

# Tipos de lasers

# LASER

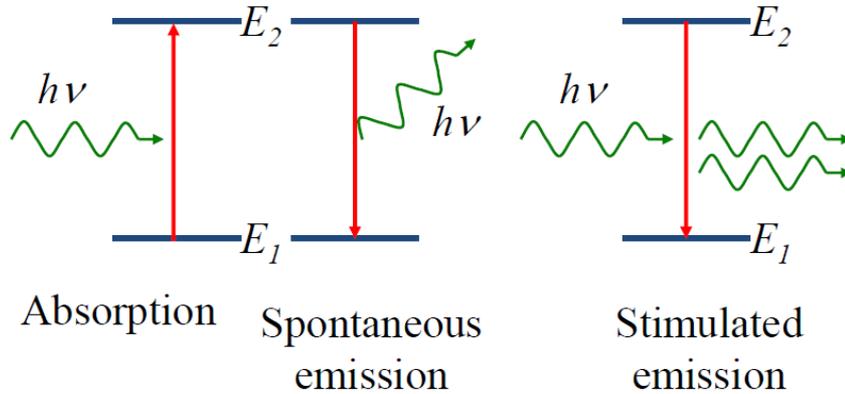
(Light Amplification by the Stimulated Emission of Radiation)

Laser é um oscilador óptico – possui um amplificador óptico ressonante onde o *output* é retro-alimentado ao *input* com casamento de fase.

- 1- Amplificador com meio de ganho saturado (meio ativo bombeado)
- 2- Sistema de retroalimentação (cavidade Fabry-Perot)
- 3- Mecanismo de seleção de frequência (amplificação ressonante)
- 4- Tipo de acoplamento de saída (espelho de reflexão parcial)

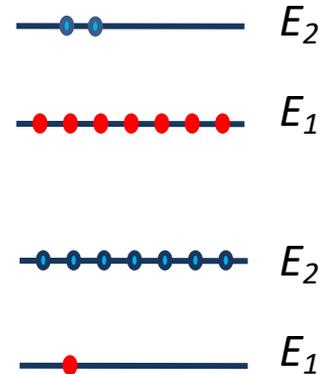
# Princípio da emissão laser

$$h\nu = E_2 - E_1$$



Quando  $n_1 > n_2$ : radiação é predominantemente absorvida  
efeito dominante - emissão espontânea

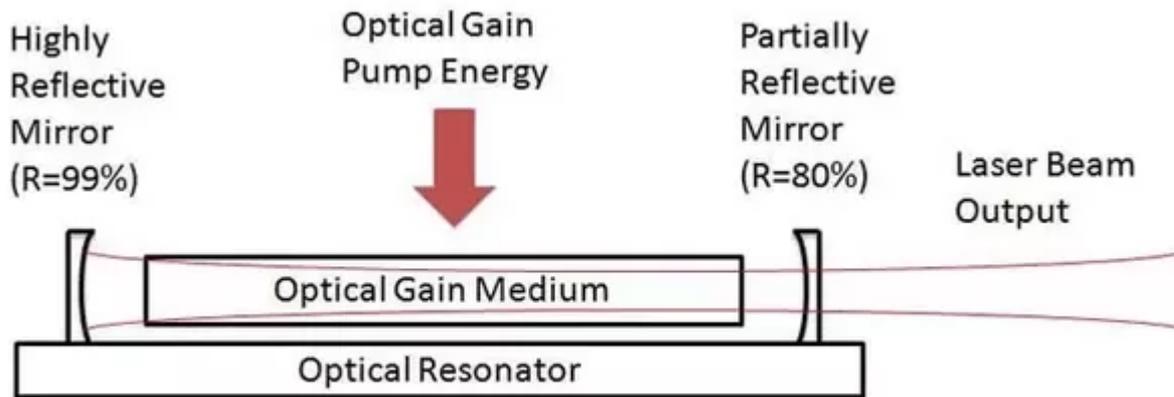
Quando  $n_2 \gg n_1$ : a maioria dos átomos ocupa  $E_2$  – fraca absorção  
efeito dominante – emissão estimulada  
luz é amplificada



Condição necessária: **inversão de população**

# Componentes principais de um laser

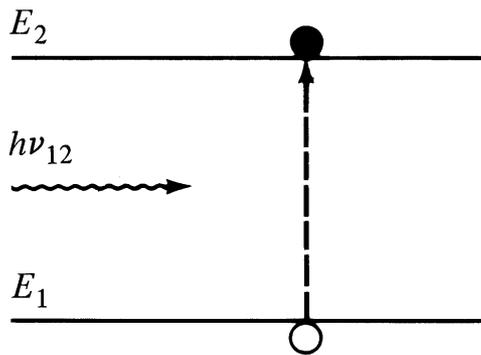
- Meio ativo (sólido, líquido, gás)
- Bombeamento (elétrico, óptico, químico)
- Cavityde óptica (ressonador óptico)



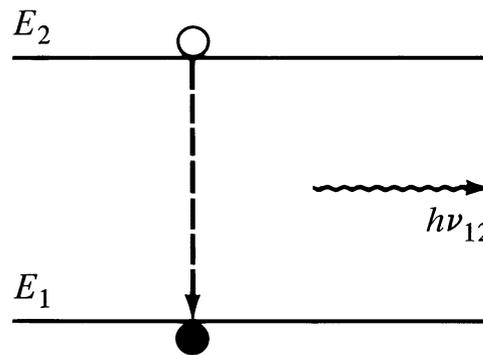
*Laser Building Blocks: the Optical Gain Medium and the Optical Resonator*

# Meio ativo (de ganho)

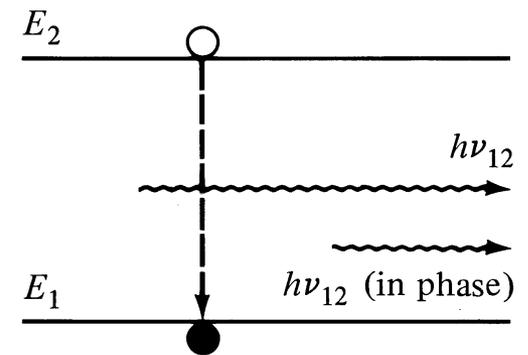
- Processos para a emissão laser
  - 1- Absorção
  - 2- Emissão espontânea
  - 3- Emissão estimulada



