



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 4, April 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.118



9940 572 462



6381 907 438



ijirset@gmail.com



www.ijirset.com

RUBY LASER

Dr. Karan Singh Gill

Assistant Professor, Dept. of Physics, Government College, Hisar, Haryana, India

ABSTRACT: A ruby laser is a solid-state laser that uses the synthetic ruby crystal as its laser medium. Ruby laser is the first successful laser developed by Maiman in 1960. Ruby laser is one of the few solid-state lasers that produce visible light. It emits deep red light of wavelength 694.3 nm. A ruby laser consists of three important elements: laser medium, the pump source, and the optical resonator. In a ruby laser, a single crystal of ruby ($\text{Al}_2\text{O}_3 : \text{Cr}^{3+}$) in the form of cylinder acts as a laser medium or active medium. The laser medium (ruby) in the ruby laser is made of the host of sapphire (Al_2O_3) which is doped with small amounts of chromium ions (Cr^{3+}). The ruby has good thermal properties.

A ruby laser is a solid-state laser that uses a synthetic ruby crystal as its gain medium. The first working laser was a ruby laser made by Theodore H. "Ted" Maiman at Hughes Research Laboratories on May 16, 1960. Ruby lasers produce pulses of coherent visible light at a wavelength of 694.3 nm, which is a deep red color. Typical ruby laser pulse lengths are on the order of a millisecond.

KEYWORDS: ruby laser, solid state, pump, medium, sapphire, chromium, thermal, pulse

I. INTRODUCTION

The pump source is the element of a ruby laser system that provides energy to the laser medium. In a ruby laser, population inversion is required to achieve laser emission. Population inversion is the process of achieving the greater population of higher energy state than the lower energy state. In order to achieve population inversion, we need to supply energy to the laser medium (ruby). In a ruby laser, we use flashtube as the energy source or pump source. The flashtube supplies energy to the laser medium (ruby). When lower energy state electrons in the laser medium gain sufficient energy from the flashtube, they jump into the higher energy state or excited state.[1,2]

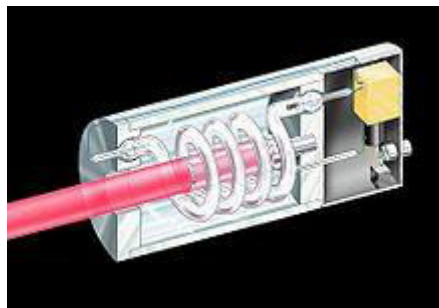


Diagram of the first ruby laser.

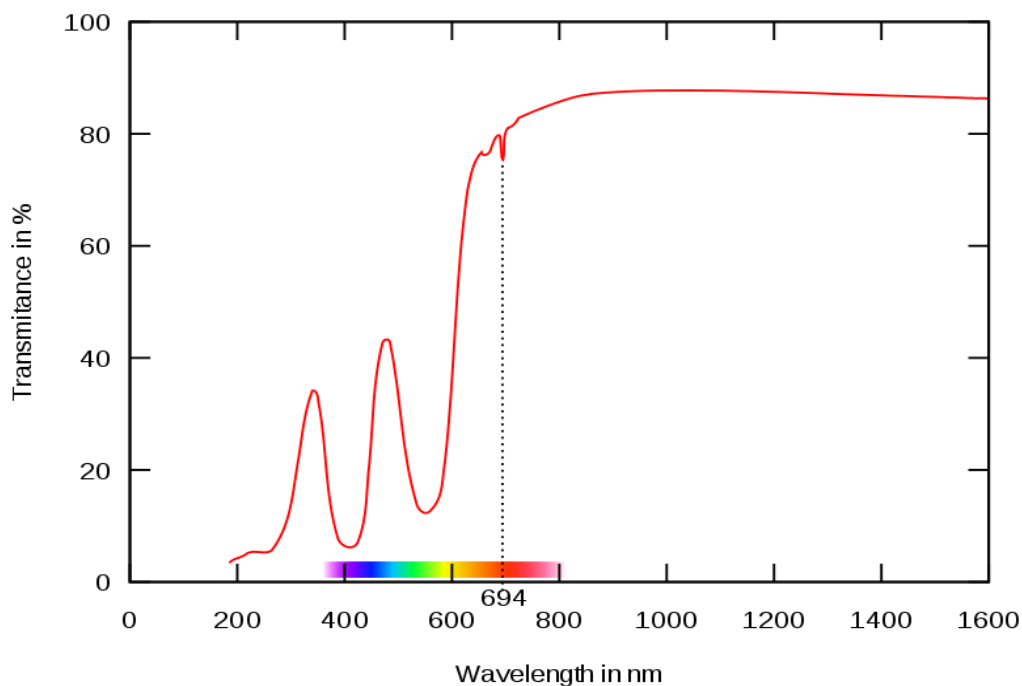
The ends of the cylindrical ruby rod are flat and parallel. The cylindrical ruby rod is placed between two mirrors. The optical coating is applied to both the mirrors. The process of depositing thin layers of metals on glass substrates to make mirror surfaces is called silvering. Each mirror is coated or silvered differently. At one end of the rod, the mirror is fully silvered whereas, at another end, the mirror is partially silvered. The fully silvered mirror will completely reflect the light whereas the partially silvered mirror will reflect most part of the light but allows a small portion of light through it to produce output laser light.

