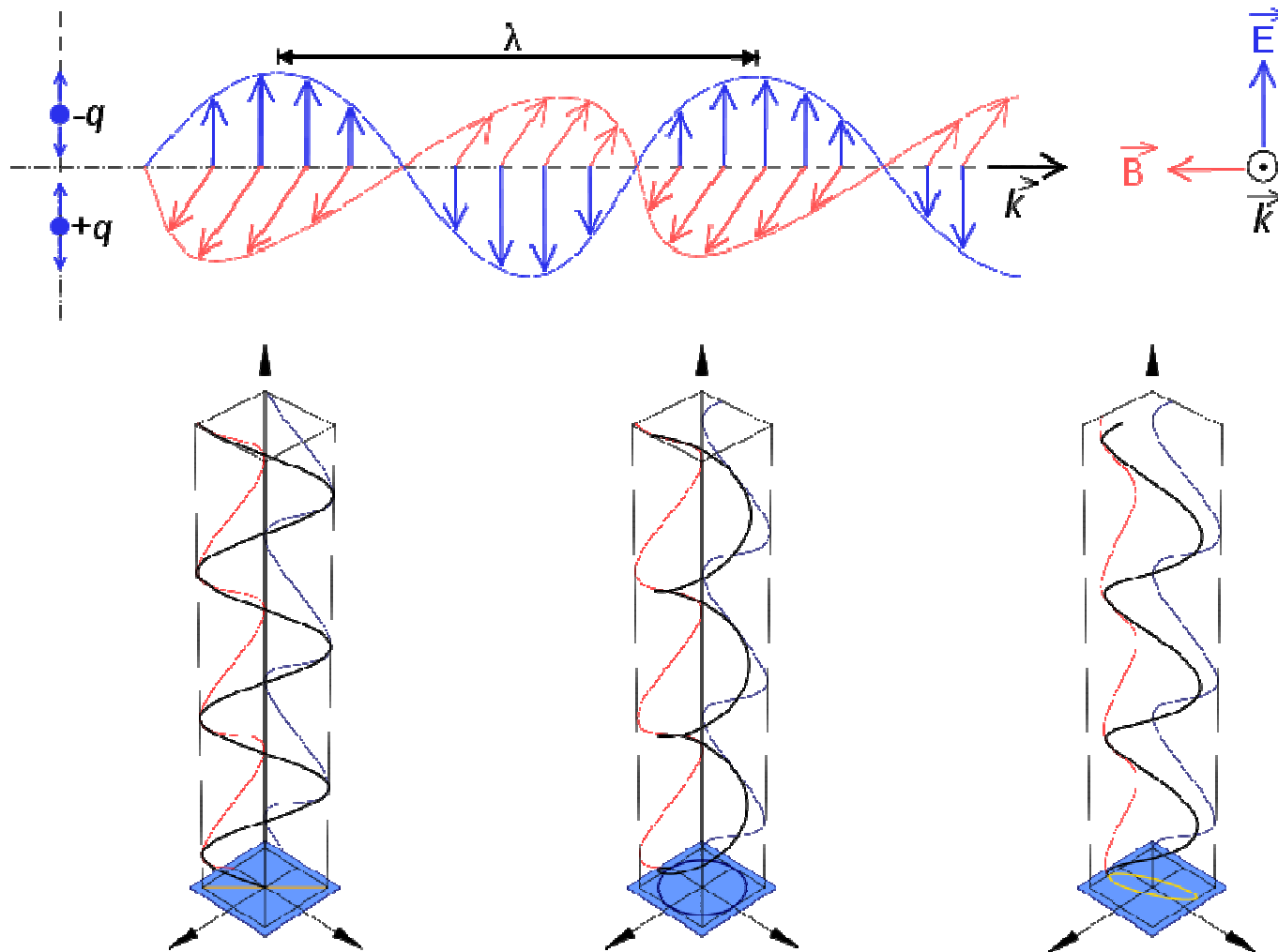
# Onda

## Feixe Gaussiano

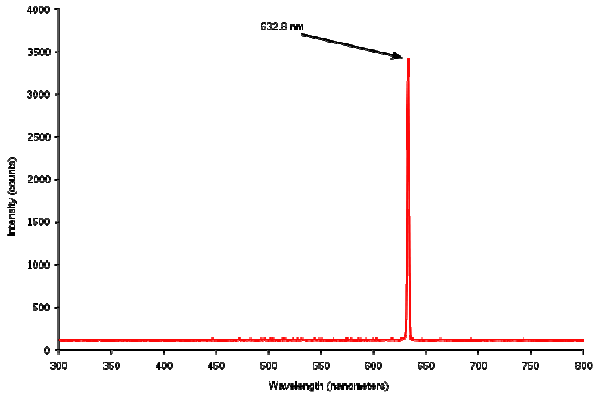
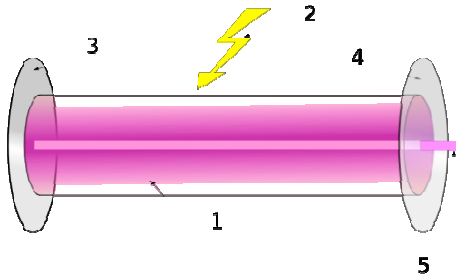


