2nd ArPS Summer School on Advanced Physics

Lectures in LASER Physics

Dr. Mohamed Abbas Ashour

Assistant professor

Higher Institute for Optics Technology (HIOT)

Researcher at LASER Institute for Research and Applications (LIRA)

Optics, Photonics and Laser group coordinator (APS)

25 – 08 -2024

Day One

- Brief history of Laser
- Laser main components
- Conditions for getting Laser.
- Rate equation (A & B coefficients)

Day Two

- Laser unique Properties
- Laser resonators
- CW vs Pulsed Laser
- Laser Hazards & Laser Safety

Day Three

Types of Lasers

Applications of Laser

Summary of the lectures

Summer School

Day One

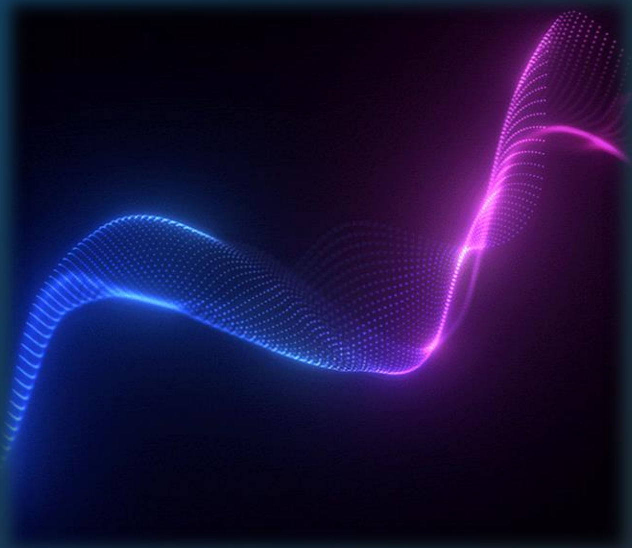
Day One

- Brief history of Laser
- Laser main components
- Conditions for getting Laser.
- Rate equation (A & B coefficients)

What is LASER ?

1960

- **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.
  - A laser is an unusual light source with unique properties.



Born
July 11, 1927
California, USA

Died
May 5, 2007
Vancouver, Canada

Laser is a solution
seeking a problems

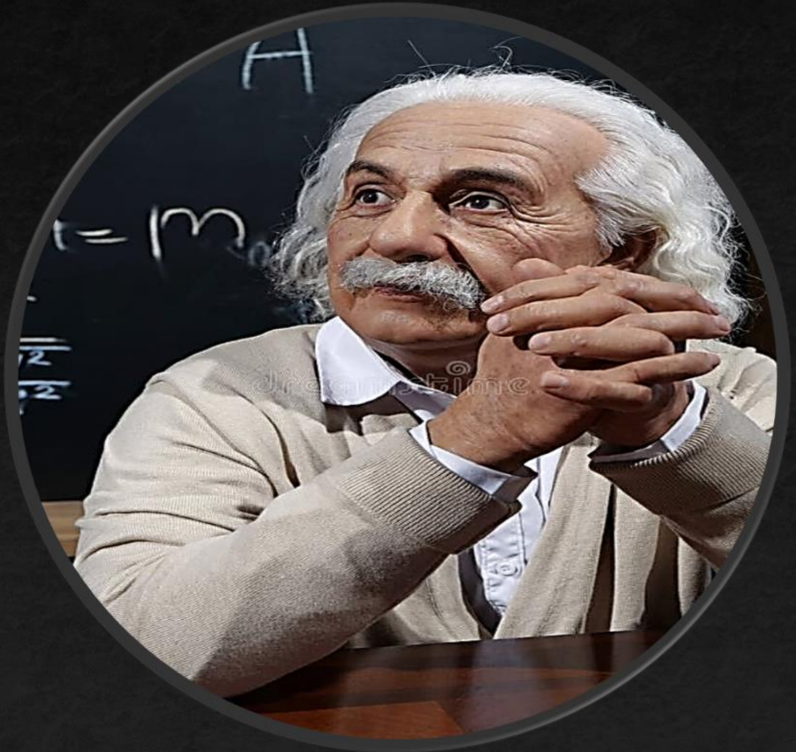
LASER

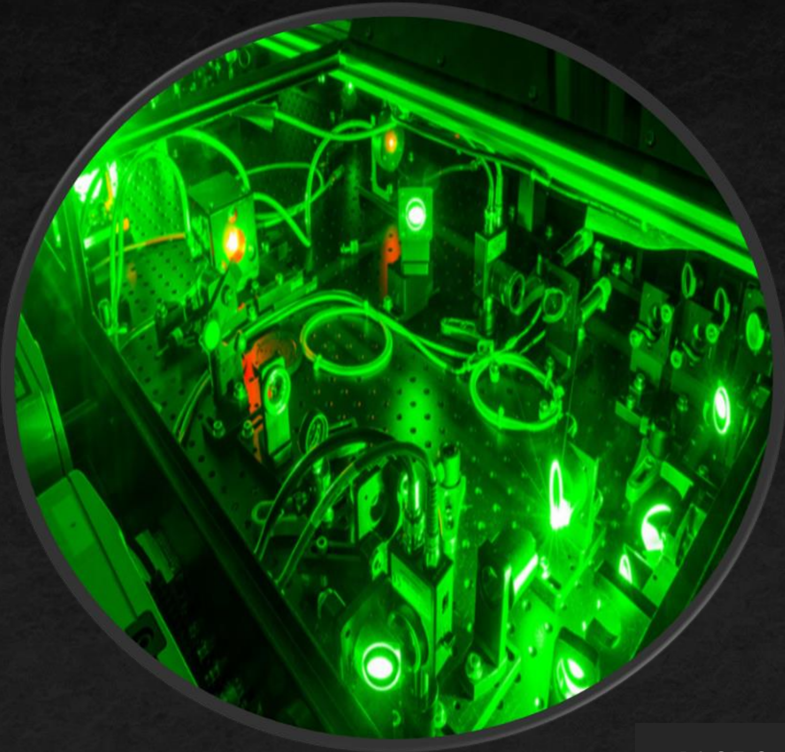
Brief history of LASER

Age before laser
1916 →1950

LASER Age
1951 →1960

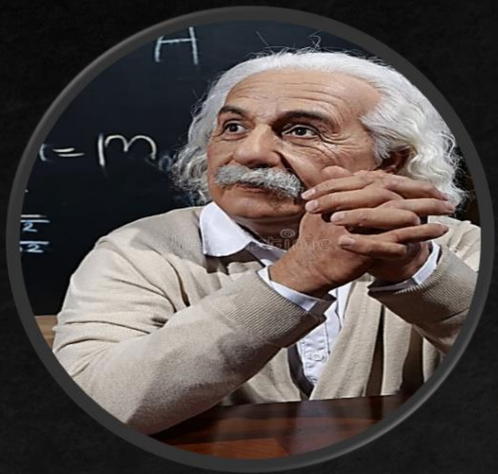
Age after LASER
1961 →….

