were from spectroscopically pure samples obtained from the Air Reduction Company. The bulb was provided with two 0.040-in. tungsten leads mounted at an angle of 90° and with the ends within the bulb separated by approximately 1 cm. The static magnetic field was 2.4 gauss, and was modulated 10% at 15 cycles/sec with a sine wave. At one point in each cycle a 30-Mc/sec oscillator was pulsed on for 3 milliseconds. This oscillator, which was coupled to the bulb through the tungsten leads, produced a discharge in the bulb, which dissociated the hydrogen molecules into atoms. The cell was operated at a temperature of 138°C. At this temperature the bulb transmitted approximately 40% of the incident sodium light and the radio-frequency sodium signal was a maximum. A war surplus $T85/APT$-5 grounded-grid, coaxial-line oscillator and a two-turn solenoid 4 in. in diameter and 4 in. long were used to produce the radio-frequency magnetic field at 1420 Mc/sec. The impedance matching was poor and there was insufficient radio-frequency power to maximize the hydrogen hyperfine transition signal.

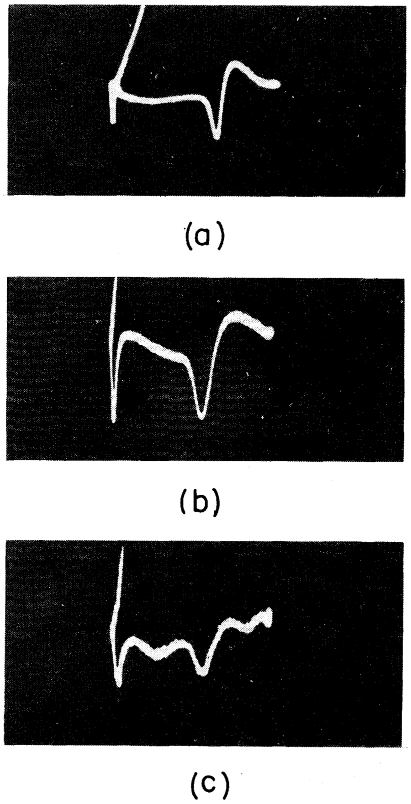
(a)
(b)
(c)

FIG. 1. For all of these traces the static magnetic field is 2.4 gauss. (a) The Zeeman transitions [$\Delta F = 0$, $\Delta M = \pm 1$] in sodium. The relative gain is one. Oscillator frequency is 1.5 Mc/sec. (b) The Zeeman transitions [$\Delta F = 0$, $\Delta M = \pm 1$] in the hydrogen atom. Oscillator frequency is 3 Mc/sec and the relative gain is 10. (c) The hyperfine transition [$F = 0$, $M = 0 \leftrightarrow F = 1$, $M = 1$] in the hydrogen atom. Oscillator frequency is at 1423 Mc/sec and the relative gain is 100. The large-amplitude noise in the trace is due to the sodium lamp.

Figure 1 shows three of the transitions observed. Figure 1(a) is the sodium signal at the frequency 1.5 Mc/sec. Figure 1(b) is the hydrogen atom low-field transition [$\Delta F = 0$, $\Delta M = \pm 1$] at 3 Mc/sec. Figure 1(c) shows the hyperfine transition [$F = 0$, $M = 0 \leftrightarrow F = 1$, $M = 1$] in the hydrogen atom at 1423 Mc/sec. The hyperfine transition [$F = 0$, $M = 0 \leftrightarrow F = 1$, $M = -1$] was also observed. The signal was still growing with increase of radio-frequency power when the maximum power available was applied.

The signal-to-noise ratio obtained with this simple apparatus suggests that with some improvements, this method could be used to remeasure the zero-field hyperfine splittings of hydrogen, deuterium, and tritium. This would be especially useful in the case of tritium as one need use only a very small sample.

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*Texas Company Fellow, 1957-58.

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OPTICAL PROPERTIES OF CRYSTALLINE BORON

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In recent years the crystallographic and electrical properties of boron have received increasing attention. Detailed studies on the crystal structure of boron have revealed three modifications, two rhombohedral types as well as one tetragonal.[1] Electrical measurements[2] of the resistivity as a function of temperature have established crystalline boron as a semiconductor with a thermal energy gap of about 1.4 ev at 0°K.

