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Optomechanics with squeezed light

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Abstract

Optical interferometry now allows for extreme displacement sensitivity, often only limited by quantum noise: quantum shot noise (QSN) and/or quantum radiation pressure noise (QRPN), a macroscopic version of quantum back-action [1]. This ultimately leads to the standard quantum limit (SQL), the smallest displacement observable for a mechanical resonator using standard laser sources (coherent states) [2]. The SQL has long been predicted but has so far eluded experimental demonstration, due to radiation-pressure effects being extremely weak for macroscopic mechanical resonators. However, both Advanced LIGO and Advanced Virgo [3] should within a couple of years be limited by QRPN at the lower side of their science frequency band and by QSN at the higher side. Thus, the SQL should be reached by these large-scale gravitational-wave detectors in the next few years. The SQL is also of particular interest to the field of optomechanics, with applications to novel sensing devices such as atomic force microscopes (AFM) or accelerometers. Therefore, any sensitivity enhancement beyond the SQL will have important applications.

The SQL can in-principle be overcome using squeezed light, a research topic that has also experienced considerable experimental progress. However, combining the optomechanical setups with squeezed light is still an experimental challenge. We plan to inject a squeezed bright beam into a dedicated table-top optomechanical system operated in a dilution fridge to investigate the SQL, and the methods to further increase the displacement sensitivity beyond the SQL. This requires frequency-dependent squeezing, which we will obtain by injecting the squeezed beam into a rotation cavity [4].

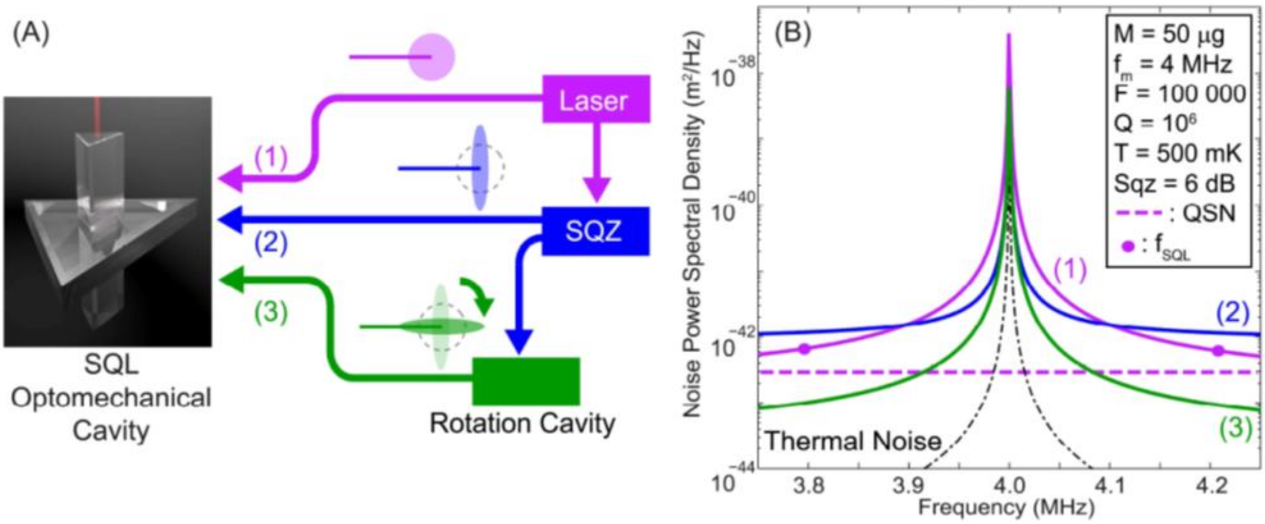

Figure: (A) Step-wise development of the project (1) - Operating a SQL optomechanical cavity (2) - Frequency-independent squeezing injection and (3) - Frequency-dependent squeezing injection. (B) Expected noise curves, with the same color code. Optomechanical resonator parameters are listed.

[1] T. Caniard et al. , *Phys. Rev. Lett.* **99**, 110801 (2007)
[2] C.M. Caves, *Phys. Rev. D* **23**, 1693 (1981)
[3] J. Assi et al., *Class. Quant. Grav.* **32**, 074001 (2015)
[4] P. Kwee et al., *Phys Rev D* **90**, 062006 (2014)