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In memory of David Nikolaevich Klyshko

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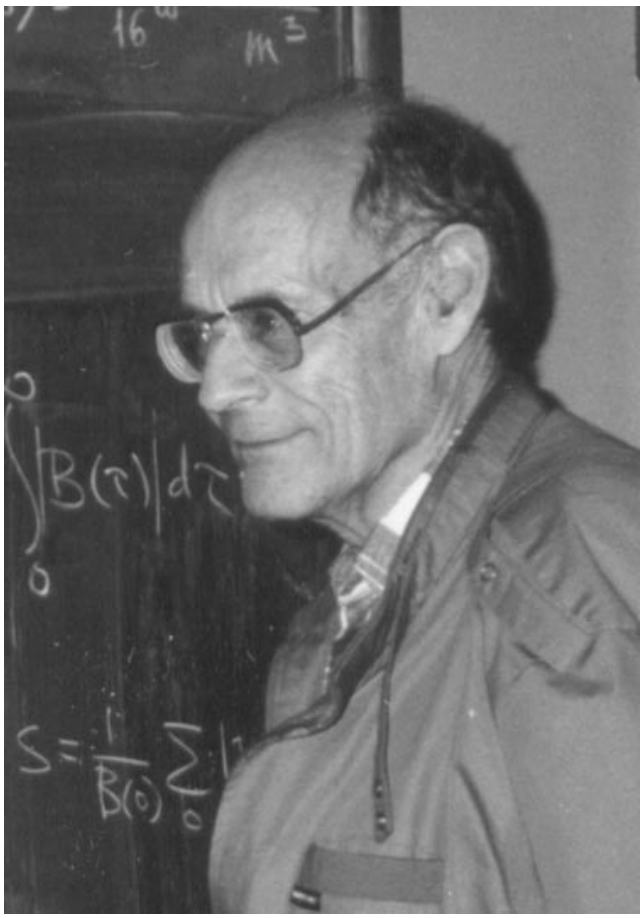
David Nikolaevich Klyshko, professor of quantum radiophysics of the physics department of the M V Lomonosov Moscow State University (MGU), died on April 10, 2000.

He was a blessed physicist. The adjectives 'outstanding' or 'talented' are but feeble approximations to the gift given to him by Nature. It seemed that generating new ideas and discovering new phenomena was the main function of his life. No hurdles thrown at him by circumstances could stop him realizing that gift...

David Nikolaevich Klyshko was born in Moscow on May 21, 1929. In 1947 he graduated from the famous Moscow school No. 110 and enrolled in the physics department of the M V Lomonosov Moscow State University. However, he had to leave: the echo of the prosecutions of the 1930s, in which his parents suffered, hit him too. Nevertheless, David Nikolaevich still managed to become a physicist with a diploma, having graduated from the physics department of Gorkiĭ State University (now Nizhniĭ Novgorod). There he moved together with the family of Ekaterina Pavlovna Peshkova (the first wife of Maxim Gorky), in which D N Klyshko was brought up after his parents were arrested. After graduation, David Klyshko returned to Moscow and began working at the Institute of Radioelectronics (IRE) where he studied paramagnetic resonance.

From his first steps in science to his last days David Nikolaevich firmly tied his fate as a scientist to quantum radiophysics (quantum electronics). First it was masers, then lasers, then laser physics and quantum optics. In 1958 David Nikolaevich was chosen to head the experimental research program in the Laboratory of Quantum Radiophysics created by S D Gvozdover at the chair of microwave radiophysics. It should be stressed here that at that moment D N Klyshko was a highly skilled experimentalist. He still considered himself an experimentalist when he achieved recognition and world renown as a theoretician. He always completed his theories by proposing specific experiments, which were later carried out by his students.

In 1964 D N Klyshko presented a PhD thesis on "Multiquantum and multiparticle transitions in radiospectroscopy and quantum radiophysics". All his referees voted for awarding the higher DSc degree. However, procedural complications thwarted this effort, and Klyshko defended his DSc thesis on "Multiphoton processes in optical and radio frequency ranges" in 1972. In this thesis, D N Klyshko not only summed up his research in multiphoton processes but also made the first and decisive step towards the creation of a novel avenue in the still very young science of quantum optics. Namely, this was the spontaneous parametric scattering of light, later called spontaneous parametric down conversion (SPDC), the phenomenon that D N Klyshko predicted in 1966. This was David Nikolaevich's moment of truth, which



David Nikolaevich Klyshko
(21.05.1929 – 10.04.2000)

revealed not only his huge creative potential but also his overpowering determination and patience — indeed, events were following a very dramatic scenario at the time. David Nikolaevich mentioned this story brirfly in his book *Photons and Nonlinear Optics* that was published in 1980 but still remains unparalleled in its scope and profoundness of the analysis of the quantum nature of light: "The first estimation of three-photon parametric scattering in piezoelectric crystals, made in 1966, showed an unexpectedly high value, with an effective temperature of $\sim$ 1000 K even for pumping at 1 W of power, and it was incomprehensible why the effect remained unnoticed earlier, in experiments on frequency subtraction in parametric amplification". In 1974 the prediction and observation of SPDC was officially classified as a discovery. In 1983 D N Klyshko and his two co-authors (A N Penin and V V Fadeev) received the State Prize "For the discovery and investigation of the phenomenon of spontaneous parametric scattering of light and its application to spectroscopy and metrology". There can be no doubt that Klyshko played the leading role in the discovery of SPDC as a new type of light scattering, and that in the history of physics

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his name must reside on a par with the names of other discoverers of the known types of scattering of light.

