Scientific Session of the Division of General Physics and Astronomy and the Division of Nuclear Physics, Academy of Sciences of the USSR (25–26 April 1984)

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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on April 25 and 26, 1984 at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences. The following reports were presented:

April 25

1. *D. N. Klyshko and A. M. Penin*. Quantum photometry using parametric scattering of light.

2. *V. S. Dneprovskiĭ*. Optical bistability in semiconductors.

3. *Kh. S. Bagdasarov, V. B. Braginskiĭ, V. I. Panov, and V. S. Il'chenko*. Anomalously low dissipation of electromagnetic waves in perfect single-crystal dielectrics.

April 26

4. *V. E. Shcherbinin*. Magnetic, magnetoelastic, and electromagnetic-acoustic methods of nondestructive testing.

5. *A. A. Samokhvalov and V. V. Osipov*. Electron-magnon interaction in magnetic semiconductors.

6. *I. O. Kulik*. Superconductivity of narrow-band metals and semiconductors and the model of superconducting glass.

The brief contents of the five reports are published below.

D. N. Klyshko and A. N. Penin. *Quantum photometry using parametric scattering of light.* Frequency-spatial spectra of three-photon parametric scattering of light carry extensive information on the properties of the scattering medium. The method of spectroscopy of piezoelectric materials, developed based on parametric scattering of light (PS), permits determining the dispersion and magnitude of the dielectric permittivity and the quadratic susceptibility over a wide spectral range from tenths to hundreds of microns. Based on the PS spectra, the frequencies and damping constants of the characteristic vibrations of the crystal lattice, characterizing their resonant contributions to the linear, quadratic, and cubic polarizability, are determined.

Another important area of application of PS is photometry. The properties of radiation appearing in the spontaneous parametric scattering of light make possible the creation of methods for measuring the quantum efficiency of photodetectors and the brightness of electromagnetic radiation, i.e., the solution of the two basic problems of photometry. In this case, the methods which make use of parametric scattering do not require the use of any kind of standard detectors and sources of radiation and they are absolute in this sense. Because they are founded on the quantum nature of the radiation, we can talk about the development of methods of absolute quantum photometry.

The radiation appearing in the case of spontaneous parametric scattering of light consists of a flux of photon pairs. The photons of one pair are characterized by a superclassical clustering in space and time. The temporal or longitudinal clustering indicates that the difference between the times at which the photons of one pair (biphotons) cross a plane perpendicular to the direction of propagation of the pump (exciting radiation incident on the medium) does not exceed $10^{-11} \ldots 10^{-12}$ s. The spatial or transverse clustering indicates that the position of the regions of localization of each of the photons of one pair in the indicated plane can be determined to within 0.01 cm, while the area of the region of localization is of the order of 0.0001 cm^2. We shall call such pairs of strongly correlated photons biphotons.

The procedure for measuring the quantum efficiency consists of the following. If two photodetectors operating in the photon counting mode (characterized by the quantum efficiency η_1 and η_2, respectively) are present, then the number of photocurrent pulses (here and below—the counting rate, the number of pulses per unit time) at the outputs of the photodetectors when they detect photons belonging to a single pair and when each detector detects its "half" of the biphoton will be equal to $M_1 = \eta_1 N$ and $M_2 = \eta_2 N$, respectively. Here N is the intensity of the flux of biphotons. The number of pulses generated by the coincidence circuit when pulses appear simultaneously at its inputs from the photodetectors will be determined by the expression $M_c = \eta_1\eta_2 N$. From here it follows that the quantum efficiency of the photodetectors can be determined by measuring three numbers ($\eta_1 = M_c/M_2$ and $\eta_2 = M_c/M_1$) and the parameters of the experimental arrangement do not affect the measurement results.

In measuring the sensitivity of photodetectors operating in the analog mode, the measurement procedure involves the multiplication of the currents in their loads and the separation of the frequency component corresponding to the average rate of arrival of biphotons.

The spatial clustering of photons also permits calibrating electrooptical converters (EOC). In this case, an image of a thin (of the order of 0.1 . . . 1 mm) layer of scattering medium is projected onto the EOC screen and the number of double flashes situated at a distance less than a fixed value and single flashes of the luminophor are counted. The ratio of the two numbers determines the efficiency of the apparatus.

