

CONFERENCES AND SYMPOSIA

PACS numbers: 01.10.Fv, 05.70.Fh, 05.70.Jk, **64.60.–i**

Traditional international conference on phase transitions and related critical and nonlinear phenomena

(Makhachkala, Republic of Daghestan, Russian Federation, September 6 – 9, 2000)

I K Kamilov, A K Murtazaev

DOI: 10.1070/PU2001v044n03ABEH000929

Abstract. **This paper gives a brief review of some results presented at the B B Kadomtsev Memorial International Conference on Phase Transitions and Nonlinear Phenomena in Condensed Media, held in Makhachkala, September 6 – 9, 2000 under the auspices of the Physics Institute of the RAS Daghestan Science Center. As part of the conference, the 4th International Workshop on the Physics of Magnetic Phase Transitions commemorating the 90th anniversary of Academician S V Vonsovskiĭ was held.**

It has already become a tradition to hold the International (earlier All-Union) Conferences on Phase Transitions and Related Critical and Nonlinear Phenomena in Makhachkala (Republic of Daghestan, Russian Federation). The previous one was held in 1998.

The most recent conference, which took place on September 6 – 9, 2000, in Makhachkala at the Physics Institute of the Daghestan Science Center (DSC) of the Russian Academy of Sciences (RAS), was titled "Phase Transitions and Nonlinear Phenomena in Condensed Media" and was dedicated to the Memory of Academician Boris Borisovich Kadomtsev. Within its framework, the Fourth International Workshop on the "Physics of Magnetic Phase Transitions", dedicated to the 90th anniversary of Academician Sergeĭ Vasil'evich Vonsovskiĭ, was held.

The conference and workshop were organized by the Division of General Physics and Astronomy of the Russian Academy of Sciences, the Scientific Section on Magnetism of the Russian Academy of Sciences, and the Physics Institute of the Daghestan Science Center of the Russian Academy of Sciences.

Both scientific events were supported by the Russian Academy of Sciences, the Ministry of Science and Technology of the Russian Federation, and the Russian Foundation for Basic Research.

Altogether 178 reports were presented at the conference and workshop (12 at full-scale sessions, 59 oral reports, and 107 printed and displayed reports) from 20 cities of Russia and from 10 CIS and other foreign countries. There were more than 150 participants at the conference. The topics of the conference embraced practically all aspects of the physics of condensed media related in one way or another to phase transitions and nonlinear and critical phenomena. The conference was divided into the following sections: magnetic phase transitions; magnetic critical phenomena; phase transitions and critical phenomena in condensed media; critical phenomena in liquids; phase transitions, nonlinear phenomena, and chaos in condensed media; and computer simulations of phase transitions and critical phenomena. A section devoted to magnetic critical phenomena, dedicated to the memory of the well-known Daghestanian physicist Prof. Kh K Aliev, actively worked within the framework of the workshop.

The purpose of the conference was to acquaint the participants with the new ideas and current state of research into phase transitions and nonlinear and critical phenomena in all areas of the physics of the condensed state and with the latest progress in these fields.

The conference was opened by the report of I K Kamilov, director of the Physics Institute of the Daghestan Science Center of the Russian Academy of Sciences and an Academy Corresponding Member, who reminisced about Academician Boris B Kadomtsev, a highly acclaimed physicist and outstanding person that contributed greatly to modern theoretical physics and, particularly, to the physics of plasma and controlled thermonuclear fusion. A considerable fraction of B B Kadomtsev's research was devoted to studying the physical properties of plasma in toroidal systems, or tokamaks. The instabilities in a plasma placed in a magnetic field have resulted in substantial difficulties in building reactors for controlled fusion. According to the theory developed by B B Kadomtsev and A V Nedospasov, instabilities in a weakly ionized plasma in a magnetic field are caused by the development of kink instabilities. Substantial progress in solid state physics was achieved after recognition of the fact that semiconductors contain an electron – hole plasma similar to a gas plasma.

