Two-photon Raman Transitions and EIT Cooling

Assigned: April 1st, 2020
Due: April 15, 2020

Problem 1: In class we derived the Hamiltonian for three-level systems, and specifically derived the effective results to drive two-photon Raman transitions. Write code to verify that the adiabatic elimination procedure is valid assuming we start in the $|0\rangle$ state, and use the following parameters:

(a) $\Delta = 100\Gamma$, $\gamma_{20} = \gamma_{21} = \Gamma/2$, and $\Omega_c = \Gamma$, and $\Omega_p = \Gamma$, and $\delta = 0$.

(b) $\Delta = 100\Gamma$, $\gamma_{20} = \gamma_{21} = \Gamma/2$, and $\Omega_c = 2\Gamma$, and $\Omega_p = \Gamma/2$, and $\delta = 0$.

(c) $\Delta = 100\Gamma$, $\gamma_{20} = \gamma_{21} = \Gamma/2$, and $\Omega_c = 2\Gamma$, and $\Omega_p = \Gamma/2$. Use the correct δ to resonantly drive the Raman transition.

Due to the large detuning this simulation will take some time to run (typically a minute or two on a PC with a moderately powerful processor). Note that in typical atomic physics experiments $\Delta \approx 10^5\Gamma - 10^6\Gamma$, but simulating this is not feasible.

Problem 2: We will now investigate EIT cooling as described by Morigi et. al. in Phys. Rev. Lett. 85, 4458 (2000). This paper is also available at arxiv.org/abs/quant-ph/0005009.

Reproduce the plot in Fig. 3 of this reference as closely as possible. You do not have to reproduce the inset. Reproduce both their Monte-Carlo result (instead using our master equation approach) as well as the rate equation result described in the paper. You may assume that the spontaneous emission is equally likely to cause decay into either ground state. This simulation will also take some time to run, this time due to the relatively large Hilbert space necessary to describe the problem. If it takes too long, feel free to reduce the initial number of motional quanta in order to reduce the size of the Hilbert space.

Hint 1: Make sure to start with a thermal state as the initial motional state.

Hint 2: Pay specific attention to the Lamb-Dicke parameters!