Project 1

I. GAUSSIAN WAVEPACKET IN A HARMONIC OSCILLATOR: PROPAGATION, AUTOCORRELATION FUNCTIONS AND SPECTRA.

- Program name: har_analytic.m,har_numeric.m
- What program does: Calculates correlation function $C(t)$ and spectrum $\sigma(\omega)$ for a 'coherent state' Gaussian in a harmonic potential.
- Reference in text:
  1. Ch. 3.3, Gaussian wavepackets.
  2. Ch. 6.eoc.3, analytic form for the correlation function, C(t), of a 'coherent state' Gaussian in a harmonic potential, and the analytical Fourier transform of $C(t)$, giving the spectrum, $\sigma(\omega)$.
  3. Ch. 14.eoc.1. Analytical solution for absorption and Raman spectroscopy for a Gaussian on a harmonic excited electronic state.
- Assignments:
  1. Compare the analytic and numeric solutions with their analytic solution in ex. 6.eoc.3.
  2. Change the displacement of the initial wavepacket. Explore the changes in $C(t)$ and $\sigma(\omega)$ as a function of the displacement.
  3. Measure the time scales of $C(t)$ and compare the related frequency scales in $\sigma(\omega)$. Verify the relationships in fig. 6.1.
  4. Compare your analytic expression for the short time $C(t)$ in ex. 6.eoc.4a with the full analytic (and numerical) result. How valid is the short time expansion?

II. GAUSSIAN WAVEPACKET IN A HARMONIC OSCILLATOR WITH EXTERNAL FORCING.

- Program name: forcedHO.m
- What program does: Calculates the evolution of a coherent state Gaussian in a forced harmonic oscillator. More precisely, it gives the center of the Gaussian in p and x as a function of time for different forcing functions, $F(t)$, by solving the eq. for $z(t)$ in ex. 3.eoc.9b.
- References in text:
  1. Ch. 3.eoc.9, analytical solution for a Gaussian in a harmonic oscillator.
  2. Ch. 15 Strong Fields. This analytic example is not discussed there, but has served as a conceptual starting point for thinking about infrared multiphoton excitation in time-dependent language.
  3. Ch. 9.4 Quantum Adiabatic Theorem. This analytic example with F(t) slowly varying can be used to verify the quantum adiabatic theorem.
- Assignments:
  1. Take $F(t) = \sin(\omega' t)$. Vary ω' and discuss the differences between
     (a) $\omega' = \omega$;
     (b) ω' a little detuned from ω (above and below);
     (c) ω' a lot detuned from ω.
  2. Take $F(t) = \sin(\omega t)$ (resonant forcing). At some time after the oscillator becomes excited, $\sin(\omega t)$ abruptly to $\sin(\omega t + \delta)$. Explore the effect of different values of δ and interpret.
  3. Take $F(t) = A$. What is $z(t)$? Why? What is the dependence on the size of A?

4. Take $F(t) = At$, and let A be very small (what does small mean?). Show that $p(t)$ stays around 0, while $x(t)$ grows. This implies that the wavepacket stays in a state which is close to the ground state of the instantaneous harmonic potential. Discuss the connection with the quantum adiabatic theorem (Ch. 9.4).