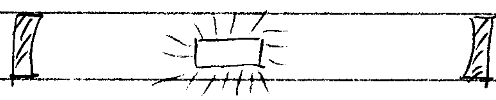
03/21/05 Lecture 20 ①

Review laser theory:

Put mirrors around fluorescent source.



(1) Mirrors: form optical cavity, support Gaussian modes

(2) Medium: characterized by gain coefficient γ, and saturation intensity I_{sat}.

$$\gamma = \sigma \Delta N = \frac{\lambda^2}{8\pi t_s} g(\nu) \Delta N$$

$$I_s = \frac{h\nu}{\sigma \tau_s} = \frac{8\pi hc t_s}{\lambda^3 \tau_s g(\nu)}$$

(3) Pumping: needed to achieve population inversion $\Delta N > 0$
relate ΔN to R using rate equations.

$$\frac{dN_i}{dt} = \text{rate (into)} - \text{rate (out of)} = 0$$

including stimulated transition by laser I.

get $$\Delta N = \frac{\Delta N_0}{1 + I/I_s}$$

Optical pumping: $$W_{i-j} = \sigma g_i \frac{I}{h\nu} = \frac{\lambda^2}{8\pi t_s} g(\nu) \frac{I}{h\nu} \times \left(\frac{g_2}{g_1}\right)$$

if $i=1$

* Lasing: oscillation occurs when $g_0 = \gamma_0 l > \Gamma = L + T$.
(l: round trip)

then: $P_{out} = \pi W^2 I_s T \left(\frac{g_0}{\Gamma} - 1 \right)$

W: beam width in medium.

* Single mode operation (less fundamental)
ring cavity, filters

Done with theory. next, examples of practical systems (about one week)

Overview of laser characteristics.

* pulsed vs. continuous (CW) operation
pulsed is more common

* output power
CW power (μW to kW)
pulse energy (up to KJ)
pulse duration (ns to fs)

* frequency
wavelength (100 nm to 30 μm)
Tunability (none to 100 nm)

linewidth

- single or multiple modes?
- Fourier-limited pulses
- Single mode stability.

* Spatial mode : TEM_{00} ?

* Pumping :
  Mechanism (electrical, flash lump, laser)
  Efficiency (up to 50%)

* cost ($ to 100k $)

Types of lasers : classify on nature of gain medium

<u>Gas : HeNe, Ar^+, CO_2, excimer</u>

Low pressure gas discharge : "fluorescent bulb with mirrors"

Usually CW, excimer pulsed
P_{out} : mW to kW
λ = 157 nm to 30 μm, isolated lines
Pumped by discharge : e^- collisions, often mediated by another species.
Low density → low gain → long medium
Inefficient (except for CO_2) ; Not tunable.
(10^{-4} to 10^{-3})

Solid state : Nd : YAG , Ti : Sapphire , Ruby

Ions in crystal or glass medium.
CW or pulsed.
600 - 1300 nm
P : 10's of mW to W.
Optically pumped : laser or flashlamp
Medium efficiency : ~ 1%
Tunability varies : Nd : YAG not tunable 1064 nm.
Ti : Sapphire 100's of nm.
high gain : short crystals

Dye : Rhodemine, DCM, Stilbene.

organic molecules in liquid solution (much like solid state)
cW or pulsed.
λ = 400 - 900 nm , continuous coverage.
P : 10's of mW to W.
Laser or flash lump pumped.
Medium efficiency
Wide tunability (~ 50 nm)
High gain.

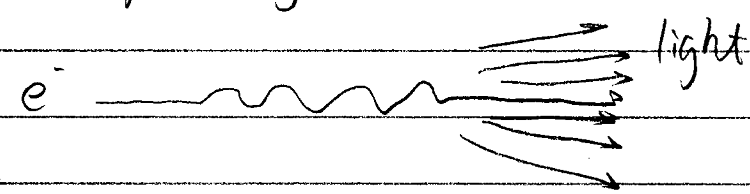
Diode : GaAs , AlGaAs , InGaAs : LED with mirrors

Typically CW.
λ = 400 - 1600 nm with gaps
up to ~ 1W.
Direct electrical pumping Very efficient → 50%

~10nm tunability.
Low cost : wide commercial use
(CD players, telecom, laser pointers)
Poor spatical mode
Highest gain : hardly need mirrors

These are major classes :
some other more specialized types

Free electron laser :
radiation from transverse acceleration of
high-energy electrons



spectrum from ~100nm to 10um
pulsed up to KW
Really expensity.

Maser : microware laser

Gain medium gas : typically H or NH_3
(1.4GHz) (2.4GHz)

use 3D cavity, size ~ λ

CW, power ~ nW
(can be electrically amplified)
very stable, microwave source, used in clocks.

OPO: Optical Parametric Oscillator.
uses nonlinear optical effects, more later.
Tunable from 400 - 1400 nm, pulsed only.

color center laser.
electrons trapped in defects in ionic crystal
λ range 1-5 μm
100's of mW, pulsed
~100 nm tunability.

Nice practical reference: Sam's Laser FAQ
www.laserfaq.org.