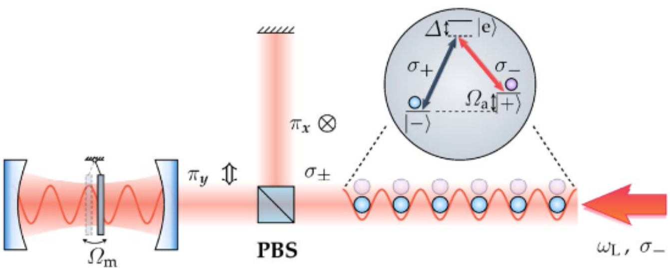
Nonequilibrium quantum phase transitions in hybrid atom-optomechanical systems

Michael Thorwart
I. Institut für Theoretische Physik, Universität Hamburg, Germany
michael.thorwart@physik.uni-hamburg.de

Hybrid quantum systems combine complementary fields of physics, such as condensed matter physics, quantum optics, and atomic physics, in one setup. One realization consists of a single mechanical mode of a nanomembrane which is placed inside an optical cavity and which is optically coupled to a far distant cloud of cold atoms residing in the optical potential of the out-coupled standing wave of the cavity light. This system shows fascinating effects, such as a nonequilibrium quantum phase transition at a critical atom-membrane interaction from a localized symmetric state of the atom cloud to a shifted symmetry-broken state [1]. The energy of the lowest collective excitation vanishes, and a strong atom-membrane entanglement arises. Also, internal atomic states can be involved in the hybrid coupling [2,3].

In these two talks, I will show how to describe such nonequilibrium hybrid quantum-many body systems theoretically, starting from their different constituents. An effective Hamiltonian to be derived will allow us to obtain generalized Gross-Pitaevskii equations. On the basis of generalized variational perturbation theory, we will be able to identify nonequilibrium quantum phase transitions and entanglement properties of the combined membrane-atom gas state [2,3]. A second part will involve also internal atomic states [2,3], such that the order of phase transition can be tuned.



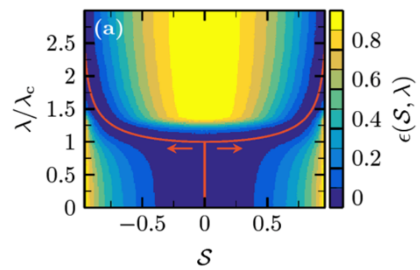


Figure: Left: Scheme of hybrid atom-optomechanical quantum system with internal atomic states. Right: Effective potential energy surface for varying control parameters, illustrating the location of the nonequilibrium quantum phase transition (red line).

References

[1] N. Mann, M. R. Bakhtiari, A. Pelster, and M. Thorwart, Phys. Rev. Lett. **120**, 063605 (2018).

[2] N. Mann and M. Thorwart, Phys. Rev. A **98**, 063804 (2018).

[3] N. Mann, A. Pelster, and M. Thorwart, New J. Phys. **21**, 113037 (2019).