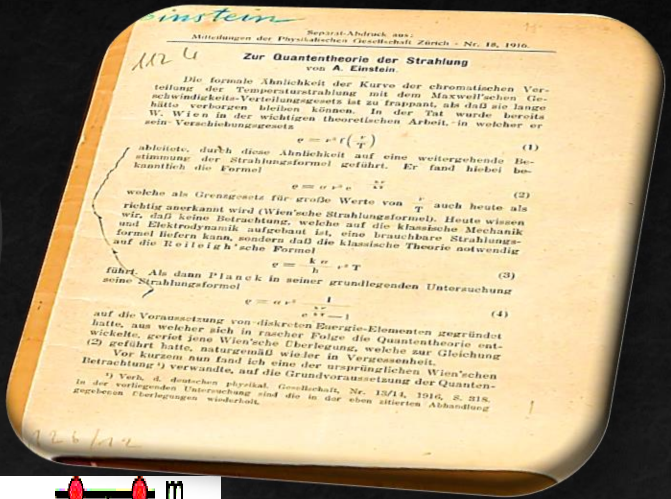




Age before LASER (1916 → 1950)

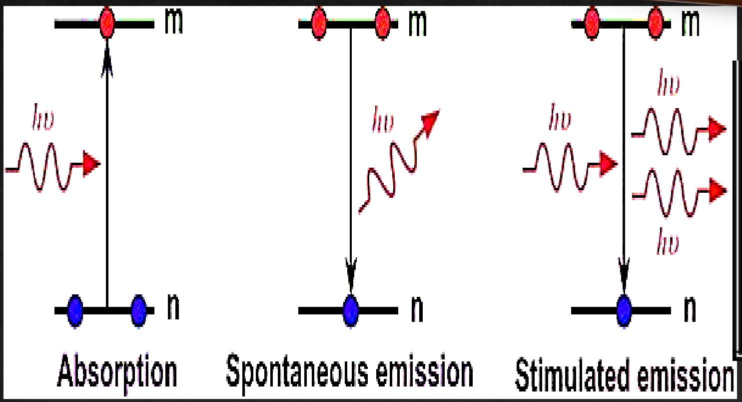
1916




Separat-Abdruck aus: Mitteilungen der Physikalischen Gesellschaft Zürich · Nr. 18, 1916.

Zur Quantentheorie der Strahlung

von A. Einstein.



$$\frac{A_{21}}{B_{21}} = \frac{8\pi h \nu^3}{c^3}$$

$$\frac{B_{21}}{A_{21}} = \left(\frac{c^3}{8\pi h}\right)\frac{1}{\nu^3}$$

1928 → 1950

1928 — Rudolf W. Ladenburg confirmed the existence of the phenomena of stimulated emission and negative absorption

1934 — Valentin A. Fabrikant predicted the use of stimulated emission to amplify "short" waves.

1947 — Willis E. Lamb and found apparent stimulated emission in hydrogen spectra.

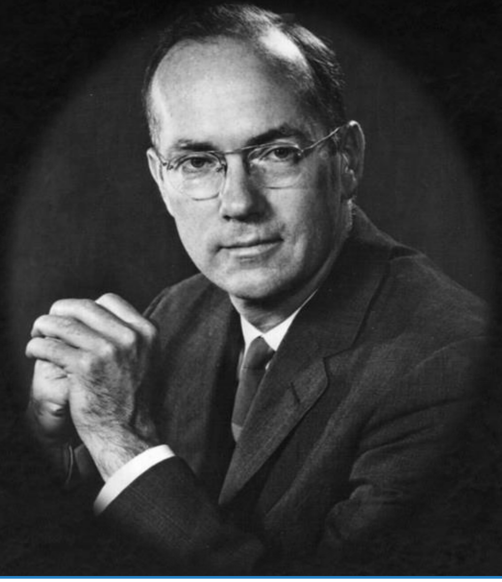
1950 — Alfred Kastler proposed the meth optical pumping.

Laser Age (1951 →1960)

1951

Joseph Weber Submitted a paper on using stimulated emissions to make a microwave amplifier

1953



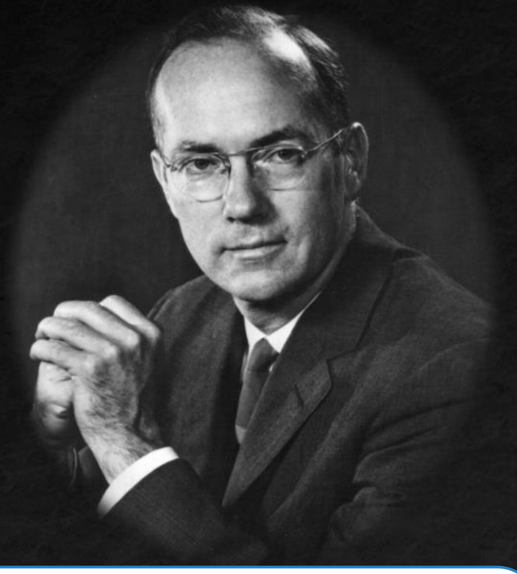
Charles H. Townes Produced the first microwave amplifier, a device operating on similar principles to the laser

1960

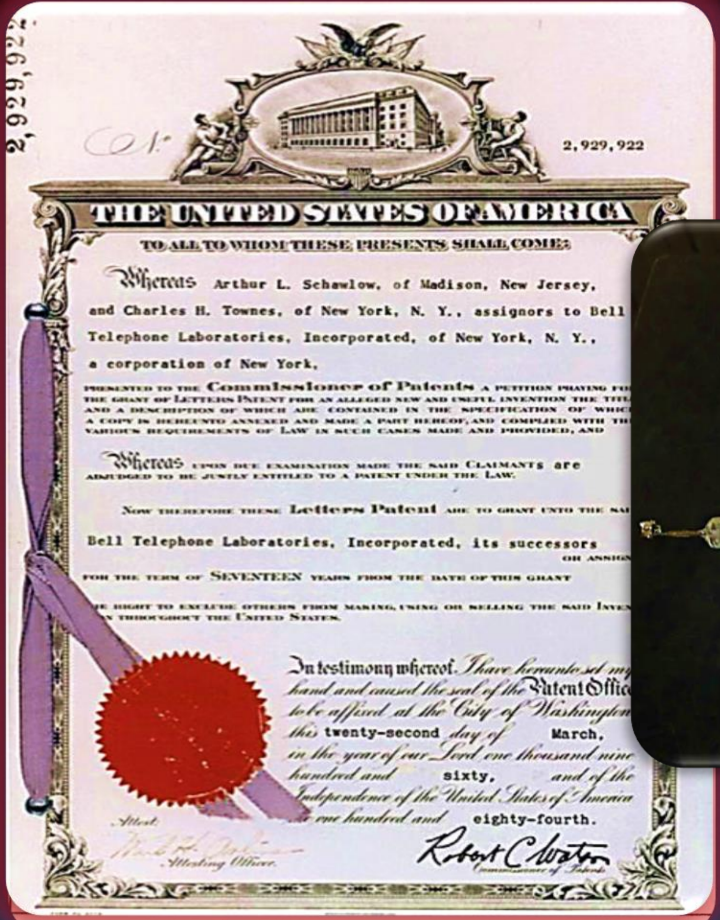
Theodore H. Maiman operated the first functioning Ruby laser at Hughes Research Laboratories.

