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Designed Quantum States of Matter

GUEST LECTURE

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Leibniz Universität Hannover
DQ-mat Colloquium
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(via Zoom-Meeting)

"Measuring macroscopic motion at and beyond the Standard Quantum Limit"

Over the last 15 years, we have seen dramatic advances in the ability to measure and control the quantum state of nano- and micro-mechanical systems, by coupling them to light or microwaves. One goal of these efforts is to provide unique mechanical functionality to future quantum technologies, analogous to mechanical devices ubiquitous in today's technology.

In this talk, I will report on our experiments with extremely coherent mechanical resonators, namely membrane resonators visible to the bare eye, patterned into a phononic crystal shielding perturbations from the environment. Using optical interferometry, we monitor the motion of the membrane with attometer sensitivity. We also directly observe the quantum "back-action" of the measurement process on the measured object in the form of quantum fluctuations of radiation pressure. By trading off imprecision and back-action, we closely approach the standard quantum limit (SQL) in the sensitivity to mechanical displacement. We then use the information gained through the measurement to obtain pure mechanical quantum trajectories (conditioned the measurement record) and target quantum states (by applying feedback). Exploiting quantum correlations born in the measurement process, we can even overcome the SQL in displacement and force measurements. Based on the same underlying correlations, we evidence entanglement in the optical output modes of the system.

I will conclude with a short outlook on potential applications of this platform for nano-scale magnetic resonance imaging, and as a memory and transducer for quantum states of light and microwaves.

All DQ-mat members and all interested are cordially invited to attend.