University of Babylon

College of Science

Department of Chemistry

Course No. Chsc 424

Undergraduate Studies

Physical chemistry
Fourth-year - Semester 2
Credit Hour: 3 hrs.
Scholar units: three units

Lectures of Molecular Spectroscopy

Second Semester, Scholar year 2021-2022

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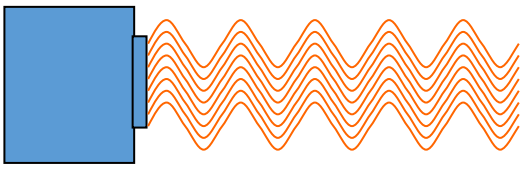
Lecture No. Ten: Laser Spectroscopy

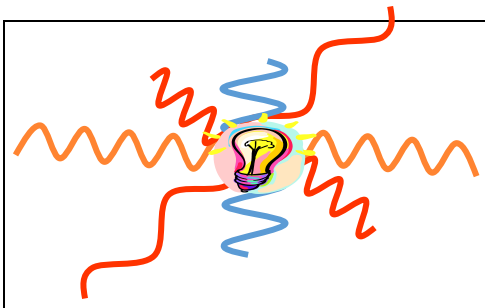
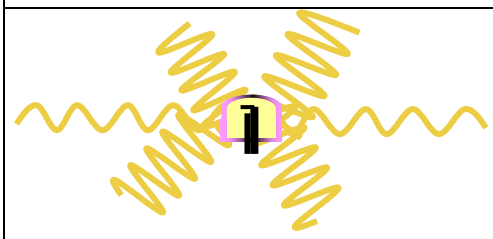
1-**Introduction**:-

The first microwave laser was made in the microwave region in 1954 by Townes & Shawlow using ammonia as the lasing medium. The first optical laser was constructed by Maiman in 1960, using ruby (Al_2O_3 doped with a dilute concentration of Cr^{+3}) as the lasing medium and a fast discharge flash-lamp to provide the pump energy.

- Laser - Stimulated Emission is light emitting due relaxation process. Since excited chemical species (atoms, molecules, ions) undergo de-excitation (from the excited state to ground state).
- Laser - is a special type of light sources or light generators. The word LASER represents Light Amplification by Stimulated Emission of Radiation.

Comparison for different radiation sources, or characteristics of light produced by Lasers and other sources

	Monochromatic (single wavelength). Coherent (in phase). Directional (narrow cone of divergence).

	<u>Incandescent lamp</u> Poly Chromatic Incoherent Non-directional
	Monochromatic light source Coherent Non-directional

2- Types of light emission.

The Spontaneous emission - chromatic & incoherent is included:

A-Excited e^-'s when returning to ground states emit light spontaneously (called spontaneous emission).

B-Photons emitted when e^-'s return from different excited states to ground states have different frequencies (chromatic).

C- Spontaneous emission happens randomly and requires no event to trigger the transition (various phase or incoherent).

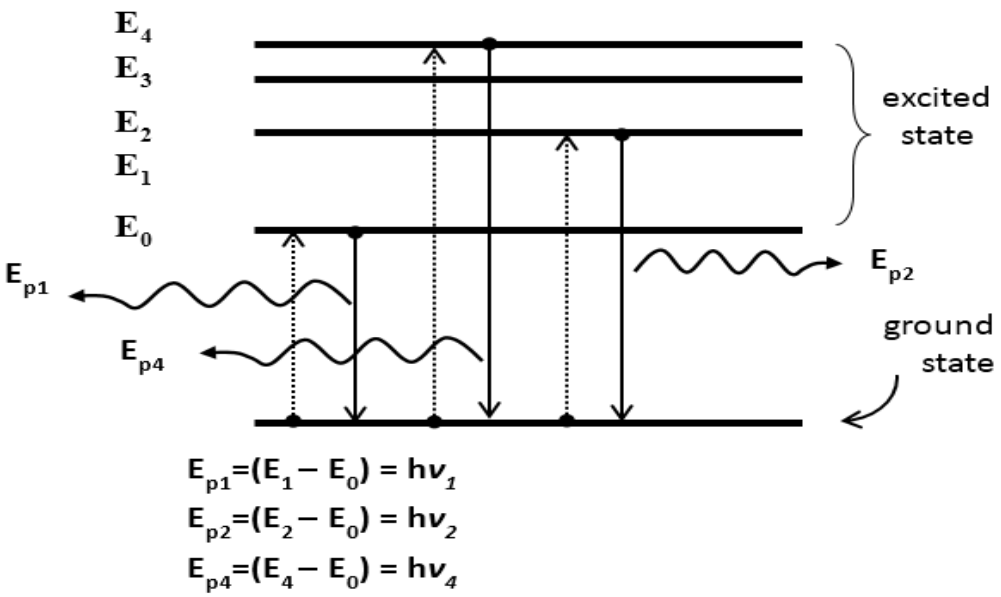


Figure 1.Digram of the energetic process for light emission.