$$I(r, z) = \frac{|E(r, z)|^2}{2\eta} = I_0 \left( \frac{w_0}{w(z)} \right)^2 \exp \left( \frac{-2r^2}{w^2(z)} \right),$$

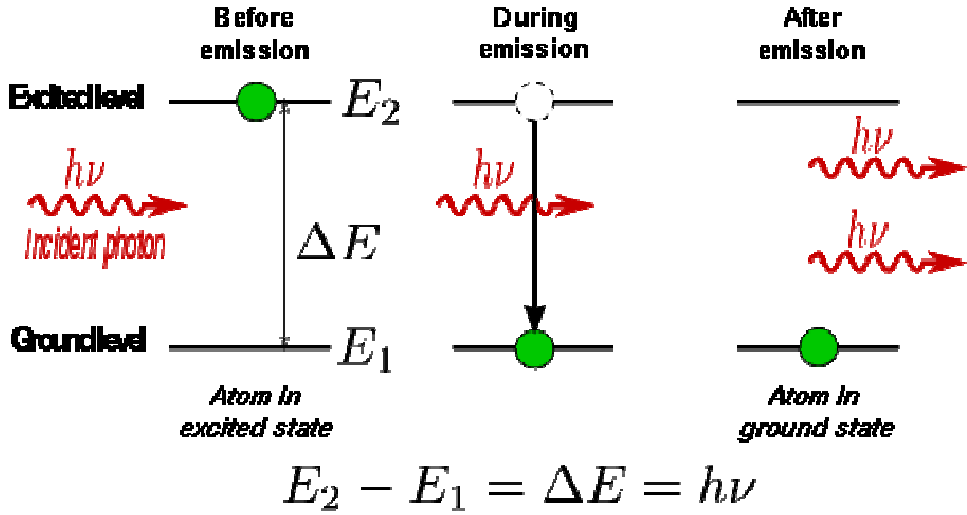
# Polarização



# Laser



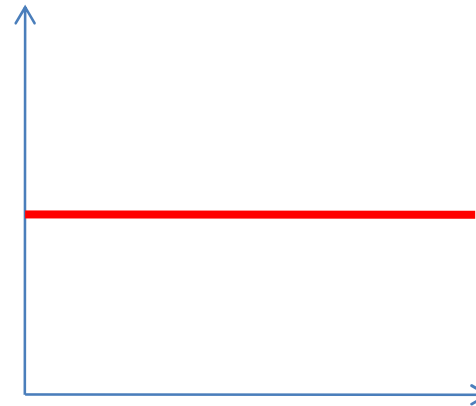
## Emissão espontânea X Emissão estimulada



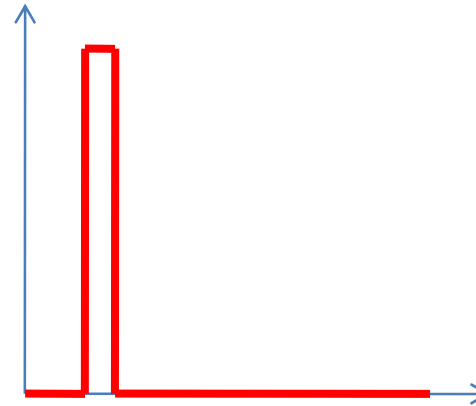
# Laser

*Modos de operação*

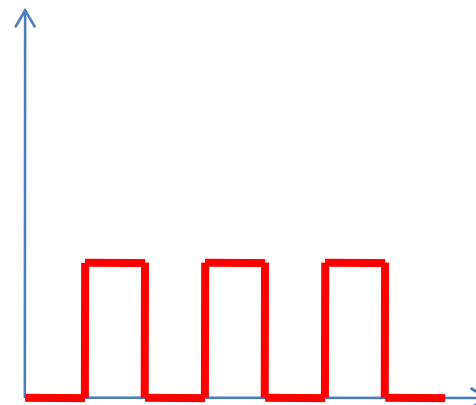
**CW**



**Pulsado – Acúmulo de energia**



**Chaveado – AM**



## Sensores Ópticos

Iluminância – fluxo luminoso/área de uma superfície (lux)

