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Coherent Population Pumping in a Bright State

Abstract : We demonstrate resonances due to coherent population pumping in a bright state (CBS), using magnetic sublevels of the closed $F_g = 2 \rightarrow F_e = 3$ hyperfine transition in ^{87}Rb. The experiments are performed at room temperature in two kinds of vapor cells—one that is pure and the second that contains a buffer gas of Ne at 20 torr. We also present the effect of pump power variation on the CBS linewidth, and explain the behavior by using a power-dependent scattering rate. The experimentally observed CBS resonances are supported by a density-matrix analysis of the system.

Coherent population trapping (CPT) is a well studied phenomenon in many three-level atoms. It is a phenomenon in which the population in the three levels is such that the atoms are in a dark non-absorbing state, where they do not interact with the light. The requirement to create such a state is that the two light beams are phase coherent, so that a quantum mechanical superposition state can be created. The name has "trapping" in it because the population cannot get out of this state by spontaneous decay. CPT has been reviewed by Arimondo[1], and its differences from the related phenomenon of electromagnetically induced transparency (EIT) have been discussed by us in earlier work[2].

One simple way to achieve the required phase coherence between the beams in CPT is to derive both beams from the same laser, and use magnetic sublevels of a degenerate transition so that the beams are nominally at the same frequency. A narrow absorption dip then appears at line center when one of the beams is scanned; the line center being the point at which the two-photon resonance condition is satisfied. The linewidth of the dip is much smaller than the natural linewidth of the excited state. But it is not a sub-natural feature because the relevant linewidth is the one for a transition between ground levels, which is often below 1 Hz. In practice, it is limited by spin-exchange collisions between the atoms. Therefore, any method to increase the coherence time (such as the presence of a buffer gas in the vapor cell or anti-relaxation coating on the walls) will result in a narrower linewidth. It is important to note that such cells are not useful for EIT experiments. This has been demonstrated by us for CPT experiments using magnetic sublevels of the ground state[2], and by others for accessing the clock transition in Cs[3].

A similar arrangement with two phase-coherent beams can be used to create a bright superposition state. The result is enhanced absorption at line center, exactly opposite to the dip seen in CPT. The linewidth is similar to that obtained in CPT, and is again limited by decoherence among the magnetic sublevels of the ground state. However, unlike in CPT, the population does not get trapped in this state because it can decay by coupling to the excited state. The conditions for observing this using magnetic sublevels of a $F_g \rightarrow F_e$ transition are:

(1) It is a closed transition, so that there is no decay out of the system.

(2) $F_e = F_g + 1$, so that the correct superposition state can be formed.

(3) $F_g \neq 0$, so that there are multiple magnetic sublevels in the ground state.

All these conditions are met for the $F_g = 3 \rightarrow F_e = 4$ transition in ^{85}Rb, which was therefore used for the first observation of such increased absorption[4;5]. The authors called the phenomenon electromagnetically induced absorption (EIA), in order to highlight the fact that there was increased absorption at line center. However, we feel that a more appropriate term would be CBS (standing for coherent population pumping in a bright state), while the term EIA is better used for enhanced absorption of a weak probe beam in the presence of two or more strong pump beams in a multilevel system[6–10].

In this work, we study CBS resonances for a transition satisfying the above conditions but in the other isotope of Rb, namely the $F_g = 2 \rightarrow F_e = 3$ transition in ^{87}Rb. We experimentally study these resonances in two kinds of vapor cells—one that is pure and contains both isotopes in their natural abundances, and the second that contains only ^{87}Rb and has a buffer gas of Ne at 20 torr (which as mentioned before, results in a narrower CBS resonance). The explanation