Laser Age (1951 →1960)

1960



March 22, 1960 Townes and Schawlow, under Bell Labs, are granted US patent for the optical MASER.



2,929,922

No

2,929,922

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas Arthur L. Schawlow, of Madison, New Jersey, and Charles H. Townes, of New York, N. Y., assignors to Bell Telephone Laboratories, Incorporated, of New York, N. Y., a corporation of New York,

presented to the Commissioner of Patents a petition praying for the grant of Letters Patent for an alleged new and useful invention the title and a description of which are contained in the specification of which a copy is hereunto annexed and made a part hereof, and complied with the various requirements of Law in such cases made and provided, and

Whereas upon due examination made the said Claimants are adjudged to be justly entitled to a patent under the Law.

Now therefore these Letters Patent are to grant unto the said Bell Telephone Laboratories, Incorporated, its successors or assigns for the term of Seventeen years from the date of this grant the right to exclude others from making, using or selling the said invention throughout the United States.

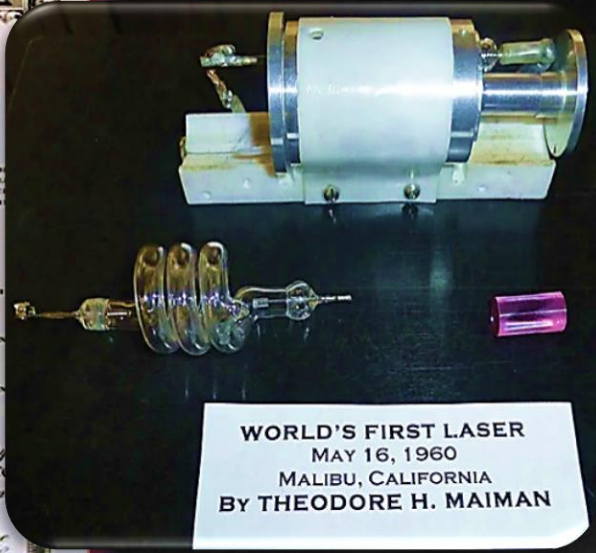
In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed at the City of Washington this twenty-second day of March, in the year of our Lord one thousand nine hundred and sixty, and of the Independence of the United States of America the one hundred and eighty-fourth.

Attest:

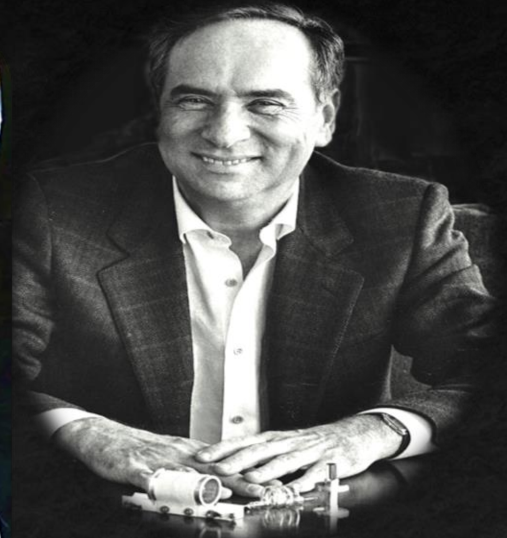
Attesting Officer.

Robert C. Watson

Commissioner of Patents.



1960

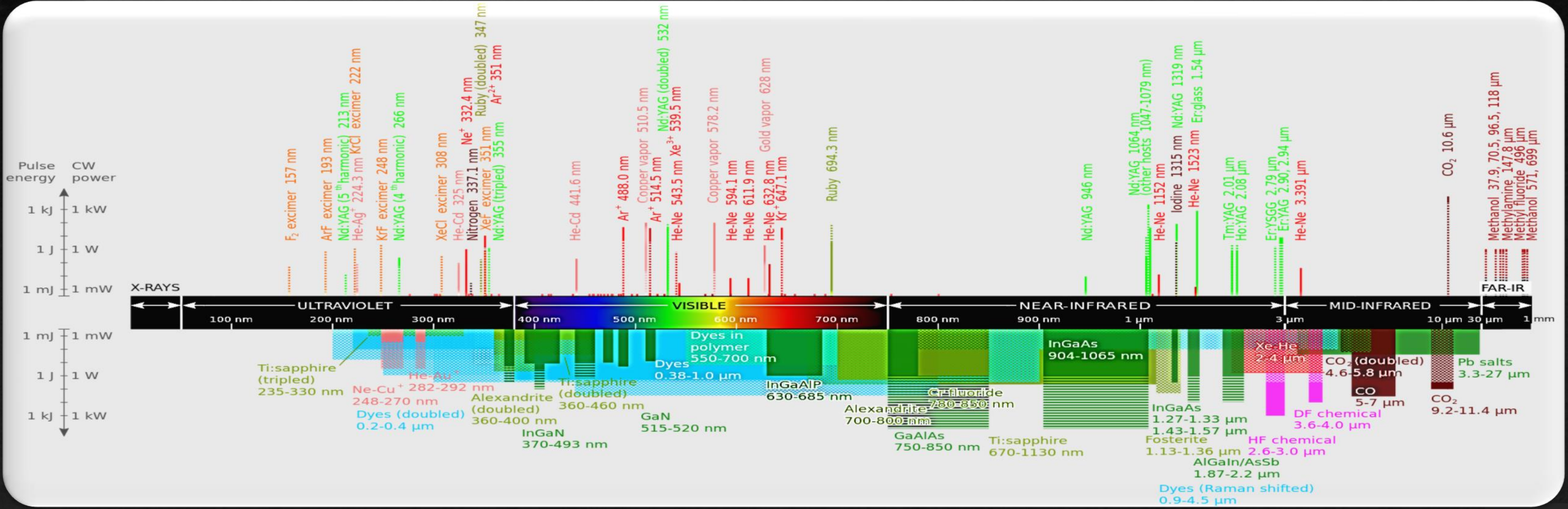


July 7, 1960: Hughes holds a press conference to announce Maiman's achievement.