Fluxo luminoso – potência de radiação emitida por  
uma fonte luminosa (lúmen)

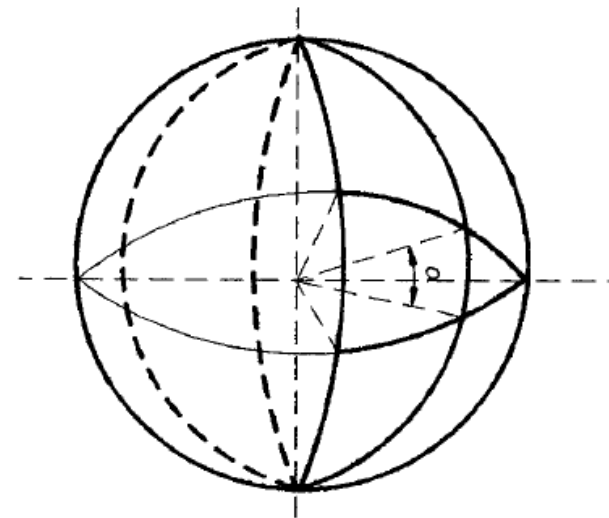
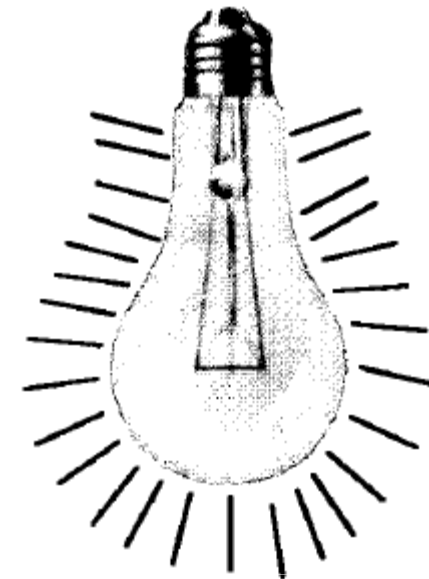
Eficiência luminosa – fluxo luminoso/potência consumida  
(lúmens/W)

Intensidade luminosa – fluxo luminoso/ângulo sólido  
(candela – cd)

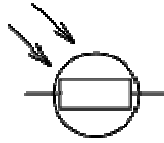
Luminância – Intensidade luminosa/superfície iluminada  
(cd/m<sup>2</sup>)

Reflectância

Emitância (lúmens/m<sup>2</sup>)



# LDR



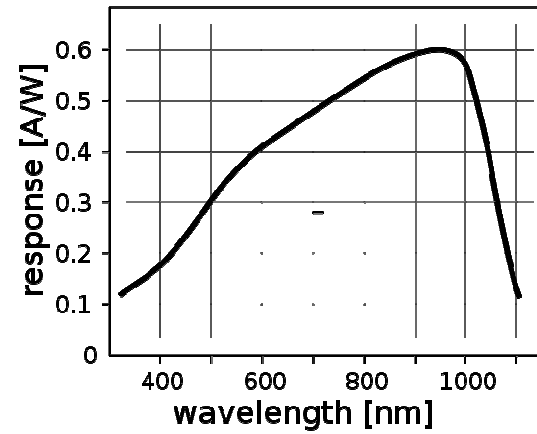
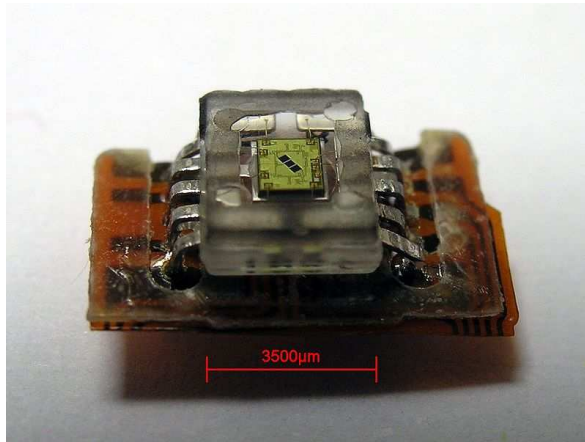
**Material semicondutor**