We note that in all cases described above radiation with a spectral width of the order of 10 cm^{-1} was incident on the detectors.

The solution of the second problem of photometry—the measurement of the brightness of electromagnetic radiation—is based on the fact that the intensity of the scattered radiation accompanying spontaneous parametric scattering, aside from the parameters of the scattering medium and the intensity of the pump, is also determined by the magnitude of the zero-point fluctuations of the electromagnetic vacuum. The effect of the zero-point fluctuations in the parametric scattering process is equivalent to the action of a field with a brightness of one photon in each mode independent of frequency and direction. For this reason, spontaneous parametric scattering of light can be interpreted as the parametric conversion of zero-point fluctuations. The process of measurement of the brightness consists of comparing the number of photons appearing in the mode of the field at the output from the medium N_1 in the case when only zero-point fluctuations participate in the conversion process $N_1 = F_{12}$ ($F_{12} = 4\pi^2\omega_2\omega_1 c^{-2}(\hat{\chi})^2 E_L^2 l^2$ is the parametric conversion factor, ω_2 is the frequency of the measured radiation, ω_1 is the frequency of the radiation detected at the output from the medium, $\hat{\chi}$ is the quadratic susceptibility of the medium, E_L^2 is the pump intensity, and l is the thickness of the scattering layer). Usually $F_{12} \simeq 10^{-8}$ and in the case when aside from zero-point fluctuations photons of the measured radiation with a brightness of N_2 photons in the mode of the field with frequency $\omega_2 = \omega_L - \omega_1$ at the input to the medium participate in the process, $N_1' = F_{12}(1 + N_2^0)$. Then the brightness of the measured radiation is determined by the expression $N_2 = (N_1'/N_1) - 1$ and the parameters of the medium do not affect the result. The transformation from absolute brightness in terms of the photons in the mode of the field to the brightness in energy units is performed via the brightness of zero-point fluctuations 1 photon per mode $= B_L = \pi\hbar c^2/\lambda^5$, where λ is the wavelength of the measured radiation.

We note that the method described above is most efficient when fluxes of radiation with high brightness, equivalent to the brightness of radiation created by a black body whose temperature falls in the range $10^3 \ldots 10^6$ K, are measured. The spectral range of the measurements can extend to tens of microns and is limited only by the absorption band of the scattering medium.

In conclusion we note that the absoluteness of the proposed methods of photometry and the independence of the results from the parameters of the apparatus in principle make possible the creation of a new class of photometric standards based on them.

[1] D. N. Klyshko, Fotony i nelineĭnaya optika (Photons and Nonlinear Optics), Nauka, 1980; Kvantovaya Elektron. (Moscow) **4**, 1056 (1977); **7**, 1932 (1980) [Sov. J. Quantum Electron. **7**, 591 (1977); **10**, 1112 (1980)].

[2] G. Kh. Kitaeva, A. N. Penin, V. V. Fadeev, and Yu. A. Yanaĭt, Dokl. Akad. Nauk SSSR **247**, 586 (1979) [Sov. Phys. Dokl. **24**, 564 (1979)].

[3] M. F. Vlasenko, G. Kh. Kitaeva, and A. N. Penin, Kvantovaya Elektron. (Moscow) **7**, 441 (1980) [Sov. J. Quantum Electron. **10**, 252 (1980)].

[4] A. A. Malygin, A. N. Penin, and A. V. Sergienko, Kvantovaya Electron. (Moscow) **8**, 1563 (1981) [Sov. J. Quantum Electron. **11**, 939 (1981)]; Pis'ma Zh. Eksp. Teor. Fiz. **33**, 493 (1981) [JETP Lett. **33**, 477 (1981)]; Dokl. Akad. Nauk SSSR (1984).

[5] D. N. Klyshko, Zh. Eksp. Teor. Fiz. **83**, 1313 (1982) [Sov. Phys. JETP **56**, 753 (1982)].

[6] D. N. Klyshko, A. A. Malygin, and A. N. Penin in: Trudy VII Vavilovskoĭ konferentsii "Nelineĭnaya optika" (Proceedings of the 7-th Vavilov Conference on Nonlinear Optics), Siberian Branch of the USSR Academy of Sciences, Novosibirsk (1981), Vol. 1, p. 206.