Age after the LASER (1961 → …..)

1961

Lasers begin appearing on the commercial market through companies such as Trion Instruments, Perkin-Elmer and Spectra-Physics.



Age after the LASER (1961 → .....)

1964: Townes, Basov and Prokhorov for their fundamental work which has led to the construction of oscillators and amplifiers based on the maser-laser-principle."

1981: Arthur Schawlow and Nicholaas Bloembergen receive the Nobel Prize in physics for their contributions to the development of laser spectroscopy.

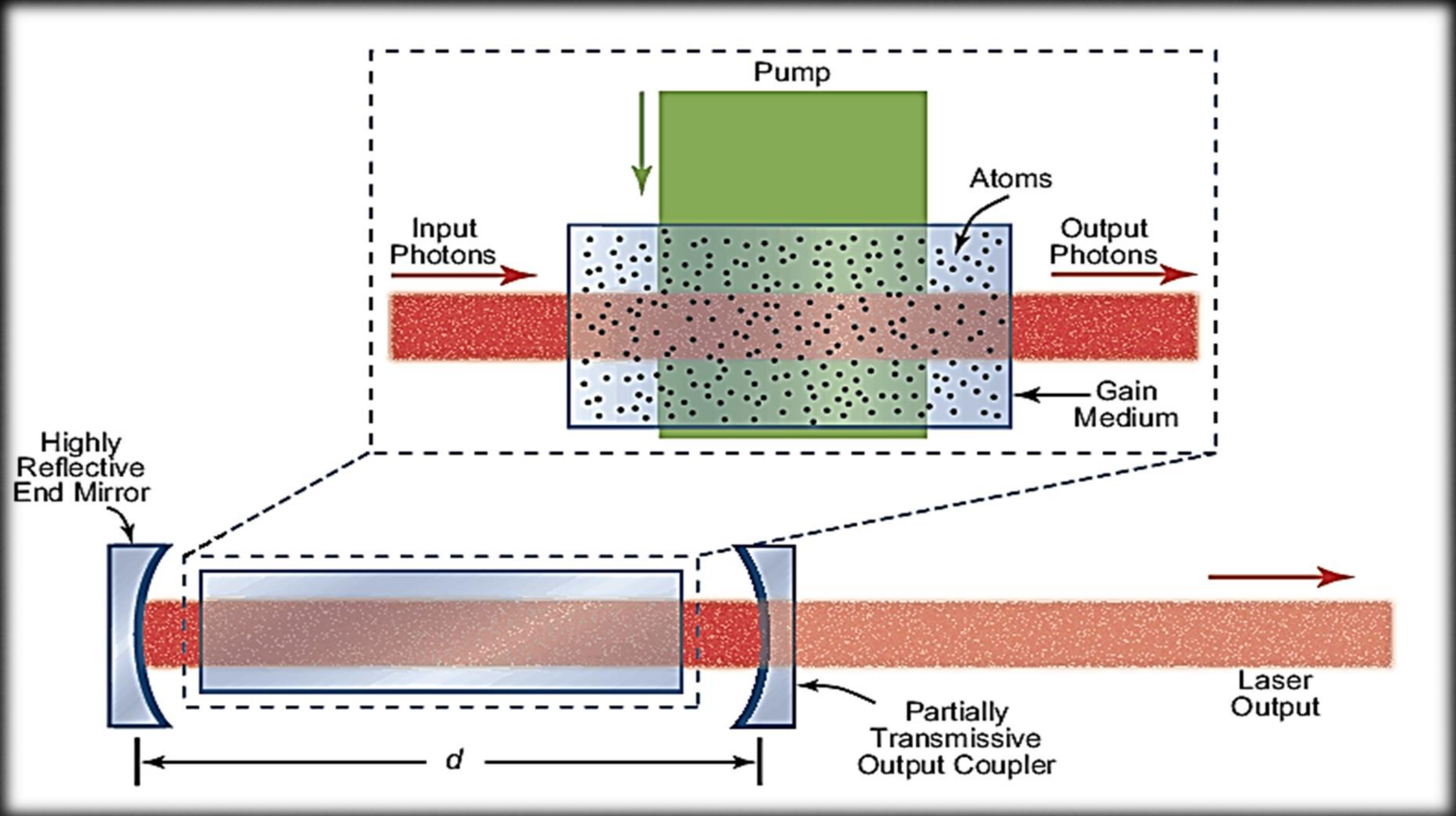
2023 → Experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter.

Day One

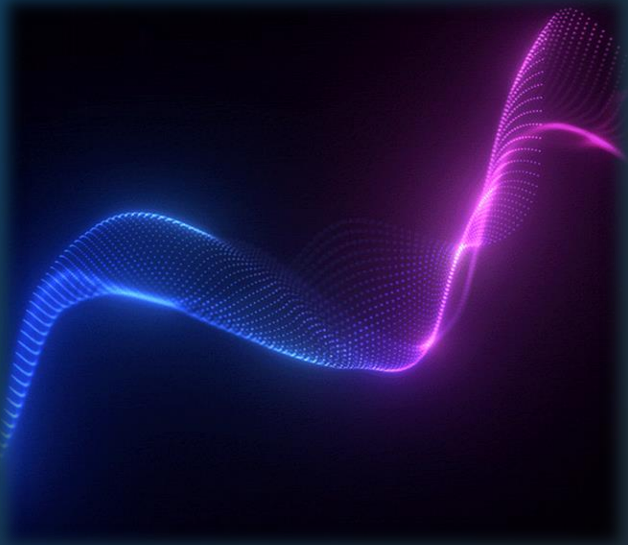
- Brief history of Laser
- Laser main components
- Conditions for getting Laser.
- Rate equation (A & B coefficients)

Laser main components

LASER



Laser main components



LASER

Day One

- Brief history of Laser
- Laser main components
- Conditions for getting Laser.
- Rate equation (A & B coefficients)

