Analytical Study of X-Ray, Gamma Ray Lasers and Masers

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***Abstract*- In This paper we present an analytical of X-Ray, Gamma ray laser and masers. A gamma-ray laser, or graser would produce coherent gamma rays, just as an ordinary laser produces coherent rays of visible light. Research to solve the difficulties inherent in the construction of a practical gamma-ray laser continues. In his 2003 Nobel lecture, Vitaly Ginzburg cited the gamma-ray laser as one of the thirty most important problems in physics. The search for a gamma-ray laser is interdisciplinary, including quantum mechanics, nuclear and optical spectroscopy, chemistry, solid-state physics, metallurgy, as well as the generation, moderation, and interaction of neutrons, and involves specialized knowledge and research in all these fields. The subject involves both basic science and engineering technology. X-rays lasers are one of the most recently development types of lasers and are not so far commercially available. The X-ray lasers produced to date operate at to pulse repetition rate of only a few pulses per day and are expensive to operate.**

***Index Terms*- X-Ray, Masers, Lasers, Gamma, Analytical etc.**

1. INTRODUCTION

A laser is a device that amplifies light and produces a high directional, high intensity beam that has very pure frequency or wavelength. It course in sizes ranging from approximately one tenth that diameter of a human hair to the size of a very high powers running from 10^{-9} to 10^{20} Watt and in the wavelength ranging from the microwave to the X-ray spectral regions with corresponding frequencies from 10^{11} to 10^{-11} Hertz. Lasers lave pulse energies as high as 10^{4} Joule and pulse durations as short as $6X10^{-5}$ sec. They can easily drill holes in the most of durable materials and can weld detached retain within the human eye. Almost everyone probably knows that the police use laser the speed measure speed. At least many drivers that have exceeded the speed limit know about it, but now many know that you also use laser several times in a day? You will find its use in CD players and in laser printers. You often find laser in action movies where the hero has to escape the laser beams when he's trying to solve a thrilling problem. The power contained in laser is both fascinating and frightening. There is nothing magical about a laser. It can be thought of as just another type of light source. It certainly has many unique properties that make it as a special source of light, but these mathematical techniques or complex ideas. The concepts, as they are developed, will be applied to all classes of laser frequencies and laser materials, so that we will develop a sense of broad field of lasers. Furthermore, we many also understand that how a laser light differs from ordinary light.

X-rays lasers are one of the most recently development types of lasers and are not so far commercially available. The X-ray lasers produced to date operate at to pulse repetition rate of only a few pulses per day and are expensive to operate. Thus, applications are currently limited to those that can justify the expense. One such application is X-ray holography of living biological materials. With a laser pulse of a few hundred picoseconds duration, this process can generate a 'stop action' three dimensional image of living species with high resolution possible with short illumination wavelength. Other applications include x-ray microscopy, crystallography, medical radiology, atomic physics studies, radiation chemistry, x-ray lithography in the fabrication of microcircuits and structures, material research act. In the interaction of electromagnetic radiation with matter, the ratio of spontaneous emission to stimulated emission as given by Einstein is

$$\frac{8\pi h v^2}{C^2}$$

In this equation the frequency v appeared in moderator with cube power clearly makes spontaneous emission very high for short wavelength. Hence making of short wavelength laser is far more difficult. The frequency of ultra violet rays and x-rays is very high and it makes stimulated emission very difficult unlike in infrared region where it is just opposite. In 1917 without realizing the invention of laser and Einstein had predicted difficulty in the making of X-ray lasers. However the importance of short wavelength of x-rays brings out the importance of x-ray laser. Shorter wavelength can be focused more tightly than light, offering much better resolution than possible in the ultraviolet an optical region.

