Optomechanics on the Hudson

New York, NY April 2-4, 2012

What would you like to find?

Welcome to the workshop “Optomechanics on the Hudson”

This workshop focuses on various (quantum and classical) aspects of optomechanics. Its main objective is to provide a specialized forum for exchanging ideas between different research groups working in this exciting area. The program of the workshop includes invited lectures given by prominent experts in the field, and contributed oral and poster presentations. Contributions from both theorists and experimentalists are encouraged. Invited lectures will provide unique opportunities for in-depth discussion of issues related to development of this area of physics as well as unique educational opportunity for graduate students and younger scientists interested in this field. In order to particpate in the workshop without presenting a paper, please submit a registration request by using the respective link in the navigation menu or following this link. Approval of these requests will depend on space availability with preference given to authors of submitted papers.

The workshop will take place in the Graduate Center of the City University of New York located in the middle of Manhattan on April 2-4, 2012. Topics covered by the workshop include, but are not limited to

- Optomechanics of nanomechanical oscillators
- Cavity cooling of optically levitating macroscopic objects
- Optomechanics with ensembles of molecules and atoms
- Optical cooling of mechanical modes of optical cavities
- Optomechanics of mechanical membranes
- Cavity enhanced optical manipulation of macroscopic objects and sensing

Contributions on these and other related topics are invited. Submission consists of an abstract (maximum 5000 characters) and a one-page paper. To submit follow the submission link on the right-hand panel. **The deadline for submission has been extended till March 16, 2012.** The authors of the accepted papers will be notified within two days of submission. Since the number of participants in the workshop is limited, the Program Committee reserves the right to stop accepting new submissions as soon as all slots are filled even before the submission deadline.

Confirmed invited speakers

to access the abstract of the invited talks (where available) click on the name of the speaker

- **Prof. Girish Agarwal**, Department of Physics, Oklahoma State University, USA
  Electromagnetically Induced Transparency and Quantum Memory in Nano Mechanical Systems
- **Prof. Peter Barker,** Department of Physics and Astronomy, University College London, UK
  Optomechanics with levitated particles
- **Prof. Dr. Klemens Hammerer**, Institute of Theoretical Physics, Leibniz Universität, Hannover, Germany
  Quantum Optomechanics and Interfaces to Atoms
- **Prof. Pierre Meystre**, College of Optical Sciences University of Arizona, Tuscon, USA.
  Quantum state transfer in cavity optomechanics
- **Prof. Mark Raizen**, Department of Physics, University of Texas at Austin, USA.
  Einstein’s impossibility
- **Prof. Dr. Helmut Ritsch**, Institute of Theoretical Physics, Universität Innsbruck, Austria.
  From cavity QED with quantum gases to optomechanics
- **Prof. Tal Carmon**, Department of Electrical Engineering and Computer Science, University of Michigan at Ann Arbor, USA.
  Brillouin Optomechanics

The selected list of contributed talks highlighting the most exciting contributions can be found here.

The workshop is organized under auspices of Initiative for Theoretical Science (ITS) of the Graduate Center of CUNY led by John Archibald Wheeler/Battelle Professor in Physics William Bialek (Princeton University and ITS at the GC CUNY). The organizing committee of the workshop includes Dr. Jack Harris (Yale University), Dr. Mark Raizen (University of Texas at Austin), Dr. Lev Deych (Queens College and the Graduate Center of CUNY), Dr. Vadim Oganesyan (College of Staten Island and The Graduate Center of CUNY).

March 16th, 2012 at 11:02 am

Abstract Submission

This form is available from December 13, 2011 to March 16, 2012

Sorry, this form is not available

December 25th, 2011 at 2:18 am

What would you like to find?

Accommodation Information

Here is the list of hotels located in the vicinity of the Graduate Center, which offer decent accomodation for reasonable prices. Still, given the generally high price of hotels in Manhattan, some of the participants may want to share rooms. If this is the case, please, contact the organizers, and we will help you with your reservation.

