Asymmetry in population distribution with respect to detuning caused by EIT/coherent scattering

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1 Introduction

While simulating a simple three-level system with a Raman transition coupling two ground states and an excited state with a finite lifetime, I noticed that there's a difference in the dynamic and the final/steady-state population distribution when the two-photon detuning changes sign.

This effect cannot be reproduced in a two-level system if we assume the two ground states scatters independently, even if we include the difference in the scattering rate of the two states caused by the slight difference in the single photon detuning when a non-zero two photon detuning. It could be reproduced, OTOH, if the initial state of the scattering is assumed to be a superposition of the two ground states. This difference is of course very important since it's also where EIT comes from.

While the result of the simulation is pretty clear and with a 2-by-2 density matrix it shouldn't be that difficult to write out the full master equation and solve it directly, I do want to understand the origin of this asymmetry better and here are some of the approaches I can think of to understand this phenomenon.

2 System description

Hamiltonian,

$$H = \frac{1}{2}(\delta\sigma_z + \Omega\sigma_x) \tag{1}$$

For scattering, we'll assume that the state $\frac{|0\rangle + |1\rangle}{\sqrt{2}}$ scatters at a rate of γ with a 50/50 branching ratio back to the $|0\rangle$ and $|1\rangle$ states.