II. HOW DOES LASER LIGHT DIFFER FROM ORDINARY LIGHT

Light is really an electromagnetic wave. Each wave has brightness and color and vibrates at a certain angle so called polarization. This is also true for laser light but it is more parallel than any other source of light. Every part of beam has the same direction and beam will therefore diverge very little. With a good laser an object at a distance of 1 Km can be illuminated with a dot about (2.3 inches_ in radius. As it is so parallel that it can also be focused to very small diameters where the concentration of light energy becomes so great that you can cut and drill with it. It also makes it possible to illuminate and examine very tiny details of a physical process. It is this property that is used in surgical appliances and in CD players. It can also be made very monochromatic so that just one light wavelength is present. This is not the case with ordinary light sources. White light contains all the colors in its spectrum but even a colored light such as a LED (light emitting diode) contains a continues interval of red wavelength. Furthermore, laser fields are very high as compared to the field strength of ordinary light. Because of its high field strength such properties of the matter can be understood which were not otherwise possible with the field strength of the ordinary light source. As a laser field due to its high field strength can interact with inter-atomic fields.

III. REQUIREMENTS OF A LASER

A laser is a coherent source of electromagnetic energy which acts as an optical oscillator and an optical amplifier. The optical oscillator is to be made up to two plane parallel mirrors like a Fabry-Perot cavity in which one of the end mirrors acts as a window for energy output while other mirror is fully reflecting. One of the end mirrors is partially reflecting by which part of the energy is fed back into the laser material. The laser material putted in the cavity is the gain medium which acts as an optical amplifier. The optical gain or amplification is possible if the number of stimulated emission per unit volume per second is superior over the requirement of such a material medium is to have the material medium (in gases, liquids, solids plasma etc.) in the state of population inversion. That means the number of molecules or atoms are some in the excited state than in the ground state then such a medium is the active medium or amplifying medium. Therefore the population inversion is to be induced by different pumping techniques or methods as per requirements of the laser. Thus, the different elements of laser are below.

- Resonator
- Gain Medium
- Optical Gain

IV. HEORETICAL CONSIDERATIONS

A. Three Energy Level Lasers

To achieve non-equilibrium conditions, an indirect method of populating the excited state must be used. To understood how this is done, we may use slightly more realistic model, that of a three level laser. Consider the group of N atoms, so that each atom is able to exist in any three energy states; levels 1, 2, 3, with energies' E_1, E_2 and E_3 and population densities N_1 , N_2 and N_3 respectively. Energy of level 2 lies between that of the ground state and level 3. Initially, the system of atoms is at thermal equilibrium and majority of the atoms will be in the ground state : - e.g. $N_1 = N$ and N_2 and $N_3 = 0$. If we now subject the atoms to light of a frequency $V_{31,}$ where $E_3 – E_1 = hv_{31,}$ the process light absorption, as there are other methods of exciting the laser medium, such as electrical discharge or chemical reactions may be used. The level 3 is sometimes referred to as the upper pump level or pump band, and the energy transition E_1 - E_3 as the pump transition.

If the atoms are pumped continuously, we will excite an appreciable number of them into level 3, such that N3> 0. In a medium suitable for laser operation, we require these excited atoms to quickly decay to energy level 2. The energy released in this transition may be emitted as a photon spontaneously (spontaneous emission). However in practice the 3 – 2 transitions labeled as R in the diagram is usually radiation less, with the energy being transferred to vibration motion of the host material surrounding the atoms without generation of a photon.

An atom in level 2 may decay by spontaneous emission to the ground state releasing a photon of frequency V_{21} (given by E_2-E_1 =h V_{21}, which is shown as the transition life time of this transition $\int_{21}$ is much longer than the lifetime of non-radiative 3 -2 transition $\int_{32}$ (if $\int_{21} >> \int_{32}$). The population of the energy level 3 will be essentially Zero)N_3=0) and a population of excited state atoms will accumulated in level 2 (N_2=0). If more than half of the N atoms can be accumulated in the state 2 then this will exceed the population of the ground state N_1. Thus a population inversion (N_2-N_1) has been achieved between level 1 and 2, and optical amplification at the frequency V_{21} can be obtained in this active medium.