(a) Absorption

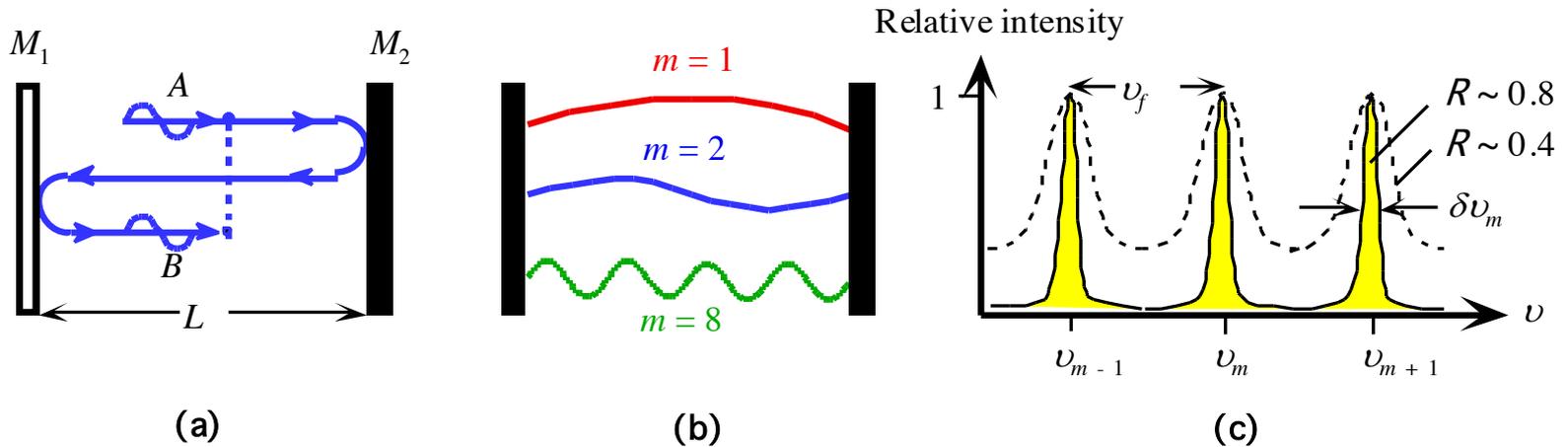


(b) Spontaneous emission



(c) Stimulated emission

# Fabry-Perot Resonator



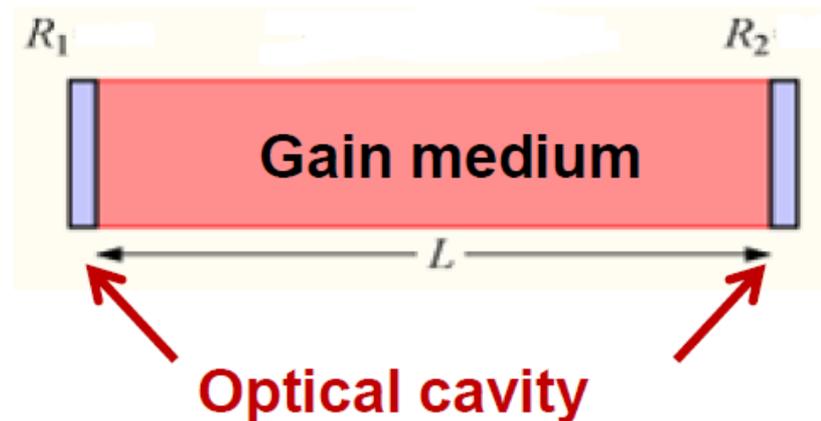
Schematic illustration of the Fabry-Perot optical cavity and its properties. (a) Reflected waves interfere. (b) Only standing EM waves, *modes*, of certain wavelengths are allowed in the cavity. (c) Intensity vs. frequency for various modes.  $R$  is mirror reflectance and lower  $R$  means higher loss from the cavity.

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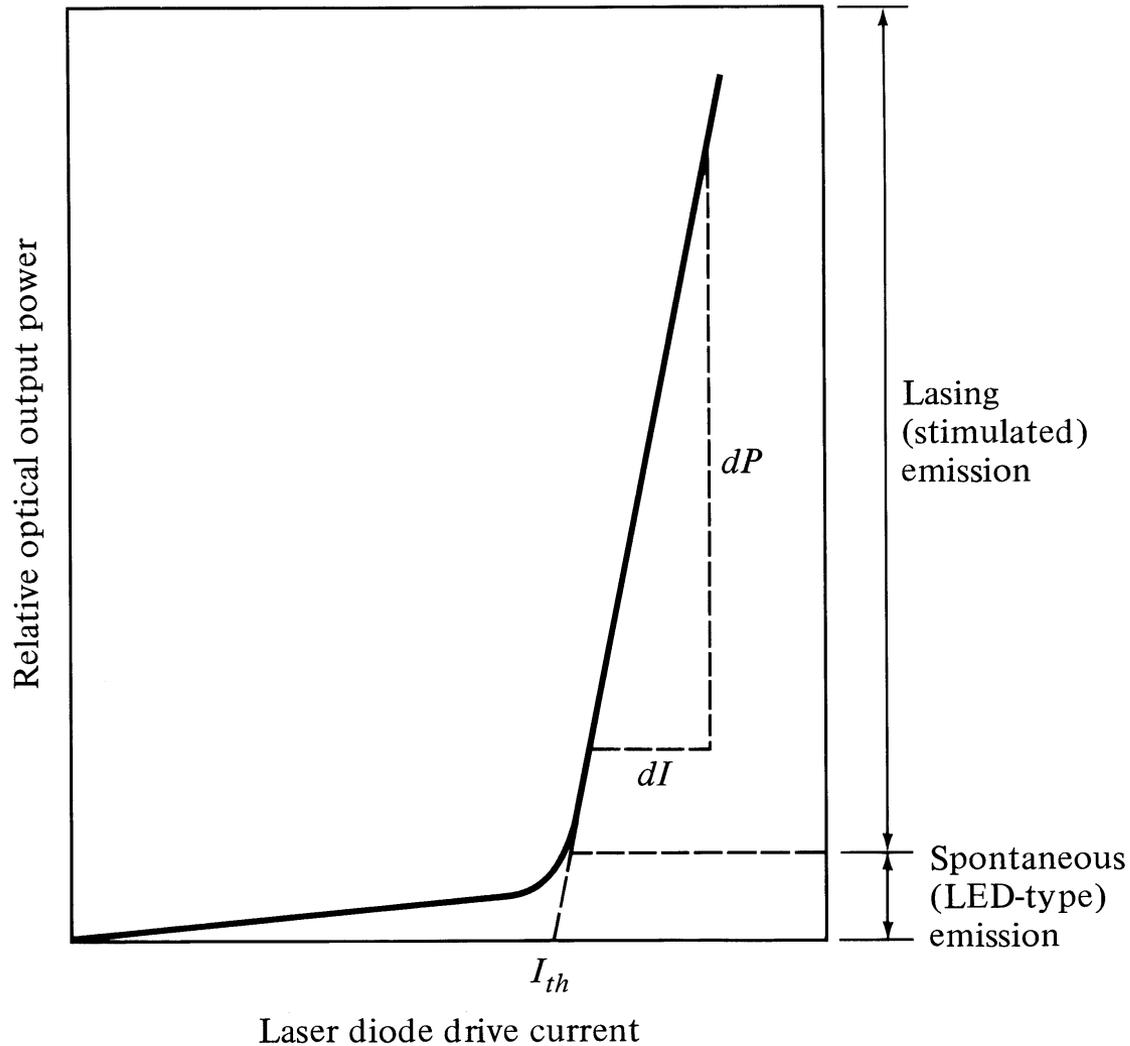
$$\text{Resonant modes : } kL = m\pi \quad m = 1, 2, 3, \dots$$

