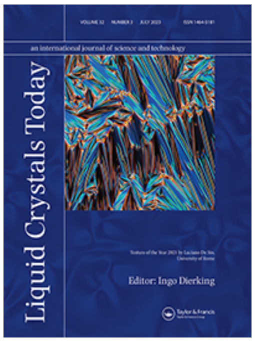

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Professor Sergey Alekseevich Pikin (1941 – 2024)

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Professor Sergey Alekseevich Pikin (1941 – 2024)

Sergey Pikin, an outstanding theoretical physicist, passed away on 12 January 2024 in Moscow at the age of 82. Professor Pikin has made significant contributions to several key areas of condensed matter physics. These include the fundamental theory of phase transitions, especially in ferromagnetics and ferroelectrics. However, he has spent most of his long career developing the theory of liquid crystals (LCs), in particular, structural phase transitions, electro-hydrodynamics and orientational turbulence, thermodynamics, and the description of modulated, chiral and polar states in LCs, including the flexoelectric effect. Sergey Pikin was much respected by his scientific peers and students. His death was a great loss for those of us, who were privileged to know him as a bright scientist and a trusted adviser. He will be sorely missed by the scientific community, his colleagues and friends.

Sergey Pikin was born on 8 April 1941 in Arkhangelsk (in the North of the former USSR) in the family of a military engineer. In 1964, he graduated from the Moscow Engineering Physics Institute (MEPhI), and in 1967 completed postgraduate studies at the Kurchatov Institute of Atomic Energy. His mentors were well-known theoretical physicists Valentin Vaks and Anatoly Larkin. With them, Sergey Pikin developed the self-consistent field method for describing phase transitions in crystals with a large interaction radius. The authors justified the applicability region for self-consistency, determined the correction to the mean-field approximation, and also developed a method for constructing the higher-order approximations [1].

Also, with Vaks and Larkin, Sergey Pikin has introduced a diagram technique for calculating the systems of interacting spins. Using this method, which is a series of successive approximations to the self-consistent limit, the thermodynamics of a Heisenberg ferromagnet was obtained across the whole range of temperatures and magnetic fields [2]. In particular, spin waves and correlation functions in a Heisenberg ferromagnet below the transition point T_K were obtained, showing that for the long wavelengths the damping of spin waves is small for all $T < T_K$ [3,4]. This diagram method is now widely used in the studies of phase transitions in ferromagnets and ferroelectrics.

Another lasting legacy is their work with Larkin entitled 'Phase transitions of the first order but nearly of the second' [5], which has introduced the concept of 'weak first order' transitions widely used in condensed matter physics today, and even cited in the Landau and Lifshitz 'Statistical Physics' textbook. The idea here is that a second-order phase transition would transform to a 'weak' first-order transition due to fluctuations interacting with the other degrees of freedom. In this pioneering work Larkin and Pikin demonstrated that if the compressibility and interaction with acoustic phonons are allowed, then coupling to these is one example leading to a weak first order transition. In 1968, Sergey Pikin received his PhD degree on phase transitions in ferromagnets.

Since December 1967, and for the rest of his career, Sergey Pikin worked at the Institute of Crystallography of the USSR Academy of Sciences, where he rose from junior to chief researcher, and then to the deputy director for research (1990–2003). It was at the Institute of Crystallography that Sergey found his love, Galina, who became his wife, muse and friend for the rest of his life, Figure 1. Sergey Pikin was not only deeply and passionately interested in science; he loved life in all its appearances, his family, friends and art. Sergey wrote poetry (publishing a collection called '*Romantic Landscape*' in 2001, painted in aquarel and graphics, and always brought classical music records from his business trips. A graphic portrait of his wife Galina, drawn by him, hangs in his house, Figure 2.

From the daughters, Anna and Elena, memoir: "Mummy, Galina, was a very determined person. Like Sergey, she was a theoretical physicist, graduated from Moscow State University and went to postgraduate school at the Institute of Crystallography, where she received her PhD degree.

Clever and beautiful, she combined her scientific work with taking care of her family. If something seemed important, there were no obstacles for her. One summer Daddy was on a business trip during our holidays. At that time we intended to go to the mountains at Arkhyz (North Caucasus) resort. Mummy did not hesitate to come with us and was climbing the mountains along with the youngsters. Our country plot was about one hundred fifty km at the south from Moscow, and our mother took care of it, growing pines, cherries, sea-

Figure 1. Galina and Sergey Pikin, 1967, Moscow.