Conditions for getting Laser

Stimulated Emission

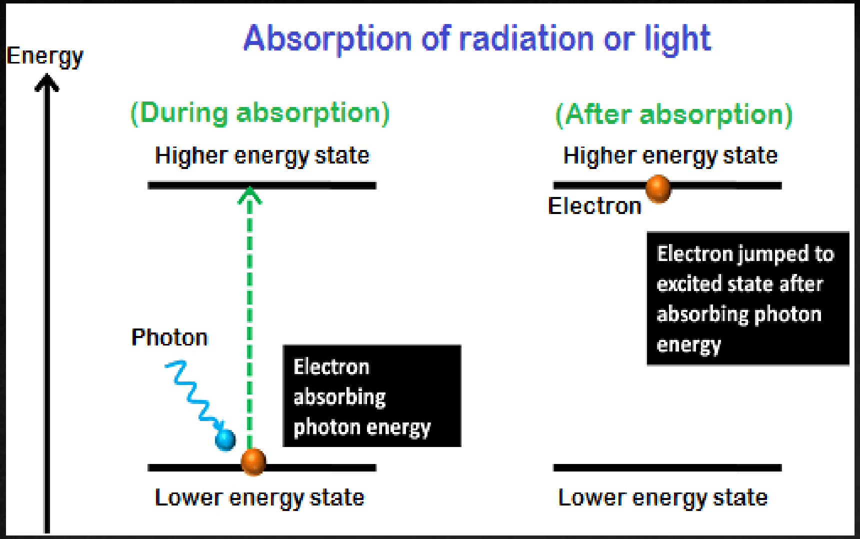
Amplification

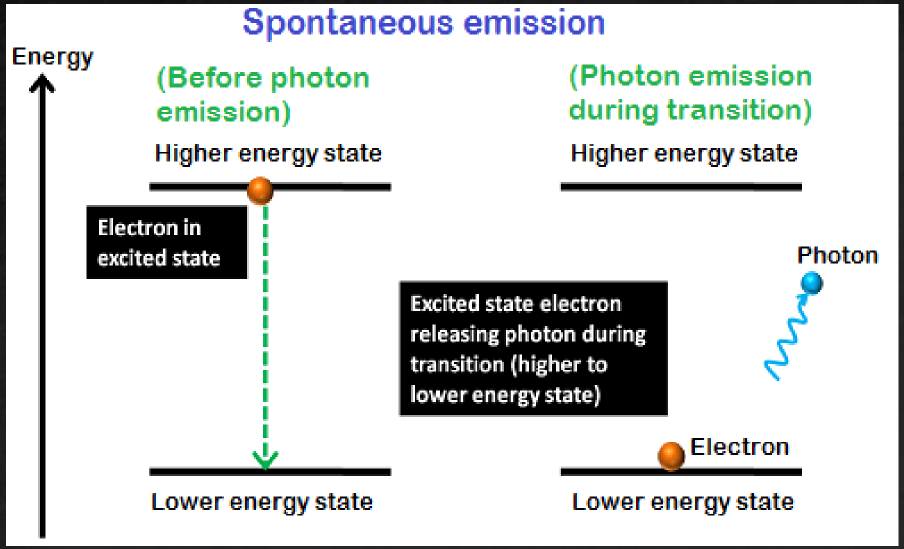
Metastable state

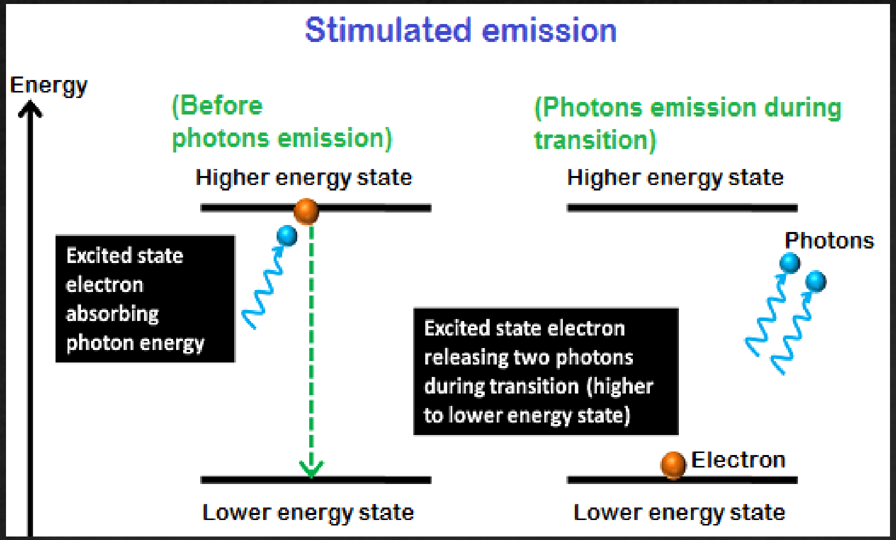
Population inversion

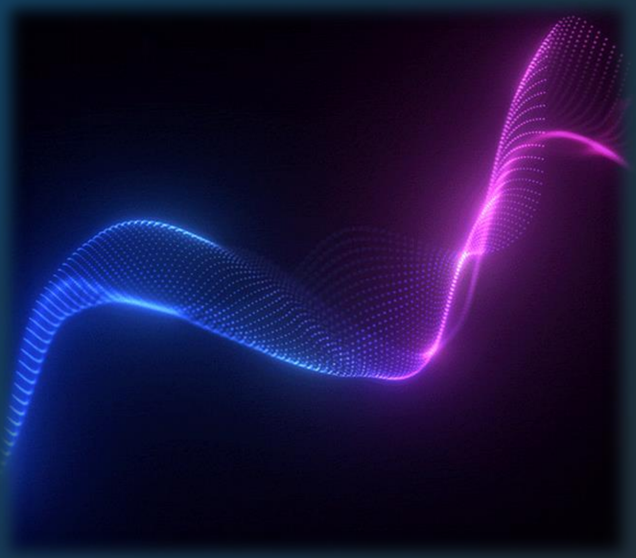