# Laser de diodo

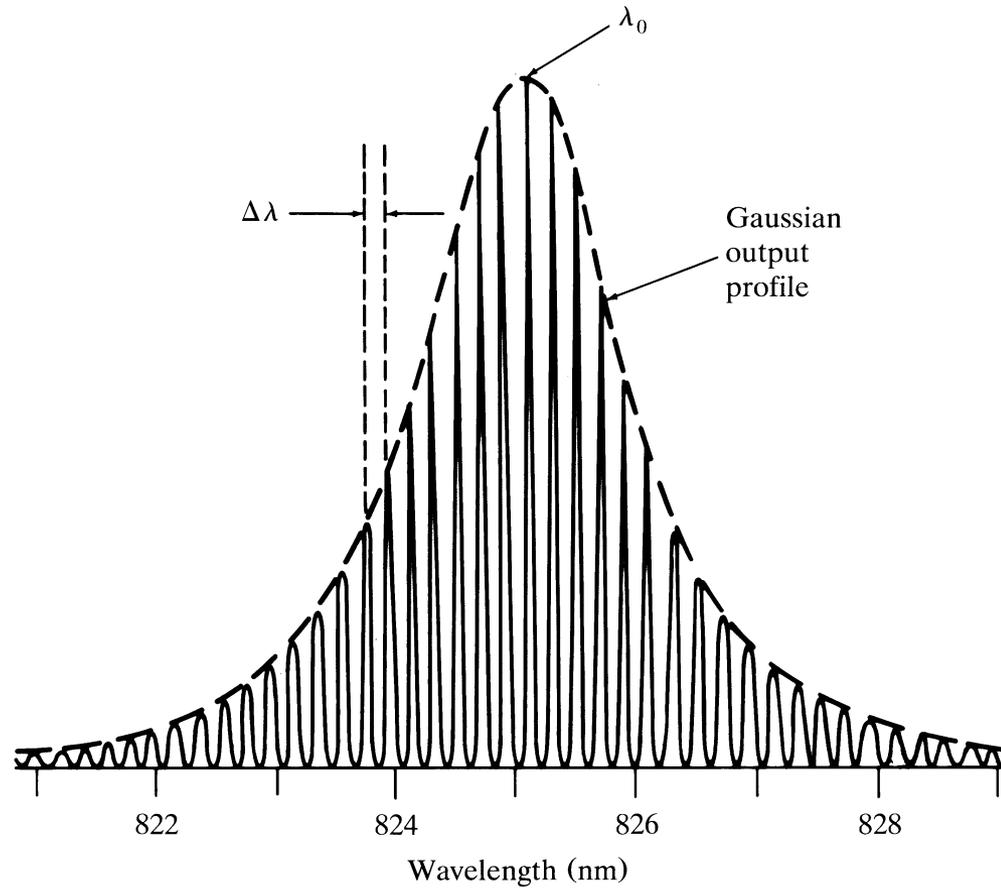
1. Meio de ganho: semicondutor
2. Bombeado eletricamente
3. Junção *band-gap* controla o comprimento de onda emitido
4. Cavidade ressonante: geometria e estrutura do sólido (secção das paredes)



# Potência de saída em função da corrente elétrica

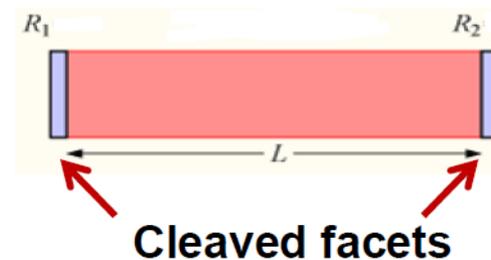


# Largura espectral de um laser de diodo

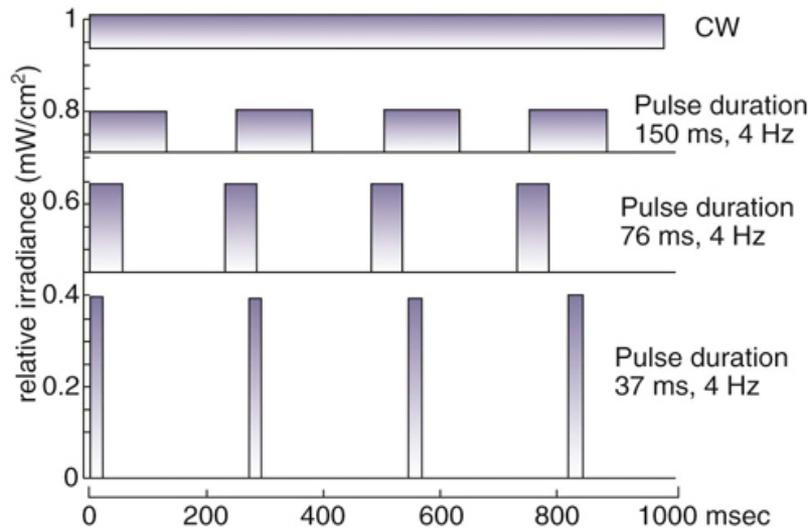


# Vantagens dos lasers de diodo

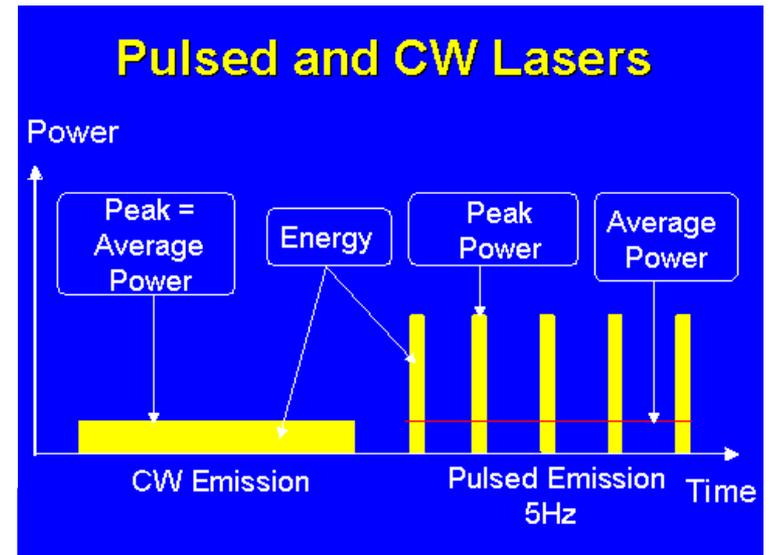
1. Meio semiconductor: alto ganho
2. Cavityde ressonante: robusta e sem necessidade de alinhamento dos espelhos.
3. Miniaturização do laser.
4. Baixo custo: tecnologia já existente.
5. Alta eficiência (potência óptica versus elétrica)
6. Alta potência de saída (considerando o tamanho pequeno)
7. Baixo limiar de corrente, baixo consumo de energia.



