QSS05 - Klaus Mølmer Questions & Answers

Klaus Mølmer

Alireza Seif: Can you please elaborate how you decide whether to have L = a + sigma^- or L1 = a , L2 = σ^- from the original physics problem? I understand the difference between the two and the implications, but how do you ab initio decide what to put in the master equation in this example?

KLAUS: The fact that you sometimes see sums of operators as Lindblad terms is because these operators both couple to the same bath degrees of freedom, and in that case the systems decay in a correlated manner. You see the same happen in superradiance where the collective Lindblad lowering operator is the sum of all atomic lowering operators. If the atoms are far apart, they with different phase factors to different plane wave modes of the field and the sum effectively cancels the cross terms, leading to the individual atomic decay.

William Phillips: One sometimes hears that there is no such thing as the wavefunction of a photon, but you seem to be describing just that. Can you say something about this?

KLAUS: I consider a pulse equivalent to a single photon wavefunction, in which we can "install" any number of photons, in the same manner as single atom wave function ca be populated by a macroscopic number of non-interacting bosonic atoms. I think the controversy about the localization of the photon is connected to the question of defining a proper position operator, and indeed, the wave packet squared is the E and B field squared, i.e., an energy density rather than a probability density.

Michael Gira: Can you really generate any pulse or do you have constraints given by the coupling strength and the Born-Markov approximation?

KLAUS: Good question: Assuming infinite bandwidth of the waveguide, our theory in principle allows any pulse to be formed by the connection between $g_u(t)$ and u(t), but the interaction with, e.g, an atom (and also with real cavities) may not be well described by the Markovian approximation. An interesting direction to pursue further!

Iñigo Arrazola: Can you recover Rayleigh scattering in some limit?

KLAUS: Yes, I consider Rayleigh scxattering to be the coherent scattering of the driving field, i.e., the one related to the mean driven dipole of the scatterer. This component is included in the theory.

Manuel Morgado: Is possible to quantify the amount of information/entanglement that these quantum pulses can carry?

KLAUS: Yes, I think that the usual measures applied to quantify entanglement, correlation, (Fisher) information in discrete quantum systems, also apply to the pulses.

William Phillips: I don't understand the idea that everything moves left to right. If there is "true" spontaneous emission (whatever that means) there is radiation going in all directions.

KLAUS: In my talk the atom was only allowed to emit towards the right, but we can actually model both transmitted and reflected pulses - see https://arxiv.org/pdf/2003.04573.pdf Fig 1.d. We also include that possibility in the analysis of the photon blockade proposal in the same article.

Íñigo Luis Egusquiza: About the difference between a flying qubit interacting with a cavity and a flying pulse with a stationary qubit. Take a huge cavity, the spectrum is effectively continuous. How are they distinct?

KLAUS: In that limit they become quite equivalent, and in large cavities it is indeed sometimes necessary to include the effective coupling of different modes.

William Phillips: Is the sequential transmission of a 2-photon state a filtering of the input mode or a conversion of that mode?

KLAUS: I would say it is a filtering acting on the joint photon number and mode shape degrees of freedom. If the mode is at an instant in time has the spatial dependence `$u(x)$`, the two photon state is psi(x1,x2)= u(x1)*u(x2). After passage of the device, the componens with x1 ~ x2 have been suppressed, psi(x1,x2) –> u(x1)*u(x2)(1-w(x1,x2)), where w(x1,x2) is zerop unless (|x2-x1 is less than c/kappa, where kappa is the decay rate of the cavity dressed state). This new state can be expanded on many modes, and for a long pulse, you will find that it has a very large overlap with the original product state. An analogy: when you write state of a BEC as a macroscopically populated single wave atom function, you ignore that of course there is never two atoms within the same Angstrom sized volume, but subtracting such components does not seriously reduce the overlap with the GP product state.

B Prasanna Venkatesh: Can we use this theory when the emitter is separated by a length comparable to the peak wavelength of the pulse?

KLAUS: Yes when light propagates at a constant speed, and does not go back and forth between separate components a simple time translation of the time arguments permits to solve the dynamics. Another issue is of course if the Markov approximation is valid if you allow dynamic changes at the time scale of propagating a walelength, i.e., an optical cycle, corresponding to frequencies equal to the width of the continuum of modes.

Adrian Parra: Can you comment on the frequency range of the continuum that you are taking into account in the description of the one-dimensional waveguide? Certain range around the scatterer's frequency?

KLAUS: Yes, for practical purposes in quantum optics we have emitters that have decay rates (Gamma) and characteristic evolution orders of magnitude slower than their transition frequency, which permits the Markov approximation. We assume the spectrum to be flat in the corresponding frequency range around the transition frequency [omega - few Gamma, omega + few Gamma]

William Phillips: But does something get thrown away?

KLAUS: Yes, the Lindblad damping term represents genuine loss, i.e., radiation that is not eventually contained in the v-mode. That loss is not an error, it is emitted radiation that flies away and that we have "traced over" like in the normal master equation of decay. The new thing is that we can in a systematic approach trace over the whole continuum except one or a few selected pulses, for which we calculate the full quantum state density matrix.

Sebastian Wald: for a single mode input to a two level atom, in what situations do we get a multi-mode output?

KLAUS: If a single pulse hits a linear system, like an oscillator, or an only weakly excited atom, the emission is also single mode (this is the regime of Rayleigh scattering, cf. a previous question. The non-linearity due to saturation of the two level atom is what causes the incoherent scattering, and for example the Mollow fluorescence triplet.

Burak Gürlek: How you take into account focusing of the pulse and its interaction with TLS? One photon pulse is at focus or at the cavity output?

KLAUS: Good questions: I assume only a single transverse mode, for example by use of a transverse wave guide. For 3D scattering on a small object, the interaction may be too weak to be of relevance for quantum applications, but we have considered the possibility do make a paraxial approximation and find a small discrete set of dominant transverse modes and for example consider only the most populated one(s).