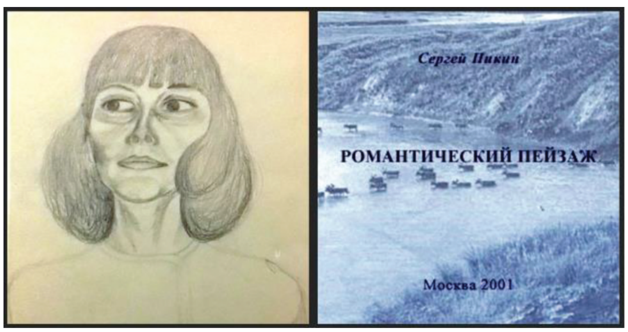

Figure 2. Art pieces.

Figure 3. Galina and Sergey Pikin, 1996, Paris.

buckthorn there. At her request, Daddy ordered apple and plum saplings, and we took care of the young trees. Now we have a wonderful garden at the dacha, which pleases us with apple harvests and in the shade of which we relax in hot summers.

Being a person of science, our mother continuously learnt new skills: she learned to bake delicious pies, sew clothes, and grew berries. She loved music, painting and theatre, and passed this love on to us. There were times when the whole family stood in a queue for hours to get to the next art exhibition. However, this time was spent in communication, so it was not a burden. The whole

Figure 4. Sergey Pikin, Germany, 1999.

family went to theatres from the Moscow Art Academy Theatre to the Studio Theatre in the South-West, and then discussed what we had seen. Mummy filled the life of our family with optimism and inspiration. For Daddy, she was both a muse and a real support, allowing him to go to work and make an excellent job without being distracted by everyday life", Figure 3.

A special place in Sergey Pikin's soul was occupied by his friends. The strong and touching friendship with people whom Sergey met in his first year at MEPhI, he carried through his whole life, through all its difficult and joyful twists and turns. Being students, they liked to travel on holidays, to go camping. And here during one of such treks on Elbrus mountain in the North Caucasus Sergey fell into an ice crack (which the instructor did not know about), and hung on a mountain ice-pick, which lay across the crack. And while the terrified instructor and his friends were gathering the necessary equipment to pull him out – ropes etc., Sergey, who was hanging in the crack on the ice-pick, was cheering them up and joking. And so, he did throughout his life, cheering up friends, colleagues and relatives in the difficult moments of life.

The beginning of Pikin career at the Institute of Crystallography coincided with a rapid explosion in the physics of liquid crystals, which until then represented only a niche field. For many years, modulated structures in dissipative anisotropic media, which liquid crystals happen to be, became the main scientific focus of Sergey Pikin. Periodic perturbations of orientational ordering in LCs mainly arise due to electrohydrodynamic (EHD) and flexoelectric effects. In the first half of the 1970s, Pikin built a rigorous theory of EHD instabilities in nematic LCs. It was known that a flow of ionic current through the LC layer containing spatially distributed charges leads to a fluid flow accompanied by periodic distortions of the director distribution field.

The threshold of the EHD instability arising under the static electric field was first estimated by Carr (1967) and Helfrich (1969). The rigorous theory of the low-frequency EHD instability in nematic LCs was developed by Pikin and Shtol'berg [6,7] and, independently, by Penz and Ford (1972). The essence of this phenomenon is that the nematic fluid with the spatially distributed charges loses its mechanical equilibrium in an electric filed, and the macroscopic motion arises. Later, Pikin with colleagues developed the theory of the azimuthal EHD instability which can be realised under special boundary conditions. In this model, the director is tilted by a small angle in a plane perpendicular to the cell plane. This changed the topology of orientational modulation in the cell from one-dimensional to two-dimensional [8–10]. Further, he developed the theoretical approach to account for the nonlinear effects in the EHD instability in the nematic LCs by formulating the general theory of the orientational turbulence in nematic LCs under an electric field [11,12]. These studies stimulated extensive theoretical and experimental research on analogous nonlinear phenomena in LCs [13–15]. The predictions of these works turned out to be in good agreement with experiment, defining the choice of optimal compositions and operation modes of the first electro-optical devices created at the time, which utilised the effect of dynamic light scattering in nematic LCs. An epoch later, at the age of 80, Sergey Pikin followed those ideas proposing new dynamic charged structures in nematics with negative anisotropy of electroconductivity in oscillating electric fields [16]

Sergey Pikin successfully collaborated with many colleagues and research centres in France, Italy and Germany. One of the first examples of such a productive cooperation came from his acquaintance with Maurice Kleman in Paris at the beginning of 1970s. At that time, the Orsay Group on Liquid Crystals, which included the most famous and talented scientists in the field of LCs, was working in Paris. Besides Sergey Pikin, almost all of them were fascinated by the study of instabilities of different types in nematic LCs. Kleman's group, of course, was no exception. Particularly, Pikin and Kleman were interested in the azimuthal instability of Couette flow of nematic, which resulted in their joint theoretical paper [10]. Separately, George Ryschenkow and W. Urbach from Kleman's group experimentally observed this phenomenon, confirming the predictions of the theory [9]. Thanks to Maurice Kleman, Sergey Pikin met many scientists, in particular Elisabeth Dubois-Violet, Franc̨oise Brochard, Pavel Pieranski, Etienne Guyon and many others. With a number of them, joint work was done and common articles were published [17].