# Laser pulsado vs CW

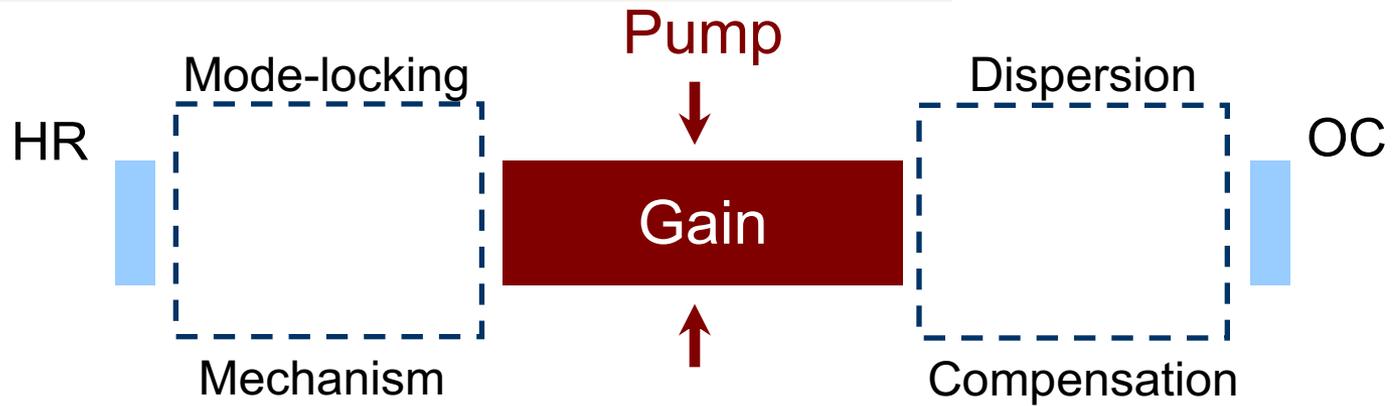


$$1 \text{ J} = 1 \text{ W.s}$$



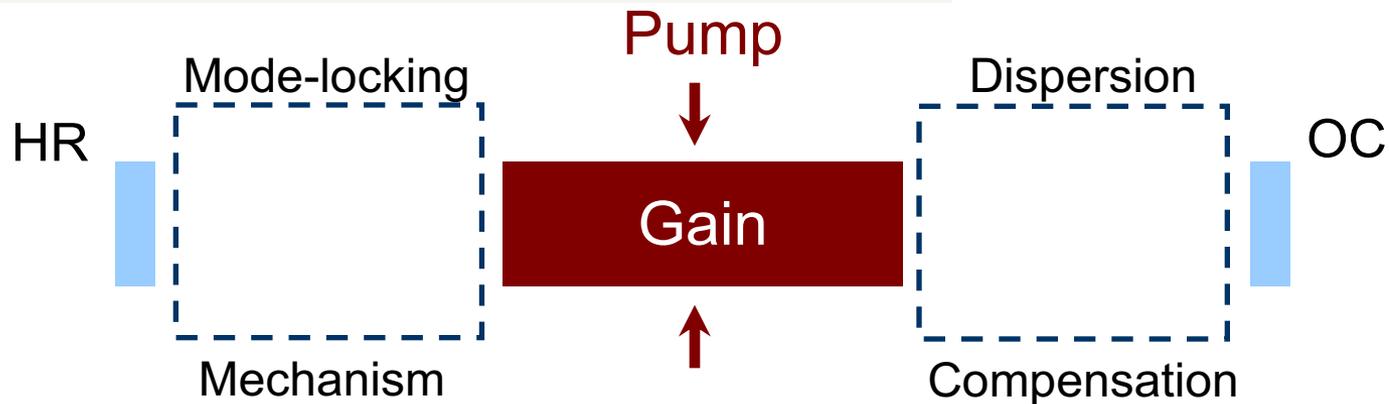
# Basic principles of ultrafast lasers

## Components of ultrafast laser system

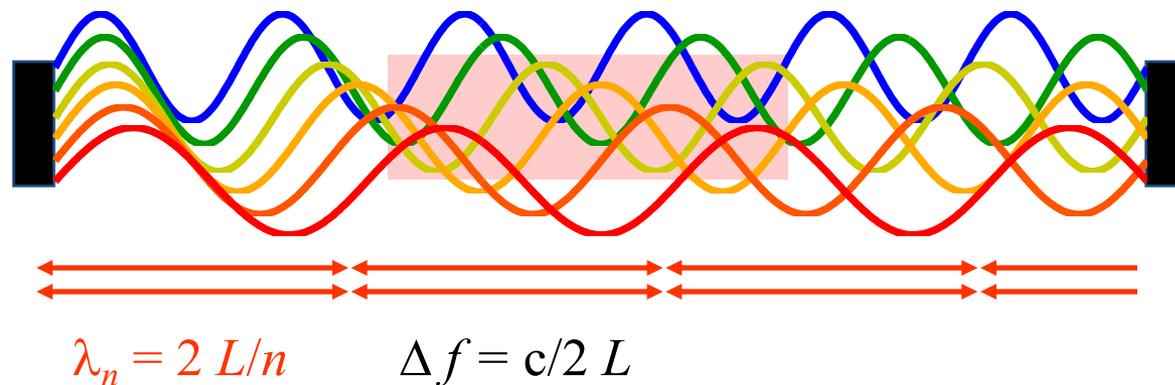


# Basic principles of ultrafast lasers

## Components of ultrafast laser system



## Cavity modes

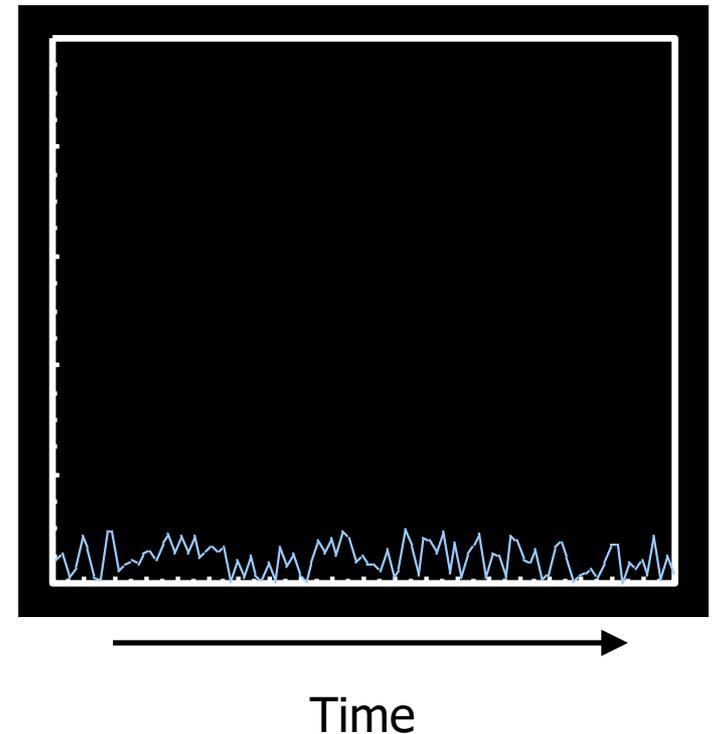