At present very little is known of the bulk optical properties of crystalline boron. Limited optical data have been reported on evaporated films and on one bulk specimen of boron of unknown purity and crystal structure.[3] We have studied the absorption and reflectivity of high-purity boron prepared by E. S. Greiner with the zone technique. The carrier concentrations are approximately 10^{13} cm^{-3} and the wavelengths range between 0.7 μ and 30 μ. The specimens were of the rhombohedral type[1] with 107 or 108 atoms per unit cell. In Fig. 1 the reflectivity R of a polished boron specimen is shown. Unlike the elementary semiconductors silicon and germanium, boron exhibits considerable variation of R, particularly near 21 μ. The wavelength dependence of R suggests a region of anomalous dispersion near 21 μ and a corresponding strong resonance absorption band is expected. Infrared transmission measurements on boron powder embedded in a KBr pellet are also seen in Fig. 1. They clearly show a strong absorption band at 21 μ in agreement with the reflectivity data. In addition, several absorption bands of smaller intensity appear at shorter wavelengths: 10.2 μ, 10.9 μ, 11.8 μ, 13.3 μ, 14.7 μ and 16.2 μ. These bands are superimposed upon a scattering background due to particle size (dashed curve). In Fig. 2 the transmission of a polycrystalline boron specimen (crystallite size ~$\frac{1}{2}$ mm) is presented for three different thicknesses: 1.3, 0.15, and 0.05 mm. Even the thickest sample exhibits considerable transmission between 1.5 μ and 4.5 μ. After thinning the specimen, extensive structure is observed in the transmission measurements as can be seen in Fig. 2. A series of bands at 4.5 μ, 6.3 μ, 8.1 μ, 9.3 μ, 9.7 μ, and 10.1 μ are revealed. Low transmission between 10.8 μ and 11.8 μ and for $\lambda \geqslant 12.6\ \mu$ indicate additional strong absorption bands in these wavelength ranges. The stronger bands with absorption coefficients of the order of 10^3 cm^{-1} and larger agree favorably with those obtained from the KBr pellet and are believed to be lattice absorption bands of elementary boron. They are responsible for the small scale variations of the reflectivity between 10 μ and 15 μ. It is interesting to note that the reflectivity value suggests a dielectric constant of $\epsilon = 8.4 \pm 0.4$ for wavelengths smaller than 20 μ while $\epsilon = 10.0 \pm 0.5$ is indicated for $\lambda > 25\ \mu$. Since capacity measurements[3] at 10 kc/sec give $\epsilon = 14$, one or more additional regions of dispersion at larger wavelengths have to be expected. Optical dispersion is commonly known for ionic crystals and has been found recently in intermetallic compounds (e.g., III-V compounds).[4] It is believed that the small but distinct dispersion observed in this boron modification is the result of significantly different electron distributions about crystallographically nonequivalent atoms. Whether the observed dispersion corresponds to

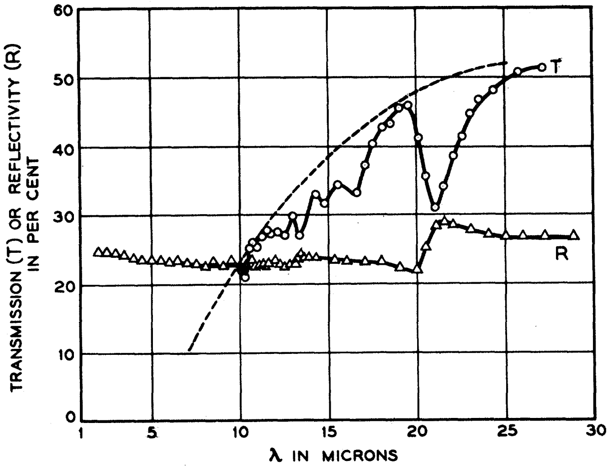

FIG. 1. Reflectivity of crystalline boron and transmission of boron powder (same material) as a function of wavelength.