3- Mechanism of simulated emission

A-Stimulated emission - monochromatic & coherent While an atom is still in its excited state, one can bring it down to its ground state by stimulating it with a photon (P_1) having an energy equal to the energy difference of the excited state and the ground state. In such a process, the incident photon (P_1) is not absorbed and is emitted together with the photon (P_2), The latter will have the same frequency (or energy) and the same phase (coherent) as the stimulating photon (P_1).

B-Laser uses the stimulated emission process to amplify the light intensity. As in the stimulated emission process, one incident photon (P_1) will bring about the emission of an additional photon (P_2), which in turn can yield 4 photons, then 8 photons, and so on….

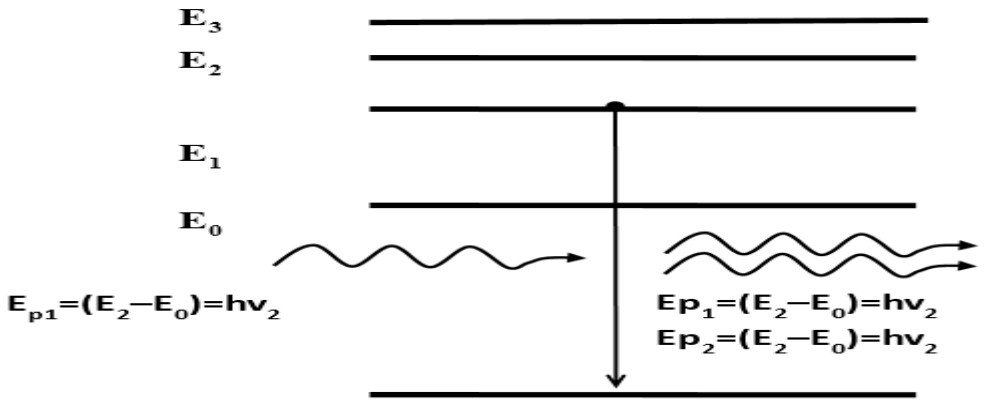


Figure 2. Diagram of mechanism for simulated emission photons.

4-**Laser - Formation & Conditions:**

The conditions must be satisfied order to sustain such a chain reaction:

A-Population Inversion (PI), a situation that there are more atoms in a certain excited state than in the ground state. PI can be achieved by a

variety means (electrical, optical, chemical or mechanical), e.g., one may obtain (PI) by irradiating the system of atoms by an enormously intense light beam or, if the system of atoms is a gas, by passing an electric current through the gas.

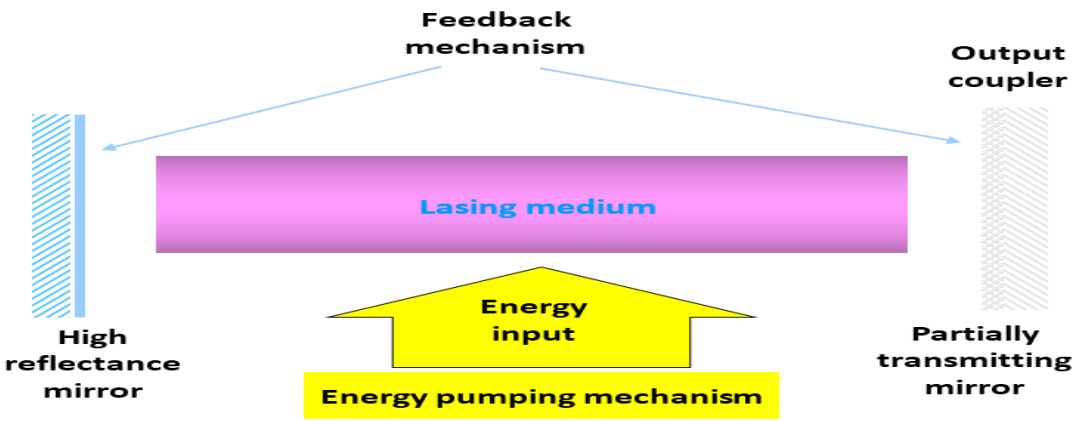
B-Presence of Metastable state(PM), which is the excited state that the excited e^-'s can have a relatively long lifetime (>10^{-8} second), in order to avoid the spontaneous emission occurring before the stimulated emission.