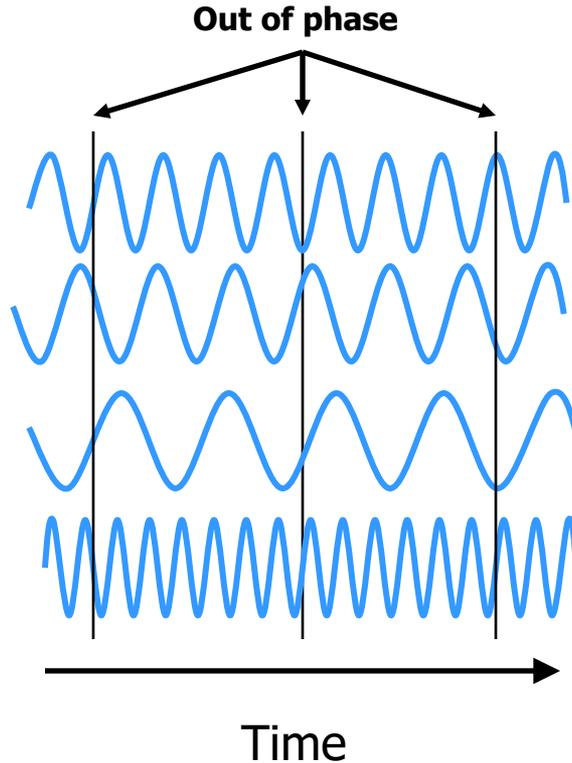


# Concepts of Mode Locking

Mode locking is a method to obtain ultrafast pulses from lasers, which are then called mode-locked lasers mode

**RANDOM** phase for all the laser modes

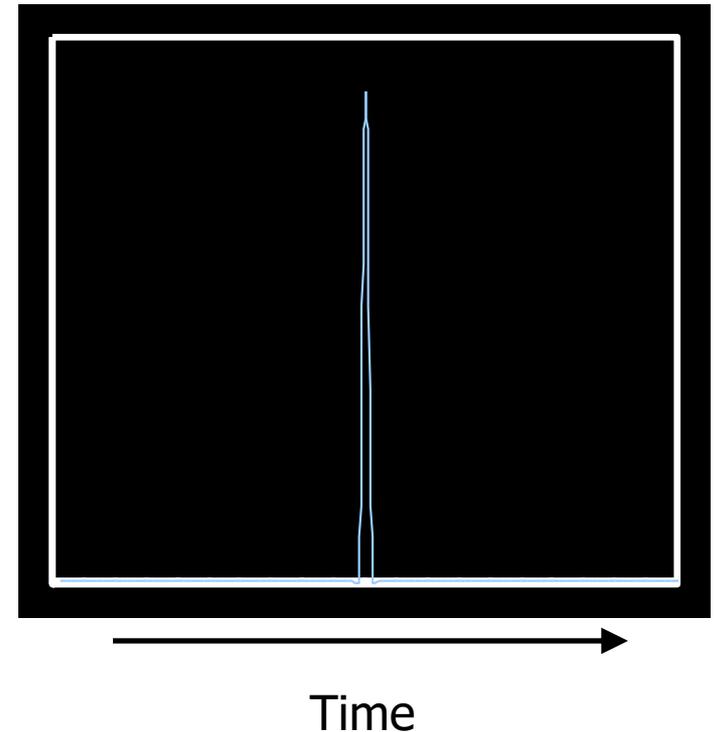
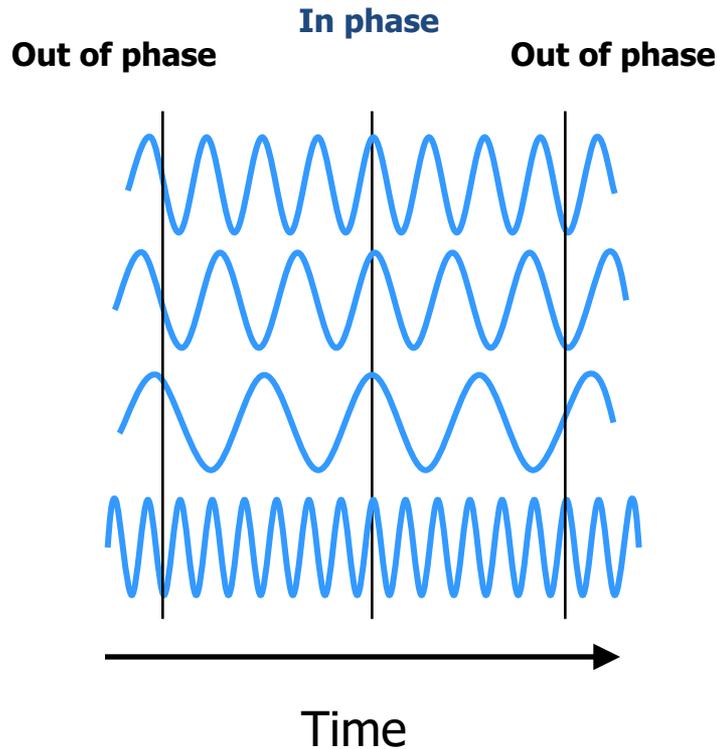
Irradiance vs. Time

