Energy Relaxation Dynamics in Harper Model coupled with a Small Number of Phonon Modes

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Energy relaxation dynamics in Harper model coupled with small number of phonon modes is numerically investigated[1,2]. The time-dependent Shrödinger equation that we simulate is

\[-i\hbar \frac{\partial \Psi(n, \{q_j\}, t)}{\partial t} = \Psi(n + 1, \{q_j\}, t) + \Psi(n - 1, \{q_j\}, t) + \]

\[
\left\{ \sum_{j=1}^{M} \left( \frac{\hat{p}_j^2}{2} + \frac{\omega_j^2 \hat{q}_j^2}{2} \right) + \sum_{n=1}^{N} \sum_{j=1}^{M} b_j V(n) \hat{q}_j + V(n, t) \right\} \Psi(n, \{q_j\}, t), \quad (1)
\]

\[V(n, t) = V(n)(1 + \frac{\epsilon}{\sqrt{L}} \sum_{i=1}^{L} \cos(\Omega_i t + \theta_i)), \quad (2)\]

where the \(\Psi(n, \{q_j\}, t)\) represent the wave function of the whole system in a site basis. As a non-perturbed electronic system\((M = 0, L = 0)\), we use Harper model, i.e. \(V(n) = 2V_0 \cos(2\pi\alpha n)\), where the \(\alpha\) is inverse golden mean \((\alpha = \frac{\sqrt{5} - 1}{2})\). It is well-known that without the interaction with phonon modes, i.e. the Harper model, all eigenstates are localized when the potential strength \(V_0\) is larger than unity and are extended when \(V_0\) is smaller than unity. In the present simulation we set \(M = 0\) or \(1\) and/or \(L = 0\) or \(1\).

We initially prepare an electron in a highly excited state and the harmonic oscillator to the ground state of the Fock state, and compute the time-dependent electronic energy and the phononic energy by the time-dependent wave packet. Effect of the localization or randomness in the potential sequence \(V(n)\) on the energy transfer between the electron and the phonon mode is investigated, in comparing to periodic or disordered systems[1-5]. The coherent state representation of the phonon mode during the relaxation of the energy will be shown to confirm the process of the phase randomization[2].