Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length and should be submitted in duplicate.

Observation of Nuclear Resonance Acoustic Absorption of In^{115} in InSb

M. MENES* AND D. I. BOLEF
Westinghouse Research Laboratories, Pittsburgh, Pennsylvania
(Received November 4, 1957)

IN many substances an important mechanism for the transfer of energy from the nuclear spin system to the lattice (spin-lattice relaxation) is the direct coupling between the nuclear spins and the lattice vibrations. Conversely, the presence of this coupling should result in an absorption of acoustic energy by the nuclei at the nuclear resonance frequency.[1] Because this nuclear spin-lattice coupling is generally due to either dipole-dipole or electric quadrupole interactions, transitions corresponding to $\Delta m=\pm 2$ as well as to $\Delta m=\pm 1$ are allowed, and therefore acoustic energy having twice the nuclear magnetic resonance frequency will also be absorbed. Proctor *et al.*[2,3] showed the existence of this absorption of acoustic energy by the nuclear spin system by saturating a nuclear magnetic resonance line acoustically.

We have observed directly the absorption of acoustic energy at the resonant frequency of In^{115} nuclei in a single crystal of InSb. The absorption was observed at both the normal nuclear magnetic resonance frequency ($\Delta m=\pm 1$) and at the double frequency ($\Delta m=\pm 2$). The sample was a cylinder of p-type InSb of approximately one cm^3 with lapped plane parallel faces. The cylinder faces were [321] planes of the crystal. A ten-megacycle X-cut quartz transducer was glued to one of the faces forming a composite mechanically resonant system. The resonance was observed by the change in mechanical Q of the sample which resulted in a change in the electrical impedance of the transducer. The transducer was made the controlling factor in the Q of the tank circuit of a modified Pound-Watkins type of spectrometer. The remainder of the equipment was conventional, using magnetic field modulation and synchronous detection with recorder output.

Figure 1 shows the signal obtained on the recorder. In Fig. 1(A) is shown the In^{115} acoustic resonance at 9.976 Mc/sec corresponding to the resonant field $H_0=10.69$ kilogauss. The [321] crystal axis along which the sound is propagated is inclined at an angle $\theta=22\frac{1}{2}$ degrees with the magnetic field. Figure 1(B) shows an acoustic resonance at the same frequency and field but at an angle $\theta=90°$. Figure 1(C) shows the acoustic resonance at the same frequency and with an angle θ of 90°, but with the field reduced to 5.35 kilogauss. This absorption corresponds to a $\Delta m=\pm 2$ transition which is forbidden in normal nuclear resonance.

Figure 2 shows in more detail the angular dependence of the absorption signal for the $\Delta m=\pm 1$ and $\Delta m=\pm 2$ transitions. It was observed that the double frequency line was somewhat narrower than the normal resonance line between maximum-slope points. A slight change in line shape with angle θ was also observed.

A quantitative measurement of the nuclear resonance acoustic absorption will give the strength of the coupling of the magnetic spins to the lattice. The technique of

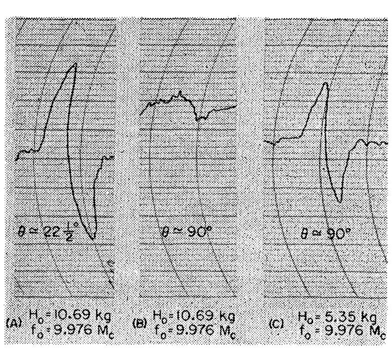

FIG. 1. (A) and (B) Recorder trace of absorption signal in In^{115} in InSb at $f_0=9.976$ Mc/sec, $H_0=10.69$ kilogauss. (C) Double frequence absorption signal at $f_0=9.976$ Mc/sec, $H_0=5.35$ kilogauss. Modulation field amplitude approximately 9 gauss. One division on recorder corresponds to 40 gauss. Field sweep was 10 gauss per minute. θ is angle between axis of acoustic propagation and the magnetic field.

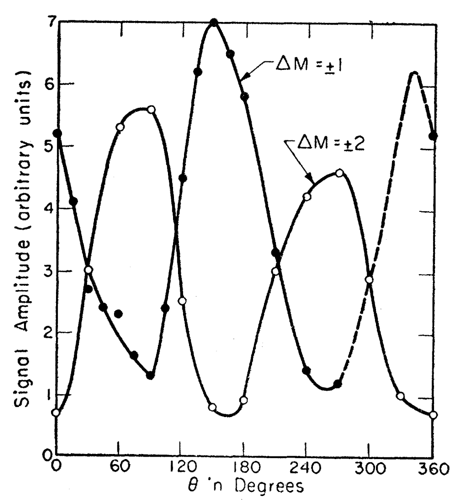

FIG. 2. Absorption signal amplitude in In^{115} in InSb as a function of θ for normal ($\Delta m=\pm 1$) absorption and double frequency ($\Delta m=\pm 2$) absorption. Experimental conditions as in Fig. 1 except that field modulation amplitude is 4 gauss.

nuclear resonance acoustic absorption eliminates the limitation due to skin effect of conventional nuclear magnetic resonance in conducting materials. It should be possible to extend acoustic absorption techniques to the study of electron spin resonance.

We wish to acknowledge the helpful assistance of P. R. Malmberg, and the cooperation of Dr. R. H. Moss in lending us the InSb crystal.

* Now at University of Pittsburgh, Pittsburgh, Pennsylvania.

