

Propagation, Broadening, and Energy Decay of Quasi-Stationary Light Pulses in Thermal Atoms

Wen-Te Liao, Thorsten Peters, En-Chao Shen, and Ite A. Yu*

*Department of Physics, National Tsing Hua University,
Hsinchu 30013, Taiwan, Republic of China*

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We theoretically study the properties of quasi-stationary light pulses, formed by simultaneously switching on two counter-propagating coupling fields of imbalanced intensities, in the retrieval of stored photonic information, in a room-temperature or hot media of gaseous atoms or molecules. An analytical solution is obtained, and its predictions are in good agreement with the results from the numerical calculation. With the analytical solution, we discuss the propagation, broadening, and energy decay of quasi-stationary light pulses.

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I. INTRODUCTION

In recent years many theoretical and experimental studies based on the effect of electromagnetically induced transparency (EIT) [1] have been conducted. To illustrate this effect we show in Fig. 1 a typical Λ -type level scheme. The two ground states $|1\rangle$ and $|2\rangle$ are resonantly coupled to the excited state $|3\rangle$ by the two co-propagating coherent probe and coupling electromagnetic fields of Rabi frequency $\Omega_p(t)$ and $\Omega_c(t)$, respectively. States $|1\rangle$ and $|2\rangle$ are considered to be metastable while state $|3\rangle$ decays at a rate Γ . Applying a strong coupling field ($\Omega_c \gg \Omega_p$) on the $|2\rangle \rightarrow |3\rangle$ transition leads to a splitting of the corresponding dressed states and results in the cancelation of the transition amplitude for the probe field due to destructive interference. The medium becomes transparent on the $|1\rangle \rightarrow |3\rangle$ transition in a frequency range proportional to Ω_c^2/Γ . Associated with this transparency is a steep variation of the refractive index around the resonance, leading to a reduction of the group velocity of a light pulse of central frequency $\omega_p = \omega_3 - \omega_1$, where $\hbar\omega_i$ is the energy of state $|i\rangle$. The first significant reduction of the group velocity of a light pulse propagating through a coherently prepared medium has been experimentally demonstrated by Hau *et al.* [2] and shortly after by Kash *et al.* [3].

Fleischhauer and Lukin [4] showed that adiabatically turning off the coupling field while a probe pulse is slowly propagating through the medium leads to a storage of this pulse in the coherence between the two ground states $|1\rangle$ and $|2\rangle$, i.e., the information carried by the probe pulse is completely stopped. Subsequently turning the coupling field back on results in the retrieval of the original probe pulse. They also showed that these slowly propagating pulses can be described in terms of “dark-state polaritons” [5], a coherent mixture of photonic and atomic excitation. After retrieval, the probe pulse will have a