1. **Hotel Grand Union,** 34 East 32nd St. New York, NY 10016, telephone (212)683-5890 ,website http://www.hotelgrandunion.com/index.html. You may want to ask directly for the manager (name Tozen) and identify yourself as a particpant of the Graduate Center event. Rooms are available at $166.

2. **Hotel Lola (formerly Thirty Thirty),** 30 East 30th Street, New York, NY 10016, Contact: Nneka, Phone: 212-651-3825, Fax: 212-651-3883, e-mail, website http://www.thirtythirty-nyc.com/ (group rates at this hotel are under discussion

3. **The Affinia Shelburne**, 303 Lexington Avenue, New York, NY 10016, Tel 212.689.5200 , www.affinia.com/AffiniaShelburne . This hotel holds a block of 10 rooms for our workshop at $241 (single and double occupancy rooms). The rooms are held till March 1st. When booking mention group name Optomechanics.

More hotels will be listed later.

February 17th, 2012 at 12:37 pm

Navigation

- Welcome
- Workshop program
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Optomechanics on the Hudson

New York, NY April 2-4, 2012

Registration Request Form

This form is only to request registration without presenting a paper. If you want to submit an abstract follow this link

Sorry, this form is not available

October 22nd, 2012 at 4:51 pm

What would you like to find?

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Optomechanics on the Hudson

New York, NY April 2-4, 2012

Highlights from contributed talks

- Romero-Isart, Oriol
  Max-Planck-Institute for Quantum Optics, Garching, Germany.
  "Levitating Quantum Mechanical Oscillators: from Optomechanics to Magnetomechanics"
- Favero, Ivan
  Université Paris Diderot
  "GaAs disks nano-optomechanics"
- Nieto-Vesperinas, Manuel
  Instituto de Ciencia de Materiales, CSIC
  "Optical forces from partially coherent light"
- Vuong, Luat T.
  Physics Department, CUNY Queens College and the Graduate Center
  "Manipulation of Gold and Silver Nanoparticles via Photo-induced Magnetism"
- Bhattacharya, Mishkat
  Department of Physics, Rochester Institute of Technology
  "Quantum mechanics of a non-dissipative, weakly driven, quadratically coupled optomechanical system"
- Lee, Donghun
  Department of physics, Yale University
  "Combined Cryogenic and Laser Cooling of a 261 kHz Mechanical Oscillator to 200 μK"
- Hoch, Scott
  Department of Physics, Yale University
  "Optomechanics in a fiber cavity"
- Dong, Guangjiong
  State Key Laboratory of Precision Spectroscopy.,East China Normal University
  "Collisionless collective sympathetic cooling of molecules with atoms within a cavity"

February 1st, 2012 at 8:52 am

Venue

The workshop takes place at the Graduate Center of CUNY located at 365 5th Avenue (the corner of 5th Ave and 34th Street) in Manhattan (see map here) . Upon entering the building, you will see a large round information/security area at the center of the lobby. Everyone entering the building must identify themselves to the security. Security personal will have the list of the workshop's participants to help expedite the process. After clearing the security, proceed toward the elevators and go up to the 4th floor. From there you will be directed toward the Science Center. We will begin registering participants on April 2nd at 8:15 AM in the Science Center. Note that Tuesday's talk will take place on 9th floor in room 9206.

March 29th, 2012 at 10:01 am

Optomechanics on the Hudson
New York, NY April 2-4, 2012

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Workshop program

Monday, April 2nd

Science Center of the Graduate Center of CUNY
365 Fifth Avenue, 4th Floor, Room 4102

Morning Session, 9:00 AM – 12:55 PM

1. Pierre Meystre (University of Arizona)
Quantum State Transfer in Cavity Optomechanics
Part I
9:00 AM – 9:50 AM
2. Girish Agarwal (Oklahoma State University)
Electromagnetic Induced Transparency and Quantum Memory in Nano- Mechanical Systems
Part I
9:55 AM – 10:45 AM