Problems with which Boris Kadomtsev had been directly involved were at the center of interest at the conference.

A special laboratory that studies nonlinear phenomena and chaos in semiconducting systems has been opened at the Physics Institute of the Daghestan Science Center of the Russian Academy of Sciences (Makhachkala, Russian Federation). A researcher of that laboratory, K M Aliev, reported on the experimental results of exhaustive studies of the nonlinear dynamics related to the development of a Kadomtsev – Nedospasov instability (a kink instability) in

I K Kamilov, A K Murtazaev Physics Institute of the Daghestan Scientific Center, Russian Academy of Sciences
ul. Yaragskogo 94, 367003 Makhachkala, Russian Federation
Tel. (8-8722) 62-8960
E-mail: kamilov@datacom.ru

Received 23 January 2001
Uspekhi Fizicheskikh Nauk **171** (3) 325 – 328 (2001)
Translated by O A Glebov; edited by M S Aksent'eva

the electron – hole plasma of germanium in longitudinal electric and magnetic fields at high supercriticality parameters in the temperature interval from 77 to 300 K. He demonstrated that the effects discovered in these experiments are similar to first- and second-order non-equilibrium phase transitions. Various scenarios of order – disorder – order transitions that take place during the development of a Kadomtsev – Nedospasov instability in the semiconductor plasma of germanium have been investigated. The effect of an external periodic signal on the behavior of the system at bifurcation points has also been investigated. Finally, the report also mentioned studies of the processes of synchronization, amplification, and stability in a system subjected to an external factor.

The report of A A Stepurenko (Physics Institute of the Daghestan Science Center, Makhachkala, Russian Federation) dealt with the collective behavior of nonlinear objects, autosolitons, in a dissipative structure in p-InSb. Stepurenko's results imply that the behavior of thermal-diffusion autosolitons in an electric and magnetic field should be interpreted as the behavior of an aggregate of interacting autosolitons rather than separate objects. The experimental data suggest that a system consisting of an aggregate of interacting solitons is capable of self-organization. Research in this area should lead to interesting and unexpected results.

Yu A Izyumov, Corresponding Member of the Russian Academy of Sciences, delivered a memorial lecture "Academician S V Vonsovskiĭ and His Contribution to the Development of the Science of Magnetism", which attracted much attention. Izyumov gave the main facts about Vonsovskiĭ's life and spoke of Vonsovskiĭ's scientific, organizational, public, pedagogical, and publishing work. Very often the importance of a scientific idea becomes clear not immediately but only after some time has passed. The polar model of a metal, developed by S V Vonsovskiĭ together with S P Shubin, is just such an idea. This model was a precursor of the well-known Hubbard model on the theory of strongly correlated electron systems. The sd-exchange model also plays an important role in the modern theory of transition and rare-earth metals and alloys. The speaker stressed that Vonsovskiĭ contributed significantly to practically all areas of the theory of magnetism. What made this lecture even more interesting was that Izyumov is a pupil and colleague of Sergeĭ Vonsovskiĭ. There was loud applause when Yu A Izyumov finished speaking.

