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RESEARCH ON THE CONTRIBUTION OF THE NOBEL PRIZE LAUREATES IN PHYSICS TO THE DEVELOPMENT OF MODERN EQUIPMENT AND TECHNOLOGIES IN TECHNICAL UNIVERSITIES

Janchai Yingprayoon[1], Zagir Azgarovich Latipov[2] and Fairuza Musovna Sabirova[2*]

[1] *International College Suan Sunandha Rajabhat University, 1 U-Thong Nok Road, Dusit, Samsen, Bangkok 10300, Thailand*
[2] *Yelabuga Institute (branch) of Kazan (Volga region) Federal University, Kazanskaya Street 89, Yelabuga, 423604, Republic of Tatarstan, Russia*

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Abstract

The article is devoted to the significance of the study of Nobel laureates in Physics in the development of technology contribution by the students of technical institutions. The basic information about the Nobel laureates in the field of Technical physics is presented. There are traced the basic physical ideas that have established their use in various technical devices and technologies. Particular attention is paid to physical discoveries that determined the form of the late twentieth century technology, in such areas as spectroscopy, laser technology and electronics. The main achievements from the twentieth century and the beginning of the XXI century have also been regarded.

Keywords: laser, transistor, electronics, information technology, research

1. Introduction

Under the current conditions within the specialist training process it is important not only to teach his main profession, but also to develop his general culture. One of the sources of intellectual and cultural development is the study of the History of science, which contributes not only to the deepening of knowledge on the subject, their conscious and lasting learning, but also the formation of common cultural competencies. The study of any science is inseparably linked with the study of the history of that science, which is one of the sources of intellectual and cultural development, contributing to the deepening of knowledge on the studied subject. A special place in the history of

*Corresponding authors, e-mail: fmsabir@mail.ru

both Science and technology occupy scientists who made discoveries and inventions, and who have been awarded the Nobel Prize in the field of Technical physics.

The Nobel Prize is one of the most prestigious international prizes, awarded annually for outstanding research, revolutionary invention or a large contribution to the culture or society. The Nobel Prize has been awarded since 1901 for works in Physics, Chemistry, Physiology or Medicine, literature and 'for peace' (Nobel Prize for Peace) [1]. The fact that the founder of the prize, Alfred Nobel, put Physics in the first place was due to the fact that already in the XIX century Physics was regarded as the most advanced branch of Natural science, which represents to the greatest extent all the main features of the phenomenon that we now understand by modern science. In the twentieth century were made discoveries that radically changed the physical picture of the world – this is the construction of Quantum mechanics and Quantum field theory, Special and General theories of relativity, the construction of the theory of the atom, the nucleus and the model of elementary particles. The discovery of radioactivity and nuclear fission, the implementation of the fission chain reaction, the construction of the theory of superconductivity, decisively influenced the technical and technological face of the world. Many physical discoveries and fundamental physical ideas have been applied in a variety of technical devices and technologies, and were evaluated by the Nobel prizes for Physics [2, 3]. On the one hand they have served and serve for the development of experimental Physics and other areas of research, and on the other – have led to the revolutionary changes in the technological position of the society [4]. That is why the study of the history of these discoveries by the students of technical institutes will play an important role in the increasing of the interest to subjects, broadening their outlook and enhance their understanding of many physical processes and phenomena, associated with the devices. The greatest opportunities to explore the information about Nobel laureates and their discoveries in the technology are disclosed in the study course 'History of Science and Technology'.

Let us point out a number of important discoveries, details of which are set out in the study of topics, related to achievements in modern equipment and technology. Thus, the revolutionary significance for the modern technology was the transistor effect discovery, the laser-maser principle and the invention of the microchip. Among the methods of analysis of substances, most revolutionary significance for the study of the structure, composition and other characteristics of the material is laser and electron spectroscopy, electronic microscope, as well as ion traps, allowing high-resolution spectroscopy. Most of these discoveries have greatly increased the speed of technological progress and have been awarded Nobel prizes for physics [5, 6].

