Mini-symposium C13
Many body quantum optics: Merging condensed matter with AMO physics

Organizer:
Dimitris G. Angelakis
Centre for Quantum Technologies, Singapore and
Technical University of Crete, Greece
Email: dimitris.angelakis@qubit.org

C13-01 Keynote
New Trends in Time Evolution with Matrix Product States
Ulrich Schollwöck
Department of Physics, University of Munich, Theresienstrasse 37, 80333 Munich, Germany

Time-dependent matrix product states (time-dependent DMRG) has developed into a very powerful tool for the simulation of the evolution of strongly correlated quantum systems far from equilibrium. However, its scope is limited by the effective restriction to one-dimensional systems as well as to relatively short times due to dynamical entanglement growth. In this talk, I want to show how a combination of time-dependent matrix product states combined with non-equilibrium dynamical mean-field theory (DMFT) can yield the dynamics of strongly correlated quantum systems also in the high-dimensional limit, while being a very good approximation in three dimensions, for much longer times than were previously feasible in the context of non-equilibrium DMFT.

C13-02 Invited
Dynamical QMC trajectory-TEBD algorithm for simulating lossy driven quantum many body systems
Ping Nang MA1, Dimitris G. ANGELAKIS2
1Center for Quantum Technologies, National University of Singapore, Singapore; 2School of Electronic and Computer Engineering, Technical University of Crete, Greece

Dissipation in quantum simulations has always been challenging to numerical physicists over the decades. In particular, the exponential scaling of the super-Hilbert space in deterministically exact Liouville superoperator approach makes it applicable to only 2 or 3 sites, rather useless in actual-size simulation. Fortunately, with stochastic Quantum Monte Carlo (QMC) trajectory algorithm, dissipative quantum simulations can be handled numerically-exact for at least up to 6-8 sites. The scalability is further enhanced with the Time-Evolving-Block-Decimation (TEBD) approach, where renormalizations in the Schmidt space greatly reduce the computational complexity exponentially, except for some controllable error introduced by the approximation scheme of Schmidt space truncation during TEBD renormalization. In this talk, we shall merge the stochastic QMC trajectory method into the TEBD algorithm under the Matrix-Product-States (MPS) formalism, and make this powerful or lossy 1D driven-dissipative quantum simulations that could scale up to 50 sites in practice. As a first application, we shall investigate how this method could be used to simulate quantum model Hamiltonians in the field of many-body 1D quantum optics. With the vast progress in Tensor-Network-State (TNS) formalism over the last decade, it is indeed reasonable to anticipate the applicability of QMC trajectory-TEBD algorithm on 2D driven-dissipative quantum systems in the near future.

C13-03 Keynote
Many-body states of light in driven cavity-networks

Rosario Fazio
Scuola Normale Superiore, 56126 Pisa, ITALY

I will discuss some properties related to the many-body physics of QED-cavities arrays in the presence of leakage and driven by an external pump. In the steady state the system may reach different phases characterised by symmetry breaking and collective behaviour. Many-body physics in these arrays can also be studied in transport. I will give an example of this by considering photon transport through chains of strongly interacting cavities.


C13-04 Invited
Probing topological phases with quantum Monte Carlo
Pinaki Sengupta1,2, Keola Wierschem1,2
1School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore; 2Department of Physics, National Taiwan University, Taipei, Taiwan

Despite the tremendous progress in the construction and classification of possible topological phases over the past decade, a fundamental roadblock still remains: given a physical system described by a microscopic Hamiltonian, how does one determine whether or not the ground state has non-trivial topological character? However, over the past year, there have been crucial breakthroughs in the calculation of topological order parameters from quantum Monte Carlo simulations. These results are indispensable for the experimental search for topological phases of matter. In this talk I shall present our results on the extended Bose Hubbard model – a microscopic Hamiltonian that can potentially be realized in cold atom experiments. Our results will provide guidelines for designing a state with non-trivial topological character and also be useful in identifying the same.

