Q 30: Optomechanics II

Time: Tuesday 14:00–15:30 Location: K 0.023

Q 30.1 Tue 14:00 K 0.023

Laser Power Stabilization via Radiation Pressure — •Marina Trad Nery and Benno Willke — Albert Einstein Institute, Hannover, Germany

This work reports a new scheme for laser power stabilization in which power fluctuations of a laser beam are detected via radiation pressure produced on a micro oscillator. The ultimate goal of this experiment is to demonstrate an improved technique that can be implemented in the future generations of Interferometric Gravitational Wave Detectors. Since these interferometers are designed to detect differential length changes of around 10^{-18} m, they require high stability in the laser source: the Relative Power Noise needs to be on the order of 10^{-9} Hz$^{-1/2}$ at frequencies around 10 Hz, the most stringent requirement in experimental physics. At such levels, vacuum fluctuations limit the sensitivity in detecting power fluctuations in the traditional scheme and new techniques are necessary to overcome this limitation and reach the desired sensitivity. The advantages of the new technique will be presented together with the details of a proof-of-principle experiment that is currently being set up at the Albert Einstein Institute, Hannover.

Q 30.2 Tue 14:15 K 0.023

Thermal noise performance of metamirrors — •Johannes Dickmann[1], Carol Bibiana Rojas Hurtado[1], Ronny Nawrodt[2], and Stefanie Kroker[1,3] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Friedrich-Schiller-Universitaet Jena, Institut fuer Festkoerperphysik, Helmholtzweg 5, 07743 Jena, Germany — [3]Technische Universitaet Braunschweig, LENA Laboratory for Emerging Nanometrology, Pockelsstraße 14, 38106 Braunschweig, Germany

Many optical and optomechanical applications are limited by the thermal noise of their components (e.g. gravitational wave detectors and cavities for laser stabilization). In a wide spectral range, the Brownian thermal noise of the optical coatings dominates the noise level. Promising alternatives to conventional multilayer mirrors are nanostructured surfaces (so called metamirrors). We achieved a unified method for the calculation of Brownian thermal noise of arbitrary shaped linear optical elements based on the Fluctuation-Dissipation theorem approach. A semi-analytical investigation of Brownian thermal noise of binary sub-wavelength grating mirrors shows a decrease of the noise power spectral density by a factor of up to 10^4, compared to conventional mirrors under representative conditions.

Q 30.3 Tue 14:30 K 0.023

Investigation of silicon optical nanostructures for light modulation by optical forces — •Carol Bibiana Rojas Hurtado[1], Johannes Dickmann[1], Walter Dickmann[2], and Stefanie Kroker[1,2] — [1]Physikalisch-Technische Bundesanstalt — [2]Technische Universität Braunschweig

A surface nanostructure is proposed as an optomechanical system, i.e. a system in which the optical modes interact with the mechanical modes via the radiation pressure. We investigate the optomechanical interaction for a resonance with high quality factor corresponding to the fundamental Transversal-Electric mode at a wavelength of about 1550 nm for near normal incidence. The structure consists of two layers of subwavelength silicon gratings on top of a silica substrate. The top grating sustains the optical modes while the bottom grating provides the mechanical susceptibility. The optical forces induced by the incoming light field lead to deformations in the gratings. We simulate that with static light fields, powers in the range of 5 mW lead to mechanical displacements in the picometer range. In our structure, this enables us to modulate the reflectivity of the surface between 35% and close to 100%. The displacement can be further enhanced by coupling it to the mechanical resonance of the structure with a modulation of the incoming light field at the eigenfrequency of the mechanical resonance. The proposed system allows the control of light with light and is promising for all-optical modulation for frequencies up to several hundreds of MHz.

