

Dynamics of many-body quantum synchronisation

Claire Davis-Tilley, Chen Teoh, and Andrew Armour

University of Nottingham, University Park, Nottingham, United Kingdom

The spontaneous synchronisation of limit-cycle oscillators is a fascinating example of a phase transition which occurs far from equilibrium. Limit-cycle oscillators have a non-zero average amplitude, but no preferred phase, and are extremely common in both the physical and biological sciences. Synchronisation has been studied in a wide range of classical systems as well as in systems such as lasers where semiclassical descriptions prove accurate. Over the last few years experiments have begun to investigate synchronisation in smaller-scale oscillator systems, including micron-sized mechanical oscillators and lasers operating in the few-photon regime. This has stimulated theorists to explore synchronisation in oscillators where a fully quantum mechanical description becomes essential. We analyse the properties of the synchronisation transition in a many-body system consisting of quantum van der Pol oscillators with all-to-all coupling using a self-consistent mean-field method. We find that the synchronised state, which the system can access for oscillator couplings above a critical value, is characterised not just by a lower phase uncertainty than the corresponding unsynchronised state, but also a higher number uncertainty. Just below the critical coupling the system can evolve to the unsynchronised steady state via a long-lived transient synchronised state. We investigate the way in which this transient state eventually decays and show that the critical scaling of its lifetime is consistent with a simple classical model.