Coffee Break 10:45 AM – 11:05 AM

3. Peter Barker (University College of London)
Manipulating and cooling complex particles.
11:05 AM – 11:55 AM
4. Scott Hoch (Yale University)
Optomechanics in a fiber cavity
12:00 AM – 12:25 PM
5. David Parrain (Universite Paris Diderot)
GaAs disks nano-optomechanics
12:30 PM – 12:55 PM

Lunch, 12:55 PM – 2:30 PM

Afternoon Session, 2:30 PM – 6:00 PM

1. Helmut Ritsch (Universität Innsbruck)
From Cavity QED with quantum gases to optomechanics: Cavity ground state cooling and optomechanics with an ultracold quantum gas
2:30 PM – 3:20 PM
2. Helmut Ritsch (Universität Innsbruck)
From Cavity QED with quantum gases to optomechanics: Light forces on beam splitters and dynamics of an optical lattice
3:25 PM – 4:15 PM

Coffee Break 4:15 PM – 4:35 PM

3. Donghun Lee (Yale University)
Combined Cryogenic and Laser Cooling of a 261 kHz Mechanical Oscillator to 200 μK
4:35 PM – 5:00 PM
4. Mishkat Bhattacharya (Rochester Institute of Technology)
Quantum Mechanics of a Non-Dissipative, Weakly Driven, Quadratically Coupled Optomechanical System
5:05 PM – 5:30 PM
5. Kyu Hyun Kim (University of Michigan at Ann Harbor)
Observation of radiation pressure induced mechanical vibrations in microfluidic resonators
5:35 PM – 5:55 PM

Tuesday, April 3rd

Science Center of the Graduate Center of CUNY
365 Fifth Avenue, 9th Floor, Room 9206

Morning Session, 9:00 AM – 12:55 PM

1. Klemens Hammerer (Leibniz Universität)
Interfaces of Optomechanics and Atoms
9:00 AM – 9:50 AM
2. Mark Raizen (University of Texas at Austin)
Maxwell's Impossibility.
9:55 AM – 10:45 AM

Coffee Break 10:45 AM – 11:05 AM

3. Pierre Meystre (University of Arizona)
Quantum State Transfer in Cavity Optomechanics
Part II
11:05 AM – 11:55 AM
4. Li Ge (Princeton University)
Quantum theory of optomechanical interaction in the presence of active medium
12:00 PM – 12:25 PM
5. Guangjiong Dong (State Key Laboratory of Precision Spectroscopy, PRC)
Collisionless collective sympathetic cooling of molecules with atoms within a cavity
12:30 AM – 12:55 PM

Lunch, 12:55 PM – 2:30 PM

Afternoon Session, 2:30 PM – 5:55 PM

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Part II
2:30 PM – 3:20 PM
2. Peter Barker (University College of London)
Optomechanics with Levitated Particles.
3:25 PM – 4:15 PM

Coffee Break 4:15 PM – 4:35 PM

3. Manuel Nieto-Vesperinas (Institute de Ciencia de Materiales)
Optical Forces from Patially Coherent Light
4:35 PM – 5:00 PM
4. Luat T. Vuong (Queens College of CUNY)
Manipulation of Gold and Silver Nanoparticles via Photo-Induced Magnetism
5:05 PM – 5:30 PM
5. Gaurav Bahl (University of Michigan at Ann Harbor)
Microfluidic optomechanical oscillators vibrating at 8.5 MHz to 11 GHz rates
5:35 PM – 5:55 PM

Wednesday, April 4th

Science Center of the Graduate Center of CUNY
365 Fifth Avenue, 4th Floor, Room 4102

Morning Session, 9:00 AM – 1:25 PM

1. Klemens Hammerer (Leibniz Universität)
Quantum effects in optomechanics
9:00 AM – 9:50 AM
2. Mark Raizen (University of Texas at Austin)
Einstein's Impossibility.
9:55 AM – 10:45 AM