A ruby laser most often consists of a ruby rod that must be pumped with very high energy, usually from a flashtube, to achieve a population inversion. The rod is often placed between two mirrors, forming an optical cavity, which oscillate the light produced by the ruby's fluorescence, causing stimulated emission. Ruby is one of the few solid state lasers that produce light in the visible range of the spectrum, lasing at 694.3 nanometers, in a deep red color, with a very narrow linewidth of 0.53 nm.[3,4]



A ruby laser rod. Inset: The view through the rod is crystal clear

The ruby laser is a three level solid state laser. The active laser medium (laser gain/amplification medium) is a synthetic ruby rod that is energized through optical pumping, typically by a xenon flashtube. Ruby has very broad and powerful absorption bands in the visual spectrum, at 400 and 550 nm, and a very long fluorescence lifetime of 3 milliseconds. This allows for very high energy pumping, since the pulse duration can be much longer than with other materials. While ruby has a very wide absorption profile, its conversion efficiency is much lower than other mediums. In early examples, the rod's ends had to be polished with great precision, such that the ends of the rod were flat to within a quarter of a wavelength of the output light, and parallel to each other within a few seconds of arc. The finely polished ends of the rod were silvered; one end completely, the other only partially. The rod, with its reflective ends, then acts as a Fabry–Pérot etalon (or a Gires-Tournois etalon). Modern lasers often use rods with antireflection coatings, or with the ends cut and polished at Brewster's angle instead. This eliminates the reflections from the ends of the rod. External dielectric mirrors then are used to form the optical cavity. Curved mirrors are typically used to relax the alignment tolerances and to form a stable resonator, often compensating for thermal lensing of the rod.[5,6]



Transmittance of ruby in optical and near-IR spectra. Note the two broad blue and green absorption bands and the narrow absorption band at 694 nm, which is the wavelength of the ruby laser.

Ruby also absorbs some of the light at its lasing wavelength. To overcome this absorption, the entire length of the rod needs to be pumped, leaving no shaded areas near the mountings. The active part of the ruby is the dopant, which consists of chromium ions suspended in a synthetic sapphire crystal. The dopant often comprises around only 0.05% of the crystal, but is responsible for all of the absorption and emission of radiation. Depending on the concentration of the dopant, synthetic ruby usually comes in either pink or red.[7,8]

