

Quantum many-body physics of phonons and photons

Florian Marquardt

*Institute for Theoretical Physics II, University of Erlangen-Nuremberg, Staudtstr. 7,
91058 Erlangen, Germany*

During the past few years, the interaction of nanomechanical vibrations and light has seen rapid progress. A whole zoo of so-called “cavity optomechanical” systems have been developed. The light field has been exploited to measure the mechanical vibrations down to the limits allowed by quantum mechanics and to laser-cool this motion down to the quantum ground state.

In this talk I will explore the myriad opportunities that will arise when one designs structures made up of many coupled mechanical and optical modes. Such structures can be realized on the basis of “optomechanical crystals”, where one designs free-standing photonic crystals which can support localized vibrational and optical modes. If an array of such localized modes is implemented, the resulting “optomechanical array” can display interesting behaviour both in the classical and in the quantum regime.

I will discuss the physics of optomechanical arrays first in the regime of small vibrations, where a linearized approach to the dynamics is valid. In that case, one can investigate the “optomechanical bandstructure”, as well as quantum operations on localized modes using pulsed schemes. I will then move on to the nonlinear dynamics, where in the classical regime the physics of synchronization can be observed (and where first experiments now exist). Finally, I will discuss the nonlinear quantum regime, where we have predicted a synchronization transition due to the competition between quantum noise and hopping of photons and phonons.