Coffee Break 10:45 AM – 11:05 AM

3. Tal Carmon (University of Michigan at Ann Harbor)
Brillouin Optomechanics
11:05 AM – 11:55 AM
4. Kjetil Borkje (Yale University)
Proposal for Entangling Remote Micromechanical Oscillators via Optical Measurements
12:00 PM – 12:25 PM
5. Oriol Romero-Isart (Max Plank Institute for Quantum Optics)
Levitating Quantum Mechanical Oscillators: from Optomechanics to Magnetomechanics
12:30 PM – 12:55 PM
6. Lev Deych (Queens College of CUNY)
Effects of cavity confinement on optical forces
1:00 PM – 1:25 PM

Lunch 1:25 PM – 3:00 PM

Round table discussion

"The present and the future of optomechanics research"

Panel: Mark Raizen, Peter Barker, Helmut Ritsch, Klemens Hammerer

3:00 PM – 4:30 PM

PDF file of this agenda can be downloaded **here**

March 20th, 2012 at 11:05 am

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2. Girish Agarwal (Oklahoma State University). *Electromagnetic Induced Transparency and Quantum Memory in Nano- Mechanical Systems. Part 1*
   9:55 AM– 10:45 AM

   Coffee Break 10:45 – 11:05

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   1:00 PM – 1:25 PM

Lunch 1:25 – 3:00

Round table discussion
"The present and the future of optomechanics research"
Panel: Mark Raizen, Peter Barker, Helmut Ritsch, Klemens Hammerer
3:00 – 4:30

Electromagnetically Induced Transparency and Quantum Memory in Nano Mechanical Systems

G S Agarwal,
Department of Physics, Oklahoma State University, Stillwater, OK 74078

Using the nonlinear nature of the radiation pressure coupling we present results for a variety of nonlinear processes like wave mixing, up conversion, parametric gain etc. We show how the nonlinearity of the coupling leads to EIT in such systems opening up the possibility of applying to opto mechanical systems all what one has learnt about EIT. We also discuss the possibility of EIT at a single photon level which is required in connection with quantum memories. Further we show how such nano mechanical systems can be used as single photon routers and efficient frequency converters of single photons.

Einstein's Impossibility

Mark G. Raizen

Center for Nonlinear Dynamics and Dept. of Physics,

The Univ. of Texas at Austin, Austin, TX 78712

ABSTRACT

In 1907, Albert Einstein considered the instantaneous velocity of a Brownian particle, and proposed that this could be used as a testing ground for statistical mechanics. However, he concluded that this would be impossible to measure in practice due to the very rapid randomization of the motion. In this talk, I will discuss our recent measurement of the instantaneous velocity of a Brownian particle, realizing Einstein's prediction from 1907. Our system is a glass microsphere trapped in air by a dual-beam optical tweezer. I will describe our ongoing efforts to measure the instantaneous velocity of a Brownian particle in new regimes, as a testing ground for statistical mechanics. In parallel experiments, we have implemented feedback cooling to control the motion of a trapped microsphere in vacuum. We are investigating optimal approaches toward cooling of the bead to the quantum ground state, and the preparation of superposition states of the bead. This system should serve as a new testing ground for quantum mechanics of macroscopic objects.

From cavity QED with quantum gases to optomechanics

Helmut Ritsch

University of Innsbruck, Innsbruck, Austria

Abstract. We study the nonlinear coupled dynamics of ultra-cold quantum gases trapped in the light field of high Q optical resonators. In the very low temperature limit the quantum nature of both, light and ultra-cold matter play equally important roles. Using the dynamically generated entanglement and properly designed measurements procedures of the light field allows controlled preparation of many-body atomic states as e.g. atom number squeezed states or Schrödinger cat states. If one traps the particles inside the optical cavity, one can create a optical potential, which is a quantized and a dynamical variable itself. In addition it mediates controllable long range interactions. The self-consistent solution for light and particles the includes new classes of quantum many-body states as super-solid states and polaron like excitations. In the deep trap limit the collective coupling of the particles and the field can be tailored to reproduce a wide range of optomechanic Hamiltonians with linear, quadratic or even higher order couplings in an environment very close to zero temperature.

