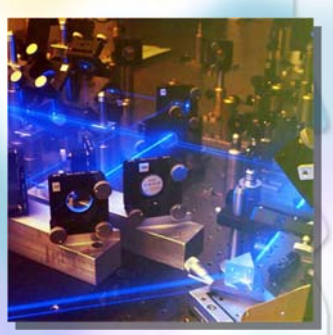
Physics Academy

Laser Physics

Introduction to Laser Essentials

Lecture 2



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The Essentials: Atoms

Bohr model of the atom

Lasing action is a process that occurs in matter.

Since matter is composed of atoms, we need to understand about the structure of the atom, and its energy states.

We shall start with the **semi-classical model**, as suggested in 1913 by **Niels Bohr**, and called: **The Bohr model of the atom**.

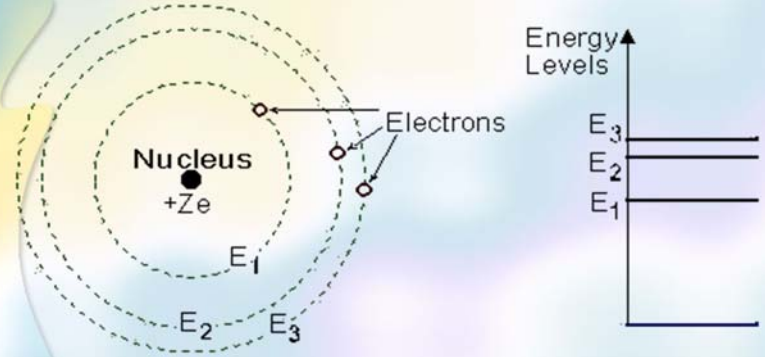
According to this model, every atom is composed of a very **massive nucleus** with a **positive electric charge (Ze)**, around it electrons are moving in specific paths.

Z = Number of protons in the nucleus,

e = Elementary charge of the electrons:

e = 1.6*10^{-19} [Coulomb]

The figure illustrates a simple, but adequate, picture of the atom, the Bohr model



Every "**allowed orbit**" of the electron around the nucleus, is connected to a specific energy level.

The energy level is higher as the distance of the "orbit" from the nucleus increases. Since for each atom there are only certain "allowed orbits", **only certain discrete energy levels exist**, and are named: **E1, E2, E3**, etc.

Energy States (Levels)

Every atom or molecule in nature has a specific structure for its energy levels.

The lowest energy level is called the **ground state**, which is **the naturally preferred energy state**. As long as no energy is added to the atom, the electron will remain in the ground state.

When the atom receives energy (electrical energy, optical energy, or any form of energy), this energy is transferred to the electron, and raises it to a higher energy level.

The atom is then considered to be in an **excited state**.

The electron can stay only at the specific energy states (levels) which are unique for each specific atom. The **electron can not be in between these "allowed energy states"**, but it can "jump" from one energy level to another, while receiving or emitting specific amounts of energy.

These specific amounts of energy are equal to the **difference between energy levels within the atom.**

Each amount of energy is called a "**Quantum**" of energy (The name "**Quantum Theory**" comes from these discrete amounts of energy).

Energy transfer to and from the atom

Energy transfer to and from the atom can be performed in two different ways:

Collisions with other atoms, and the transfer of kinetic energy as a result of the collision. This kinetic energy is transferred into internal energy of the atom.

Absorption and emission of electromagnetic radiation.

Since we are now interested in the **lasing process**, we shall concentrate on the second mechanism of energy transfer to and from the atom.

Photons and the energy diagrams

Electromagnetic radiation has, in addition to its wave nature, some aspects of "**particle like behavior**".

In certain cases, the electromagnetic radiation behaves as an ensemble of discrete units of energy that have momentum. These discrete units (quanta) of electromagnetic radiation are called "**Photons**".

The relation between the **amount of energy (E)** carried by the photon, and its **frequency (*ν*)**, is determined by the formula (first given by Einstein):

$$E = h\nu$$

The proportionality constant in this formula is **Planck's constant (h)**:

$$h = 6.626*10^{-34}\ \text{[Joule-sec]}$$

This formula shows that **the frequency of the radiation (*ν*), uniquely determines the energy of each photon in this radiation.**

$$E = h\,\nu$$

This formula can be expressed in different form, by using the relation between the frequency (*ν*) and the wavelength: $c = \lambda * \nu$ to get:

$$E = h * c/\lambda$$

This formula shows that **the energy of each photon is inversely proportional to its wavelength**. This means that each photon of shorter wavelength (such as violet light) carries more energy than a photon of longer wavelength (such as red light).

Since h and c are universal constants, so either wavelength or frequency is enough to fully describe the photon.

Introduction to LASER

What is LASER?

