DETECTION OF VERY WEAK MAGNETIC FIELDS (10^{-9} GAUSS) BY ^{87}Rb ZERO-FIELD LEVEL CROSSING RESONANCES

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Zero-field level crossing resonances have been observed on the ground state of ^{87}Rb. The width, a few microgauss, and the signal to noise ratio, about 2.5×10^3, allow the measurement of 10^{-9} gauss fields.

Zero field level crossing resonances in excited states of atoms are well known (Hanle [1] effect). The same effect may be observed on the ground state of optically pumped atoms [2]: if a static field H_0, perpendicular to the pumping beam F, is scanned around zero, resonant variations are observed on the absorbed or re-emitted light. The width of the resonances, $\Delta H_0 = 2/\gamma\tau$, is inversely proportional to the relaxation time, τ, and the gyromagnetic ratio, γ, of the ground state. These resonances have first been observed on the ground state of the odd isotopes of Cd and Hg [2], for which $\tau \approx 1$ sec, $\gamma \approx 2 \times 10^3$ rad/s. gauss (nuclear paramagnetism in the ground state); in this case $\Delta H_0 \approx 10^{-3}$ gauss. For alkali atoms, the paramagnetism is of electronic origin: γ is about 10^3 times larger; one can obtain $\tau \approx 1$ sec with deuterated paraffin coated cells [3], so that very narrow resonances with $\Delta H_0 \approx 10^{-6}$ gauss are expected [4].

In order to eliminate the magnetic noise present in the laboratory, and the inhomogeneities which broaden considerably the resonances [5], we have put the cell inside a magnetic shield made of 4 concentric cylinders of mu-metal (1 m long, 2 mm thick). The shielding efficiency is about 10^4-10^5. We use paraffin coated cells, without buffer gas, so that there is a motional averaging of the residual magnetic field inhomogeneities. We have effectively observed in this way Hanle resonances: width: 1.4 μG; signal to noise: 20.

In order to detect very weak magnetic fields we have also increased the signal to noise by using a new type of detection of the resonances. We apply an r.f. field $H_1 \cos \omega t$ parallel to H_0; $\omega/2\pi \approx 400$ Hz is large compared to the width of the resonances. When H_0 is scanned around 0, theory shows that modulations appear on the absorbed pumping light, at the various harmonics $p\omega$ of ω [6]. These modulations undergo a resonant variation around zero values of H_0, with a dispersion shape for p odd and an absorption shape for

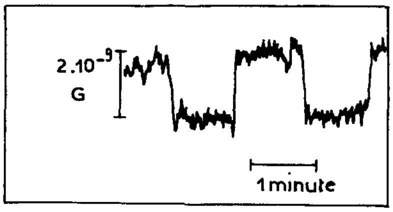

Fig. 1. Response of the signal to a square pulse of magnetic field of 2.1×10^{-9} gauss amplitude (time constant 3 s).

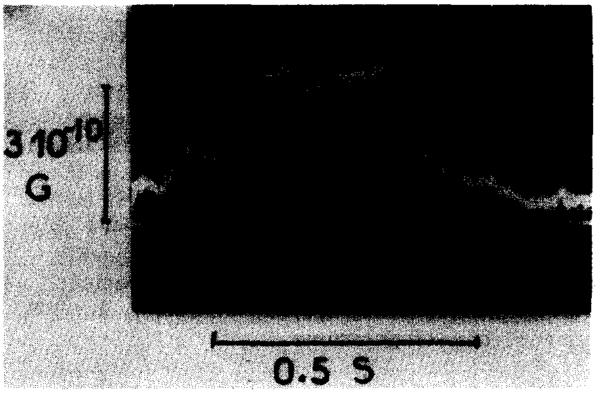

Fig. 2. Response of the signal to repetitive square pulses of magnetic field of 3×10^{-10} gauss amplitude (time constant 0.1 s; 3000 runs).

p even and the same width as the Hanle curve (strictly independent of the r.f. power). We make a selective amplification of the modulation ω (p = 1) and a phase sensitive detection with a time constant of 3 sec. By this way, we have got, for optimal pumping beam intensity, a signal to noise ratio of 2.5×10^3 with a width of 5 μG.

For detection of very weak magnetic fields, we fix H_0 at the zero value, corresponding to the maximum slope of the dispersion shaped resonance . We can test the sensitivity of the apparatus by sending on sweeping coils square pulses of current corresponding to a given variation, δH_0, of H_0. Fig. 1 shows the signal obtained for $\delta H_0 = 2.1 \times 10^{-9}$ gauss. This sensitivity can be still improved for repetitive signals by using noise averaging multichannel techniques. Fig. 2 shows 3×10^{-10} gauss amplitude pulses.

Such a high sensitivity, the highest to our knowledge, seems promising for several applications: measurement of the very weak interstellar fields, biomagnetism [7], measurement of the static magnetization of very dilute magnetic samples, . . .

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ANHARMONICITY AND GRÜNEISEN PARAMETER IN GERMANIUM

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Assuming anharmonic contributions as composed of purely volume dependent and self energy parts, the values of the Grüneisen parameter γ, for Ge, are shown, qualitatively to be due to both of these contributions.

Recent interest has been revived in solids for which the behaviour of Grüneisen parameter, customarily describing the anharmonic properties of solids, shows some deviations from the monotonic increase in gamma with temperature. The solids include mainly those that crystallize in diamond type structure. Blackman [1] attributed the anomaly, viz. a minimum, to the low lying transverse modes in the phonon spectrum. A few calculations in Ge show that this minimum is very sensitive to the nature of the dispersion in transverse modes. Even the decrease of dispersion corresponding to about 10% change at the zone boundary is enough to shift the value of gamma from the negative to the positive region. But a shallow minimum is unavoidable if at all the effect of dispersion which might be as simple as the one obtained from the Born von Karman theory for the monatomic linear chain, is considered (unpublished).

Furthermore, an investigation of the Grüneisen gamma also involves the temperature dependence of the frequency ν_j corresponding to the jth modes implicitly. This contribution, from

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