Population Dynamics of Atoms induced by Partially Coherent Laser Fields

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Efficient population transfer to thermally unpopulated atomic or molecular levels is of great importance in laser spectroscopy and collisional dynamics of atoms and molecules. The technique of rapid adiabatic passage (RAP)(1) has played a major role in population transfer in a 3-level system. In this method, the first laser pulse couples the initial state to an excited state which is connected by a second laser pulse to the final state. If the second pulse appropriately proceeds the first pulse, complete population transfer takes place when the interaction is adiabatic. Besides, it has been suggested that the basic idea of *p* pulses in a 2-level system can be extended to multilevel systems. Generalized p pulses(2) induce complete population transfer to a prescribed target state with high selectivity, which have exact 2-level analogs. B.W. Shore *et al.*(3) have examined similarities and differences in the above two schemes, where monochromatic fields are used. A. Kuhn *et al.*(4) have studied the feasibility of complete population transfer between atomic levels by stimulated Raman adiabatic passage with partially coherent pulsed lasers.

In this paper, population transfer in a three level atomic system by rapid adiabatic passage and the generalized *p*-pulse method is numerically investigated when partially coherent laser fields were used. The fast integral algorithm developed by Fox *et al*(5) is employed in this study to simulate a non-monochromatic laser, which fully takes into account the statistical properties of the laser field and has no restriction of either a long or a short correlation time. According to the theory for an ideal single mode laser far above threshold, we assume that the phase of a laser field obeys the Langevin equation : $d\phi(t)/dt = \varepsilon(t)$, $\langle \varepsilon(t)\varepsilon(t+\tau)\rangle = b\beta \exp(-\beta|\tau|)$. *bb* is the variance of the fluctuations and *1/b* corresponds to the correlation time of the fluctuations. In rapid adiabatic passage, the required minimum Rabi frequency has been found to achieve population transfer efficiency higher than 90 % when the time delay between laser pulses is in the counterintuitive pulse sequence, Dt_d=-*Dt,* where *Dt* is the pulsewidth of a Gaussian laser in full width at hal maximum (FWHM) :

$$\Omega^0 \rangle 3.0\left(\frac{1}{\Delta\tau} + \frac{1}{\sqrt{\tau^{sp}\Delta\tau}}\right) + \beta\sqrt{1.0 + N} \quad (1)$$

where t_{sp} is the lifetime of the intermediate level and *N* is defined to be the ratio of the laser bandwidth imposed by phase fluctuations to the Fourier-transform-limited bandwidth of the Gaussian pulses. For example, population transfer efficiency as a function of the peak Rabi frequency is shown in Fig. 1, when *N=1, Dt=10 ns, b=0.26 GHz, b=0.53 GHz.* On the contrary, there is no condition to achieve complete population transfer in the generalized p pulse method. The transfer efficiency decreases rapidly as N and *b* increase. Figure 2 (a) represents the transfer efficiency as a function of *W₀Dt* under the condition of *b>>b.* In the same condition as Fig. 1, population transfer efficiency of about 60 % could be achieved in this method as shown in Fig. 2 (b).

The remarkable difference in transfer efficiency between two methods is attributed to the fact that the atomic coherence can not be generated in the p pulse method when partially coherent lasers are used.

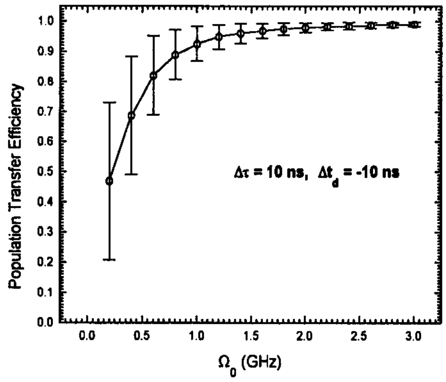
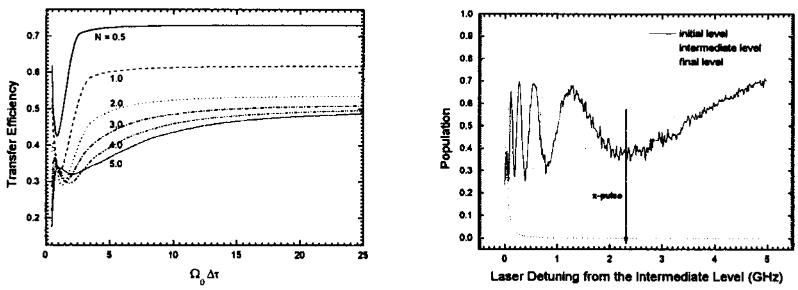


Fig. 1. Population Transfer efficiency as a function of the peak Rabi frequency : *N=1, Dt=10 ns, b=0.26 GHz, b=0.53 GHz.*



(a) (b)

Fig. 2. (a) transfer efficiency as a function of *W₀Dt* under the condition of *b>>b*, (b) leve populations in the generalized p pulse method as a function of the intermediate level detuning : *N=1, Dt=10 ns, b=0.26 GHz, b=0.53 GHz.*

References

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