2. Nobel Prize in Physics for the discovery of the laser and the new methods of substance research

At the heart of many research methods is the use of laser. At the institution course of Physics (sections Optics and Quantum Physics), the principle of its action and the properties of the radiation types are studied. Within the study of this topic it should be pointed out that its invention was made by American and Russian scientists and was awarded the Nobel Prize in Physics. In 1954, American physicist Charles Hard Townes (together with J. Gordon and H. Zeiger) and independently from them, Nikolai G. Basov and Alexander M. Prokhorov created the first quantum generator (maser) by molecules of ammonia**.** Generation was carried out at the wavelength of 1.25 cm, and the population inversion is achieved by spatial separation of the excited and unexcited molecules in a strongly inhomogeneous electric field. In 1958, Townes formulated the requirements for the construction of the maser, operating in the infrared, visible and ultraviolet light range. N.G. Basov and A.M. Prokhorov offered a method to achieve population inversion using an electromagnetic pump (three-level system) and created the first quantum paramagnetic amplifiers on this principle (1955). This method was also used in creating the first laser in 1960, in which as the working medium single crystal ruby was used. By Basov a semiconductor laser with electronic and optical pumping was offered (1957), and also thermal and chemical methods of laser pumping were developed (1960-1964). Already in 1964, Townes together with Basov and Prokhorov were awarded the Nobel Prize in Physics for their fundamental work in the field of quantum electronics that led to the construction of generators and amplifiers based on the principle of the maser − the laser.

Under modern conditions, the basis for the study of the structure, composition and other characteristics of the material is atomic and molecular spectroscopy. In 1981, American physicists Nicolaas Bloembergen and Arthur Leonard Schawlow received the Nobel Prize for their work in the field of precise laser spectroscopy of atoms and molecules [*The Nobel Prize in Physics*, 1981, www.nobelprize.org/nobel_prizes/physics/laureates/1981, accessed on 10.08.2014]. N. Bloembergen in 1962 developed the theoretical foundations of nonlinear laser spectroscopy, taking into account that the intensity of the laser radiation is high and traditional linear methods do not work anymore. He offered a method of mixing two or more light waves, which was experimentally verified immediately after the laser creation. Having described the expected interaction of three laser beams, which produces the fourth beam, the frequency of which can be controlled with high accuracy, N. Bloembergen laid the theoretical basis for the creation of tunable laser, capable of generating light in the ultraviolet and infrared. Earlier, A.L. Schawlow (together with Townes, 1954-1958) proved the possibility of the laser creation. He developed methods of nonlinear laser spectroscopy of high-resolution and developed methods of spectroscopy that allow suppressing the Doppler broadening of spectral lines.

Ideas and methods of nonlinear optics and laser spectroscopy are widely used in the diagnosis of substance. They allow determining the trace elements in the surrounding material. Methods are used for the study of intermolecular interactions in liquids, diagnostics of fast processes in gaseous and condensed media. It made possible, in particular, to discover features of rapid laser-induced melting and disordering of the crystal lattice, laser annealing and amorphization of semiconductors.

For molecules, the binding energy of the electrons in the inner shells depends on the type of chemical link, so the method of analysis with an extremely high resolution, known as electron spectroscopy for chemical analysis (ESCA), is widely used in Analytical and Physical chemistry to determine the composition of the substance. This method was offered by the Swedish physicist Kai Manne Siegbahn. In 1981 K. Siegbahn received the second half of the Nobel Prize for the development of the method of electronic high-resolution spectroscopy that uses electrons, emitted from the outer or inner electron shells under the action of X-rays with a very well-defined energy. In 1950, he developed the electron spectrometer with double focusing and with its help received very narrow electron spectra, peaks of which corresponded to the electrons binding energies in the inner shells of the atoms in the studied material. The analysis method with an extremely high resolution offered by K. Siegbahn and his staff quickly became a permanent laboratory method. Currently, the binding energy is studied in practically all elements of the periodic system with accuracy, significantly higher than in the x-ray spectroscopy [www.nobelprize.org/nobel_prizes/physics/laureates/1981]. ESCA turned out to be particularly useful for the study of surfaces and has been applied in the study of surface phenomena such as catalysis on platinum during petroleum refining and metal corrosion. ESCA is used for the analysis of particles in the polluted air. Installations designed by K. Siegbahn, are commercially available in many countries.