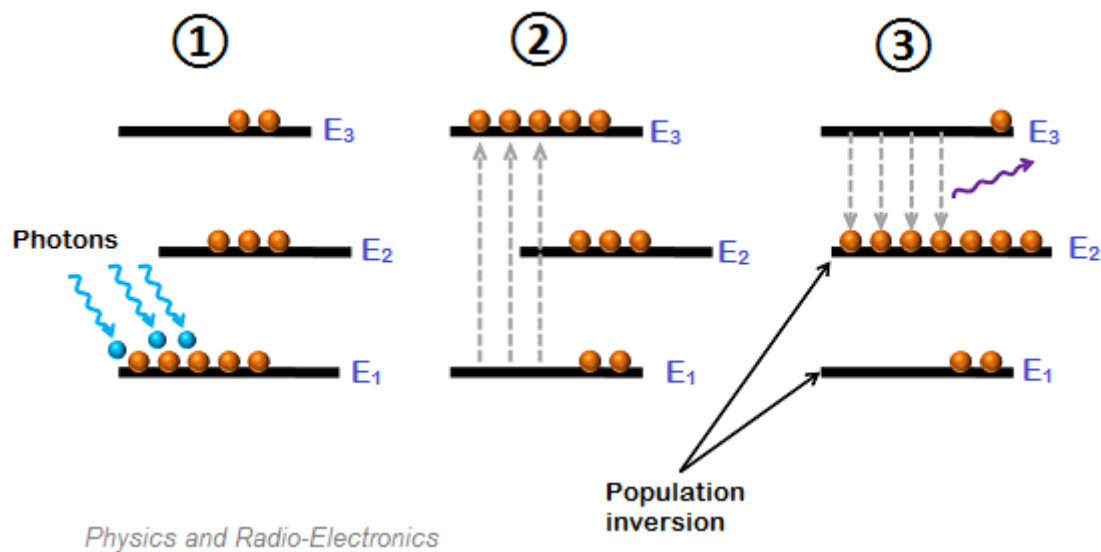
II. DISCUSSION

The ruby laser is a three level solid-state laser. In a ruby laser, optical pumping technique is used to supply energy to the laser medium. Optical pumping is a technique in which light is used as energy source to raise electrons from lower energy level to the higher energy level.

Consider a ruby laser medium consisting of three energy levels E_1 , E_2 , E_3 with N number of electrons.

We assume that the energy levels will be $E_1 < E_2 < E_3$. The energy level E_1 is known as ground state or lower energy state, the energy level E_2 is known as metastable state, and the energy level E_3 is known as pump state.[9,10]

Let us assume that initially most of the electrons are in the lower energy state (E_1) and only a tiny number of electrons are in the excited states (E_2 and E_3)



When light energy is supplied to the laser medium (ruby), the electrons in the lower energy state or ground state (E_1) gains enough energy and jumps into the pump state (E_3).

The lifetime of pump state E_3 is very small (10^{-8} sec) so the electrons in the pump state do not stay for long period. After a short period, they fall into the metastable state E_2 by releasing radiationless energy. The lifetime of metastable state E_2 is 10^{-3} sec which is much greater than the lifetime of pump state E_3 . Therefore, the electrons reach E_2 much faster than they leave E_2 . This results in an increase in the number of electrons in the metastable state E_2 and hence population inversion is achieved.[11]



Maiman's original ruby laser

After some period, the electrons in the metastable state E_2 falls into the lower energy state E_1 by releasing energy in the form of photons. This is called spontaneous emission of radiation.

When the emitted photon interacts with the electron in the metastable state, it forcefully makes that electron fall into the ground state E_1 . As a result, two photons are emitted. This is called stimulated emission of radiation.

When these emitted photons again interacted with the metastable state electrons, then 4 photons are produced. Because of this continuous interaction with the electrons, millions of photons are produced.

In an active medium (ruby), a process called spontaneous emission produces light. The light produced within the laser medium will bounce back and forth between the two mirrors. This stimulates other electrons to fall into the ground state by releasing light energy. This is called stimulated emission. Likewise, millions of electrons are stimulated to emit light. Thus, the light gain is achieved.[12,13]

The amplified light escapes through the partially reflecting mirror to produce laser light.

