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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR was held on 25 and 26 March 1981 at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences. The following papers were presented:

March 25

1. *N. A. Irisova*, Submillimeter spectroscopy of solids. Basic problems. Methods. Apparatus.
2. *G. V. Kozlov, A. A. Volkov, and S. P. Lebedev*, Dielectric spectroscopy of soft modes in ferroelectrics.
3. *V. N. Murzin*, Submillimeter spectroscopy of collective and bound carrier states in semiconductors.

March 26

4. *V. A. Kuz'min*, Quarks and cosmology.
5. *A. A. Ansel'm*, Development of theory after the "Standard Model" ("Grand" Unification, "Technicolor").

Brief contents of four of the papers are presented below.

N. A. Irisova. *Submillimeter spectroscopy of solids. Basic problems. Methods. Apparatus.* From its first appearance and to the present day, spectroscopy has been one of the most informative and precise methods for physical investigation of the macroscopic and microscopic properties of matter. However, although it has successfully mastered both the optical and radio bands, spectroscopy was unable until recently to penetrate the narrow segment of the spectrum between the IR and microwave bands—the so-called submillimeter band. As a result, a "submillimeter spectroscopic gap" had formed by the early 1960s in the frequency range 10^{11} Hz $\leqslant \nu \leqslant 10^{12}$ Hz, i.e., $0.3 \leqslant \lambda \leqslant 3$ mm.

The solution of quite a few problems of solid-state physics that are of both scientific and applied importance depends on research in the submillimeter band. Submillimeter spectroscopy becomes fundamentally important in cases in which the energies and characteristic frequencies of the phenomena to be studied lie in precisely this band, so that it can yield fundamental scientific data that are inaccessible to other methods of investigation. For example, submillimeter spectroscopy can give us new information on absorption mechanisms in crystals and crystallattice dynamics and on the properties of excitons, impurity complexes, and excited states of impurities in semiconductors; it can help significantly in study of the nature of phase transitions in solids, and in ferroelectrics in particular, in ordered magnetic systems, and in superconductors.

The development of submillimeter spectroscopy is no less important in other areas of science. For physics, these areas also include plasma diagnostics, spectroscopy of gases, cosmic radiospectroscopy, and study of liquids, especially water. Submillimeter research is highly promising in biology, especially for the study of resonant interactions with biological objects at the level of the living cell, and for determination of the effects of radiation on the living organism as a whole. The propagation of submillimeter radiation in the atmosphere, space communications, radar, analysis of impurities in specially pure substances, and nondestructive quality control are perhaps most important among the applied studies.

Diametrically opposite approaches to the mastery of submillimeter spectroscopy of solids has been taken in the USSR and abroad. Abroad, effort has been concentrated on the development of Fourier-spectroscopy methods and instruments as a continuation and further development of the methods of classical spectroscopy, which is based on the use of nonmonochromatic thermal radiation. Our approach, that of monochromatic spectroscopy, was a logical extension of the work done at the Physics Institute of the Academy of Sciences (FIAN) on microwave radiospectroscopy under the direction of A. M. Prokhorov.

We perceive a fundamental advantage of monochromatic submillimeter spectroscopy over Fourier spectroscopy in the fact that monochromatic spectroscopy combines very high resolutions $\rho = \nu/\delta\nu$ (ν is the frequency and $\delta\nu$ is the smallest spectral segment that can be resolved) with a broad dynamic band in which the registered signal $D = P_{\max}/P_{\min}$ may vary ($P_{\max}$ and $P_{\min}$ are the highest and lowest values of the registered signal). This radically broadens experimental possibilities, providing not only for spectroscopy of solids that have high-Q resonant absorption, but also study of solids under conditions accompanied by sharp changes in properties, for example directly in phase-transition ranges.

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The quantities ρ and D are interrelated in Fourier spectrometers: an increase in the size of the resolvable spectral interval $\delta\nu$ results in a simultaneous increase in ρ and a decrease in D. In addition, as we advance into the longwave region of the spectrum, the ρ of Fourier spectrometers decrease in proportion to λ, while the D decrease even more sharply owing to the sharp drop in the spectral density of the thermal radiation. As a result, the resolution and dynamic range of the monochromatic spectrometers that we have developed are several orders higher than the corresponding characteristics of the best Fourier spectrometers in the region of the submillimeter band in which the bands of Fourier and monochromatic spectrometers overlap. However, Fourier spectroscopy also has its advantages—for example, in studies to be made in very broad wavelength ranges and in passive spectroscopy. Thus, these two spectroscopic techniques are not antagonistic, and should complement one another in reasonable fashion.

