Introduction to lasers

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Course outline

Chapter 1: Introduction, some examples of applications / main features of laser light

Chapter 2: Amplifier gain

Chapter 3: Laser Oscillator

Chapter 4: Features of laser emission

- ✓ Laser efficiency
- ✓ Spatial characteristics
- ✓ Spectral characteristics

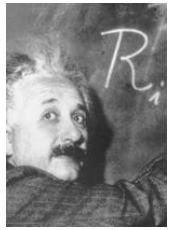
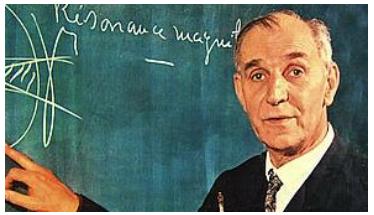
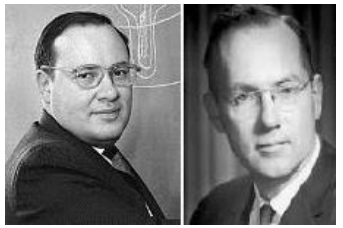
Chapter 5: Laser operating regimes

- ✓ Continuous-wave regime
- ✓ Q-switch regime
- ✓ Mode-locked regime

Chapter 6: Some solid-state lasers

Chapter 1 - Introduction

- Laser: acronym of Light Amplification by Stimulated Emission of Radiation
- Scientific milestones

  - 1917: Stimulated emission  A. Einstein
  - 1949: First optical pumping and first population inversion  A. Kastler
  - 1958: Confinement of the electromagnetic field in an open cavity: Fabry-Perot cavity  A. Shawlow and C. Townes
  - 1960: First laser (Ruby laser)  T. Maiman

3 main elements

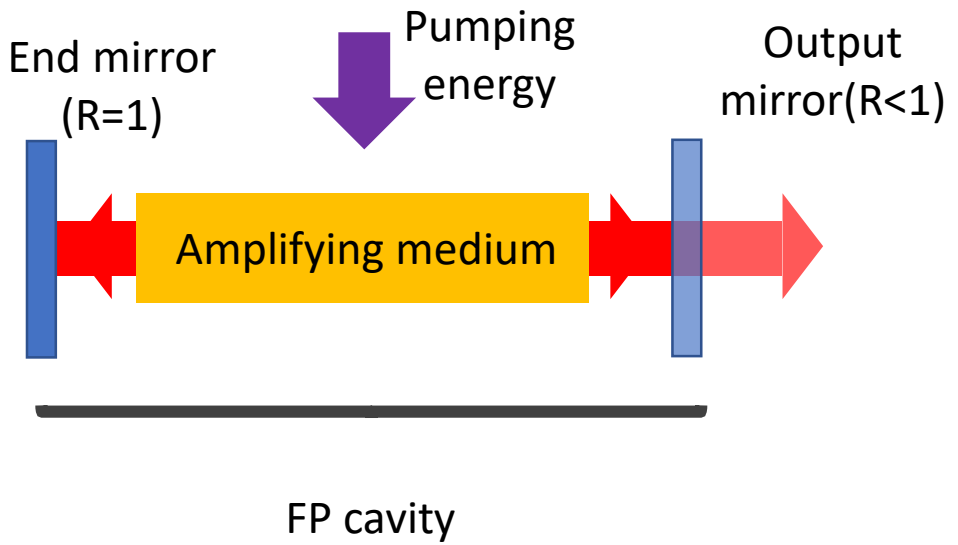
❶ **Amplifying medium (stimulated emission)**

Crystal, optical fiber, semiconductor, gas

❷ **Optical pumping system**

Photon absorption, electrical discharge, carrier injection (laser diode)

❸ **Resonant cavity: Fabry Perot, ring cavity**



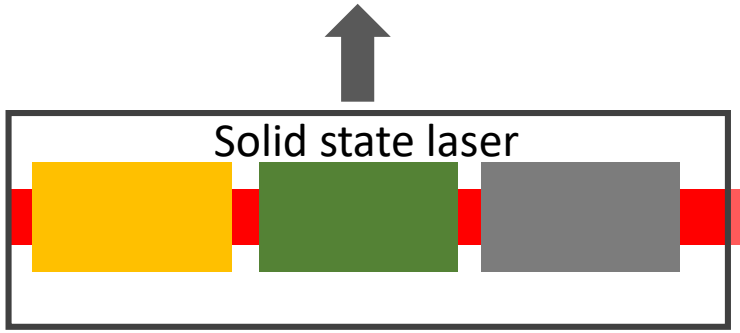
FP cavity

Laser: « transformer box for light »

- Spatial Mode selection→ Space concentration
- Pulse generation→ Time concentration
- Frequency shift + frequency mode selection→ Spectral concentration

Flashlamps
Laser diodes
(Single, fiber coupled, stack)

Pumping source



Laser beam

M^2 compares the divergence between the beam under consideration a Gaussian beam of same waist size.