III. RESULTS

One of the first applications for the ruby laser was in range finding. By 1964, ruby lasers with rotating prism q-switches became the standard for military rangefinders, until the introduction of more efficient Nd:YAG rangefinders a decade later. Ruby lasers were used mainly in research. The ruby laser was the first laser used to optically pump tunable dye lasers and is particularly well suited to excite laser dyes emitting in the near infrared. Ruby lasers are rarely used in industry, mainly due to low efficiency and low repetition rates. One of the main industrial uses is drilling holes through diamond, because ruby's high-powered beam closely matches diamond's broad absorption band (the GR1 band) in the red.[14,15]



Components of original ruby laser

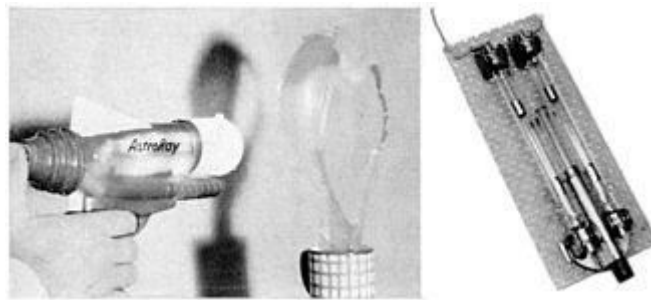
Ruby lasers have declined in use with the discovery of better lasing media. They are still used in a number of applications where short pulses of red light are required. Holographers around the world produce holographic portraits with ruby lasers, in sizes up to a meter square. Because of its high pulsed power and good coherence length, the red 694 nm laser light is preferred to the 532 nm green light of frequency-doubled Nd:YAG, which often requires multiple

pulses for large holograms.[8] Many non-destructive testing labs use ruby lasers to create holograms of large objects such as aircraft tires to look for weaknesses in the lining. Ruby lasers were used extensively in tattoo and hair removal, but are being replaced by alexandrite and Nd:YAG lasers in this application.[16]

IV. CONCLUSIONS

The ruby laser was the first laser to be made functional. Built by Theodore Maiman in 1960, the device was created out of the concept of an "optical maser," a maser that could operate in the visual or infrared regions of the spectrum.

In 1958, after the inventor of the maser, Charles Townes, and his colleague, Arthur Schawlow, published an article in the Physical Review regarding the idea of optical masers, the race to build a working model began. Ruby had been used successfully in masers, so it was a first choice as a possible medium. While attending a conference in 1959, Maiman listened to a speech given by Schawlow, describing the use of ruby as a lasing medium. Schawlow stated that pink ruby, having a lowest energy-state that was too close to the ground-state, would require too much pumping energy for laser operation, suggesting red ruby as a possible alternative. Maiman, having worked with ruby for many years, and having written a paper on ruby fluorescence, felt that Schawlow was being "too pessimistic." His measurements indicated that the lowest energy level of pink ruby could at least be partially depleted by pumping with a very intense light source, and, since ruby was readily available, he decided to try it anyway.



Ruby laser pistol constructed by Stanford Univ. physics professor in 1964 to demonstrate the laser to his classes. The plastic body recycled from a toy raygun contained a ruby rod between two flashtubes (*right*). The pulse of coherent red light was strong enough to pop blue balloons (*shown at left*) but not red balloons which reflected the light.

Also attending the conference was Gordon Gould. Gould suggested that, by pulsing the laser, peak outputs as high as a megawatt could be produced.

As time went on, many scientists began to doubt the usefulness of any color ruby as a laser medium. Maiman, too, felt his own doubts, but, being a very "single-minded person," he kept working on his project in secret. He searched to find a light source that would be intense enough to pump the rod, and an elliptical pumping cavity of high reflectivity, to direct the energy into the rod. He found his light source when a salesman from General Electric showed him a few xenon flashtubes, claiming that the largest could ignite steel wool if placed near the tube. Maiman realized that, with such intensity, he did not need such a highly reflective pumping cavity, and, with the helical lamp, would not need it to have an elliptical shape. Maiman constructed his ruby laser at Hughes Research Laboratories, in Malibu, California. He used a pink ruby rod, measuring 1 cm by 1.5 cm, and, on May 16, 1960, fired the device, producing the first beam of laser light.