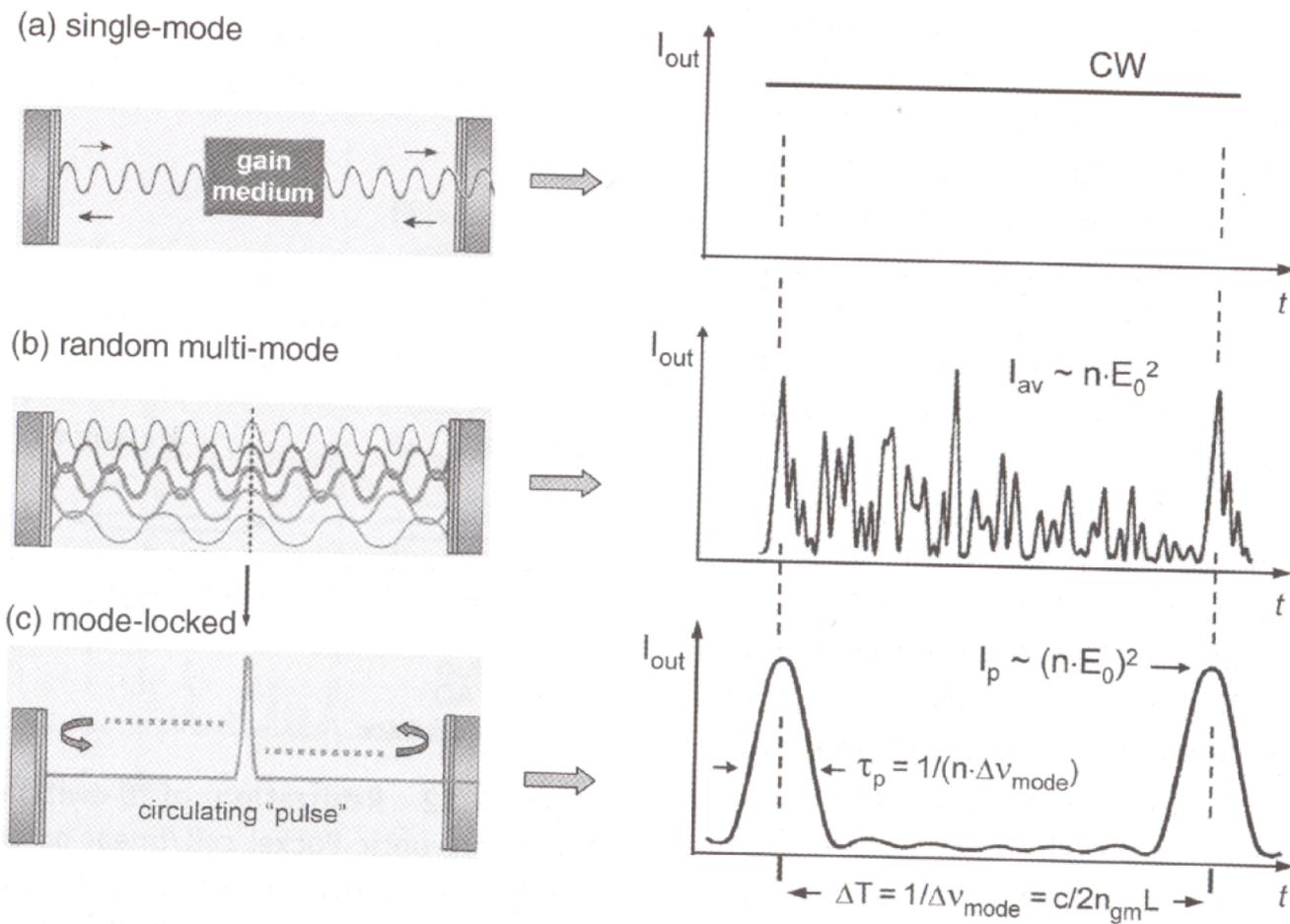


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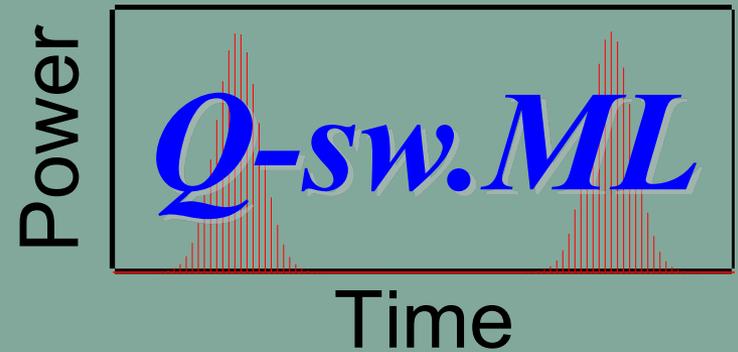
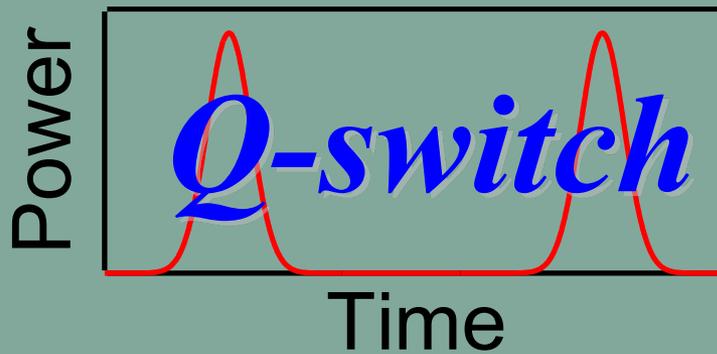
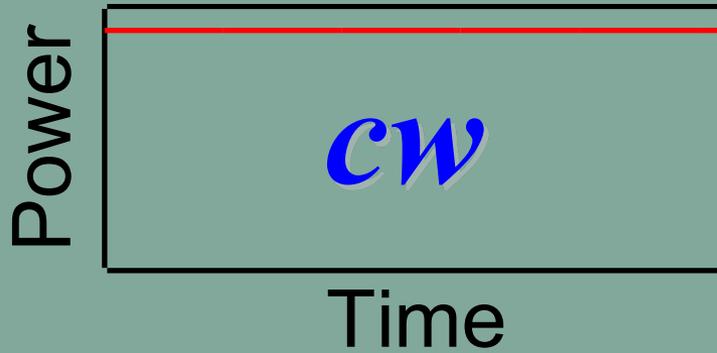
**LOCKED** phases for all the laser modes





**Figure 3.13** Temporal characteristic of laser output intensity: (a) for a single-mode CW laser; (b) for a random multi-mode CW laser; (c) for a mode-locked ultra-short pulse laser