The stretch of more than 40 years — from 1958 to the day of his untimely death — was the time in the life of David Nikolaevich when, in the state of uninterrupted creative inspiration, he built the foundations of quantum optics and solved numerous problems this posed. There is a whole direction in this science that he developed himself. Ideas and predictions of new effects poured from his creative laboratory at such rate that experimenters could not cope with the flow; it will take them a long time to bring into life David Nikolaevich's legacy.

Speaking about D N Klyshko's contribution to quantum and nonlinear optics, one should first of all mention the theory of spontaneous parametric scattering of light (SPDC). Spontaneous parametric scattering occupies a central place in modern quantum optics because this is currently the simplest and most efficient method of generating correlated states of photons (or biphotons, as D N Klyshko called them). He was the first to analyse the unique statistics of fields emitted in SPDC (*Pis'ma v ZhETF*, 1969 [*JETP Letters*, 1969]). The SPDC effect came to replace the two-photon decay of excited atoms which was previously used to demonstrate the Einstein – Podolsky – Rosen (EPR) paradox and to experimentally verify Bell's inequalities, thereby giving a powerful spur to the progress of quantum optics. Very recently, this rapidly developing field of science led to such unanticipated and beautiful effects as anticorrelation, quantum cryptography and quantum teleportation — they are all essentially based on SPDC. Soon after the SPDC theory, D N Klyshko worked out the theory of hyper-Raman scattering (*ZhETF*, 1970 [*JETP*, 1970]).

D N Klyshko was the first to realize that spontaneous parametric scattering and Raman scattering by polaritons (an effect known before SPDC was discovered) have a common nature and constitute two limiting cases of the same effect (*Pis'ma v ZhETF*, 1969 [*JETP Letters*, 1969]). He suggested a unified description for the two, based on the model of effective cubic susceptibility. The new theory stimulated work on spectroscopic applications of SPDC. Klyshko's theory also included a description of the active spectroscopy of polaritons (*Kvanovaya Elektron.,* 1975 [*Sov. J. Quantum Electron., 1975]*).

Important contributions to modern optics were SPDC-based methods that Klyshko developed for quantum metrology: absolute measurement of the spectral brightness of radiation and absolute calibration of photodetectors needing no reference sources or radiation receivers. Both these methods of quantum metrology were experimentally implemented at the beginning of the 1980s.

David Nikolaevich possessed an outstanding insight into the art of experiment — this is why his experimental predictions were so accurate and gave the experimentalist an almost 100% guarantee of success. On the other hand, his publications analyzing the results of completed experiments typically clarified the most baffling situations. Some of the beautiful experiments that Klyshko suggested still await implementation, for example, finding correlation between the Stokes and anti-Stokes components of Raman scattering (*Kvantovaya Elektron.*,1977 [*Sov. J. Quantum Electron.*, 1977]) and measuring odd moments of the field in thermal radiation (*Dokl. Akad. Nauk SSSR*, 1979 [*Sov. Phys. Dokl.*, 1979).

D N Klyshko developed several new theoretical approaches to quantum and nonlinear optics: the generalization of Kirchhoff's law to non-geometric and nonlinear optics (*Izv. Akad. Nauk SSSR, Ser. Fiz.*, 1982 [*Bull. Russ. Acad. Sci., Phys.*, 1982]), the theory of nonunitary transformations in optics, the advanced wave model for describing correlation and interference experiments in quantum optics (*Phys. Lett. A*, 1988).

It was not accidental that the effect of second-order interference of non-classical fields emitted in SPDC was already pointed out in Klyshko's early papers (*ZhETF*, 1968 [*JETP*, 1968]) — indeed, it is this effect that gives the SPDC lineshape in a spatially bound crystal. This effect, almost unnoticed at the time, is nontrivial in the sense that interference here manifests itself in spontaneous emission that is 'seeded' by vacuum noise. Later Klyshko analysed second- and fourth-order interference in SPDC and generalized it to the case of scattering in several spatially separated crystals (*Phys. Rev. A*, 1997).

In his latest publications, Klyshko paid much attention to problems of methodology and interpretation of quantum mechanics and quantum optics, such as, for example, the Einstein – Podolsky – Rosen paradox, which he interpreted as a violation of Kolmogorov's axioms in quantum mechanics; the postulate of wave function reduction, for which he suggested an experimental verification procedure; operational criteria of the non-classical nature of light; and many others. He offered profound fundamental similarities and classical analogies that he used in discussing experiments and that always served a single goal: to achieve maximum clarity in the formulation and the solution of physics problems.

D N Klyshko founded a school of quantum optics in Russia. The school fostered six DSc scientists and very many PhDs. Its pedagogical style was as unique as was Klyshko's style in science. His students received not only knowledge from him but also that intangible, indescribable something that makes a true scientist.

Not only the chair of quantum radiophysics, and not only the physics department and Moscow State University, but equally the entire global scientific community lost one of their most brilliant researchers and teachers, one of the 'last of the Mohicans' of the disappearing breed of highly erudite Russian intelligentsia. They are replaced by their students, who are in many ways different and also highly talented. One hopes that they imbibed the values that David Nikolaevich taught them in his unostentatious way.

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G Kh Kitaeva, S P Kulik, T V Laptinskaya,
L P Pitayevskiĭ, P A Prudkovskiĭ, A N Penin,
V I Trukhin, V V Fadeev, M V Chekhova