3. Tunnel effect and the discovery of the research methods based on it

A major role in the development of methods for the substance studying played the discovering of the tunnel effect. Classical Physics says that in an electrical circuit, broken by the barrier of the insulator, the current will not flow. Quantum mechanics presumes a slightly different situation: if the barrier is narrow enough electrons can 'tunnel' through it. This sub-barrier passage occurs because the position of the electron can not be determined of absolutely accurate and, therefore, there is always some probability that the electron will appear on the other side of the barrier. The thinner the barrier the greater the tunnelling probability. Although this effect was predicted back in the early 30s, but by the middle of 50s it has not been proven experimentally. In 1957, Japanese physicist Leo Esaki, who worked in the Sony company, discovered experimentally a similar effect in semiconductors and built the first tunnel diode. In those years, the study of the tunnel effect was news in Science, and it had been studied by many scientists. In 1960, American physicist of Norwegian origin Ivar Giaever from the General Electric conducted the first observation of the tunnelling effect in superconductors, in which electrons tunnelled from one superconductor to the other, and studied the laws of this phenomenon. Particularly he offered the possibility of the use of the tunnelling effect for temperature measurement. In 1962, English physicist Brian David Josephson, who had graduated from Cambridge University two years earlier, predicted a new type of tunnelling, which really was soon discovered; he was called 'Josephson effect'. This effect is observed when a superconducting current flow through a very thin dielectric layer, separating two superconductors (the so-called Josephson contact). If the current does not exceed a certain value through the Josephson contact, the voltage drop across the contact is absent (the so-called stationary Josephson Effect). If the current, flowing through the contact is more than critical, there is a voltage drop and the contact can radiate high frequency electromagnetic waves. This is the nonstationary Josephson effect, which was discovered in 1965 by Giaever. Tunnel effect made it possible to supply various precise experiments and construct highly sensitive devices for physical investigations. The Giaever tunnelling method has quickly become one of the most basic ways to observe and determine the properties of superconductors. And on the basis of the Josephson effects there have been made sensitive detectors of very weak voltage changes. Apart from purely scientific interest, this effect is acquiring extensive practical value in recent years. In 1973, L. Esaki and I. Giaever won the Nobel Prize for the discovery of the tunnel effect in semiconductors and superconductors, and B.D. Josephson – for tunnelling effects theory development.

An important role in the study of the structure of matter, the invention of an electron microscope and a scanning tunnelling microscope have played, which were awarded the Nobel Prize in 1986 [www.nobelprize.org/nobel_ prizes/physics/laureates/1986]. As early as 1928, the German physicist Ernst Ruska (together with Max Knoll) began their works on the creation of the first magnetic transmission electron microscope, where instead of light rays, accelerated beams of electrons were used. They moved in a high vacuum, focused by magnetic electron lenses. In 1933 he built the first electron microscope in which objects have been studied in the form of thin sections, and received the first image of the object formed by the electron beams. After more than half a century, in 1986 for his invention and development of the first electron microscope E. Ruska was awarded half of the Nobel Prize. Electron microscope of E. Ruska found an application in various fields of Science, including the study of metals, viruses, protein molecules and other biological structures. The invention of E. Ruska also stimulated the invention of the scanning tunnelling microscope − a device, designed to study the structure of surfaces of various media.

In 1986, for the practical implementation of a scanning tunnelling microscope, members of IBM Research Laboratory in Zurich, the German physicist Gerd Karl Binnig and Swiss physicist Henrich Rohrer were awarded the second half of the Nobel Prize. In the late 70's‒early 80's they decided to use the tunnel effect for the study of surface materials. The basic principle, underlying the device, comprises the scanning of the surface of a solid body in vacuum by a thin tip of a needle. Between the tip and the sample voltage is applied, and the distance between them is maintained so small that electrons can tunnel through it. As a result, appearing flow of electrons is called a tunnelling current. The magnitude of the tunnelling current exponentially depends on the distance between the sample and the tip of the needle. Consequently, by moving a tip over the sample and measuring the current, it is possible to map the surface at the atomic scale [*G.K. Binnig*, in *Encyclopedia of World Biography*, 2005, www.encyclopedia.com/topic/Gerd_Binnig.aspx#1-1G2:3435000034-full, accessed on 10.08.2014]. Scanning tunnelling microscope has become a common tool in many research laboratories. This technique is used in semiconductor physics and microelectronics or the study of DNA molecules.