Keywords: Quantum gas, Cavity QED, Optomechanics
PACS: 03.75.Lm, 42.50.-p, 05.30.Jp

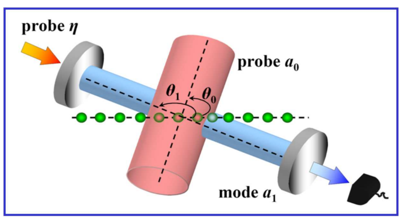

FIGURE 1. Optical probing of atoms in a lattice: the atoms are loaded into a prescribed lattice across a high Q cavity. Cavity transmission and probe light scattering into the cavity mode reveal the quantum statistics of the atomic distribution.

INTRODUCTION

As matter influences the propagation of light waves, light can be used to manipulate matter waves. In typical situations as optical traps or cavity QED one of the two effects dominates. However, confining a cold gas in a high finesse optical resonator creates a novel situation, where particles and photons dynamically influence their motion by momentum exchange on equal footing. The particles create a dynamic refractive index diffracting the light waves, which interfere and in turn form structured optical potentials guiding the particles motion[**?**]. Thus a quantum degenerate gas in an optical lattice inside a cavity represents the key system for *quantum optics with quantum gases*, where the quantum description of both, light and atomic motion is equally important.

MEASUREMENT AND STATE PREPARATION

In a quantum description of light and particle motion the dynamics immediately creates entanglement of atomic motion and the light modes. As a first application we can use the fact that the measurement of the scattered light thus detects atomic quantum statistics and projects the many-body atomic state in a designable fashion. For a generic case we present an analytical solution for this measurement dynamics valid for macroscopic Bose-Einstein condensates (BEC) with large atom numbers. The theory can be well applied for optical large optical lattices or even a BEC in a double-well potential[**? ? ? ?**].

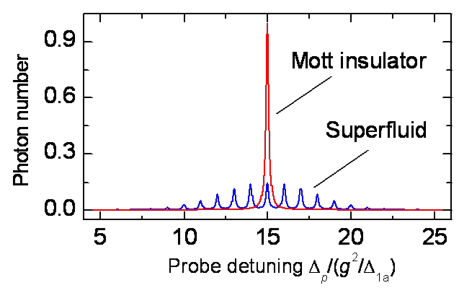

FIGURE 2. Expectation value of transmission spectrum for quantum gas in an optical lattice. The quantum superposition of different site occupation numbers in a super-fluid generates many possible transmission peaks, while for a Mott state with fixed atom number per site only one resonance appears.

COUPLED QUANTUM DYNAMICS

Optomechanics with ultracold quantum gases

Beyond measurement induced backaction, one can also study the light forces will influence high field seeking atoms moving between the two mirrors. For weak forces a linear approximation for the density perturbation of the BEC immediately leads to an implementation of the standard optomechanical coupling Hamiltonian[**?** **?**].

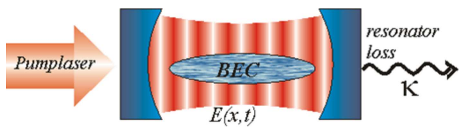

FIGURE 3. A BEC trapped within in a linear optical cavity generates a quantum refractive index. Atom light interaction creates density waves entangled with the field amplitude. For weak perturbation the system can be described by a standard optomechanical Hamiltonian with the atomic density behaving equivalent to a movable mirror.

In the opposite limit of a deep optical potential the particles are strongly confined near the potential minima at the antinodes of the optical field. Here the particle motion can be linearized and we get a photon number (intensity) dependent confinement and backaction of the particles on the field. In a harmonic trap approximation this realizes quadratic optomechnical coupling and a nonlinear field response[**?**].

