Dimensional Crossover in Critical Behavior of Thin XY-films: Equilibrium and Non-equilibrium Properties

I.S. Popov, A.P. Popova, P.V. Prudnikov

Dostoevsky Omsk State University, Omsk, Russia

The study of non-equilibrium critical behavior causes considerable fundamental and applied scientific interest. In recent years, particular interest is the study of quasi-two-dimensional systems [1], in particular, the question of the dimensional crossover in the transition from two-dimensional systems to three-dimensional [2]. In the two-dimensional XY model, the long-range order is destroyed by transverse fluctuations of the spin density at all nonzero temperatures [3]. However, this system has a topological Berezinskii-Kosterlitz-Thouless transition at $T = T_{BKT}$ and there is Berezinskii low-temperature phase $T < T_{BKT}$, where all temperatures T are critical points. There is a continuous set of fixed points of the renormalization-group transformation for the two-dimensional case and quasi-long-rage order (QLRO) is presented in system. On the other hand, the critical behavior of the three-dimensional XY-model in vicinity of T_C is described by the fixed point of «ferromagnetic-paramagnetic» phase transition and classical long-range order (LRO) is presented at $T < T_C$ [4].

The present paper presents a studying of the Kosterlitz–Thouless transition in thin films, and we gives an answer of how disappear phenomena which associated with the topological phase when films thickness N is increased. We determined the dependence of the phase transition temperature $T_{BKT}(p)$ as a function of the N. We obtained that in limit $N \to \infty$ the temperature T_{BKT} tends to T_C of three-dimensional XY-model. The obtained dimensional dependencies are in good agreement with the previous theoretical results [4].

We shown that, the spin stiffness $\rho_S(T)$ gradually decreases at the T_{BKT} from the value $\rho_S(T_{BKT}) = 2T_{BKT}/\pi$ ($N = 1$) to the value $\rho_S(T_{BKT}) = 0$ for $N \to \infty$. We revealed that a quantity $\rho_S(T_{BKT})/T_{BKT}$ has a power dependence $N^{-\sigma}$, where $\sigma = 0.875(24)$.

It was investigated the dynamical dependencies of magnetization $m(t)$ and its dispersion $D_m(t)$, second and fourth order cumulants $U_2(t)$ и $U_4(t)$ of magnetization for non-equilibrium relaxation of the system from the high-temperature and low-temperature initial states. We show dimensional crossover from the dynamic scaling dependencies of the two-dimensional XY-model to the classical dependencies of the three-dimensional system.

The reported study was supported by RFBR according to the research projects № 17-02-00279, 18-42-550003, 18-32-00814 and grants MD-6868.2018.2, МК-4349.2018.2 of the President of the Russia. The simulations were supported in through computational resources provided by the Shared Facility Center “Data Center of FEB RAS” (Khabarovsk), by the Supercomputing Center of Lomonosov Moscow State University, by Moscow Joint Supercomputer Center and by St. Petersburg Supercomputer Center of the Russian Academy of Sciences.

1. *V.V. Prudnikov, P.V. Prudnikov, and M.V.ºMamonova*, Phys. Usp. **60**, 762 (2017).
2. *P.V. Prudnikov, V.V. Prudnikov, M.A. Menshikova, et al.*, J. Magn. Magn. Mater. **387**, 77 (2015).
3. *S.E. Korshunov*, Phys. Usp., **49,** 225 (2006).
4. *M. Hasenbusch*, J. Stat. Mech., P02005 (2009).