About the same time, Sergey Pikin, together with his student Yuri Bobylev, started working on the theory of flexoelectric instabilities in nematic LCs [18]. Flexoelectricity is a phenomenon similar to piezoelectricity (when polarisation is induced by mechanical deformation, or vice versa), except in flexoelectricity the gradient of deformation causes the dielectric response – because of the different symmetry, flexoelectricity occurs even in centrosymmetric phases, including nematic and smectic LCs. In the inverse flexoelectric effect, an external electric field generates periodic perturbations of orientational ordering in LCs, and if boundary conditions are involved – electric field needs to exceed threshold values. When observed between crossed polarisers, this manifests itself in the form of periodic stripes (domains) directed along the initial direction of the nematic director. It was shown that, in addition to the relation between dielectric anisotropy and the difference of the flexoelectric coefficients, the important condition for these effects is the relation between the specific electrical conductivity of the LC and the thickness of the cell. These flexoelectricity studies have become classical and have received full experimental confirmation, and remain relevant to date, defining the active direction of research for decades to come [19–23]. The theory of the flexoelectric effect was carried out in a close collaboration with experimental colleagues well-known in the broad LC community – Lev Blinov, Mikhail Barnik, Boris Umansky and Sergey Yablonsky.

Based on the results of these studies, Sergey Pikin received his Habilitation and later became Professor in Solid State Physics. In 1981, the Moscow publisher 'Nauka' published the monograph 'Structural Transformations in Liquid Crystals', which was the first systematic theoretical description of orientational instabilities, electro-hydrodynamics, modulated, chiral and polar states in LCs. This book was later translated into English and published by Wiley [24]. The results of LC research of this period were recognised by the awarding to Prof. Pikin in 1985 as the author's team member of the USSR State Prize, with the citation ' … for the series of fundamental studies of photorefractive and liquid crystals for optical information-processing systems'.

Utilising his fundamental knowledge of structural phase transitions, jointly with Vladimir Indenbom, Pikin developed the phenomenological theory of phase transitions and polar properties of chiral smectics C (C*) liquid crystals, which leads to their ferroelectric properties [25].

The chirality of smectic C* molecules leads to the formation of helical structures, which plays a key role in producing ferrooelectric polarisation, but also allows an additional contribution to the spontaneous polarisation due to the flexoelectric effect [25–28]. The theory has obtained the dielectric permittivity of the helical smectic C*, both of the Goldstone mode associated with the partial helix unwinding and of the 'soft' mode corresponding to a synchronous change of polarisation and tilt angle of molecules in the smectic layers [25,27,28]. Later, Sergey Pikin with Mikhail Osipov have also developed the microscopic statistical theory of ferroelectricity in smectic C*, the approach which was the beginning of another important series of statistical-mechanical models in liquid crystals and beyond [29]. The new results clarifying the microscopic origin of the polarisation in the C* phase showed that the partial ordering of the short molecular axes was the key to this physics [30]. Experimental studies carried out by Boris Ostrovskii, Lev Blinov, Leonid Beresnev, and Evgeny Pozhidaev have confirmed the theory and laid the foundation for new LC applications based on ferroelectric response.

Over the years, Prof. Pikin with many colleagues have worked on a variety of topics and problems in the field of LCs. Of particular note is the nonlinear kink-switching model for repolarisation processes in ferroelectric LC thin films [26,31,32] and study of mono- and bistabilty in ferroelectric LC cells [33]. Sergey Pikin has collaborated with many experimental groups and generously shared his theoretical insights. For more than a decade, he was inspiring various experimental studies in the group lead by Wolfgang Haase at Darmstadt University of Technology in Germany. For example, Sergey Pikin proposed to interpret complex relaxation processes in certain ferroelectric LCs in terms of domain modes [34], and explained sophisticated observed sequences of antiferro- and ferroelectric mesophases in new LC materials in a relatively simple way as a competition of different short-pitch helicoidal modes [35]. During these years Sergey Pikin and Wolfgang Haase became good friends. They have travelled together throughout the whole south Germany and Wolfgang has shown Sergey a lot of hidden architectural gems. W. Haase has started one of his talks at a European Conference with the following words: the experimental work has been undertaken by Beresnev under the guidence of Pikin and Blinov, and S. Pikin has explained the results. And I (W. Haase) have the privilege to present the work.