Low quality
- high divergence (M^2~100-1000)
- CW or pulsed (ms)
- « broad » spectrum

Optical efficiency (Pout/Pin)
~20-70%

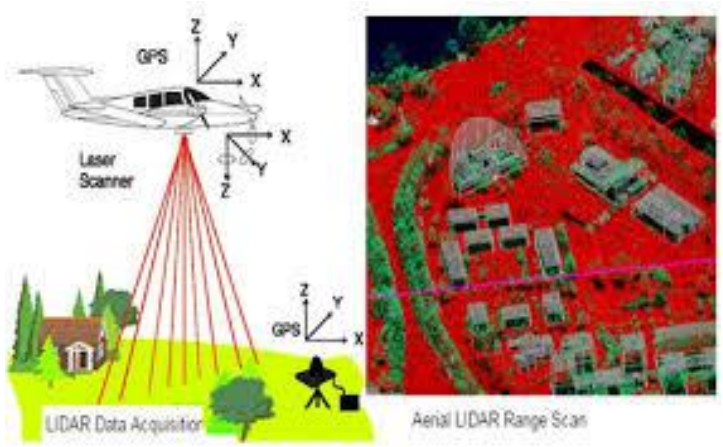
High quality
- low divergence (M^2~1-5)
- CW or pulsed (ns, ps, fs)
- narrow spectrum

CW = Continuous_wave

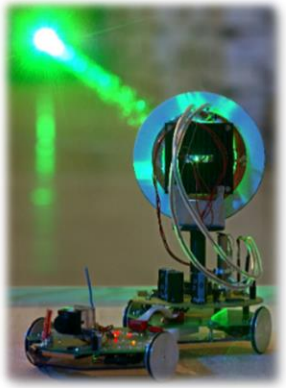
A few applications / laser light features

❑ space concentration

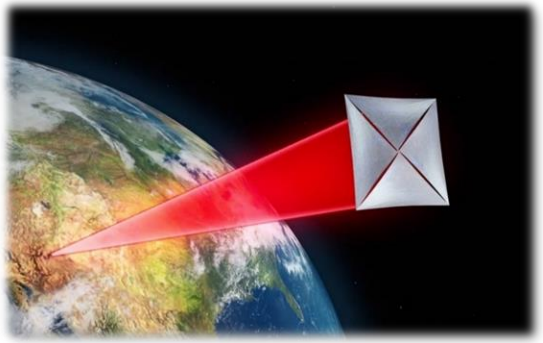
- Low divergence beam



LIDAR (Light detection and ranging): determination of the type or concentration of gas in the atmosphere, wind speed, distance measurement to a target....



