RESONANCE INDUCED IN AN EFFECTIVE FIELD BY MODULATED LIGHT

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It is known that simultaneous action on a spin system by a constant magnetic field $H_0 \parallel OZ$ and a radio-frequency magnetic field $H_1(t)$ rotating with frequency ω in the plane XOY is equivalent, in a coordinate frame rotating with frequency ω, to the action of an effective field $H_e = [(H_0 - \omega/\gamma)^2 + H_1{}^2]^{1/2}$. In this coordinate system, the spins precess around the field H_e but, unlike the laboratory frame, this precession is incoherent, i.e., there is no phase correlation between the motion of the individual spins. There are various methods [1,2] for establishing definite phase relations between the spin motions in the field H_e, i.e., for introducing coherence in the rotating coordinate system; all are based on the use of a second rf field of frequency $\omega_e = \gamma H_e$.

We consider in this communication a new possibility of producing rf coherence in a system of magnetic sublevels in an effective field H_e, by using optical excitation whose intensity is modulated in accordance with the law $I_Z(t) = I_{0Z}(1 + \varepsilon \cos \Omega t)$, and the modulation frequency Ω is equal to the frequency ω_e of spin precession in the effective field. It must be emphasized that transitions between the sublevels in the rotating coordinate system are induced in this case in the absence of any rf field at this frequency.

The occurrence of resonance in the effective field under the influence of the modulated optical excitation can be explained by means of the following qualitative consideration. Let the resonance condition $\omega - \omega_0 = 0$ be satisfied in the laboratory frame, and then $H_e = H_1$ in the rotating frame. If the light intensity I_Z is constant, then the spins, which precess in a plane perpendicular to H_e, are isotropically distributed, and this distribution does not change in time. But if the light intensity I_Z varies at the frequency of the spin precession around the H_e axis, then the magnetization produced by the light at the instant t_0 in the direction of the OZ axis is no longer balanced by the magnetization produced at the instant $t_0 + \pi/\Omega$, and consequently a nonzero macroscopic magnetization precessing around H_e arises in the rotating system of coordinates. Thus, modulated optical excitation of the spin system leads to the appearance of coherent superposition of atomic states in the effective field, i.e., to a situation similar in main outline to the experiments of Bell and Bloom in the laboratory frame [3].

A theoretical analysis, based on quantum theory of optical orientation [4] for a system of optically oriented atoms in the ground state, has fully confirmed the foregoing qualitative considerations. A detailed exposition of the obtained theoretical and experimental results will be published later. We confine ourselves here only to a report of some of the consequences of the theory and to a description of the experiment confirming them.

The expression obtained by us for the time variation of the off-diagonal density-matrix elements describing the coherence in the atomic system contains terms that oscillate at a frequency ω and are modulated at a frequency Ω, the modulation amplitude having a resonant character near $\Omega = \omega_e$. When the resonance signal is registered by determining the absorption of a transverse beam of linearly polarized light, the expression for the intensity of light passing through an ensemble of atoms takes the form (for a two-level system)

$$S = c\epsilon \frac{\sin 2\alpha}{\Gamma_0^2 + (\omega_e - \Omega)^2}[\sin\nu(\Gamma_0 \sin\omega t - \Delta\omega_e \cos\omega t)\sin\Omega t - \tag{1}$$
$$- 1/2 \sin 2\theta(\Gamma_0 \cos\omega t + \Delta\omega_e \sin\omega t)\cos\Omega t],$$

where Γ_0- damping constant of the ground state, α - angle between the polarization vector of the transverse light beam and the OZ axis, ν - angle between H_e and the OZ axis, and c - proportionality coefficient.

To check on the theoretical conclusions, an experiment was performed on optically oriented Cs^{133} vapor at 25°C. A modulated beam of circularly polarized resonant radiation propagated along the field H_0, and the modulation frequency of the light could be continuously varied. The detuning $\omega - \omega_0$ and the amplitude H_1 of the rf field were chosen so as to make the frequency $\omega_e/2\pi$ equal to 2.5 kHz. The resonance signal was determined by registering the change in the modulation of the absorption of the linearly polarized transverse light beam at the frequency ω. After first amplifying the signal at the carrier frequency ω with a narrow-band amplifier, its

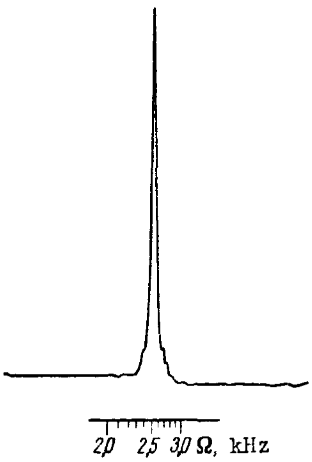

Fig. 2. Cs^{133} resonance signal in effective field, vs. angle between polarization vector of transverse light beam and magnetic field H || OZ. The magnitude of the resonance signal is measured along the radius vector in arbitrary units.

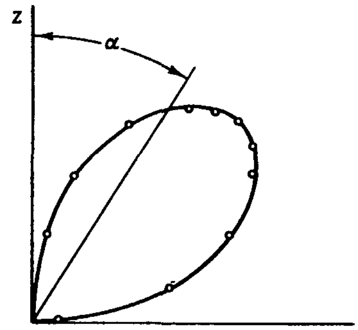

Fig. 1. Optically induced resonance of Cs^{133} in effective field.

envelope, with frequency Ω, was detected. As shown in Fig. 1, resonance was observed at the frequency $f = \Omega/2\pi = 2.5$ kHz, in a position corresponding exactly to the deductions of the theory. Figure 2 shows the dependence of the resonance signal at $\Omega = \omega_e$ on the angle α. The points on the solid curve, which is a polar plot of sin 2α, represent the experimental values. The agreement between the experimental results and the theoretical conclusions is good. Measurements of the dependence of the resonance signal on the depth of modulation of the light ϵ have fully confirmed its linear character, as follows from (1).

As seen from Fig. 1, the width of the observed resonance is ~70 Hz and is determined exclusively by the thermal and optical relaxations in the cell.

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