

FROM THE HISTORY OF PHYSICS

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On the 60th anniversary of Nobel Prize for discovery of laser-maser principle

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Abstract. The paper describes a brief history of the 1964 Nobel Prize received by N G Basov, A M Prokhorov, and Charles Townes 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." The role of domestic scientists in the advent of new areas of physics and industrial and medical technologies based on the use of lasers is emphasized.

Keywords: Nobel Prize, masers, lasers, application of lasers

A paper dedicated to the 50th anniversary of the implementation of the laser was published in the January 2011 issue of the journal *Uspekhi Fizicheskikh Nauk* (*UFN*) [1]. It quite carefully examined the priorities of the work that led to one of the most important discoveries of the 20th century — the laser-maser principle — for which the Soviet scientists Nikolai Gennadievich Basov [2] and Aleksandr Mikhailovich Prokhorov [3] and the American scientist Charles Townes were awarded the 1964 Nobel Prize in Physics. The role of Soviet scientists was also reflected quite fully at different times in Refs [4–6].

Nevertheless, downplaying the contribution of domestic scientists to the development of quantum electronics, laser physics, and nonlinear optics has always occurred, although this was hardly the result of conscious actions. Most likely, this was the result of poor familiarity with publications in Russian-language journals, despite the fact that Soviet physics journals had been translated into English since the mid-1950s [7].

Currently, this trend has intensified many times over and there is no way to recognize it as unconscious, even if we greatly desired to. An artificial isolation of Russian science is being pursued.

October 2024 marks the 60th anniversary of the Nobel Prize award to N G Basov, A M Prokhorov, and C Townes for work that changed the face of the world around us.

This remarkable date provides a good reason to at least briefly recall those distant years and the role of domestic scientists in shaping the modern state of science and, using a specific example, to show that organized discrimination against Russian scientists harms, primarily, not Russia, but the entire global scientific community.

Frequently encountered statements that the Nobel Prize was awarded for the making of masers and lasers, sources of coherent electromagnetic radiation in the microwave and optical ranges, respectively, are inaccurate, to say the least. It was awarded 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."

It must be emphasized that the implementation of the ideas expressed by the recipients of the 1964 Nobel Prize in Physics, without any exaggeration, changed the face of the world around us. Really, the Internet, optical communications, fiber optics, information support, medicine, and modern industrial and military technologies are unthinkable without the use of lasers. No less important, and perhaps most important, is the use of lasers to study the fundamental properties of the material world. A laser is a device capable of concentrating energy in time and space to values that are inaccessible by any other means. Lasers are responsible for the emergence of new branches of physics, such as nonlinear optics, nonlinear spectroscopy, holography, and the interaction of high-intensity radiation with matter.

It is also significant that, during the period from 1964 to 2012, about 50 Nobel Prizes in physics were received, of which 11 were in the most direct way related to the award received by N G Basov, A M Prokhorov, and C Townes.

In 1952, in a report at a meeting of the Presidium of the USSR Academy of Sciences, N G Basov and A M Prokhorov, proceeding from theoretical analysis, pointed out the possibility of making amplifiers and generators of electromagnetic radiation using the phenomenon of stimulated transitions in quantum systems with an inverted level population (see Ref. [8]).

As Aleksandr Mikhailovich Prokhorov said in his Nobel lecture, he was prompted to analyze the possible oscillation in an inverted system by the 1916 work of Albert Einstein. First introduced in this work was the concept of stimulated emission of excited atoms under the influence of an external field.

In the literature, one can find a statement that Einstein postulated the existence of stimulated emission when considering the thermodynamic equilibrium between atomic particles, whose distribution over energy levels is described by the Boltzmann formula, and photons with a continuous spectrum described by the Planck formula. But this was the necessity to fulfill the energy conservation law and not a postulate.