In recent years, as such conferences have become a tradition, attention has focused on studies of phase transitions and critical and nonlinear phenomena by methods of computational physics. A review of the current status of studies (and a number of results) of phase transitions and critical phenomena in specific spin – lattice models was given by A K Murtazaev (Physics Institute of the Daghestan Science Center, Makhachkala, Russian Federation). The speaker stressed the fact that the modern stage in the studies of phase transitions and critical phenomena requires more complicated and realistic models with crossover. In studying such models the existing analytical methods based on the theory of the renormalization group and the ε-expansion meet with considerable difficulties. More than that, renormalization group theory is not purely microscopic, and describing crossover phenomena by this theory is one of the most important problems that has yet to be solved. Only methods of computational physics guarantee a purely microscopic approach to studying critical phenomena in complex systems. In his report Murtazaev analyzed the results of investigations concerning phase transitions and critical phenomena both in well-known models (the Ising and Heisenberg models) and in complex models of real magnetic substances using the Monte Carlo method. This method, when combined with finite-size scaling theory and cluster algorithms, provides a powerful, versatile, and effective instrument for studying phase transitions and statistical critical phenomena. Lately such methods have also been used to investigate dynamic critical phenomena. The critical dynamics of the Ising and Heisenberg models have been studied in-depth. Although estimates of the values of the critical exponent z obtained through the use of the Monte Carlo method are reasonable, the picture that has emerged in this area of research cannot be considered complete and well-defined (with the Ising model being the one possible exception). Murtazaev especially noted that the stochastic dynamics used in the Monte Carlo method provide a correct description of the final equilibrium state of the system but that there is still no direct proof that the formal Monte Carlo dynamics give a proper description of the relaxation process in the system. Moreover, the special algorithms written for studying the critical region have a strong influence on the relaxation rate, which leads to a strong dependence of the relaxation time on the type of algorithm. Hence, verification of the results of Monte Carlo studies of critical dynamics is still a pressing problem. This problem is important both for the theory of phase transitions and critical phenomena and for computational physics.

An interesting problem was touched upon by A I Sokolov (St. Petersburg State Electrotechnical University 'LETI', Russian Federation). So far the critical behavior of three-dimensional Ising- and Heisenberg-type lattice models has been thoroughly studied. The critical exponents and other universal parameters of these models have been calculated with a record-high accuracy and reliability by using the field-theoretic variant of the renormalization group method. At the same time, much less is known about the effectiveness of the standard technique of the field-theoretic variant of the renormalization group theory in the two-dimensional case. The thing is that for the two-dimensional Ising model the four-loop expansions obtained by the Padé – Borel method yielded values of critical exponents that differed substantially from the exact ones. The use of conformal mappings for summing the appropriate series improved the accuracy of renormalization-group estimates, but still no agreement between these estimates and the exact values of the critical exponents was achieved. Will the allowance for the next terms in the renormalization-group expansions of functions restore the agreement between the renormalization-group estimates and the Onsager results? A I Sokolov and coworkers carried out interesting studies in search of the answer to this question. Their preliminary results can be formulated as follows: the allowance for five-loop expansion terms somewhat improves the agreement with the exact results, but the difference between these results and the renormalization-group estimates still remains larger than the corresponding error bracket. As noted by the researchers, the 'trouble' is especially evident when one deals with the small exponents α and η, for which the discrepancies are especially large. In the discussion of the results it was noted that for the theory of phase transitions and critical phenomena it is highly important that this situation be clarified and all the questions that emerge here be answered unequivocally.

Real magnetic materials possess a whole spectrum of properties that are usually ignored in model systems. Nevertheless, these properties play an important role in processes that occur near a phase transition point. One such property is the lattice compressibility. S V Belim (Omsk State University, Russian Federation) reported on the special features of tricritical behavior of a disordered three-dimensional compressible Ising system in the two-loop approximation combined with the Padé – Borel summation technique. The data presented in the report show that the effects of inhomogeneous deformations lead to a stable, fixed impurity-tricritical point. The corresponding calculations for the tricritical points of the disordered system yield $\nu = 0.562599$, $\alpha = 0.312203$, $\gamma = 1.104517$, and $\eta = 0.036750$. Obviously, these values differ from similar values for a homogeneous system.

The study of processes related to breaking the total spin conservation law in magnetic materials is highly important both for the theory of dynamic critical phenomena and for explaining the special features of the spectrum of spin waves in antiferromagnetic systems that consist of two or more subsystems. In some antiferromagnets the spin subsystems do not interact within the exchange approximation due to the symmetry of the lattice. Examples are the compounds R_2CuO_4 (R = Pr, Nd, Sm, and Eu). As a result, there usually emerges a noncollinear magnetic structure. This fact can be explained by assuming that there exists a short-range pseudodipole interaction. S V Maleev (St. Petersburg Nuclear Physics Institute, Russian Federation) spoke about this in his report. He also showed that the gap in one of the branches of the spectrum of spin waves is determined precisely by this interaction. A theoretical analysis of the strong temperature dependence of the gap width for $T \ll T_N$ suggested that any anisotropy that breaks the total spin conservation law leads to a strong interaction between the spin waves and that infrared divergence emerges in the lowest order. Thus, it was stressed that further studies of infrared instabilities in antiferromagnets (instabilities related to violation of the total spin conservation law) are necessary.