[1] S. A. Al'tshuler, J. Exptl. Theoret. Phys. U.S.S.R. **28**, 49 (1955) [translation: Soviet Phys. JETP **1**, 37 (1955)].
[2] W. Proctor and W. Tantilla, Phys. Rev. **101**, 1757 (1956).
[3] W. Proctor and W. A. Robinson, Phys. Rev. **104**, 1344 (1956).

Optically Detected Field-Independent Transition In Sodium Vapor

WILLIAM E. BELL AND ARNOLD L. BLOOM
Varian Associates, Palo Alto, California
(Received November 11, 1957)

THE hyperfine transition $m_F=0\rightarrow m_F=0$ $(\Delta F=1)$ in the ground state of alkali atoms is of interest because it is virtually independent of magnetic field in weak fields, which suggests its use in atomic frequency standards.[1] Previously these transitions have been observed in atomic beam experiments,[1,2] and Carver and Dicke[3] have observed the transition in Rb^{87} vapor by using optical methods to obtain polarization together with microwave detection. In this note we report observation of the resonance in sodium vapor by optical detection, using the techniques developed earlier by Dehmelt[4,5] and by us.[6]

The experimental arrangement is shown in Fig. 1. Unfiltered, unpolarized light from a sodium lamp is transmitted in the direction of the earth's magnetic field through a quartz absorption cell placed in a resonant cavity. The absorption cell contains sodium metal and vapor at about 125°C in argon buffer at 10-cm Hg pressure[7] and the cavity, operating in the TE_{010} mode, is tunable around 1772 Mc/sec. The transmitted light is observed by photocell. Passage through the hyperfine resonances by the frequency-modulated rf generator causes a decrease in intensity of the transmitted light which is indicated on an oscilloscope.

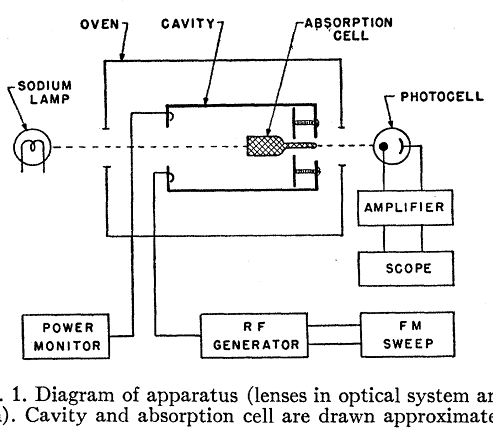

FIG. 1. Diagram of apparatus (lenses in optical system are not shown). Cavity and absorption cell are drawn approximately to scale.

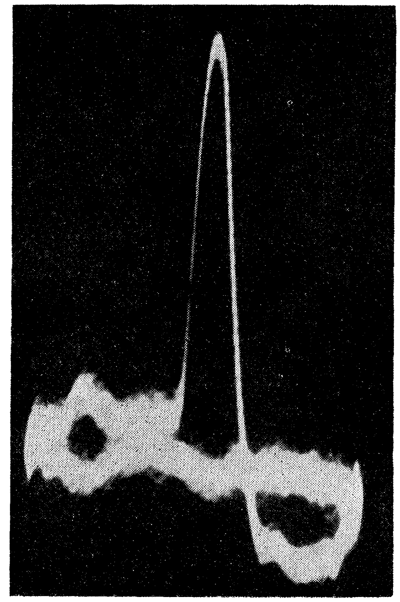

FIG. 2. Oscilloscope signal of field-independent resonance.

According to the earlier analyses,[5,6] optical pumping and detection by transmitted light is feasible only if there are differences in the rates, P_i, at which atoms in the different ground state sublevels absorb light. In the earlier work on sodium, employing circularly polarized light and a D_1-D_2 intensity difference, it was assumed that the P_i's depended only on the optical matrix elements. In this situation, however, the two $m_F=0$ levels always have the same value of P_i and no signal can be observed. What is required, instead, is a difference in light *intensity* exciting atoms out of these two levels. It is assumed that in the present experiment an intensity difference is achieved in the following way. Light incident at the front part of the absorption cell is absorbed and scattered separately by sodium atoms in the two F levels, since the hyperfine splitting is greater than the Doppler- and pressure-broadened optical absorption line width. The rate of attenuation is proportional to the number of magnetic sublevels in each F level—3 and 5 for the lower and upper F levels respectively. This provides the necessary intensity difference at the rear of the absorption cell and produces there a greater population in the upper states.

Figure 2 shows the oscilloscope signal when the noise bandwidth is about 10^3 cps. Most of the observed noise is traceable to fluctuations in lamp brightness. The $0\rightarrow0$ line can be readily told apart from the other

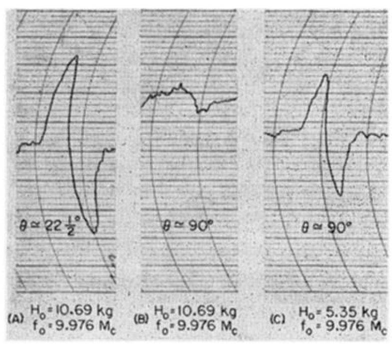

FIG. 1. (A) and (B) Recorder trace of absorption signal in In^{115} in InSb at $f_0=9.976$ Mc/sec, $H_0=10.69$ kilogauss. (C) Double frequence absorption signal at $f_0=9.976$ Mc/sec, $H_0=5.35$ kilogauss. Modulation field amplitude approximately 9 gauss. One division on recorder corresponds to 40 gauss. Field sweep was 10 gauss per minute. θ is angle between axis of acoustic propagation and the magnetic field.