LASER

Stimulated Emission



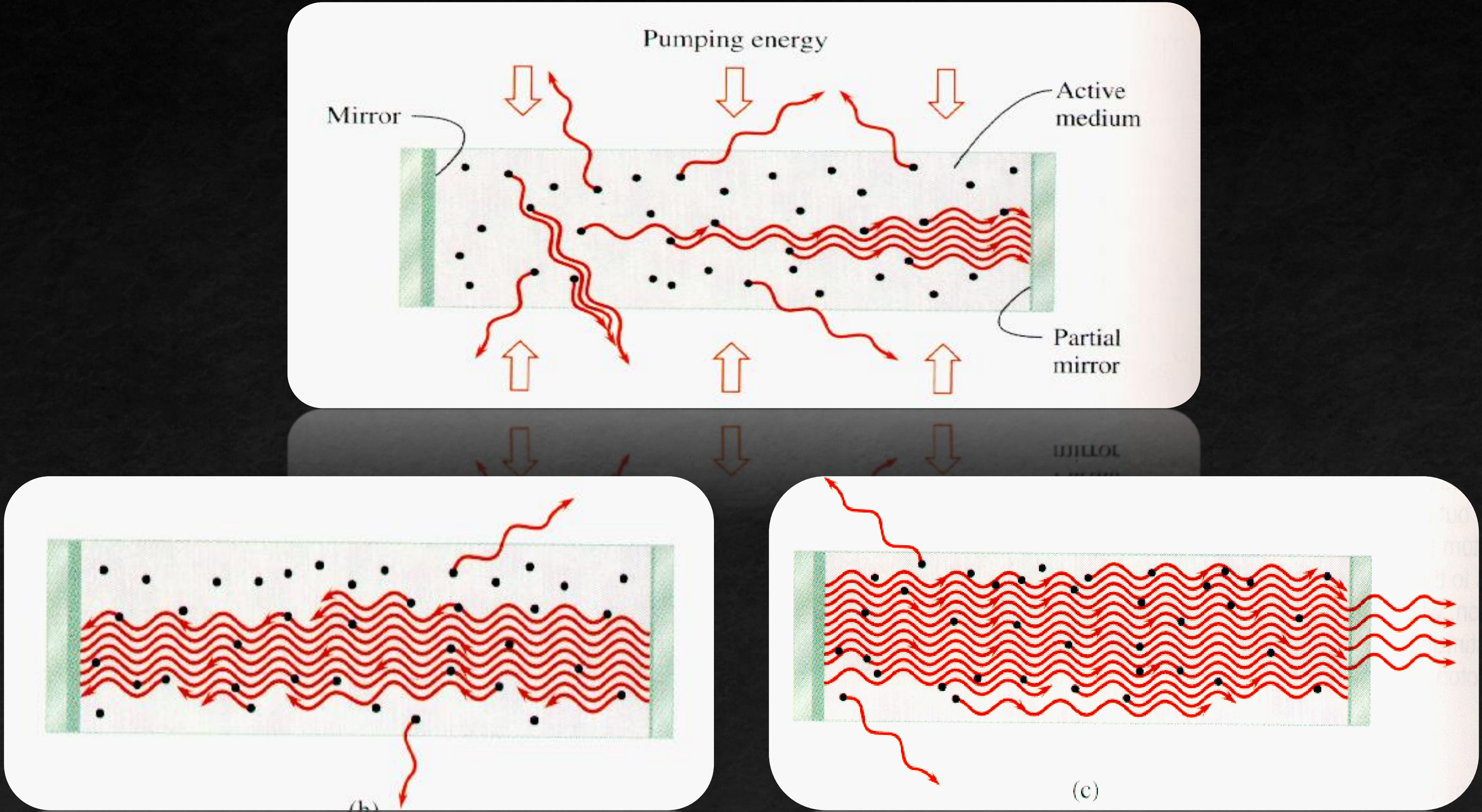






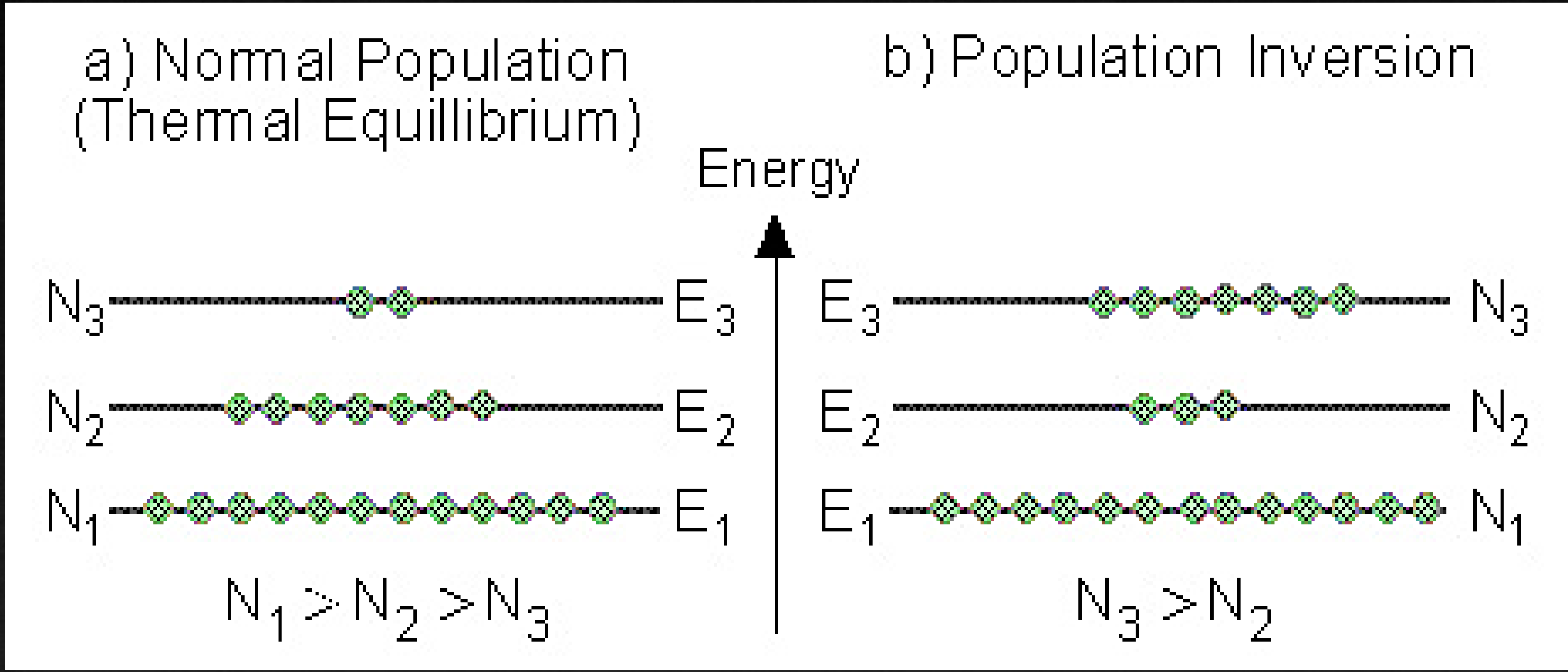
LASER

Amplification



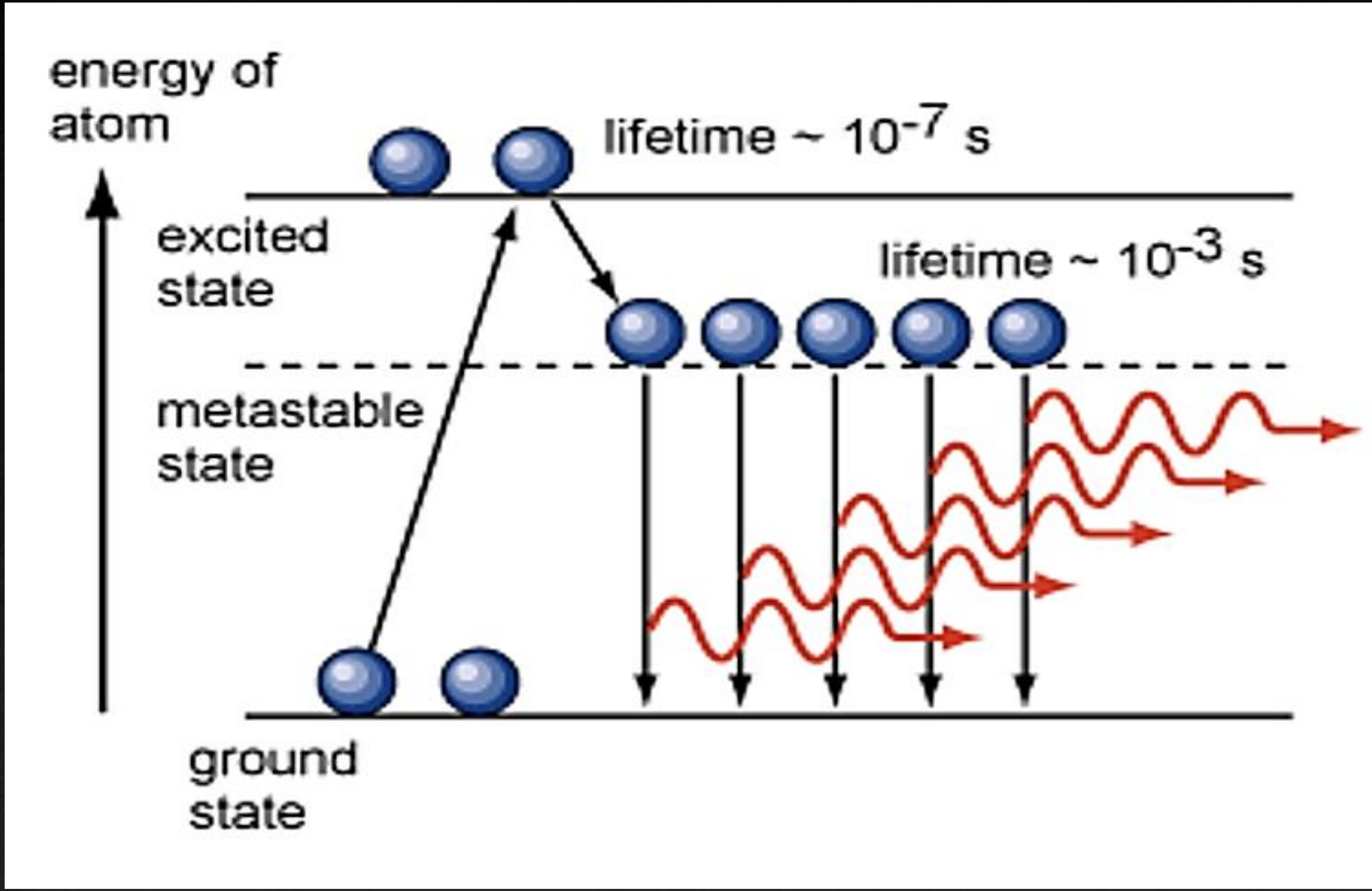
LASER

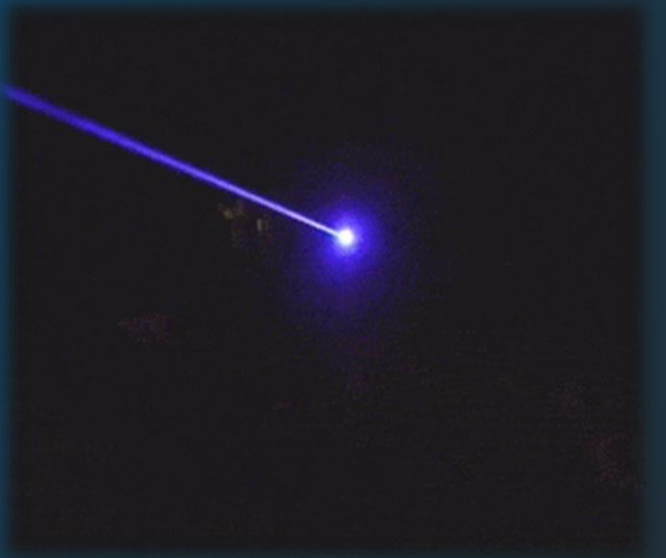
Population inversion