Theodore Maiman's original ruby laser is still operational. It was demonstrated on May 15, 2010, at a symposium co-hosted in Vancouver, British Columbia by the Dr. Theodore Maiman Memorial Foundation and Simon Fraser University, where Dr. Maiman was adjunct professor at the School of Engineering Science. Maiman's original laser was fired at a projector screen in a darkened room. In the center of a white flash (leakage from the xenon flashtube), a red spot was briefly visible.



The ruby lasers did not deliver a single pulse, but rather delivered a series of pulses, consisting of a series of irregular spikes within the pulse duration. In 1961, R.W. Hellwarth invented a method of q-switching, to concentrate the output into a single pulse.[16]

Ruby laser pistol constructed by Stanford Univ. physics professor in 1964 to demonstrate the laser to his classes. The plastic body recycled from a toy raygun contained a ruby rod between two flashtubes (right). The pulse of coherent red light was strong enough to pop blue balloons (shown at left) but not red balloons which reflected the light.

In 1962, Willard Boyle, working at Bell Labs, produced the first continuous output from a ruby laser. Unlike the usual side-pumping method, the light from a mercury arc lamp was pumped into the end of a very small rod, to achieve the necessary population inversion. The laser did not emit a continuous wave, but rather a continuous train of pulses, giving scientists the opportunity to study the spiked output of ruby. The continuous ruby laser was the first laser to be used in medicine. It was used by Leon Goldman, a pioneer in laser medicine, for treatments such as tattoo removal, scar treatments, and to induce healing. Due to its limits in output power, tunability, and complications in operating and cooling the units, the continuous ruby laser was quickly replaced with more versatile dye, Nd:YAG, and argon lasers.[17]

REFERENCES

1. Maiman, T.H. (1960) "Stimulated Optical Radiation in Ruby". Nature, 187 4736, pp. 493–494.
2. ^ "Laser inventor Maiman dies; tribute to be held on anniversary of first laser". Laser Focus World. 2007-05-09. Retrieved 2007-05-14.
3. ^ Principles of Lasers By Orazio Svelto – Plenum Press 1976 Page 367–370.
4. ^ Laser Fundamentals by William Thomas Silfvast – Cambridge University Press 1996 Page 547-549.
5. ^ Solid-State Laser Engineering by Walter Koechner – Springer-Verlag 1965, p. 2.
6. ^ F. J. Duarte, and L. W. Hillman (Eds.) (1990). Dye Laser Principles. Academic. pp. 240–246.
7. ^ <http://accreditedgemologists.org/lightingtaskforce/OpticalAbsorptionand.pdf>^[bare URL PDF]
8. ^ Silfvast, William Thomas. Laser Fundamentals. Cambridge University. p. 550.
9. ^ The History of the Laser By Mario Bertolotti. IOP Publishing 2005 pp. 211–218
10. ^ How the Laser Happened: Adventures of a Scientist By Charles H. Townes – Oxford University Press 1999 pp. 85–105.
11. ^ How the Laser Happened: Adventures of a Scientist By Charles H. Townes – Oxford University Press 1999 p. 104.
12. ^ Beam By Jeff Hecht – Oxford University press 2005 pp. 170–172
13. ^ How the Laser Happened: Adventures of a Scientist By Charles H. Townes – Oxford University Press 1999 p. 105
14. ^ "Video: Maiman's first laser light shines again". SPIE Newsroom. 2010-05-20. Retrieved July 9, 2010.
15. ^ Solid-State Laser Engineering by Walter Koechner. Springer-Verlag 1965 p. 1
16. ^ Astronautics 1962. p. 74 <http://www.gravityassist.com/IAF3-1/Ref.%203-49.pdf>
17. ^ Lasers in Aesthetic Surgery by Gregory S. Keller, Kenneth M. Toft, Victor Lacombe, Patrick Lee, James Watson – Thieme Medical Publishers 2001 p. 254.



INNO  SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.118



ISSN  INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details