In 1989, the German physicist Wolfgang Paul and American physicist Hans Georg Dehmelt were awarded the Nobel Prize for the development of ion trap technology, enabling high-resolution spectroscopy. W. Paul invented the first ion traps, operating under the influence of a combination of plane electric and magnetic fields, able to focus particles in two dimensions, affecting the magnetic and electric dipole moments. H. Dehmelt used for study an electron Penning trap, formed by a homogeneous magnetic field of 5 Tesla and a weak electric quadrupole field. He developed a method for the electron studying, which will significantly improve the accuracy of measurements. H. Demelt's work on the measurement of the properties of the electron was the most sensitive way to check the physical theory [7]. Paul's traps significantly promoted high-quality measurements of the properties of the ions such as charge, mass and magnetic properties. Paul's traps proved well to test quantum mechanical theories of the emission and absorption of light. Non-exhaustive list of refined fundamental values, measured by the discoveries of the laureates: the mass ratio of the proton and the electron, nuclear spin frequencies of the hydrogen atoms, the electric dipole moment of the neutron, the test for the symmetry of properties of the fundamental physical laws and others.

Thus, one of the most advanced methods of substances' research are laser and electron spectroscopy, as well as the invention of the electron microscope and ion traps. These inventions were awarded Nobel Prizes in Physics, and the information about the contribution of the prestigious award winners is reasonable to include in the study of the Physics course (sections Optics, Quantum and Atomic Physics), special subjects, as well as the course of 'History of Science and Technology'.

4. Nobel Prize in Physics in the field of information technology

Revolutionary significance for modern technology have the important discoveries made in the field of information technology. The discovery of the transistor effect, the invention of the microchip is the result of the merger of many achievements.

Modern semiconductor era, which became the basis of information technology, began in 1947 with the discovery of the transistor effect, made by American physicists William Shockley, Walter Brattain and John Bardeen. W. Brattain and J. Bardeen created a point-contact transistor based on a piece of germanium, to which the metal contacts are attached (emitter, base and collector), and W. Shockley offered to replace metal conductor contacts by two p-n-passages. In 1950 the first germanium transistor (plane transistor) was created, which is a system of a thin layer of p-type, which is located between two layers of n-type with metal contacts in each layer. Because of their small size, ease of construction, low energy requirements and low cost transistors quickly replaced vacuum tubes in all of radio devices, with the exception of high-power devices that are used, for example, in broadcasting or industrial high frequency radio heating installations. In 1954, by the members of the Texas Instruments American company, the transition from germanium to the silicon transistor was made. Later, the field transistor was developed (1960), which became widely used in electronics. In 1956 W. Shockley founded a laboratory named after him, which became one of the origins of Silicon Valley. For the discovery of the transistor effect W. Shockley, W. Brattain and J. Bardeen received the Nobel Prize in 1956. J. Bardeen is the only person who received two Nobel Prizes in Physics: in 1972 for a fundamental theory of conventional superconductors, together with Leon Cooper and John Schrieffer. Now this theory is called the Bardeen-Cooper-Schrieffer theory (BCS theory). It should be noted that the study of semiconductors was made by Soviet scientists as well: A.I. Ioffe, V.P. Zhuze, I.V. Kurchatov, E.F. Gross, Y.I. Frenkel. Diffuse theory of p-n-heterotransition was the basis of the theory of Shockley [8].

In 1958, the American scientist Jack Kilby demonstrated the possibility of producing of all the discrete elements on silicon and made the first integrated microcircuit, built on a germanium crystal. All of its electronic components are mounted on a single block using strips made of gold. In 1959, an American engineer Robert Norton Noyce found a high absorption capacity of aluminium to silicon and suggested the use of aluminium deposited strips. Namely planar technology and aluminium, as a material for wiring is used in modern integrated circuits. With the invention of a monolithic integrated circuit − the microchip − Kilby and Noyce laid the conceptual and technical foundation for the widest field of modern microelectronics. R.N. Noyce died in 1990 and didn't become the Nobel Prize laureate. J. Kilby was awarded the Nobel Prize in 2000. He is also the inventor of the pocket calculator and the thermal printer (1967).