تعتبر تكنولوجيا الليزر من العلوم المتطورة التي تدخل في العديد من التطبيقات مثل استخدام الليزر في التطبيقات الطبية والاتصالات والأبحاث العلمية والهندسية والعسكرية. وأي مستخدم لليزر مهما اختلف تخصصه فهو بحاجة إلى فهم مبدأ عمل الليزر أي ما يعرف بفيزياء الليزر.

إن الليزر هو عبارة عن جهاز يحول الطاقة من مصادر مختلفة إلى صورة أشعاع كهرومغناطيسي. وهذا تعريف بسيط للبدأ في الموضوع وتوضيح فكرة عمل الليزر حيث أننا نحصل في النهاية على شعاع كهرومغناطيسي (ضوء) يمتلك العديد من الخواص التي تميزه عن أي مصدر ضوئي.

What is LASER?

وقد جاءت تسمية كلمة ليزر من الأحرف الأولي لفكرة عمل الليزر أي أن:

The word LASER is an acronym for

Light Amplification by Stimulated Emission of Radiation.

وتعني تكبير الضوء بواسطة الانبعاث الاستحثاثي للإشعاع الكهرومغناطيسي.

وقد تنبأ بوجود الليزر العالم البرت اينشتاين في 1917 حيث وضع الأساس النظري لعملية الانبعاث الاستحثاثي stimulated emission وتم تصميم أول جهاز ليزر في 1960 بواسطة العالم T.H. Maiman باستخدام بلورة الياقوت ويعرف بليزر الياقوت.Ruby laser

What is LASER?

Light Amplification by Stimulated Emission of Radiation.

Light: All light is a form of electromagnetic radiation that is visible to the human eye.

Amplification: This is simply the process of making something bigger or more powerful. When you turn up the volume on a radio, you are amplifying the sound; but with lasers, amplification makes the light brighter.

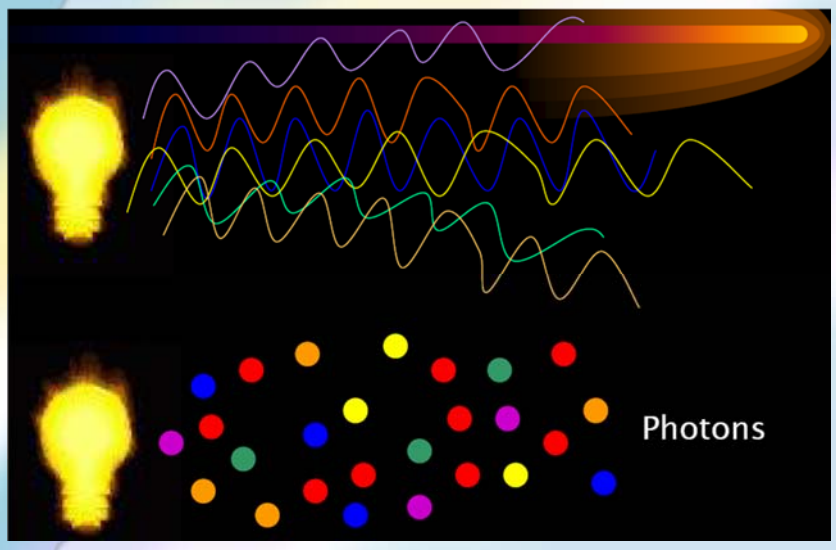
Stimulated: To stimulate means to stir to action. Laser light is created when a burst of light (electricity) excites the atoms in the laser to emit photons. These photons then stimulate the creation of additional identical photons to produce the bright laser light.

Emission: The word "emission" refers to something that is sent out or given off. Stimulated laser emission consists of large numbers of photons that create the intense laser light.

Radiation: The laser light is a form of energy that radiates, or moves out, from the laser source.

تاريخ تطور الليزر

1864 - 1940 : History of Astronomical Spectroscopy
1917 : Einstein postulates photons and stimulated emission
1954 : First microwave laser
1960 : First optical laser
1965 : Microwave laser discovered in the Orion nebula
1965 : Discovery of cosmic background radiation using microwave laser
1966 : First gas dynamic laser
1970 : First postulate of laser action in stars
1973 : Discovery of laser action in quasars
1979 : Near Infrared laser star found in Orion nebula
1981 : Carbon dioxide laser discovered in atmosphere of mars and venus
1984 : First x-ray laser
1993 : Gas contact plasma laser
1994 : Artificial laser guide stars
1995 : Far infrared laser star discovered by Kuiper Airborne Observatory
1996 : Ultraviolet laser star discovered by Hubble Space Telescope
2000 : Survey of the worlds most powerful research and military lasers



خصائص شعاع الليزر

شـعاع الليـزر يمتلـك خصـائص تميـزه عـن أيـة مصـدر مـن مصـادر الإشـعاع الكهرومغناطيسي وهذه الخصائص هي :

1. Monochromaticity. 2. Directionality. 3. Coherence.	هذه الخصائص جعلت لشعاع الليزر العديد من التطبيقات في كافة المجالات