LASER

Meta stable state





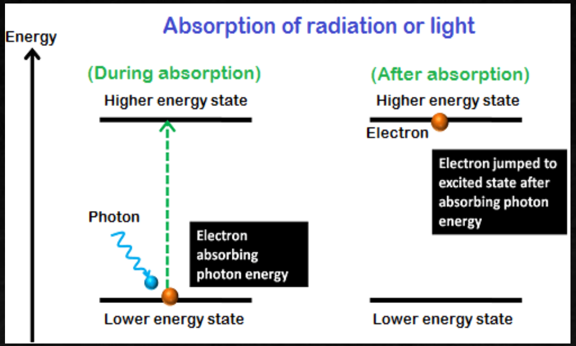
LASER

Day One

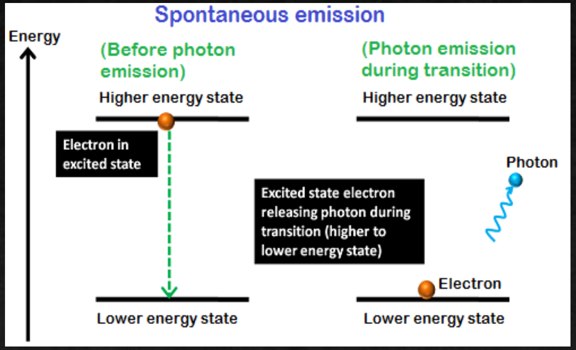
- Brief history of Laser
- Laser main components
- Conditions for getting Laser
- Rate equation (A & B coefficients)