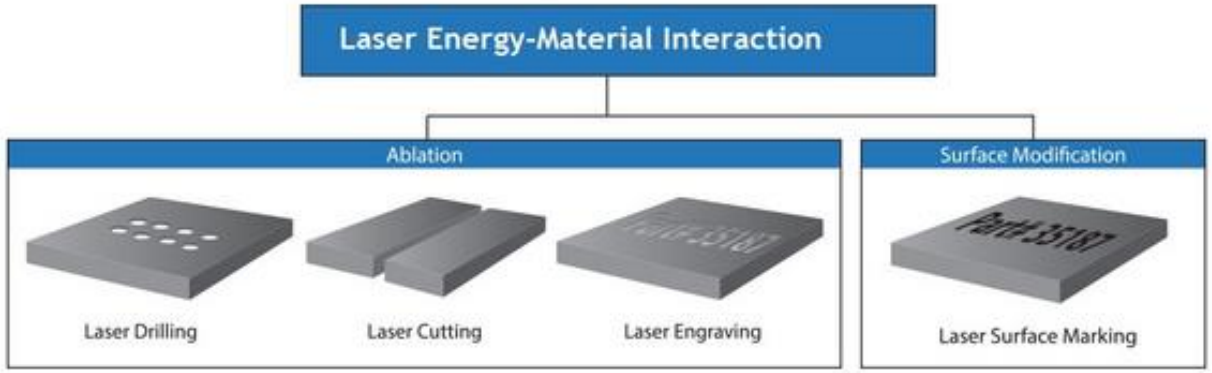
wireless power transmission



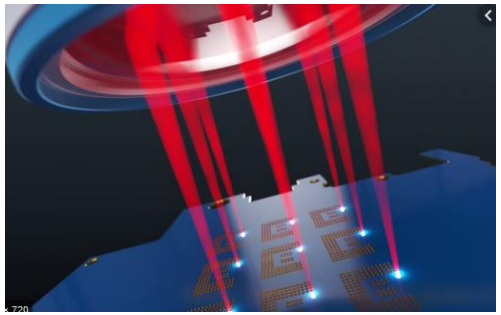
Interstellar travel using laser-powered sails
(20-30% of the speed of light)

❑ Space concentration

- Focusing



Material processing



Drilling in parallel

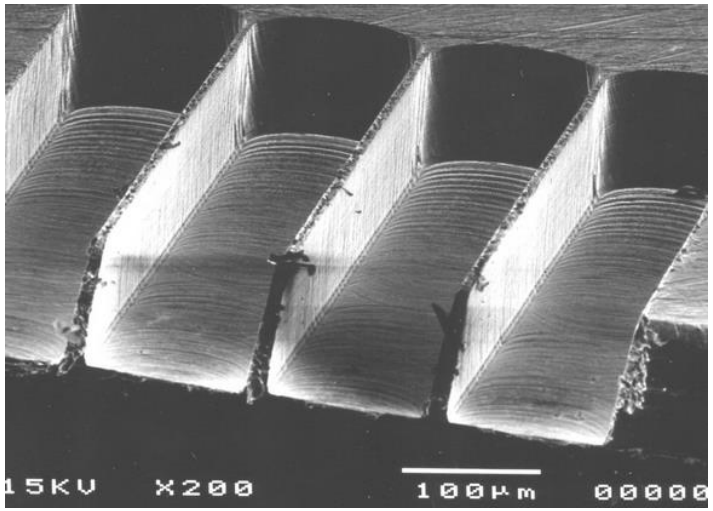
Cutting

❑Time concentration

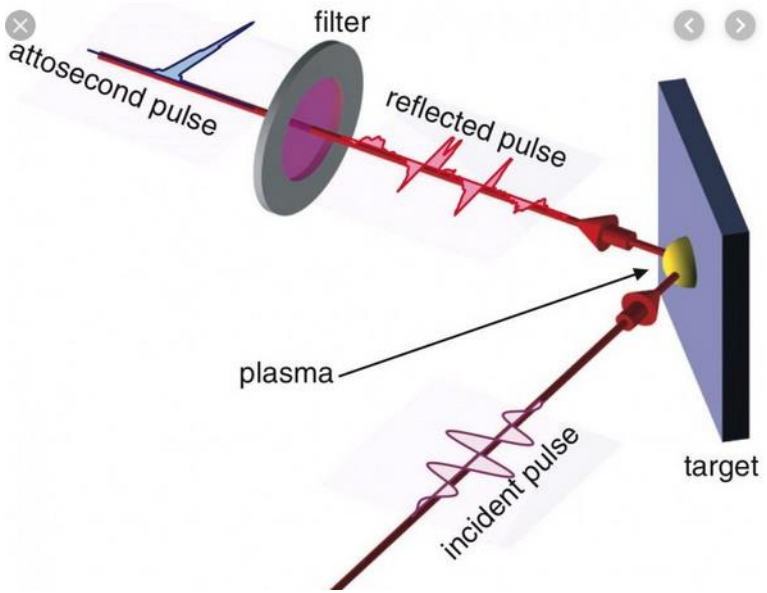
Femtosecond to nanosecond Pulses

tattoo removal

Tissue Ablation and
Micro & Nano Surgery



Micro and nanostructuring: waveguide writing, microfluidic channeling, Silicon scribing



High harmonic generation (due to strong nonlinear interactions when a laser light is focused into a gas (usually at reduced pressure)
Instead of synchrotron radiation

❑Spectral concentration

- Capability to control the laser frequency with high accuracy $\Delta\nu/\nu \# 10^{-14}$

  → frequency reference

  → Atom manipulation, atom cooling (Atom optics)