N K Dan'shin (Donetsk Physico-Technical Institute of the Ukrainian National Academy of Sciences) made a review of the experimental data on the high-frequency and acoustic properties of antiferromagnets with weak ferromagnetism (the rare-earth orthoferrites $RFeO_3$, where R = Er, Tm, Y, Yb, Dy, Ho, Sm, and Nd) and proposed a theory that fully takes into account the mechanism of formation of the dynamics of the given magnetic materials. It is shown that the dynamical properties of these materials follow from the precessional and longitudinal movements of magnetization, the longitudinal susceptibility, and the interaction between the ordered magnetic subsystem and the dipole subsystems. Attention has been focused on the results of studies of magnetic substances in the vicinity of orientational phase transitions. The review also covers the main ideas of the theory that allows for all the above-mentioned interactions. At present this theory qualitatively (and sometimes quantitatively) explains the experimentally observed behavior of the gap in the spectra of the quasispin branches near spontaneous orientational phase transitions and also in the vicinity of orientational phase transitions induced by a magnetic field.

Alloys with shape memory and the phase transitions that occur in them always arouse much interest among researchers. V V Koledov (Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, Moscow) reported on the results of studies of phase transitions in magnetic materials with shape memory placed in strong magnetic fields. Such research is especially important in connection with the search for materials whose shape and size can be controlled by external magnetic fields. Koledov and his coworkers demonstrated the results of the effect of strong magnetic fields (up to 12 T) on a structural phase transition and the existence of a reversible structural phase transition in the magnetic field at constant temperature and pressure in Heusler alloys $Ni_{2+x}Mn_{1-x}Ga$.

Lately a new class of magnetic substances, manganites, have attracted much attention of researchers. Naturally, there were several reports at the conference in which the properties of these interesting objects were discussed. K I Kugel' (Institute of Theoretical and Applied Electrodynamics, Moscow, Russian Federation) pointed out the special role that charge ordering of the ions Mn^{3+} and Mn^{4+} play in the formation of many properties of the manganites $R_{1-x}A_xMnO_3$ (R = La, Pr, Nd; A = Ca, and Sr), $R_{2-x}A_xMnO_4$, and $R_{2-2x}A_{1+2x}Mn_2O_7$. It was stressed that the simultaneous coexistence and competition of spin, charge, and orbital ordering determines the extremely complex shape of the diagrams for manganites. The fact that the strong spin – charge – lattice coupling plays an important role in the formation of properties of manganites was demonstrated by K I Kamilov (M V Lomonosov Moscow State University, Russian Federation), who used the praseodymium manganites as an example. He presented experimental data obtained through studies of the properties of these manganites as functions of the temperature and strong pulsed magnetic fields.

Partially substituted manganites with a perovskite structure persist in commanding attention. The interest stems from the new and unusual physical properties (huge magnetoresistance, structural and magnetic phase transitions induced by a magnetic field, polar ordering, etc.) and the fact that there are numerous interpretations and explanations of these phenomena. In view of all this, the reported given A B Batdalov (Physics Institute of the Daghestan Science Center, Makhachkala, Russian Federation) was listened to with great attention. He presented the results of measurements of the magnetic-field and temperature dependence of the specific heat, thermal conductivity, and electrical resistance of the manganite $Sm_{0.55}Sr_{0.45}MnO_3$. It was shown that the temperature dependence of the measured quantities exhibits hysteresis loops caused by changes in T_C induced by changes in the lattice parameters that occur in a structural phase transition.

