Q 71: Quantum Optics: Cavity and Waveguide QED III

Time: Friday 14:30–15:30 Location: F442

Q 71.1 Fri 14:30 F442

Waveguide QED with Mössbauer Nuclei — •Petar Andrejic[1], Leon Merten Lohse[2,3], and Adriana Palffy[4] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]Deutsches Elektronen-Synchrotron — [3]Georg-August-Universität Göttingen — [4]Julius-Maximilians-Universität Würzburg

Grazing incidence X-ray waveguides have become a well established platform for X-ray quantum optics. In these systems the waveguide mediated collective coupling of the X-rays plays a significant role. Recently a formalism has been developed to describe the collective nuclear response using the classical electromagnetic Green's function for the waveguide [1,2]. However, so far these works have considered only translationally symmetric systems, and plane wave driving fields. We show that driving the waveguides at forward incidence instead allows for direct excitation of multiple guided modes, with centimetre scale attenuation lengths. In this regime, micro-patches of embedded Mössbauer nuclei absorb and emit collectively into a super-position of these modes, with the resultant radiation field displaying pronounced interference beats on a micrometre scale. By considering variations in the size and positions of the micro-patches, it is feasible to engineer the resultant inter-nuclear coupling, with potential for applications in quantum simulation and experimental exploration of mesoscopic quantum dynamics.

[1] X. Kong, D. E. Chang, and A. Pálffy, Phys. Rev. A 102, 033710 (2020)

[2] P. Andrejić and A. Pálffy, Phys. Rev. A 104, 033702 (2021)

Q 71.2 Fri 14:45 F442

Quantum State Preparation in a Micromaser — •Andreas J C Woitzik[1], Edoardo Carnio[1,2], and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg im Breisgau, Federal Republic of Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg im Breisgau, Federal Republic of Germany

Quantum algorithms process information encoded into quantum states via an appropriate unitary transformation. Their purpose is to deliver a sought-after target state that represents the solution of a predefined computational problem. From a physical perspective, this process can be interpreted as a quantum state control problem, where a given target state is to be prepared with an optimally tailored unitary transformation. In this talk we adopt the one-atom (or micro-) maser, i.e., a string of atoms interacting sequentially with a cavity mode, to study the transfer of quantum information in state space. We aim, in particular, for the relation between the cavity's convergence towards a given target state and the entanglement content of the injected atomic string.

Q 71.3 Fri 15:00 F442

Star-to-chain transformations for ultra-strong coupling — David D. Noachtar[1], Johannes Knörzer[1,2], and •Robert H. Jonsson[1,3] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Institute for Theoretical Studies, ETH Zurich, Switzerland — [3]Nordita, Stockholm, Sweden

The ultra-strong coupling regime requires non-perturbative methods, for example, to calculate the radiation emitted from an atom. We show how star-to-chain transformations can be combined with methods based on matrix product state or Gaussian methods, respectively. Being well known in the study of open quantum systems, we demonstrate that the approach allows us to also treat field observables - both in vacuum states and thermal states of the field. As applications we consider giant atoms in the ultra-strong coupling regime [1], and the emission from a uniformly accelerated emitter in the Unruh effect [2].

[1] D. D. Noachtar, J. Knörzer, and R. H. Jonsson, "Nonperturbative treatment of giant atoms using chain transformations", Phys. Rev. A 013702, (2022).

[2] R. H. Jonsson, and J. Knörzer, "Star-to-chain transformations for relativistic matter-light interaction", in preparation.

Q 71.4 Fri 15:15 F442

Few-mode theory beyond the rotating-wave approximation — •Felix Riesterer, Lucas Weitzel, Dominik Lentrodt, and Andreas Buchleitner — Institute of Physics Albert-Ludwigs University of Freiburg Hermann-Herder-Str. 3 D-79104 Freiburg

For ideal cavities, the quantization of the electromagnetic field is rather simple. In real cavities with finite losses, however, the mode spectrum of the resonator becomes continuous, which makes the mathematical treatment numerically expensive and only possible with advanced techniques. It is then desirable to obtain a simplified description of the continuum, to model the field and quantum dynamics in open cavities. To overcome this problem, one uses projections to an equivalent system which is analog to the Jaynes-Cummings model coupled to an external heat bath, which can then be treated with the Lindblad formalism. In this process, the so-called rotating wave approximation has to be applied, where counter-rotating terms are omitted. In this work, we consider a generalized system-bath model by adding the counter-rotating terms to the commonly considered Hamiltonian. Our approach is aimed at understanding how these models can be applied or generalized for complex resonators with large losses, as they are encountered, e.g., in plasmonic cavities.