Because at least half of the population of atoms must be excited from the ground state to obtain a population inversion and this can be done if the laser medium must be strongly pumped. A three level system could also be possible to have the radiative transition between levels 3 and 2, and non-radiative transition between levels 2 and 1. In this case, pumping requirements are weaker.

V. DIFFERENT PROBLEMS AND DISSUSSION

X-rays lasers are one of the most recently development types of lasers and are not so far commercially available. The X-ray lasers produced to date operate at to pulse repetition rate of only a few pulses per day and are expensive to operate. Thus, applications are currently limited to those that can justify the expense. One such application is X-ray holography of living biological materials. With a laser pulse of a few hundred picoseconds duration, this process can generate a ‘stop action’ three dimensional image of living species with high resolution possible with short illumination wavelength. Other applications include x-ray microscopy, crystallography, medical radiology, atomic physics studies, radiation chemistry, x-ray lithography in the fabrication of microcircuits and structures, material research act.In the interaction of electromagnetic radiation with matter, the ratio of spontaneous emission to stimulated emission as given by Einstein is

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VI. REVIEW OF RELATED LITERATURE

A. Introduction Studies

The high rate of technology advancement in today’s world is astounding. These technological advances are having an enormous impact on all aspects of life and their impact on the practice of medicine is not to be underestimated. One are of medicine that is under ration of imaging into the process of cancer detection, diagnosis, and intervention. Radiation therapy is a prime example of this change. The role of the medical physicist in the radiation therapy process accelerates the development and introduction of these technologies into the clinical setting. As a result, imaging is now a pervasive component of radiation therapy with all major imaging modalities represented and numerous examples in which these modalities have been adapted to the treatment machine to allow increased accuracy and precision in the delivery of dose. While the objectives of these developments are clear, they raise numerous issues regarding the skills and resources that ensure these technologies are appropriately integrated and applied. Specifically, these developments place enormous pressure on the clinical staff to extend their knowledge base and their scope of responsibility.

In 2007, the IAEA assembled a team of medical physicists with experience in radiation therapy and imaging and charged them to examine the increasing role of imaging in the radiation therapy process and make recommendations related to their observations. A report was commissioned that should achieve the following objectives.

- Review the status of mature imaging modalities currently employed in radiation therapy practice. These include pretreatment imaging for target definition to in-room imaging for improved precision and accuracy of delivery.
- Review the availability and applicability of existing practice and quality assurance guidance documents related to the use of imaging information in the radiation therapy process.
- Identify of shortcomings in these documents while being cognizant of the broad range of needs found in the IAEA Member states.
- Develop a set of recommendations to the IAEA related to the needs and opportunities for further development with respect to imaging in radiation therapy. These recommendations may take the form of either detailed, prescriptive recommendations (e.g. formation of a CRP, prepations of a TECDOC) or broader recommendations regarding future directions.

The resulting report was to be employed for internal use the Agency, providing a perspective on the issues related to imaging in radiation therapy and assisting the Agency in accommodating these issues in the years ahead.

B. Imaging in the radiotherapy process

In the developed countries, radiation therapy is employed in over 50% of cancer patients at some point in the management of their disease. As a local therapy, radiation therapy seeks to exploit technology to conform the treatment to the targeted structure while avoiding surrounding critical normal tissue. Overall, the process of radiation therapy has become increasingly complex as the technology for its delivery advances. Recent developments in radiation collimation (e.g. multi-leaf collimators), computation (inverse planning), and imaging (target definition and targeting.) have resulted in a far more complex radiation therapy process which promises higher quality of intervention, dose escalation, and/or reduced toxicity. The radiation therapy process contains many steps with imaging distributed throughout the process.

