Ageing and memory effects in non-equilibrium critical behavior of 3D diluted Ising model with low-temperature initial state

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The macroscopic systems show abnormally slow dynamics near second phase transition critical point T_c In the vicinity of T_c the relaxation time diverges as $t_{rel} \sim |T - T_c|^{-z\nu}$ with $T \to T_c$, where z - dynamic critical exponent and ν - correlation length exponent. Therefore statistical system quenched to exact critical point does not achieve equilibrium state during full relaxation process. Near T_c a system demonstrates several interesting effects such as ageing and memory phenomena, and violation of the fluctuation-dissipation theorem (FDT) [1, 2]. The ageing is shown at the times $t \ll t_{rel}$ only and appears in two times dependency of the correlation and the response functions. There are 2 significant times exists: observation time t and waiting time t_w. The last one is the time between preparation of a system and the moment of beginning calculate an observable like autocorrelation function, also known as *system age*. During none-equilibrium time evolution the ageing shows up in slowing down of system relaxation with waiting time increasing and demonstrates different none-ergodic effects such as the memory about initial and any middle states while $t, t_w \ll t_{rel}$ and violation of FDT [3].

There are two initial states of a system exists in order to investigate its influence on critical behaviour. The first is *high temperature* initial state when a system was prepared with $T_0 > T_c$ before being quenched and the magnetization equals to zero $m_0 = 0$. The another is *low temperature* initial state with $T_0 < T_c$ and $m_0 \neq 0$. After preparation the system are placed to the thermostat with $T = T_c$ and time evolution starts. At the time t_w we have begun the measuring of two-time autocorrelation and response functions during regime $1 \ll t, t_w \ll t_{rel}$. At the moment the none-equilibrium relaxation for different statistical systems are better investigated for the case of high temperature initial state (look at review [2]). In the work [4] it was carried out numerical Monte-Carlo investigation of disorder influence on three dimensional Ising model relaxation prepared in high temperature initial state. The ageing was observed and the asymptotic fluctuation-dissipation ration X^∞ were calculated for systems with different spin concentrations. At the same time the relaxation from low temperature initial state is much less studied now.

We have performed the numerical investigation of the influence of disorder on dynamical non-equilibrium evolution of 3D site-diluted Ising model from low-temperature initial state with the magnetization $m_0 = 1$. It is shown that two-time dependencies of the autocorrelation and integrated response functions for systems with spin concentrations $p = 1.0$; 0.95; 0.8; 0.6 and 0.5 demonstrate ageing properties with anomalous slowing-down relaxation and violation of the fluctuation-dissipation ratio. It was revealed that during non-equilibrium critical dynamics in long-time regime $t - t_w >> t_w >> 1$ the autocorrelation functions for diluted systems are extremely slow due to pinning of domain walls on impurity sites. The autocorrelation function power-law delay becomes the same as for time dependence of the magnetization in the critical point and is characterized by exponent $(-\beta/z\nu)$. We have found that the asymptotic fluctuation-dissipation ratio $X^\infty = 0$ for diluted systems with spin concentration $p < 1$ while the pure system is characterized by $X^\infty = 0.784(7)$. Also we have investigated memory effects in disordered systems with cyclic their quenched to $T < T_c$ during ageing regime of critical relaxation.

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Referencies

1. Henkel M., Pleimling M. Non-Equilibrium Phase Transitions, Volume 2: Ageing and Dynamical Scaling far from Equilibrium (Theoretical and Mathematical Physics) // Springer, Heidelberg, 2010, p. 544.
2. Calabrese P., Gambassi A.. Ageing properties of critical systems // J. Phys. A., 2005, **38**.
3. Bochkov G.N., Kuzovlev Yu.E. Fluctuation-dissipation relations: achievements and misunderstandings // Phys. Usp., 2013, **56**, p. 590.
4. Prudnikov V.V., Prudnikov P.V., Pospelov E.A., Vakilov A.N. Influence of disorder on critical ageing in 3D Ising model // Phys. Lett. A, 2015, **379**, 774.