

Simulation and control of complex quantum systems

Simone Montangero^{1,*}

¹*Institute for complex quantum systems & IQST, Ulm University
Albert-Einstein-Allee 11, 89075 Ulm, Germany.*

The numerical simulation of strongly correlated quantum systems is a major challenge in different branches of modern physics as condensed matter, quantum information, cold atoms and lattice gauge theories. Indeed, numerical simulations lie at the hearth of our theoretical understanding of many different phenomena and of the support, design and verification of experimental setups ranging from single optical tables to large particle physics facilities. Optimal control techniques have been widely applied in different fields, as for example in Nuclear Magnetic Resonance, and have been recently extended to encompass many-body quantum systems dynamics paving the way to the design of novel experiments and to the optimal engineering of quantum- and nano-technologies. These tools, together with our increasing capability of performing efficient numerical simulations of many-body quantum systems, allow for the first time to explore at the quantum level the fundamental limits of the manipulation of many-body systems, in terms of (thermodynamical) resources (energy, time, information...) and complexity (system size, integrability...). Possible fields of applications of these investigations ranges from quantum information processing, to ultra-sensitive sensors, and optimal light-harvesting protocols.

We illustrate some recent developments in numerical tensor network methods to simulate strongly correlated quantum systems, present an efficient algorithm to optimally control their dynamics and some fundamental bounds to the resources needed to achieve such control. Finally, we report on novel theoretical and experimental applications of these methods, in particular we present some time-optimal protocols to drive cold atoms in optical lattices and in atom chips.

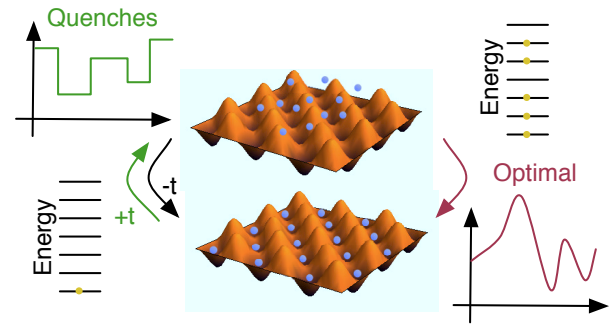


FIG. 1. Optimal control allows to engineer a route to reverse complex quantum many-body dynamics also when standard time-reversal procedure is not achievable.