Marie Curie ITN cQOM
Summary of the Scientific Achievements

Name of Fellow: Paolo Piergentili
Principal Investigator: Prof. Dr. Roman Schnabel
Academic / Industrial Institution: Hamburg Universität
Start Date of ITN Fellowship: 01.05.2014
End Date of ITN Fellowship: 31.05.2016
Date of Report: 20.06.2016

1. Description of research work

As part of the Marie Curie ITN cQOM project, I joined Prof. Roman Schnabel's research group as a Ph.D. fellow. My task was to begin a new cryogenic membrane-in-the-middle experiment. The experimental goal is to place a Si_3N_4 membrane in the middle of a one-sided Fabry-Perot cavity, and measure the motion of the membrane with precision at the standard quantum limit. To demonstrate this precision, the noise power spectral density of the outgoing light from the optomechanical cavity is measured over a frequency band that is close to the fundamental mode of the membrane. The frequency band is chosen such that we can observe the transition from quantum radiation pressure noise to shot noise, while all classical noise levels are much below these quantum noises. By varying the power of the probe beam and observing the scaling of the noises, it is possible to distinguish between classical and quantum noise. In this way, we can convincingly show that the membrane is probed at the standard quantum limit. In order to achieve this goal it is necessary to characterize and reduce the noises in the system, in particular laser amplitude and phase noise.

2. Goals achieved and/or progress towards them

In the time that I was an ITN fellow, my colleagues and I identified an appropriate research goal and the experimental techniques that we would use to achieve it. The first step was to install a new dilution refrigerator in the laboratory with a unique vibration damping system that had been designed to isolate an experiment from external vibrations. We set up a new fibre laser system operating at 1550 nm, and began characterizing the amplitude noise of the laser's output in order to understand if it would be a critical source of noise in our planned experiment. As a consequence an amplitude noise stabilization system has been developed in order to have a laser beam that is shot noise limited at the power that is injected into the optomechanical cavity. An unbalanced Mach Zehnder fiber interferometer to detect phase noise has also been implemented. We began testing designs for the optomechanical Fabry-Perot cavity, as well as trying out membrane clamping techniques and procedures to align the optical cavity with the membrane inside, at room temperature. We tested and implemented piezo positioners for aligning the optomechanical cavity inside the dilution refrigerator. The work on the project is still in progress. Professor Schnabel's research group moved from Hannover to Hamburg and the experiment has therefore been rebuilt in Hamburg.

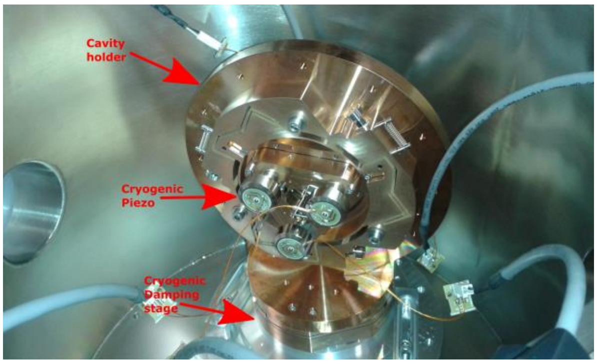

Figure: Photo of the optomechanical cavity. The arrows show the different components of the cavity. The cavity holder is mounted on top of a damping stage that isolates the optomecanical cavity from the cryostat. The cryogenic piezos are mounted on the mirrors of the cavity and allow to realign the cavity at cryogenic temperatures. The membrane is inside the cavity holder between the two mirrors.

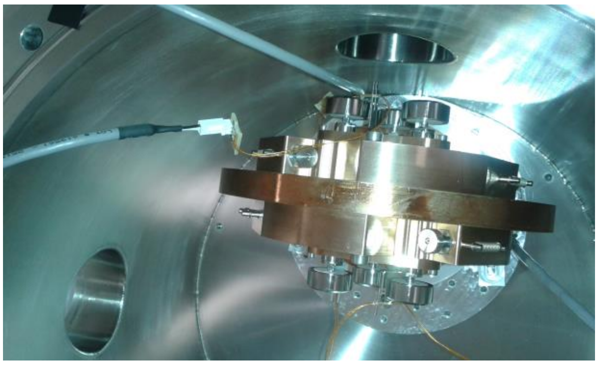

Figure: Top view of the optomechanical cavity.

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

- Lausanne, 21-23 July 2014 – Finite Element Modeling Workshop by Prof. T. Kippenberg
- Diavolezza, 1-5 Feb 2015, Annual Workshop
- Vienna, 14 – 15 May 2015: Levitation in (quantum) physics by Prof. Aspelmeyer

4. Participation and role in dissemination and outreach activities

Introducing my opto-mechanics research within cQOM to Hamburg University by presenting a poster at the Institute for Laser Physics on Dec. 1st, 2015.

5. Career plans after ITN

Staying with current host institution (to complete PhD by expected graduation date: beginning of 2019)