Long-lasting relations have developed with the group of Lev Blinov, and also with Vladimir Chigrinov on various aspects of LC display applications. In later years, this collaboration led to an extended visit to Vladimir Chigrinov, then at University of Science and Technology in Hong Kong, where they worked on a diffusion model of photo-induced director orientation [36]. This model explained the particulars of photoalignment technology in liquid crystal devices, which is now widely used in practice to create so-called 'command surfaces' used to manipulate the orientation of LC molecules in a cell and constitute the basis of the modern LCD TV technology.

In the 21st century, new scientific directions were emerging at the intersection of physics, chemistry and biology. Naturally, Prof. Pikin could not resist throwing himself onto one such problem, that of molecular motors which play a fundamental role in the cellular vital activity. He proposed a physical description of chiral rotary molecular motors, where the fundamental relationships between the dynamic characteristics of the motors and their basic macroscopic parameters were established [37]. He also demonstrated the role of molecular chirality in cellular processes. Later, with Eugeny Loginov, Pikin developed a simple statistical approach to the Boyer model of the molecular motor ATPase, using the Fokker–Planck equation approach [38]. Using the kinetic equations within his earlier model of chiral kink movement under the transverse electric field, Pikin proposed a model of the type-II enzyme–DNA complex motion along the DNA chain [39]. Sergey Pikin also developed the comparative physical description for the functioning of various restriction enzymes and for their role in DNA cleavage [40]. In another work of that period, studying DNA motion under the action of enzymes of different types, he had shown that the structure and function of the enzymes is similar to those in chiral smectic C-type LCs, and thus can be described within the formalism of the generalised forces and currents [41]. It is a bit mysterious that one of Pikin's early PhD students, Eugene Terentjev, who is a Professor in Cambridge, has followed a different 'trajectory' starting from LCs, but later also focused on rotary molecular motors and the role of helices in their operation (Sci. Rep., 2016, 2020). Separately, Sergey Pikin has made an interesting study of the structure of the solid core of Earth, undergoing the phase transition between its solid and liquid components, offering his unique vision of this problem [42].

More recently Prof. Pikin 'discovered' the world of multiferroics and other exotic magnetic crystals and, utilising his deep understanding of magnetic phase transitions and crystallography, proposed several non-trivial concepts in this rapidly developing field. These unusual materials are of interest due to coexistence of magnetism and ferroelectricity. In certain perovskite-type crystals, a helical spin structure and the weak ferromagnetism can coexist. Pikin offered a phenomenological explanation of the thermodynamic state of perovskite-type crystals, accounting for the temperature dependence of spontaneous polarisation and sublattice magnetisation. The application of an AC electric field causes a linear change in the magnetic moment, opposite to the change of the electric field. This effect has been observed experimentally in some perovskite crystals, and developing this theory to explain the phenomenon has earned Sergey Pikin and Igor Lyubutin the Shubnikov Prize of the Crystallography Institute (Moscow) in 2014 [43–45].

For many years (1998–2016), Prof. Pikin was the Head of the Department of Theoretical Studies of the Institute of Crystallography, following Prof. Indenbom in this post. The Department has developed a powerful team of theorists carrying out excellent work in various fields of modern condensed matter physics. He has brought up generations of PhDs, many of whom have achieved great success in their chosen fields of science and occupy prominent positions at universities in Russia and around the world. Sergey Pikin was a wonderful mentor. Colleagues and students frequently approached him with their scientific questions, and simply for advice. He always carefully listened to them, politely and tactfully formulated his understanding of the problems and ways to address them. He never imposed his point of view, but rather offered to think and reflected on the essence of the problem.

Prof. Pikin is the author of more than 200 scientific papers, including six monographs. He was a member of the editorial boards of 'Crystallography Reports' and 'Molecular Crystals and Liquid Crystals'. In 1999, Sergey Pikin was awarded the Humboldt Prize (Germany) for his work in the field of liquid crystals, Figure 4 Prof. Pikin was also honoured with the Freedericks Medal for outstanding contributions in the field of liquid crystal physics, which he was one of the first to receive.

Sergey Pikin possessed remarkable human qualities, combining wisdom and integrity, modesty and genuine intelligence. Beyond his professional achievements, Prof. Pikin was a kind and supportive mentor who took his time to guide and encourage those around him. His daughters, Anna and Elena, and grandson Nicholas should be rightly proud of his memory. He will be missed by all of us. The impact of Sergey Pikin's life and work will continue to resonate with us and the broader scientific community.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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