To increase the amplification coefficient of integrated circuits, as well as increasing the operating frequency and power it was offered to use transistors with heterojunctions. Such heterostructures consist of two semiconductors, atomic structures of which correspond well to each other but have different electronic properties [9]. For the discovery of semiconductor heterostructures (in the 60s) and their application in optoelectronics, second half of the prize was awarded the Russian physicist Zhores Ivanovich Alferov and the American physicist of German origin Herbert Krömer in 2000. Thanks to this discovery, it became possible to provide a fibre-optic connection (it is, in particular, the basis of today's Internet) lasers, operating at room temperature (widely used in Medicine and other fields), semiconductor lasers, which are used in space technology and in everyday life, for example, audio and video disc players. In addition, without these discoveries the quality mobile communication would have been impossible.

Nobel Prize in Physics in 2009 was awarded to Chinese scientist Charles K. Kao and American physicists Willard Boyle and George E. Smith for the research in the field of information technology [www.nobelprize.org/nobel_prizes/physics/laureates/2009]. C. Kao was at the very beginning of the fibre optic transmission technology, developed in 1960's-70. In 1969, W. Boyle and G. Smith invented the first successful technology of the conversion of the optical image into electrical signals, using the original digital sensor − Charge-Coupled Device (CCD). So there was invented a device that allows directly, bypassing the films, receiving digital photos. Their work led to the first real revolution in applied science, then in the high-technology, and in the last decade they have become a part of our daily lives.

From these data it can be concluded that many of the discoveries made in the field of Technical Physics, were awarded the prestigious Nobel Prize decades later, only after they have received a wide practical application. But it is important to point out that not only time-tested discoveries are awarded the prize, but also those, which focused on the development of information technology. Thus, the Nobel Prize in Physics in 2010 was awarded for studies of graphene − a two-dimensional carbon material exhibiting unusual and at the same time very useful properties. Its discovery promises not only new technologies, but also the development of fundamental Physics, which can be a result of new knowledge about the structure of matter. Nobel Prize laureates in Physics in 2010 became Andre Geim and Konstantin Novoselov – professors of University of Manchester (UK), graduates of the Moscow Physical-Technical Institute [Science and life, *The Nobel Prize in Physics 2010. The new face of carbon*, www.nkj.ru/archive/articles/18837/html, accessed on 10.08.2014]. The Nobel Prize in Physics for 2012 was awarded to the French physicist Serge Haroche and American scientist David J. Wineland for innovative experimental techniques to measure and control individual quantum particles [*The Nobel Prize was given for the basics of quantum computers*, RIA News, ria.ru/science/20121009/769951125.html#ixzz2vlgA56m6/.html, accessed on 10.08.2014; *Prize for computer and watch*, www.gazeta.ru/science/2012/10/09_a_4805637.shtml, accessed on 10.08.2014]. Wineland's works laid the foundation for the creation of the atomic clock technology − devices for measuring time, in which the atoms play the role of the 'pendulum'. Frequency radiation of atoms during their transition from one energy level to another regulates the course of quantum clock. This frequency is so stable that allows atomic clocks measuring time more accurately than astronomical methods.

Studies, carried out by Haroche, can become the basis for future quantum computers that will process information with great speed. Innovative methods allowed every scientist, working in Quantum optics to take the first steps in creation of a new type of super-fast computers – quantum computers, working on the peculiarities of the quantum nature of particles. Quantum computers may change our daily lives in this century as dramatically as it did the usual computers in the previous century.

5. Conclusions

Many discoveries in Physics have been used in various technical devices and technologies. From the examples, presented in the article, we can conclude the significant contribution of the Nobel Prize winners in Physics in the development of modern information technology and research techniques of the atomic nucleus and elementary particles. The important role played physical discoveries that will shape the face of the late XX − early XXI century, in such areas as spectroscopy, laser technology, electronics. All these discoveries and inventions have been evaluated by the highest scientific award − the Nobel Prize in Physics.

Studying the history of the discoveries of Nobel Prize winners in Physics, in Technical physics area plays an important role in the preparation of engineering institutions' students, as it allows to 'revive' the process of exploring many disciplines, to strengthen educational and cognitive activity of students. In addition, it contributes to a high school graduate creation both as a qualified specialist and as a culturally and personally developed person. Information about the history of discoveries and inventions that have received the prestigious award, can be used in the study course in Physics (Optics, Quantum physics, Atomic physics) and a number of special disciplines (Electrical engineering, Electronics, Fundamentals of spectroscopy). Teaching experience has shown that the most appropriate is to study the subject in the course of 'History of Science and Technology', in the section devoted to modern achievements in Physics and technology.

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