It took decades to realize that it was the concept of stimulated emission that constitutes the cornerstone of the

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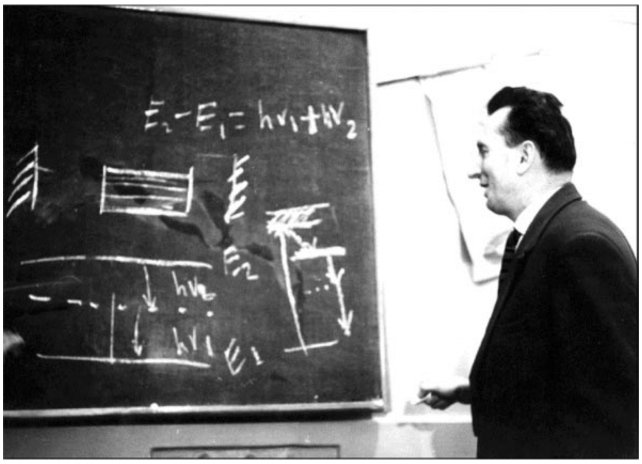


Photo 1. Report by A M Prokhorov on the principles of laser operation at a seminar at Lebedev Physical Institute (LPI) in 1964.

emerging quantum electronics. However, it is a fallacy to believe that using this fundamental phenomenon alone would suffice to construct masers and lasers.

The fundamental problem that had to be solved was how to produce a population inversion. This task was particularly difficult for the optical range. For optical transitions, in contrast to the 'maser' radio range, the upper levels at room temperature are practically unpopulated. It was necessary to create conditions such that the population of the upper levels was significant and exceeded the number of atoms in the lower state. In doing this, it is necessary to take into account the strong spontaneous emission that occurs in optics and devastates the population of the upper state.

An equally important problem was the organization of positive feedback to turn the amplifier into an oscillator. In the 'maser' centimeter range, this problem was solved using a volume cavity, whose dimensions should be comparable to the wavelength of the generated radiation. The wavelengths of optical radiation are shorter than 1 micron, which made the use of volume cavities in the optical range at that time impossible, since the then existing level of technology did not allow achieving such a degree of miniaturization.

Inasmuch as a sufficiently long time has passed since the awarding of the Nobel Prize in 1964, it is possible to objectively assess the role of domestic scientists N G Basov and A M Prokhorov in the origination of new areas of physics and, in particular, in the construction of the laser [1].

In 1955, they proposed an effective universal method for producing population inversion in a three-level system under the influence of an external pump source (Photo 1). This idea made a decisive contribution to the construction of lasers. The three-level pumping system is currently used in all types of solid-state lasers, but not only solid-state ones.

To implement positive feedback for short-wavelength radiation, A M Prokhorov proposed using a Fabry–Perot interferometer as a cavity: a pair of plane parallel plates (mirrors), which were called an open cavity (Photo 2). In this case, the radiation wavelength turns out to be much shorter than the dimensions of the cavity.

Self-excitation conditions and an expression for the quality factor of the system were obtained. The idea was confirmed experimentally in the work of A M Prokhorov and A I Barchukov [9].

The proposal and implementation of an open resonator and a three-level pumping scheme removed all restrictions for

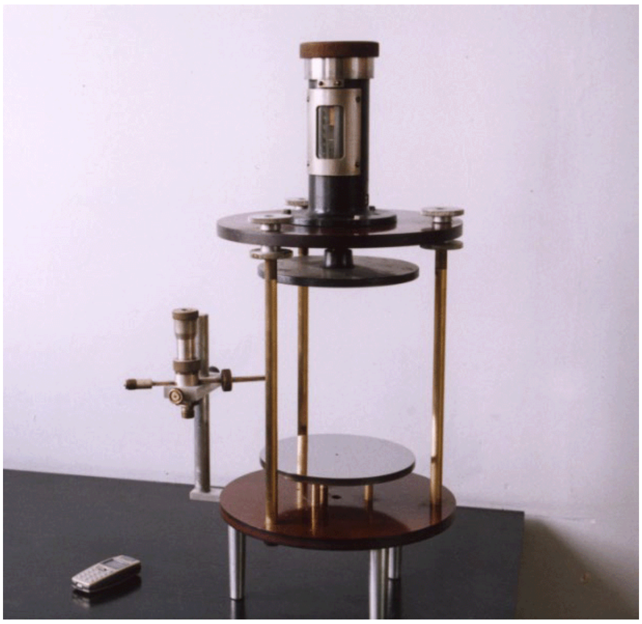


Photo 2. First open resonator.

