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Nobel Prize in Physics 1964



Charles Hard Townes | **Nicolay Gennadiyevich Basov** | **Aleksandr Mikhailovich Prokhorov**

The Nobel Prize in Physics 1964 was divided, one half awarded to Charles Hard Townes, the other half jointly to Nicolay Gennadiyevich Basov and Aleksandr Mikhailovich Prokhorov *"for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle"*.

RESEARCH INFORMATION:

The Nobel Prize for physics is in this year given for the invention of the maser and the laser. "Maser" stands for "microwave amplification by stimulated emission of radiation", and the word "laser" is obtained by replacing "microwave" by "light".

The key to the invention is the concept of stimulated emission which was introduced by Einstein already in 1917. By a theoretical analysis of the Planck radiation formula he found that the well-known process of absorption must be accompanied by a complementary process implying that received radiation can stimulate the atoms to emit the same kind of radiation. In this process lies a potential means for amplification. However, the stimulated emission was long regarded as a purely theoretical concept which never could be put to work or even be observed, because the absorption would be the completely dominating process under all normal conditions. An amplification can occur only if the stimulated emission is larger than the absorption, and this in turn requires that there should be more atoms in a high energy state than in a lower one. Such an unstable energy condition in matter is called an inverted population. An essential moment in the invention of the maser and the laser was, therefore, to create an inverted population under such circumstances that the stimulated emission could be used for amplification.

The first papers about the maser were published 10 years ago as a result of investigations carried out simultaneously and independently by Townes and co-workers at Columbia University in New York and by Basov and Prochorov at the Lebedev Institute in Moscow. In the following years there were designed a number of masers of widely different types, and many people made important contributions to this development. In the type that is now being mostly used the maser effect is obtained by means of the ions of certain metals imbedded in a suitable crystal. These masers work as extremely sensitive receivers for short radiowaves. They are of great importance in radio astronomy and are being used in space research for recording the radio signals from satellites.

The optical maser, that is, the laser, dates from 1958, when the possibilities of applying the maser principle in the optical region were analysed by Schawlow and Townes as well as in the Lebedev Institute. Two years later the first laser was operating.

The step from the microwaves to visible light means a 100000-fold increase in frequency and causes such changes in the operation conditions that the laser may be regarded as an essentially new invention. In order to achieve the high radiation density required for the stimulated emission to become dominating, the radiating matter is enclosed between two mirrors that force the light to traverse the matter many times. During this process the stimulated radiation grows like an avalanche until all the atoms have given up their energy to the radiation. The fact that the stimulated and stimulating radiation have exactly the same phase and frequency is essential for the result of the process. By virtue of resonance all parts of the active medium combine their forces to give one strong wave. The laser emits what is called coherent light, and this is the decisive difference between the laser and an ordinary light source where the atoms radiate quite independent of each other.

Lasers have now been made in many different shapes. The first, and still most frequently used, type consists of a ruby rod, a few inches long, with the polished and silvered end faces serving as mirrors. The radiation leaves eventually the crystal through one of the end faces which is made slightly transparent. The ruby consists of aluminium oxide with a small admixture of chromium. The chromium ions give to the ruby its red colour, and they are also responsible for the laser effect. The inverted population is produced by the light from a xenon flash lamp. This is absorbed by the ions, putting them in such a condition that they can be stimulated to emit a red light with a welldefined wavelength.

Normally, a large number of successive pulses of laser light is emitted during the time of one flash from the lamp, but by retarding the release until the stored energy has reached a maximum all the energy can be put into one big pulse. The power of the emitted light can then reach more than a hundred million watts. Since, moreover, the emerging ray bundle is strictly parallel, the whole energy can be concentrated by means of a lens on a very small area, producing an enormous power per unit area. From a scientific point of view it is especially interesting that the electrical field strength produced in the light wave may amount to some hundred million volts/cm and thus surpass the forces that keep the electron shells of the atoms together. The high photon density opens up quite new possibilities for studying the interaction of radiation and matter.

Another type of laser, in which the light is emitted from a gas excited by an electric discharge, produces continuously a radiation with a very sharply defined wavelength. This radiation can be used for measurements of lengths and velocities with a previously unattainable precision.

The invention of the laser has provided us with a powerful new tool for research in many fields, the exploitation of which has only just started. Its potential technical applications have been much publicised and are therefore well known. Regarding, especially, the extreme power concentration obtainable with a laser, it should be noted that this effect is limited to short time intervals and very small volumes and therefore attains its main importance for micro-scale operations. It should be emphasized, finally, that the use of a laser beam for destructive purposes over large distances is wholly unrealistic. The "death ray" is and remains a myth.

Dr. Townes, Dr. Basov and Dr. Prochorov. By your ingenious studies of fundamental aspects of the interaction between matter and radiation you have made the atoms work for us in a new and most remarkable way. These magic devices called maser and laser have opened up vast new fields for research and applications which are being exploited with increasing intensity in many laboratories all over the world. On behalf of the Royal Swedish Academy of Sciences I extend to you our warm congratulations and now ask you to receive the Nobel prize from the hands of His Majesty the King.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1964/press.html