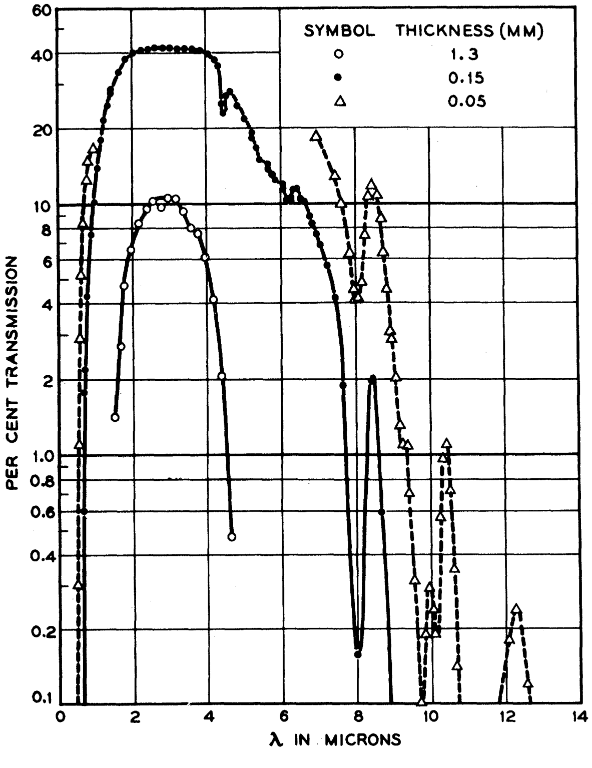

FIG. 2. Transmission of crystalline boron *versus* wavelength for three thicknesses of the specimen.

the vibration of specific boron atoms or to vibrations of certain atom groups cannot yet be stated.

As can be seen from Fig. 2, the transmission of boron decreases strongly for wavelengths smaller than approximately 2 μ. A plot of the calculated absorption coefficient as a function of photon energy indicates that two absorption mechanisms are present. The absorption rises rapidly with increasing energy for $h\nu > 1.2$ ev. This sharp rise is considered to correspond to optical transitions across the forbidden energy gap. For 0.6 ev $\leq h\nu \leq$ 1.2 ev, the absorption increases less rapidly with the photon energy. Several possible causes may be cited for this latter absorption: transitions to or from states within the forbidden gap, interband transitions arising from a complicated band structure, scattering effects due to lattice imperfections. A more detailed study of these questions is in progress.

We wish to acknowledge the aid of J. A. Gutowski who prepared some of the specimens for the measurements and G. Sorin who helped in taking some of the infrared data.

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BROKEN ATOMIC BEAM RESONANCE EXPERIMENT*

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All past atomic beam resonance experiments have been limited to cases in which the atoms undergo no collisions between the source and the detector. However, several years ago Ramsey[1,2] pointed out that the separated oscillatory field resonance method[3] in principle could be extended to cases in which the atoms in the beam were subject to collisions either with other atoms or with suitable solid surfaces in the region between the two oscillatory fields. It was pointed out[2] that such experiments not only would provide information on the nature of the collisions but also might make possible resonance experiments of unprecedented accuracy if the atoms could be stored for considerable lengths of time in a box with suitable surfaces.

It is the purpose of the present note to point out the first success of such a broken atomic beam experiment. The arrangement of the apparatus for the experiment was as shown in Fig. 1. Cesium atoms from a heated oven emerged into a six-pole deflecting magnetic field[4] region from which only the atoms in the hyperfine state $F = 4$ could emerge. The atoms then entered the first oscillatory field region followed by a small box of such a configuration that no atom could pass through the box without undergoing at least two wall collisions. The atoms then entered the second oscillatory field region which was followed in turn by another six-pole deflecting magnetic field through which only $F = 4$ atoms could pass. The characteristic Ramsey separated oscillatory field resonance pattern[3] was then sought corresponding to atomic transitions between the $F = 4$, $M = 0$ and $F = 3$, $M = 0$ state.

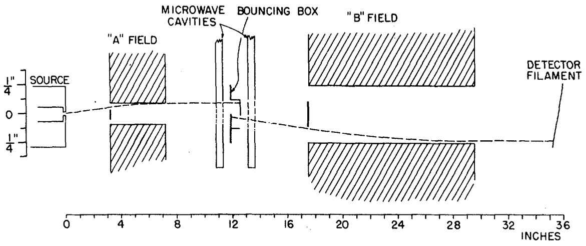

FIG. 1. Experimental arrangement of the broken atomic beam.

The first box tried possessed walls of unheated teflon. With these no Ramsey pattern could be observed in the emerging beam, though a pattern corresponding to transitions in a single microwave cavity was observed. However, when the box was heated to 100°C the characteristic Ramsey pattern was observed, despite the fact that the atoms of the beam had to undergo at least two collisions between the