In most lasers, the chemical species (atoms, molecules or ions) in the lasing medium are not "pumped" directly to a metastable state. They are excited to an energy level higher than a metastable state, then drop down to the metastable state by spontaneous non-radiative de-excitation.

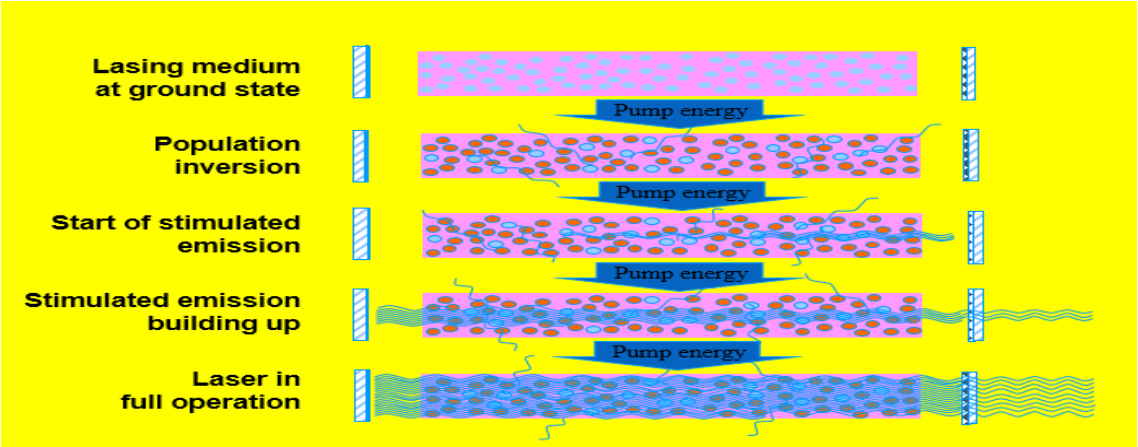
C-Photon Confinement (PC), the emitted photons must be confined in the system long enough to stimulate further light emission from other excited atoms. This is achieved by using reflecting mirrors at the ends of the system. One end is made totally reflecting & the other is slightly transparent to allow part of the laser beam to escape.

5-**Laser - Functional Elements:**

They found several components for laser production as the following diagram.



Laser Action



6-**Types of Lasers**:

There are many different types of lasers:-

A-The lasing medium can be gas, liquid or solid (insulator or semiconductor).

B-Some lasers produce continuous light beam and some give pulsed light beam.

C-Most lasers produce a light wave with a fixed wavelength, but some can be tuned to produce a light beam of wavelength within a certain range.

Laser type	The physical form of the lasing medium	Wave length (nm)
Helium-neon laser	Gas	633
Carbon dioxide laser	Gas	10600 (far-infrared)
Argon laser	Gas	488, 513, 361 (UV), 364 (UV)
Nitrogen laser	Gas	337 (UV)
Dye laser	Liquid	Tunable: 570-650
Ruby laser	Solid	694
Nd: Yag laser	Solid	1064 (infrared)
Diode laser	Semiconductor	630-680

7- **Laser – Applications:**

The laser can be applied in many areas

A-Commerce

The compact disk, laser printer, copiers, optical disk drives, bar code scanner, optical communications, laser shows, holograms, laser pointers

B-Industry

Measurements (range, distance), alignment, material processing (cutting, drilling, welding, annealing, photolithography, etc.), non-destructive testing, sealing

C-Medicine

Surgery (eyes, dentistry, dermatology, general), diagnostics, ophthalmology, oncology

D-Research

Spectroscopy, nuclear fusion, atom cooling, interferometry, photochemistry, the study of fast processes

E-Military

Ranging, navigation, simulation, weapons, guidance, blinding.

Applications:-

Q1// A laser emits light with a frequency of $4.69 \times 10^{14}\ s^{-1}$.

A) What is the energy of one photon of the radiation from this laser?

B) If the laser emits 1.3×10^{-2}J during a pulse, how many photons are emitted during the pulse?

Answer:-

A) $E_{photon} = h\nu = 6.63 \times 10^{-34}\text{Js} \times 4.69 \times 10^{14}\ s^{-1} = 3.11 \times 10^{-19}$ J

B) No. of photons = $(1.3 \times 10^{-2}\text{J})/(3.11 \times 10^{-19}\text{J}) = 4.2 \times 10^{16}$ photons are present in one pluses.