**Variação de resistência com luz**

**Tempo de resposta de dezenas de ms (desvantagem???)**



# Fotodiodo



*Modo fotovoltaico*  
*Modo fotocondutivo*



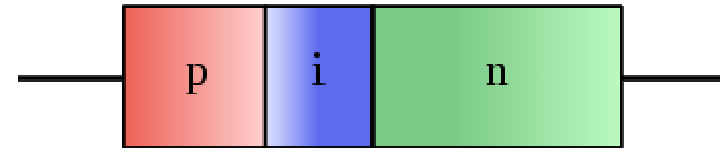
# Fotodiodo

## *Características construtivas*

*Tipo PN – fotodiodo x fototransistor*

*Tipo PIN*

*Tipo avalanche (APD)*



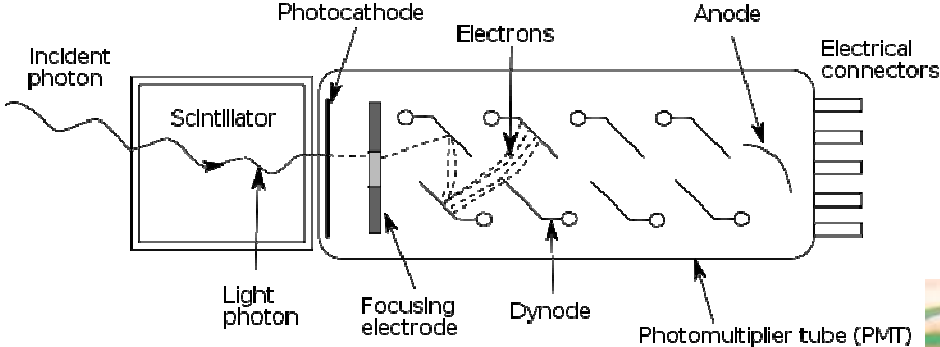
*Sensibilidade (Responsivity) – A/W, A/Im*

*Corrente de escuro (Dark current)*

*Potência equivalente de ruído (Noise-equivalente power)*

*Resposta em frequência – capacitância da junção*

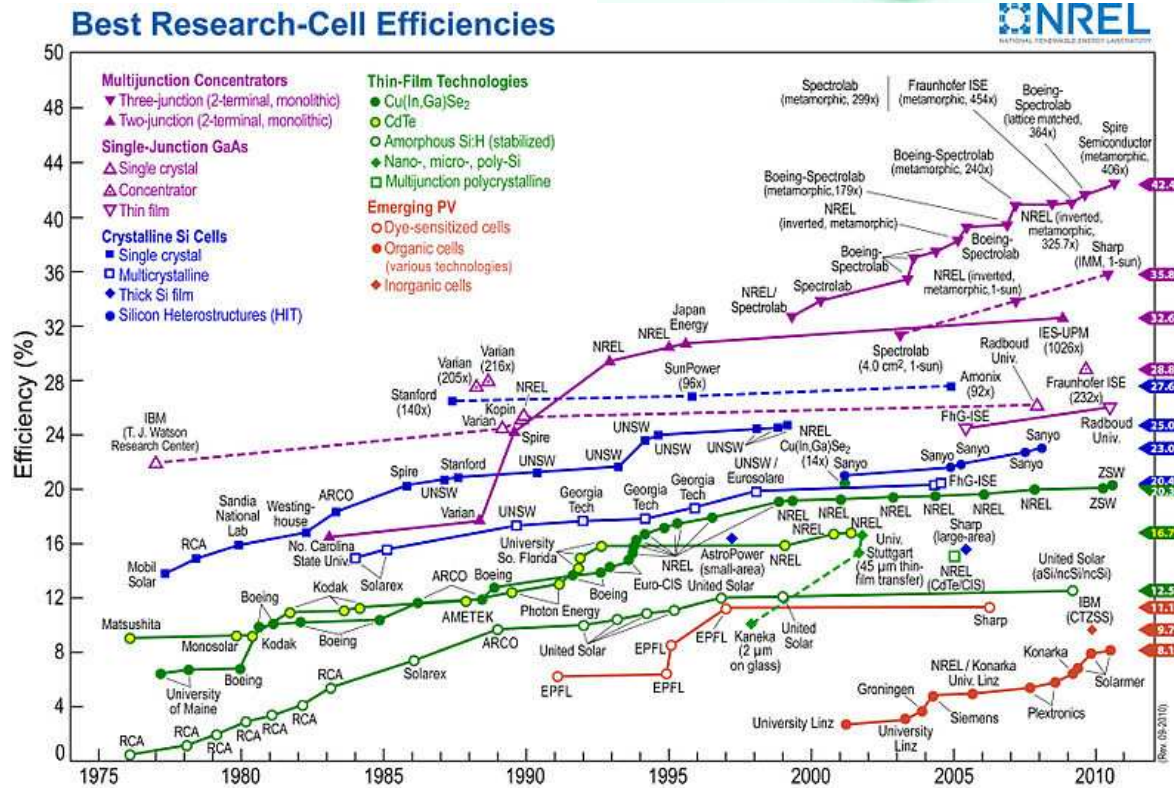
# Fotomultiplicador



Ausência de ruído Johnson



# Células fotovoltaicas



# CCD x CMOS

Ruído, escalabilidade, estabilidade temporal

