Dynamical Scaling in Time dependence of Correlation Length in Non-equilibrium Critical Relaxation of Pure and Site-diluted 2D XY-model

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A two-dimensional systems with continuous symmetry occupy a special place among low-dimensional systems. It is known that the long-range order is broken in these systems at any finite temperature. However, the case of the 2D XY-model is characterized by realization of topological Berezinskii–Kosterlitz–Thouless (BKT) phase transition at temperature T_{BKT}. The 2D XY model is used to describe the behavior and the properties of a whole class of physical systems, in particular, ultrathin magnetic films and planar magnets with easy-plane anisotropy [1]. Despite extensive research [2], the influence of structural disorder on non-equilibrium critical phenomena in the 2D XY-model not finally resolved. The influence of structural defects on the dynamic dependencies of the correlation length $\xi(t)$ is not investigated. Dynamic dependencies of physical quantities in critical dynamics have scaling properties, where the correlation length $\xi(t)$ is of paramount importance.

Non-equilibrium critical behavior in the structurally disordered 2D XY-model is attributed to non-equilibrium processes in the vortex subsystem, spin-wave processes, and interaction of these subsystems with structural defects. These effects lead to a significant complication of the dynamic properties of the system. In particular, the aging effects in disordered 2D XY-model are transformed into subaging and superaging phenomena [3].

The present work is devoted to study of the dynamic and scaling dependence of the correlation length $\xi(t)$, second and fourth order cumulants $U_2(t)$ and $U_4(t)$, and two-time dependent autocorrelation function $C(t, t_w)$ for pure and site-diluted 2D XY-model with different spin concentrations p. We have shown that in a pure system scaling dependencies are satisfied with $\xi(t) \sim t^{1/2}$ for relaxation from low-temperature initial state and with $\xi(t) \sim (t/\ln t)^{1/2}$ for relaxation from high-temperature initial state, which correspond to the existing concepts about the dynamics of $\xi(t)$ in pure 2D XY-model [4]. However, the presence of structural disorder in system leads to a complication of the dynamic scaling dependencies of directly calculated $\xi(t)$ and cumulants $U_2(t)$ and $U_4(t)$. Dynamical scaling with $\xi(t) \sim t^{1/2}$ and $\xi(t) \sim (t/\ln t)^{1/2}$ [4] is violated, and collapse of dynamical scaling dependencies on $\xi(t)/L$ for systems with various linear sizes L is not observed in the entire low-temperature phase with $T < T_{BKT}(p)$. However, implementation of dynamical scaling dependencies on $\xi(t)/L$ takes place at $T = T_{BKT}(p)$ as in pure system. These features of the scaling dependencies were revealed for relaxation from both high-temperature and low-temperature initial states. We connect these dynamical features with the pinning of bound vortex-antivortex pairs by structural defects existing at $T < T_{BKT}(p)$.

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