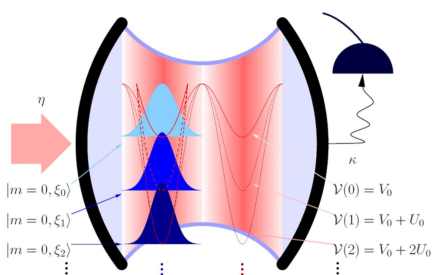

FIGURE 4. A deeply trapped quantum gas in a standing wave optical cavity generates an intensity dependent refractive index inducing a Kerr type nonlinear response. This leads to squeezing and entanglement of the light and the particles at different sites.

Coupling a second cavity mode as e.g. in a ring cavity or confocal cavity than can add linear coupling term which in the sideband limit allows ground state cooling of the center of mass mode[**?** **?**]. A single quantum trajectory for this cooling process is shown in Fig. **??**. 1

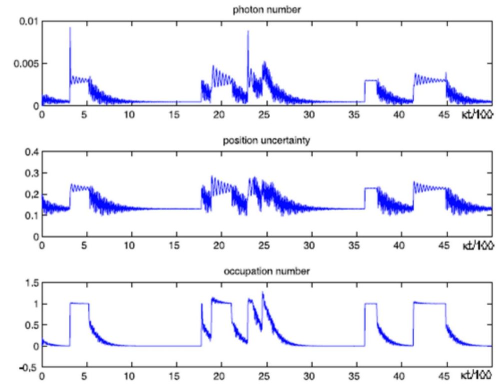

FIGURE 5. In a ring cavity two degenerate resonant light modes modes can be used for trapping and ground state cooling of the particles. Close to $T = 0$ observation of the emitted light reveals quantum jumps of the trapped particle(s) between the lowest trap states.

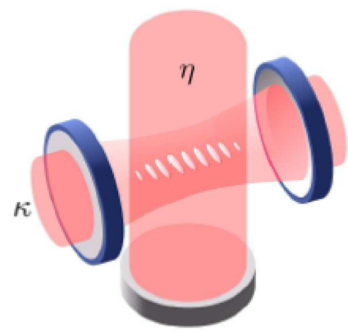

FIGURE 6. Selfordered distribution of atoms in a cavity with transverse pump. Above a certain pump strength the atoms order in a tube like structure at every second antinode of the cavity mode, which mediates superradiant pump scattering into the cavity mode.

Selfordering and super-radiant scattering

Above a certain threshold illumination intensity the particles order in a regular crystalline structure, where they form ordered periodic patterns with Bragg planes optimally coupling the pump laser into the resonator.[**?** **?**]. At T 0 this model shows a quantum phase transition analogous to the Dicke phase transition and the resulting atomic state exhibits typical characteristics of a supersolid[**?**].

HYBRID SYSTEMS

Interestingly such a setup can be directly generalized to include a movable mirror or membrane on one side. Here the tailored frequency response of the atomic ample can be used to cool the mirror even for a relatively bad cavity[**?**]

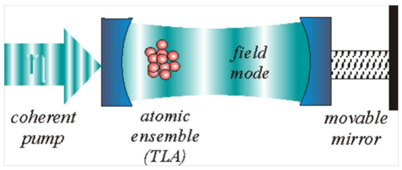

FIGURE 7. An ensemble of cold atoms in a cavity with movable mirror can be tailored to give a narrow optical resonance and suppress Stokes scattering from the mirror or enhance the anti-Stokes emission to efficiently cool the mirror motion.

CONCLUSIONS

The full quantum dynamics of ultracold gases coupled to high-Q cavity modes exhibits a wide range of new physical effects which can be studied with great control and precision. It bridges the gap between the quantum physics with single particles and quantum optics with solid mechanical objects. In hybrid setups cavity mediated interaction can be tailored to generate quantum correlations and entanglement of atom and mirror system.

ACKNOWLEDGMENTS

The work was supported by the Austrian Science Fund FWF (P20391 and F4013).

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