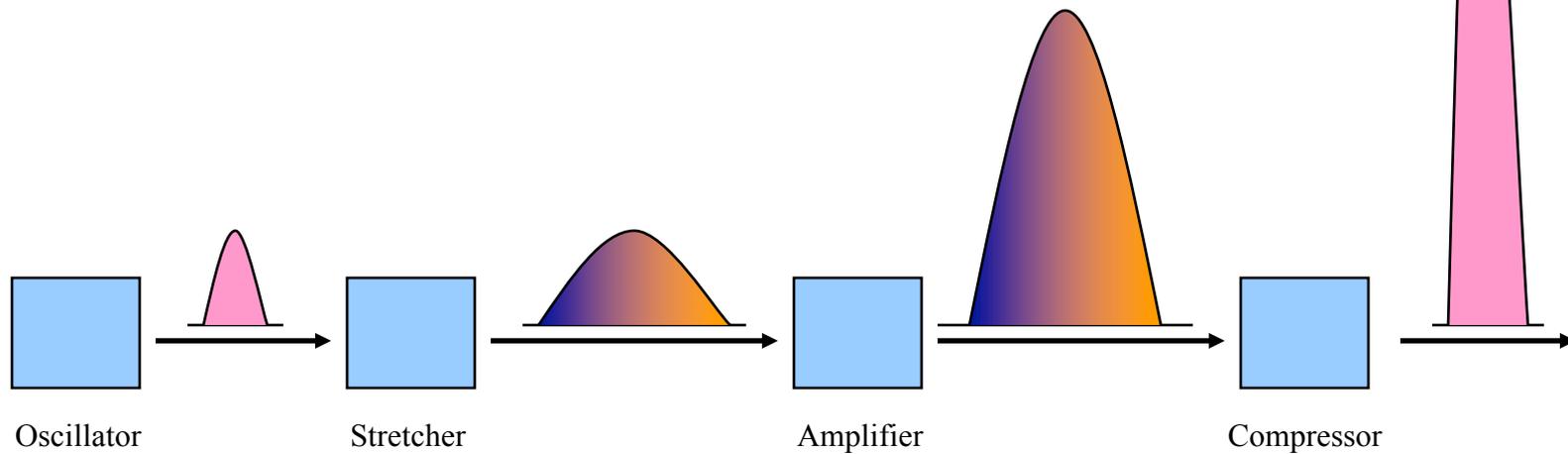
# Types of Laser Output



# Amplification of fs Pulses

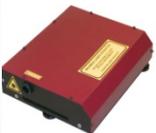
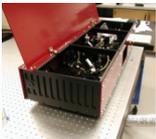
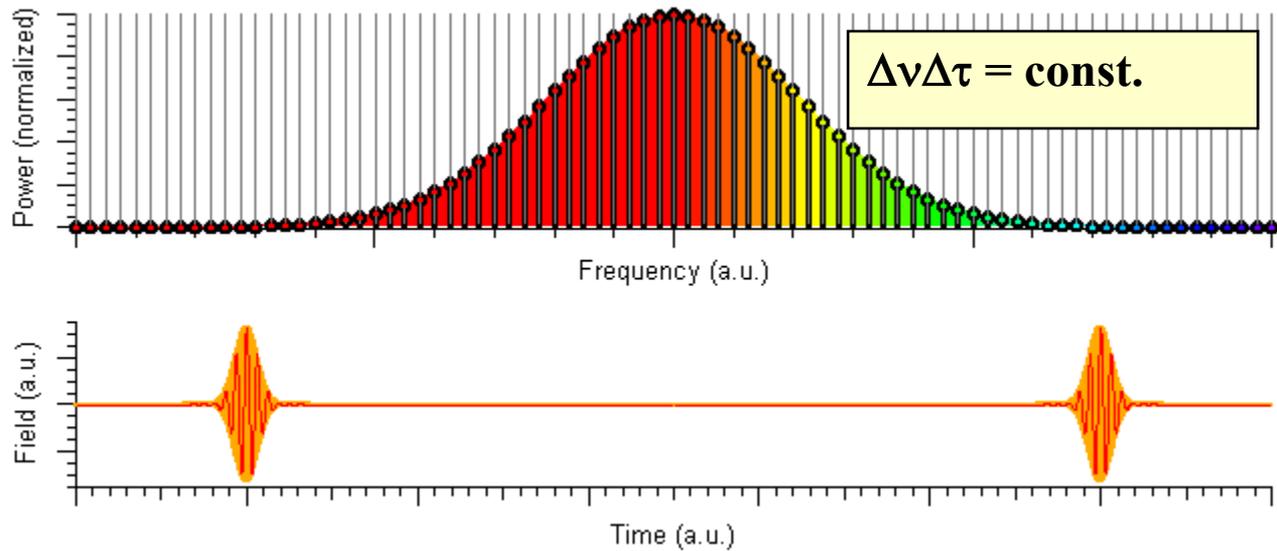
Concept:

- Stretch femtosecond oscillator pulse by  $10^3$  to  $10^4$  times
- Amplify
- Recompress amplified pulse



# Basic principles of ultrafast lasers

## Bandwidth vs Pulsewidth



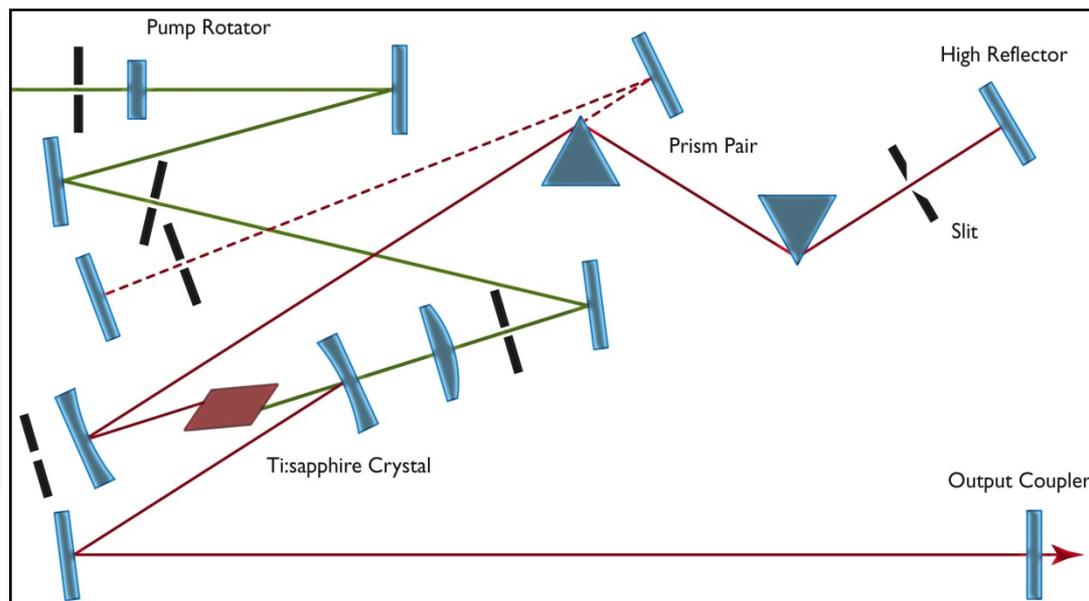
# Cavity configuration of Ti:Sapphire laser