Q 30.4 Tue 14:45 K 0.023

Fresnel-Reflection-Free Self-Aligning Nanospike Interface between a Step-Index Fibre and a Hollow-Core Photonic-Crystal-Fibre Gas Cell — •Riccardo Pennetta, Shangran Xie, Frances Lenahan, Manoj K. Mridha, David Novoa, and Philip St.J. Russell — Max Planck Institute for the Science of Light, Staudtstrasse 2, 91058 Erlangen, Germany

The development of low-loss hollow-core photonic crystal fibres has opened new opportunities for investigating intense light-gas interactions over distances thousands of times longer than the Rayleigh length. In these experimental configurations, macroscopic gas cells or vacuum chambers are typically employed and laser light is launched into the system through windows using standard optical components. While effective, the resulting systems are bulky and sensitive to external perturbations, which is a crucial issue especially at high power levels, since even tiny misalignments can increase the overlap between the incident beam and the fibre microstructure. Here, we report a fully integrated interface delivering efficient, reflection-free, single-mode, and optomechanically self-aligned coupling between a step-index fibre and a gas-filled hollow-core photonic crystal fibre. Based on adiabatic evolution of the light field along a tapered silica nanospike, the device offers a universal solution for interfacing solid and hollow-core fibres. It can be sealed to allow operation either in ultra-high vacuum or at high pressure. As an example, stimulated Raman scattering and molecular modulation of light are demonstrated in a H2-filled hollow-core photonic crystal fiber using the device.

Q 30.5 Tue 15:00 K 0.023

Broadband optomechanically self-aligned coupling to liquid-filled hollow-core photonic crystal fibre using a fused silica nanospike — •Richard Zeltner, Riccardo Pennetta, Shangran Xie, and Philip St.J. Russell — Max Planck Institute for the Science of Light, Erlangen, Germany

Hollow-core photonic crystal fibre (HC-PCF) confines and guides light in a hollow core that can be filled with low index media, allowing efficient light-matter interactions over long path lengths. HC-PCF thus provide a promising platform for a variety of optofluidic experiments, for example in photochemistry and spectroscopy. Many applications require efficient and stable coupling of broadband light into the core modes, which can be challenging if free-space or butt-coupling are used. Here we introduce a new technique that permits broadband, optomechanically self-aligned light delivery into a liquid-filled HC-PCF. A fused silica nanospike, fabricated by thermally tapering and chemically etching a single-mode fibre to a final tip diameter of 350 nm, is inserted into the HC-PCF. When a strong laser beam is launched into the nanospike via the untapered fibre end, optomechanical interactions between the nanospike and the HC-PCF modes gives rise to strong optical forces that align the tip at core centre. With the tip trapped at core centre, a broadband (bandwidth of 500 nm) supercontinuum signal could be efficiently, and close to achromatically, launched into the HC-PCF. The optomechanical trapping forces render the coupling robust against perturbations and Fresnel back-reflections are decreased to insignificant levels compared to free-space or butt-coupling.

Q 30.6 Tue 15:15 K 0.023

Combined sympathetic and feedback cooling in an atom-optomechanical hybrid system — •Tobias Wagner[1], Philipp Christoph[1], Felix Klein[1], Hai Zhong[2], Alexander Schwarz[2], Roland Wiesendanger[2], Klaus Sengstock[1], and Christoph Becker[1] — [1]ZOQ-Center for Optical Quantum Technologies, Luruper Chaussee 149, 22761 Hamburg — [2]Institute of Applied Physics, University of Hamburg, Jungiusstraße 9-11, 20355 Hamburg

We present our latest efforts towards realization of a hybrid quantum system consisting of a quantum gas of bosonic atoms (e.g., a Bose-Einstein condensate) optically coupled to a cryogenically precooled mechanical oscillator operated at $T \approx 500\,$mK. We routinely cool a high-stress Si_3N_4 membrane to mean phonon occupancy of $\langle n \rangle \approx 16$ using combined quantum optical cooling schemes, i.e., sympathetic cooling with a laser cooled ensemble of atoms and active feedback cooling.

In this talk we will report in detail on the characterization and optimization of the combined cooling technique. We discuss possible improvements, which should allow us to cool the membrane further down into the ground state and open the door to investigate e.g. entanglement between membrane and BEC in this promising hybrid system. This work is supported by the DFG via grants of Wi1277/29-1, BE 4793/2-1 and SE 717/9-1.