Controlled quantum many-body dynamics: nonlinearity, reversibility, complexity

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The control of quantum states is an important building block for fundamental investigations and technological applications of quantum physics. However, quantum many-body systems exhibit complex behaviors that make them difficult to manipulate, in particular in the presence of intrinsic dephasing, decoherence or decay. One strategy to control such quantum states is to implement operations faster than the characteristic timescales of the prejudicial processes, using for example optimal control theory (OCT). The speedup can be exploited to experimentally realize elaborate manipulations, for instance precisely controlled ultra-fast single electron spin gates using specially designed microwave fields [1] or a sequence of state transfer pulses for interferometry [2].

The maximum achievable speedup is influenced non-trivially by inter-particle interactions, but their effect can be compensated for if many-body nonlinearity is properly taken into account (see Fig. 1).

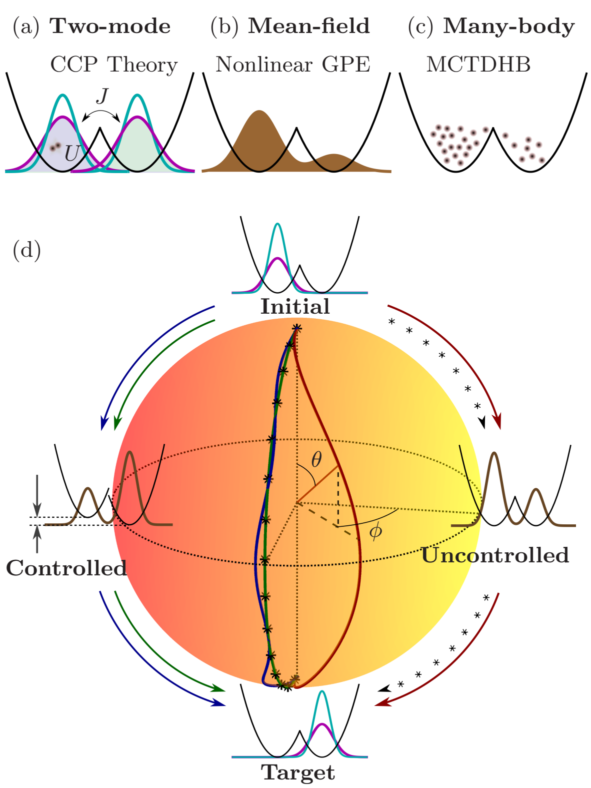

Figure 1: Effect of nonlinearity on the optimal dynamics of a Bosonic Josephson Junction [3].

Reversibility of quantum dynamics can also be attained experimentally via optimal control [4]. The bandwidth of the corresponding control pulses allows for a characterization of quantum many-body processes [5], and for dynamical discrimination between different level of complexity in quantum many-body systems.

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