There were also many reports devoted to theoretical and experimental studies of phase transitions and critical phenomena occurring in liquids. Some of the speakers discussed the results of thermophysical studies conducted at the Physics Institute of the Daghestan Science Center of the Russian Academy of Sciences. The properties on which attention has been focused are the isochoric specific heat, *PVT*-properties, viscosity, thermal conductivity, and surface tension of complex liquid systems within a broad range of state parameters, including the critical region. The reports presented the results of studies of single-component, binary, and ternary stratified systems.

The report of G G Guseĭnov (Physics Institute of the Daghestan Science Center, Makhachkala, Russian Federation) touched on the problems of studying phase transitions and critical phenomena in microporous media. Such media are convenient objects for investigating the effect of finite dimensions of the systems on phase transitions and critical phenomena. The speaker presented interesting results of his studies of thermal conductivity of carbon dioxide in the critical region in microporous glass with the pore sizes being 16 μm and 160 μm under different pressures. In particular, it was demonstrated that the peak in thermal conductivity becomes smaller and is shifted towards lower temperatures in comparison to that for pure carbon dioxide. Such behavior can be explained by size effects. In a discussion that followed it was noted that quantitatively analyzing the influence of size effects on the critical properties demand new investigations to be carried out in this area of research; also stable porous samples of 10-nm to 1-μm in size and extra pure substances are needed.

The results of studies of critical phenomena in liquids suggest that extensive research in the field of higher-order critical phenomena (the higher-order critical point, the double critical point, and the tricritical point) in complex liquid systems continues.

In the course of the discussion it was noted that the problem of determining the region in which the classical equation is still valid and finding the region of crossover from nonclassical critical behavior to classical van der Waals behavior in complex thermodynamic systems has yet to be solved.

The report of A M Askhabov, in which he formulated his idea about self-organization of the condensed state of matter, merits special attention. According to this idea, not only separate atoms and molecules or small aggregates of such entities play an important role in structure formation, but so do fairly large atomic aggregates, or nanosized clusters. According to Askhabov's theory, the main building blocks in the growth of crystals are special clusters, or 'quatarons' (the term was invented by Askhabov), which are spherically shaped and form in a nonactivation manner in an oversaturated medium. Quatarons and fullerenes are the main forms of structural organization of matter at the nanometer level. Here the initial form is a quataron, while a fullerene is an inevitable consequence of the saturation of the chemical bonds between the atoms that form the quataron. Askhabov has been developing this idea for several years. At the end of the report session he presented an interesting table that lists and compares the characteristic properties of quatarons and the crystalline state of matter.

What distinguishes these conferences is the great number of young researchers involved, largely graduate students (Physics Institute of the Daghestan Science Center of the Russian Academy of Sciences, Daghestan State University, Bashkir State University, Daghestan State Teachers' Training University, Omsk State University, L V Kirenskiĭ Physics Institute of the Siberian Branch of the Russian Academy of Sciences, and other institutions). As noted by many participants (e.g. Yu A Izyumov and V G Shavrov), the situation with the influx of promising young scientists into science is much better in the small towns and they have no real desire to go abroad to do research. The atmosphere and conditions at the conference were organized in such a way that the young scientists always had the opportunity for close association with eminent researchers. This is conducive to raising the interest of young talents in science and to keeping them there.

The present small review of some of the reports delivered at the conference and workshop gives an idea of the main topic and the problems discussed at these scientific get-togethers.

The conference and workshop program was carried out to the letter. Analyzing the 'end product' of the conference and workshop, we would like to note that notwithstanding the poor financing of basic research in Russia there were many results in practically all areas of the physics of phase transitions and critical phenomena that meet world standards. Several areas are being actively researched, and the influx of young talent into sciences has not stopped. The interesting cultural program proposed by the organizational committee included, among other things, a visit to ancient Derbent, recreation in the mountains, and a visit to the Gedzhukhskiĭ winery center with a tasting of wines.