Rate equation

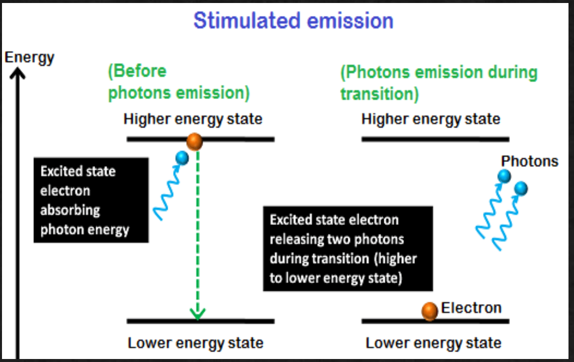
$$\frac{dN_2}{dt} = +B_{12}N_1\rho(v)$$

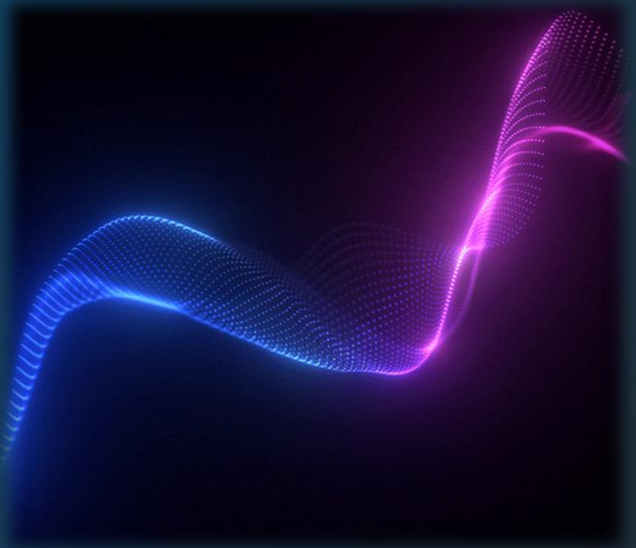


$$\frac{dN_2}{dt} = -A_{21}.N_2$$



$$\frac{dN_2}{dt} = -B_{21}N_2\rho(v)$$





LASER

Rate equation

$$\frac{dN_2}{dt} = +B_{12}N_1\rho(v)$$

$$\frac{dN_2}{dt} = -A_{21}.N_2$$

$$\frac{dN_2}{dt} = -B_{21}N_2\rho(v)$$

$$B_{12}\rho(\nu_0)N_1 = A_{21}N_2 + B_{21}\rho(\nu_0)N_2.$$

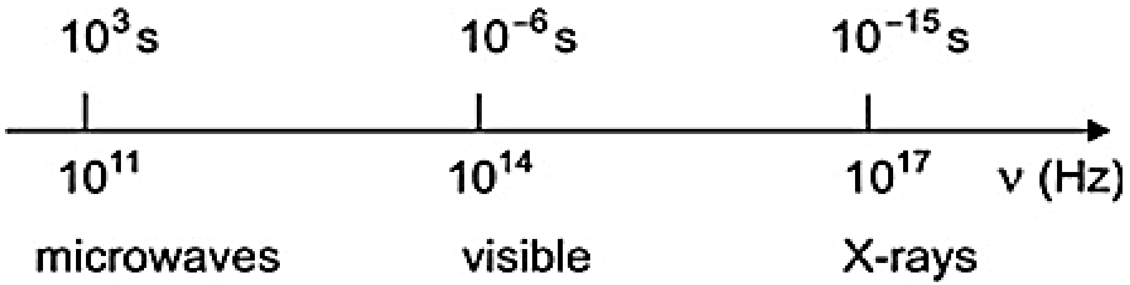
$$B_{21} = B_{12},$$

$$A_{21} = \frac{8\pi\nu^2}{c^3}h\nu B_{21}$$

LASER

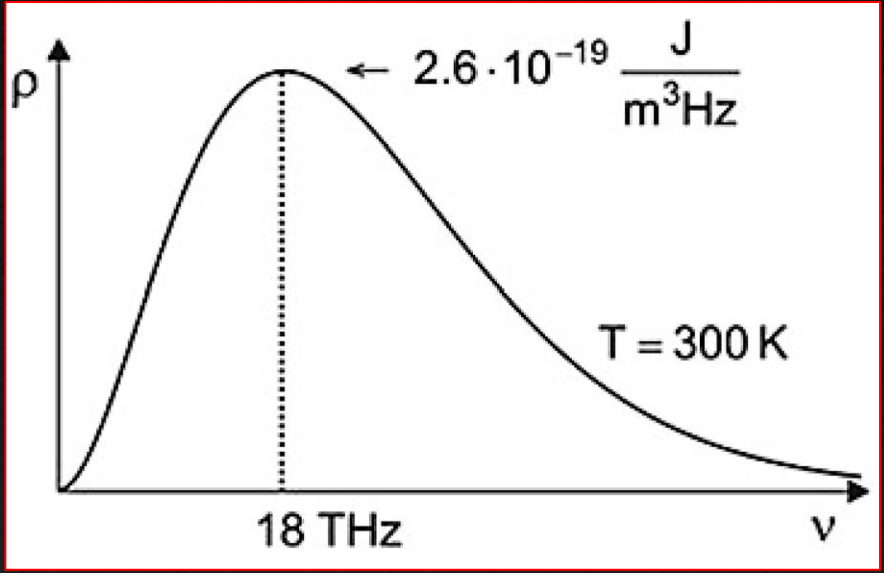
Rate equation

Fig. 6.5 Natural lifetime



$$N_2(t) = N_2(0)\, e^{-A_{21}t} = N_2(0)\, e^{-t/\tau_{sp}}.$$

$$A_{21} = 1/\tau_{sp}.$$



LASER

Einstein coefficients

Table 6.1 Einstein coefficients

Laser	λ	n	τ_{sp}	$A_{21}(s^{-1})$	B_{21} $(m^3\ J^{-1}\ s^{-2})$
HeNe	633 nm	1	100 ns	10^7	1.5×10^{20}
CO_2	10.6 µm	1	5 s	0.2	1.4×10^{16}
Nd:YAG	1.06 µm	1.82	230 µs	4.3×10^3	5.1×10^{16}
TiS (E ∥ c)	830 nm	1.74	3.8 µs	2.6×10^5	1.7×10^{18}
Fiber	1.5 µm	1.5	10 ms	10^2	6.6×10^{15}
Semiconductor	810 nm	3.6		3×10^9	3.7×10^{21}

LASER

Think

Q1: Why no two-level Laser system?

Q2: Why can't we get an X-Ray Laser?

References

1. *Renk, K. F. (2012). Basics of laser physics. Berlin: Springer Berlin Heidelberg.*
2. *Träger, F. (Ed.). (2012). Springer handbook of lasers and optics (Vol. 2, pp. 937-983). New York, NY, USA:: Springer.*
3. *Milonni, P. W., & Eberly, J. H. (2010). Laser physics. John Wiley & Sons.*

Thank you for your time

Enjoy your day