The ideas of monochromatic submillimeter spectroscopy have come to practical fruition in the creation of a new class of spectrometers that use the radiation of frequency-tunable electronic generators such as backward-wave tubes, and are therefore known as BWT spectrometers. Soviet-built BWT generators developed under the direction of N. D. Devyatkov and M. B. Golant possess unique characteristics: with intrinsic monochromaticities better than 10^7 and radiated powers in the milliwatts, they offer more than 50% electronic frequency tuning, so that a set of 10 instruments provides continuous coverage of the entire submillimeter band.[1,5]

An original proposal that one-dimensional wire grids with periods much smaller than the wavelength should be used[3,4] was the turning point to which we may trace progress in the development of submillimeter-band metrics (the combination of the measurement apparatus and spectral measurement techniques adequate to it). The conduction anisotropy of the grid means that, depending on the polarization direction of the plane wave interacting with the grid, the coefficients of reflection and transmission vary through three orders of magnitude. At the same time, such grids possess unique broad-band capability. Thus, for example, a gold grid made from wires 15 μm in diameter with a period of 40 μm has power reflectivity better than 99.5% over the entire submillimeter band. Theoretical studies (based on the work of L. A. Vaĭnshteĭn[2]) and complete experimental investigations of the amplitude and phase characteristics of the grids for both polarization directions made it possible to use them to build a set of high-precision quasioptical measuring units in a joint effort with the Central Design Office of Unique Devices of the USSR Academy of Sciences under the direction of E. V. Mashintsev. This apparatus later served as a prototype for three generations of BWT spectrometers. The third-generation spectrometers work with built-in computers, which control mode selection and the registration of spectrograms and the operation of specific measuring elements, store the acquired data, and handle numerical processing of these data. The use of computers does more than simply reduce measurement time, making it possible to complete in one day measurements that would previously have required over a month; it has also significantly broadened the range of experimental options and, in the final analysis, the range of objects that can be investigated.

The necessary values of the basic spectrometer characteristics were determined from the requirements of spectroscopy for solids that have extreme property values in the submillimeter band. For example, the resolution $\rho = 2\cdot 10^4$ that has been attained makes it possible to study the narrowest of the known absorption lines: the spectra of impurities in specially pure semiconductors at $T = 4$ K. The dynamic range $D = 10^5$ provides for study of crystals directly in the range of the paraelectric-ferroelectric phase transition, which is accompanied by sharp changes, of the order of $10^4 - 10^3$, in the values of ε' and ε''. BWT spectrometers function throughout the entire submillimeter band (0.25 to 4 mm), and the measurements are made with linearly polarized radiation whose orientation in spece is precisely defined. All the spectral-measurement techniques that have been developed are based on the use of plane-parallel specimens with transverse dimensions greater than the wavelength and thicknesses comparable to it. The methodological equipment of the spectrometers, which includes single-beam, two-beam, and multibeam measurement systems, provides for spectroscopy of specimens with all practically possible values of the complex dielectric constant ε' and ε''. The quasioptical-channel designs are simple and make it possible to change from one measuring scheme to another and to insert auxiliary devices such as cryothermostats, magnets including super-conductive magnets, etc. into the measurement channel. This makes it possible to measure specimens not only under natural conditions, but also as the temperature is varied from 4 to 1000 K, under the action of external electric and magnetic fields, with compression of the specimens, etc.

The FIAN now has seven submillimeter BWT spectrometers in continuous service. They have been used in a broad range of spectral studies of various classes of solids and to determine characteristic submillimeter-band parameters of about a hundred dielectrics, ferroelectrics, semiconductors, and magnetics. The measurements in the submillimeter band have been the first of their kind in most cases.

Submillimeter studies in the spectroscopy of gases, liquids, plasmas, and solids are now being advanced very successfully in a long list of scientific agencies, first among which we should mention the Institute of Applied Physics of the USSR Academy Sciences, the Institute of Radio Electronics of the USSR Academy of Sciences, the Kurchatov Institute of Atomic Energy, and the Moscow City Polytechnic Institute. We may therefore state that the submillimeter spectroscopic gap has been successfully bridged.

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