the transition from the earlier made maser to the oscillator of coherent optical radiation — a laser.

Similar research was carried out in parallel in the USA in the groups of C Townes, A L Schawlow, and N Bloembergen.

However, the priority of domestic scientists in using the effect of stimulated transitions from excited states to create a source of coherent radiation and the use of a three-level pumping circuit and an open resonator is undeniable [1].

So, by 1960, the construction of the foundation of laser physics was completed.

From publications of that time, it follows that, based on the above foundation, the first ruby crystal laser was launched by T N Meiman in the USA in 1960 and by M D Galanin, A M Leontovich, and Z A Chizhikova in the USSR in 1961 [10] (Photo 3). As part of research for official use carried out at the S I Vavilov State Optical Institute (SOI), a ruby crystal laser was launched on June 2, 1961 by L D Khazov and I M Belousova [11].

From the recollections of eyewitnesses, it follows that the staff members of the SOI and Lebedev Physical Institute

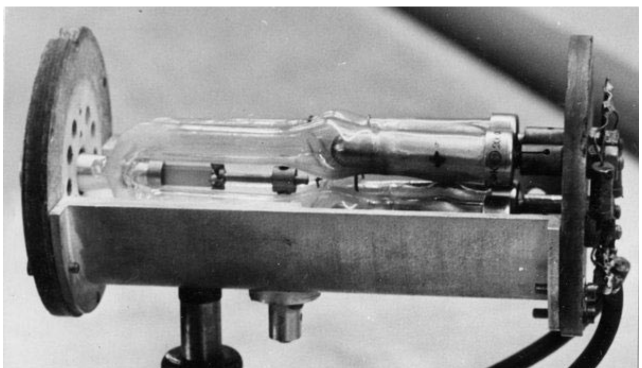
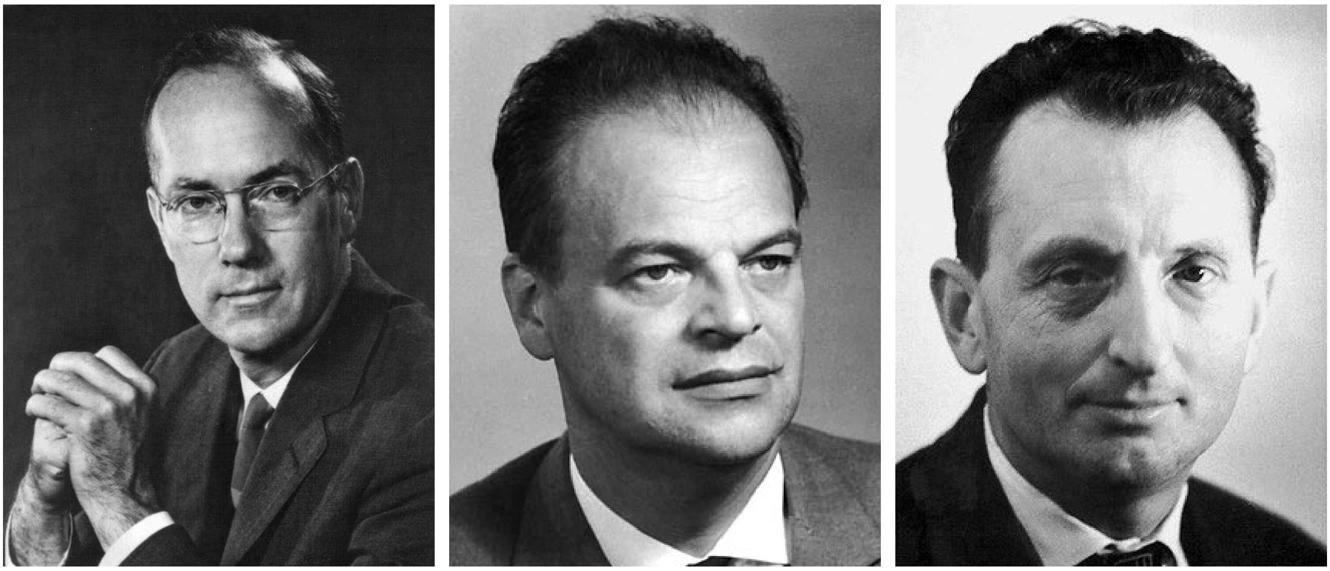


