Proseminar zu Grundkonzepten: Blatt 1

H. Ritsch

27.11.2017

Quantum dynamics of a single field mode

Consider a single optical field mode of frequency ω of the electromagnetic field inside an optical resonator described by a harmonic oscillator

- **Real space oscillator dynamics:**
  Open the QO-toolbox homepage (https://www.qojulia.org/) and look through the harmonic oscillator example (copy it in your notebook). Plot the position distribution of superposition states of the field.

- **Dynamics in a Fock-basis:**

  1. Introduce a finite Fock-basis and define the ladder operators $a, a^\dagger$ and the Hamiltomian H for $n < N_0$ photons (i.e. a maximal energy of $E_{max} = \hbar\omega(N + 1/2)$).
  2. Check the commutation relations of $(a, a^\dagger, H)$. (Is there a problem ?) Use the ladder operator to construct the eigenstates of H and check their energies.
  3. Define the translation operator $D(\alpha) = exp(\alpha a^\dagger - \alpha^* a)$ and construct a coherent state. Calculate mean values and variances of their field and energy.
  4. Do the same for the squeezing operator $S(\epsilon) = exp(\epsilon(a^\dagger)^2 - \epsilon^* a^2)$.
  5. Plot photon number distributions and Q-function
     Hinweis: Verwenden Sie *(qfunc,wfunc)*
  6. Calculate the approximate time evolution of a squeezed state by repeatably applying the operator $U(dt) = expm(-i * H * dt/\hbar)$. Plot the field mean values and variances as function of time.
  7. Use the build in function *timeevolution_schroedinger* to redo this. For fun: create a movie of Q(t).

- **Master equation:**

  Let us add cavity decay now.

  1. Define the jump operator J and jump rate κ and use the build in function *timeevolution_master* to add the effect of cavity decay. Plot again mean values and uncertainties in the field as function of time.
  2. Add a driving field η to the Hamiltonian and calculate time evolution and steady states.