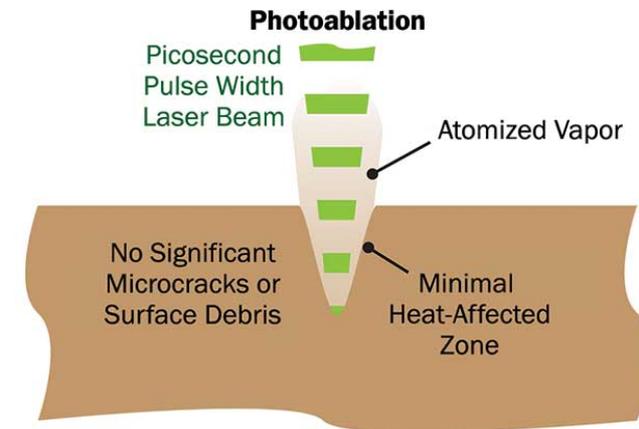
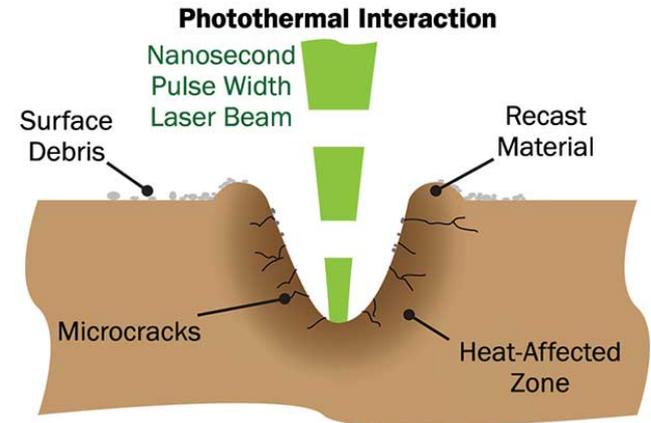
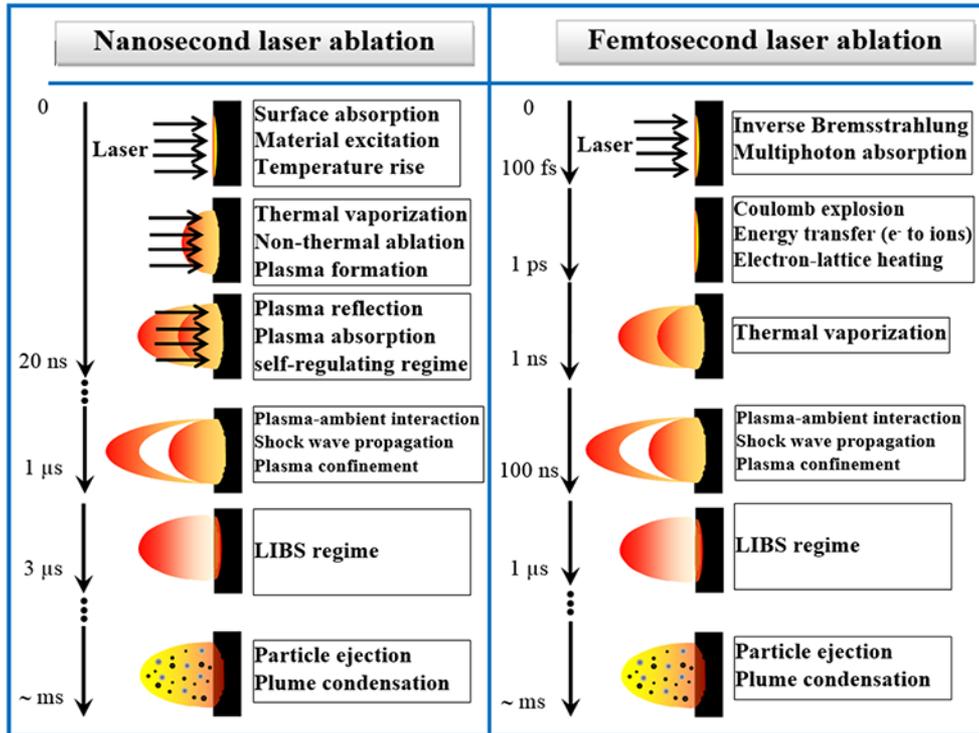
Tuning range 700-1000 nm  
Pulse duration < 20 fs  
Pulse energy < 10 nJ  
Repetition rate 80 – 1000 MHz  
Pump power: 2-15 W

## Typical applications:

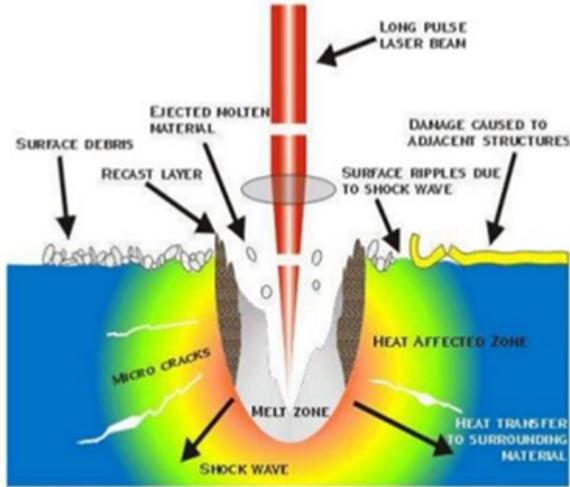
- time-resolved emission studies
- multi-photon absorption spectroscopy
- imaging



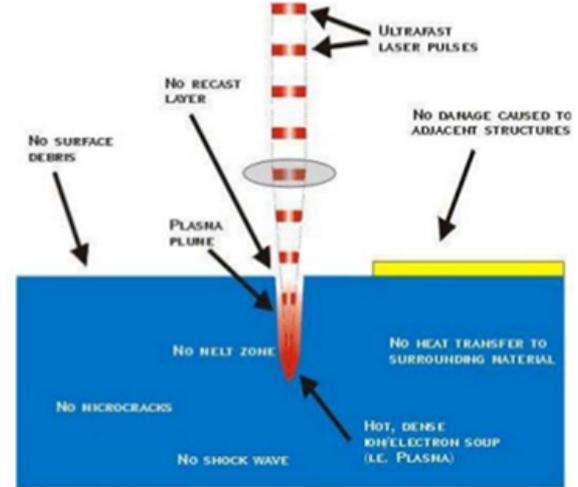
# Largura de pulso



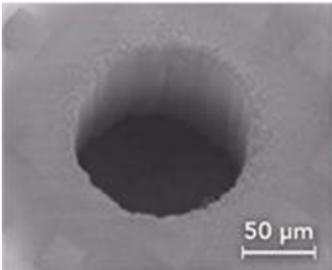
## Long pulse



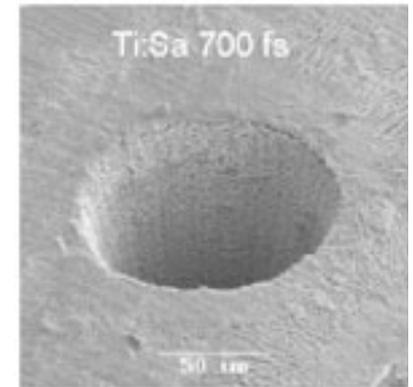
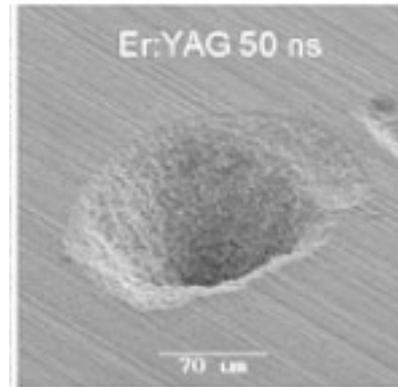
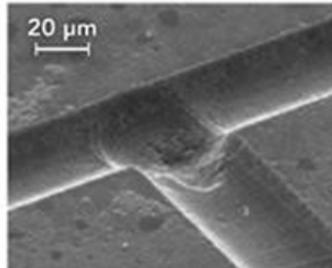
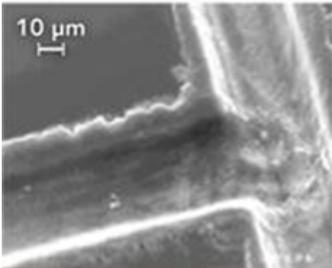
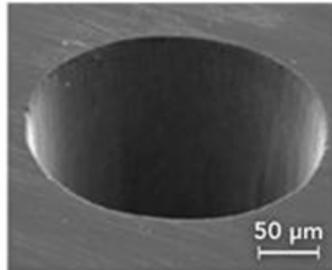
## Short pulse



With nanosecond laser



With femtosecond laser



(Vidro)