Photo 3. With this setup, M D Galanin, A M Leontovich, and Z A Chizhikova obtained lasing from a ruby crystal on September 18, 1961 [10].



Laureates of the 1964 Nobel Prize in Physics "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" (from left to right): C Townes, N G Basov, A M Prokhorov.

Nobel medal.

(LPI) knew each other well, but due to departmental barriers they acted independently.

Subsequent years saw dozens of reports on obtaining lasing with the use of active media in different aggregate states. Early publications included demonstrations of the effect and studies of the fundamental properties of laser radiation. Early work made it possible to recognize, perhaps not to the fullest extent, the widest potentialities of the practical use of lasers.

However, fundamental research alone was not enough for this. It was necessary to develop completely new technologies, which did not exist then either in the USSR or in the USA. It called for searching for and producing new materials, developing methods for their precision processing, designing optical pumping sources and precision mirror deposition technology, which later fostered the development of nanotechnology, and much more.

All this invited the development of new technological equipment, the production of high-purity reagents, methods and instruments for monitoring the physical properties of materials, and other absolutely necessary components.

In record time, new institutes, design bureaus, and high-tech production facilities were set up in the USSR, and specialists were trained. As a result, in a short period of time, the USSR turned, along with the USA, into one of the two laser superpowers. N G Basov and A M Prokhorov played a significant role in the implementation of this process, under whose leadership a number of important programs of national importance were executed.

Further tasks based on the resultant solid foundation that determined receiving the 1964 Nobel Prize[1] were expanding the spectral range of radiation from ultraviolet to infrared, developing lasers with a tunable wavelength, reducing the divergence of a laser beam to the theoretical limit, increasing power and improving efficiency, and generating pulses of different durations down to ultrashort ones, including durations determined by the theoretical limit. Solving these problems has made it possible to widely use lasers in various fields of human activity.

The organic connection between basic and applied science is brilliantly confirmed by the example of the development of laser physics. A path has been traversed from the "fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle" to the emergence of new areas of nonlinear physics and new areas of industry and medicine.

[1] The Nobel lectures given by the laureates in Stockholm on December 11, 1964 were published in *UFN* [12–14]. (*Editor's note*.)

During the origination and development of quantum electronics, laser physics, and nonlinear optics, there was a fairly close connection between domestic and foreign scientists. Many fundamental problems were solved precisely owing to these connections. It is also impossible not to note the role of Soviet scientists in organizing scientific research and founding scientific schools in countries where science was just emerging. As already noted, these processes, under political pressure, are currently being subject to unreasonable revision. Fortunately, this does not apply to all countries, but, nevertheless, the harm from them for world science is very significant. I would like to believe that discrimination against domestic scientists is a temporary phenomenon and, for the common good, will sooner or later end and everything will come to a natural logical conclusion.

The personal choice of the 1964 Nobel Prize laureates seems absolutely correct and justified.

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