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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 May 28 and 29, 1980 at the Academy's P. N. Lebedev Institute of Physics. The following papers were presented:

May 28

1. *A. P. Levanyuk and D. G. Sannikov*, Present status of the theory of phase transitions in ferroelectrics.

2. *I. V. Ivanov*, Low-temperature ferroelectrics: dielectric nonlinearity and parametric interactions in the microwave band.

3. *O. G. Vendik*, Ferroelectric films (soft-mode dynamics, microwave applications).

May 29

4. *A. M. Gal'per, Yu. D. Kotov, and B. I. Luchkov*, The diffuse cosmic gamma radiation.

5. *V. E. Nesterov and O. F. Prilutskiĭ*, Discrete sources of cosmic gamma radiation.

6. *V. G. Kirillov-Ugryumov, R. Z. Sagdeev, and Yu. P. Semenov*, The outlook for observational gamma astronomy.

We publish below brief contents of the papers.

A. P. Levanyuk and D. G. Sannikov. *Present status of the theory of phase transitions in ferroelectrics.* Much experimental material on various kinds of phase transitions has now been accumulated. The phenomenological approach based on Landau's theory of phase transitions[1] is found to be most efficient for interpretation and classification of this material. The phase transitions in ferroelectrics are a typical example of structural transitions, and one that is relatively well understood, since the ferroelectrics are a convenient object for study and are of practical interest. It is the characteristic features of various types of structural phase transitions as exemplified by the ferroelectrics that are the subject of the present discussion.

Structural phase transitions, i.e., transitions in which there is a change in the symmetry of the crystal (we exclude isomorphic transitions from consideration), are of two broad classes: commensurable and noncommensurable. We shall confine ourselves for the sake of argument to displacement-type transitions. Here the change of symmetry attending the transition is determined by the atomic displacements that correspond to one normal coordinate, i.e., to one "wave of displacements" of atoms. In most known cases, the period of this displacement wave is 1, 2, 3, or 4 times larger than the period of the symmetric-phase crystal lattice. These transitions are called commensurable. Noncommensurable phase transitions, in which the period of the atomic-displacement wave is not a multiple of (not commensurable with) the period of the symmetric-phase crystal lattice, have recently been observed in various compounds (including ferroelectrics). As a result, the crystal loses periodicity in a certain direction in the noncommensurable phase, which, for practical purposes, means a very large unit-cell size.

The difference between commensurable and noncommensurable phase transitions is manifested in different kinds of dispersion of the soft branch of the normal lattice vibrations. In the case of the commensurable phase transition, the soft mode is localized in k space, i.e., the minimum of the soft branch is situated at a certain point of the Brillouin zone that does not vary with temperature. These points are symmetrically-determined and correspond to the values $ka/2\pi = 1$, 2, 3, and 4, where a is the lattice constant.[2]

In the case of a noncommensurable phase transition, the position of the soft-branch minimum is not determined by the symmetry of the crystal and therefore varies with temperature. The value of $ka/2\pi$ that corresponds to the soft mode is an arbitrary and, generally speaking, irrational number, i.e., k and $2\pi/a$ are not commensurable.

Figure 1 shows the soft optical branches of crystal vibrational spectra for three cases—the commensurable phase transition, a) without change in the translational symmetry of the crystal and b) with doubling of the lattice constant, and c) the noncommensurable phase transition.

The transition in barium titanate corresponds to case a). A phenomenological theory of such transitions was developed by Ginzburg.[3] The order parameter in this theory is the polarization, which is proportional to the

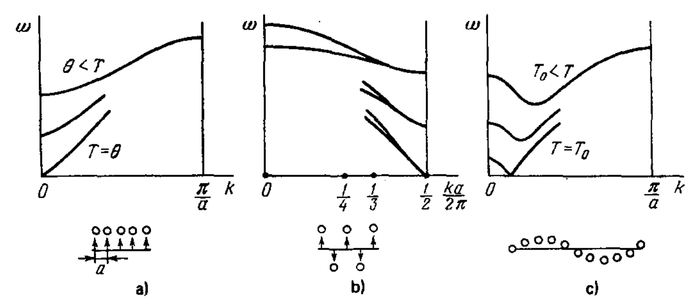

FIG. 1.

coordinate of the soft mode. Ginzburg's theory explained the dielectric anomalies and other properties not only of barium titanate, but also of many other ferroelectrics.

The ferroelectric phase transition in gadolinium molybdate corresponds to case b) in the figure. Here polarization is not an order parameter and appears on the phase transition only because it is proportional to the quadratic combination of the coordinates of the doubly degenerate soft mode. Indebom[4] was the first to draw attention to the possibility of such ferroelectric transitions. They were later observed experimentally and designated improper phase transitions (see Ref. 5). The dielectric anomalies in improper ferroelectrics are quite different from those in proper ones. The Curie-Weiss law is not observed, and the second-order phase transition is not eliminated by an electric field, as it is in proper ferroelectrics, which are described by Ginzburg's theory.

The improper phase transition in the ferroelectrics sodium nitrate and thiourea corresponds to case c) in the figure. A sequence of two transitions is observed in these crystals as the temperature is lowered, the first to the noncommensurable phase, and the second to the ordinary (commensurable) polar phase. The structure of the noncommensurable phase can be characterized as a polarization wave with a period an order of magnitude or more larger than the lattice constant.

The position of this polarization wave is not fixed in an infinite crystal, i.e., the wave can shift without encountering resistance in an ideal, defect-free crystal. The presence of the theoretically predicted new branch of acoustic-type oscillations—the so-called phason branch—is the result. Unlike acoustic phonons, the longwave phasons are always overdamped and should not be manifest in either the infrared absorption spectra or the light-scattering spectra. Still, there is definite interest in experiments to study oscillations corresponding to the phason branch, which are possible at sufficiently large $k \sim k_0$. Other interesting experiments might be performed to observe the electric quadrupole moment in the noncommensurable phase, which is anomalously large owing to the presence of the polarization wave (the quadrupole moment was even used originally to identify the noncommensurable phase in rubidium trihydroselenite); to study the generation of the second optical harmonic, which is also anomalously large; to investigate the NMR spectrum, which has its own peculiarities; to study the anomalous properties of dielectric susceptibility, heat capacity, etc. The noncommensurable phase is distinctive in that its properties are strongly influenced by defects. This effect results from the possibility of the displacement waves being fixed by the defects.

A phenomenological theory of the noncommensurable superstructure was first derived by Dzyaloshinskiĭ[6] for magnetics. A similar approach has also been used for noncommensurable phase transitions in ferroelectrics.[7] One of the possible macroscopic, i.e., symmetric, causes of noncommensurable transitions was already indicated in a 1941 paper by Lifshits.[2]

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[3]V. L. Ginzburg, *ibid*. **15**, 739 (1945), **19**, 36 (1949); Usp. Fiz. Nauk **38**, 490 (1949); Fiz. Tverd. Tela **2**, 2031 (1960) [Sov. Phys. Solid State **2**, 1824 (1961)].

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[5]A. P. Levanyuk and D. G. Sannikov, Usp. Fiz. Nauk **112**, 561 (1974) [Sov. Phys. Usp. **17**, 199 (1974)].

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[7]A. P. Levanyuk and D. G. Sannikov, Fiz. Tverd. Tela **18**, 423, 1927 (1976) [Sov. Phys. Solid State **18**, 245, 1122 (1976)].