포화흡수분광학에서의 비정상상태 효과 관찰

Observation of Nonstationary effects on the saturation spectroscopy

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We have studied the nonstationary effects in saturated absorption spectroscopy(1) of the ^{87}Rb D_2 line. Varying the size of the σ^+ polarized pump laser beam, we observed saturated absorption spectra for the $\sigma^\pm$ polarized probe beam. For equal polarizations of the pump and probe beams, we found that the resonance signal for the $F_g=1 \rightarrow F_e=2$ line, and the crossover lines between $F_g=1 \rightarrow F_e=2$ and $F_g=1 \rightarrow F_e=1$(and 0) lines increased to a greater extent than the others. This observation can be understood from the calculated time-evolution of the populations of the ground-state sublevels by means of a rate equation model. We also compared experimental data for other conditions with the calculated results. We found good agreement between the calculated results and the data.

The dependence of SAS signals on the laser beam size, i.e., transit time(2,3) is mainly due to the time evolution of the populations of the ground state. Figure 1 shows how the populations evolve in time for the 1→0,1,2 lines, where the frequency of the pump laser is resonantly tuned at 1→2, 1→1, and 1→0 lines from the top panel. We see that the populations arrive at their steady-state ones within ~5 us except for $|1,-1>$ at the 1→2 pump frequency (top panel). This is due to the weak transition strength between $|F_g=1, m=-1>$ and $|F_e=2, m=0>$. Since the typical atomic transit time, which is several us (8.4 us for the laser beam diameter of 2 mm), is comparable to the optical pumping time (several us), we can observe the nonstationary effects in the SAS spectra. The time-dependence of the populations in Fig. 1 can be easily calculated from the rate equations(4).

In order to study quantitatively how the beam size affects the amplitudes of the signals, we measured the amplitude of each signal normalized to that of L_1 and X_{10} for the σ^+ pump – σ^+ probe and σ^+ pump – σ^-probe polarization configurations, as shown in Figs. 2(a) and 2(b), respectively. These references (L_1 and X_{10}) are chosen, because we know that these arrive very fast at their steady-state values from the calculation. In Fig. 2, we can see good agreement between the experimental and calculated results. In particular, we observe that the magnitude of X_{21}, X_{20}, and L_2 increase more than the others in Fig. 2(a). As the beam size increases, the magnitude of X_{21} becomes larger than that of the L_0 resonance line at the size of ~5 mm, which is in excellent agreement with the calculated results. In Fig. 2(b), we can see the relatively large increase of signal

L_2 compared to others. In Figs. 2(a) and 2(b), we can see that the signals X_{21} and X_{20} increases are greater than the calculated results which we ascribe as due to the broadening of the signals. The large increase of the magnitude of L_2 [seen in both Figs. 2(a) and 2(b)], X_{21} and X_{20} [seen in Fig. 2(a)] is due to the slow decrease of the population at $|F_g=1, m=-1>$.

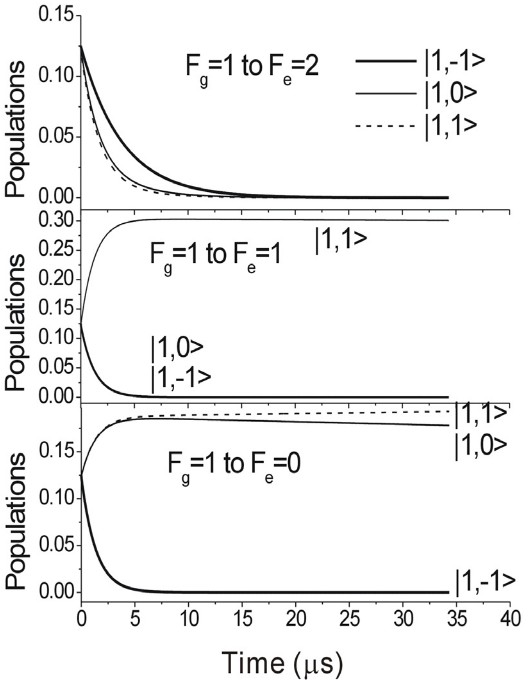

Fig 1. The time evolution of the ground state populations for 1→0,1,2 transition lines. The polarization of the pump beam is $\sigma^+$and the intensi쇼 is 3.0uW/mm^2

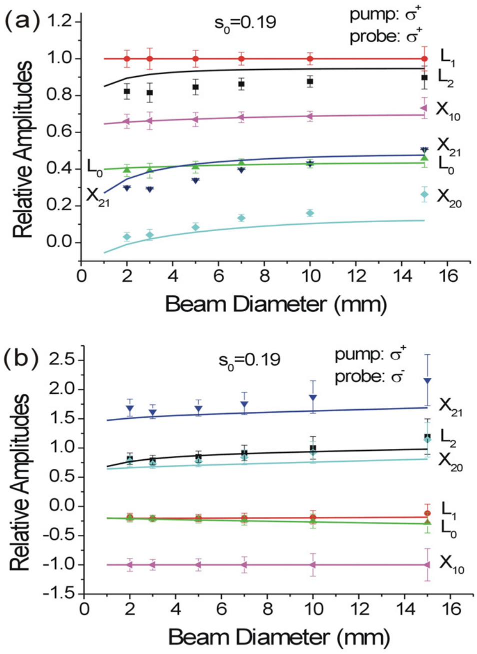

Fig 2. The dependence of the relative intensity of the signals on the pump beam diameter with σ^+ pump and σ^+ (a)[σ^- (b)]probe polarization configurations. The curves(dots) represent the theoretical (experimental) results.

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