Floquet engineering in isolated and open quantum systems

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Driving a quantum system out of equilibrium can provide a challenge for its theoretical description. However, it also offers the opportunity to control its state and properties beyond the strict constraints of thermal equilibrium. Of particular interest are time-periodically driven (aka Floquet) systems. Thanks to their discrete translation symmetry in time, they are described by a theoretical framework, known as Floquet theory, which preserves some of the structures known from the description of undriven quantum systems. For instance, Floquet systems possess quasi-stationary states, called Floquet states, with a periodic time-dependence and their stroboscopic evolution in steps of the driving period is described by an effective time-independent Hamiltonian. These properties can be used to understand their behavior, at least in certain limits, and to design schemes for controlling quantum systems via periodic driving. The latter is known as Floquet engineering.

In the first lecture, I will give an intuitive introduction to Floquet engineering in isolated systems, using the examples of a driven double well and the realization of artificial magnetic fields in a tight-binding lattice. I will, moreover, provide an introduction to basic concepts of quantum Floquet theory and discuss how driving-induced heating challenges Floquet engineering.

In my second lecture, I will then consider open Floquet systems, i.e. periodically driven systems in contact with a thermal bath. Focusing on the limit of ultraweak system-bath coupling, where we find the system to be described by a rate equation, I will argue that these systems generically approach non-equilibrium steady states (NESS). In contrast to equilibrium states, these NESS break detailed balance. This leads to the idea of dissipative Floquet engineering, where both drive and environment are used to engineer NESSs. I will illustrate this concept by discussing generalized non-equilibrium Bose condensation.

References:

[1] A. Eckardt and E. Anisimovas, *High-frequency approximation for periodically driven quantum systems from a Floquet-space perspective*, New J. Phys. **17**, 093039 (2015).

[2] A. Eckardt, Colloquium: *Atomic quantum gases in periodically driven optical lattices*, Rev. Mod. Phys. **89**, 011004 (2017).

[3] D. Vorberg, W. Wustmann, H. Schomerus, R. Ketzmerick, and A. Eckardt, *Non-equilibrium steady states of ideal bosonic and fermionic quantum gases*, Phys. Rev. E **92**, 062119 (2015).

[4] A. Schnell, L.-N. Wu, A. Widera, and A. Eckardt, *Floquet-heating-induced Bose condensation in a scar-like mode of an open driven optical-lattice system*, Phys. Rev. A **107**, L021301 (2023).