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Quasi-steady state descriptions for photo-doped Mott insulators

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Doping charge carriers into Mott insulators provides a pathway to produce intriguing emergent phenomena [1]. In equilibrium systems, doping can be chemically controlled. On the other hand, photo-doping, where particles are excited across the Mott gap, provides an alternative way. Compared to chemical-doping, photo-doping creates a wider variety of charge carriers, which may lead to the emergence of fascinating nonequilibrium states. In particular, when the gap is large, the lifetime of photo-carriers is exponentially enhanced, leading to quasi-steady states after intraband cooling of photo-carriers.

In this talk, we introduce two types of theoretical descriptions to systematically explore quasi-steady states of photo-doped Mott insulators [1]. The first approach is the so-called nonequilibrium steady state approach, where we approximate a photo-doped state as a nonequilibrium steady state stabilized by external baths. The second approach is the quasi-equilibrium approach, where we treat a photo-doped state as an equilibrium state of an effective model using the generalized Gibbs ensemble. In the first part, we explain the idea of these approaches and their relations, providing the overview of relevant works. In the second part, we discuss the concrete application of the quasi- equilibrium approach to the 1D extended Hubbard model [2,3]. Using numerical and analytical methods, we show the emergence of the so-called η -pairing phase and the string charge-density- wave phase in the photo-doped Mott insulators. In particular, we show that the wave function of photo-doped states in the large on-site interaction limit can be exactly expressed as $|\Psi\rangle = |\Psi_{\mathrm{charge}}\rangle|\Psi_{\mathrm{spin}}\rangle|\Psi_{\eta-\mathrm{spin}}\rangle$, which indicates the separation of spin, charge and η –spin degrees of freedoms. Here η –spin represents the type of the photo-carriers, i.e. doublons and holons. This state is analogous to the celebrated Ogata-Shiba state of the doped Hubbard model in equilibrium. The expression provides us useful insight into the origin and properties of the photo-doped states. Our results demonstrate that the emergent degrees of freedom activated by photo-doping can lead to intriguing quantum states absent in equilibrium.

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