C13-05 Invited
Properties of ultracold bosons in the honeycomb lattice
Benoît Grémaud1,2,3,4
1Merlion MajuLab, CNRS-UNS-NUS-TNU International Joint Research Unit UMI 3654, Singapore; 2Laboratoire Kastler Brossel, Ecole Normale Supérieure CNRS, UPMC; 4 Place Jussieu, 75005 Paris, France, 3Centre for Quantum Technologies, National University of Singapore, 4Science Drive 2, Singapore 117543, Singapore; 1Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542, Singapore

Using both mean-field and quantum Monte-Carlo approaches, we have investigated the ground state properties of ultracold bosons loaded in a honeycomb lattice with on-site repulsive interactions. First, we emphasize that, for imbalanced nearest-neighbor hopping amplitudes, the system depicts Mott-insulator phases at half-integral filling, which have clear experimental signatures in the velocity distribution. Second, we consider the situation where the onsite chemical potentials on the two sublattices are different. For the non-interacting system, it is well known that this imbalance destroys the conical intersections and results in a non-vanishing Berry curvature in the band structure. In the interacting case, we show that a non-vanishing Berry curvature appears in the Bogoliubov bands, i.e. in the excitations of the system, resulting in well-defined experimental signatures in the transport properties of the system.

C13-06 Invited
Experimental Efforts Towards Exploring/Merging Condensed Matter Systems with AMO Physics
Rainer Dumcke
Centre for Quantum Technologies, Division of Physics & Applied Physics, School of Physical & Mathematical Sciences, Nanyang Technological University, Singapore
Technological University, Singapore

I will discuss different strategies how experimentally AMO systems can be employed to explore condensed matter systems. One in particular fruitful approach is to mimic solid state systems with ultra cold atoms. In recent years several key experiments have been performed framing this field. In particular I will discuss the use of tailore optical potentials and the possibility of using ultra-cold atoms on a ring an ring-lattice to characterize and realize persistent current states.

The creation and manipulation of current states constitutes one of the most important advances in ultra cold atoms. I will discuss our current experimental efforts towards realizing these systems.

Another approach is to use ultra cold atoms as a probe to explore characteristics of a particular solid state system. Here I will discuss the current status of experiments probing solid state characteristics by employing ultra cold atoms. Focusing in particular on the investigation of superconductors. I will also discuss our efforts reaching even one step further to coherently couple solid state systems with ultra cold atoms.

C13-07 Invited

THz emission in dipolariton systems

I.A. Shelykh

1Division of Physics and Applied Physics, Nanyang Technological University, 637371, Singapore; 2Science Institute, University of Iceland, Dunhagi-3, IS-107 Reykjavik, Iceland

Dipolaritons are mixed light-matter quasiparticles formed in double quantum wells embedded in microcavities. Resonant excitation of the cavity mode can induce oscillations of the indirect exciton density with a characteristic frequency of Rabi flopping. This results in oscillations of classical Hertz dipoles array which generate superradiant emission on a terahertz (THz) frequency.

In our talk we will consider how the effects of the many-body interactions affect the process of the THz emission. We demonstrate that corresponding nonlinearities play dramatic role and can help in obtaining of the stable THz output in the regime of the continuous pump. Resulting THz signal may be sufficiently enhanced using the supplementary THz cavity tuned in resonance with the oscillation frequency, which paves way to realization of micro-scale THz laser with tunable characteristics.


C13-08 Invited

Dynamics of localized waves: coherent forward scattering peak in disordered systems

Christian Miniatura

1Merlion MajuLab, CNRS-UNS-NUS-NTU International Joint Research Unit, UMI 3654, Singapore; 2Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543, Singapore; 3INLN, Université de Nice-Sophia Antipolis, CNRS, 1361 route des Lucioles, 06560 Valbonne, France
4Institute of Advanced Studies, Nanyang Technological University, 60 Nanyang View, Singapore 639773, Singapore

As recently discovered [PRL 109 190601 (2012)], Anderson localization (AL) in a bulk disordered system triggers the emergence of a coherent forward scattering (CFS) peak in momentum space, which twins the well-known coherent backscattering (CBS) peak observed in weak localization experiments. Going beyond the perturbative regime, we address here the long-time dynamics of the CFS peak in a 1D and 2D random systems [PRA 90, 043605 (2014), arXiv:1410.0774]. Focusing on the 2D case, we show that CFS generally arises due the confinement of the wave in a finite region of space, and explain under which conditions it can be seen as a genuine signature of AL. In the localization regime, our numerical results show that the dynamics of the CFS peak is governed by the level repulsion between localized states, with a time scale related to the Heisenberg time. This is in perfect agreement with recent findings based on the nonlinear sigma model. In the stationary regime, the width of the CFS peak in momentum space is inversely proportional to the localization length, reflecting the exponential decay of the eigenfunctions in real space, while its height is exactly twice the background, reflecting the Poisson statistical properties of the eigenfunctions.