Imaging has become the primary source of information in the design of radiation therapy. As such, it is of critical importance that (i) the signal contained in these images is well understood, and (ii) the spatial distribution is precise and accurate. Failure in this aspect to do so can result in serious deleterious effects including failure to control the disease and /or induction of unforeseen toxicities.

VII. FUNDAMENTAL IDEAS INITIATED LASER

In early literature, particularly from researchers as Bell Telephone Laboratories, the laser was often called the optical maser. The usage has since become uncommon, and as of 1998 even Bell Labs uses the term laser. In 1917, Albert Einstein in has paper on the quantum theory of dedications laid the fundamental for the invention of the laser and its predecessor, the maser, in a ground breaking rededication of Max Planck's Law of radiation based on the concept of probability coefficients later on to be termed as Einstein coefficients. In 1928, Rudolph W. Ladenburg confirmed the existence of stimulated emission.

In 1939, Valentine A. Fabrikant (USSR) predicated the use of stimulated emission to amplify "short waves.

In 1947, Willis E Lamb and R.C Rutherford found apparent stimulated emission in hydrogen spectra and made the first demonstration of stimulated emission.

In 1950, Alfred Kastler (Nobel Prize For Physics 1966) proposed the method of optical pumping which was experimentally confirmed by Brossel, Kastler and winter tow years later.

A LASER is a MASER that works with higher frequency photons in the ultraviolet or visible light or infra-red spectrum (photons are bundles of electromagnetic energy commonly thought as" rays of light" which travel in oscillating waves of various wavelengths) so far as radiation is treated as a wave. AS, MASER stands for Microwave Amplification by Stimulated Emission of Radiation.

A. Initial Concepts of Maser

In 1953, Charles H. Townes and graduate students James P. Gordon and Herbert J. Zeiger produced the first Maser, a devise operating on similar principles to the laser, but producing microwave rather than infrared or visible radiation, Townes's MASER was incapable of continuous output. Nicolay Basov and Aleksandra Prokhorov of the Soviet Union indecently on quantum oscillator and solved the problem of continuous output systems by using more than tow energy levels. These systems could release stimulated emission without falling to ground state, thus maintaining population inversion. The first papers about the Maser were published in 1954 as a result of investigations carried out simultaneously and independently by Charles Townes and ago workers as Columbia University in New York by Dr Basov and Dr Prokhorov at the Lebedev Institute in Moscow. These three gentlemen received the Nobel Prize of Physics in 1960 for their contribution in research and particularly in laser physics.

The fundamental physical principle motivating the MASER is the concept of stimulated emission. A maser beam is made up of entirely of stimulated emission. Finally, we can say that a MASER is a LASER of microwave region. With stimulated emission, a photon of absorption wavelength absorption. The atoms absorb this photons, and quickly emit tow photons to get back to its lower energy state. Both of these newly emitted photons are of wavelength π.

The process of stimulated emission in a MASER may understand as follow:

A. All of the molecules are in upper state and a photon of wavelength π is incident from left. (B) The photon π stimulated emission from the molecule, so there are now two photons of wavelength π, in phase. (C) These photons stimulate emission from the next tow molecules resulting in four photons of wavelengths π Basically, a man-made maser is a device that sets up a series of atoms or molecules and excites them to generate chain reaction or amplification of photons. Met stable emission states make MASERS and LASERS possible. To get the proper wavelengths to generate the chain reaction, first electricity or another energy source is "pumped" into a chamber filled with a particular atoms or molecules. Then his "pumping" radiation causes the transition of atoms from ground state to higher energy excited state. From this short-lived state the atoms come down through non-radiative transition to the long-lived met stable state. Once in met stable state many atoms can be accumulated in one place and in the same state. The LASER or MASER beam, stimulated emission, arises when all these accumulated atoms stimulated emission, arises when all these accumulated atoms simultaneously make transition to the ground state, releasing their energy of wavelength π, creating a beam of microwave radiation (or visible light in case of laser) which can be sent on the other atoms to cause the chain reaction. Since all the resulting photons have the same wavelength and the maser beams are extremely focused and coherent.

