Induced Absorption Resonance on the Open $F_g = 1 \rightarrow F_e = 2$ Transition of the $D_1$ Line of the $^{87}$Rb Atom

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Narrow atomic resonances are always important in spectroscopy, particularly in metrology. A new type of resonances was recently discovered in a degenerate two-level system and was called induced absorption resonance [1]. Rautian [2] pointed out that spontaneous coherence transfer plays an important and universal role in the formation of spectra. If transitions with approximately equal frequencies and role in the formation of spectra. If transitions with coherence transfer plays an important and universal resonance [1]. Rautian [2] pointed out that spontaneous two-level system and was called induced absorption resonance was recently discovered in a degenerate spectroscopy, particularly in metrology. A new type of same in microwave and optical ranges, as well as in $\gamma$ optics. This motivation stimulated us to analyze induced absorption resonance in the rubidium vapor and to present the results in this paper.

Induced absorption resonance was first detected on the closed transition of the $D_1$ line of the Rb atom that absorbs two in-phase copropagating light waves [1]. It was pointed out that induced absorption resonance was observed when the degeneracy factor of the excited state exceeded the degeneracy factor of the ground state, i.e., $0 < F_g \leq F_e = F_g + 1$ [6]. This effect was theoretically described in [7] for various intensities of the pump field, magnetic moments, and polarizations.

Signals associated with induced absorption resonance were also observed in experiment [8], where the Hanle configuration was used (laser light propagated along the magnetic-field direction). In that experiment, the atomic Rb vapor was pumped by a single linearly polarized wave. In the case of the degeneracy of the lower level of the ground state, bright resonances were detected in fluorescence with a concomitant increase in absorption. Those experimental results were theoretically analyzed in [9]. In the more recent work [10], it was shown that an increase in absorption in the Hanle configuration should also be expected when a laser beam is perpendicular to the magnetic field.

As was mentioned above, induced absorption resonance was observed on the closed transition of the degenerate ground state. The weak induced absorption resonance was also observed on the open $F_g = 2 \rightarrow F_e = 2.3$ transition in the $^{85}$Rb atom [8]. However, on the other open transition $F_g = 1 \rightarrow F_e = 2$ of the $D_1$ line of the $^{87}$Rb atom, the effect was not detected [11, 12]. It was assumed that this was due to optical pumping and the low degeneracy factor of the corresponding atomic states.

In this paper, we present the results of the experimental investigation of induced absorption resonance on the open $F_g = 1 \rightarrow F_e = 2$ transition of the $D_1$ line.

1 Among other mechanisms of the formation of the induced absorption resonance, Goren et al. [4] analyzed population transfer between Zeeman sublevels.
of the $^{87}$Rb atom that were obtained in the double-beam scheme [1] and in the Hanle configuration [8]. The observed effect appeared to be weak (0.2% of the total absorption due to the optical-pumping-induced depletion of the population). Optical pumping does not completely destroy spontaneous coherence transfer, which is responsible for the formation of induced absorption resonance, because the atoms interact with light for a finite time. Thus, this experiment corroborates that induced absorption resonance occurs on all $F_g = F_g + 1$ transitions both closed and open. The numerical calculation confirms the conclusions drawn using those experimental results.

We describe both experiments. The first experiment is the same as in [11]. Figure 1a shows the layout of the setup. An external-cavity laser was tuned to the $D_1$ or $D_2$ line of the $^{87}$Rb atom (see Figs. 1c, 1d). A laser beam passed through a half-wave plate and a cell 3.0 cm in length that contained isotopically pure $^{87}$Rb. The vapor density was controlled by the cell temperature. The transmission was detected by a photodiode $d$. The cell was placed in a three-shell magnetic screen. The longitudinal magnetic field is produced by a solenoid placed inside the screen. The static magnetic field gives rise to the appearance of Zeeman sublevels. The splitting was equal to the splitting $\mu_B B/\hbar$ between the neighboring Zeeman sublevels, where $\mu_B$ is the Bohr magneton.

In the case of the $^{87}$Rb atom, the splitting is equal to 0.7B MHz/G.

In the second experiment, two external-cavity lasers were used. The frequency of the laser creating coherence remained unchanged, whereas the frequency of the probe laser was scanned. The radiation of the strong laser after the passage through a quarter-wave plate became circularly polarized in the direction $s^+$, whereas the radiation of the probe laser was polarized in the opposite direction $s^-$. Downstream of the cell, beams were split by a quarter-wave plate and polarization cube (PBS) and were detected by photodetectors $d_1$ and $d_2$.

The magnetic-field dependence of the light transmission at four frequencies in the Hanle experiment was shown in Fig. 2. The cell temperature was equal to 50°C, the light power was 0.1 mW, and the beam diameter was equal to 1.5 mm. The transmission increases near the region where the magnetic field is zero for all the transitions except for the $F = 1 \rightarrow F' = 2$ transition (see Fig. 1c). The relative amplitudes of the resonances are not changed. The magnitude of the induced absorption resonance on the $F = 1 \rightarrow F' = 2$ transition is very small and is equal to 0.2% of the total 60% absorption. The shape of the resonance is shown in Fig. 3.