Marie Curie ITN cQOM
Summary of the Scientific Achievements

Name of Fellow: Mikhail Korobko
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Academic / Industrial Institution: University of Hamburg
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1. Description of research work

As part of the Marie Curie ITN cQOM project I was developing an optical Fabry-Perot cavity with a SiN membrane in the middle. The membrane motion couples to the light field in the cavity, causing the change in the phase of the light as well as in the amplitude. The goal is to achieve measurement precision at the Standard Quantum Limit. For that the dominating noise sources in the system should be the quantum radiation pressure noise driving the membrane motion, and the shot noise limiting the detection precision. The challenge is to measure the spectrum of the membrane motion touching the SQL at the frequency above the resonance of the fundamental mechanical mode. For that all classical noise sources should be significantly lower than the quantum noise. Thus it is essential to stabilize the power as well as frequency of the laser beam, isolate the optical cavity from acoustic vibrations and reduce the Brownian thermal motion of the membrane by placing it in the cryogenic environment.

As the detection of the spectrum is fully limited by the quantum noise the further increase in sensitivity can be achieved by the injection of the squeezed vacuum inside the optomechanical setup. Depending on the squeezing quadrature either back-action or shot-noise can be reduced, but also the correlation between them can be achieved thus allowing to dip below the SQL. We also investigate the second approach: producing the squeezing directly inside the optomechanical cavity by placing the nonlinear crystal in the cavity. This allows for a different type of correlation structure that can enhance the sensitivity further below the SQL or change the sensitivity-detection bandwidth product below the classically allowed limit.

2. Goals achieved and/or progress towards them

During my work on the project the team established the research aims and developed the experimental techniques that would be necessary to achieve them. We began installing a new dilution refrigerator unit in the laboratory, facing many issues during the installation process. We designed the quasi-monolithic optomechanical cavity and developed an alignment procedure. We also set up a laser amplitude stabilization system and began characterizing the frequency noise of the laser. The electronics for detection and lock-in were built and characterized. The theoretical analysis of the optomechanical system was carried out, and the computer simulation was done.

As the first step towards the optomechanics with squeezed light we investigate theoretically the prospects of the internal squeezing in optomechanics for enhancing the sensitivity-bandwidth product, and perform the proof-of-principle experiment (Figure 1). In this experiment we emulate the optomechanical signal by injecting the phase modulated beam into the optical

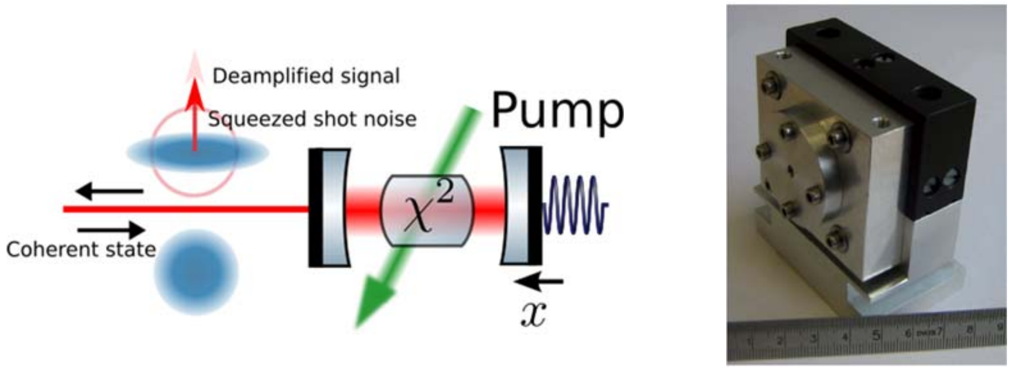

Figure 1. *Left:* the principle behind the internal squeezing: optomechanical interaction is amplified by the nonlinear crystal inside the cavity, the signal gets deamplified less than the shot noise squeezed, yielding gain in the signal-to-noise ratio. *Right:* optical parametrical amplifier cavity used in a proof-of-principle experiment on internal squeezing.

parametrical amplifier cavity and show that it enhances the sensitivity-bandwidth product of the setup.

Future steps towards observing the quantum behaviour of the mechanical oscillator will be placing the membrane-in-the-middle setup on the cryogenic environment, fully characterizing it and observing the quantum noise limited spectrum, and then injection of the squeezed vacuum in the cavity to go below the Standard Quantum Limit.

3. Training received (complementary/soft skills, ITN workshops attended)

1. ITN cQOM workshop "Finite Element Modeling", 2014, Lausanne, Switzerland
2. ITN cQOM annual workshop, 2015, Diavolezza, Switzerland
3. ITN cQOM workshop "Levitation in (quantum) physics", 2015, Vienna, Austria
4. ITN cQOM Workshop on Microfabrication 2016, Ghent, Belgium

4. Participation and role in dissemination and outreach activities

1. Introducing my optomechanics research within cQOM to Hamburg University by presenting a poster at the Institute for Laser Physics on Dec. 1st, 2015
2. Talk on the ITN cQOM Workshop on Microfabrication 2016 (Ghent), “Internal squeezing for enhancing the sensitivity-bandwidth product in optomechanics”

5. List of conferences attended

1. Les Houches Summer Physics School on Optomechanics, 2015
2. LIGO-Virgo Scientific Collaboration Autumn meeting, 2015 Budapest, Hungary
3. 605. WE-Heraeus-Seminar on MACROSCOPIC ENTANGLEMENT, 2016 Bad Honnef, Germany
4. DPG Spring Meeting 2016, Hamburg. Germany
5. Gordon Research Seminar on Mechanical Systems in the Quantum Regime, 2016, Ventura, USA
6. Gordon Research Conference on Mechanical Systems in the Quantum Regime, 2016, USA
7. LIGO-Virgo Scientific Collaboration Spring meeting 2016, Pasadena, USA

6. Publications (with links)

Internal squeezing for enhancing the sensitivity-bandwidth product in optomechanics (*in preparation)*

7. Career plans after ITN

Complete the PhD by the end of 2018 in the current host institution