VIII. CONCLUSION

In the present course of investigation the laboratory status of x-ray lasers and Y-ray lasers have been studied. In recent years for lasers of x-ray regions many different schemes have been proposed. The most successful of the schemes has been the collision ally pumped x-ray lasers, which are produced in plasmas containing ions in a highly charged state. Within the ions, electrons move between the ground state and various higher energy levels so that the conditions are achieved for producing x-rays. Collision ally pumped x-ray lasers are highly useful because they can operate over a wide range of pump conditions and with a variety of targets. As Nova laser in USA is the landmark in the research of lasers of x-ray region. The Nova uses a very high-energy pulse of light about a nanosecond and picoseconds long to cause lasing at x-ray frequencies.

In future, x-ray lasers are likely to become widespread because of their growing range of uses. For example: they will be used for biological imaging of materials science, as a probe for imaging and understanding of high density plasmas and x-ray microscopy. For Y-ray lasers suitable nuclear species have been identified from all the available isotopes. But their effective pumping could not have been possible due to narrow absorption widths in nuclei. By having an improvement in the Doppler line width. The Y-ray laser appears to be feasible. But the other latest method of the production of Y-ray lasers seems to tube hopeful by the experimental observation of positronium molecule by David Cassidy and A.P. Mills reported in the Nature on 13th September. 2007. In the last I would like to mention that in the future we would be having a monochromatic Y-ray named as GASER, having a photon energy of more than several MeV.

REFERENCES

[1] The Nobel Prize in Physics 1996, Presentation Speech by Professor Ivar Waller. Retrieved 1 January 2007.

[2] Gould, R. Gordon. " the LASER Light Amplification by Stimulated Emission of Radiation". The Ann Arbor Conference on Optical Pumping, June 1959.

[3] Maiman, T.H. " Stimulated Optical Radiation in Ruby". Nature, 187 4739, PP. 493-494, 1960.

[4] Hecht, jeff "Beam: The Race to Make the Laser", USA Oxford Univ. Press. ISBN 0-19-514210-1, 2005.

[5] B.B. Laud, " Lasers and Non-linear Optics", New Age Publication, 2004.

[6] Http://en.wikipedia.org/wiki/laser

[7] K. Thyagarajan A.K. Ghatak, "Lasers Theory and Applications," Publication, 2005.

[8] William Thomas Silfast, "Laser Fundamentals". Edition 2003.

[9] Einstein, A., "On the Quantum Theory of Radiation", Phys. Z. 18,121, 1917

[10] R.C. Elton, " X-Ray Lasers". New York: Academic Press, 1990.

[11] S. Sukewer and C.H. Skinner, "Soft X-Ray Lasers and Their Applicaton" Science 247:15 53-7, 1990.

[12] a b Gould, R. Gordon (1959). "The LASER, Light Amplification by Stimulated Emission of Radiation". In Franken, P.A. and Sands, R.H. (Eds.). The Ann Arbor Conference on Optical Pumping, the Universtiy of Michigan, 15 June through 18 June 1959. P. 128. OCLC 02460155.

[13] "laser". Reference.com. Retrieved 2008-05-15.

[14] Conceptual physics, Paul Hewitt, 2002.

[15] Powerful laser is Brightest light in the Universe' The world's Most powerful laser as of 2008 might create supernova-like shock waves and possibly even antimatter (New Scientist, 9 April 2008)

[16] Homemade laser Project by Kip Kedersha.

[17] "The Laser: basic principles" an online course by Prof. F. Balembios and Dr. S. Forget. Instrumentation for Optics, 2008.

[18] Northrop Grumman's Press Release on the Firestrike 15kw tactical laser product.

[19] Website on Lasers 50th anniversary by APS, OSA, SPlE.

[20] Virtual Museum of Laser History, From the Touring Exhibit by SPIE.