# Abstracts

### **Darrick Chang**, *ICFO Barcelona*

**Cold atoms coupled to photonic crystals: a platform for creating tunable long-range interactions**

Significant efforts have been made to interface cold atoms with micro- and nano-photonic systems in recent years. Originally, it was envisioned that the migration to these systems from free-space atomic ensemble or macroscopic cavity QED experiments could dramatically improve figures of merit and facilitate scalability toward more complex quantum devices. However, a more interesting question is whether nanophotonic systems can yield intrinsically new capabilities to manipulate quantum light-matter interactions, which cannot be readily realized in their macroscopic counterparts.
First, we will present a brief overview of the state-of-the-art in experiments that couple cold atoms to photonic crystal waveguides. We then describe a novel form of atom-light interaction in this platform, which can facilitate the realization of quantum systems with long-range interactions. In particular, we show that atoms trapped near photonic crystals can become dressed by localized photonic "clouds" of tunable size. This cloud behaves much like an external cavity, but one which follows the position of the atom. This dynamically induced cavity allows one to mediate and control long-range interactions between atoms, providing a powerful new tool for quantum simulation with ultracold atoms.

### **Chris Greene**, *Purdue University* (1h tutorial)

**Physics of few-body bound states and collisions**

This tutorial will summarize the connection between bound states and low energy collisions. There will also be a brief overview of the role of the scattering length in determining properties of ultracold gases and Rydberg systems. Time permitting, the adiabatic approximation will be developed and the Landau-Zener theory of nonadiabatic transitions will be introduced.

### **Arno Rauschenbeutel**, *TU Wien* (1h tutorial)

**Chiral interaction of light and matter in confined geometries**

When light is strongly transversally confined, significant local polarization components that point in the direction of propagation arise. In contrast to paraxial light fields, the corresponding intrinsic angular momentum of the light field is position-dependent - an effect referred to as spin-orbit interaction of light. Remarkably, the light's spin can even be perpendicular to the propagation direction. The interaction of emitters with such light fields leads to new and surprising effects. For example, when coupling gold nanoparticles or atoms to the evanescent field surrounding a silica nanophotonic waveguide, the intrinsic mirror symmetry of the particles' emission is broken. This allowed us to realize chiral nanophotonic interfaces in which the emission direction of light into the waveguide is controlled by the polarization of the excitation light [1] or by the internal state of the atoms [2], respectively. Moreover, we employ this chiral interaction to demonstrate nonreciprocal transmission of light at the single-photon level through a silica nanofiber [3]. The resulting optical diode is the first example of a new class of nonreciprocal nanophotonic devices which exploit the chiral interaction between quantum emitters and transversally confined photons.

References:
[1] J. Petersen, J. Volz, and A. Rauschenbeutel, "Chiral nanophotonic waveguide interface based on spin-orbit coupling of light," Science 346, 67 (2014).
[2] R. Mitsch, C. Sayrin, B. Albrecht, P. Schneeweiss and A. Rauschenbeutel, "Quantum state-controlled directional spontaneous emission of photons into a nanophotonic waveguide," Nature Commun. 5, 5713 (2014).
[3] C. Sayrin, C. Junge, R. Mitsch, B. Albrecht, D. O'Shea, P. Schneeweiss, J. Volz and A. Rauschenbeutel, "Optical diode based on the chirality of guided photons," arXiv:1502.01549.

**James Millen,** *University of Vienna*

**Control and cooling of nanoparticles in vacuum**

Nanoscale devices are beginning to fulfil their potential as cutting edge technology, for example by acting as ultrasensitive sensors, and as signal transducers. By cooling the motion of nano-oscillators, their motion can enter the quantum regime, promising transduction and storage of quantum information, quantum limited measurements, and the exploration of quantum physics at large mass scales. By freeing and isolating your nano-object, either through levitation or launching in vacuum, the Q factor is greatly enhanced, and decoherence pathways are minimized. In this talk I will present progress in cooling levitated nanospheres to the milli-Kelvin level using optical and electric fields, and work on controlling free nanoparticles in ultra-high vacuum.

**Christian Schwemmer**, *LMU München*

**Systematic Errors in Current Quantum State Tomography Tools**

Common tools for obtaining physical density matrices in experimental quantum state tomography cause systematic errors. For example, using maximum likelihood or least squares optimization to obtain physical estimates for the quantum state leads to a systematic underestimation of the fidelity and an overestimation of entanglement. Such strongly biased estimates can be avoided using linear evaluation of the data or by linearizing measurement operators yielding reliable and computational simple error bounds.

**Walter Boyajian**, *ITP Innsbruck*

**Compressed quantum simulation and computation of the 1D XY-model**

We present the derivation of compressed quantum circuits, running on a small number of qubits, which can be used to simulate specific behaviours of exponentially larger systems. In order to derive these circuits, we use the fact that quantum computation in circuits comprising of nearest neighbour matchgates can be simulated by exponentially smaller quantum circuits. We consider a 1D XY-model of n qubits and present compressed quantum circuits that can be used to simulate the behaviour of thermal as well as any eigenstate of the system. In particular, the circuits presented here run on log(n) or log(n)+1 qubits and can be used to measure the magnetization, number of kinks and correlations occurring in the system.

**Esteban Castro,** *Vienna Theory*

**Entanglement of quantum clocks through gravitational interaction**

In general relativity, the picture of space-time assigns an ideal clock to each space-time point. Being ideal, gravitational effects due to these clocks are ignored and the flow of time according to one clock is not affected by the presence of surrounding clocks. However, if time is defined operationally, as a pointer position of a physical clock that obeys the laws of quantum mechanics and general relativity, such a picture is at most a convenient fiction. We show that the mass-energy equivalence implies gravitational interaction between the clocks, which necessarily entangles them through time dilation effect and leads to a loss of coherence of a single clock. Hence, the time as measured by a single clock is not well-defined. However, the general relativistic notion of time is recovered in the classical limit of clocks.

**Ehud Altman,** *Weizmann Institute, Rehovot*

**The peculiar nature of light-matter fluids**

Recent experiments with many-body systems, strongly coupled to light, challenge our common notions of quantum matter. The emergence of many-body correlations is augmented with the need to pump these systems with lasers, defining a new class of matter far from thermal equilibrium. In this talk I will focus on the fundamental questions raised by experiments purporting to show evidence for Bose condensation of exciton-polaritons in two dimensional quantum-well optical cavities. What is the nature of the phase transition at which these correlations are established? Can a two dimensional superfluid exist under the non-equilibrium conditions set by the drive?

I will present surprising answers to these question, arguing in particular that the non-equilibrium fluctuations are fundamentally different from the effect of temperature. In isotropic systems these fluctuations hinder the formation of algebraic correlations that would have been established in an isotropic two dimensional thermal Bose fluid. The condensate seen in current experiments is thus interpreted as an intermediate scale crossover phenomena, while a correlated “fluid of light” with no equilibrium counterpart is established at longer scales. We further predict that equilibrium-like condensation can occur only in sufficiently anisotropic systems, but it does so in a peculiar reentrant manner. We obtain these results through a mapping of the long-wavelength condensate dynamics onto the Kardar-Parisi-Zhang equation.